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DL-2

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DL-8

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GLOSSARY

absorbed dose

Energy transferred to matter when ionizing radiation passes through it. Absorbed dose is measured in rads.

absorption

The process by which the number and energy of particles or photons entering a body of matter are reduced by interaction with the matter.

acclimation

The acclimation or adaptation of a particular species over several generations to a marked change in the environment.

activity

A measure of the rate at which a material is emitting nuclear radiation, usually given as the number of nuclear disintegrations per unit of time. A unit of radioactivity is the curie (Ci), which equals 3.7×10^{10} disintegrations per second.

adsorption

The adhesion of a substance to the surface of a solid or solid particles.

AEC

Atomic Energy Commission. A five-member commission established by the Atomic Energy Act of 1954 to supervise the use of nuclear energy. The AEC was dissolved in 1975 and its functions transferred to the Nuclear Regulatory Commission (NRC) and the Energy Research and Development Administration (ERDA); ERDA became the U.S. Department of Energy (DOE) in 1977.

aerobic

Processes that can occur only in the presence of oxygen.

air quality

A measure of the levels of pollutants in the air.

air quality standards

The prescribed level of pollutants in the outside air that cannot be exceeded legally during a specified time in specified areas.

air sampling

The collection and analysis of air samples for detection or measurement of radioactive substances.

alluvial

Deposited by a stream or running water.

- ambient air**
The surrounding atmosphere, usually the outside air, as it exists around people, plants, and structures. (It is not the air in immediate proximity to emission sources.)
- anaerobic**
Processes that occur in the absence of oxygen.
- anion**
A negatively charged ion.
- aquatic biota**
The sum total of living organisms of any designated aquatic area.
- aquifer**
An underground bed or stratum of earth, gravel, or porous stone that contains water. The water can be pumped to the surface through a well or it might emerge naturally as a spring.
- archaeological sites (resources)**
Areas or objects modified or made by man and the data associated with these features and artifacts.
- arenaceous limestone**
Limestone with a texture or appearance of sand.
- artifact**
An object produced or shaped by human workmanship of archaeological or historic interest.
- ash**
Inorganic residue remaining after ignition of combustible substances.
- atmosphere**
The layer of air surrounding the earth.
- backfill**
Material used to refill an excavation.
- background exposure**
See exposure to radiation.
- background radiation**
Normal radiation present in the lower atmosphere from cosmic rays and earth sources. Background radiation varies considerably with location.
- bedrock**
Any solid rock exposed at the earth's surface or overlain by unconsolidated surface material such as soil, gravel, or sand.

benthos

The plant and animal life whose habitat is the bottom of a sea, lake, or river.

beta particle

An elementary particle emitted from a nucleus during radioactive decay. It is negatively charged, is identical to an electron, and is easily stopped by, for example, a thin sheet of metal.

bioaccumulation factor

Concentration of a substance (e.g., chemical or radionuclide) in fish flesh or other body parts divided by the concentration of that substance in the water in which the fish is living.

biocide

Chemical agent used to prevent or remove fouling organisms such as bacteria, fungi, algae, clams, etc., from entering or fouling intake and heat exchangers of powerplant/reactor cooling water systems.

biofouling

Aquatic organisms such as bacteria, fungi, algae, clams, etc., that colonize water-flow structures, often causing restricted water flow (i.e., cooling water systems of powerplants/reactors).

biological dose

The radiation dose, measured in rems, absorbed in biological material.

biosphere

The portion of the earth and its atmosphere capable of supporting life.

biostratigraphy

The study of stratigraphy via fossilized remains.

biota

The plant and animal life of a region.

blowdown

Water discharged from a recirculating cooling system to control concentration of salts or other impurities.

BOD

Biological oxygen demand, the oxygen required for oxidation of soluble organic matter by bacterial action in the presence of oxygen.

Btu

British Thermal Unit, a unit of heat; the quantity of heat required to raise the temperature of 1 pound of water by 1 degree Fahrenheit. One Btu equals 1055 joules (or 252 calories).

^oC Degree Celsius. The Celsius temperature scale is related to the Fahrenheit scale as follows:

$$^{\circ}F = ^{\circ}C \frac{9}{5} + 32$$

cancer

The name given to a group of diseases that are characterized by uncontrolled cellular growth.

carbon monoxide

A colorless, odorless gas that is toxic if breathed in high concentration over a certain period of time. It is a normal component of most automotive exhaust systems.

carcinogen

An agent capable of producing or inducing cancer.

carcinogenic

Capable of producing or inducing cancer.

Carolina bay

Wetland area found on the Southeastern Atlantic coastal plain; a shallow depression.

cc

Cubic centimeters, cm^3 or cc (1 cc = 1 milliliter).

CCDF

Complementary cumulative distribution function.

ci

See curie.

clastic dike

A sedimentary dike formed by broken rocks from overlying or underlying material.

concentration

The amount of a substance contained in a unit quantity of a sample.

condensate

Water obtained by cooling the steam (overheads) produced in an evaporator system. Also, any liquid obtained by cooling saturated vapor.

CO₂

Carbon dioxide, a colorless, odorless, nonpoisonous gas that is a normal component of the ambient air.

coolant

A substance, usually water, circulated through a processing plant to remove heat.

cooling tower

A structure designed to cool water by evaporation. In this EIS, the water being cooled absorbs heat to condense the steam in the evaporator system.

correlatable

Able to establish a connection between geological formations or events.

Cretaceous

End of Mesozoic era, between 136 and 65 million years ago.

crystalline metamorphic rock

Rock consisting wholly of crystals.

cumulative effects

Additive environmental, health, and socioeconomic effects that result from a number of similar activities in an area.

curie (Ci)

A unit of radioactivity equal to 3.7×10^{10} (37 billion) disintegrations per second. A curie is also a quantity of any nuclide or mixture of nuclides having one curie of radioactivity.

daughter

A nuclide formed by the radioactive decay of another nuclide, which is called the parent.

decay heat

The heat produced by the decay of radioactive nuclides.

decay, radioactive

The spontaneous transformation of one nuclide into a different nuclide or into a different energy state of the same nuclide. The process results in the emission of nuclear radiation (alpha, beta, or gamma).

decomposition

The breakdown of a substance into its constituent parts.

demography

The statistical study of human populations including size, density, distribution, and vital statistics such as age, sex, and ethnicity.

depauperate

Poor or impoverished, falling short of what occurs naturally; i.e., reduced numbers and species of biological organisms.

depositional regimes
A systematic laying or throwing down of material over a substantial area.

detector
Material or device (i.e., instrument) that is sensitive to radiation and can produce a response signal suitable for measurement or analysis.

detritus
Dead organic tissues and organisms in an ecosystem.

distillation
Separation process achieved by creating two or more coexisting zones that differ in temperature, pressure, or composition.

DOE
United States Department of Energy.

dose
The energy imparted to matter by ionizing radiation. The unit of absorbed dose is the rad, equal to 0.01 joules per kilogram of irradiated material in any medium.

dose commitment
The dose that an organ or tissue receives during a specified period of time (e.g., 50 or 100 years) as a result of intake (by ingestion or inhalation) of one or more radionuclides from 1 year's release.

dose equivalent
A term used to express the amount of effective radiation when modifying factors have been considered. It is the product of absorbed dose (rads) multiplied by a quality factor and any other modifying factors. It is measured in rems (Roentgen equivalent man).

dose rate
The radiation dose delivered per unit time (e.g., rems per year).

dosimeter
A small device (instrument) that measures radiation dose (e.g., film badge or ionization chamber) and is carried by a radiation worker.

drift
Mist or spray carried out into the atmosphere with the effluent air from cooling towers.

DWPF
Defense Waste Processing Facility, under construction at the Savannah River Plant. It is designed to process defense waste into a suitable form for terminal storage or disposal.

D₂O

Deuterium oxide or heavy water.

ecology

The science dealing with the relationship of all living things to each other and to the environment.

ecosystem

A complex of the community of living things and the environment forming a functioning whole in nature.

EDC

See environmental dose commitment.

effluent

Liquid waste discharged into the environment, usually into surface streams. In this EIS, effluent refers to discharged wastes that are nonpolluting in their natural state or as a result of treatment.

effluent standards

Defined limits of waste discharge in terms of volume, content of contaminants, temperature, etc.

EIS

Environmental impact statement, a document prepared pursuant to Section 102(2)(c) of the National Environmental Policy Act (NEPA) of 1969 for a major Federal action significantly affecting the quality of the human environment.

electron

An elementary particle with a unit negative charge and a mass 1/1837 of the proton. Electrons surround the positively charged nucleus and determine the chemical properties of the atom.

element

One of the 105 known chemical substances that cannot be divided into simpler substances by chemical means. All nuclides of an element have the same atomic number.

emission standards

Legally enforceable limits on the quantities and kinds of air contaminants that may be emitted into the atmosphere.

endangered species

Plants and animals in an area that are threatened with either extinction or serious depletion.

energy

The capacity to produce heat or do work. Electrical energy is measured in units of kilowatt-hours.

GL-7

entrapment

The capture and inclusion of organisms in the cooling water systems of powerplants/reactors. The organisms involved are generally 9 to 13 millimeters long, depending on the intake screen mesh size, and include phyto- and zooplankton, fish eggs and larvae (ichthyoplankton), shellfish larvae, and other forms of aquatic life.

environment

The sum of all external conditions and influences affecting the life, development, and ultimately, survival of an organism.

environmental dose commitment (EDC)

A dose representing exposure to, and ingestion of, environmentally available radionuclides for 100 years following 1 year's release of radioactivity.

environmental fate

The result of the physical, biological, and chemical interactions of a substance released to the environment.

environmental transport

The movement through the environment of a substance; it includes the physical, chemical, and biological interactions undergone by the substance.

Eocene

Lower Tertiary Period, after Paleocene but before Oligocene.

epoch

Length of time (geology).

erosion

The process in which uncovered soil and clay are carried away by the action of wind or water.

estuarine

Pertaining to an area where salt and fresh water come together and are affected by tides.

exposure to radiation

The incidence of radiation on living or inanimate material by accident or intent. Background exposure is the exposure to natural background ionizing radiation. Occupational exposure is the exposure to ionizing radiation that takes place during a person's working hours. Population exposure is the exposure to a number of persons who inhabit an area.

°F

degree Fahrenheit. The Fahrenheit temperature scale is related to the Celsius scale as follows:

$$^{\circ}\text{C} = \frac{(^{\circ}\text{F} - 32)}{1.8}$$

fall line

Imaginary line marking the point that most rivers drop steeply from the uplands to the lowlands.

fallout

The descent to earth and deposition on the ground of particulate matter (which might be radioactive) from the atmosphere.

fault

A fracture or a zone of fractures within a rock formation along which vertical, horizontal, or transverse slippage has occurred.

faunal

Animal and plant fossils of a certain rock unit.

feldspar

Most common group of aluminum silicate minerals (containing other metals, such as potassium, sodium, and iron) that form rock.

ferruginous

Containing iron oxide.

fission

The splitting of a heavy atomic nucleus into two approximately equal parts, which are nuclei of lighter elements, accompanied by the release of energy and generally one or more neutrons. Fission can occur spontaneously or can be induced by neutron bombardment.

fission products

Nuclei formed by the fission of heavy elements (primary fission products). Also, the nuclei formed by the decay of the primary fission products, many of which are radioactive.

fluvial

Relating to, or living in or near, a river.

flux

Rate of flow through a unit area.

- food chain**
The pathways by which any material entering the environment passes from the first absorbing organism through plants and animals to humans.
- fuel**
A substance used to produce heat (e.g., from chemical energy by combustion, or from nuclear energy by nuclear fission).
- gal**
Gallon.
- gamma rays**
High-energy, short-wave length electromagnetic radiation accompanying fission and emitted from the nucleus of an atom. Gamma rays are very penetrating and require dense (e.g., lead) or a thick layer of materials for shielding.
- gamma spectrometry**
Identification and quantification of radioisotopes by measurement of the characteristic gamma rays emitted by elements undergoing radioactive decay.
- g/cm²**
Grams per square centimeter, a measure of pressure. Atmospheric pressure is about 1055 g/cm².
- genetic effects**
Radiation effects that can be transferred from parent to offspring; radiation-induced changes in the genetic material of sex cells.
- geology**
The science that deals with the earth: the materials, processes, environments, and history of the planet, especially the lithosphere, including the rocks and their formation and structure.
- g/L**
Grams per liter.
- glauconitic**
Mineral aggregate containing glauconite, giving it a green color.
- gneiss**
Rock formed from bands of granular minerals alternating with bands of minerals that are flaky, or have elongate prismatic habits.
- gradient**
Slope, particularly of a stream or land surface.
- groundwater**
The supply of water under the earth's surface in an aquifer.

gypsum

Mineral containing hydrous calcium sulfate.

half-life (effective)

The time required for a radionuclide contained in an organism to reduce its activity by one half as a combined result of radioactive decay and biological elimination.

halogens

The group of five chemically related nonmetallic elements that include fluorine, chlorine, bromine, iodine, and astatine.

hardwoods

Trees that are angiosperms and yield wood that has a hard consistency.

health physics

The science concerned with recognition, evaluation, and control of health hazards from ionizing radiation.

heat exchanger

A device that transfers heat from one fluid (liquid or gas) to another or to the environment.

heavy metals

Metallic elements of high molecular weight, such as mercury, chromium, cadmium, lead, and arsenic, that are toxic to plants and animals at known concentrations.

heavy water

Water in which the molecules contain oxygen and deuterium, an isotopic form of hydrogen that is heavier than ordinary hydrogen.

high-level waste

High-level liquid waste or the products from the solidification of high-level liquid waste or irradiated fuel elements if discarded without reprocessing.

historic resources

The sites, districts, structures, and objects considered limited and nonrenewable because of their association with historic events or persons, or social or historic movements.

holding pond

A pond constructed to retain water from a cooling water system before release to a water body.

Holocene

Epoch of Quaternary Period from end of Pleistocene to present time.

hydraulic conductivity
Water flow rate in liters per day through a 1-square-foot cross-section under a unit hydraulic gradient.

hydraulic (water) head
Height of water with a free surface above a subsurface point.

hydrocarbons (HC)
Organic compounds consisting primarily of hydrogen and carbon. Hydrocarbons are emitted in automotive exhaust and from the incomplete combustion of fossil fuels such as coal.

hydrograph
Graph showing water characteristics such as velocity, or flow, in relation to time.

hydrology
The science dealing with the properties, distribution, and circulation of natural water systems.

hydrosphere
The water portion of the surface of the earth as distinguished from the solid portion, the lithosphere.

hydrostratigraphic unit
Rock or soil body extending laterally for a considerable distance; sometimes abbreviated HSU.

ichthyoplankton
The early life stages of fish (eggs and larvae) that spend part of their life cycle as free-floating plankton.

impingement
The process by which aquatic organisms too large to pass through the intake screens of a powerplant/reactor become caught on the screens and unable to escape.

incorporated places
Political units incorporated or combined as cities, boroughs, towns, and villages.

indigenous labor pool
An area's native labor pool composed of workers normally residing in the area who do not leave the area after termination of a construction project.

induced radioactivity
Radioactivity that is created when substances are bombarded with neutrons, as in a reactor.

inert gas

A gas that is totally unreactive.

in-movers

Workers who move into an area during construction and leave when the project is finished. As referred to in this document, in-movers also include some weekly travelers.

insolation

Solar radiation incident on the water surface.

intensity

The energy or the number of photons or particles of radiation incident on a unit of time. Intensity of radioactivity is the number of atoms disintegrating per unit of time.

interfluvial

Falling in the area between two streams.

ion

An atom or molecule that has gained or lost one or more electrons and thus has become electrically charged.

ion exchange

Process in which a solution containing soluble ions to be removed is passed over a solid ion exchange column, which removes the soluble ions by exchanging them with labile ions from the surface of the column. This process is reversible; the trapped ions can be eluted from the column and the column regenerated.

ionization

The process whereby ions are created. Nuclear radiation can cause ionization, as can high temperatures and electric discharges.

ionizing radiation

Radiation capable of displacing electrons from atoms or molecules, thereby producing ions.

irradiation

Exposure to radiation.

isotope

An atom of a chemical element with a specific atomic number and atomic weight. Isotopes of the same element have the same number of protons but different numbers of neutrons.

kaolin

Clay mineral group characterized by a silicon oxygen sheet and an aluminum-hydroxyl sheet alternately linked to form a two-layer crystal lattice.

kilometer

A metric unit of length equal to 0.62137 mile.

leachate

Liquid that has percolated through solid waste or other media and has extracted from the solids dissolved or suspended materials into the liquids.

leaching

The process whereby a soluble component of a solid or mixture of solids is extracted as a result of percolation of water around and through the solid.

leukemia

A form of cancer characterized by extensive proliferation of nonfunctional, immature white blood cells (leukocytes).

lignite

A brownish-black coal between stages of peat and sub-bituminous coal.

limonite

Hydrous ferric oxides occurring naturally but having unknown origins.

liters per second

A metric unit of flow rate equal to 15.85 gallons per minute.

lithology

Rock descriptions by color, structure, grain size, etc.

lithosphere

The solid part of the earth composed predominantly of rock.

long-lived nuclides

Radioactive isotopes with half-lives greater than 30 years.

lps

Liters per second.

m³/m

Cubic meters per minute.

m³/s

Cubic meters per second.

macroinvertebrates

Those invertebrates that can be seen by the unaided eye that are retained in a U.S. Standard sieve (0.595 millimeters).

marine terrace

Narrow coastal strip altered by marine deposit and erosion.

maximum permissible dose

That dose of ionizing radiation established by competent authorities as an amount below which there is no appreciable risk to human health; at the same time, it is below the lowest level at which a definite hazard exists.

mechanical draft (cooling tower)

A type of cooling tower that uses fans to provide air flow for promoting evaporative cooling (see natural draft).

megawatt (MW)

A unit of power equal to 1000 kilowatts (kW) or 1 million (10^6) watts.

mg

Milligram (one-thousandth of a gram).

mica

Variously colored, or colorless mineral silicates, crystallizing in monoclinic forms that separate into thin leaves.

micro (μ)

Prefix indicating one millionth. One microgram equals one-millionth of a gram or 10^{-6} gram.

micrometer (μm)

A unit of length equal to one one-millionth (10^{-6}) of a meter.

micron

A micrometer (10^{-6} meter).

migration

The natural travel of a material through the air, soil, or groundwater.

ml

Milliliter (one-thousandth of a liter).

mm

Millimeter (one-thousandth of a meter).

mobility

The ability of a chemical element or a pollutant to move into and through the environment.

moderator

A material used to slow neutrons from fission to thermal energies.

molecule

A group of atoms held together by chemical forces. A molecule is the smallest unit of a compound that can exist by itself and retain all its chemical properties.

monitoring

Process whereby the level and quality of factors that can affect the environment and human health are measured periodically to regulate and control potential impacts.

mrem

Millirem (one-thousandth of a rem).

mutagen

Physical, chemical, or radiative agent capable of inducing mutation (above the spontaneous background level).

mutagenesis

The occurrence or induction of mutation, a genetic change that is passed on from parent to offspring.

mutation

An inheritable change in the genetic material (in a chromosome).

nano

Prefix indicating one thousandth of a micro unit; one trillionth; 1 nanocurie = 10^{-9} curie.

National Register of Historic Places

A list maintained by the National Park Service of architectural, historic, archaeological, and cultural sites of local, state, or national significance.

natural draft (cooling tower)

A type of cooling tower that relies on the difference in density between the entering air and internal heated air to provide air flow for promoting evaporative cooling (see mechanical draft).

natural radiation or natural radioactivity

Background radiation.

nCi

Nanocuries, 10^{-9} curies.

NEPA

National Environmental Policy Act of 1969.

neutron

An uncharged elementary particle with a mass slightly greater than that of the proton and found in the nucleus of every atom heavier than hydrogen. A free neutron is unstable and decays with a half-life of about 13 minutes into an electron and a proton.

neutron flux

Number of neutrons flowing through a specified area per unit of time.

NH₃

Ammonia, a pungent, reactive colorless gas, which is irritating to the eyes and moist skin in high concentrations.

NO_x

The oxides of nitrogen, primarily NO and NO₂. These are often produced in the combustion of fossil fuels. In high concentration they constitute an air pollution problem.

nodes

The intersection of horizontal and vertical grids.

NRC

U.S. Nuclear Regulatory Commission.

nuclear energy

The energy liberated by a nuclear reactor (through fission or fusion) or by radioactive decay.

nuclear powerplant

A facility that converts nuclear energy into electrical power. Heat produced by a reactor is used to make steam to drive a turbine that drives an electric generator.

nuclear reaction

A reaction in which an atomic nucleus is transformed into another element, usually with the liberation of energy as radiation.

nuclear reactor

A device in which a fission chain reaction is maintained and which is used for irradiation of materials or the generation of electricity.

nucleus

The small, positively charged core of an atom that contains nearly all of the atom's mass.

nuclide

An atomic nucleus specified by its atomic weight, atomic number, and energy state. A radionuclide is a radioactive nuclide.

once-through (cooling system)

A cooling system that utilizes water from a river one time for cooling and then returns it to the river.

organic degreasers

Cleaning agents having organic chemical structures.

outcrop

Part of a geologic formation above the surface of the earth.

Paleocene
Epoch of Tertiary Period between the Gulfian of the Cretaceous Period and before the Eocene.

particulates
Solid particles small enough to become airborne.

pD
The negative log of the deuterium (heavy hydrogen) ion concentration in solution; analogous to the term pH, which refers to the normal hydrogen ion concentration.

penplain
Almost featureless, plain land surface.

perched
A water-bearing area of small lateral dimensions lying above a more extensive aquifer.

permeability
Ability of water to flow through porous rock or soil.

person-rem
The radiation dose commitment to a given population; the sum of the individual doses received by a population segment.

pH
A measure of the hydrogen ion concentration in aqueous solution; specifically, the negative logarithm of the hydrogen ion concentration. Acidic solutions have a pH from 0 to 7; basic solutions have a pH greater than 7.

photon
Electromagnetic radiation; a quantum of electromagnetic energy having properties of both a wave and a particle but without mass or electric charge.

physiography
Description of earth surface features, including air and water as well as land.

Piedmont province
Large area forming a plateau at the base of the Appalachian mountains, extending from New Jersey to Alabama.

piezometric maps
Lines of equal groundwater pressure drawn on a map.

piezometric surface
The surface to which water in an aquifer would rise by hydrostatic head.

Plant stream

Any natural stream on the Savannah River Plant. Surface drainage of the Plant is via these streams to the Savannah River.

Pleistocene

An epoch of the Quaternary Period between Pliocene and Holocene.

Pliocene

An epoch of the Tertiary Period between Miocene and Pleistocene.

plume

The visible emission into the air from a flue, chimney, or cooling tower. Also, a segment or area within a body of water that has measurably distinct characteristics (e.g., higher temperatures as from heated effluent).

pollution

The addition of any undesirable agent to an ecosystem in excess of the rate at which they can be degraded, assimilated, or dispersed by natural processes.

ppb

Parts per billion (10^{-9}); one thousandth of a part per million.

ppm

Parts per million. This unit is commonly used to represent the degree of pollutant concentration when the concentration is small. In air, ppm is usually volume pollutant per one million volumes of air; in water, a weight per one million weight units.

primary road

Interstate, state, and regional routes including rural arterial routes and their extensions into or through urban areas.

pyrite

Isometric mineral: FeS_2 (iron sulfide).

quality factor

The factor by which absorbed dose, in rads, is multiplied to obtain a quantity expressing the irradiation incurred by various biological tissues taking into account the biological effectiveness of the various types of radiation.

quartz

Crystalline silica: SiO_2 .

quartzite

Very hard, metamorphosed sandstone.

Quaternary age
The period from the end of the Tertiary age to the present.

rad
Acronym for radiation absorbed dose, the basic unit of absorbed dose equal to the absorption of 0.01 joule per kilogram of absorbing material.

radiation
The emitted particles and photons from the nuclei of radioactive atoms. Some elements are naturally radioactive whereas others are induced to become radioactive by bombardment in a reactor. Naturally occurring radiation is indistinguishable from induced radiation.

radiation detection instrument
Devices that detect and record the characteristics of ionizing radiation.

radiation monitoring
Continuous or periodic determination of the amount of radiation present in a given area.

radiation protection
Legislation, regulations, and measures to protect the public and industrial laboratory workers from harmful exposure to radiation.

radiation shielding
Reduction of radiation by interposing a shield of absorbing material between a radioactive source and a person, laboratory area, or radiation-sensitive device.

radiation standards
Permissible exposure levels of radiation and regulations governing same.

radioactivity
The spontaneous decay or disintegration of unstable atomic nuclei, accompanied by the emission of radiation.

radioisotopes
Nuclides of the same element (same number of protons in their nuclei) that differ in the number of neutrons and that spontaneously emit particles or electromagnetic radiation.

receiving waters
Rivers, lakes, oceans, or other bodies of water into which treated or untreated wastewaters are discharged.

recirculating (cooling system)
A cooling system that uses the same water cyclically to absorb heat and be cooled again. A percentage of new water must be added continuously to make up for evaporative and blowdown losses.

rem

Acronym for roentgen equivalent man, the unit of dose for biological absorption. It is equal to the product of the absorbed dose in rads, a quality factor, and a distribution factor.

residence time

The period of time during which a substance resides in a designated area.

roentgen (R)

A unit of exposure to ionizing radiation equal to or producing one coulomb of charge per cubic meter of air.

runoff

The portion of rainfall, melted snow, or irrigation water that flows across ground surface and eventually is returned to streams. Runoff can carry pollutants into receiving waters.

sandstone

Clastic rock containing large, individual particles visible to the unaided eye.

sanitary landfilling

An engineered method of solid waste disposal on land in a manner that protects the environment. Waste is spread in thin layers, compacted to the smallest practical volume, and covered with soil at the end of each working day.

SCDHEC

South Carolina Department of Health and Environmental Control

screen

Tool used to allow particles of a certain size through while retaining larger particles.

secondary road

A rural, major collector route.

sedimentation

The settling of excess soil and mineral solids of small particle size contained in water.

seep lines

Small zone where water leachate percolates slowly to the surface; a series of groundwater or leachate springs.

seismic

Pertaining to any earth vibration, especially an earthquake.

seismicity

The tendency toward the occurrence of earthquakes.

- settling tank**
A tank in which settleable solids are removed by gravity.
- sewage**
The total of organic waste and wastewater generated by an industrial establishment or a community.
- sewer**
Any pipe or conduit used to collect and carry away sewage or stormwater runoff.
- sewerage**
The entire system of sewage collection, treatment, and disposal.
- shield**
An engineered body of absorbing material used to protect personnel from radiation.
- short-lived nuclides**
Radioactive isotopes with half-lives no greater than about 30 years (e.g., cesium-137 and strontium-90).
- siliceous cement**
Cement with an abundance of silica.
- siltstone**
Silt having the texture and composition of shale, but lacking its fine lamination.
- sink**
An area from which water drains or is removed.
- sludge**
The precipitated solids (primarily oxides and hydroxides) that settle to the bottom of the storage tanks containing liquid high-level waste.
- slug**
Small, isolated body of water.
- slurry**
A suspension of solid particles (sludge) in water.
- softwoods**
Trees, particularly evergreens and shrubs, that produce seeds in a cone.
- SO₂**
Sulfur dioxide, a heavy pungent colorless gas (formed in the combustion of coal). SO₂ in high concentration is considered a major air pollutant.

SO_x
The oxides of sulfur, primarily SO₂ and SO₃. SO_x is a common air pollutant.

sparger
A discharge nozzle that provides quick dispersion of one fluid (liquid or gas) into another.

spill
The accidental release of radioactive material.

spray irrigation
The practice of dispersing treated aqueous effluents by spraying land in controlled amounts. Treated effluent is rich in nutrients that can be utilized by plants.

SREL
Savannah River Ecological Laboratory, an ecology research institution operated by the University of Georgia under contract from DOE.

SRL
Savannah River Laboratory.

SRP
Savannah River Plant.

stable
Not radioactive.

stack
A vertical pipe or flue designed to exhaust gases and suspended particulates.

stack gases
Gases emitted from a stack.

stationary source
A source of emissions into the environment that is fixed rather than moving, as an automobile.

storage
Retention of radioactive waste in manmade containment, such as a tank or vault, in a manner permitting retrieval; distinguished from disposal, which implies no retrieval.

storage coefficient
Volume of water released from storage in a vertical column of 0.93 square meter when the water table declines 0.93 meter.

stratified

Formed or arranged in layers.

stratigraphy

Division of geology dealing with the definition and description of rocks and soil of both major and minor natural divisions.

study area

A specific geographic area isolated from surrounding areas for the purpose of examining and analyzing specific phenomena and activities.

surface water

All water on the surface, as distinguished from groundwater.

surficial deposit

Most recent geological deposit lying on bedrock or on or near the earth's surface.

Tertiary age

First period of Cenozoic era, thought to be between 65 and 2 million years ago.

thermal pollution

Degradation of water quality by introduction of a heated effluent.

threshold dose

The minimum dose of a given substance that produces a measurable environmental factor.

tolerance

The relative capability of an organism to endure an unfavorable environmental factor.

topography

The configuration of a surface area, including its relief or relative elevations and the position of its natural and manmade features.

toxicity

The quality or degree of being poisonous or harmful to plant or animal life.

transmissivity

The rate at which water of prevailing kinematic viscosity is transmitted through a unit width under a unit hydraulic gradient.

Triassic Period

First period of the Mesozoic era, thought to be between 225 and 190 million years ago.

tritium (H-3)

A radioactive isotope of hydrogen, a weak beta emitter with a half-life of 12.5 years.

TSP

Total suspended particulates, the concentration of particulates in suspension in the air irrespective of the nature, source, or size of the particulates.

turbidity

Measure of sediment or suspended foreign particle concentration in solution.

unconsolidated

Loosely arranged or unstratified sediment.

USGS

United States Geological Survey.

venting

Release of gases or vapors under pressure to the atmosphere.

waste heat

Heat in materials at temperatures that are close to ambient and hence not valuable for production of power. Waste heat must be discharged to the environment.

water pollution

Presence of one or more contaminants in such degree as to be detrimental to the intended use of the water.

watershed

The area drained by a stream.

water table

The upper surface of groundwater.

zooplankton

Planktonic (floating) animals that supply food for fish.

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APPENDIX A

IDENTIFICATION OF COOLING WATER ALTERNATIVES FOR EVALUATION IN THE EIS

A.1 INTRODUCTION

This appendix describes the cooling water alternatives considered for C- and K-Reactors and the D-Area coal-fired powerhouse. It also discusses the process used to identify the cooling water alternatives that are evaluated in this environmental impact statement (EIS).

A.2 INITIAL ALTERNATIVES

As documented in the Thermal Mitigation Study (DOE, 1984), DOE initially considered two categories of cooling water alternatives: (1) those that would provide some reduction in the temperature of thermal discharges but that would not meet the 32.2°C Class B water classification standard of the State of South Carolina; and (2) those that could meet the 32.2°C water classification standard.

A.2.1 ALTERNATIVES NOT MEETING THE 32.2°C STANDARD

For alternatives that would not meet Class B water classification standards (such as rubble dams, small cooling lakes, and the current once-through cooling water systems), the South Carolina legislature and the U.S. Environmental Protection Agency (EPA) would have to approve a new stream classification (i.e., a change in the designation of several onsite streams from Class B to some other classification) after DOE had submitted a use attainability analysis in accordance with EPA regulations (40 CFR 131).

Because of the concern over both the applicability of EPA and State regulations that prohibit designating the use of a stream for waste transport or waste assimilation and the inapplicability of criteria contained in EPA's regulations [40 CFR 131.10(g)] by which a change in designated uses could be justified, DOE eliminated from further consideration those alternatives that would not meet Class B water classification standards.

The following items describe the initial cooling water alternatives for C- and K-Reactors that were eliminated:

- Spray canals. This alternative would add a gravity-powered spray cooling system to the cooling water outlets of C- and K-Reactors to cool the discharged water by spraying it into the air before it enters the receiving water body. Both the 68°C maximum discharge temperature and the 66°C average summer temperature would be only slightly below the water temperatures that result from direct discharge (i.e., 73°C and 71°C, respectively).

- Small lakes. This system would use five to ten small rubble dams each on Four Mile Creek and Pen Branch to create small lakes; it would provide some thermal mitigation, compared to direct discharge, to the lower portions of these waterways and to the Savannah River swamp. Under extreme summer conditions, the 45°C discharge temperatures would represent a 28°C reduction below direct discharge (73°C), but they would not meet the 32.2°C temperature standard at any time during the year.
- Small lakes with upstream spray cooling (one set). This alternative is very similar to the small lakes alternative (above), but would include a gravity spray module in the outfall canal. It would result in some limited thermal mitigation in comparison to direct discharge, but would not provide much more cooling than the small lakes alternative alone. The 32.2°C water classification standard would not be met at any time during the year.
- Small lakes with upstream and downstream spray cooling (two sets). This alternative would add two gravity spray cooling modules to the basic small lakes alternative described above. The first spray system would obtain some cooling before the discharge water enters the receiving water body. The second spray module would be in the last shallow lake formed in either stream. The cooling from this system would be about 5°C greater than that resulting from the small lakes with upstream spray cooling (one set) described above. In comparison to direct discharge, this alternative would reduce water temperatures from 73°C to 39°C under extreme summer conditions and from 69°C to 34°C during the spring. It would be in compliance with the 32.2°C temperature limit only during the winter (29°C).
- Energy recovery systems. The systems that were considered included both onsite steam generation and the use of a Rankine cycle to generate electricity. The option of onsite steam generation would remove only 0.3 percent of the heat from the effluent stream, or a 0.3°C drop in effluent temperature at the outfall. The Rankine cycle would lower the effluent temperature from 71°C to 49°C.

A.2.2 ALTERNATIVES MEETING THE 32.2°C STANDARD

For those alternatives that could meet the Class B water classification standards, DOE identified subcategories of potential generic cooling water systems for C- and K-Reactors and for the D-Area coal-fired powerhouse. The subcategories identified for C- and K-Reactors consisted of cooling towers, cooling lakes and ponds, and cooling lake/pond and cooling tower combinations. For the D-Area powerhouse, the subcategories included cooling towers, direct discharge to the Savannah River, and increased flow with mixing. DOE then developed minimum requirements for the identification in more detail of the specific alternatives in each subcategory. These requirements included sufficient surface area in cooling lakes or ponds for heat dissipation, and sufficient cooling capacity in once-through and recirculating cooling towers

to attain a 32.2°C discharge temperature during extreme meteorological conditions. Using these minimum requirements, DOE initially identified 22 potential cooling water alternatives for C- and K-Reactors and four alternatives for D-Area. The following list describes these alternatives:

C-Reactor Alternatives

- C-1 1200-acre once-through cooling lake on Four Mile Creek with an embankment about 1.6 kilometer above Road A
- C-2 1200-acre recirculating cooling lake on Four Mile Creek with an embankment about 1.6 kilometer above Road A
- C-3 1400-acre once-through cooling lake between Pen Branch and Four Mile Creek below the railroad track
- C-4 Recirculating cooling tower with a 20-acre offstream holding pond
- C-5 Once-through cooling tower with a 100-acre offstream holding pond
- C-6 Once-through cooling tower to a 500-acre once-through cooling lake on a tributary of Four Mile Creek with an embankment about 305 meters above the confluence with Four Mile Creek
- C-7 800-acre cooling lake with a 400-acre hot arm to a once-through cooling tower with an embankment on Four Mile Creek about 1280 meters above Road A
- C-8 1700-acre once-through cooling lake on Four Mile Creek with an embankment about 1280 meters above Road A
- C-9 1700-acre once-through cooling lake on Four Mile Creek with an embankment about 152 meters above Road 4, and the reactor discharge pumped to the cooling lake

K-Reactor Alternatives

- K-1 1400-acre once-through cooling lake between Pen Branch and Four Mile Creek above the railroad track
- K-2 1400-acre recirculating cooling lake between Pen Branch and Four Mile Creek above the railroad track
- K-3 1300-acre once-through cooling lake on Pen Branch with an embankment 1219 meters below Road C
- K-4 1300-acre recirculating cooling lake on Pen Branch with an embankment 914 meters below Road C
- K-5 Recirculating cooling tower with a 20-acre offstream holding pond

- K-6 Once-through cooling tower with a 100-acre offstream holding pond
- K-7 Once-through cooling tower to a 600-acre once-through cooling lake on Indian Grave Branch with an embankment about 305 meters above the confluence with Pen Branch
- K-8 800-acre cooling lake with a 400-acre hot arm to a once-through cooling tower with an embankment located about 610 meters above Road A on Pen Branch
- K-9 1600-acre once-through cooling lake with an embankment in the same location as the 800-acre lake with 400-acre hot arm (above)
- K-10 1700-acre once-through cooling lake on Pen Branch with an embankment about 2134 meters below Road C, and the reactor discharge pumped to the cooling lake

C- and K-Reactors Alternatives

- C/K-1 3000-acre recirculating cooling lake on Mill Creek with an embankment about 610 meters above the confluence with Tinker Creek
- C/K-2 3000-acre once-through cooling lake on Mill Creek with an embankment about 610 meters above the confluence with Tinker Creek

C-, K-, and L-Reactors Alternatives

- C/K/L-1 3000-acre once-through and recirculating cooling lake on Mill Creek with an embankment about 610 meters above the confluence with Tinker Creek

D-Area Powerhouse Alternatives

- D-1 Direct discharge to the Savannah River
- D-2 Once-through cooling tower
- D-3 Increased flow with mixing
- D-4 Recirculating cooling tower

A.3 SCREENING OF ALTERNATIVES

After the identification of the 26 cooling water alternatives that could meet Class B water classification standards, DOE used a screening process to determine which of these systems would be the most reasonable for implementation.

As documented in the Thermal Mitigation Study, the screening process consisted of the successive application of exclusionary criteria and discriminatory criteria. The application of "exclusionary" criteria led to the elimination of five cooling-lake alternatives for C- and K-Reactors. The "exclusionary" criteria are listed below:

1. The temperature of the receiving stream shall not exceed 32.2°C after mixing unless a Section 316(a) demonstration can be successfully performed.
2. The temperature of a receiving stream shall not be raised more than 2.8°C above ambient after mixing unless a Section 316(a) demonstration can be successfully performed.
3. Cooling lakes shall have a minimum surface area of 400 acres at a temperature of 32.2°C or less to support a successful Section 316(a) demonstration.
4. The average annual production loss shall be equal to or less than 10 percent for the purpose of screening.

This screening step eliminated the following alternatives:

No.	Alternative	Reasons for elimination
<u>C-Reactor</u>		
C-2	1200-acre recirculating cooling lake	Too small to provide needed cooling capacity
C-8	1700-acre once-through cooling lake	Hot arm of about 500 acres would not provide required cooling capacity
<u>K-Reactor</u>		
K-2	1400-acre recirculating cooling lake	Too small to provide needed cooling capacity
K-4	1300-acre recirculating cooling lake	Too small to provide needed cooling capacity
K-9	1600-acre once-through cooling lake	Hot arm of about 500 acres would not provide required cooling capacity

DOE screened the possible alternatives for the D-Area coal-fired powerhouse in the same manner as that used for the two reactors. However, it did not apply the criteria for maintaining a surface area of 400 acres at 32.2°C or less. The process found all four of the possible alternatives for the powerhouse to be feasible and eliminated none at this point.

The final step in the screening process was the application of the five "discriminatory" criteria listed below to identify "reasonable compliance alternatives":

1. Environmental impacts (i.e., thermal and flow effects resulting from the effluent discharge; habitat modifications such as impacts to wetlands and uplands; water quality; intake/discharge rates; impingement and entrainment; impacts to endangered and threatened species; and transport of radionuclides)
2. Implementation schedule (i.e., the estimated time to construct the alternative)
3. Costs (capital and operating)
4. Engineering and construction (i.e., the technical feasibility of engineering and constructing the alternative, such as pumping hot water over long distances, close approaches to wet bulb temperatures, nonstandard engineering and construction techniques)
5. Relative operating complexity (i.e., multiple reactor cooling systems versus recirculation systems versus once-through systems)

After the application of the discriminatory criteria, DOE eliminated the following nine alternatives:

No.	Alternative	Reasons for elimination
<u>C-Reactor</u>		
C-1	1200-acre once-through cooling lake	Environmental impacts, production loss, relative costs
C-9	1700-acre once-through cooling lake	Environmental impacts, relative costs, scheduling
<u>K-Reactor</u>		
K-3	1300-acre once-through cooling lake	Environmental impacts, production loss, relative costs
K-10	1700-acre once-through cooling lake	Environmental impacts, relative costs, scheduling
<u>C- and K-Reactors Combined</u>		
C/K-1	3000-acre recirculating cooling lake	Relative costs, production loss, operating complexity, engineering considerations
C/K-2	3000-acre once-through cooling lake	Environmental impacts, operating complexity, relative costs

No.	Alternative	Reasons for elimination
<u>C-, K-, and L-Reactors Combined</u>		
C/K/L-1	3000-acre once-through and recirculating cooling lake	Operating complexity, scheduling
<u>D-Area Powerhouse</u>		
D-2	Once-through cooling tower	Relative costs, operating complexity compared to direct discharge
D-4	Recirculating cooling tower	Relative costs, operating complexity compared to direct discharge

As a result of the successive application of the exclusionary and discriminatory criteria, DOE identified the following alternatives as reasonable for implementation for C- and K-Reactors and the D-Area coal-fired powerhouse:

C-Reactor Alternatives

- C-3 1400-acre once-through cooling lake between Pen Branch and Four Mile Creek below the railroad track
- C-4 Recirculating cooling tower with a 20-acre offstream holding pond
- C-5 Once-through cooling tower with a 100-acre offstream holding pond
- C-6 Once-through cooling tower to a 500-acre once-through cooling lake on a tributary of Four Mile Creek with an embankment about 305 meters above the confluence with Four Mile Creek
- C-7 800-acre cooling lake with a 400-acre hot arm to a once-through cooling tower with an embankment on Four Mile Creek about 1280 meters above Road A

K-Reactor Alternatives

- K-1 1400-acre once-through cooling lake between Pen Branch and Four Mile Creek above the railroad track
- K-5 Recirculating cooling tower with a 20-acre offstream holding pond
- K-6 Once-through cooling tower with a 100-acre offstream holding pond

- K-7 Once-through cooling tower to a 600-acre once-through cooling lake on Indian Grave Branch with an embankment about 305 meters above the confluence with Pen Branch
- K-8 800-acre cooling lake with a 400-acre hot arm to a once-through cooling tower with an embankment located about 610 meters above Road A on Pen Branch

D-Area Powerhouse Alternatives

- D-1 Direct discharge to the Savannah River
- D-2 Increased flow with mixing

A.4 ALTERNATIVES CONSIDERED IN THIS EIS

As part of the scoping process, DOE invited interested parties to comment on the alternatives it would consider in this environmental impact statement (Federal Register, 50 FR 30728). Because of unfavorable topographic features in the areas around C- and K-Reactors and the resulting high capital costs for constructing large cooling lakes, DOE proposed that this statement consider only the once-through and recirculating cooling towers. In addition, DOE proposed that it not perform a detailed evaluation of the alternative calling for direct discharge of D-Area effluents to the Savannah River because of its higher capital costs, the longer schedule for implementation, and the potential reduction in habitat for endangered species that would be caused by the reduction in flow in Beaver Dam Creek. During the scoping period, DOE received no comments related to its preliminary determination of reasonable alternatives to be considered in the environmental impact statement.

Based on the screening process as documented in the Thermal Mitigation Study (DOE, 1984) and DOE's preliminary determination (50 FR 30728), DOE has decided to consider in detail in this environmental impact statement the alternatives of once-through and recirculating cooling towers for the C- and K-Reactors in addition to the "no-action" alternative (required by the Council on Environmental Quality for implementing the procedural provisions of the National Environmental Policy Act). For the D-Area coal-fired powerhouse, the Department has decided to consider in detail the alternatives of increased pumping to the raw water basin, direct discharge to the Savannah River, and "no action."

REFERENCE

- DOE (U.S. Department of Energy), 1984. Thermal Mitigation Study, Compliance with Federal and South Carolina Water Quality Standards, Savannah River Plant, Aiken, South Carolina, DOE/SR-5003, Savannah River Operations Office, Aiken, South Carolina.

APPENDIX B

THERMAL MODELING

B.1 INTRODUCTION

The thermal performance information presented in Sections 2.2, 2.3, and 2.4 of this environmental impact statement (EIS) was calculated with the aid of three models. The Cooling-Tower Performance (CTPERF) model computes effluent stream (water and air) temperatures from mechanical-draft towers as a function of influent stream properties and tower design. The Surface-water Heat, Savannah River Plant (SHSRP) model computes downstream temperatures along the SRP streams (Four Mile Creek, Pen Branch, Steel Creek, and Beaver Dam Creek) that receive cooling water effluent. The latter computation is performed as a function of effluent stream and extant meteorological properties. The Savannah River Dilution-D Area (SRDD) model computes the temperature or dilution distribution in the Savannah River from D-Area based on discharge design and river flow.

In addition to a discussion of these three thermal performance models, this appendix also provides a brief description of the model (FOG) that has been used to calculate cooling system fogging, icing, visible plumes, and drift deposition.

B.2 COOLING-TOWER PERFORMANCE MODEL (CTPERF)

B.2.1 MODEL DESCRIPTION

The cooling of artificially heated water, such as the heated secondary cooling water at C- and K-Reactors, is a surface transport phenomenon between the water and the heat receptor (in this case the atmosphere). The mechanical-draft cooling towers described in Chapter 2 of this EIS are efficient in this heat transfer because they maximize the exposed surface area of the water (via droplet formation) and introduce a heat sink (air) that does not contain residual heat from tower operation (due to the buoyancy of the heated air stream).

The heat-transfer process involves, chiefly, the transfer of latent heat due to the evaporation of a small portion of the water; a secondary cooling process is the transfer of heat due to the temperature difference between air and water. The theoretical limit to which the influent water temperature can be cooled is determined by the temperature and moisture content of the influent air stream. The wet-bulb temperature (t_{wb}), which is the temperature of saturated air at the same enthalpy (heat content) as the influent air, is an indication of the temperature and moisture content of the influent air and, as such, represents the theoretical limit to which the influent water temperature can be cooled. Practically, the cold-water temperature approaches, but does not equal, the wet-bulb temperature. The closeness of the approach depends on tower design parameters such as air-water contact time and droplet size (Perry, 1963).

The present analysis is based on the generally accepted Merkel equation (Perry, 1963)

$$\frac{KaV}{L} = \int_{t_2}^{t_1} \frac{dt}{h'-h} \quad (1)$$

where K = mass transfer coefficient, gm/hr/m²
a = contact area, m²/m³ of tower volume
V = active cooling volume, m³
L = water flow rate, gm/hr
h' = enthalpy of saturated air at the water temperature, cal/gm
h = enthalpy of influent air stream, cal/gm
t₁ = temperature of influent water stream, °C
t₂ = temperature of effluent water stream, °C

Equation 1 expresses the mechanism of each droplet of water being surrounded by a film of air and the enthalpy difference between the film and surrounding air providing the driving force for the heat transfer. The left-hand side of Equation 1 is entirely in terms of tower-operating parameters, while the right-hand side is entirely in terms of air and water properties.

The latter characteristic of Equation 1 facilitates its use to compute tower performance. Tower design conditions (t₁, t₂, and t_{wb}) completely specify the value of the integral on the right-hand side of Equation 1. This value, called the tower characteristic, is dependent only on tower design parameters. Accordingly, t₂ can be obtained by implicitly solving Equation 1 for any given air wet-bulb temperature (t_{wb}), which defines h, hot-water temperature (t₁), and tower characteristic (determined, as described above, from design conditions). In addition, effluent air temperature is calculated by a heat balance approach; that is, the heat lost by the water in the tower is equated to the heat gained by the air.

As discussed above, the enthalpy difference h'-h is the driving force for cooling. The larger this difference, the more rapid the cooling of the water. Mathematically, the right-hand side of Equation 1 is the area under the $\frac{1}{h'-h}$ vs. t curve from t₂ to t₁.

At large values of t (i.e., close to t₁), the fraction $\frac{1}{h'-h}$ is very small.

As t decreases, the fraction correspondingly increases until, at t = t_{wb}, the fraction becomes infinite (the theoretical limit of cooling). This behavior of the integral can be related to the left-hand side of Equation 1, which indicates (for given flow rates) the tower characteristics. The cooling of the water from its initially high temperatures is very rapid and uses a small fraction of the tower. The cooling of the water at low temperatures is very slow and uses the major part of the tower. In terms of tower design, the size of the tower increases (approximately) exponentially for each increment of cooling desired.

CTPERF model results have shown excellent comparison with published tower design curves (Dickey and Cates, 1973).

B.2.2 MODEL USE

CTPERF was used to calculate a long-term hourly temperature record of tower effluent water. Influent air wet-bulb temperatures were those measured at Bush Field for the 30-year period 1953 to 1982 (NCDC, 1983). Table B-1 contains minimum, mean, and maximum monthly average wet-bulb temperatures for the period of record. Also included in this table are extreme (high) 1-hour, 1-day, and 5-day values of this parameter.

Once-through tower influent water temperatures, T_1 , were based on monthly average reactor intake (Savannah River) temperatures (DOE, 1984a). These reactor intake temperatures were elevated by the temperature rise through the reactor heat exchangers, which can be described (Neill and Babcock, 1971; NUS Corporation, 1984) as

$$\Delta T = 65.79 - .6568 T_{in} \quad (2)$$

where ΔT = maximum reactor power secondary cooling water temperature rise across reactor heat exchangers, °C

T_{in} = reactor intake temperature, °C

Adding T_{in} to Equation 2 yields

$$T_1 = 65.79 + .3433 T_{in} \quad (3)$$

Table B-1 contains monthly average and extreme reactor intake and tower influent temperatures for a once-through cooling system.

Recirculating influent water temperatures are determined by imposing Equation 3 on the tower performance calculations. That is, rather than specifying the influent tower water temperature, T_1 , and calculating the effluent water temperature, T_2 , the calculation imposes the functional relationship

$$T_1 = 65.79 + .3433 T_2 \quad (4)$$

onto the implicit cooling-tower calculations.

B.2.3 MODEL RESULTS

The above information was used to calculate the 30-year, hour-by-hour cooling-tower effluent temperature, T_2 , for once-through (preliminary design conditions: $T_1 = 80^\circ\text{C}$, $T_2 = 32.2^\circ\text{C}$, $T_{wb} = 26.7^\circ\text{C}$) and recirculating (preliminary design conditions: $T_1 = 70^\circ\text{C}$, $T_2 = 12.8^\circ\text{C}$, $T_{wb} = 10^\circ\text{C}$) towers (NUS Corporation, 1984). Table B-1 includes the minimum, mean, and maximum monthly average effluent water temperature for each system type. Also

Table B-1. Monthly and Extreme Cooling-Tower Analysis Temperatures (°C)

Temperature	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Extreme
Wet-bulb temperature													
Minimum monthly average	-1	1	4	11	15	19	21	21	16	10	6	2	25 ^a
Mean monthly average	4	5	9	13	17	21	22	22	20	14	9	5	26 ^b
Maximum monthly average	11	10	12	16	20	22	24	23	21	17	11	11	28 ^c
Savannah River temperature													
Monthly average	8	8	11	15	18	21	23	23	22	19	15	11	28 ^b
Once-through tower influent temperature, monthly average	69	69	70	71	72	73	74	74	73	72	71	70	76
Once-through tower effluent temperature													
Minimum monthly average	23	24	24	26	27	29	30	29	28	26	25	24	32 ^a
Mean monthly average	24	25	26	27	28	29	30	30	29	27	26	25	32 ^b
Maximum monthly average	26	26	26	28	29	30	31	31	30	28	26	26	33 ^c
Recirculating tower influent temperature													
Minimum monthly average	68	68	69	70	72	73	73	73	72	70	69	68	75 ^a
Mean monthly average	69	69	70	71	72	73	74	74	73	71	70	69	75 ^b
Maximum monthly average	71	70	71	72	73	74	74	74	73	72	71	71	75 ^c
Recirculating tower effluent temperature													
Minimum monthly average	6	7	9	14	17	20	21	21	18	13	10	7	25 ^a
Mean monthly average	9	10	12	15	19	21	23	23	21	16	12	10	26 ^b
Maximum monthly average	14	13	14	17	21	23	24	24	22	19	14	14	28 ^c

^a5-day average
^b1-day average
^c1-hour average

included in this table are the extreme 1-hour, 1-day, and 5-day values of T_2 . The effluent water temperatures listed in Table B-1 are those included in the Chapter 2 thermal performance analyses for seasonal average (winter = January-February, spring = April-May, summer = July-August) and extreme conditions (i.e., 1-hour, 1-day, and 5-day extreme temperatures).

The once-through towers are to State Class B water classification standards of a maximum instream temperature of 32.2°C at the point of discharge to the creeks. Table B-1 shows that the tower discharge will meet this requirement except for the 1-hour extreme case (1°C over the limit). Final tower design and operation will ensure that the 32.2°C requirement is always met.

The recirculating towers are also to meet State Class B water classification standards. Preliminary design parameters suggest towers designed such that tower effluent (reactor inflow) temperatures are at least as low as the reactor inflow temperatures in the existing system (Savannah River temperatures). A comparison of the mean recirculating tower effluent temperatures to the Savannah River temperatures in Table B-1 indicates that the former are actually slightly lower than the latter (annual average). Differences in the two occur during late winter/early spring (when the air temperature increases faster than the river temperatures) and fall (when the air temperature decreases faster than the river temperature).

B.3 SURFACE-WATER HEAT, SAVANNAH RIVER PLANT MODEL (SHSRP)

B.3.1 MODEL DESCRIPTION

As in the case of CTPERF, the cooling of artificially heated surface waters is a transport phenomenon between the water and the heat receptor (the atmosphere). Unlike the cooling towers, however, other processes contribute to this heat transfer.

The flux of heat across the water surface has various components that can be either positive (heat entering the water) or negative (heat exiting the water). The major processes are solar radiation, atmospheric radiation, back radiation from the water body, evaporation, and conduction.

The net solar heat flux, θ_{sn} , consists of incident solar radiation minus reflected solar radiation. The incident, clear-sky, solar radiation is a function of latitude, time of day, and time of year. In addition, reflection, scattering, and absorption by gases, water vapor, and particulates in the atmosphere will affect this term. Accordingly, empirical representations are usually used to calculate the temporal distribution of incident solar radiation at a particular site. Reflected solar radiation from the water surface ranges from 5 to 10 percent of incident radiation (Thackston and Parker, 1971). A value of 6 percent was used in producing the baseline data for this study. The reduction of incident solar radiation by cloud cover is described by the factor $(1 - .65c)$ where c is the cloud cover (range of 0 to 1). The net temporal distribution of solar radiation used as the baseline for this study was produced by the UHSPOND code (Codell and Nuttle, 1980). The back

radiation from the water surface is essentially "black body" radiation. The latter is described by the Stephan-Boltzmann law (Bird, Stewart, and Lightfoot, 1966):

$$\theta_b = \epsilon \sigma (T_s + 273)^4 \quad (5)$$

where ϵ = atmospheric emissivity (1 for a theoretical black body), θ = Stephan-Boltzmann constant (1.17×10^{-6} cal/m²-day-°K), and T_s+273 = absolute temperature of the water surface in °K. The emissivity of the water is well-known as 0.97 (Ryan and Stolzenbach, 1972). The long-wave atmospheric radiation, θ_a , is also described by Equation 5, except that the temperature used is that of the atmosphere, T_a . The emissivity of the atmosphere can be empirically described as

$$\epsilon = 9.4 \times 10^{-6} (T_a + 273)^2 (1 + 1.17c^2) \quad (6)$$

where the cloud-cover term describes the darkening of the sky and the attendant increase in emissivity. The net atmospheric radiation, θ_{an} , is taken as 97 percent (the water surface reflecting 3 percent) of the incident radiation (Ryan and Stolzenbach, 1972).

The evaporative heat flux, θ_e , from the water surface is mechanically equivalent to the latent heat of vaporization of the water being evaporated into an atmospheric boundary layer (which is in equilibrium with the water surface) and subsequently transported to the atmosphere. This transport (convection) of heat has two components: forced convection (due to the wind) and free convection (due to buoyancy effects).

The forced convection term, θ_{e1} , is empirically described as

$$\theta_{e1} = kW_2 (e_s - e_a) \quad (7)$$

where k is a constant, W_2 is the wind speed 2 meters above the water surface in meters per second, e_s is the saturated vapor pressure at the temperature of the water surface in mm Hg, and e_a is the vapor pressure of the air.

The form of the free convection term, θ_{e2} , is taken from experimental work of free convection over a flat plate modified by the fact that water vapor is lighter than air (and, therefore, evaporation increases the buoyancy forces) (Ryan and Stolzenbach, 1972). The result is

$$\theta_{e2} = 18.4 (T_{sv} - T_{av})^{1/3} (e_s - e_a) \quad (8)$$

where $T_v = (T+273)/(1-378e/p)$, $e = e_a$ and $T = T_a$ for $T_v = T_{av}$, $e = e_s$ and $T = T_s$ for $T_v = T_{sv}$, and p = atmospheric pressure in mm Hg.

The total evaporative heat flux, θ_e , is then the sum of $\theta_{e1} + \theta_{e2}$. A value of $k = 31.3$ (for the units given above) has been found to be appropriate (Ryan and Stolzenbach, 1972).

Previous studies have shown that the evaporative heat flux as calculated by Equations 7 and 8 is too large. A multiplicative constant, C, can be defined that results in a better approximation to the actual flux. A value of 0.78 has been found elsewhere (Firstenberg and Fisher, 1976) and is used here.

Heat conducted from the water to the atmosphere via the atmospheric boundary layer must be transported analogously to the convection of evaporative heat flux. The heat conduction flux, θ_c , is related to θ_e through the Bowen Ratio; that is

$$\theta_c/\theta_e = R(T_s - T_a)/(e_s - e_a) \quad (9)$$

where $R = .46 \text{ mm Hg}/^\circ\text{C}$ (Ryan and Stolzenbach, 1972).

The total heat flux, θ , into the water surface is then:

$$\theta = \theta_{sn} + \theta_{an} - \theta_b - \theta_e - \theta_c \quad (10)$$

Equation 10 allows the total heat flux to be calculated, given the solar radiation, air temperature, cloud cover, water temperature, wind speed, and relative humidity. For a given set of meteorological conditions, the only variable in this list is the water temperature, T_s . For the site streams, where the flow will be vertically well mixed (due to turbulent and shallow flow) and plug flow in character (due to the long, narrow nature of the streams and the assumed steady flow and meteorology), the equation describing the conservation of heat can be written as (Harleman, 1972)

$$\frac{UdT}{dx} = \frac{\theta}{\rho cd} \quad (11)$$

where U = average cross-section velocity, m/sec

T = water temperature, $^\circ\text{C}$

x = downstream distance, m

ρ = density of water, gm/m^3

c = specific heat of water, $\text{cal}/\text{gm}-^\circ\text{C}$

d = depth, m

θ = total heat flux into the water surface, $\text{cal}/\text{m}^2\text{-sec}$

Equation 11 quantitatively expresses that the change in heat content of the creek over a given distance (left-hand side of equation) is equal to the heat passing through the water surface over this distance (right-hand side of equation). For a given discharge and a given distance, all parameters in Equation 11 are known except for T and θ . Equation 11 together with Equation 10 allows the computation of T vs. x .

To facilitate the computation and illustrate the behavior of the solution, the concepts of surface-heat-exchange coefficient and equilibrium temperature are

introduced. The surface-heat-exchange coefficient, K , relates the change in heat transfer rate to the change in water surface temperature (Edinger and Geyer, 1965):

$$K = - \frac{\partial \theta}{\partial T} \quad (12)$$

The equilibrium temperature, T_e , is the temperature that the water temperature approaches for a given set of meteorological conditions (analogous to the wet-bulb temperature for cooling towers) and is that temperature at which $\theta = 0$ (calculated from Equation 10). Integrating Equation 12 and noting the definition of T_e yields:

$$\theta = -K (T - T_e) \quad (13)$$

which, when substituted in Equation 11, results in:

$$\frac{dT}{T - T_e} = \frac{-KW}{\rho c Q} dx \quad (14)$$

where Q = flow rate, m^3/sec
 W = surface width, m
 $Q/W = Ud$

Equation 14 can be integrated (for constants K , Q , W , and T_e) to give:

$$\frac{T_1 - T_e}{T_2 - T_e} = \exp \left[\frac{KW}{\rho c Q} (x_2 - x_1) \right] \quad (15)$$

where the subscript 1 indicates the inflow location and subscript 2 indicates the outflow location.

In typical applications (e.g., steam power plants) where the heat-exchange temperature rise is relatively small (e.g., $10^\circ C$), Equation 15 can be directly applied. However, for such applications as the highly elevated discharge temperatures from the existing C- and K-Reactor systems, the value of K cannot be considered constant over the large ranges of temperature, $T_1 - T_2$. This is illustrated in Figure B-1, which shows K vs. T for typical site summer meteorological conditions. [Analogous to the cooling tower analysis, the rate of cooling at high temperatures (high K) is much more rapid than that at low temperatures (low K) due to the exponential relationship between K and the water temperature]. Accordingly, SHSRP computes Equation 15 iteratively; that is, a series of small temperature steps, $T_1 - T_2$, are taken and the summation of the corresponding values of $X_2 - X_1$ is calculated. The process is repeated until the summation matches the required value.

B.3.2 MODEL USE

SHSRP was used to calculate downstream temperature distributions during seasonal average meteorological conditions for the various cooling-system alternatives for C- and K-Reactors and the D-Area powerhouse. Meteorological

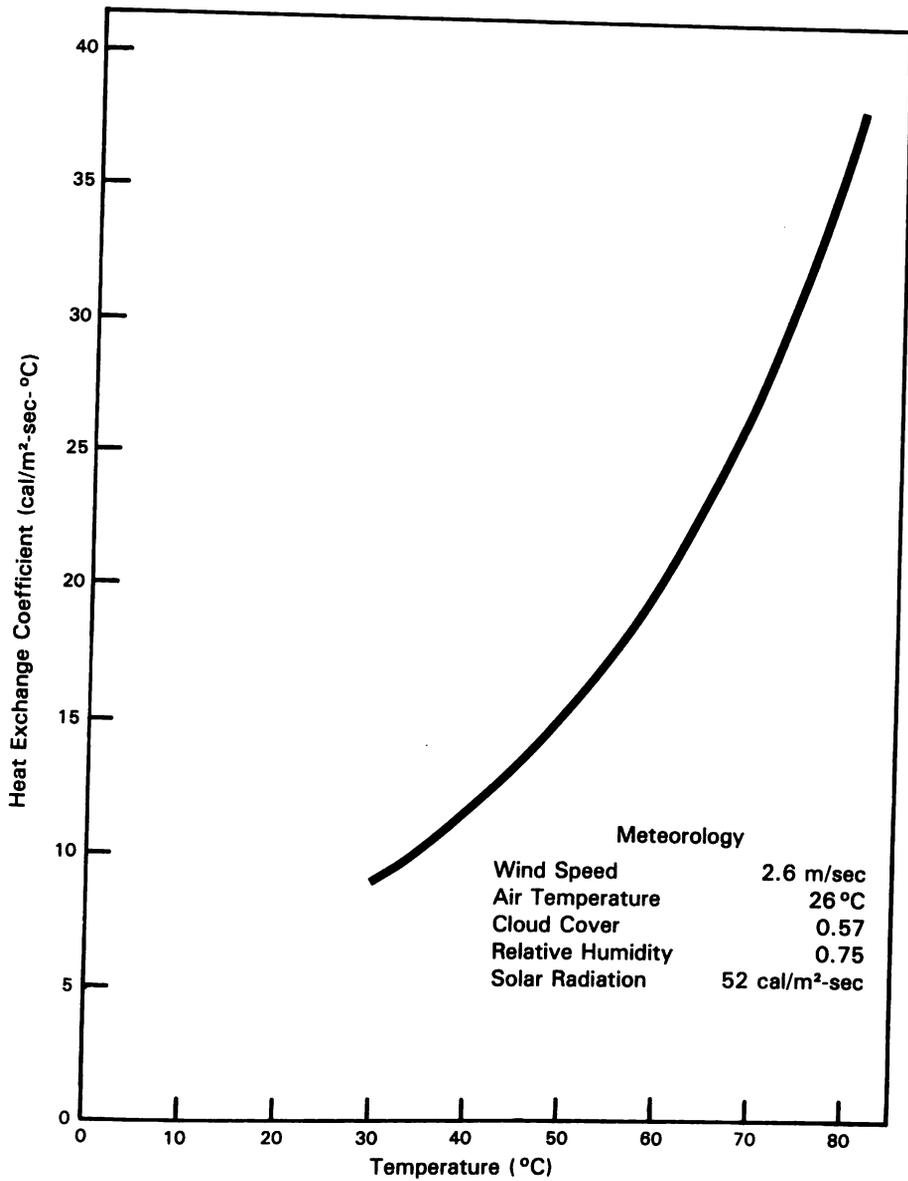


Figure B-1. Heat Exchange Coefficient vs Temperature (Typical Summer Conditions)

conditions (wind speed, air temperature, cloud cover, solar radiation, and relative humidity) were taken as those measured at Bush Field for the 30-year period 1953 to 1982 (NCDC, 1983). Table B-2 contains the minimum, mean, and maximum monthly average meteorological parameter values for the period of record.

Equilibrium temperatures for daily average meteorological conditions were calculated for the 30-year period, and monthly averages of these values are given in Table B-2. July 12-16, 1980, was identified as a severe 5-day period (mean equilibrium temperature = 33°C) and was used in the analysis to illustrate downstream temperature distributions during such conditions.

B.3.3 MODEL RESULTS

The above information was used to calculate the downstream temperatures in Four Mile Creek, Pen Branch, and Beaver Dam Creek during seasonal average (winter = January-February, spring = April-May, summer = July-August) and summer extreme (July 12-16, 1980) meteorological conditions. Downstream temperatures for the various alternatives and creeks, as illustrated in Figure B-2, are compiled in Table B-3.

The tower discharge temperatures are based on the appropriate values from Table B-1. The once-through tower discharge flow rate is 11 cubic meters per second and the recirculating tower discharge (blowdown) flow rate is 0.6 cubic meter per second (DOE, 1984b). The Four Mile Creek and Pen Branch flows, other than reactor effluent, are approximately 0.6 and 0.3 cubic meter per second, respectively, and are assumed to be at equilibrium temperature (Brown et al., 1972).

The existing system discharge flow is approximately 11 cubic meters per second and consists of heat exchanger effluent (at the same temperature as the once-through tower influent) plus auxiliary flow (assumed to be at Savannah River temperature). The D-Area discharge flow is about 2.6 cubic meters per second (4.5 cubic meters per second during summer extreme conditions for the increased pumping alternative); its temperature is equal to the Savannah River temperature plus 8°C (plus 4°C during summer extreme conditions for the increased pumping alternative).

Table B-3 shows the large, incremental change in stream temperatures in going from the existing system to the once-through towers. A further decrease in stream temperatures (as well as a large decrease in stream flow) occurs when recirculating towers are used. Downstream temperatures increase when these systems are used because the equilibrium temperatures (which the stream temperatures approach) are higher than those of the discharge. The downstream temperatures increase because of both positive heat flux (into the water surface) and mixing with creek flow (other than reactor effluent), which is assumed to be at equilibrium temperature.

Table B-2. Monthly and Extreme Meteorological Parameters Used in the Analysis of Downstream Temperatures

Parameter	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Extreme ^a
Wind speed, m/sec													
Minimum monthly average	2.3	2.9	3.2	2.6	2.3	2.1	2.1	2.1	1.9	1.9	2.0	2.3	
Mean monthly average	3.2	3.5	3.6	3.4	2.9	2.8	2.6	2.5	2.5	2.6	2.8	3.0	2.7
Maximum monthly average	3.8	4.3	4.3	4.5	3.6	3.7	3.1	2.9	3.2	3.3	3.4	3.8	
Air temperature, °C													
Minimum monthly average	2	4	7	14	19	23	24	24	20	15	9	4	
Mean monthly average	7	8	12	17	21	25	26	26	23	17	12	8	30
Maximum monthly average	13	13	16	19	24	27	28	28	25	20	14	13	
Cloud cover, fraction													
Minimum monthly average	.35	.27	.40	.36	.42	.37	.40	.32	.31	.16	.33	.46	
Mean monthly average	.58	.54	.56	.50	.55	.56	.61	.54	.53	.42	.47	.54	.15
Maximum monthly average	.73	.78	.73	.65	.77	.67	.80	.72	.71	.67	.61	.70	
Solar radiation, cal/m²-sec													
Minimum monthly average	21	27	34	43	43	48	40	41	36	30	27	20	
Mean monthly average	26	34	41	51	53	56	53	52	44	40	31	25	77
Maximum monthly average	33	44	48	57	61	65	64	63	54	49	36	28	
Relative humidity, fraction													
Minimum monthly average	.59	.53	.56	.60	.63	.61	.66	.68	.71	.64	.63	.62	
Mean monthly average	.71	.67	.66	.66	.71	.72	.75	.76	.77	.74	.72	.72	.72
Maximum monthly average	.82	.76	.73	.79	.79	.80	.82	.84	.83	.83	.77	.80	
Equilibrium temperature, °C													
Minimum monthly average	3	7	10	18	23	27	28	27	23	17	11	5	
Mean monthly average	8	10	15	21	25	28	30	29	26	20	13	9	33
Maximum monthly average	14	15	18	23	28	30	31	31	28	22	16	13	

^aExtreme parameter values are a 5-day average of values for the period July 12-16, 1980; this period is one of severe equilibrium temperatures.

Table B-3. Downstream Temperature Distributions (°C) for Site Creeks

Location	Winter average			Spring average			Summer average			Summer extreme		
	Once- Existing system towers	Recir- culating towers	Once- through towers	Existing system towers	Once- through towers	Recir- culating towers	Existing system towers	Once- through towers	Recir- culating towers	Existing system towers	Once- through towers	Recir- culating towers ^a
C-Reactor (Four Mile Creek)												
Discharge (1) ^b	66	24	10	69	28	17	71	30	23	73	32	25
Road A (2)	53	23	9	56	27	20	59	30	26	61	32	29
Road A-13 (3)	46	21	9	50	26	20	53	30	27	55	32	32
Swamp delta (4)	39	20	9	43	26	21	47	30	27	48	32	32
K-Reactor (Pen Branch)												
Discharge (5)	66	24	10	69	28	17	71	30	23	73	32	25
Road A (6)	60	24	9	64	27	19	67	30	26	68	32	29
Railroad bridge (7)	53	22	9	56	27	20	59	30	26	61	32	29
Swamp delta (8)	43	21	9	47	26	20	50	30	26	52	32	32
D-Area^c (Beaver Dam Creek)												
Discharge (9)	16			25			31			36		32 ^a
Swamp delta (10)	15			24			31			36		32
Ambient creek ^d	9	9	9	23	23	23	29	29	29	33	33	33

^aIncreased pumping alternative for D-Area.

^bCorrespond to locations on Figure B-2.

^cIncreased pumping alternative is equivalent to existing system for seasonal average conditions.

^dApproximated by equilibrium temperature.

B.4 SAVANNAH RIVER DILUTION - D-AREA MODEL (SRDD)

B.4.1 MODEL DESCRIPTION

The dispersion of a source of water with a temperature (or concentration) elevated above that of the receiving water can be thought of as occurring in two steps. The "near field" is the area in the immediate vicinity of the discharge in which the mechanical mixing engendered by the difference in discharge and receiving water momentum dominates the dispersion process. After the discharge momentum has dissipated, the "far field" mechanism of receiving water turbulence causing mixing of the discharge and receiving waters is dominant. If the discharge momentum is relatively small (i.e., discharge velocity approximately equal to receiving water velocity), the near field can be (conservatively) neglected.

The far field dispersion of a steady nondecaying point source discharge into a current of velocity, u , can be described by (NRC, 1977):

$$\frac{\partial uC}{\partial x} = \frac{\partial}{\partial y} K_y \frac{\partial C}{\partial y} + K_z \frac{\partial C}{\partial z} \quad (16)$$

where C = temperature or concentration excess above ambient
 u = ambient velocity, m/sec
 x = downstream distance, m
 y = lateral distance (i.e., perpendicular to current), m
 z = depth, m
 K_y, K_z = lateral and vertical diffusion coefficient, m^2/sec

Longitudinal diffusion is assumed to be negligible when compared with advection in the same direction. Also, temperature can be considered to be a non-decaying (i.e., no heat transfer to the atmosphere) source within the region of interest because the affected areas are small. In any case, omission of surface heat transfer is a conservative assumption.

Equation 16 states that the excess concentration is moved downstream by advection (movement by the current, left side of Equation 16) and laterally and vertically in the direction of decreasing concentration by turbulence (first and second term on right side of Equation 16, respectively). If u , K_y , and K_z are taken to be constants, then Equation 16 becomes:

$$u \frac{\partial C}{\partial x} = K_y \frac{\partial^2 C}{\partial y^2} + K_z \frac{\partial^2 C}{\partial z^2} \quad (17)$$

For an infinite receiving water, laterally and vertically surrounding the discharge point, the analytical solution to Equation 17 is:

$$\frac{C}{C_0} = \frac{Q}{4\pi x \sqrt{K_y K_z}} \exp \left[\frac{-u(y_0 - y)^2}{4K_y x} \right] \exp \left[\frac{-u(z_0 - z)^2}{4K_z x} \right] \quad (18)$$

where C_0 = excess temperature (or concentration) of the discharge
 Q = discharge flow, m^3/sec
 y_s = lateral distance of source from coordinate origin
 z_s = vertical distance of source from coordinate origin

and the discharge is assumed at $x = 0$.

The Gaussian distribution of Equation 18 can be generalized for a receiving water of finite dimensions by adding images of the concentration distribution, Equation 18, from the bounding surfaces; that is, the infinite distribution of Equation 18 can be "folded" back into the water body at the boundaries, with the folded excess concentrations each being a component of the total excess concentrations. One can picture an infinite number of folds (e.g., the left-hand side of the lateral distribution would be folded at the left boundary and would have to be folded there, etc.) for each side (of the source) for both the lateral (shorelines) and vertical (surface and bottom) directions (i.e., four infinite series). The mathematical description of these images or folds is (NRC, 1977):

$$\frac{C}{C_0} = \frac{Q}{4\pi \times \sqrt{K_y K_z}} f(y) f(z) \quad (19)$$

where:

and $w = y$ or z

$W = B$ (receiving water width) if $w = y$ or D (receiving water depth) if $w = z$

Note that $f(y)$ and $f(z)$ describe the infinite folds of the first and second exponential terms, respectively, of Equation 18.

A further refinement of the analysis stems from the assumption of a point source discharge. Equation 19 can be generalized to account for an arbitrary discharge geometry by integrating over the discharge dimensions (i.e., consider the discharge an infinite number of point sources), where Q would then be the discharge flow per unit discharge size (i.e., length for a line source or area for a plane source). Such an integration of Equation 19 would have to be performed numerically and would be very time-consuming, computationally. Accordingly, an analytical approximation to this integration has been used.

The areal nature of the discharge source is accounted for by taking a virtual source distance x_v ; x_v corresponds to the distance, x , at which (for $y = y_s$ and $z = z_s$) C/C_0 equals 1 in Equation 19. Accordingly, Equation 19 is modified by replacing x with $x + x_v$. The use of a virtual source distance assures conservation of mass, avoids the mathematical singularity at $x = 0$, and ensures that the calculated concentration (or temperature) at the source is equal to that being discharged.

B.4.2 MODEL USE

The model described in Section B.4.1 was generalized for use in calculating the temperature distribution in the Savannah River from the multiple-source D-Area sparge discharge system. Based on preliminary design assumptions, the system would consist of approximately 65 discharge pipes, 20 centimeters in diameter and 9 meters long, spaced at 3-meter intervals and aligned along the river bank. SRDD models such a system by considering each of the discharge pipes as a component to the overall temperature (or concentration) distribution. Distances x are measured, for each pipe, from that pipe ($x = 0$ is taken at the upstream pipe). Virtual source distances, x_v , are calculated individually for each pipe (i.e., C/C_0 equals 1 at each pipe, accounting for the contributions of all upstream sources).

The total discharge flow is 2.6 cubic meters per second, 0.04 cubic meter per second per discharge pipe; the discharge water velocity is 1.2 meters per second, and its excess temperature is 8°C (above the temperature of the river). Table B-4 lists the Savannah River parameters used in the analysis. The approximate river cross-section at the discharge (average width = 61 meters, average depth = 3.2 meters) was known for a base river flow of 188 cubic meters per second. Log-log interpolations of river gage heights at Jackson for this flow (gage height = 2.28) and for 490 cubic meters per second [gage height = 4.62 meters (USGS, 1981)] were performed for the seasonal flows. The change in gage height between the interpolated value and that at the base flow was assumed to be the change in average depth at the discharge. Typically, as the flow increases, the width, depth, and velocity of the river increases. Average widths were assumed to be the mean of 61 meters (known width at the base flow) and that width that would result in the same average river velocity as that at the base flow. These assumptions will result in river dimensions that accede to the typical river dimension-flow characteristics described above.

Table B-4. Savannah River Parameters Used in Analysis

Parameter	Winter average	Spring average	Summer average	Summer extreme
Flow (m ³ /sec)	345.0	371.0	212.0	159.0
Width (m)	70.0	71.0	65.0	59.0
Depth (m)	4.6	4.8	3.5	2.9
Temperature (°C)	8.0	17.0	23.0	28.0
Horizontal diffusion coefficient (m ² /sec)	.26	.26	.26	.26
Vertical diffusion coefficient (m ² /sec)	.0026	.0026	.0026	.0026

For the region near the discharge (about 100 meters from the discharge), the temperature distribution will be (for a given velocity) insensitive to the river dimensions. This occurs because the plume has not had time to grow sufficiently such that the images from the far boundaries (Georgia shoreline and river bottom) are important. In addition, the temperature at any given coordinate decreases with increasing river velocity. This is apparent from Equation 19, which shows that the river velocity, u , enters the temperature function as $\exp(-u)$.

The chosen horizontal diffusion coefficient is based on studies of the Savannah River approximately 20 kilometers downstream (Steel Creek) from the discharge (Du Pont, 1981, Appendix A). The vertical diffusion coefficient is typically one to two orders of magnitude smaller than the horizontal diffusion coefficient (NRC, 1977; Yotsukura and Sayre, 1976; Fisher, 1969). Calculations with $K_z = 0.0026$ and 0.026 square meter per second indicate that the former yields larger values of maximum isotherm width and cross-sectional area. However, at distances farther downstream than considered here, the discharge will be fully mixed vertically and the distribution will be independent of K_z . $K_z = 0.0026$ square meter per second was used in the analysis.

B.4.3 MODEL RESULTS

Table B-5 lists the river withdrawal and discharge temperatures along with the zones of passage for each seasonal case. The extreme summer conditions result in the smallest zones of passage. Figure B-3 shows the maximum cross-sectional area (as a fraction of the total), and downstream extent (meters from the discharge pipe furthest upstream) as a function of excess temperature for extreme summer conditions. Excess temperatures corresponding to those extents less than 3 meters downstream from the discharge pipe located farthest downstream will actually exist intermittently in the river; that is, such isopleths (greater than 2.8°C) exist near each discharge pipe but will dissipate between pipes.

Figure B-3 also shows the suggested width and cross-sectional area of the zone of passage. This figure shows that the direct discharge will be well within the suggested zone-of-passage criteria.

B.5 FOG MODEL

The occurrences of ground-level fogging, icing, elevated visible plumes, and ground deposition rates of dissolved solids in drift in the environmental impact statement were calculated by the NUS computer code FOG (Fisher, 1974). The FOG model provides predictions of these environmental impacts over a geographical area surrounding the site. For these analyses, sequential hourly meteorological data representative of the geographical areas surrounding C-Area and K-Area at the Savannah River Plant were used for the 5-year period from January 1975 to October 1979.

The FOG model simulates the dispersion of a plume from evaporative cooling systems using sequential meteorological data. It defines a bent-over plume using the Briggs plume rise equations (Briggs, 1969) out to the distance at which the plume levels off, and Gaussian dispersion equations at greater

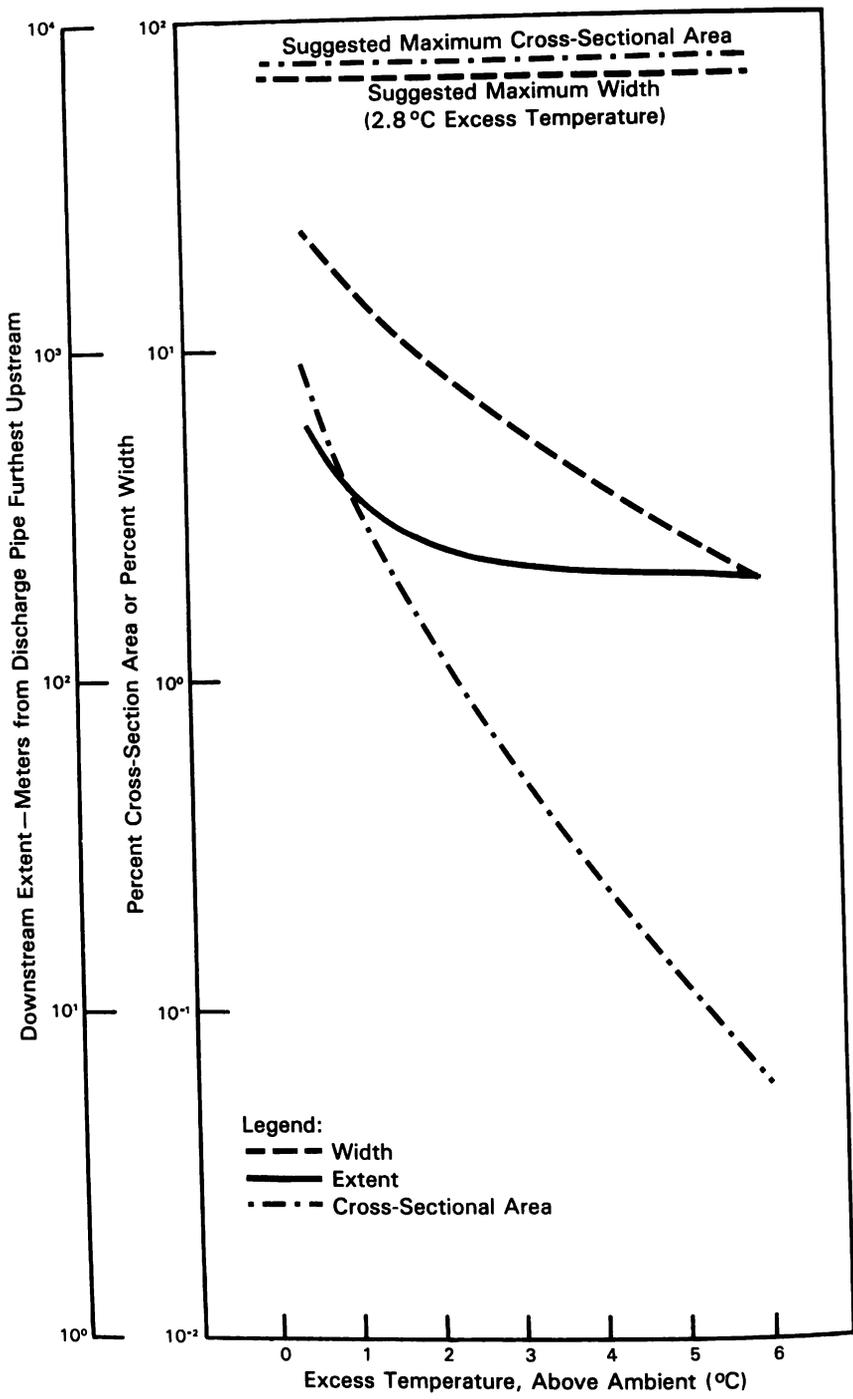


Figure B-3. Extreme Summer Plume Characteristics

Table B-5. Temperatures and Zone of Passage Sizes for D-Area Coal-fired Powerhouse Direct Discharge into Savannah River

Parameter	Winter average	Spring average	Summer average	Summer extreme
Temperature (°C)				
Withdrawal from river	8.0	17.0	23.0	28.0
Discharge	16.0	25.0	31.0	36.0
Maximum river cross-sectional area (percent of total) having temperature (°C) less than				
2.8 (excess)	99.7	99.7	99.5	99.3
32.2 (absolute)	100	100	100	99.7
Maximum river width (percent of total) having temperature excess (°C) less than				
2.8 (excess)	95	95	94	93
32.2 (absolute)	100	100	100	96

distances. The plume buoyancy employed in the calculations is computed from the effluent temperature and airflow rate at the exit of the cooling tower and from the ambient dry-bulb temperature and relative humidity. The merging of plumes from the round, mechanical-draft, multifan cooling towers is considered using equations developed by Briggs (1974) for a cluster of cells.

The plume is assumed to propagate rectilinearly, and any meandering effects due to wind shifts are neglected. Atmospheric stability classes are those calculated from the standard deviation of wind direction fluctuations or, if these data are unavailable, from those reported by the National Weather Service for every hour for the period under consideration. The dispersion parameters used were those of Pasquill-Gifford (DOE, 1984c). Formulations for critical wind speed relative to the aerodynamic downwash of the exhaust plumes, in the wake of the tower under high wind conditions, are also included in the FOG model.

In addition to the preliminary design information contained in Chapter 2, the following assumptions were made in the analysis of fogging, icing, visible plumes, and ground deposition rates of dissolved solids:

Circulating water flow = 11.3 cubic meters per second
Drift rate (percent of circulating water flow) = 0.006 percent
Total dissolved solids concentrations (TDS) = 53 parts per million
Cycles of concentration for recirculating towers = 3
Drift droplet size (mass median diameter) = 376 microns
Air flow rate for a once-through tower = 6,866 cubic meters per second
Air flow rate for a recirculating tower = 13,848 cubic meters per second

B.5.1 INDUCED GROUND-LEVEL FOGGING

For the purposes of these analyses, induced ground-level fog is defined as a reduction in ground-level visibility to 1000 meters or less as a result of the operation of the cooling system. Huschke (1959) defines the 1000-meter distance as the limit on visibility above which fog is not considered to occur. The water content of the plume at ground level is calculated by means of the Gaussian dispersion analysis discussed above; all moisture in excess of that required to saturate the ambient air is assumed to form condensed water droplets. An empirical equation (Pettersen, 1956) is then used to relate the atmospheric water content to the horizontal visibility.

B.5.2 INDUCED GROUND-LEVEL ICING

The frequencies of occurrence of various ice thicknesses resulting from the operation of the cooling towers were also calculated by FOG code subroutines that simulate the formation and accumulation of ice and calculate the frequencies of ice occurrences.

The ice-formation routines predict accumulations of ice around a cooling system from the impingement of condensed water and drift droplets. Calculations of ice buildup are made for horizontal flat surfaces (e.g., roads). The rate of ice buildup can be limited either by the liquid water delivery rate to the collecting surface or by the heat balance necessary to sustain freezing conditions.

The dispersion of the relatively small condensed water droplets is treated the same as that of the vapor plume (i.e., by diffusion), while the transport of the drift droplets follows the ballistic trajectory method employed for the salt deposition calculations. The FOG model performs an energy balance on the surface or volume of interest. Ice formation is assumed to occur only when the ambient temperature is less than 0°C. Ice buildup on horizontal ground-level surfaces is assumed to result only from fallout of the drift droplets. Because the much smaller condensed water droplets have negligibly small settling velocities, the condensed water droplets are assumed not to impinge on flat horizontal surfaces. Melting due to solar radiation is included in the simulation for flat surfaces.

B.5.3 ELEVATED VISIBLE PLUMES

The FOG code was also used to calculate the frequencies of occurrence of elevated visible plumes over each grid point under consideration. The total flux of air through a cross-section of the plume normal to the plume axis is calculated at successive downwind distances. The amount of entrained air is computed as the difference between the total air flow and the air flow leaving the cooling system. The entrained air and effluent air from the cooling system are assumed to be thoroughly mixed isobarically and thermodynamic properties of the resulting mixture are calculated. A visible plume is predicted to occur at a particular point if calculations show that the mixed plume is supersaturated.

B.5.4 DRIFT DEPOSITION

Drift deposition analysis by the FOG code involves the following three calculations: (1) the sequential release of the entrained drift droplets from the effluent plume; (2) the subsequent horizontal transport of the drift droplets; and (3) the deposition rates at prespecified downwind distances for each wind direction.

It is assumed in the FOG model that the initial concentration of drift droplets follows a Gaussian distribution normal to the plume axis. The release of the entrained droplets at any point within the plume depends on the relative magnitudes of the terminal fall velocity of the droplets and the vertical velocity of the air in the plume. At each downwind distance under consideration, these two velocities are compared for each of the various size categories of drift droplets, and a fraction of the droplets released. This process is repeated until all drift droplets are released from the plume. This drift is carried by the ambient wind until it is deposited on the ground. The rate of fall of the drift droplets depends on the droplet size, which is changed by evaporation processes. These, in turn, depend on the physical and transport properties of both the liquid droplets and the surrounding air. A stepwise procedure is employed in the FOG code to compute the trajectory of the droplets by considering these transport, evaporation, and settling rate effects.

Drift deposition rates are calculated for each sequential meteorological record and these are then summarized to obtain the deposition (mass per unit area-year) over the entire grid.

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APPENDIX C

ECOLOGY

C.1 INTRODUCTION

This appendix is based primarily on information contained in the Comprehensive Cooling Water Study (Du Pont, 1985). This study began in 1983 to evaluate the environmental effects of the intake and release of cooling water on the structure and function of aquatic ecosystems on the Savannah River Plant. This appendix utilizes the information supplied in the first annual report of the Comprehensive Cooling Water Study (Du Pont, 1985), which covers preliminary data collected in 1982 and additional data collected through August 1984.

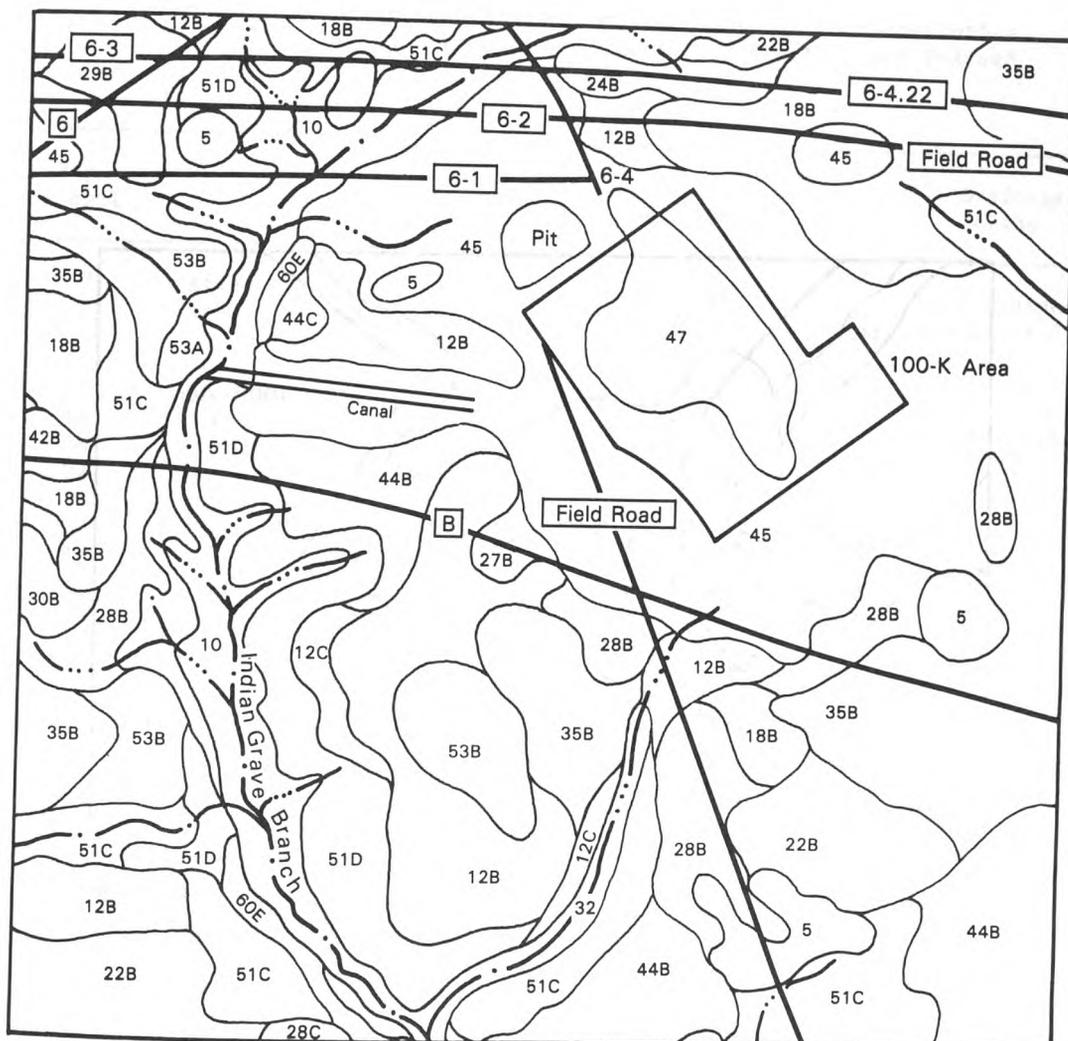
In 1972, the Savannah River Plant became a National Environmental Research Park. The Plant contains one of the most intensively studied environments in this country. More than 700 scientific publications have resulted principally from research efforts by three organizations on the Plant: the Savannah River Laboratory, the Savannah River Ecology Laboratory, and the U.S. Forest Service (Wiener and Smith, 1981). Other research efforts include (1) surveys of the aquatic ecology of the Savannah River since 1951 by the Academy of Natural Sciences of Philadelphia, (2) temperature and flow monitoring of the river by the United States Geological Survey (USGS) since 1959, (3) remote sensing of the Plant using aerial imagery, and (4) various ecological studies by the State of South Carolina and by industry. In addition, visiting scientists from other universities and laboratories in the United States have performed research. This appendix also utilizes these studies as appropriate.

This appendix emphasizes Beaver Dam Creek, Four Mile Creek, Pen Branch, the Savannah River swamp, the Savannah River, and the "important" biota that reside there. These areas could be affected by the cooling water alternatives considered in this environmental impact statement. "Important" biota are those species that are (1) commercially or recreationally valuable, (2) endangered or threatened, (3) important to the well-being of the species included in categories 1 and 2, or (4) critical to the structure and function of the ecosystem.

C.2 SOILS

Soils are an important component of the environment because they influence the occurrence and distribution of the vegetation, wildlife, and potential land use by man. Figures C-1, C-2, and C-3 and Table C-1 show the distribution of soils in the vicinity of C-Reactor, K-Reactor, and the D-Area coal-fired powerhouse respectively. The C-Reactor soil map covers an area of approximately 1670 acres, while the K-Reactor map covers approximately 1770 acres. C- and K-Areas contain 19 soil types, of which udorthents and arents and urban are the most prevalent. These soils consist of material that has been previously deposited or material that remains after some of the soil has

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Legend:
— Road
- - - Creek

Note: Table C-1 identifies the map symbols used in this figure

Figure C-2. Distribution of Soil Types in the K-Reactor Area

C-3

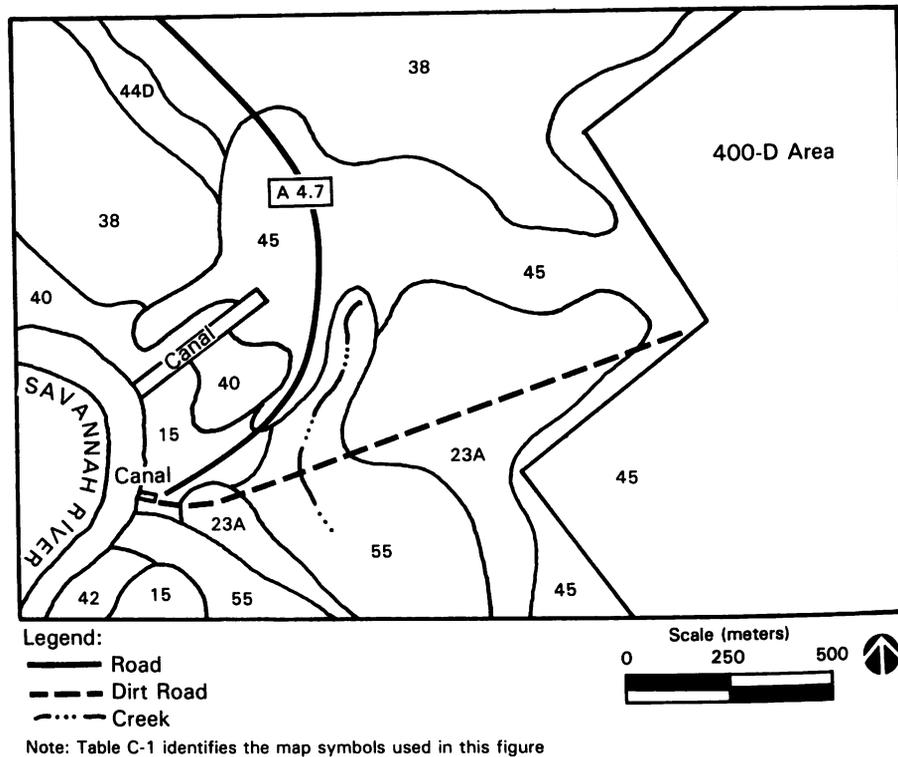


Figure C-3. Distribution of Soil Types in the D-Area

Table C-1. Occurrence, Distribution, and Selected Characteristics of Soils Surrounding C-Reactor, K-Reactor, and D-Area^a

Map symbol	Soil name	Texture (A horizon)	Drainage class
2	Ailey	Loamy sand	Well drained
5	Arents and udorthents	Sand or loam or sandy clay loam	Poorly drained
10	Osier	Loamy sand	Poorly drained
12	Blanton	Sand	Well drained
15	Tawcaw	Silty clay	Poorly drained
18	Dothan	Loamy sand	Well drained
22	Fuquay	Loamy sand	Well drained
23	Smithboro	Silt loam	Poorly drained
27	Lakeland	Sand	Well drained
29	Neeses	Loamy sand	Well drained
30	Norfolk	Loamy sand	Well drained
34	Ogeechee	Loamy fine sand	Poorly drained
35	Orangeburg	Loamy sand	Well drained
38	Rembert	Sandy loam	Poorly drained
40	Shellbluff	Loam	Poorly drained
42	Toccoa	Clay loam	Well drained
44	Troup	Sand	Well drained
45	Udorthents and arents	Loam	Poorly drained
46	Udorthents-Urban	Sandy clay loam	Well drained
47	Urban	Variable	Variable
50	Vaucluse	Loamy sand	Well drained
51	Vaucluse-Ailey complex	Loamy sand	Well drained
53	Wagram	Loamy sand	Well drained
55	Chastain	Loam	Poorly drained
56	Williman	Loamy fine sand	Poorly drained

^aAdditional information for Figures C-1, C-2, and C-3: Capital letters that follow numerical map symbols designate slope classes: A = 0-2 percent, B = 2-6 percent, C = 6-12 percent, D = 12-18 percent, E = 18-25 percent.

been removed; the material contains fragments or discontinuous layers of diagnostic horizons or layers. Streambed soils of Four Mile Creek and Indian Grave Branch consist primarily of Osier loamy sand; reactor operations have scoured and eroded these soils. The dominant texture of the surficial horizons is loamy sand and sand; slopes typically range less than 12 percent, and most soils are well drained.

Figure C-3 shows the distribution of soils between the D-Area powerhouse and the Savannah River. The D-Area soil map covers an area of approximately 880

acres and consists of five major soil types. The udorthents-arents soil complex comprises more than 50 percent of the area. These soils consist of deposited material or material that remains after the surface layers have been removed or disturbed. The remaining soil types consist of Chastain clay loam, Smithboro loam, Tawcaw silty clay, Shellbluff loam, and Toccoa clay loam, all of which are frequently flooded and, except for the Toccoa series, are poorly drained. The Toccoa series is moderately well drained with good permeability.

C.3 VEGETATION - GENERAL SITEWIDE

The location of the Savannah River Plant is an area where the oak-hickory-pine forest and the southern mixed forest intermingle (Kuchler, 1964). The southern floodplain forest (Kuchler, 1964), which adjoins major rivers such as the Savannah, is also present. Dominant canopy species of the oak-hickory-pine forest include hickory, shortleaf and loblolly pine, white oak, and post oak. Beech, sweetgum, magnolia, slash and loblolly pine, white oak, and laurel oak characterize the canopy of the southern mixed forest. The southern floodplain forest typically consists of tupelo, many species of oak, and bald cypress. Species representative of each forest type exist on the Savannah River Plant. In addition, farming, fire, adaptive features, and topography have strongly influenced SRP vegetation. There is no virgin forest in the region (Braun, 1950).

Since 1952, the U.S. Forest Service has managed the land surface at the Savannah River Plant for the Department of Energy and its predecessor agencies. The Forest Service manages the land for multiple-use purposes, including environmental and ecological research areas, wildlife management areas for threatened or endangered species, and timber management areas (USDA, 1983).

Table C-2 summarizes the nine major land cover classes for the Savannah River Plant. The dominant land-use type is upland pine/hardwood (70.1 percent) followed by wetland (20.4 percent). About 66 percent of the SRP wetlands are bottomland hardwood forests, which occur primarily along streams and in the river swamp. A relatively small percentage (14 percent) of SRP wetlands are cypress and tupelo swamp forest, found predominantly in the Savannah River swamp. Normally, scrub-shrub and emergent marsh areas occur in thermal and post-thermal areas (Du Pont, 1985).

Table C-3 summarizes the wetland land-use types for the major SRP stream wetland communities.

C.3.1 FOUR MILE CREEK

Four Mile Creek, with Beaver Dam Creek, drains more than 22,480 acres. The Four Mile Creek floodplain has approximately 1900 acres of wetlands, primarily bottomland hardwood (72 percent) (Table C-3). Downstream from C-Reactor, open water and emergent marsh near the stream have replaced the original hardwood community. Away from the thermally affected areas in the floodplain, there is

Table C-2. Land Use Types^a

Land cover class	Area (acres)	Percentage
Upland pine/hardwood	135,100	70.1
Clear areas/power lines	11,200	5.8
Roads	4,100	2.1
Production areas	3,100	1.6
Subtotal	<u>153,500</u>	<u>79.6</u>
Wetland		
Bottomland hardwoods	25,900	13.4
Cypress-tupelo	5,500	2.9
Water ^b	4,400	2.3
Scrub-shrub	1,900	1.0
Emergent marsh	1,500	0.8
Subtotal	<u>39,200</u>	<u>20.4</u>
Total	192,700	100.0

^aAdapted from Du Pont, 1985.

^bIncludes Savannah River.

a hardwood canopy occupying 445 acres. Overall, C-Reactor discharges have impacted about 1147 acres of Four Mile Creek wetlands. Discharges from F- and H-Areas and beaver activity have flooded original bottomland hardwood areas above the K-Reactor outfall, allowing scrub-shrub (260 acres) and emergent marsh (50 acres) wetlands to become established (Du Pont, 1985).

C.3.2 PEN BRANCH

Pen Branch and Indian Grave Branch drain about 13,590 acres above the swamp. Indian Grave Branch receives the effluent cooling water from K-Reactor. Pen Branch has about the same amount of wetlands (1725 acres) as Four Mile Creek (Table C-3). Similar to Four Mile Creek, emergent marsh (115 acres) and water (145 acres) are common below the K-Reactor discharge. Some hardwoods exist on the outer perimeter of the thermally affected areas (325 acres), but most occur in nonthermal tributaries (340 acres) or upstream of the K-Area cooling water releases (Du Pont, 1985).

Table C-3. Areas of Major SRP Stream Corridor Wetlands Communities (acres)^a

Stream system	BH	SS	EM	CT	W	Total	Percent of total
Four Mile Creek							
Above C-Reactor (nonthermal)	925	255	50	0	0	1230	
Below C-Reactor (thermal)	445	0	65	0	150	660	
Total	<u>1,375</u>	<u>260</u>	<u>115</u>	<u>0</u>	<u>150</u>	<u>1,890</u>	8.3
Pen Branch							
Above K-Reactor (nonthermal)	725	60	0	0	0	785	
Below K-Reactor (thermal, nonthermal tributaries)	325	0	115	0	145	585	
Total	<u>1,390</u>	<u>65</u>	<u>125</u>	<u>0</u>	<u>145</u>	<u>1,725</u>	7.6
Other (Upper Three Runs, Lower Three Runs, Steel Creeks)							
Total SRP	<u>18,170</u>	<u>645</u>	<u>260</u>	<u>15</u>	<u>35</u>	<u>19,125</u>	84.1
	<u>20,930</u>	<u>970</u>	<u>500</u>	<u>15</u>	<u>330</u>	<u>22,745</u>	

^aAdapted from Du Pont, 1985.

Abbreviations:

- BH - Bottomland hardwoods
- SS - Scrub-shrub
- EM - Emergent marsh
- CT - Cypress-tupelo swamp forest
- W - Open water

C.3.3 BEAVER DAM CREEK

Beaver Dam Creek is a small stream that conveys thermal effluents from the D-Area coal-fired powerhouse. The creek is located 1 to 3 kilometers west of Four Mile Creek. A narrow band of bottomland hardwoods and scrub-shrub forest borders the stream from the D-Area process-water outfall to the Savannah River swamp (Du Pont, 1985).

C.3.4 SAVANNAH RIVER SWAMP

About 9400 acres (8 percent) of the Savannah River swamp forest lies on the Savannah River Plant (from Upper Three Runs Creek to Steel Creek). The swamp is primarily cypress-tupelo forest (47 percent) and drier bottomland-hardwood

islands (40 percent; Table C-4). On the islands, a few pine trees are able to survive (2.2 percent). The remainder of the SRP swamp consists of scrub-shrub vegetation communities near the entry points of the thermal and post-thermal streams. Dense cypress-tupelo forest has been replaced by the mixture of scrub-shrub, and persistent and nonpersistent marsh vegetation in these delta areas. The delta areas comprise about 15 percent of the SRP swamp, have more plant heterogeneity, and are changing (Du Pont, 1985).

Table C-4. Area of Land Cover Classes Found in SRP Swamp (March 31, 1981)^{a,b}

Class	Area (acres)	Percent of swamp
Persistent emergent marsh (PE)	135	1.4
Nonpersistent emergent marsh (NPE)	375	4.0
Scrub-shrub (SS)	385	4.1
Mixed deciduous swamp forest (MDSF)	4430	47.2
Mixed deciduous bottomland forest (MDBF)	3775	40.2
Needle-leaved evergreen forest (NEF)	205	2.2
Open water in swamp (W) ^c	65	0.7
Unclassified (U)	20	0.2
Total	9390	100.0

^aObtained by analyzing multispectral scanner data (2440 meters AGL) provided by the Energy Measurements Group of EG&G, Las Vegas, Nevada.

^bAdapted from Du Pont, 1985.

^cDoes not include 545 acres of Savannah River water adjacent to the swamp; probably includes some algal beds.

C.4 WILDLIFE

The Savannah River Plant was approximately two-thirds forested and one-third cropland and pasture when the U.S. government acquired it 35 years ago (Dukes, 1984). The abandoned fields were allowed to pass through vegetational succession or were planted with pine; 90 percent of the Plant is now forested. The Plant is large, is topographically variable, has a diverse vegetational history, and is in an area where major habitat types come together and inter-spere. Human access is limited; therefore, the faunal and floral diversity and abundance is high (DOE, 1984).

Because the proposed alternatives will primarily affect the fauna that utilize the floodplains/wetlands, this section emphasizes species that depend on floodplain/wetland habitats for at least some part of their life cycle.

C.4.1 AMPHIBIANS AND REPTILES

Of the more than 90 species of reptiles and amphibians known to occur on the Plant, 61 use the SRP streams and wetlands. Most of these species inhabit post-thermal stream and swamp habitats in the vicinity of Steel Creek (Du Pont, 1985). The following list (adapted from Du Pont, 1985) contains the semi-aquatic species of reptiles and amphibians characteristic of SRP streams and swamps:

Amphibians

- Salamanders - greater siren
two-toed amphiuma

- Frogs - green treefrog
bird-voiced treefrog
bullfrog
bronze frog
pickerel frog
pig frog

Reptiles

- Snakes - brown water snake
banded water snake
red-belly water snake
mud snake
rat snake
rainbow snake
cottonmouth

- Turtles - snapping turtle
stinkpot
striped mud turtle
slider turtle
river cooter
Florida cooter

- Alligators - American alligator

Other species might occasionally occupy these habitats. (For a complete listing of species refer to Du Pont, 1985.)

No amphibians or reptiles persist on a routine basis in areas of severe thermal alteration, although some species of frogs live in aquatic habitats that experience elevated temperatures and have deposited eggs in aquatic sites where lethal temperatures occurred (Du Pont, 1985).

Frogs and toads also exhibit life history changes under elevated thermal conditions, particularly as tadpoles, by developing and metamorphosing more rapidly and at a smaller size than larvae living under normal temperature conditions (Du Pont, 1985).

The slider is the most prevalent species of turtle on the Plant. This species apparently thrives in areas of moderately elevated water temperatures where it experiences faster growth rates and attains larger body sizes than turtles from local natural habitats; this can be attributed to improved diet quality, a longer growing season, and more rapid ingestion rates (Du Pont, 1985).

The striped mud turtle has been collected near the thermally elevated delta of Pen Branch. Original captures of this species on the Plant were near Steel Creek before L-Reactor shutdown in 1968. No biological responses of this species to thermal conditions have been identified (Du Pont, 1985).

American alligators inhabit thermally affected streams such as Beaver Dam Creek and refuge areas along Four Mile Creek and Pen Branch (see Section C.6 for more details). A few other reptile species, primarily water snakes and turtles, might also occur in these areas, but not in numbers characteristic of ambient-temperature streams in the region (Du Pont, 1985).

C.4.2 AVIFAUNA

Several investigators have studied SRP avifauna. Norris (1963) surveyed the Plant in 1963. Fendley (1978) began a study of the wood duck in the Steel Creek drainage system in 1973 that has continued to the present. Angerman has conducted winter bird counts for several years (DOE, 1984). Dukes (1984) has summarized the avifauna studies on the Plant.

Biologists have identified 213 species of birds on the Savannah River Plant. Angerman (1979; 1980) listed 59 species on the Plant during recent Christmas bird counts. Game birds, particularly quail and dove, were abundant before the U.S. Government acquired the land. For a few years, the removal of land from agriculture did not decrease the quail population. In the early 1960s, this population reached a record high but then began to decline because the conversion of agricultural fields to forests reduced the carrying capacity of the land.

Wild turkey, although present on the Plant at acquisition, were not very numerous. In 1972, the South Carolina Wildlife and Marine Resources Department started a program that utilizes the Plant as a breeding ground for wild turkey for stocking other parts of the State. Thirty-six birds were released on the Plant between 1972 and 1974. Population growth was slow at first, but the turkey population has increased greatly in the last few years. To date, about 135 turkeys have been captured and used to restock other areas of the State.

Waterfowl are present on the Plant, primarily during winter migrations. After the construction of Par Pond, winter waterfowl species increased in number and diversity. An estimated 10,000 to 15,000 ducks and coots spend the winter on

the Plant. Most of these birds are on Par Pond and other large ponds and Carolina bays. Another 1000 to 2000 ducks spend the winter in the lower swamps and on the Savannah River. Wood ducks and hooded mergansers are the only waterfowl that commonly nest on the Plant.

In general, when clearing or cutting operations open wetland areas of the swamp or streams, a suitable habitat develops for ducks, wood storks, and other birds not normally found in mature cypress and tupelo stands. The increased flows and temperatures from reactor effluents to Four Mile Creek, Steel Creek, and Pen Branch have resulted in the development of such openings in the swamp. During the summer of 1972, bird surveys conducted on the deltas of Upper Three Runs Creek, Pen Branch, and Steel Creek in areas with similar densities of dead or living trees found no significant differences in non-aquatic bird communities in species diversity or richness in the natural (Upper Three Runs Creek), thermal (Pen Branch), and post-thermal (Steel Creek) swamps. However, more woodpeckers, crows, and herons occurred at Pen Branch than at Upper Three Runs Creek. The introduction of thermal effluents has produced a large stand of dead trees that serve as nesting and feeding sites for the large woodpecker and crow populations. Crows and herons represented more than 50 percent of the birds at Pen Branch Delta. Low numbers of these same species were seen near the open channel of Upper Three Runs Creek. When the canopy at Pen Branch was opened, suitable habitats became available to these larger species. The nonaquatic bird populations of the Four Mile Creek delta would be similar to those at Pen Branch.

A comparison of the number of mallards observed during 1982 aerial surveys in the Steel Creek delta area, Pen Branch delta, Four Mile Creek delta area, and Beaver Dam Creek revealed that the delta areas of Four Mile, Steel, and Beaver Dam Creeks received substantial use by this species. However, waterfowl were not observed in Pen Branch Delta. Mallard use of the Four Mile Creek delta area was generally higher than that of Steel Creek. Mallards in the Four Mile Creek delta area were associated with open channels that branch off the main delta at a 90-degree angle. These channels provide heavily used waterfowl habitat except during periods when the water level is higher (flooding) or when the water is hotter.

The wood stork, an endangered species, forages on the site and is discussed in Section C.6 in more detail.

C.4.3 MAMMALS

The Savannah River Plant includes the ranges of more than 40 species of mammals. The population of a few species increased rapidly after the Government closed the Plant to the public in 1952, and some species decreased. The most notable expansion was in the deer herd; the present population is estimated at about 3500. The population grew so rapidly that by the mid-1960s deer-vehicle collisions were common and range deterioration was apparent. Controlled public hunts were started in 1965 to reduce the deer population. From 1965 to 1983, hunters harvested an average of 1126 deer annually.

When the occupants of the SRP moved in 1952, they abandoned some domestic hogs, which increased in numbers and became detrimental to young forest plantations. Initially, a controlled program of shooting and trapping was used to reduce the hog population. Currently, deer hunters can shoot these feral hogs, and through 1983 had harvested about 700. The present estimated population of feral hogs is between 500 and 1000. Except for deer, beaver, and feral hogs there is no authorized predation by man on the Plant.

The following eight species of mammals found on the Plant are considered semiaquatic and are generally associated with the wetland/floodplain habitats:

Order Insectivora - Shrews and Moles

Family Talpidae

Condylura cristata - Star-nosed mole

Order Lagomorpha - Rabbits and Hares

Family Leporidae

Sylvilagus palustris - Marsh rabbit

Order Rodentia - Rodents

Family Castoridae

Castor canadensis - Beaver

Family Cricetidae

Ondatra zibethicus - Muskrat
Oryzomys palustris - Rice rat

Order Carnivora - Carnivores

Family Procyonidae

Procyon lotor - Raccoon

Family Mustelidae

Lutra canadensis - River otter
Mustela vison - Mink

Order Marsupialis - Marsupials

Family Didelphiidae

Didelphis marsupialis - Opossum

None of these semiaquatic mammals inhabit reactor effluent streams during periods of elevated water temperatures. Beaver and otter, however, reoccupy these streams within 24 hours of reactor shutdown (Du Pont, 1985).

C.5 AQUATIC BIOTA

Six major aquatic habitat types occur on the Savannah River Plant: small ponds, Carolina bays, reservoirs, streams, and the Savannah River and its associated floodplain swamp. The surface areas of these waters vary in size from less than 1 acre to about 2700 acres. Flows in the various streams range from intermittent to more than 11 cubic meters per second.

Water flow patterns through the swamp system bordering the Savannah River are complex; these patterns change depending on water levels in the Savannah River. Patterns are quite diverse; distinct water courses alternate with braided channels and broad flats of barely perceptible water movement. Many fish species use the swamp system as a spawning and rearing ground. Its use depends on high water levels, which make more spawning habitat available. The swamp is also one of the most variable habitats, exhibiting depth fluctuations of 4 meters or more along with the input of thermal effluents.

C.5.1 AQUATIC FLORA

Attached algae (periphyton) are the predominant primary producers in running-water environments like the Savannah River. Much of the phytoplankton (floating algae) community consists of true planktonic forms as well as detached periphytic forms that are discharged from upstream reservoirs and from backwaters and tributary streams.

Diatoms dominate the algal flora of the Savannah River, although blue-green algae are at times an important component, particularly at upstream locations that are subject to organic enrichment from municipal effluents, industrial effluents, and agricultural runoff. The greatest algal diversity consistently occurs during the summer, coincident with low river flow and decreased turbidity, which allows greater light penetration.

Approximately 400 species of algae have been identified from the Savannah River near the Savannah River Plant (Patrick, Cairns, and Roback, 1967). Since 1951, when algal studies began at the Plant, the diversity has decreased. Patrick, Cairns, and Roback (1967) suggested that this reflects an increase of organic loading to the river from the area above the Plant (ANSP, 1961, 1974).

Aquatic macrophytes in the river, most of which are rooted, are limited to shallow areas of reduced current in oxbows and along the shallow margins of tributaries. Eight species of vascular plants have been identified from the river adjacent to the Savannah River Plant; the most abundant are water milfoil, hornwort, alligator weed, waterweed, and duck potato (Georgia Power Company, 1985).

In the SRP streams that receive thermal effluents, the flora are greatly reduced, reflecting the influence of high flows and elevated water temperatures. The thermal gradient ranges from temperatures too high for most living organisms (70°C), through a thermophilic bacteria and algal zone, down to near-ambient temperatures where the water enters the Savannah River. In

addition, the streams are sufficiently narrow to produce nearly horizontal and vertical thermal constancy; thus, the only refuges from the hot water are in tributaries or adjacent sloughs. Reactor effluent has increased the total flow by a factor of 10 to 20 times the normal stream flow. This flow has broadened and eroded the streambeds; eliminated rooted, aquatic vascular plants (macrophytes); reduced the overhead canopy, exposing the stream to sunlight; and accumulated silt deposits in some peripheral zones along the banks.

C.5.1.1 Beaver Dam Creek

Beaver Dam Creek immediately below the D-Area discharge structure is characterized by a deep (1 to 2.5 meters) channel and a substrate of shifting sand, fly ash, organic deposits, and occasional clay outcrops (Du Pont, 1985). Riparian vegetation is dominated by a narrow band of bottomland hardwoods and scrub-shrub forest, where wax myrtle, tag alder, willow, and buttonbush are dominant. Emergent macrophytes are present in off-channel areas, such as in oxbows, behind sand bars, and in swamp areas along the margins of the stream near the delta. These areas are dominated by cattail, cutgrass, and water primrose. Aquatic flora is dominated by thermophilic bacteria and blue-green algae (Du Pont, 1985).

C.5.1.2 Four Mile Creek

A relatively deep (0.3 to 1.5 meter), fast-flowing (about 140 centimeters per second) zone occurs where the main flow of Four Mile Creek courses toward the Savannah River (Du Pont, 1985). In this area the flora is sparse, reflecting the influence of high flow and elevated (greater than 40°C) water temperatures. The substrate is primarily sand, organic matter, silt, and clay. In backwaters and shallow areas, particularly on clay outcrops, thick mats of blue-green algae cover the bottom. Riparian vegetation is dominated by tag alder and wax myrtle. Farther downstream toward the swamp, the stream is braided over a marsh-like area where a few standing dead bald cypress remain. In this area, defined and deeper channels are relatively free of vegetation. There are, however, thick growths of emergent macrophytes dominated by sedges, cutgrass, false nettle, and water purslane. In the shallower areas, thick mats of bluegreen algae cover the bottom.

C.5.1.3 Pen Branch

The upper reaches of Pen Branch are characterized by a substrate of sand and silt clay, while deep organic deposits occur in the many side channels (Du Pont, 1985). Blue-green algal mats similar to those in Four Mile Creek cover the substrate. Riparian vegetation includes sedges, grasses, wax myrtle, and buttonbush, while duckweed is abundant in the many side pools and channels.

The delta region of Pen Branch is characterized by an open and closed canopy of living and dead bald cypress and tupelo. Many channels braid through the area and the flow is generally in a shallow sheet. The dominant vegetation consists of smartweed, arrowhead, creeping burhead, water primrose, sedges, and duckweed. Fewer emergent plants are located at the closed canopy areas of the delta.

C.5.2 AQUATIC FAUNA

C.5.2.1 Macroinvertebrates

The structure and function of macroinvertebrate assemblages can indicate long-term conditions in a stream, due to their sensitivity to stress from pollution, and can be used in water quality evaluation (Weber, 1973). Thermal discharges have complex effects on macroinvertebrate communities (Hutchinson, 1976; Ward and Stanford, 1982). Increased water temperatures can accelerate or delay the emergence patterns of aquatic insects (Wise, 1980) and increase or decrease the number of generations (Parkin and Stahl, 1981; Rodgers, 1980). In some cases, elevated thermal regimes can significantly reduce species richness (Ferguson and Fox, 1978; Howell and Gentry, 1974). Other macroinvertebrate taxa can respond positively to increased water temperatures. For example, relative abundances of oligochaetes, nematodes, gastropods, and chironomid midges increase with thermal enrichment (Nichols, 1981; Rasmussen, 1982; Laybourn, 1979; Wood, 1982; Vincent, 1967; Ferguson and Fox, 1978).

To evaluate the response of macroinvertebrates to thermal stress and also to evaluate the long-term recovery of the macroinvertebrate community, samples were collected from nonthermal (Meyers Branch), thermal (Beaver Dam Creek, Four Mile Creek, and Pen Branch), and post-thermal (Steel Creek) streams, and from swamp locations on the Savannah River Plant between November 1983 and May 1984 (Du Pont, 1985).

In addition, samples were collected at the mouths of Upper Three Runs Creek, Steel Creek, and Lower Three Runs Creek from September 1982 through August 1983 (Specht et al., 1984).

The number of macroinvertebrate taxa collected from each stream station varied considerably between thermal and nonthermal stations (Table C-5). The thermally perturbed sites had the fewest taxa. Many of the taxa recorded at these sites were not resident species, but were species that had invaded and colonized during reactor shutdown periods; most were eliminated when the reactor restarted.

In general, fewer macroinvertebrate taxa and lower densities of organisms were collected from thermal sites than from post-thermal or nonthermal sites (Table C-5). The macroinvertebrate communities of the thermal sites were dominated by oligochaetes (segmented worms), nematodes (round worms) and Diptera (primarily midges), while thermally sensitive taxa, such as mayflies, stoneflies, and caddisflies were absent or occurred in very low densities. Nonthermal and post-thermal sites exhibited a much more diverse assemblage of macroinvertebrate taxa. At thermal sites, collector-gatherers clearly dominated the macroinvertebrate functional groups, while at nonthermal sites there was a more even distribution of functional groups, indicative of a more balanced biological community.

Table C-5. Composition of Stream Macroinvertebrate Community, Presented as Sum of Densities (no./m²), December 1983 - May 1984^a

Taxa	Stations ^b							
	Mildly thermal	Severely thermal			Nonthermal			
	1	2	3	4	7	8	11	12
Coelenterata	75	0	0	0	0	0	84	0
Turbellaria	0	0	0	0	10	17	117	8
Nematoda	12,747	4,965	6,707	2,763	3,750	1,205	10,284	5,221
Annelida								
Oligochaeta	19,718	412	6,178	45,612	15,185	18,001	8,812	7,923
Hirudinea	0	0	0	0	0	0	75	0
Crustacea								
Isopoda	0	0	0	0	8	0	83	0
Amphipoda	302	2	8	84	385	27	302	1,001
Decapoda	0	0	0	0	0	0	0	0
Hydracarina	557	8	6	75	640	210	2,354	590
Insecta								
Collembola	0	8	0	0	8	8	8	8
Odonata	153	0	0	0	0	302	0	75
Ephemeroptera	17	86	87	161	3,727	4,511	4,987	1,871
Plecoptera	0	0	0	0	385	2,172	2,455	2,955
Hemiptera	0	0	0	0	0	0	0	0
Megaloptera	0	0	0	0	49	6	2	17
Neuroptera	0	0	0	0	0	0	0	0
Trichoptera	127	151	11	120	5,347	2,489	2,981	4,368
Lepidoptera	0	0	0	0	0	0	8	0
Coleoptera	17	0	42	97	2,022	1,415	1,786	1,058
Diptera	5,860	3,023	19,575	13,287	100,199	66,233	76,290	84,085
Gastropoda	1,971	17	358	1,512	75	379	22	316
Pelecypoda	4,828	0	2	0	302	3,779	75	12,828

^aSource: Du Pont, 1985.

^bStations 1 (Beaver Dam Creek), 2 and 3 (Four Mile Creek), 4 (Pen Branch), 7 and 8 (Steel Creek), 11 and 12 (Meyers Branch).

C.5.2.2 Fish

The Savannah River and its associated swamp and tributaries exhibit a diverse fish fauna typical of other southeastern coastal plain rivers and streams. Many ecological studies during the past 30 years have included the adult fish of the Savannah River. Matthews (1982) reviewed those studies published by the Academy of Natural Sciences of Philadelphia between 1951 and 1976. Bennett and McFarlane (1983) summarized the general distribution of fish within the major drainage systems of the Savannah River Plant. McFarlane, Frietsche, and Miracle (1978) and Dudley, Mullis, and Farrel (1977) reported the results of fisheries studies in the portion of the river near the Plant. In addition, the Georgia Game and Fish Division (1982) reported on an electrofishing survey conducted at 24 locations between the New Savannah River Bluff Lock and Dam and Port Wentworth. Rulifson, Huish, and Thoesen (1982) compiled data on anadromous species, many of which are important in the Savannah River. The most intensive study to date of the fish community of the SRP streams and the Savannah River (Du Pont, 1985) began in 1983.

This section summarizes the influence of thermal effluents on the fish community, specifically the distribution and abundance of adult and larval fish communities in nonthermal, post-thermal, and thermal streams; the effects of entrainment and impingement of adults and ichthyoplankton; the movement of fish into thermal streams; and the thermal tolerance of larval fish (Du Pont, 1985).

Fishes of Savannah River Plant Streams

Adult Fish of SRP Streams

Adult fish sampling began in September 1983 in nonthermal (Meyers Branch), thermal (Pen Branch and Four Mile Creek), and post-thermal (Steel Creek) streams (Figure C-4).

Nonthermal Streams - Relative abundance was greatest at the Meyers Branch station near Road 9 during the March 17 collection (Table C-6). The collection (401 fish) was dominated numerically by the yellowfin shiner (63 percent), bluehead chub (7 percent), pirate perch (5 percent), tessellated darter (5 percent), redbreast sunfish (4 percent), and spotted sunfish (3 percent). Steel Creek near Road B exhibited similar species composition and abundance during the March 10 collection; this collection (270 fish) was composed of 14 species and was dominated by yellowfin shiner (52 percent), bluehead chub (10 percent), northern hogsucker (9 percent), redbreast sunfish (9 percent), and flat bullhead (5 percent).

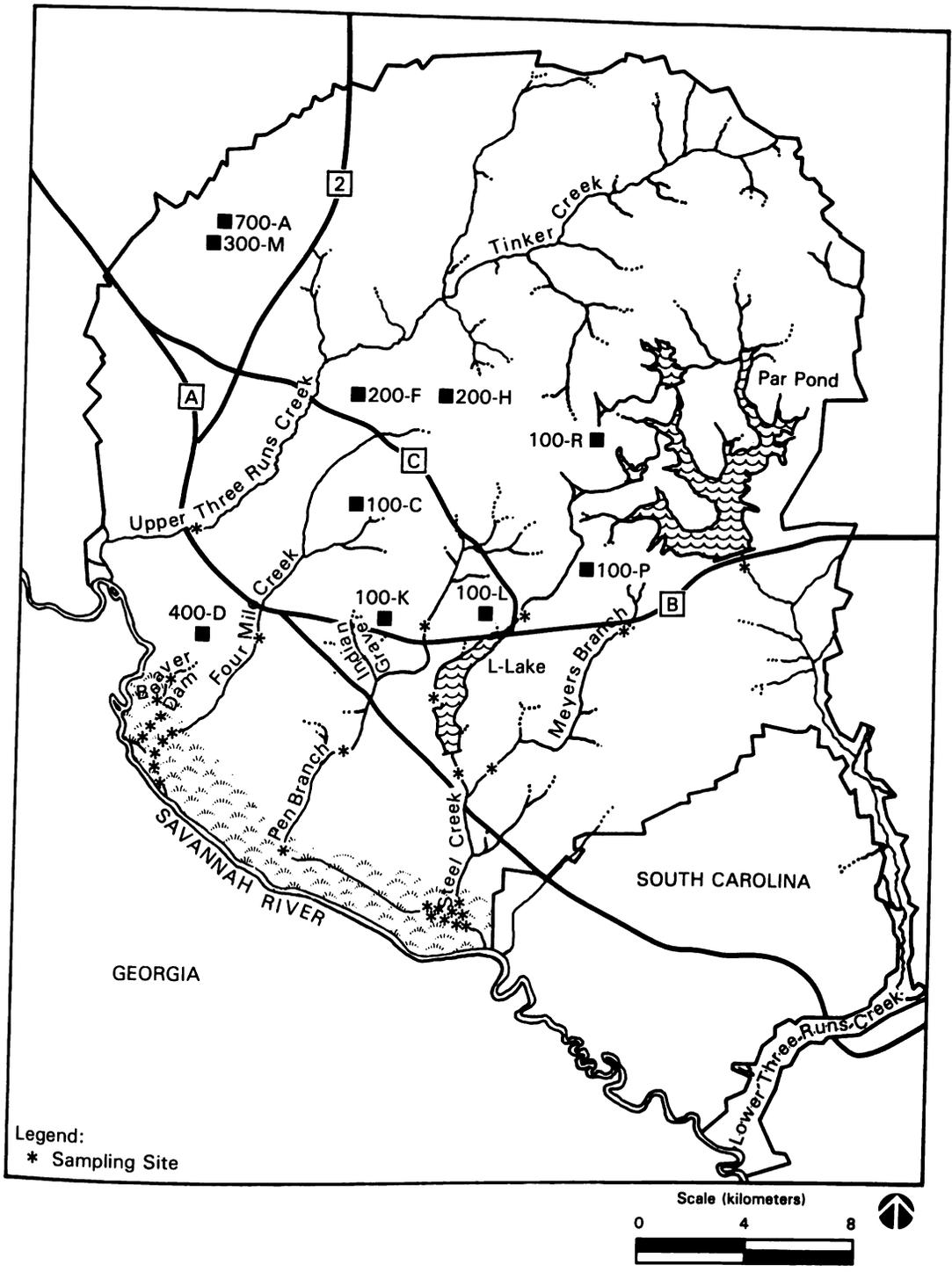


Figure C-4. Fisheries Sampling Sites in SRP Creeks

Table C-6. Number of Fish Collected in SRP Streams, September 1983 - April 1984^a

Species	Location ^b											
	Nonthermal					Post-thermal					Thermal	
	MB Sept.	MB Mar. 17	SC 1 Sept.	SC 1 Mar. 10	SC 2 Mar. 14	PB 1 Apr. 2	PB 2 Sept.	PB 2 Mar. 29	PB 3 Sept.	PB 3 Mar. 26		
American eel	3 (1.0) ^c	6 (1.5)		7 (2.6)	9 (3.1)	1 (13.1)	2 (1.0)	2 (2.0)	2 (0.8)			
Pirate perch	15 (5.2)	20 (4.9)				8 (10.5)	23 (11.9)	8 (8.1)	9 (3.7)	11 (7.6)		
Creek chubsucker						1 (1.3)	3 (1.6)	2 (2.0)	6 (2.5)	2 (1.4)		
Lake chubsucker	3 (1.0)	2 (0.5)	1 (0.7)	2 (0.7)	2 (0.7)	11 (14.5)	1 (0.5)	1 (1.0)				
Northern hogsucker	3 (1.0)	5 (1.2)	9 (6.1)	25 (9.3)								
Banded pygmy sunfish					1 (0.3)							
Bluespotted sunfish		1 (0.2)										
Warmouth					1 (0.3)							
Dollar sunfish					2 (0.7)	12 (15.8)	1 (0.5)					
Mud sunfish	2 (0.7)					23 (30.3)	2 (1.0)	2 (2.0)				
Redbreast sunfish	19 (6.5)	15 (3.7)	19 (12.8)	25 (9.3)	6 (2.1)	1 (1.3)	9 (4.7)	5 (5.1)	16 (6.6)	17 (11.7)		
Spotted sunfish	16 (5.5)	13 (3.3)	1 (0.7)	1 (0.4)	11 (3.8)		14 (7.3)	8 (8.1)	14 (5.8)	7 (4.8)		
Flier					1 (0.3)							
Largemouth bass	2 (0.7)				1 (0.3)				1 (0.4)			
Unknown shiner	1 (0.3)						16 (8.3)		11 (4.6)			
Creek chub				1 (0.4)								
Bluehead chub	24 (8.2)	29 (7.2)	24 (16.2)	27 (10.0)	1 (0.3)		11 (5.7)	7 (7.1)	18 (7.5)	3 (2.1)		
Pugnose shiner					1 (0.3)							
Coastal shiner					36 (12.3)							
Dusky shiner					154 (52.7)							
Yellowfin shiner	167 (57.4)	251 (62.6)	79 (53.4)	141 (52.2)	27 (9.2)		84 (43.5)	42 (42.4)	138 (57.3)	58 (40.0)		
Lined topminnow					1 (0.3)					1 (0.7)		
Mosquitofish				2 (0.7)	1 (0.3)							

20

Table C-6 Number of Fish Collected in SRP Streams, September 1983 - April 1984.^a (Continued)

Species	Location ^b										
	Nonthermal					Post-thermal			Thermal		
	MB Sept.	MB Mar. 17	SC 1 Sept.	SC 1 Mar. 10	SC 2 Mar. 14	PB 1 Apr. 2	PB 2 Sept.	PB 2 Mar. 29	PB 3 Sept.	PB 3 Mar. 26	
Redfin pickerel	6 (2.1)	3 (0.7)				2 (2.6)	15 (7.8)	3 (3.0)		1 (0.7)	
Chain pickerel					3 (1.0)			2 (2.0)			
Yellow bullhead	1 (0.3)		2 (1.4)		1 (0.3)	4 (5.3)	6 (3.1)	3 (3.0)	1 (0.4)	4 (2.8)	
Brown bullhead					2 (0.7)	13 (17.1)		1 (1.0)			
Flat bullhead	2 (0.7)	6 (1.5)	8 (5.4)	15 (5.6)			4 (2.1)	1 (1.0)	4 (1.7)	6 (4.1)	
Speckled madtom	6 (2.1)	9 (2.2)	2 (1.4)	17 (6.3)	15 (5.1)			5 (5.1)	9 (3.7)	7 (4.8)	
Margined madtom	5 (1.7)	12 (2.9)		2 (0.1)				2 (1.0)	9 (3.7)	11 (7.6)	
Tadpole darter								1 (1.0)		2 (1.4)	
Tesselated darter	12 (4.1)	19 (4.7)		1 (0.4)	12 (4.1)			4 (4.0)	1 (0.4)	7 (4.8)	
Savannah darter		6 (1.5)									
Sawcheek darter					1 (0.3)						
Blackbanded darter	4 (1.4)	4 (0.9)	3 (2.0)	4 (1.5)	3 (1.0)				2 (0.8)	7 (4.8)	
Number of fish	291	401	148	270	292	76	193	99	241	145	
Number of species	18	16	10	14	23	10	15	17	15	16	

^aSource: Du Pont, 1985.

^bLocation Codes: MB = Meyers Branch

SC 1 = Steel Creek at Road B

SC 2 = Steel Creek at Cypress Bridge

PB 1 = Pen Branch above Road C

PB 2 = Pen Branch at Road C

PB 3 = Pen Branch at Road B

^cPercent composition in parentheses.

Post-Thermal Streams - The March 14, 1983, collection (Table C-6) from Steel Creek represented 23 species and 292 individuals. This sample exhibited the greatest species diversity, possibly due to its proximity to the Savannah River swamp. The collection was dominated by shiners (75 percent), darters (6 percent), and bullheads and madtoms (12 percent). This assemblage is a mixture of species usually associated with both stream channels and pools, backwaters, and vegetated areas along the channel.

Thermal Streams - Three locations were sampled on Pen Branch upstream of the K-Reactor outfall. A sample of site PBI, collected on April 2, 1984, was dominated by species associated with benthic-detritus microhabitats; it consisted of 76 individuals and 10 species (Table C-6). This sample was dominated by the mud sunfish (30 percent), brown bullhead (17 percent), dollar sunfish (16 percent), lake chubsucker (14 percent), and pirate perch (10 percent). Noticeably absent were species generally associated with fast-flowing water (i.e., darters).

Seventeen species of fish totaling 99 individuals were collected on March 29, 1984. Species composition was dominated by yellowfin shiner (42 percent) and sunfish (15 percent). Although there was a reduction in the total number of fish collected between September and March, the species composition remained nearly the same, indicating some degree of stability for the fauna.

One other location on Pen Branch exhibited relative abundance and species composition similar to those of the other streams surveyed. On March 26, 1984, 145 individuals representing 16 species were collected (Table C-6). The most abundant species were the yellowfin shiner (58 percent), sunfish (24 percent), and madtom (20 percent).

Movement of fish into the channels of thermal creeks (Pen Branch and Four Mile Creek) during reactor outages is directly related to the duration of a reactor outage. Thirty species of fish were collected in thermal creeks; 24 species were common to both Pen Branch and Four Mile Creek. Centrarchids were the fish collected most commonly, accounting for 47 percent and 45 percent of the fish collected from Pen Branch and Four Mile Creek, respectively. Other dominant taxa included the lake chubsucker (16-26 percent), the golden shiner (11-12 percent), and the longnose gar (1-14 percent).

However, samples collected from Four Mile Creek above the delta during a 50-day reactor shutdown in February 1984 were dominated exclusively by mosquitofish (Du Pont, 1985).

In general, fewer adult fish and a reduced species composition were noted from thermal streams than from post-thermal or nonthermal streams (Table C-6). The adult fish communities of the thermal streams above the outfalls were dominated by small fish (i.e., shiners and sunfish). However, during reactor shutdowns, the thermal streams below the outfall are dominated by mosquitofish. Post-thermal areas exhibited the greatest species diversity and reflected species composition typical of small headwater streams.

Ichthyoplankton of SRP Streams

Ichthyoplankton were sampled at 5 nonthermal, 16 post-thermal, and 14 thermal sites in SRP streams from mid-March through July 1984 (Paller et al., 1984). Nonthermal sites included three locations on Upper Three Runs Creek and two locations on Meyers Branch. Post-thermal sampling sites included three locations in Lower Three Runs Creek and 13 stations in Steel Creek. Three thermal streams, Beaver Dam Creek, Four Mile Creek, and Pen Branch, were sampled.

Nonthermal Streams - Ichthyoplankton abundance in the nonthermal streamswamp area during 1984 was dominated by centrarchids (sunfish), catostomids (suckers), and percids (darters) (Table C-7). The spotted sucker was the most abundant species (55 percent) in the upper reaches of Upper Three Runs Creek, while crappie (21 percent) were the most prevalent species at the creek mouth. Ichthyoplankton densities were moderate to low (mean = 42 per 1000 cubic meters) at all stations. Meyers Branch was dominated by sunfish or bass (45 percent) and darters (30 percent). Densities were relatively low at the station near the mouth (18-67 per 1000 cubic meters), suggesting very little ichthyoplankton transport into Steel Creek from the upper reaches of Meyers Branch, which exhibited densities of 23 to 183 per 1000 cubic meters. The greater densities in the upper part of Meyers Branch might be related to more suitable spawning habitat. Several beaver dams in this area might provide good habitat for centrarchid spawning.

Post-Thermal Streams - During 1984, a total of 2785 ichthyoplankters were collected from Steel Creek and Lower Three Runs Creek (Table C-7). Relative abundance was much higher than that found in the nonthermal or thermal streams and were primarily the result of the locations of the sample collections. Generally, densities at swamp and creek mouth stations were substantially higher than at creek stations upstream from the swamp. The most dominant taxa during all collections were centrarchids (sunfish and bass, 28 percent), minnows (25 percent), and darters (12 percent). Blueback herring (4 percent) were abundant in the creek mouths during April. The mean ichthyoplankton density was 175 per 1000 cubic meters during the March-to-June sampling period.

The predominant taxa collected from Lower Three Runs Creek were sunfish or bass (46 percent), crappie (20 percent), and darters (12 percent). The high densities collected in Lower Three Runs Creek were a result of samples collected immediately downstream of the Par Pond Dam (mean density = 1062 per 1000 cubic meters); they represent intense spawning activity in this tailwater area in combination with larval production in Par Pond that might have overflowed into the tailwater.

Thermal Streams - The D-Area effluent entering Beaver Dam Creek is considerably cooler than the reactor effluent (70°C) entering the other thermal creeks. Temperature data collected as part of the ichthyoplankton sampling program indicated that the upper reaches of Beaver Dam Creek (Road A-12) averaged 20° to 25°C, while Four Mile Creek near Road A-13 averaged 30° to 45°C during the April-through-May sampling period. Temperatures

Table C-7. Number and Relative Abundance of Ichthyoplankton Collected from Nonthermal, Post-Thermal and Thermal Creeks of the Savannah River Plant March 14 - June 3, 1984

Taxa	Nonthermal					Onsite creeks ^b					PB
	UTR	MB	SC	SCMB	LTR	Post-thermal	BDC	FMC	Thermal		
American shad			13(0.9)						1(0.5)		
Gizzard or threadfin shad	12(5.6) ^c	3(2.0)	12(0.9)		23(1.7)				19(8.6)		16(7.9)
Blueback herring	4(1.9)		65(4.7)		20(1.5)				9(4.1)		21(10.3)
Unidentified shad or herring	3(1.4)		14(1.0)		16(1.2)				3(1.4)		4(2.0)
Spotted sucker	118(55.1)		14(1.0)		3(0.2)				4(1.8)		
Unidentified suckers	3(1.4)	4(2.7)	57(4.1)		15(1.1)						4(10.5)
Pirate perch			41(3.0)						3(1.4)		
Sunfish and/or bass	3(1.4)	66(44.9)	387(28.1)		626(46.1)				84(37.9)		65(32.0)
Crappie	44(20.6)		34(2.5)		266(19.6)				25(11.3)		5(2.5)
Yellow perch	2(0.9)		12(0.9)	2(4.1)	29(2.1)				1(0.5)		5(13.2)
Darters	9(4.2)	44(29.9)	167(12.1)	13(26.5)	158(11.6)				20(9.0)		1(0.5)
Mudminnows			5(0.4)								1(2.6)
Swampfish			10(0.7)								10(26.3)
Minnows	9(4.2)	14(9.5)	356(25.8)	33(67.3)	16(1.2)				15(6.8)		14(6.9)
Carp	2(0.9)								1(0.5)		3(1.5)
Pickereel			1(0.1)								
Topminnow					1(0.1)						1(2.6)
Mosquitofish		1(0.7)	29(2.1)		23(1.7)				8(3.6)		3(7.9)
Silverside		15(10.2)	162(11.7)	1(2.0)	161(11.9)				29(12.6)		28(13.8)
<u>Unidentifiable ichthyoplankton</u>	<u>5(2.3)</u>	<u>15(10.2)</u>	<u>162(11.7)</u>	<u>1(2.0)</u>	<u>161(11.9)</u>				<u>29(12.6)</u>		<u>45(22.2)</u>
Total	214	147	1379	49	1357	222	203	38			
Grand total		361		2785		463					
Number of locations sampled	3	2	13	3	3	5	6	3			

^aAdapted from Du Pont, 1985.
^bkey: UTR=Upper Three Runs Creek; MB=Meyers Branch; SC=Steel Creek; SCMB=Steel Creek above Meyers Branch; LTR=Lower Three Runs Creek; BDC=Beaver Dam Creek; FMC=Four Mile Creek; PB=Pen Branch
^cpercent composition in parenthesis.

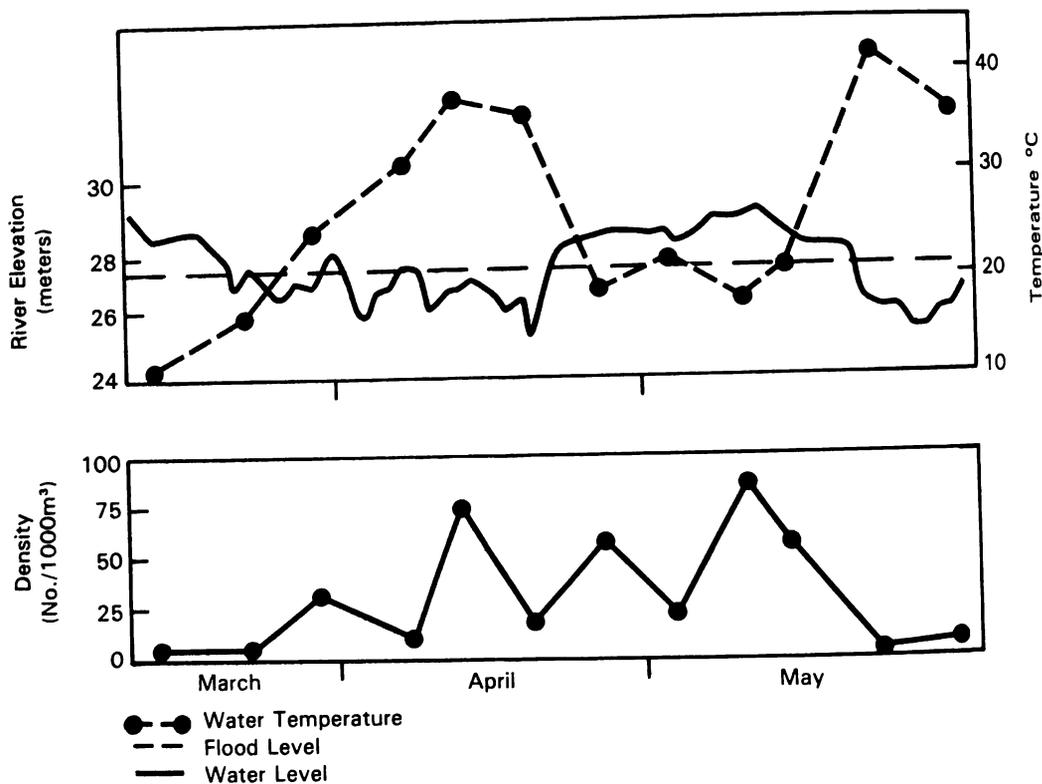
decreased in Beaver Dam Creek from Road A-12 to the lowermost swamp station due to the gradual cooling of the water as it progressed downstream. However, temperatures increased at the mouth, probably due to an influx of heated water from Four Mile Creek through a channel connecting the lower reaches of Four Mile and Beaver Dam Creeks.

Ichthyoplankton densities in thermal streams ranged from total absence to very low abundance. Ichthyoplankton collected in the reactor streams between the outfalls and the swamp are believed to represent individuals that were transported into the streams from adjacent refugia, including nonthermal tributary streams, during periods of high river flow. These refugia appear to support self-sustaining (i.e., reproducing) populations of fish. In addition, ichthyoplankton abundance in thermal portions of the Savannah River swamp appears to be quite variable and strongly influenced by water levels in the Savannah River. It is also possible that the thermally impacted areas are utilized for spawning during high river flows, when flow patterns for the heated water are altered drastically.

A total of 463 ichthyoplankters were collected from the three thermal streams [Beaver Dam Creek (222), Four Mile Creek (203), and Pen Branch (38)] during the March-to-June 1984 sampling period (Table C-7). Sunfish or bass dominated the catch at both Beaver Dam Creek (38 percent) and Four Mile Creek (32 percent) while minnows (10 percent) and darters (10 percent) were dominant at Pen Branch. Beaver Dam Creek exhibited greater ichthyoplankton density and species diversity than the other thermal streams, but it did not produce the density of ichthyoplankton expected (considering the level of thermal loading observed was not much greater than in the more productive areas of the post-thermal Steel Creek delta).

C-Reactor did not operate during most of March 1984; therefore, mean temperatures in Four Mile Creek were only 5° to 10°C above Savannah River temperatures. Ichthyoplankton were not collected from the Road A station or the thermal delta during March, but were found in low densities in the swamp and creek mouth. Blueback herring were the most dominant in the delta while brook silversides were most dominant in the creek mouth.

C-Reactor was operating during April and May 1984; it produced temperatures in Four Mile Creek ranging from 33.9° to 50.1°C at Road A, and from 30.1° to 44.8°C at Road A-13. As expected, Four Mile Creek produced very little ichthyoplankton in its upper reaches (the area above Road A) with the exception of brook silverside and unidentifiable eggs; these eggs probably drifted into the channel of the creek from adjacent refuge areas. Temperatures in the heated swamp were lower and much more variable (18° to 42°C) due to the alteration of water flow patterns during river flooding. The extreme temperature variability in the heated swamp was due to the intermittent intrusion of relatively cool river water into the swamp during periods of high river level (Figure C-5). The river water displaced the thermal plume and created suitable habitat for fish in areas that had been thermally unsuitable. Most of the larvae collected from the swamp during April and May apparently were spawned during periods of high river level when



Source: Adapted from Du Pont (1985)

Figure C-5. A Comparison of the Ichthyoplankton Density in the Four Mile Creek Delta with Water Temperature and Savannah River Level

the swamp was inundated with river water. Some larvae were collected when the temperatures were high during April; however, these might have drifted into the thermal swamp from adjacent cool-water refuge areas.

Very few ichthyoplankton (38) were collected from Pen Branch during the March-to-June 1984 sampling period. Ichthyoplankton were either absent from the samples or present in low densities. The dominant species in the delta was the mosquitofish. This species is more tolerant of high temperatures than most, with an ultimate maximum temperature of 37.3°C (Hart, 1952). Most individuals were found in somewhat cooler refuge areas along the shoreline of the main thermal channel. Darters and minnows dominated the catch from above the reactor discharge area.

Researchers observed that, generally, ichthyoplankton densities at swamp and creek mouth stations were substantially higher than at creek stations upstream from the swamp. Sampling in the vicinity of the post-thermal Steel Creek delta revealed that spawning activity differs substantially in the different microhabitats available in that area. The deep-water, open-canopy areas were clearly the most productive for ichthyoplankton, with centrarchids (sunfish and bass), cyprinids (minnows), and percids (darters) dominating the collections. Although clupeids (herring and shad) were collected in the delta/swamp areas, the numbers were much lower than the numbers observed at creek mouth stations. Generally, it appears that anadromous species make minimal use of swamp areas for spawning and restrict spawning activities to creek mouth areas.

Ichthyoplankton densities in thermal streams were low. Ichthyoplankton collected in the reactor streams between the outfalls and the swamp are believed to represent individuals that were transported into the streams from adjacent refugia, including nonthermal tributary streams. These refugia appear to support self-sustaining (i.e., reproducing) populations of fish. Ichthyoplankton that are transported into the reactor effluent streams when reactors are operating are undoubtedly killed.

Ichthyoplankton abundances in thermal portions of the Savannah River swamp are quite variable and appear to be strongly influenced by water levels in the Savannah River. During periods of high river flow, ichthyoplankton appear to be transported into the thermally impacted portions of the swamp from adjacent unimpacted areas. It is also possible that the thermally impacted areas are utilized for spawning during high river flows, because flow patterns for the heated water are drastically altered during such periods.

Ichthyoplankton densities in Beaver Dam Creek are lower than expected considering the low degree of thermal enrichment. Factors other than temperature probably are influencing fish spawning activities in this area of the swamp.

Adult Fish of the Savannah River Swamp System

The Savannah River Swamp System (SRSS) represents a very heterogeneous system of habitats supporting a diverse fish community of 60 to 65 species. Most species are resident; however, seven are either anadromous or catadromous. Anadromous (migrating from saltwater to freshwater to spawn) species include blueback herring, American shad, hickory shad, striped mullet, mountain mullet, and Atlantic needlefish. The only catadromous (migrating from freshwater to saltwater to spawn) species is the American eel. Several recreationally and commercially important species have been collected in the swamp; thus, the SRSS could be an important spawning habitat and nursery grounds for these species. This section summarizes the data collected on the adult fish community in the swamp system from October 1983 to April 1984 (Du Pont, 1985).

Adult fish were collected at three areas in the swamp: the Steel Creek delta; the Four Mile Creek delta, and a channel near Pen Branch (near Stave Island).

More than 1500 fish representing 40 species were collected from the swamp. The high species diversity was due to the wide array of habitat types available. The Steel Creek delta sample consisted of 32 species, of which brook silversides, various shiners, and largemouth bass dominated all catches.

Species diversity at stations in the delta-swamp area of Pen Branch were similar - 21 species dominated by brook silversides and various shiners.

Four Mile Creek stations differed among themselves and also from the other three delta-swamp stations. Fifteen species of fish were collected; gizzard shad and largemouth were the dominant species. Compared to the other stations, minnows were poorly represented at this station.

Researchers captured 149 migratory fish, of which longnose gar (48 percent), blueback herring (23 percent), channel catfish (10 percent), and various shad (12 percent) were the dominant species. Researchers first observed blueback herring during the first week of March, while American shad did not appear until the last week of March. Conversations with local fishermen suggest that American shad were more numerous than blueback herring or hickory shad during 1984, and that a major run of blueback herring did not occur in Steel Creek.

Several trends are evident concerning the structure of fish communities within the SRSS. It appears that the increased species composition and the dominance by centrarchids and cyprinids are attributed to the diversity of microhabitats in the area. The swamp system is composed of extensive open water channels and macrophyte beds of various size. Centrarchids (bass and sunfish) and various suckers dominated the areas with extensive cover while minnows and brook silverside were most prevalent in the shallow open-water areas beneath the closed canopy. The swamp areas below the thermal streams were lower in habitat diversity and species composition.

Fishes of the Savannah River

Adult Fishes of the Savannah River and Creek Mouths

This section summarizes the results of adult fish collections at 12 locations in the Savannah River, the intake canals, and the lower reaches of the five major SRP creeks. The data cover the sampling period from October 1982 to August 1983; these data are based on studies conducted by Environmental and Chemical Sciences, Inc. under contract to E. I. du Pont de Nemours and Company (Paller et al., 1984).

Researchers collected nearly 10,000 adult fish representing 66 species in the river, the intake canals, and the lower reaches of the major SRP creeks during the sampling period.

The electrofishing collections (Table C-8) indicated that sunfishes, especially redbreast, were the most abundant small species (except minnows), while bowfin and spotted sucker were among the most abundant large species during most or all of the year. Flat bullhead and channel catfish were important species, as indicated by hoop net collections, comprising 32 to 63 percent of the catch. Largemouth bass never comprised less than 7.9 percent of the electrofishing samples during any collection period. Other important species were American eel, white catfish, longnose gar, striped mullet, silver redhorse, chain pickerel, and quillback carpsucker.

Species composition varied due to seasonal changes in fish movement and activity (e.g., spawning). The most conspicuous change was a decrease in the relative abundance of sunfish during January (Table C-8). Bowfin, spotted sucker, flat bullhead, and channel catfish were more abundant during January. The greatest number of species was captured during May (37), possibly because of migratory movements or seasonal changes in activity related to spawning. Recruitment of young of the year might have increased the relative abundance of some species during August.

The sampling stations were located in four basic habitat types: the river proper, intake canals, the mouths of thermal creeks (Four Mile and Beaver Dam Creeks), and ambient creeks (Upper Three Runs, Lower Three Runs, and Steel Creeks).

In general, bluegill, black crappie, and chain pickerel were more abundant in the intake canals than in the other habitats, probably due to their preference for slow-moving water and weed beds. Redbreast sunfish were generally most abundant in the river and bowfin in the ambient creeks, especially Steel Creek. Four Mile Creek attracted numerous gar, bowfin, and gizzard shad during January, but was largely devoid of fishes during the other months. Channel catfish and various bullheads clearly dominated the hoopnet collections at all stations and seasons, probably due to gear selectivity. During the study period, the mean weekly water temperature of the thermal creeks was 14°C; it was 7°C in ambient creeks during the January sampling

Table C-8. Percent Composition by Number and Weight of Fishes Collected Quantitatively by Electrofishing in the Savannah River and Creek Mouths, October 1982 - August 1983^a

Taxa	1982		1983					
	October		January		May		August	
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
Bowfin	13.6	53.3	15.1	37.9	2.4	20.6	4.8	36.4
American eel	3.6	1.3	0.3	0.3	1.2	1.4	2.4	1.7
Blueback herring	2.4	0.1	0.0	0.0	0.3	0.2	0.0	0.0
American shad	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.1
Gizzard shad	1.9	1.6	4.5	1.6	2.1	1.7	1.5	1.7
Threadfin shad	0.0	0.0	2.3	0.1	3.3	0.5	0.8	0.0
Quillback carpsucker	0.0	0.0	0.0	0.0	0.3	9.2	0.3	7.0
Spotted sucker	13.5	26.5	22.7	32.0	6.9	26.0	5.3	18.7
Silver redhorse	0.9	2.2	1.4	2.3	2.1	9.6	1.0	4.2
Unidentified redhorse	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0
Golden shiner	0.0	0.0	0.3	0.1	0.5	0.1	0.4	0.0
Flier	0.0	0.0	0.9	0.1	0.3	0.1	0.0	0.0
Bluespotted sunfish	0.0	0.0	0.0	0.0	5.7	0.1	0.7	0.0
Redbreast sunfish	22.4	1.9	7.1	0.5	13.9	4.0	22.7	4.1
Pumpkinseed	0.0	0.0	0.3	0.1	0.6	0.1	1.8	0.2
Wormouth	1.2	0.1	0.0	0.0	1.8	0.4	1.2	0.2
Bluegill	11.2	0.5	2.6	0.2	5.5	1.0	9.0	1.2
Dollar sunfish	1.4	0.0	0.0	0.0	4.8	0.2	7.3	0.3
Redear sunfish	3.3	0.8	7.7	2.4	3.6	1.9	2.7	1.9
Spotted sunfish	7.1	0.9	4.8	0.2	9.3	1.3	9.3	1.2
Largemouth bass	7.9	4.0	8.5	3.9	9.8	7.8	9.0	4.9
White crappie	0.7	0.1	0.3	0.1	0.1	0.1	0.0	0.0
Black crappie	0.7	0.1	3.7	0.7	2.0	0.6	1.1	0.5
Striped mullet	1.5	1.5	1.1	0.4	2.4	4.3	6.7	9.3
White bass	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Striped bass	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Yellow perch	2.0	0.4	2.0	0.2	2.7	0.9	2.1	0.6
Pirate perch	0.9	0.1	0.0	0.0	0.9	0.1	2.1	0.0
Redfin pickerel	0.7	0.1	5.4	0.1	3.4	0.2	1.6	0.1
Chain pickerel	1.3	0.2	3.4	1.2	11.2	2.1	3.7	1.7
Mudminnow	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0
Longnose gar	0.5	0.4	4.0	2.8	1.7	3.8	0.9	1.1
Florida gar	0.0	0.0	0.0	0.0	0.4	0.5	0.0	0.0
White catfish	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0
Brown bullhead	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0
Flat bullhead	0.0	0.0	0.3	0.1	0.2	0.1	0.1	0.2
Channel catfish	0.2	0.8	0.0	0.0	0.3	0.6	1.1	2.4
Carp	0.3	3.2	1.4	13.1	0.0	0.0	0.0	0.0
Hogchoker	0.8	0.1	0.0	0.0	0.1	0.1	0.2	0.1
Total percent	100.0	99.9	100.1	99.9	99.9	100.0	99.8	99.7
Total number	1628		352		2365		2175	
Total wt. (kg)		670.1		248.1		468.2		505.8

^aSource: Du Pont, 1985.

period. Largemouth bass and sunfishes dominated May catches at both thermal and ambient creek stations, although only 46 fish were collected in thermal creeks compared to 244 in ambient creeks. During May, the mean temperature was 31°C in the thermal creeks and 19.2°C in ambient creeks. Very few fish were collected from the thermal creeks during October or August (4 and 24, respectively). The mean temperature of the thermal creeks during the sampling periods was 27.7°C in October and 32°C in August; it was 15.0°C and 23°C, respectively, during the same months in ambient creeks.

Although the researchers did not sample small fishes and minnows quantitatively, they documented species occurrence and distribution. Species abundance was consistently less in the intake canals than in the river; mosquitofish, brook silversides, and lined topminnows were the most abundant in the canals. Small fish were absent from the mouths of Four Mile Creek and very scarce in Beaver Dam Creek during May and August. The low number of minnow species and small fish collected in these creeks paralleled the large fish collections and are probably the result of high temperatures during May and August (24.5° to 41.2°C).

Researchers used the number of fish collected quantitatively with electrofishing to estimate the relative density (number of fish per 100 meters of shoreline) (Du Pont, 1985). The relative densities of fishes in the 1G and 3G intake canals (0.5 to 8.4 per 100 meters) was equivalent to the relative density in the river; however, the average weight of fish in the intake canals was approximately 40 percent lower than that in the river due to the predominance of bluegill and other small sunfishes. The seasonal relative abundances in the intake canals were comparable to those in the river.

Relative densities and seasonal trends in the mouths of the ambient temperature creeks were similar to those in the river, with low densities in January (0.3 to 0.5 per 100 meters) and higher densities in the other months (Table C-9). In contrast, the relative density in thermally influenced Four Mile Creek peaked during January (5.9 per 100 meters) at levels greater than those at the other transects (0.2 to 2.9 per 100 meters); this indicates a wintertime aggregation of fishes in the heated waters, which were as much as 7°C warmer than ambient river temperatures. Fish avoided Four Mile Creek during May, August, and October because of the excessively high water temperatures (29° - 41°C compared to 16° - 25°C in ambient creeks). Densities in Beaver Dam Creek during May and August (2.8 and 1.3 per 100 meters, respectively) were higher than in Four Mile Creek, but considerably lower than those in ambient creeks or river stations. Temperatures in Beaver Dam Creek were 5° to 7°C above ambient river temperatures, but were not as high as those in Four Mile Creek.

Table C-9. Mean Relative Density of Fishes (No./100 m of Shoreline) at Electrofishing Sample Sites in the Savannah River, Intake Canals, and Tributary Creeks, October 1982 - August 1983^a

Location	1982		1983					
	October		January		May		August	
	Total fish	Mean no./100 m	Total fish	Mean no./100 m	Total fish	Mean no./100 m	Total fish	Mean no./100 m
RIVER TRANSECTS								
RM 128.9	- ^b	-	-	-	168	7.0	83	3.5
RM 129.1	-	-	-	-	252	10.5	120	5.0
RM 137.1	123	5.1	22	0.9	70	2.9	128	5.3
RM 141.5	189	7.9	36	1.5	133	5.5	137	5.7
RM 141.7	189	7.9	70	2.9	131	5.5	145	6.0
RM 150.4	167	7.0	52	2.2	189	7.9	146	6.1
RM 150.8	133	5.5	15	0.6	155	6.5	133	5.5
RM 152.0	-	-	-	-	191	8.0	81	3.4
RM 152.2	-	-	-	-	114	4.8	87	3.6
RM 155.2	143	6.0	13	0.5	122	5.1	115	4.8
RM 157.0	123	5.1	4	0.2	70	2.9	87	3.6
RM 157.3	161	6.8	42	1.8	118	4.9	155	6.5
INTAKE CANALS								
1G RM 157.1	144	6.0	35	1.5	161	6.7	148	6.2
3G RM 155.3	121	5.0	11	0.5	201	8.4	199	8.3
CREEKS								
Lower Three Runs	-	-	-	-	73	6.1	51	5.4
Steel	69	8.6	3	0.5	97	8.1	101	8.4
Four Mile	4	0.7	47	5.9	12	1.0	8	0.7
Beaver Dam	-	-	-	-	34	2.8	16	1.2
Upper Three Runs	60	5.0	2	0.3	74	6.3	235	19.6

^a Source: Du Pont, 1985.

^b(-) locations not sampled.

Researchers determined the approximate distances between the capture and recapture sites for 68 fish that were tagged in the river, canals, and creeks during the sampling program (Du Pont, 1985). Ninety-one percent were recaptured within 15 days at or near the point of tagging, indicating limited short-term movements. However, tag returns by fishermen indicated that some fish undertook extensive migrations (as far as 55 miles) upstream or downstream from the tagging location over a period of weeks or months.

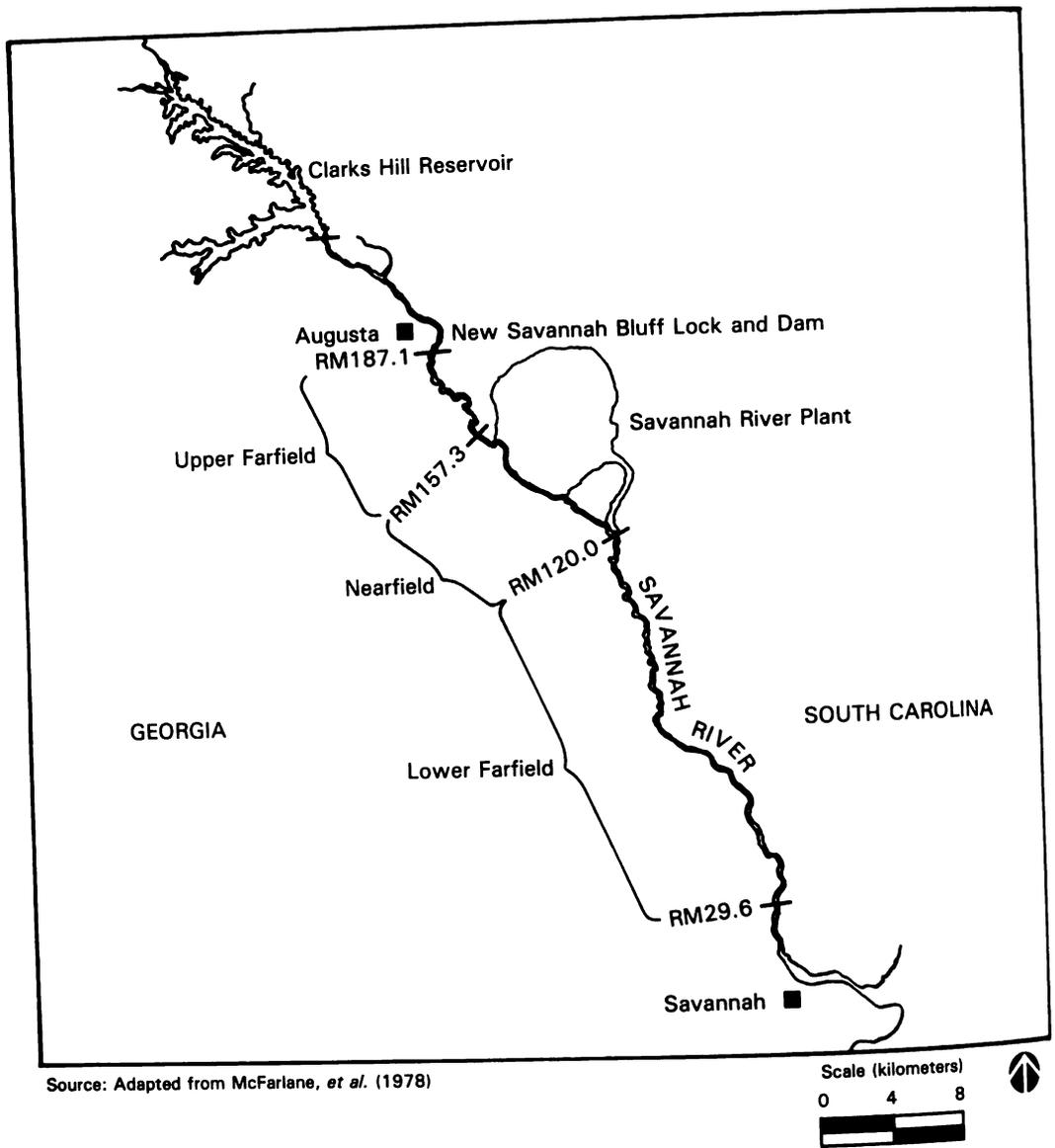
Ichthyoplankton of the Savannah River and Stream Mouths

The abundance of ichthyoplankton is one measure of the reproductive success of fishes; concentrations of ichthyoplankton can indicate important spawning sites, identify impacted and control areas, and provide information for entrainment and impingement losses. During 1983, researchers conducted a comprehensive study on the distribution of ichthyoplankton in a 253.5-kilometer section of the Savannah River and associated tributaries upstream and downstream of the Plant. This section summarizes the results of the ichthyoplankton sampling conducted from March through August 1982 and from February through July 1983 (ECS, 1982; Paller et al., 1984; Du Pont, 1985).

In 1982, the collections program included seven transects across the Savannah River, two intake canals, and three creeks; the program expanded in 1983 to include 26 river transects, two intake canals, and 33 creeks (Figure C-6). The expanded program covered the section between river mile (RM) 29.6 and RM 187.1 (from approximately the freshwater/saltwater interface near Savannah, Georgia, to just below the new Savannah Bluff Lock and Dam below Augusta, Georgia). The 1983 sampling program divided the river into three sections for descriptive purposes: (1) upper farfield - upstream of the Plant, three transects; (2) nearfield - adjacent to the Plant, 15 transects; and (3) lower farfield - downstream of the Plant, 10 transects.

1982 Collections - Researchers collected 5176 fish larvae and 5029 fish eggs in 2138 samples on 13 sampling dates between March 11 and August 29, 1982. Larval fish populations were clearly dominated by the herring and shad family (Clupeidae, Table C-10). Herring and shad larvae together comprise almost 50 percent of all fish larvae collected.

During the survey, researchers identified eggs of several important species (American shad, striped bass, and blueback herring). These three species constituted 90 percent of the total eggs collected (Table C-11). Of the 5029 fish eggs collected, 3550, or about 71 percent, were the American shad. McFarlane, Frietsche, and Miracle (1978) reported that more than 96 percent of the fish eggs collected in their 1977 study were American shad. In the 1982 investigation, striped bass eggs comprised the second highest number collected (494, or about 10 percent of all eggs collected during the study). Striped bass spawning had not been documented in the central Savannah River before 1982.



Source: Adapted from McFarlane, *et al.* (1978)

Figure C-6. Lower Farfield, Nearfield, and Upper Farfield Sections of the Savannah River

Table C-10. Number and Relative Abundance of Larval Fish Collected at All Stations in the Savannah River, March-August 1982^a and February-July 1983^b

Group	Total number collected		Percentage composition	
	1982	1983	1982	1983
Unidentified clupeids	1740	2957	33.6	6.9
Unidentified minnows	980	5557	18.9	13.0
Spotted sucker	825	1913	15.9	4.5
<u>Dorosoma</u> spp.	482	8234	9.3	19.3
Sunfish and bass	294	1778	5.7	4.2
Yellow perch	206	1658	4.0	3.9
Blueback herring	127	5648	2.5	13.2
American shad	110	653	2.1	1.5
Other	89	723	1.7	1.7
Unidentified suckers	88	321	1.7	0.8
Darter	88	1035	1.7	2.4
Carp	52	1370	1.0	3.2
Pirate perch	48	3105	0.9	7.3
Unidentified catfish	21	27	0.4	0.1
Sturgeon	15	10	0.3	0.1
Gar	6	9	0.1	0.1
Atlantic needlefish	4	6	0.1	0.1
Swamp fish	1	7	0.1	0.1
Crappie		7257		17.0
Mudminnow		6		0.1
Mosquitofish		4		0.1
Pickrel		129		0.3
Silverside		160		0.4
Striped bass		88		0.2
Total	5176	42,655	100.0	100.0

^aAdapted from ECS, 1982.

^bAdapted from Paller et al., 1984, which includes only daytime samples.

Table C-11. Number and Relative Abundance of Eggs Collected in the Savannah River, March-August 1982^a and February-July 1983^b

Group	Total number collected		Percentage composition	
	1982	1983	1982	1983
Clupeidae				
American shad	3550	3612	70.6	50.7
Blueback herring	380	417	7.5	5.9
Percidae				
Perch and darters	87	309	1.7	4.3
Percichthyidae				
Striped bass	494	852	9.8	12.0
Other	<u>518</u>	<u>1928</u>	<u>10.4</u>	<u>27.1</u>
Total	5029	7118	100.0	100.0

^aAdapted from ECS, 1982.

^bAdapted from Paller et al., 1984, which includes only daytime samples.

The distribution of fish larvae was generally uniform at the river stations; shad, herring, and spotted sucker larvae were dominant (Table C-10). Fish eggs tended to be more concentrated in the middle portion of the river and often near the bottom. The intake canals had high densities of larvae and low densities of eggs. The eggs entrained into the canals probably settled to the bottom because of low flow rates. Steel Creek and Upper Three Runs Creek contained many larvae and were sites for blueback herring spawning. High temperatures in Four Mile Creek precluded any extensive spawning.

Peak spawning activity occurred in May 1982. In May and June, the abundance of fish eggs and larvae was significantly higher in nighttime collections than in daytime collections. Researchers also collected 15 sturgeon larvae in 1982; thirteen were Atlantic and two were shortnose sturgeon.

1983 Collections - River - Researchers collected 42,655 fish larvae and 7118 fish eggs from the Savannah River between February 1 and July 31, 1983 (Tables C-10 and C-11). The most abundant taxa was the Clupeidae, which includes the anadromous species blueback herring, American and hickory shad, and threadfin and gizzard shad. Clupeids comprised approximately 40 percent of the larvae and 82 percent of the eggs collected. Other important ichthyoplankton collected (in decreasing order of abundance) were crappie, unidentified cyprinids, pirate perch, suckers, yellow perch, and carp. Striped bass comprised 13.5 percent of the eggs collected.

Ichthyoplankton collections from the 26 river transects indicated pronounced temporal and spatial trends. Relative abundance over the entire river ranged from 1.8 per 1000 cubic meters in February to 283.4 per 1000 cubic meters in May. Densities were highest downstream of the Savannah River Plant during March, April, and May; highest near the Plant during April and May; and highest upstream of the Plant during May and June. This indicates seasonal progression of spawning up the river from the lower farfield to the upper farfield sections.

Researchers correlated these spatio-temporal trends in density with temperature; they probably occurred because the lower river warmed to suitable spawning temperatures before the upper river. Other reasons for high ichthyoplankton densities sometimes observed downstream of the Savannah River Plant were spawning migrations into the lower river, the presence of large productive spawning creeks in the lower river, and the drift of larvae into the lower river from upstream spawning areas.

The eggs and larvae of the American shad were present in all three river areas. Researchers collected 3612 eggs and 653 larvae of this species (Tables C-10 and C-11). The highest observed densities occurred during May at River Mile 157.3. Mean densities for the 6-month collection period were higher above River Mile 89.3 than below. Thus, the region of maximum American shad spawning in 1983 included, but was not limited to, the SRP area.

Blueback herring eggs and larvae were also present in all three river areas. The highest observed densities occurred in April at River Mile 97.5. During all months, densities of this species were greater in the lower farfield than in the nearfield and upper farfield areas.

Researchers collected 852 striped bass eggs and 88 larvae during the 1983 river study (Tables C-10 and C-11). Striped bass ichthyoplankton were prevalent only in May and June, and were found in all sections of the river. These results indicate that the striped bass used the entire length of the Savannah River that was sampled (from River Mile 29.6 to River Mile 166.6).

Researchers identified 10 sturgeon larvae during the routine 1983 ichthyoplankton studies; four were shortnose sturgeon (in March) and six were Atlantic sturgeon (in April, May, and June). All were collected between River Miles 69.9 and 157.0. Three other shortnose sturgeon larvae were collected during other sampling in 1983.

During several months, some fish taxa exhibited somewhat higher densities in the intake canals than in the adjacent river. In March and May, crappie ichthyoplankton densities were higher in the canals, as were blueback herring in April and shad in June. These data suggest that crappie, blueback herring, and shad were spawning in the intake canals in 1983. However, all three taxa exhibited comparable or higher densities elsewhere in the river, indicating that other locations were equally important or more important as spawning sites.

1983 Collections - Stream Mouths - A total of 27 creeks, ranging from small intermittent streams to major tributaries were sampled for ichthyoplankton from February through July. Five of these creeks - Beaver Dam Creek, Upper and Lower Three Runs Creeks, Four Mile Creek, and Steel Creek - drain portions of the Savannah River Plant. Researchers collected 5714 larvae and 1423 eggs from all the streams during 1983 (Table C-12).

Streams on the Plant accounted for 8.8 and 14.4 percent of the fish eggs and larvae, respectively. Ninety-four percent of all eggs collected were from Spirit Creek (1230) and Steel Creek (103) (Table C-12). The high number of fish eggs collected at Spirit Creek were threadfin or gizzard shad, taken during May and June. Clupeids were the numerically dominant taxa in all streams; however, crappie, centrarchids, and yellow perch were also important.

The number of ichthyoplankters transported from creek to river ranged from approximately 0.1×10^6 from Lower Boggy Gut to 342×10^6 from Coleman Lake (Table C-12). Steel Creek and Beaver Dam Creek accounted for 77.2×10^6 and 7.5×10^6 ichthyoplankters, respectively, the greatest production of any of the SRP streams. Some creeks exhibited high densities but low transport numbers due to their low discharge rates.

Considerably more fish spawning occurred in Four Mile Creek in 1983 than in 1982, apparently due to unusually high river levels that reversed stream flow and lowered water temperatures enough to allow fish to enter the creek and from the transport of ichthyoplankton from nearby refuge areas into the creek when river levels receded. Centrarchids, blueback herring, and shad dominated the larval catch. Ichthyoplankton densities were low to moderate in March, peaked at 332 per 1000 cubic meters on April 4, and declined to zero by early June (Table C-12). Larvae collected during May were taken at temperatures between 35° and 37°C and represent larvae transported from refuge spawning areas in the Four Mile Creek watershed. Although more ichthyoplankton were collected in 1983, similar medium-sized streams had higher densities and longer spawning periods. The mean temperature in these creeks was often as much as 15°C lower than that in Four Mile Creek. Apparently, the elevated temperatures in this stream limited spawning. Transport of ichthyoplankton from Four Mile Creek was very low (2.7×10^6), ranking it as twenty-first of the 27 streams sampled (Table C-12).

During sampling trips, researchers collected 138 fish larvae and 10 fish eggs on Beaver Dam Creek (Table C-12). Sunfish, silversides, and yellow perch dominated species composition. Due to excessively high river levels, Beaver Dam Creek was not sampled during February, March, or most of April.

Table C-12. Ichthyoplankton Abundance in 27 Savannah River Tributaries Located Between RM 30 and 187.2. February - July 1963^a

Creek, RM	Mean discharge (m ³ /sec)	Number dates sampled	Larvae collected	Eggs collected	Taxa collected	Mean ichthyoplankton density (no./1000 m ³)	Maximum density (no./1000 m ³)	Date of maximum density	Dominant taxa on date of max. density	Number-b ichthyoplankton transported x 10 ⁶
Collin, 30.0	195.5	22	238	0	14	49	225	03/18	Blueback herring crappie	180.2
Myers, 35.4	150.1	16	155	0	15	42	185	05/05	Unidentified clupeid	157.6
Coleman Lake, 40.3	237.9	22	309	1	13	62	266	03/18	Blueback herring crappie	341.9
Lockners, 43.2	24.8	20	238	0	14	126	500	07/08	Sunfish	81.1
Ebenezer, 44.8	36.9	23	502	5	15	105	802	03/18	Crappie	53.3
Selnes Landing, 47.7	1.2	11	70	2	14	194	1145	05/12	Yellow perch	1.1
Pink, 51.1	8.7	6	86	0	8	105	195	06/30	Other shad	9.4
Lake Parachuchia, 64.2	79.6	18	653	9	14	263	738	03/24	Blueback herring	279.2
Black, 78.4	6.4	4	5	1	4	29	49	03/17	Blueback herring pirate perch	3.4
Pike, 84.1	30.1	17	112	0	11	77	377	07/27	Sunfish	30.8
Ware, 88.6	1.4	2	50	0	7	664	1093	05/25	Carp	4.5
Buck, 92.6	28.1	20	708	13	16	383	2669	05/11	Blueback herring	185.3
Briar, 97.6	86.4	23	760	3	15	140	938	04/13	Blueback herring unidentified clupeid	220.7
The Gault, 109.0	6.7	3	34	0	9	75	100	04/28	Blueback herring	1.3
Smith Lake, 126.5	48.5	22	329	5	14	90	712	04/12	Crappie	148.1
Lower Three Runs, 129.0	2.7	10	72	0	12	187	1698	05/03	Crappie	2.1
Sweetwater, 133.5	33.4	13	102	4	14	51	194	05/03	Pirate perch	19.9
Lower Boggy Gut, 141.3	4.2	3	7	1	5	17	43	03/15	Crappie	0.1
Steel, 141.6	26.2	24	518	103	14	123	507	04/05	Blueback herring	77.2
Four Mile, 150.6	4.1	16	40	7	11	50	332	04/05	Blueback herring	2.7
Bever Dam, 152.1	8.3	13	138	10	10	74	320	05/03	Yellow perch	7.4
Upper Three Runs, 157.2	15.8	19	56	5	10	25	334	05/03	Crappie, yellow perch	2.4
Upper Boggy Gut, 162.2	9.5	9	32	2	9	43	116	06/08	Sunfish	2.2
McBean, 164.2	5.1	5	78	1	11	93	186	07/07	Other shad	6.3
Hollow, 176.1	14.5	16	107	21	13	53	229	03/22	Crappie	34.4
Spirit (183.3)	8.6	19	300	1230	13	157	4412	06/02	Other shad	38.0
Butler, 187.2	13.3	9	15	0	4	37	185	05/12	Minnow	4.4

^aSource: Du Pont, 1965

^bCalculated as sum of ichthyoplankton density x creek discharge for each sampling data extrapolated to intervals between sampling dates.

Subsequent sampling indicated a peak density of 320 per 1000 cubic meters (primarily sunfish) in early May, which declined to low densities by July. Similar-sized streams had higher densities, due largely to high concentrations of shad. Temperatures in Beaver Dam Creek were generally 3° to 7°C higher than in similar-sized creeks. Although elevated temperatures might have reduced spawning later in the year in Beaver Dam Creek, the effect was not as pronounced as that in Four Mile Creek. The number of ichthyoplankters transported from Beaver Dam Creek (7.4×10^6) was equivalent to or greater than from other creeks that did not have large numbers of threadfin or gizzard shad.

Effects of Cooling Water Intakes

The once-through cooling water systems for C- and K-Reactors each withdraw about 11 cubic meters of water per second from the Savannah River through the 1G and 3G pumphouses. An additional 1 cubic meter per second enters these intakes to provide makeup water for P-Area. The 5G pumphouse provides cooling water to the D-Area powerhouse at about 3 cubic meters per second. The current combined cooling water flow requirement for these facilities is about 26 cubic meters per second. This withdrawal of river water could affect the fishes inhabiting areas on or adjacent to the Savannah River Plant in two ways:

- Entrainment of fish eggs and larvae through the cooling water system
- Impingement of larger fishes on the intake screens

Estimates of the impacts of entrainment and impingement are based on field data collected during past and present sampling programs performed in the vicinity of the Plant (Du Pont, 1985; Paller, O'Hara, and Osteen, 1985; Paller and Osteen, 1985). The following section discusses the results of these investigations.

Entrainment - The entrainment of ichthyoplankton depends on several factors, including the density of eggs and larvae in the Savannah River, the amount of spawning in the intake canals, the volume of water withdrawn by each pump, and, in the case of the 1G intake, the density of organisms in Upper Three Runs Creek (Du Pont, 1985). This stream enters the Savannah River just upstream of the 1G canal; approximately 50 percent of the creek water flows into the canal (Paller et al., 1984).

Estimates of larval entrainment into the 1G and 3G pumphouses are based on plankton collections from each intake canal. Estimates for the 5G pumphouse are based on collections made in the river upstream of the canal. The total number of larvae entrained per day was calculated by multiplying the average density of larvae collected in the samples by the total volume of water pumped into each intake during the 24-hour sampling period.

Estimates of the entrainment of fish eggs into the 3G and 5G pumphouses are based on plankton collections from the river at transects immediately upstream of the intake canals. Samples taken in the canals could not be used because few fish eggs were collected in these locations, probably because velocities in the canals were too low to support drifting pelagic eggs, which settled to

the bottom and suffocated in the mud (McFarlane, 1982). The estimate of eggs entrained into the 1G pumphouse is based on data from the sampling in both the river and in Upper Three Runs Creek (in proportion to their contribution to the flow into the intake canal). Daily totals of egg entrainment were calculated in the same manner as those for larvae.

The estimate of the total entrainment of ichthyoplankton during the spawning season was calculated by multiplying the daily entrainment rates of eggs and larvae by the number of days between samples, generally a week, and adding them. Annual entrainment is considered to occur during the February-through-July spawning season, because there are generally few ichthyoplankton in the river from September to January (McFarlane, Frietsche, and Miracle, 1978; ECS, 1983a,b,c; Paller et al., 1984). Table C-13 summarizes the seasonal entrainment estimates for both eggs and larvae for 1977, 1982, 1983, and 1984.

The results of the 1983 field-sampling program indicate that the three intake structures entrained at least 17 species of larval fishes. The most abundant family of fish collected was clupeids, herrings, which comprised 59 percent of the total larval entrainment. The single most abundant taxa was the genus Dorosoma (gizzard and threadfin shad), with 10.5×10^6 larvae (37 percent). Other abundant taxa were crappie, blueback herring, and minnows, which represented 14.1, 9.5, and 9.0 percent, respectively.

The total calculated larval fish entrainment for the Savannah River Plant from February to July 1983 was 28.0×10^6 individuals, of which 12.9×10^6 (46.1 percent) were from the 1G pumphouse, 13.3×10^6 (47.5 percent) were from the 3G pumphouse, and 1.8×10^6 (6.4 percent) were from the 5G pumphouse (Table C-13).

The total entrainment of larval fish for the 1983 spawning season (28.0×10^6) was about 56 percent higher than the 17.9×10^6 larval fish entrained for the same period in 1982 (ECS, 1983a,b,c) and about 43 percent higher than the 19.6×10^6 reported for the 1977 spawning season (McFarlane, Frietsche, and Miracle, 1978). The estimate of larval fish entrainment for 1983 is probably more accurate than the previous estimates because it is based on weekly rather than bimonthly sampling. The difference between 1982 and 1983 entrainment might be related to river levels, which were generally low in 1982; this resulted in reduced flooding of riverine lowlands and swamps, which normally provide important spawning and nursery areas for many fishes. In contrast, river levels were exceptionally high during 1983, providing more suitable spawning habitat than in drier years, thereby producing higher numbers of ichthyoplankton.

The total egg entrainment from February to July 1983 was calculated to be 9.1×10^6 , of which 4.2×10^6 were entrained at the 1G pumphouse, 4.1×10^6 at the 3G pumphouse, and 7.2×10^5 at the 5G pumphouse (Paller et al., 1984) (see Table C-13). The most abundant species was American shad, which represented 58.6 percent of all eggs entrained. The other abundant group was striped bass, which represented 13.2 percent of the total egg entrainment. About 25 percent of the eggs could not be identified.

Table C-13. Comparison of Ichthyoplankton Entrainment

Year	SRP pumphouses			Total
	1G	3G	5G	
1977 ^a				
Eggs	--	--	--	6.8 x 10 ⁶
Larvae	--	--	--	19.8 x 10 ⁶
Total	--	--	--	19.8 x 10 ⁶
1982 ^b				
Eggs	8.7 x 10 ⁶	8.2 x 10 ⁶	1.2 x 10 ⁶	18.1 x 10 ⁶
Larvae	5.2 x 10 ⁶	12.0 x 10 ⁶	0.7 x 10 ⁶	17.9 x 10 ⁶
Total	13.9 x 10 ⁶	20.2 x 10 ⁶	1.9 x 10 ⁶	36.0 x 10 ⁶
1983 ^c				
Eggs	4.2 x 10 ⁶	4.1 x 10 ⁶	7.2 x 10 ⁵	9.1 x 10 ⁶
Larvae	12.9 x 10 ⁶	13.3 x 10 ⁶	1.8 x 10 ⁶	28.0 x 10 ⁶
Total	17.1 x 10 ⁶	17.4 x 10 ⁶	2.5 x 10 ⁶	37.2 x 10 ⁶
1984 ^d				
Eggs	2.7 x 10 ⁶	2.6 x 10 ⁶	4.6 x 10 ⁵	5.8 x 10 ⁶
Larvae	7.7 x 10 ⁶	8.8 x 10 ⁶	1.0 x 10 ⁶	17.6 x 10 ⁶
Total	10.4 x 10 ⁶	11.4 x 10 ⁶	1.5 x 10 ⁶	23.4 x 10 ⁶

^aAdapted from McFarlane, Frietsche, and Miracle, 1978, and McFarlane, 1982.

^bAdapted from ECS, 1983a,b,c.

^cAdapted from Paller et al., 1984.

^dAdapted from Paller, O'Hara, and Osteen, 1985.

The estimated entrainment of fish eggs for the 1983 spawning season was about one-half the number estimated for 1982 (9.1 x 10⁶ versus 18.1 x 10⁶). However, the 1983 estimate was about 34 percent larger than the entrainment projection made for 1977 (McFarlane, Frietsche, and Miracle, 1978). These differences could be related to differences in methodology, differences in year-class strength, or the extremely high water that occurred during the spring of 1983.

During the 1984 field-sampling program, there were at least 17 species of larval fish entrained at the three intake structures (Paller, O'Hara, and Osteen, 1985). The most abundant fish family collected was the Clupeidae, the herring and shad, which comprised 50 percent of the total larval fish entrained. The single most abundant taxa was crappie, with 4.3 x 10⁶ larvae

(24.5 percent). Other abundant taxa were unidentified clupeids, blueback herring, and other shad (gizzard and/or threadfin shad), which comprised 23.8, 13.2, and 12.7 percent of the total larvae entrained, respectively. Generally, there were no differences in the taxonomic composition between the three pumphouses.

The total calculated larval fish entrainment for the Savannah River Plant from February to July 1983 was 17.6×10^6 individuals, of which 7.7×10^6 (44 percent) were from the 1G pumphouse, 8.8×10^6 (50.3 percent) were from the 3G pumphouse, and 1.0×10^6 (5.6 percent) were from the 5G pumphouse (Table C-13).

The total entrainment of larval fish for the 1984 spawning season (17.6×10^6 larvae) was 37.4 percent less than the 28.1×10^6 larvae entrained in 1983 (Paller et al., 1984). However, the number entrained during 1984 was similar to the number of entrained larvae reported for 1982 (17.9×10^6 ; ECS, 1983a) and 1977 (19.8×10^6 ; McFarlane et al., 1978). The similarities in entrainment numbers for 1982 and 1984 and the dissimilarities between 1983 and 1984 could be attributed in part to river level. The highest river levels in 1983 increased the availability of shallow vegetated areas of river and swamp for use as spawning habitat and nursery grounds, resulting in larger ichthyoplankton numbers. The lower river levels in 1984 and 1982 provide less ideal habitat for spawning and presumably produced fewer larvae. Differences in year-class strength in some of the anadromous fish also could have affected the number of fish entrained by the pumphouse.

The total fish egg entrainment from February through July 1984 was estimated to be 5.8×10^6 eggs, of which 2.7×10^6 eggs (46.6 percent) were entrained at the 1G pumphouse, 2.6×10^6 eggs (45.4 percent) at the 3G pumphouse and 4.6×10^5 eggs (8.0 percent) at the 5G pumphouse (see Table C-13). The most abundant egg species was American shad which represented 50.4 percent of the total eggs entrained. The other abundant groups of eggs entrained were striped bass and "other" eggs which represented 30.7 and 15.2 percent of the total eggs entrained, respectively.

The estimated entrainment of fish eggs for the 1984 spawning season (5.8×10^6) was the lowest recorded to date (Paller, O'Hara, and Osteen, 1985). The egg entrainment losses decreased by about 37 percent from 9.1×10^6 eggs entrained in 1983 (Paller et al., 1984). This variability could be related to differences in year-class strength of the most dominant ichthyoplankters.

Any evaluation of the impact of the Savannah River Plant on fish eggs and larvae of the Savannah River should examine the relationship of the entrainment of ichthyoplankton to the total ichthyoplankton transported past the intakes. Ichthyoplankton values at RM 157.3 were combined with those from Upper Three Runs Creek to produce an estimate of the total number of ichthyoplankters susceptible to potential entrainment. The total number of eggs and larvae entrained at the 1G pumphouse was 17.1×10^6 during 1983 and

10.4×10^6 during 1984. Therefore, approximately 4.4 and 3.7 percent of the total ichthyoplankton that passed the 1G intake canal were entrained during 1983 and 1984, respectively.

Total ichthyoplankton transported past the 3G intake canal and the 5G pump-house was 405×10^6 organisms during 1983 and 216×10^6 during 1984. During 1983 the number of eggs and larvae entrained at the 3G pump-house was 17.4×10^6 individuals, or approximately 4.3 percent of the total, while during 1984 11.4×10^6 (5.3 percent) individuals were entrained. At the 5G pump-house, 2.5×10^6 (0.6 percent) were entrained during 1983 and 1.5×10^6 (0.7 percent) during 1984. Thus, the Savannah River Plant entrained approximately 9.3 and 8.3 percent of the ichthyoplankton that passed by its intake canals during the February-through-July 1983 and 1984 spawning seasons, respectively. This value includes ichthyoplankton that drifted from the river and those that were spawned in the canals.

Impingement - Studies to measure and evaluate the loss of fish trapped on the traveling intake screens began in 1977 (McFarlane, Frietsche, and Miracle, 1978). They resumed in March 1982 (ECS, 1983 a,b,c) and continued in 1983 and 1984 (Paller et al., 1984; Paller, O'Hara, and Osteen, 1985; Paller and Osteen, 1985) as part of the expanded ongoing Savannah River aquatic ecology program (Du Pont, 1985). Results of these investigations indicate that several factors, including the number of pumps in operation, the volume of water pumped, the river water level, the water temperature, and the density and species of fish in the intake canal, influence the impingement rate to some degree.

Impingement sampling on 98 dates between December 1982 and August 1983 resulted in the collection of 3604 fish representing 48 species. This exceeds the 35 species collected in 1977 (McFarlane, Frietsche, and Miracle, 1978). The number of fish impinged daily ranged from 0 to 540 and averaged 37 fish per day. The weight of the impinged fish ranged from 1 gram to 11.4 kilograms and averaged 932 grams per day.

The majority of the fish were in the family Centrarchidae (sunfish; 70.7 percent); taxa represented in lower numbers included herring and shad (14.8 percent), catfish (3.2 percent), minnows (2.4 percent), pirate perch (2.4 percent), and hogchokers (2.3 percent). All other taxa combined accounted for less than 5 percent of the fish trapped on the screens. One juvenile Atlantic sturgeon (length 14.6 centimeters, weight 11.3 grams) was impinged in January 1983. The most common species trapped was the bluespotted sunfish (35 percent of the total); other species accounting for at least 5 percent of the impinged fish included threadfin shad (8.5 percent), gizzard shad (5.2 percent), warmouth (6.5 percent), and redbreast sunfish (5.8 percent).

The number of fish trapped on the traveling screens was lowest during the summer and autumn months and highest in the spring. The high number of fish impinged in the spring of 1983 corresponds to elevated river levels from mid-March to early May. During this time, the river level was above 27 meters for all but 2 days; it reached a maximum elevation of 30.3 meters on April 20. In

contrast, river elevations during the rest of the sampling period reached a maximum of 29.1 meters and were below 27 meters about 80 percent of the time. The relative abundance of bluespotted sunfish and pirate perch in the impingement samples increased during high water conditions. Both are typical swamp species that might have been flushed from nearby swamps by high water.

Analyses of the 1983-1984 impingement data (Paller and Osteen, 1985) indicate that a daily average of 18 fish was trapped on the screens at the intake structures. This is lower than the average of 37 fish per day estimated for the 1982-1983 sampling year. The highest monthly rate of impingement occurred in May (47.9 fish per day) while the lowest was in October (3.0 fish per day). The average daily weight of fish impinged was about 500 grams, ranging from 204 grams per day in October to 1458.5 grams per day in May. This is about half of the mean weight of 932 grams per day reported for the 1982-1983 sampling year. Centrarchids (sunfish) and clupeids (mostly threadfin shad) were the most common groups of fish impinged, each accounting for 30 to 40 percent of the collections.

Rates of impingement at the 1G and 3G intakes were generally similar during 1983-1984, while impingement rates at the 5G intake were much lower. This is in contrast to 1982-1983, when the 5G intake had the highest overall rate of impingement. However, the high rate at 5G during 1982-1983 was due primarily to the impingement of a large number of bluespotted sunfish on a few sampling dates.

High rates of impingement during certain periods, in both the 1982-1983 and 1983-1984 sampling years, were generally associated with high river levels. Rates during 1982-1983 appear to be unusually high compared to data from other years. During 1977, an average of 7.3 fish per day were impinged (McFarlane, Frietsche, and Miracle, 1978). The impingement rate for 1982 was 19 fish per day (ECS, 1983a,b,c).

Under average conditions, the estimated total numbers of fish impinged each year due to operations of C- and K-Reactors and the D-Area powerhouse would range from 2555 to 13,505, based on the 1977, 1982-1983, and 1983-1984 data.

Surveys of the recreational fishery (see Section C.7 for more details) in the freshwater portions of the Savannah River indicate that the species caught in greatest numbers by anglers are bream (i.e., bluegill, warmouth, and sunfish), crappie, and catfish (i.e., catfish and bullheads). These species comprised from 57 to 70 percent of the total number of fish collected during the 1983-1984 and 1982-1983 impingement studies (i.e., 1102 of 1938 and 2474 of 3604 individuals, respectively). Therefore, on an annual basis, about 3700 to 9300 sportfish would be impinged.

The largemouth bass is another important sportfish; it is the second most-sought-after freshwater species in the Savannah River. However, because it is not often caught, it does not rank high in annual catch statistics. This

species is impinged rarely, comprising only about 0.2 to 0.5 percent of the total fish collected (i.e., 8 of 3604 individuals during 1982-1983 and 9 of 1938 during 1983-1984). The projection of annual impingement losses under present operating conditions is about 28 to 30 largemouth bass.

Thermal Effects on Larval Fish

Fish kills from cold shock can be equally important in environments such as Four Mile Creek and Pen Branch that are thermally constant for long periods of time during extended reactor operation, and then cool rapidly when reactor operations stop (Du Pont, 1985).

Studies of the thermal tolerance of early life stages of largemouth bass, bluegill, and channel catfish indicated that these species can tolerate higher (several degrees) temperature than the highest observed spawning temperature. The optimal temperatures for largemouth bass and channel catfish larvae were found to be 24°C and 28°C, respectively. The 24-hour median lethal temperature for largemouth bass larvae was found to range from 32° to 36°C, while that for bluegill larvae was 36° to 38°C. The incipient lethal temperature for channel catfish larvae was determined to be 33° to 36°C. Studies on cold shock conducted on early life stages of largemouth bass and channel catfish indicated that neither species would be likely to suffer mortality if stream temperatures returned to ambient levels during the late spring spawning season (Du Pont, 1985).

C.6 ENDANGERED AND THREATENED SPECIES

The Endangered Species Act of 1973, as amended (16 U.S.C. 1531 et seq.) is intended to prevent the further decline of endangered and threatened species and to bring about the restoration of these species and their habitat. The U.S. Fish and Wildlife Service (FWS) and the National Marine Fisheries Service (NMFS) jointly administer this Act. The Act affords protection to some 300 species of native American plants and animals. A species can be listed Federally under either of two categories, "endangered" or "threatened," depending on its status and the degree of the threat posed to it. "Endangered" refers to a species or subspecies that is in danger of extinction throughout all or a significant portion of its range. "Threatened" means any species or subspecies that is likely to become endangered in the foreseeable future throughout all or a significant portion of its range. When a species is proposed for either the endangered or the threatened status, areas essential to its survival or conservation are also proposed as "critical habitat," when appropriate. Compliance with the Endangered Species Act requires Federal agencies to consult with the U.S. Fish and Wildlife Service and/or the National Marine Fisheries Service regarding the implementation of a proposed action. If the FWS or the NMFS indicates that an endangered or threatened species (or one proposed as such) or critical habitat could be present in the area of the proposed action, a biological assessment must be prepared. This assessment is used as a basis for evaluating the effects on Federally protected species through the formal consultation process.

The State of South Carolina has a Nongame and Endangered Species Conservation Act (Section 50-15, 1976, S.C. Code of Laws). Rules established to implement the act protect Federally protected endangered and threatened wildlife that occurs in South Carolina (R.123-150), sea turtles (R.123-150.1) and predatory birds of the orders Falconiformes and Strigiformes (R.123-160). The State does not afford protection to flora other than Federally protected species (DOE, 1982). Additions to the State protection listings can be made by the South Carolina Wildlife and Marine Resources Commission.

Table C-14 lists species of flora and fauna that have been seen on the Savannah River Plant (Dukes, 1984) and have been identified by the Federal or State of South Carolina Government as endangered, threatened, or of special concern. The Savannah River Plant contains no lands that have been designated as critical habitat for any species.

The following sections address the endangered species that occur on the Savannah River Plant. Much of the information presented in this section is summarized from the Comprehensive Cooling Water Study (Du Pont, 1985). (Additional information concerning other species listed in Table C-14 can be found in DOE, 1984.)

C.6.1 AMERICAN ALLIGATORS

Formerly high alligator population levels in the United States were greatly reduced by habitat alteration, indiscriminate killing, and legal as well as illegal commercial harvest (Du Pont, 1985). By the 1950s, alligator populations were at an all-time low. Since that time, State and Federal law enforcement, as well as public education, have allowed the alligator to recover throughout much of its range. Population recovery in certain areas has been more dramatic and effective than in others. In some areas of the southeast legal harvest of this species is again possible. However, the present legal status of the alligator (both Federal and State) in this region of South Carolina is still "endangered" (DOE, 1979).

Alligators will feed on most aquatic and semiaquatic vertebrates and some terrestrial animals as well. Limited data suggest that fish make up the bulk of the diets of alligators on the Savannah River Plant (Du Pont, 1985). American alligators have relatively broad temperature tolerances; the critical thermal maximum is estimated to be 38°C and animals have survived exposure to temperatures as low as 2° to 4°C (Colbert, Cowles, and Bogert, 1946; Hagan, Smithson, and Doerr, 1983).

The American alligator occupies most major aquatic habitats on the Plant where water temperatures are suitable and food supplies are adequate (Du Pont, 1985). Large alligator populations occupy Par Pond and Beaver Dam Creek, areas that receive cooling water but have only moderately elevated temperatures. The Par Pond population has been studied most intensively; historically it has shown

Table C-14. Species on the Federal List of Endangered Species or the South Carolina List of "Endangered," "Threatened," or "Of Special Concern" Species That Might Occur on the Savannah River Plant^a

Species	Status			Observations on or near SRP
	Federal	State	Special	
	Endangered	Threatened	concern	
<u>Mammals</u>				
<u>Ursus a. americana</u> (Black bear)		X		No resident population on SRP, observation infrequent in past
<u>Lynx rufus</u> (Bobcat)			X	Common on SRP
<u>Lutra canadensis</u> (River otter)			X	Observed along ambient streams of SRP
<u>Spilogale p. putorius</u> (Eastern spotted skunk)			X	Common on SRP
<u>Condylura cristata parva</u> (Star-nosed mole)			X	Collected infrequently near Risher Pond, Ellenton Bay, Rainbow Bay, and Steel Creek floodplain
<u>Birds</u>				
<u>Picoides borealis</u> (Red-cockaded woodpecker)			X	A few scattered colonies in pine stands of SRP; see text for more details
<u>Haliaeetus l. leucocephalus</u> (Bald eagle)			X	A few individuals have been observed at Par Pond; no resident population

Table C-14. Species on the Federal List of Endangered Species or the South Carolina List of "Endangered," "Threatened," or "Of Special Concern" Species That Might Occur on the Savannah River Plant^a (continued)

Species	Status			Observations on or near SRP
	Federal	State	Special	
	Endangered	Threatened	concern	
<u>Birds (continued)</u>				
<u>Mycteria americana</u> (Wood Stork)	X	X		Individuals have been observed foraging in the Savannah River swamp; see text for more details
<u>Pandion haliaetus</u> (American osprey)		X		A few individuals have been observed as migrants over SRP
<u>Accipiter cooperii</u> (Cooper's hawk)		X		A few individuals have been observed near Sun Bay and Rainbow Bay
<u>Bubo virginianus</u> (Great horned owl)			X	A few individuals have been observed near Rainbow Bay
<u>Melanerpes erythrocephalus</u> (Red-headed woodpecker)			X	Common on SRP
<u>Picoides villosus</u> (Hairy woodpecker)			X	Common on SRP
<u>Lanius ludovicianus</u> (Loggerhead shrike)			X	Infrequently observed on SRP
<u>Aythya valisineria</u> (Canvas back)			X	
<u>Ictinia mississippiensis</u> (Mississippi kite)			X	

Table C-14. Species on the Federal List of Endangered Species or the South Carolina List of "Endangered," "Threatened," or "Of Special Concern" Species That Might Occur on the Savannah River Plant^a (continued)

Species	Status			Observations on or near SRP
	Federal	State	Special	
	Endangered	Threatened	concern	
<u>Reptiles</u>				
<u>Alligator mississippiensis</u> (American alligator)	X			Common on Par Pond, Beaver Dam Creek, and in the SRP Savannah River Swamp; see text for more details
<u>Clemmys guttata</u> (Spotted turtle)			X	Uncommon
<u>Natrix cyclopion</u> (Green water snake)			X	Collected commonly from Ellenton Bay
<u>Seminatrix pygaea</u> (Carolina swamp snake)			X	Uncommon; collected from Ellenton Bay
<u>Virginia valeriae</u> (Smooth earth snake)			X	Collected from deciduous forests mixed with older pines; found near Pond C or Par Pond, Lost Lake, and Rainbow Bay
<u>Pituophis m. melanoleucus</u> (Pine snake)			X	Uncommon
<u>Micrurus f. fulvius</u> (Eastern coral snake)			X	Uncommon

Table C-14. Species on the Federal List of Endangered Species or the South Carolina List of "Endangered," "Threatened," or "Of Special Concern" Species That Might Occur on the Savannah River Planta (continued)

Species	Status		Observations on or near SRP
	Federal	State	
	Endangered	Special concern	
<u>Reptiles (continued)</u>			
<u>Ohisaurus attenuatus</u>			
<u>longicaudus</u> (Eastern slender glass lizard)		X	Uncommon; has been collected near Risher Pond, Rainbow Bay, Sun Bay, and Steel Creek floodplain
<u>Amphibians</u>			
<u>Ambystoma t. tigrinum</u> (Eastern tiger salamander)		X	Found throughout SRP
<u>Pseudacris triseriata feriarum</u> (Upland chorus frog)		X	Locally common
<u>Hyla avivoca ogechiensis</u> (Bird-voiced treefrog)		X	Locally common in the Savannah River swamp
<u>Rana gryllio</u> (Pig frog)		X	Observed near Steel Creek Bay and Steel Creek delta
<u>Rana palustris</u> (Pickerel frog)		X	Rare; a few have been captured from Risher Pond

Table C-14. Species on the Federal List of Endangered Species or the South Carolina List of "Endangered," "Threatened," or "Of Special Concern" Species That Might Occur on the Savannah River Plant^a (continued)

Species	Status			Observations on or near SRP
	Federal	State	Special concern	
<u>Fish</u>				
<u>Acipenser brevirostrum</u> (Shortnose sturgeon)	X			Rare; a few larvae (10) have been collected in the Savannah River near the SRP pumphouses and two larvae were collected in intake canals; see text for more details
<u>Acipenser oxyrinchus</u> (Atlantic sturgeon)		X		Rare; a few larvae have been collected near SRP pumphouses
<u>Alosa aestivalis</u> (Blueback herring)			X	Common in the Savannah River; present in Par Pond
<u>Alosa mediocris</u> (Hickory shad)			X	Collected downstream of SRP in the Savannah River
<u>Invertebrates</u>				
<u>Elliptio fraterna</u> (Brother spike mussel)	X			Collected from Savannah River below Lower Three Runs Creek
<u>Alasmidonta triangulata</u> (Triangle floater mussel)		X		Collected from Savannah River below SRP
<u>Carunculina pulla</u> (Savannah shore mussel)		X		Collected from Savannah River near Lower Three Runs Creek

Table C-14. Species on the Federal List of Endangered Species or the South Carolina List of "Endangered," "Threatened," or "Of Special Concern" Species That Might Occur on the Savannah River Plant^a (continued)

Species	Status			Observations on or near SRP
	Federal	State	Special	
	Endangered	Threatened	concern	
<u>Invertebrates (continued)</u>				
<u>Elleptio lanceolata</u> (Yellow lance mussel)			X	Collected from ambient streams of SRP and the Savannah River
<u>Anodonta couperiana</u> (Barrel floater mussel)			X	Collected from Savannah River and Lower Three Runs Creek at Donora Station
<u>Strophitus undulatus</u> (Strange floater mussel)			X	Collected from Savannah River downstream of Steel Creek
<u>Lampsilis cariosa</u> (Yellow mucket mussel)			X	Collected from Savannah River and Lower Three Runs Creek
<u>Lampsilis radiata splendida</u> (Red mucket mussel)			X	Collected from Savannah River, Lower Three Runs Creek, and Tinker Creek
<u>Procambarus hirsutus</u> (Crayfish)			X	Collected from ambient streams of SRP
<u>Tortopus incertus</u> (Mayfly)			X	Collected from clay banks in the Savannah River near Upper Three Runs Creek and Steel Creek mouth

Table C-14. Species on the Federal List of Endangered Species or the South Carolina List of "Endangered," "Threatened," or "Of Special Concern" Species That Might Occur on the Savannah River Plant^a (continued)

Species	Status			Observations on or near SRP
	Federal	State	Special	
	Endangered	Threatened	concern	
<u>Plants</u>				
<u>Echinacea laevigata</u> (Smooth coneflower)	X			Along Burma Road
<u>Nestronia umbrellula</u> (North American sandlewood)			X	Dry wood bluffs along Upper Three Runs Creek
<u>Habenaria lacera</u> (Green fringed-orchid)			X	Rainbow Bay, Sun Bay, and Mill Creek Reserve Site areas
<u>Ludwigia spathulata</u> (Spathulate seedbox)			X	Sun Bay and transplanted to Rainbow Bay area
<u>Enchinodorus parvulus</u> (Little burhead)			X	Lost Lake and Sun Bay
<u>Rhexia aristosa</u> (Ann-petaled meadow-beauty)			X	Craig Pond
<u>Ipomopsis rubra</u> (Standing cypress)			X	On roadbank of Highway 125 just east of SRP boundary in Barnwell County, SC
<u>Corcopsis rosea</u> (Pine tickseed)			X	Karen's Pond and Flamingo Bay

^aSource: Dukes, 1984.

population parameters that indicated reduced reproduction in relation to more southerly populations. However, recent surveys indicated more extensive reproduction and a normalization of the age and sex structures (Du Pont, 1985). Recent surveys also indicate that Beaver Dam Creek might represent the most dense population of American alligators on the Plant (Du Pont, 1985). At least 40 individuals were documented in less than 6 kilometers of the stream; clear evidence (i.e., two "pods" of hatchlings located 100 meters apart) indicated recent and successful reproduction (Du Pont, 1985).

Reproducing populations of alligators are also known to occur in both post-thermal SRP stream systems, Steel Creek and Lower Three Runs Creek (Du Pont, 1985). A few alligators have also been observed to move upstream in the reactor effluent streams when the reactors are not operating. Experimental studies confirm that alligators avoid lethal water temperatures associated with reactor startup, even in winter when the animals' metabolic rates are low (Du Pont, 1985).

SRP operations have impacted the alligator population in many different ways. The creation of manmade reservoirs has dramatically increased the amount of aquatic habitat available to alligators and has, therefore, increased the carrying capacity of the Plant for this species (Du Pont, 1985).

The thermal alteration of aquatic habitats on the Plant has also impacted the resident alligator population (Du Pont, 1985). Temperature elevations greater than 38°C result in the loss of this habitat to alligators. Alligators respond to moderate thermal increases by moving to other locations. Observations suggest that alligators might utilize vertical and horizontal temperature profiles established by thermal loading to maintain their body temperatures at a preferred level; definitive data have not been collected (Murphy, 1981). Alligators around areas of thermal loading might also profit from extended breeding seasons or increased productivity by prey species. A serious negative influence of moderate levels of thermal loading appears to result from the induction of a premature reproductive season combined with differential use of thermal areas by adult male and female alligators (Murphy, 1981). The protection afforded the alligator from indiscriminant killing and direct human disturbance on the entire SRP site is of considerable importance (Du Pont, 1985).

The current information available on the alligators of the Savannah River Plant suggests the following predicted trends: low density populations distant from thermally altered areas will continue at a low density with the exception of localized increases. The alligators inhabiting Par Pond should continue a trend toward a more normal size distribution and sex ratio as the reservoir matures and the older adults are replaced with younger individuals (Du Pont, 1985).

C.6.2 WOOD STORKS

During the last 50 years the wood stork population has declined from an estimated 20,000 breeding pairs in the early 1930s to approximately 4800 pairs in 1980 and 3650 pairs in 1983 (Ogden and Nesbitt, 1979; Ogden and Patty, 1981; DOI, 1983). The United States Fish and Wildlife Service has listed the wood stork as an endangered species (DOI, 1984).

The most northern and inland wood stork colony is located at "Big Dukes Pond," a cypress swamp 12.6 kilometers northwest of Millen, Jenkins County, Georgia (Du Pont, 1985). This colony, referred to as the Birdsville colony, is the source of the birds foraging on the Savannah River Plant. The Plant is 45 kilometers from the Birdsville colony, a distance within the 60- to 70-km radius that wood storks can travel during daily feeding flights (Du Pont, 1985).

The wood stork method of feeding is highly specialized. Wood storks wade in shallow pools, 15 to 30 centimeters deep, with their bills extended slightly forward and submerged as far as the external nares and opened about 8 centimeters at the tips. When a stork touches fish or other prey with its bill, the bird snaps the bill shut, capturing the prey. This method has been termed "tactolocation." This feeding technique allows wood storks to forage in muddy or turbid water where birds that hunt visually cannot feed. To feed efficiently, storks forage in ponds where prey are concentrated. It is important that the birds feed in areas where prey are densely concentrated during the breeding season because food requirements are greatest when adults are caring for chicks (Kahl, 1964; Du Pont, 1985).

Wood storks are colonial nesters. They build large nests in trees, usually over standing water. Nest heights range from a few meters above water in mangrove swamps to the tops of the tallest cypress trees (*Taxodium* sp.) (Ogden and Nesbitt, 1979). Storks use cypress trees for nesting habitat most often; however, in southern Florida they use red mangrove (*Rhizophora mangle*) (Kahl, 1964).

Wood storks breed during the dry season when evaporation in shallow ponds concentrates the prey (Du Pont, 1985). Breeding lasts about 120 days, with additional time for courtship and nest-building. Two to five white eggs are incubated for 28 to 30 days. During the first 30 days after hatching, the young are attended by one parent while the other parent forages. During this period the chicks gain the ability to thermoregulate and grow to a size at which they are no longer vulnerable to their major predators: crows and vultures. As the food demand of the chicks exceeds the level which one parent can provide, the young are left alone at the nest while both parents forage. The young leave the rookery after about 65 days (Kahl, 1964).

Kahl (1964) estimated that during the breeding season the minimum fish biomass needed by a nesting pair of storks and an average of 2.25 fledge young was 201 kilograms. Feeding habitat, including cypress swamps and domes, scrub cypress, freshwater marshes, and mixed hardwood swamp, must be available

within 60 to 70 kilometers of the stork colony. These habitats must also be productive enough to maintain fish populations at levels sufficient to allow an annual take by the colony equal to about 201 kilograms times the number of nesting pairs (Du Pont, 1985).

Wood stork feeding sites for the Birdsville colony were studied during the second half of the nesting season in 1983 and for most of the 1984 nesting season (Myers, 1984; Coulter, 1986). Feeding sites were located by following storks from the nesting colony and by surveying the SRP Savannah River swamp and other habitats near the colony. The following information was gathered from this research:

- Wood storks at Birdsville produced an average of 2.2 fledglings per successful nest (113 nests) during 1983. About the same number of young were observed in 1984 (2.4 fledglings and 23 nests).
- Wood storks feed up to 80 kilometers from the colony, but a majority (91 percent) of feeding flights during 1983 were less than 50 kilometers. During 1984, more than 80 percent of the foraging sites were within 20 kilometers and 55 percent were within 10 kilometers of the colony.
- Of the 50 feeding sites located during 1983, 18 percent were located in SRP swamps (3 sites at the Steel Creek delta, 5 sites at Beaver Dam Creek, and 1 site near the Pen Branch delta) in 1983. Similar areas on the Plant were used in 1984, along with additional foraging sites in the swamp between Pen Branch and Four Mile Creek. Two wood storks were observed feeding in Kathwood Lake on August 5, 1984; no other sightings were recorded during the surveys.
- Before fledging (when young birds leave the nest) in 1984, 33 percent of the feeding sites were located on the Savannah River Plant. However, of the total number of adult storks observed feeding at that time, 64 percent were at SRP sites and 36 percent were off the Plant.
- After fledging, juvenile wood storks did not feed at SRP sites in 1983.
- In 1983, storks fed in shallow pools with an average of 6.2 acres and depths between 10 and 32 centimeters. Five habitat types (black gum swamp, cypress swamp, shrub swamp, open marsh, and manmade ponds) were used as feeding sites.
- Although larger numbers of wood storks were observed at Beaver Dam Creek, the density of large vertebrates ranked below that for the average site in 1983. Powerhouse restart might have occurred between the discovery of feeding wood storks and sampling of the site, thus biasing density estimates. Higher water, after the restart of the powerhouse, probably dispersed the fish that were concentrated in shallow pools (Myers, 1984).

- Direct and indirect effects from thermal effluent discharge from SRP facilities probably limits the potential use of the Savannah River swamp by foraging adult wood storks.
- If the Birdsville colony is stable and/or growing, it might become relatively more important if the Florida colonies continue to decline.

C.6.3 SHORTNOSE STURGEON

The shortnose sturgeon is listed by the National Marine Fisheries Service (NMFS) as an endangered species in the United States (Du Pont, 1985). This species is found only on the east coast of North America in tidal rivers and estuaries. Until recently, the presence of shortnose sturgeon had not been documented in the middle reaches of the Savannah River. However, in 1982 and 1983, shortnose sturgeon larvae were collected near the Savannah River Plant as part of the SRP aquatic ecology program (Matthews and Muska, 1983). Because the shortnose sturgeon is anadromous, protection of this species is under jurisdiction of the NMFS. Critical habitat for this species has not been designated by the NMFS (Du Pont, 1985).

Breeding populations of shortnose sturgeon are normally associated with estuary-river complexes that have a strong flow of fresh water. The shortnose sturgeon's endangered species status has stimulated recent investigations that have shown it to be more abundant in some drainage systems than had been previously known (Brundage and Meadows, 1982).

Shortnose sturgeon have been found in rivers, estuaries, and the ocean with their greatest abundance occurring in the estuary of their respective rivers (Dadswell et al., 1982). The few fish that have been captured at sea were found within a few miles of land near the mouth of an estuarine system. The species is primarily anadromous, but access to the sea is apparently not a requirement for reproductive success. Landlocked populations have been reported in the Holyoke Pool section of the Connecticut River (Taubert, 1980a,b) and the Lake Marion-Moultrie system in South Carolina (Marchette and Smiley, 1982).

Spawning of shortnose sturgeon occurs between February and May, depending on the latitude. The major factor governing spawning appears to be temperature, although other factors include the occurrence of freshets and substrate character (Dadswell et al., 1982). Several investigators have reported shortnose sturgeon spawning to occur between 9° and 19°C (Heidt and Gilbert, 1978; Dadswell, 1979; Taubert, 1980a; Buckley and Kynard, 1981). Specific spawning grounds for populations in southeastern rivers have not been described. The shortnose sturgeon exhibits a migration pattern between spawning grounds, feeding grounds, and overwintering areas.

Although a segment of the Savannah River shortnose sturgeon population spawns upstream of SRP cooling water intake canals, entrainment of eggs is unlikely (Du Pont, 1985). Sturgeon eggs are demersal and are usually deposited on rubble and gravel substrate (Buckley, 1982; Taubert, 1980b). Whether this

substrate is utilized or available to the Savannah River population is not known. However, the negative buoyancy and strongly adhesive, gelatinous nature of the eggs preclude significant downstream transport or dispersion of eggs through the water column (Pottle and Dadswell, 1979).

Ten shortnose sturgeon larvae have been identified in ichthyoplankton samples collected in the Savannah River (Du Pont, 1985; Paller, O'Hara, and Osteen, 1985). Of these, one larva was collected in the 1G pumphouse intake canal, one larva was collected in the 3G pumphouse canal, and the remaining eight larvae were collected adjacent to or downriver of the SRP. These collections indicate that some shortnose sturgeon larvae might be entrained. However, it is not possible to estimate entrainment losses due to the low number of specimens collected. Given the small number of shortnose sturgeon larvae collected and the relatively extensive ichthyoplankton sampling effort in the vicinity of the SRP site (Paller, O'Hara, and Osteen, 1985), the number of larvae entrained probably is small and their loss does not represent an adverse effect on the Savannah River shortnose sturgeon population (Du Pont, 1985).

In January 1983, one 147-millimeter juvenile Atlantic sturgeon was impinged on the intake screens (Du Pont, 1985). Thus, shortnose sturgeon might be impinged. However, there is no evidence that Atlantic or shortnose sturgeon commonly inhabit the intake canals. Shortnose sturgeon, unless injured, should be able to avoid the intake screens because their swim speed exceeds the pumphouse intake velocity (Du Pont, 1985).

Potential direct thermal effects on the shortnose sturgeon are limited to existing and any future thermal plumes in the Savannah River. Thermal plumes should not affect adults because they can avoid these areas; at present, a large zone of passage exists in the Savannah River for all migratory species (Du Pont, 1985). Eggs are not planktonic and therefore should not drift through the plumes; however, newly hatched larvae could be swept into the plume under conditions of high water flow or drift downstream as part of a normal dispersion process. Although there are no temperature tolerance data on larval shortnose sturgeon, larvae drifting through the plume near the mouth of Four Mile Creek might not survive. This potential effect is expected to be limited because only adults spawning immediately above the thermal plume and larvae drifting through the hottest part of the thermal plume would be affected (Du Pont, 1985).

The National Marine Fisheries Service had previously concurred in DOE's determination that the population of shortnose sturgeon in the Savannah River would not be affected adversely by SRP operations (Oravetz, 1983).

C.6.4 RED-COCKADED WOODPECKER

The red-cockaded woodpecker was once a common bird in the mature pine forests of the southeast. Today its range and population have been reduced through loss of habitat. It is unique among North American woodpeckers in its selection of mature, living pines for cavity excavation (Jackson, 1978). The

disappearance of mature pine forests (Whalenberg, 1946, 1960; Lennartz et al., 1983) has resulted in fragmentation of the required habitat. As a result, many red-cockaded woodpecker populations exist in isolated mature pine reserves (Jackson, 1977).

The red-cockaded woodpecker has a complex cooperative breeding system (Lennartz and Harlow, 1979). These birds live in groups called clans, are nonmigratory, and maintain large year-round territories (Ligon, 1970). The clan can consist of from two to nine birds, but there is never more than one breeding pair. The other adults are usually males called helpers. Some clans have no helpers, but others might have as many as three. The helpers assist in incubating eggs, making new cavities, feeding the young, and defending the clan's territory. A breeding male can live for several years. When he dies, one of the helpers usually inherits the status of breeding male (Lennartz and Harlow, 1979).

A clan nests and roosts in a group of cavity trees called a colony. Cavities are made in live pine trees. Each clan member tries to have a cavity for roosting. Birds without cavities in live trees often roost in forks between limbs or in cavities of dead trees. The red-cockaded woodpecker takes months and even years to excavate a cavity. A cavity is seldom completed in one year, and most take several years of work (Jackson, Lennartz, and Hooper, 1979).

The red-cockaded woodpecker nests between late April and July. Only the breeding male courts and mates with the female. The female usually lays two to four eggs in the breeding male's roost cavity. The breeding male stays with the eggs at night and the clan members take turns incubating during the day. The eggs hatch in 10 to 12 days. Young birds leave the nest in about 25 days (Ligon, 1970). The clan spends a great deal of time looking for food. Most of the foraging is concentrated on the trunks of live pine trees. The birds will scale the bark and dig into dead limbs for spiders, ants, cockroaches, centipedes, and the eggs and larvae of various insects.

The clan defends year-round a territory surrounding the colony. Territories range from less than 100 acres to more than 250 acres. The total area used by the clan can be as large as 1000 acres.

The Savannah River Forest Station's wildlife management program has concentrated on red-cockaded woodpecker habitat improvement since 1979. In July 1980, an intensive program was started to reduce encroaching hardwood understory in several colonies. The objective was to provide the open, park-like mature pine stands that are required. This type of habitat is scarce at the Savannah River Plant. About one-third of the forest area has been planted since 1951 and will require 30 or more years to provide suitable habitat. Much of the remaining area is either scrub oak or bottomland hardwoods.

The Forest Service is in the process of evaluating inventoried colonies of red-cockaded woodpeckers and their habitats and determining which habitats should be improved. No active colonies are located near the areas of proposed alternative cooling water system construction. In 1986, the Plant had one active (breeding) colony located near the northern plant border and two lone males located near the southeastern Plant border (F. Brooks, U.S. Forest Service, personal communication with J. L. Oliver, NUS Corporation, February 20, 1986).

C.7 COMMERCIALLY AND RECREATIONALLY VALUABLE BIOTA

Commercially valuable plant biota on the Savannah River Plant include approximately 175,000 acres of timber that are managed by the U.S. Forest Service. The commercial value of SRP timber that was managed and sold by the Forest Service in 1982 was \$1.7 million; this included pine and hardwood sawtimber, pine pulpwood, and cordwood hardwoods. Approximately 71 percent of the timber sales consisted of pine pulpwood. The longterm trend in planting activities has been an increase in the number of loblolly pine and a decrease in slash pine. The latter is more susceptible to injury from ice glazing and has not been planted since 1970. More than 1,530,000 seedlings of loblolly pine and 160,000 seedlings of longleaf pine were planted in 1980 (USDA, 1983).

Public hunts of deer and feral hogs began in 1965 on the Plant, managed by the U.S. Forest Service. These hunts minimize deer-car accidents and maintain habitat quality. Since 1981, E. I. du Pont de Nemours and Company personnel have had the planning and management responsibility for these hunts.

The annual number of hunter-days increased from 700 in 1966 to 6325 in 1980; paralleling this trend was an increase from 198 deer harvested in 1966 to 961 in 1980. The harvest of feral hogs ranged from 10 in 1972 to 32 in 1980. There also has been a relatively consistent decline in the number of deer-car accidents. In the late 1960s and early 1970s, deer-car accidents ranged in the 50s; only 11 incidents were reported in 1980.

Other game species that have commercial and recreational value but that are protected from hunting include the bobcat, fox, mink, muskrat, opossum, otter, rabbit, raccoon, skunk, squirrel, migratory waterfowl, bobwhite quail, mourning dove, wild turkey, Wilson's snipe, and woodcock.

The Savannah River supports both commercial and sports fisheries. Table C-15 lists the species and catches of fish taken commercially from the river from 1970 to 1979. Many of these fisheries are confined to the marine and brackish waters of the coastal regions of South Carolina and Georgia.

The only commercial fishes of significance near the Savannah River Plant are the American shad, the channel catfish, and the Atlantic sturgeon. These species, except for sturgeon, are exploited to a limited degree by nonprofessional local fishermen. There is no fishery specifically for hickory shad in South Carolina or Georgia; however, many are taken each year incidental to the catch of American shad (Ulrich et al., 1978).

Table C-15. Commercial Landing Data for Fish Taken from Savannah River, 1970-1979^a

Species	Combined catches in Georgia and South Carolina (kg)									
	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Carp	0	250	252	1,503	590	998	136	453	136	363
Catfish	544	157	222	518	726	1,814	1,043	1,043	363	1,043
Black drum	0	0	0	0	0	227	272	0	0	0
Red drum	0	0	0	0	45	0	181	499	136	0
Hickory shad	318	384	291	725	91	227	91	136	181	91
Spotted sea trout	0	0	0	324	227	2,500	1,800	181	181	0
American shad	43,591	25,568	25,439	33,912	26,263	20,412	8,618	20,820	54,432	57,607
Sturgeon	726	23	1,967	551	136	45	363	862	454	227
Suckers	0	0	0	0	0	0	91	0	0	0
Common eels	0	0	0	0	0	91	0	45	0	45
Mullet	0	0	0	0	0	227	0	91	0	0
Striped bass	816	735	1,013	1,071	0	0	0	0	0	0

^aSource: Du Pont, 1982.

Sport fishermen are the principal consumers of river fishes, primarily sunfish and crappie. Striped bass, which is classified as a game fish in South Carolina and Georgia (Ulrich et al., 1978), is a favorite quarry of fishermen in the Augusta area.

Commercial and recreational fisheries for blueback herring exist in South Carolina (Ulrich et al., 1978), but none are taken commercially in Georgia because of State netting restrictions.

Although species of commercial or sport fishing importance in the Savannah River might use SRP streams, DOE does not allow fishing or other exploitation of commercial species on the Plant.

The Fisheries Section of the Georgia Department of Natural Resources published the results of a creel survey in the estuarine and fresh-water sections of the Savannah River from December 29, 1979, to December 26, 1980 (Georgia Game and Fish Division, 1982). The most abundant species harvested in the fresh-water section were bluegills (29.1 percent), redbreast sunfish (27.5 percent), warmouth (10.6 percent), bullheads (7.1 percent), and crappie (6.2 percent). Those fish species comprising the greatest weight were bluegills (19.8 percent), redbreast sunfish (21.1 percent), warmouth (8.2 percent), largemouth bass (7.3 percent), and crappie (7.0 percent). Based on electrofishing studies conducted by the Georgia Game and Fish Division, the relative abundance of sunfish in the freshwater section of the river is high, as is the actual angler success rate. The success rate for largemouth bass (0.04 percent fish per hour) was low. The average-size striped bass (5.21 kilograms) creeled in fresh water was over four times greater than the average-size striped bass (1.19 kilograms) creeled in the estuary.

The most abundant species harvested in the estuarine section were croakers and spots (24.5 percent), white catfish (17.4 percent), silver perch (11.3 percent), and other species (26.3 percent). Species comprising the greatest weight were white catfish (23.9 percent), red drum (16.0 percent), and sea trout (12.9 percent). Angler success rates for all species were very low.

The greatest fishing effort in the estuary was expended for sea trout (42.1 percent), striped bass (29.9 percent), and red drum (17.3 percent). The five most sought-after species in fresh water were largemouth bass (38.0 percent), sunfish (30.5 percent), redbreast sunfish (12.7 percent), crappie (7.7 percent), and catfish (5.4 percent).

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APPENDIX D

RADIOCESIUM INVENTORY AND TRANSPORT AND ATMOSPHERIC TRITIUM RELEASES

This appendix discusses the existing releases of radionuclides, principally radiocesium, to the Beaver Dam Creek, Four Mile Creek, and Indian Grave Branch/Pen Branch systems; describes the estimated distribution and inventory of radiocesium in the sediments, fish, and water of the creeks, swamp, and Savannah River; examines the transport of radiocesium offsite; and predicts the concentrations in the Savannah River and downstream water-treatment plants as a result of implementation of the alternative cooling water systems. This appendix also describes the atmospheric releases of tritium associated with the discharge of cooling water from existing and alternative cooling water systems.

D.1 RELEASES OF RADIOCESIUM

The principal sources of radiocesium in the environment at the Savannah River Plant have been reactor effluent discharges to onsite streams and releases from the chemical separations facilities in F- and H-Areas. From 1955 through 1980, about 560 curies of radiocesium were discharged to all onsite streams (DOE, 1984a).

From 1960 through 1980, approximately 21.9 and 16.2 (both decay corrected to 1980) curies of cesium-137 were discharged to Four Mile Creek and Indian Grave Branch/Pen Branch from C- and K-Reactors, respectively (Table D-1). These discharges resulted from leaching of reactor fuel elements with cladding failures that exposed the underlying fuel to water. The direct sources of these releases were heat-exchanger cooling water, spent-fuel storage and disassembly-basin effluents, and process water from C- and K-Reactor areas. In addition to these reactor effluent discharges, approximately 0.7 curies of cesium-137 (decay corrected to 1980) was released to Four Mile Creek from the chemical separations facilities in F- and H-Areas, and 21.9 curies (decay corrected to 1980) of cesium-137 was released to Four Mile Creek as a result of an overflow of high-level waste in 1967. Generally, the longer lived cesium-137 will be of greater interest than cesium-134; for ease of discussion, radiocesium will usually be referred to as cesium-137 (DOE, 1984a). However, when the change in radionuclide transport due to operation of the alternative cooling water systems is considered, both forms of cesium are identified.

Through 1980, releases of radiocesium to Beaver Dam Creek amounted to only 0.004 curie (decay corrected). These small releases occurred from the D-Area heavy-water production facility (Du Pont, 1985a). A summary of releases through 1980 to Beaver Dam Creek is also presented in Table D-1.

Table D-1. Radiocesium Releases (Ci) 1960 Through 1980^{a,b}

Creek	Radionuclide	Source	Total release	Total release, decay corrected to 1980
Beaver Dam Creek	Cs-134	D	-	-
	Cs-137	D	-	<u>0.004</u>
				Total: 0.004
Four Mile Creek	Cs-134	C	0.063	0.01
	Cs-137	C	31.092	21.9
	Cs-137	F	0.632	0.53
	Cs-137	H	0.206	0.18
	Cs-137	H ^c	<u>41.160</u>	<u>30.8</u>
			Total: 73.15	Total: 53.42
Indian Grave Branch/ Pen Branch	Cs-134	K	0.19	0.03
	Cs-137	K	<u>24.442</u>	<u>16.2</u>
			Total: 24.63	Total: 16.23

^aDu Pont, 1985a.

^bAll releases are direct liquid releases to onsite streams.

^cIn 1967, overflow of high-level waste to ground and nearby storm sewer occurred when flow from 242-H evaporator to Tank 9 was restricted by formation of crystals.

D.2 DISTRIBUTION OF RADIOCESIUM

D.2.1 SEDIMENTS

Most of the cesium-137 that has been discharged to onsite creeks by SRP operations and fallout from offsite weapons testing became associated with the silts and clays found in the streambed and suspended solids. The principal mechanisms for this association were (1) cation and sorption processes exchange with kaolinite and gibbsite clay minerals, and (2) chelation with naturally occurring organic material. Table D-2 shows the variation in sand, silt, and clay content; total carbon content; and ion exchange capacity in sediment depth increments of 0-5 and 5-10 centimeters in floodplain soils of the three creeks (Du Pont, 1985a). A distribution coefficient of $K_d = 3960$, measured for sediments from Four Mile Creek and Steel Creek (Kiser, 1979), and the work by Prout (1958) demonstrate the affinity of cesium-137 for the sediments and suspended solids in the creek systems.

Table D-2. Results of Floodplain Sediment-Characterization Analysis for Beaver Dam Creek, Four Mile Creek, and Indian Grave Branch/ Pen Branch^a

Creek	Location/ depth increment	Composition (%)			Total organic carbon (%C)	Cation- exchange capacity (meq/100g)
		Sand	Silt	Clay		
Beaver Dam Creek	Downstream of D-Area effluent					
	0-5 cm	39	42	19	8.7	7.5
	5-10 cm	51	36	13	10.4	2.3
	Road A-12.2 South					
	0-5 cm	40	24	36	11.4	7.6
	5-10 cm	17	26	57	5.9	8.0
	Mouth					
	0-5 cm	17	53	30	2.1	11.7
	5-10 cm	41	32	27	1.2	7.7
Four Mile Creek	Road 3					
	0-5 cm	79	12	9	7.1	7.8
	5-10 cm	90	4	6	2.4	2.5
	Road A					
	0-5 cm	33	42	25	0.1	10.1
	5-10 cm	33	29	38	0.3	11.2
	Delta					
	0-5 cm	34	42	24	5.5	10.9
	5-10 cm	46	28	26	2.6	6.2
	Mouth					
0-5 cm	52	29	19	1.9	15.9	
5-10 cm	51	28	21	1.2	13.5	
Indian Grave Branch/ Pen Branch	Road 3					
	0-5 cm	61	20	19	7.4	3.8
	5-10 cm	75	14	11	6.2	3.8
	Indian Grave Branch at Road B					
	0-5 cm	19	60	21	1.3	5.8
	5-10 cm	19	60	21	0.9	4.1

Table D-2. Results of Floodplain Sediment-Characterization Analysis for Beaver Dam Creek, Four Mile Creek, and Indian Grave Branch/ Pen Branch^a (continued)

Creek	Location/ depth increment	Composition (%)			Total organic carbon (%C)	Cation- exchange capacity (meq/100g)
		Sand	Silt	Clay		
Indian Grave Branch/ Pen Branch (continued)	Swamp between Four Mile Creek and Pen Branch					
	0-5 cm	23	43	34	7.1	13.4
	5-10 cm	17	37	46	5.0	11.9
	Delta					
	0-5 cm	15	48	37	4.7	13.2
	5-10 cm	49	28	23	3.3	9.7
	Stave Island					
	0-5 cm	72	6	22	24.1	17.3
	5-10 cm	68	11	21	18.0	15.6

^aDu Pont (1985a).

As a result of these affinities, sedimentation and sorption processes control the distribution of cesium-137 within the creeks and deltas and the adjoining Savannah River swamp. The resuspension, transport, and deposition of sediment are governed by the hydraulic properties of the sediment and streambeds and by the creeks' flow regimes.

Almost all sediment redistribution occurred between 1955 and 1968, the period of major reactor discharges. Since 1968, little change has occurred in the sedimentation patterns or in the channel-delta configurations (Ruby, Reinhart, and Reel, 1981).

D.2.1.1 Beaver Dam Creek Sediments

Concentrations of cesium-137 in Beaver Dam Creek sediments are presented in Table D-3. Cesium-137 concentrations ranged from 0.20 picocurie per gram at the south arm near Road A-12.2 to 1.13 picocurie at the mouth. These concentrations are very low compared to data from the other onsite streams.

Table D-3. Concentrations of Cesium-137 (pCi/g, Dry Weight) in Beaver Dam Creek Sediments^a

Core location	Concentration
Below 400-D	(b)
South Arm Road A-12.2	0.20
Mouth	1.13

^aDu Pont, 1985a.

^bNot detectable above background.

D.2.1.2 Four Mile Creek Sediments

Cesium-137 has been monitored routinely in Four Mile Creek sediments since 1977. These data are presented in Table D-4 (Du Pont, 1985a,b). Sediment cesium-137 concentrations along Four Mile Creek ranged from 0.4 to 20.3 (mean = 8.6) picocuries per gram, dry weight, at the creek-swamp confluence and from 11 to 80.3 (mean = 35.3) picocuries per gram, dry weight, at Road A-7 upstream of thermal influence. In general, concentrations at both Four Mile Creek stations clearly reflected SRP releases, while Savannah River floodplain sediment concentrations downstream of Four Mile Creek were within ranges associated with global fallout as high as 1.0 picocurie per gram.

D.2.1.3 Pen Branch/Indian Grave Branch Sediments

Cesium-137 has been monitored routinely in Pen Branch/Indian Grave Branch sediments since 1977. Table D-5 presents these data (Du Pont (1985a,b)). Because the Pen Branch flow joins the flow of Steel Creek before its entry into the Savannah River, the routine floodplain sediment-monitoring stations at the Steel Creek mouth and in the Savannah River downstream of Little Hell Landing were used for data analysis for both the Pen Branch and Steel Creek systems (Du Pont, 1985a).

D.2.1.4 Swamp and Savannah River Sediments

Beginning in 1974, comprehensive radiological surveys were made of the Savannah River swamp, including the 1235-acre, uninhabited, privately owned Soil Creek Plantation Swamp (Figure D-1), and of the soil and the vegetation. Soil cores collected in 1974 showed that about 70 percent of the cesium-137 was confined to the upper 6 to 7 centimeters but that cesium was detectable at depths of 25 centimeters (Ashley and Zeigler, 1975). The 1982 values were appreciably less than those for 1974, but slightly lower on the average than those for 1977. Mean values at comparable locations averaged 33.3 (1982), 39.8 (1977), and 75.9 picocuries per gram (1974) (Du Pont, 1983b).

Table D-4. Concentrations of Cesium-137 (pCi/g, Dry Weight) in Four Mile Creek Sediments

Source	Location (sampling year)	Concentrations
Du Pont, 1985a ^a	Road A-7 (1984)	70.6
	Road 3 (1984)	43.3
	C-Reactor effluent (1984)	0.26
	Road A (1984)	28.8
	Road A-12.21 (1984)	24.1
	Road A-12.2 (1984)	6.9
	Swamp entrance (1984)	10.5
	Swamp entrance (1984)	10.4
	Swamp entrance (1984)	10.3
	Swamp entrance (1984)	29.0
	Mouth (1984)	0.53
	Mouth (1984)	0.79
Du Pont, 1985b	Road A-7 (1977-1983)	35.2 ± 55.0 ^b
	Four Mile Creek Swamp (1977-1983)	8.6 ± 15.9
	Savannah River downstream of Four Mile Creek (1977-1983)	0.4 ± 0.5
Du Pont, 1985b	Road A-7 (1984)	18 ± 0.18 ^c
	A-7A, Beaver Pond (1984)	49 ± 0.60
	Discharge at swamp (1984)	0.5 ± 0.02

^aDu Pont, (1985a); these data are grouped into two categories. The first 12 entries are one-time samples, each 7.6 centimeters deep and 15.2 centimeters wide, collected in 1984. The last six entries are 7-year averages of floodplain sediment samples. These are 7.6-centimeter-deep multiple samples composited for analysis that were collected between 1977 and 1983.

^bError term is 2 standard deviations of 7-year mean.

^cError term is 2-sigma counting error.

D.2.1.5 Savannah River Sediments

In 1974, riverbed sediments from downstream of the Savannah River Plant contained average radiocesium concentrations from about 2 picocuries per gram at the U.S. Highway 301 bridge (River Mile 118.7) near Millhaven, Georgia, to 6.5 picocuries per gram at the Georgia Highway 119 bridge (River Mile 61.5) near Clio, Georgia. Table D-6 summarizes more recent monitoring data for Savannah River sediments.

Table D-5. Concentrations of Cesium-137 (pCi/g, Dry Weight) in Indian Grave Branch/Pen Branch Sediments

Source	Location (sampling year)	Concentrations
Du Pont 1985a ^a	Road B-3 (1984)	0.10
	K effluent at Road B on Indian Grave Branch (1984)	0.6
	Road A-13.1 (1984)	7.7
	Road A-13.2 (1984)	0.10
	Swamp along Road A-13 (1984)	2.2
	Swamp along Road A-13 (1984)	5.0
	Swamp entrance (1984)	0.31
	Swamp entrance (1984)	0.57
	Swamp entrance (1984)	0.72
	Swamp entrance (1984)	0.31
	Swamp near Stave Island (1984)	1.3
	Swamp near Stave Island (1984)	0.43
	Pen Branch discharge at swamp (1977-1983)	4.2 ± 6.5 ^b
	Steel Creek-Pen Branch Mouth (1977-1983)	14.4 ± 46.3
	Savannah River downstream of Little Hell Landing (1977-1983)	2.7 ± 7.9
Du Pont, 1985b	Pen Branch discharge at swamp (1984)	0.3 ± 0.02 ^c

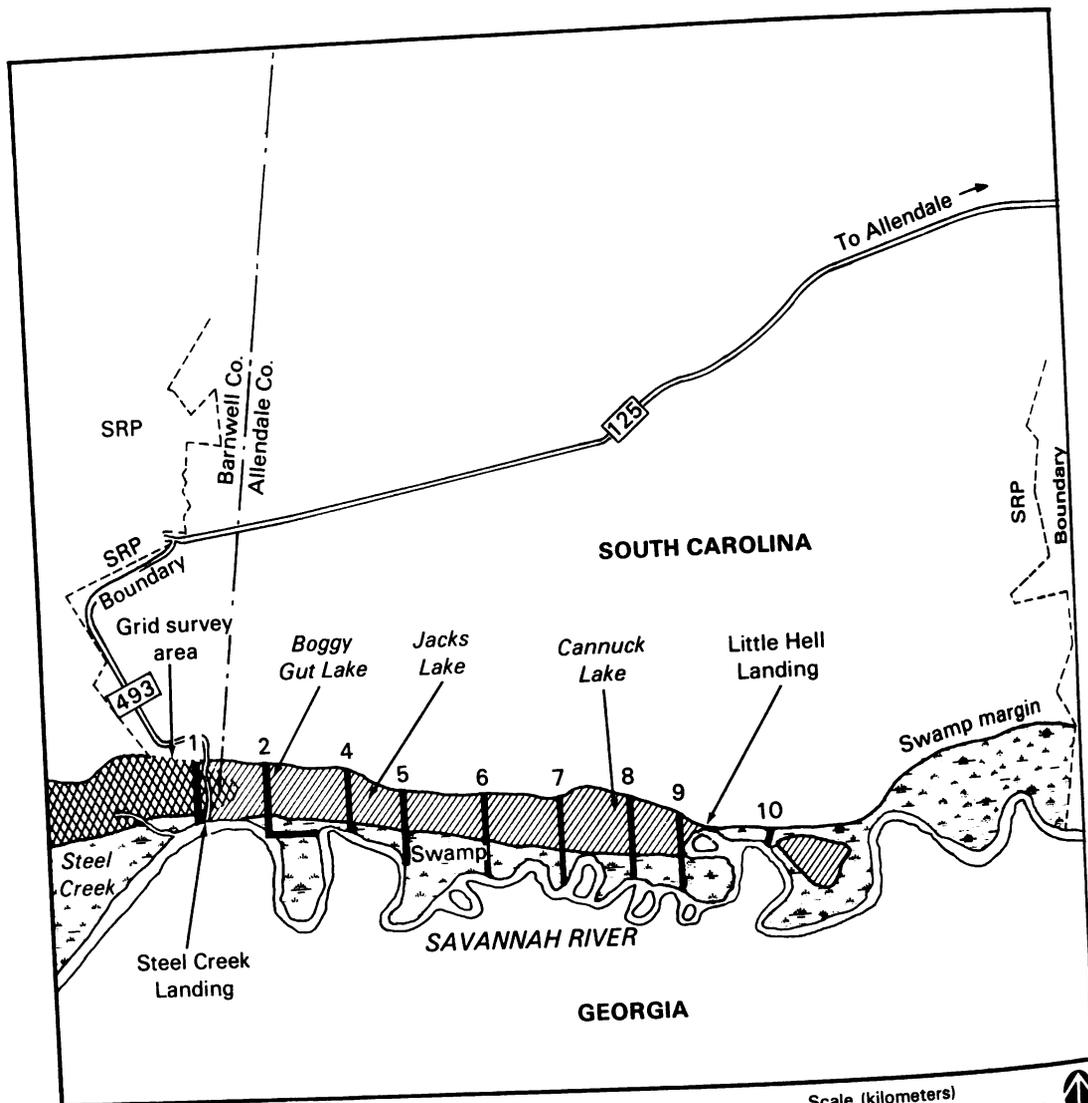
^aDu Pont, 1985a; these data are grouped into two categories. The first 12 entries are one-time samples, each 7.6 centimeters deep and 15.2 centimeters wide, collected in 1984. The last six entries are 7-year averages of floodplain sediment samples. These are 7.6-centimeter-deep multiple samples composited for analysis that were collected between 1977 and 1983.

^bError term is 2 standard deviations of 7-year mean.

^cError term is 2-sigma counting error.

D.2.1.6 Beaufort-Jasper Water Treatment Plant Sediments

A radiological survey of the raw-water and backwash holding-pond sediments at the Beaufort-Jasper water treatment plant was performed in November 1982 (Du Pont, 1985a). Cesium-137 concentrations in the sediment from the raw-water holding pond are about one-tenth those from the backwash pond sediment, which is principally floc. Backwash floc from the North Augusta water treatment



Legend:

-  Detectable Cs-137 deposition
-  Area of highest Cs-137 deposition

Total contaminated offsite area is 940 acres

Source: Du Pont, 1983a

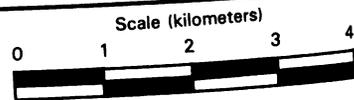


Figure D-1. Locations of Transects Used for Collecting Soil Cores and Vegetation Samples in Savannah River Swamp, Including 1235-acre Creek Plantation Swamp

plant, which is upriver from the Plant, has cesium-137 concentrations similar to those at the Beaufort-Jasper plant. These cesium-137 concentrations are low, generally less than 1 picocurie per gram, and within the concentration range of cesium-137 in sediments from other locations in South Carolina not influenced by the Savannah River Plant (Hayes, 1983a).

Table D-6. Cesium-137 Concentrations (pCi/g, Dry Weight) in Savannah River Sediments (0-8cm depth)^a

Location	River mile	Average, 1975-1979	1980	1981	1982	1983	1984
Demier's Landing ^b Downriver of Four Mile Creek	160.5	0.5	0.2	0.07	0.03	0.13	0.21
Upriver of Little Hell Landing	150.2	0.7	0.2	0.4	0.25	0.20	(d)
Downriver of Little Hell Landing	136.6	0.8	0.2	0.7	0.7	0.25	0.34
Upriver of Lower Three Runs Creek	134.0	3.9	0.4	0.5	0.1	0.39	0.37
U.S. Highway 301 bridge	129.5	0.8	0.4	0.5	(d)	0.32	0.76
GA Highway 119 bridge	118.7	1.7	1.1	0.07	0.5	0.50	(d)
	61.5	6.5 ^c	(d)	(d)	(d)	(d)	(d)

^aSources: Ashley and Zeigler, 1976, 1978a,b, 1981; DOE, 1984a.

^bControl above plant.

^cBased on 1975 data only.

^dNo analysis performed.

D.2.2 BIOTA

When C- and K-Reactors are not operating, the Four Mile Creek and Pen Branch delta areas provide roosting and feeding habitat for migratory ducks. The cesium-137 concentration in flesh from these ducks is expected to reflect their cesium-contaminated environment (Marter, 1974; Fendley, 1978). Whole-body bioaccumulation factors for fish taken from the river at the U.S. Highway 301 bridge from 1965 to 1970 average about 2903 picocuries per gram (Table D-7). The mean bioaccumulation factor for 20 species of fish (527 specimens) from Steel Creek was found to be 2019 whole-body and 3029 flesh (Smith, Sharitz, and Gladden, 1982a,b; Ribble and Smith, 1983). A fish flesh bioaccumulation factor of 3000, 1.5 times the value recommended in the NRC LADTAP-II computer code (Simpson and McGill, 1980), was chosen for dose-assessment analyses in this document.

Table D-7. Radiocesium Whole-Body Bioaccumulation Factors for Fish from Steel Creek and Savannah River^a

Year	Steel Creek (Road A)		Savannah River ^b	
	Maximum	Average	Downriver of Steel Creek	Hwy 301 bridge
1965	--- ^c	--	1626	3902
1966	--	--	1975	1111
1967	--	--	5528	1707
1968	2385	1355	4058	2174
1969	5490	2353	4848	7273
1970	3958	1639	1111	1250
1981	3792 ^d	2019 ^e	--	--
Arithmetic mean		1842	3191	2903
Geometric mean		1802	2700	2295

^aAdapted from Marter, 1970a,b; Du Pont, 1982; and Smith, Sharitz, and Gladden, 1982a,b.

^bValues are averages.

^cData not available.

^dMean of 53 specimens of largemouth bass, for which maximum whole-body bioaccumulation factors were measured in 1981. Maximum bioaccumulation factor measured for largemouth bass was 4780. One specimen of American eel had a bioaccumulation factor of 8300.

^eMean of 527 specimens representing 20 species.

D.2.3 WATER

D.2.3.1 Beaver Dam Creek

Based on the low concentration of cesium-137 in Beaver Dam Creek sediment and the nature of operations in D-Area, which do not involve cesium-137, the concentration in water is expected to be negligible.

D.2.3.2 Four Mile Creek

Cesium-134 and cesium-137 concentrations for Four Mile Creek water measured 12 times per year at Road A are presented in Table D-8. From 1978 to 1984, the average concentrations remained low and relatively constant, ranging from 0.45 to 1.4 picocuries per liter for cesium-134, and from 0.30 to 1.6 picocuries per liter for cesium-137.

Table D-8. Average Annual Concentrations of Cesium-134 and Cesium-137 (pCi/liter) in Water of Four Mile Creek and Indian Grave Branch/Pen Branch^{a,b}

Creek	Location	Concentration							Average	
		1978	1979	1980	1981	1982	1983	1984		
Four Mile Creek	Road A	cesium-134	0.78	(c)	(c)	0.77	0.45	1.3	1.4	0.94
		cesium-137	0.48	(c)	(c)	0.58	0.30	1.6	0.65	0.72
Pen Branch	Road A	cesium-134	1.4	(c)	(c)	1.2	1.0	2.0	1.4	1.4
		cesium-137	0.26	(c)	(c)	0.40	0.53	1.6	0.12	0.58

^aSources: Ashley et al., 1982; Zeigler, Culp, and Smith, 1983; Ashley, Padezanin, and Zeigler, 1984a; Du Pont, 1985b; and Ashley and Zeigler, 1981, 1984.

^bMeasured values were near the limit of detection (1.0 picocurie per liter using standard techniques) for cesium.

^cNo value reported.

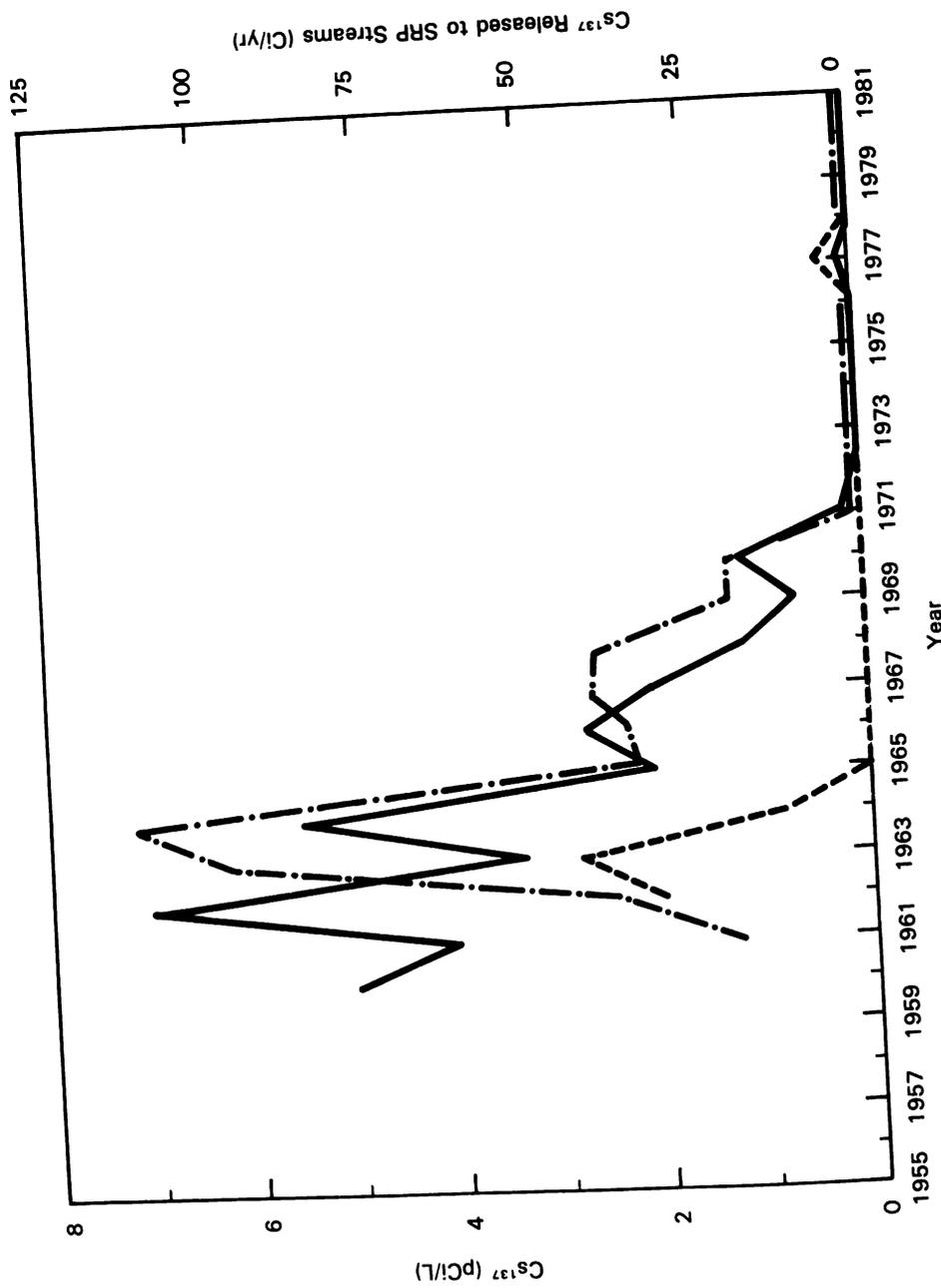
D.2.3.3 Pen Branch/Indian Grave Branch

Table D-8 also lists the cesium-134 and cesium-137 concentrations for Pen Branch/Indian Grave Branch. A range similar to that of Four Mile Creek was observed for Pen Branch/Indian Grave Branch. From 1978 to 1984, average concentrations ranged from 1.0 to 2.0 picocuries per liter for cesium-134, and from 0.12 to 1.6 picocuries per liter for cesium-137.

D.2.3.4 Savannah River

The concentrations of cesium-137 in the Savannah River have been monitored routinely since 1960. The highest concentrations were measured in the early 1960s as a result of SRP releases and nuclear weapons test fallout (Figure D-2).

Radiocesium concentrations will be diluted as the flow of the Savannah River increases downriver from the Savannah River Plant, and as these radionuclides are deposited in the river channel and floodplain. Based on river flow records for 1960 to 1969, an increase in flow of 11 percent can be expected between the U.S. Highway 301 bridge (River Mile 118.7) near Millhaven, Georgia, and the Georgia Highway 119 bridge (River Mile 61.5) near Clio, Georgia. Ratios of drainage areas suggest that river flow will increase by 18 percent between River Mile 118.7 and River Mile 39.2, the location of the intake structure for



Legend:
- - - Upriver of SRP
— Downriver of SRP
- · - SRP Releases
· · · SRP Releases
Source: Hayes and Boni, 1983

Figure D-2. Cesium-137 Concentrations in the Savannah River, 1960-1980

the Beaufort-Jasper water treatment plant. Using tritium as a tracer, Hayes (1983b) measured an average annual increase in flow from 1976 to 1981 of about 20 percent between these two locations. An additional 28-percent reduction in the concentration of cesium-137 can be expected to occur through deposition, sorption, and reequilibration of the radionuclide with river channel and floodplain sediments (Hayes and Boni, 1983).

D.2.3.5 Water-Treatment Plants

The North Augusta, South Carolina, water-treatment plant is about 20 River Miles above the Savannah River Plant. There are no known individuals who consume Savannah River water for a distance of about 120 River Miles downriver of the Plant. At this distance (River Mile 39.2) and beyond (River Mile 29.0) are the Beaufort-Jasper and Cherokee Hill water-treatment plants, respectively. The Beaufort-Jasper water-treatment plant pumps water from the river through a 2.4-kilometer-long inlet canal that connects to an open canal. This open, unlined canal flows 29 kilometers to the water-treatment plant (Du Pont, 1983a). The Cherokee Hill water-treatment plant pumps water from the Savannah River above the U.S. Interstate Highway 95 bridge; the water is piped about 11 kilometers to the plant (Du Pont, 1983a).

Studies made in 1965, when the instantaneous cesium-137 concentration in Savannah River water at the U.S. Highway 301 bridge was 1.47 picocuries per liter, suggest that cesium-137 concentrations are reduced by about 48 percent (due to dilution and association with river channel and floodplain sediments) by the time the water reaches downstream water supply intakes. The Cherokee Hill water-treatment plant further reduces the amount of cesium-137 in water by about 32 percent or a total reduction from the Highway 301 bridge of about 80 percent. Dilution and association with sediments along the open canal and the treatment process at Beaufort-Jasper removes about 50 percent of the cesium-137 from the raw water, or a total reduction from the Highway 301 bridge of about 97 percent. Thus, as summarized in Table D-9, the concentration of cesium-137 in the finished water from the water-treatment plants is a small fraction of the concentration at the U.S. Highway 301 bridge (Hayes and Boni, 1983).

D.3 INVENTORY OF CESIUM-137

The decay-corrected inventory of cesium-137 releases to onsite streams from 1960 through 1980 totaled 414.18 curies (Du Pont, 1985a). Most cesium-137 releases to onsite streams during this period originated from L- and P-Reactor areas (to Steel Creek) and R-Reactor area (to Lower Three Runs Creek). Two methods (Table D-10) were used to estimate the inventory of cesium-137 remaining in the onsite streams. The first method (Method 1, Table D-10) is based on the extensive sampling of Steel Creek. Studies of cesium-137 in Steel Creek based on core samples up to 1 meter in length and categorized by soil type, sample depth interval, and creek section identified 67.1 curies (decay corrected to 1981) between the area above L-Reactor and the delta (Smith, Sharitz, and Gladden, 1982a,b). This value is about 33 percent of the amount of cesium-137 released to Steel Creek (201.23 curies). To calculate the

Table D-9. Cesium-137 Concentrations and Reduction Ratios for Savannah River and Water-Treatment Plants^a

Location	Concentration (pCi/liter)	Total Reduction (%)
North Augusta ^b	0.03	
Highway 301 ^c	1.47	
Highway 17 ^c	0.77	47.6
Cherokee Hill ^b	0.29	80.3
Beaufort-Jasper ^b	0.04	97.3 ^d

^aMeasurements made in 1965; adapted from Hayes and Boni, 1983.

^bConcentration in finished (potable) water.

^c"Raw" Savannah River water; approximate river flow rates of 200 cubic meters per second at Highway 301 and 225 cubic meters per second at Highway 17 at time of cesium-137 sampling.

^dBy the year 2000, expected reduction factor for Beaufort-Jasper will be 79.3 percent because of planned changes in intake canal.

estimated inventory of cesium-137 remaining in the other streams, the release values were multiplied by 0.33, assuming that the Steel Creek ratio of remaining cesium-137 to the total amount released is the same for all streams. The second method (Method 2, Table D-10), from the Comprehensive Cooling Water Study (Du Pont, 1985a), uses a mass-balance approach. Using this approach, the amount of cesium-137 (decay corrected to 1980) remaining in an onsite stream was calculated by multiplying the total cesium-137 released to the stream between 1960 and 1980 by about 76 percent, or the ratio of total cesium-137 released to all SRP streams (about 414 curies, decay corrected to 1980) minus the total cesium-137 in transport (about 100 curies, decay corrected to 1980) to the total cesium-137 released to all SRP streams.

The three creeks of concern - Four Mile Creek, Beaver Dam Creek, and Pen Branch/Indian Grave Branch - contain only about 17 percent of the total cesium-137 remaining onsite. This amounts to 23.22 curies if Method 1 is used to derive the estimate.

D.4 REMOBILIZATION OF RADIOCESIUM

The amount of cesium-134 and cesium-137 transported from onsite streams to the Savannah River and the adjacent swamp resulting from the implementation of the

Table D-10. Cesium-137 Inventory Remaining in Onsite Streams as Estimated by Two Methods^a

Stream	Total release 1960 through 1980 ^b (Ci)	Percent of total release ^c	Method 1 (using Steel Creek sampling data) ^d (Ci)	Method 2 (mass balance approach) ^e (Ci)
Four Mile Creek	53.42	12.9	17.81	40.59
Beaver Dam Creek	0.0	0.0	0.0	0.0
Indian Grave/ Pen Branch	16.23	3.9	5.41	12.27
Total of all SRP streams	414.18	100	138.10	314.65

^aSources: DOE, 1984a; Du Pont, 1985a.

^bSum of cesium-134 and cesium-137 activities (Du Pont, 1985a). All values decay corrected to 1980.

^cTotal decay-corrected (to 1980) cesium-137 releases from 1960 through 1980.

^dL-Reactor EIS (DOE, 1984a) uses 67.1 curies as the estimate of cesium-137 remaining in Steel Creek. This value is about 33 percent of amount of cesium-137 released to Steel Creek (201.23 curies). Values for other streams were calculated by multiplying release value by 0.33, assuming that the ratio of remaining cesium-137 to the total released for Steel Creek is the same for the other onsite creeks. All values decay corrected to 1980.

^eValues calculated by multiplying percentage of total releases by 314.65 (414.18 - 99.53) curies. All values decay corrected to 1980.

alternative cooling water systems for C- and K-Reactors was estimated on the basis of detailed monitoring in Steel Creek (DOE, 1984a) and routine monitoring in Four Mile Creek and Pen Branch. Based on measurements in Steel Creek at stream flows of about 3.5 cubic meters per second, Hayes (1983c) noted that concentrations of cesium-137 in Steel Creek water appeared to be governed by a reequilibration process between the water and the cesium in the creekbed and floodplain sediments and, hence, transport is proportional to creek flow.

Flow information (Jacobsen et al., 1972, Du Pont, 1985a, and Chapter 2 of this EIS) was used to calculate creek flow for the cooling water alternatives. A reactor-use factor of 80 percent was used for conservatism. The calculated flows are presented in Table D-11.

Table D-11 also presents the estimated cesium-134 and cesium-137 source-term values for once-through and recirculating cooling water alternatives located on Four Mile Creek and Indian Grave Branch.

To estimate the change in cesium-134 and cesium-137 remobilization in Four Mile Creek or Pen Branch as the result of implementation of an alternative cooling water system, the total flow was multiplied by the average concentrations of cesium-134 and cesium-137 in the respective creeks (see Table D-11). For example, the recirculating cooling-tower alternative discharges to Four Mile Creek at about 1.35 cubic meters per second. With the once-through cooling tower (either gravity or pump feed, and either mechanical or natural draft) or the existing system (no-action alternative), the discharge to Four Mile Creek is 9.51 cubic meters per second. Multiplying the flow rate by the average cesium-134 and cesium-137 concentrations in the creek yields the source term in curies per year. For the once-through cooling tower (either gravity or pump feed, and either mechanical or natural draft) or the existing system, the source terms are 2.82×10^{-1} and 2.16×10^{-1} curies per year for cesium-134 and cesium-137, respectively. For the recirculating alternative, the source terms are 4.0×10^{-2} and 3.07×10^{-2} curies per year for cesium-134 and cesium-137, respectively. Because the once-through cooling tower or the existing system would result in no change in cesium remobilization (flow rates remain essentially the same), subtracting the source term for the recirculating alternative from the source term for the once-through cooling-tower or the no-action alternative would yield the change in release of cesium-134 or cesium-137 to the Savannah River.

For C-Reactor (release to Four Mile Creek), the recirculating cooling-tower alternative would result in a decrease in the release of cesium-134 and cesium-137 by approximately 0.24 and 0.18 curie per year, respectively; for K-Reactor, it would result in a decrease in release of approximately 0.43 and 0.18 curie, respectively.

Table D-11. Parameter Values Used to Calculate Source Terms and Remobilization Estimates

Parameter	Four Mile Creek	Indian Grave Branch/ Pen Branch
Cs-134 average (pCi/liter) ^a	0.94	1.40
Cs-137 average (pCi/liter) ^a	0.72	0.58
Flow rate (m ³ /sec)		
For the existing system and once-through cooling tower	9.51 ^{b,c}	10.8 ^c
For the recirculating cooling towers	1.35 ^{b,c}	1.08 ^c
Source term (Ci/yr) ^a		
For the existing system and once-through cooling-tower		
Cs-134	2.82 x 10 ⁻¹	4.77 x 10 ⁻¹
Cs-137	2.16 x 10 ⁻¹	1.97 x 10 ⁻¹
For the recirculating cooling towers		
Cs-134	4.00 x 10 ⁻²	4.77 x 10 ⁻²
Cs-137	3.07 x 10 ⁻²	1.97 x 10 ⁻²

^aThese average concentrations represent measurements, which were made using standard techniques, that are near the limit of detection for cesium-137 (Table D-8). Multiplying the creek flow by these concentrations produces conservative overestimates of the annual releases compared to those produced by ultrasensitive measurements of cesium-137 in the Savannah River downstream of the Savannah River Plant (Du Pont, 1985b).

^bJacobsen et al., 1972.

^cDu Pont, 1985a.

Table D-12 lists the estimated amounts of cesium-134 and cesium-137 remobilized for each alternative cooling water system, calculated as outlined above.

Table D-12. Estimated Changes in Cesium-134 and Cesium-137 Releases to Savannah River from C- and K-Reactors in First Year for Each Cooling Water Alternative^a

Alternative	Reactor	Change in release (Ci)	
		Cs-134	Cs-137
Recirculating cooling towers	C ^b	-0.24	-0.18
Once-through cooling tower, ^c existing system to Four Mile Creek	C	0.0	0.0
Recirculating cooling towers	K ^d	-0.43	-0.18
Once-through cooling tower, ^c existing system to Indian Grave Branch	K	0.0	0.0

^aDOE, 1984a.

^bDischarges from C-Reactor flow into Four Mile Creek.

^cEither a mechanical- or a natural-draft once-through cooling-tower that receives its water by pumping or gravity feed.

^dDischarges from K-Reactor flow into Indian Grave Branch/
Pen Branch.

D.5 TRITIUM AND OTHER RADIONUCLIDE RELEASES

D.5.1 TRITIUM RELEASES AND INVENTORY

Tritium accounts for more than 99 percent of the radioactivity in the Savannah River. From 1960 through 1978, about 1.4×10^6 curies of tritium of SRP origin were in transport in the Savannah River. The peak tritium concentration in river water downstream of the Plant was 14 picocuries per milliliter, recorded in 1961 and 1963. A summary of tritium concentration data appears in Table D-13.

The sources of tritium in liquid effluents include direct release from SRP facilities (42 percent) and migration of tritium from the burial ground, F- and H-Area seepage basins, and the K-Area containment basin (58 percent) (Du Pont, 1984a). Migration occurs when tritium that has been released to the basin in previous years reaches SRP streams via groundwater that outcrops into the streams. Tritium migrating from the C-Area seepage basins has not been detected.

Table D-13. Average Tritium Concentrations (pCi/ml) in Four Mile Creek, Beaver Dam Creek, Indian Grave Branch/Pen Branch, and Savannah River^a

Location	Concentration								Average
	1953-1981	1978	1979	1980	1981	1982	1983	1984	
Beaver Dam Creek effluent		47	28	34	38	73	69	50	48.4
Four Mile Creek Road A		200	96	80	61	61	58	61	88.1
Indian Grave Branch/ Pen Branch K effluent		2.1	23	7.1	3.6	7.8	19	7.6	10.0
Road A		38	46	31	35	32	29	32	34.7
Savannah River Above Plant	1.04	0.39	0.38	0.39	0.21	0.36	0.31	0.33	0.34
Above Four Mile Creek	(b)	1.9	1.6	1.4	2.9	3.2	2.5	2.5	2.3
Highway 301	7.55	3.9	3.1	3.2	4.1	4.3	3.3	3.3	3.6

^aSources: Ashley and Zeigler, 1981; Zeigler, Culp, and Smith, 1983; Ashley, Padezanin, and Zeigler, 1984a,b); Du Pont, 1985a,b; Ashley et al., 1982.

^bNot analyzed.

Table D-14 presents the tritium releases through 1980 for individual streams. Tritium monitoring data indicate that essentially all tritium released from the Plant in liquid effluents moves down SRP streams to the Savannah River (Du Pont, 1984a, 1985b).

Tritium releases to the Savannah River have decreased significantly since the early 1960s when the maximum tritium releases occurred (Du Pont, 1985a,b). The following process control improvements have caused the reduction:

- The elimination of a continuous purge from the reactor-area disassembly basins in the late 1960s, which allowed longer holdup time for tritium decay (the half-life of tritium is 12 years) and some evaporation.
- The development of equipment and techniques to flush and contain the tritium-bearing moderator present on fuel and target housings during disassembly-basin discharge.
- The diversion of disassembly-basin purges from streams to seepage basins in P- and C-Areas in 1978, which allowed a longer holdup time for radioactive decay before migration to streams via groundwater.

In addition, total tritium releases were reduced by the shutdown of R-Reactor in June 1964 and of L-Reactor from February 1968 until October 1985.

D.5.2 EFFECTS OF ALTERNATIVE COOLING WATER SYSTEMS ON TRITIUM RELEASES

Source terms used to calculate the current cumulative impact from liquid releases to the Savannah River are presented in Table D-15. Changes in releases of tritium as a result of alternative cooling water systems are presented in Table D-16.

The release of tritium to the Savannah River for the C- and K-Reactor once-through cooling-tower alternatives (pumped or gravity feed and mechanical or natural draft) is expected to be reduced by about 50 curies per year because of increased evaporation and a corresponding increase in the tritium released to the atmosphere. Similarly, the tritium released to the Savannah River from the C- and K-Reactor recirculating cooling-tower alternatives would also be reduced by about 425 curies and a correspondingly greater increase in the tritium released to the atmosphere. The difference between the release rates of the recirculating cooling towers and once-through cooling tower is based on the differences in cooling-tower evaporation and blowdown rates.

D.5.3 OTHER RADIONUCLIDE RELEASES TO ONSITE STREAMS

Source terms for other radionuclides are presented in Table D-15.

Table D-14. Tritium Releases to Four Mile Creek, Beaver Dam Creek, and Indian Grave Branch/Pen Branch Through 1980^a

Creek	Source ^b	Release (Ci)
Four Mile Creek	C	249,380
	F	260
	F sbm	39,324
	H	1,172
	H sbm	<u>98,432</u>
Total		388,568
Beaver Dam Creek	D ^c	124,090
Indian Grave Branch/ Pen Branch	K	212,180
	K sbm	<u>145,390</u>
Total		357,570

^aDu Pont, 1985a.

^bsbm = seepage basin migration. Entries not so labeled represent areas of direct liquid releases.

^cReleases were from D-Area heavy-water production facility.

Table D-15. Tritium and other Radionuclide Releases Used for Calculating Changes in Release Rates (Ci/yr)^a

Nuclide	Beaver Dam Creek	Four Mile Creek	Indian Grave Branch/ Pen Branch	Total release ^b
H-3	2.80×10^3	1.35×10^4	1.18×10^4	3.08×10^4
Co-58,60	-	2.64×10^{-5}	2.94×10^{-4}	7.41×10^{-4}
Sr-89,90	1.42×10^{-2}	5.49×10^{-1}	1.32×10^{-3}	5.72×10^{-1}
Pu-239	3.25×10^{-4}	1.13×10^{-2}	7.86×10^{-5}	1.19×10^{-2}
U-235,238	-	-	-	6.23×10^{-2}

^aValues are 5-year averages, 1980 through 1984, provided by Du Pont.

^bTotal releases also include Tims Branch/Upper Three Runs Creek, Par Pond/Lower Three Runs Creek, and Steel Creek.

Table D-16. Changes in Release of Tritium to Savannah River from C- and K-Reactors in First Year for Each Cooling Water Alternative^a

Alternative cooling water system	Reactor	Change in release (Ci)
Recirculating cooling towers	C	-425
Once-through cooling tower, ^b discharge to Four Mile Creek	C	-50.0
Recirculating cooling towers	K	-425
Once-through cooling tower, ^b discharge to Indian Grave Branch	K	-50.0

^aDOE, 1984b.

^bEither a mechanical- or a natural-draft once-through cooling-tower that receives its water by pumping or gravity feed.

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APPENDIX E

ARCHAEOLOGICAL AND HISTORIC RESOURCES

In accordance with the National Environmental Policy Act of 1969, Executive Order 11593, the National Historic Preservation Act of 1966 (as amended in 1980), and the Archaeological and Historic Preservation Act of 1974, archaeological and historic surveys were conducted for the analysis of the environmental consequences of the cooling water alternatives proposed for C- and K-Reactors and the D-Area powerhouse. These surveys focused on the watersheds of Pen Branch, Four Mile Creek, and Beaver Dam Creek, into which cooling water is discharged from these facilities.

This appendix describes the results of these surveys. In addition, it contains a list of sites in the six-county area near the Savannah River Plant (SRP) that are included in the National Register of Historic Places.

E.1 PEN BRANCH AND FOUR MILE CREEK ARCHAEOLOGICAL AND HISTORIC RESOURCES

An intensive archaeological survey of the Pen Branch and Four Mile Creek areas was conducted by the Savannah River Plant Archaeological Research Program, South Carolina Institute of Archaeology and Anthropology, from May 16 through August 17, 1984, at the request of the DOE Savannah River Operations Office (Martin, Hanson, and Brooks, 1984). At the time the survey was performed, cooling lakes were among the potential cooling water alternatives under consideration; consequently, the survey focused on the proposed impoundment areas. However, the areas that might be disturbed by the alternatives addressed in this environmental impact statement were also encompassed by the survey. Table E-1 lists the sites included in this survey.

The survey located 65 discrete archaeological resources in the Pen Branch and Four Mile Creek watersheds. Analysis of the data recovered during the survey revealed human occupation from the Early Archaic through the Mississippian Period and from the 1780s through the 1950s. Table E-1 lists each of the sites by identification number, and presents information regarding periods of site occupation, site type, National Register eligibility, and recommended future activities at the site. Figure E-1 shows the location of all these sites.

The sites located during the survey were divided into three groups to evaluate their eligibility for nomination to the National Register (36 CFR 63.3): (1) those sites that are not significant, (2) those that are potentially significant, and (3) those that are significant. Sites characterized as significant have sufficient content, integrity, and scientific importance to warrant their eligibility for the National Register. Such sites would suffer adverse effects from any human activity that altered or destroyed the immediate environment.

Table E-1. Archaeological Resource Summary for Sites Recovered During Survey of Pen Branch and Four Mile Creek

Site	Period of occupation ^a	Type of site ^b	Eligible for nomination to <u>National Register</u>	Recommended site preservation plan if ground disturbance occurs
38BR54	19th century	Prehistoric: habitation Historic: scatter	No	None
38BR58/59	2,4,5,6	Habitation	No	None
38BR62	1,2,5,6	Habitation	No	None
38BR63	4,5	Intrusive	No	None
38BR65	(?)	Intrusive	No	None
38BR71	1,2	Habitation	Yes	Data recovery: sample excavations; intensive excavations
38BR76	4,5	Limited activity	No	None
38BR77	(?)	Habitation	No	None
38BR78	4	Limited activity	No	None
38BR96	(?)	Limited activity	No	None
38BR97	4,5,6	Habitation	Yes	Data recovery: sample excavations; intensive excavations
38BR98	4	Limited activity	Yes	Data recovery: sample excavations; intensive excavations

Table E-1. Archaeological Resource Summary for Sites Recovered
During Survey of Pen Branch and Four Mile Creek
(continued)

Site	Period of occupation ^a	Type of site ^b	Eligible for nomination to <u>National Register</u>	Recommended site preservation plan if ground disturbance occurs
38BR99	(?)	Limited activity	No	None
38BR100	(?)	Limited activity	No	None
38BR280	8 (1880-1950)	Historic: dwelling	Yes	Data recovery: documentary search; intensive excavations
38BR282	8 (1880-1950) 4,5	Historic: dwelling Prehistoric: habitation	Yes	Data recovery: documentary search; sample excavations; intensive excavations
38BR289	8 (19th-20th century)	Mill dam	Yes	Data recovery: documentary search
38BR292	8 (19th-20th century)	Mill dam	Yes	Data recovery: documentary search
38BR297	3,4,5,6	Limited activity	Yes	Data recovery: sample excavations; intensive excavations
38BR298	(?)	Limited activity	No	None
38BR299	2,3,4,5 6,7	Habitation	Yes	Data recovery: sample excavations; intensive excavations
38BR305	8 (19th-20th century)	Mill and dam	Yes	Data recovery: documentary search; intensive excavations

Table E-1. Archaeological Resource Summary for Sites Recovered
During Survey of Pen Branch and Four Mile Creek
(continued)

Site	Period of occupation ^a	Type of site ^b	Eligible for nomination to <u>National Register</u>	Recommended site preservation plan if ground disturbance occurs
38BR310	4,5,8 (19th-20th century)	Prehistoric: limited activity Historic: dwelling	Yes	Data recovery: sample excavations; intensive excavations
38BR316	(?)	Intrusive	No	None
38BR318	3,4,5,6	Habitation	Yes	Data recovery: sample excavations; intensive excavations
38BR319	(?)	Limited activity	No	None
38BR322	(?)	Limited activity	No	None
38BR323	(?)	Limited activity	No	None
38BR335	(?)	Limited activity	No	None
38BR339	(?)	Intrusive	No	None
38BR345	4,5,6	Limited activity	No	None
38BR352	(?)	Limited activity	Yes	Data recovery: sample excavations; intensive excavations ⁸
38BR353	(?)	Limited activity	No	None
38BR355	3,4,5,6	Habitation	No	None
38BR357	1,2,3	Limited activity	No	None

Table E-1. Archaeological Resource Summary for Sites Recovered
 During Survey of Pen Branch and Four Mile Creek
 (continued)

Site	Period of occupation ^a	Type of site ^b	Eligible for nomination to <u>National Register</u>	Recommended site preservation plan if ground disturbance occurs
38BR530	(?)	Limited activity	No	None
38BR531	2,3,4,5,6	Habitation	Yes	Data recovery: intensive excavations
38BR532	4	Limited activity	Yes	Data recovery: sample excavations; intensive excavations
38BR533	(?)	Limited activity	No	None
38BR534	(?)	Limited activity	No	None
38BR535	4,5,6	Habitation	Yes	Data recovery: intensive excavations
38BR536	(?)	Limited activity	No	None
38BR537	6	Limited activity	No	None
38BR538	4,5	Limited activity	No	None
38BR539	4,5,6	Habitation	Yes	Data recovery: sample excavations; intensive excavations
38BR540	3,4,5,6	Habitation	Yes	Data recovery: intensive excavations
38BR541	1,4,6	Habitation	Yes	Data recovery: sample excavations; intensive excavations

Table E-1. Archaeological Resource Summary for Sites Recovered
During Survey of Pen Branch and Four Mile Creek
(continued)

Site	Period of occupation ^a	Type of site ^b	Eligible for nomination to <u>National Register</u>	Recommended site preservation plan if ground disturbance occurs
38BR542	3,4,5,6	Habitation	Yes	Data recovery: intensive excavations
38BR543	(?)	Limited activity	No	None
38BR544	(?)	Limited activity	No	None
38BR545	4,5,6	Habitation	Yes	Data recovery: sample excavations; intensive excavations
38BR547	(?)	Limited activity	No	None
38BR548	(?)	Limited activity	No	None
38BR549	(?)	Limited activity	No	None
38BR550	5	Limited activity	No	None
38BR551	8 (20th century)	Historic dump	No	None
38BR552	5,6	Limited activity	No	None
38BR555	4,5,6	Limited activity	No	None
38AK148	5,6	Limited activity	No	None
38AK149	4,5,6	Limited activity	No	None

Table E-1. Archaeological Resource Summary for Sites Recovered During Survey of Pen Branch and Four Mile Creek (continued)

Site	Period of occupation ^a	Type of site ^b	Eligible for nomination to <u>National Register</u>	Recommended site preservation plan if ground disturbance occurs
38AK163	2,5	Limited activity	No	None
38AK414	(?)	Limited activity	No	None
38AK415	5	Limited activity	No	None
38AK417	4,5,6	Habitation	Yes	Data recovery: sample excavations; intensive excavations
38AK418	5	Limited activity	Yes	Data recovery: sample excavations; intensive excavations

^a1 = Early Archaic Period (9500-7500 B.C.)

2 = Middle Archaic Period (7500-3000 B.C.)

3 = Late Archaic Period (3000-1000 B.C.)

4 = Early Woodland Period (1000 B.C.-A.D. 1)

5 = Middle Woodland Period (A.D. 1-700)

6 = Late Woodland Period (A.D. 700-1000)

7 = Mississippian Period (A.D. 1000-1700)

8 = Historic Period (A.D. 1700-Present)

? = prehistoric lithic or ceramic debris--no specific time period

^bDetermined by the type and function of the artifact assemblage present at a site and its strategic location. A habitation site is defined as a base camp or area of long-term use where artifacts would be curated and manufactured and not necessarily taken along during food forays. Limited activity sites are defined as temporary, specialized, extractive sites (utilizing a specific local resource) with scarcity and lack of diversity within the artifact assemblage. Intrusive sites are those where artifacts located in the locale are the result of soil borrowing from another unknown area for pre-SRP construction activities. A historic dwelling is defined as the structural remains of a 19th-20th century building.

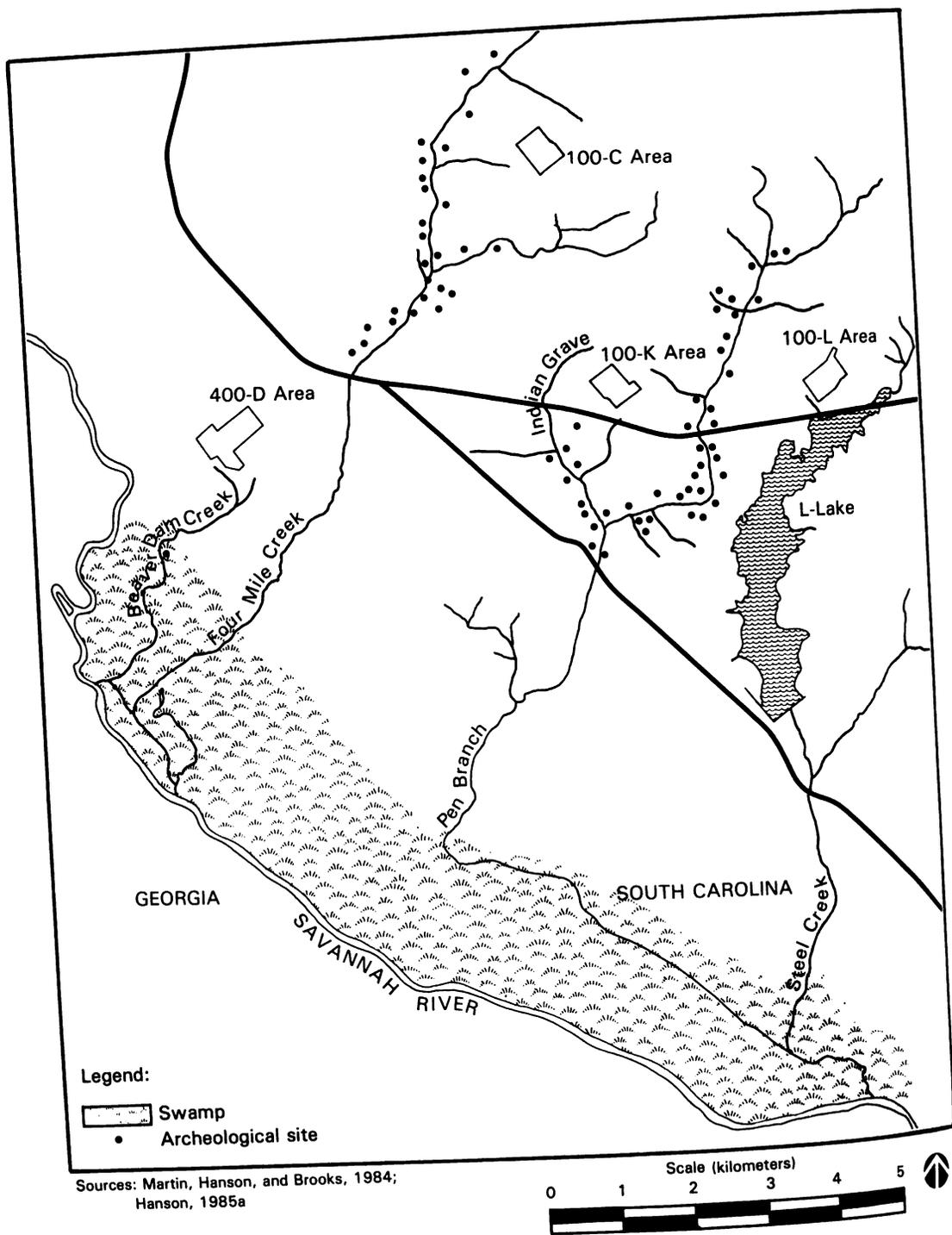


Figure E-1. General Map of the Survey Area Indicating Site Location

Of the 65 sites, 42 are considered not significant because of the lack of site integrity and the limited research potential. Various factors have contributed to the problem of low site integrity, including pre-1950s agricultural practices, pre-SRP construction activities, road construction and maintenance, and pine-plantation management practices.

The only site potentially affected by the construction of cooling towers (38BR548) is included in these 42 sites. Site 38BR548 is a small, prehistoric lithic and ceramic scatter located on a terrace edge adjacent to the bank of the northern branch of Four Mile Creek. A total of 16 systematic shovel tests was conducted at this site. No further work is recommended for this site because the potential yield of additional research information is negligible. A request for concurrence with the determination of "no effect" based on the absence of significant archaeological resources in the prepared construction areas has been made to the State Historic Preservation officer (Twining, 1985).

E.2 BEAVER DAM CREEK ARCHAEOLOGICAL AND HISTORIC RESOURCES

During October and November of 1985, an intensive archaeological survey was conducted along Beaver Dam Creek and in an area west of the creek near D-Area. The purpose of the survey was to locate and evaluate any archaeological resources that could be affected by implementation of cooling water alternatives in the D-Area, such as increased flow with mixing or direct discharge to the Savannah River via pipeline (Hansen, 1985a).

Shovel testing was employed along the stream near the edge of the terrace, as this area may be disturbed by increases in water flow in the creek. Testing revealed only one site, 38BR450, along the stream. Site 38BR450, known as the Pie Site, is a large, multicomponent, prehistoric base camp/village situated at the junction of Beaver Dam Creek and the Savannah River swamp (Figure E-1). Originally recorded in 1982 as part of the general survey of the Savannah River Plant, this site has been tested extensively in order to determine its extent, depth, and composition. The site has a high level of archaeological integrity and significance for addressing contemporary research problems in the region.

Based on these findings, site 38BR450 will be recommended for eligibility for nomination to the National Register of Historic Places. Field examination of the site with respect to its proximity to the creek and the possible increase in water flow of 10 cm above normal levels indicates that no inundation of the location will occur. The site is buffered by a dense growth of natural vegetation which serves to protect it from the projected minor flow changes. The implementation of cooling water alternatives in D-Area would result in neither erosive action nor inundation of the prehistoric property. Concurrent with the request for determination of National Register eligibility for the site, a request for a determination of "no effect" will be submitted to the State Historic Preservation Officer (Hansen, 1985a).

A field survey was also conducted in the area west of Beaver Dam Creek that may be disturbed by pipeline construction activities associated with the direct discharge alternative for D-Area. The survey documented that the area

had been extensively disturbed during initial SRP construction in the early 1950s, and no further evidence of intact archaeological resources was found. A review of the National Register of Historic Places also indicated that no sites are located in the area west of Beaver Dam Creek (Hansen, 1985b).

E.3 REGIONAL ARCHAEOLOGICAL AND HISTORIC RESOURCES

In March 1985, 67 sites in the six-county area near the Savannah River Plant had been listed in the National Register (Table E-2). Richmond County, Georgia, has the largest number of sites (26), most of them in and around the City of Augusta. Aiken County, South Carolina, has 18 sites.

Table E-2. National Register Sites in the Six-County Area
Near the Savannah River Plant^a

Name	Location
AIKEN COUNTY, SOUTH CAROLINA	
Chancellor James Carrol House	Aiken
Coker Springs	Aiken
Legare-Morgan House	Aiken
Phelps House	Aiken
Dawson-Vanderhorst House	Northeast of Aiken
Fort Moore-Savano Town site	Beech Island vicinity
Redcliffe	Northeast of Beech Island
Graniteville Historic District	Graniteville
Silver Bluff	West of Jackson
Charles Hammond House	North Augusta
Rosemary Hall	North Augusta
Joye Cottage	Aiken
Chinaberry (Williams-Converse House)	Aiken
St. Mary Help of Christians Church	Aiken
Willcox's	Aiken
Pickens House	Aiken
Georgia Avenue-Butler Avenue Historic District	North Augusta
White Hall (Aiken Winter Colony)	Aiken
ALLENDALE COUNTY, SOUTH CAROLINA	
Antioch Christian Church	Southwest of Allendale
Erwin House	Southwest of Allendale
Gravel Hill Plantation	Southwest of Allendale
Red Bluff Flint Quarries	Allendale vicinity
Roselawn	Southwest of Allendale
Smyrna Baptist Church	South of Allendale
Lawton Mounds	Johnsons Landing vicinity
Fennell Hill	Peeples vicinity
Virginia Durant Young House	Fairfax
BAMBERG COUNTY, SOUTH CAROLINA	
General Francis Marion Bamberg House	Bamberg
Woodlands	Southeast of Bamberg
Rivers Bridge State Park	Ehrhardt vicinity
Voorhees College Historic District	Denmark vicinity
Bamberg Historic District	Bamberg

Table E-2. National Register Sites in the Six-County Area Near the Savannah River Plant^a (continued)

Name	Location
BARNWELL COUNTY, SOUTH CAROLINA	
Banksia Hall	Barnwell
Church of the Holy Apostles	Barnwell
Church of the Holy Apostles Rectory	Barnwell
Old Presbyterian Church	Barnwell
Bethlehem Baptist Church	Barnwell
COLUMBIA COUNTY, GEORGIA	
Kiokee Baptist Church	Appling
Stallings Island	Northwest of Augusta
Woodville	Winfield vicinity
Columbia County Courthouse	Appling
RICHMOND COUNTY, GEORGIA	
Academy of Richmond County	Augusta
Augusta Canal Industrial Historic District	Augusta
Augusta Cotton Exchange	Augusta
Stephen Vincent Benet House	Augusta
Brahe House	Augusta
First Baptist Church of Augusta	Augusta
Fitzsimons-Hampton House	Augusta
Gertrude Herbert Art Institute	Augusta
Harris-Pearson-Walker House	Augusta
Meadow Garden	Augusta
Old Medical College Building	Augusta
Old Richmond County Courthouse	Augusta
Sacred Heart Catholic Church	Augusta
St. Paul's Episcopal Church	Augusta
Augusta National Golf Club	Augusta
Gould-Weed House	Augusta
Lamar Building	Augusta
Reid-Jones-Carpenter House	Augusta
Woodrow Wilson Boyhood Home	Augusta
College Hill	Augusta vicinity
Broad Street Historic District	Augusta
Pinched Gut Historic District	Augusta
Summerville Historic District	Augusta
Greene Street Historic District	Augusta
Springfield Baptist Church	Augusta
Meadow Garden-George Walton House	Augusta

^aData from DOI (1979, 1980, 1981, 1982, 1983, 1984, 1985).

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APPENDIX F

FLOODPLAIN/WETLANDS ASSESSMENT

F.1 INTRODUCTION

Executive Orders 11988 (Floodplains Management) and 11990 (Protection of Wetlands) and U.S. Department of Energy (DOE) regulation "Compliance with Floodplain/Wetlands Environmental Review Requirements" (10 CFR 1022) specify the requirements for a floodplain/wetlands assessment.

The proposed action and cooling water alternatives discussed in this EIS, with the exception of the D-Area direct discharge alternative, do not occur within the base floodplain or wetlands. Consequently, the practicability test for identifying and evaluating alternatives outside the base floodplain is not required except for the D-Area direct discharge alternative, which is discussed in Section F.4.2. However, the implementation of the cooling water alternatives for C- and K-Reactors and the D-Area powerhouse could potentially impact the base floodplain and wetlands. These impacts are identified and assessed in Chapter 4 of this EIS. The impact identification and assessment requirements for the EIS are also applicable and equivalent to the requirements for floodplain/wetlands protection.

This appendix references the EIS wherever possible and addresses only those impacts of the alternative cooling water systems that could affect the base floodplain and wetlands.

One of the primary areas of concern of the floodplain/wetlands Executive Orders is the protection of lives and properties. Access to the Savannah River Plant is strictly controlled. No dwellings, hospitals, schools, nursing homes, or other structures are located within the base floodplain. Therefore, no individual or private property would be affected if the cooling water alternatives were implemented.

Another principal area of concern in the floodplain/wetlands Executive Orders is the impact on floodplain values. The cooling water alternatives would have little or no impact on cultural resources, agricultural, aquacultural, or forestry resources as they relate to floodplain values. Archaeological and historic resource surveys, which are discussed in Appendix E, identified no significant sites requiring impact mitigation. Because of the controlled access to the Savannah River Plant, no agricultural or aquacultural practices are allowed, and none would be affected by implementation of any of the cooling water alternatives. The implementation of any of the alternatives (except the no-action alternative for C- and K-Reactors) would enhance the forest resource values.

The cooling water alternatives will, however, impact water and biological resources. This appendix discusses positive and negative, direct (concentrated) and indirect (dispersed), and short-term and long-term impacts associated with the construction and operation of the alternatives for each of the floodplain/wetland areas as they relate to both water and biological resources.

Short-term impacts are temporary changes occurring during and immediately following implementation of an alternative. Impacts related to construction activities such as site clearing and sedimentation runoff are examples of short-term impacts. Long-term impacts can persist for a considerable time, and might continue indefinitely. Loss of mature swamp forest trees due to discharge of thermal effluents is an example of a long-term impact. Direct impacts, as this term is used in this EIS, are concentrated at or near the site of the action; indirect impacts occur at a site remote from the action. Impacts can be beneficial (i.e., positive) or harmful (i.e., negative). The alternative cooling water systems for C- and K-Reactors include the construction and operation of once-through cooling towers (either gravity or pump feed and either mechanical or natural draft), recirculating cooling towers, and the continuation of direct discharge - or no action. The alternatives considered for the D-Area coal-fired powerhouse include increased flow with mixing, direct discharge to the Savannah River, and continuation of the present operation - or no action. The proposed action and alternatives are discussed in detail in Chapter 2.

F.2 FOUR MILE CREEK (C-REACTOR)

F.2.1 ONCE-THROUGH COOLING TOWER (PREFERRED ALTERNATIVE)

F.2.1.1 Construction Impacts

Water Resources

The principal direct impact to water resources in the Four Mile Creek floodplain/wetlands during construction would be on water quality. Construction activities would cause a temporary increase in suspended solids due to runoff erosion, a negative impact. Temporary measures such as berms, drainage ditches, drains, sedimentation basins, grassing, and mulching would control runoff until permanent erosion-control measures were implemented. Construction activities would have no measurable effect on groundwater recharge or the ability of the floodplain/wetlands to moderate floods. Water quality impacts are discussed in more detail in Chapter 4.

Biological Resources

Construction activities would occur on upland sites and would not directly impact the floodplain/wetlands. The principal indirect impact would be from sediment loading on fish and macroinvertebrates. This short-term impact would

probably be minimal because Four Mile Creek in the vicinity of the proposed construction is sparsely inhabited due to the high water temperatures caused by existing reactor operations.

F.2.1.2 Operational Impacts

Water Resources

The principal direct impact to water resources in the Four Mile Creek floodplain/wetlands would be on water quality. Water temperatures would be reduced from a maximum of 73°C to 32.2°C in the summer, only 1°C above projected ambient temperatures, a positive impact. In the winter, the discharge temperature would decrease even more to approximately 24°C (15°C above ambient creek temperature). Lowered water temperatures would also improve water quality by increasing the dissolved oxygen concentration.

Implementation of the once-through cooling tower (either gravity or pump feed, and either mechanical or natural draft) would result in a reduction of both suspended solids and the sedimentation rates of the delta, a positive impact. Some of the suspended solids would be removed by settling during passage through a holding pond. However, if no holding pond were constructed, erosion and sedimentation would be slightly higher. The sedimentation rates of the delta should decrease as plant growth becomes reestablished along the stream banks, a positive impact, due to the prevention of further vegetative loss caused by thermal effluents. Operations would have no measurable impact on the ability of the floodplain/wetlands to moderate floods or groundwater recharge. Stream flow, which would be reduced slightly from 11.3 to about 10.4 cubic meters per second, should cause a slight reduction in suspended solids concentrations, a positive impact. Water quality and hydrology impacts are discussed in more detail in Chapter 4.

Biological Resources

The most significant ecological impact would be a reduction in the loss of wetland habitat due to the thermal effects of the discharges, a positive impact. Vegetation would become reestablished on portions of the 1147 acres of affected wetlands, and the vegetation loss rate in the swamp of 28 acres per year due to thermal impacts would be reduced (see Chapter 4). The reduction in stream flow could also contribute to a slight reduction in canopy loss from flooding and increased sedimentation, a positive impact.

Implementation of this alternative should enhance the diversity of plant and animal life over present conditions, a positive impact. Spawning conditions for indigenous and migratory fish species would be greatly improved. The final cooling tower would be designed and operated to meet the requirements stipulated for Maximum Weekly Average Temperature (MWAT) for fish survival during a winter shutdown (EPA, 1977; Muhlbaier, 1986); this would be a positive impact.

Two of the four endangered species that occur on the Savannah River Plant would be positively affected by this alternative. Because the water temperature resulting from this alternative would be well below the thermal maximum temperature tolerance of the American alligator (Alligator mississippiensis), additional habitat for this species would be provided.

Reducing the temperature below the thermal maximum for fish would allow fish to recolonize Four Mile Creek, a positive impact. The fluctuating water levels could, in turn, concentrate fish, the principal prey of the endangered wood stork (Mycteria americana); this would be a positive impact, because loss of foraging habitat has contributed to the decline of the wood stork (Du Pont, 1985).

Because this alternative would not require any changes in the cooling water intake structures or flow rates, there would be no change in the entrainment or impingement impacts. Consultation between DOE and the National Marine Fisheries Service has determined that SRP operations would have no adverse impacts on the endangered shortnose sturgeon (Acipenser brevirostrum) (Oravetz, 1983). Biological impacts are discussed in more detail in Chapter 4.

Vegetation near the cooling tower would be subject to salt deposition attributable to drift from the tower. Cooling tower drift could cause vegetation stress, either directly by deposition of salts on the foliage or indirectly from excess accumulations of salts in the soil. Salt stress in plants could occur via various mechanisms; such stress includes: (1) increased osmotic potential of the soil solution affecting the availability of soil moisture to the plant; (2) alteration of the mineral nutrition balance in the salt tissue; and/or (3) toxic effects due to specific ion concentrations in the plants (Bernstein, 1975; Hanes, Zelazny, and Blaser, 1970; Allison, 1964; Levitt, 1980).

Tolerances and susceptibility to salt deposition are highly variable, depending on both the plant species and other conditions in the environment. Vegetative studies indicated that thresholds for development of visible salt stress symptoms on the most sensitive species were approximately 83 kilograms (183 pounds) per acre per year of sodium chloride salt (INTERA, 1980). Studies indicate that at sodium chloride deposition rates of about 41 kilograms (90 pounds) per acre per year, agricultural productivity can be reduced (Mulchi and Armbruster, 1981).

The composition of the drift is equivalent to that of the circulating water. The concentration of substances in the circulating water for this alternative is shown in Table 3-3. The substance of particular interest with regard to its potential for damage is the chloride ion. The other constituents listed in the table either are at such low concentrations as to be negligible or are potentially beneficial.

The implementation of this alternative would result in an estimated total solids deposition of 1.0 kilogram (2.2 pounds) per acre per year within 2 kilometers of the cooling tower. The sodium chloride deposition rates from the cooling tower are much less than the critical values, reported by Mulchi and Armbruster (1981), INTERA (1980), and NRC (1979), that can cause reduced productivity of plant species. Therefore, no significant impacts on vegetation are expected with this alternative.

F.2.2 RECIRCULATING COOLING TOWERS

F.2.2.1 Construction Impacts

Water Resources

The principal impacts to water resources in the Four Mile Creek floodplain/wetlands during construction would be similar to those described for the once-through cooling-tower alternative described in Section F.2.1.1. Suspended solids due to runoff erosion should be slightly lower, and a projected 50 acres of upland habitat would be disturbed versus 90 acres for the once-through cooling-tower alternative during construction activities.

Biological Resources

Biological resource impacts would be similar to those associated with the construction of the once-through cooling tower, discussed in Section F.2.1.1.

F.2.2.2 Operational Impacts

Water Resources

Implementation of this alternative would primarily affect water quality. As with the once-through cooling tower alternative, effluent temperatures would closely duplicate ambient temperatures, a positive impact. Under winter conditions, the average discharge temperature would be about 10°C, only 1°C above the ambient stream temperature. Dissolved oxygen levels would improve if this alternative were implemented and would comply with State Class B water classification standards throughout the year, a positive impact. Nutrient concentrations would increase at the tower outfall under this alternative, but total loading (quantity) of nutrients and other chemicals transported to the swamp/river system would not increase.

Water consumption from the Savannah River would be reduced from about 11.3 cubic meters per second to about 1.7 cubic meters per second, a positive impact.

The implementation of this action would result in even greater reductions in suspended solids and the sedimentation rates of the delta than the once-through alternative. The most significant reduction in sedimentation and delta growth rate impacts would come about from the reduction in stream flow rates, a positive impact. Under this alternative, discharge flows would

decrease from 11.3 cubic meters per second to about 0.6 cubic meter per second, and stream channel depth and width would be reduced substantially. Operations would have no measurable impact on the ability of the floodplain/wetlands to moderate floods or groundwater recharge.

Biological Impacts

The most significant ecological impact would be a reduction in the loss of wetland habitat due to the reduced thermal effects of the discharge and sedimentation associated with the delta growth, a positive impact. Vegetation would become reestablished on portions of the 1147 acres of affected wetlands and the vegetation loss rate associated with the delta growth (28 acres per year, average 1974-1984) would be substantially reduced.

Stream flows and temperatures would more closely follow ambient conditions and would allow for the improvement of plant and animal diversity over present conditions, a positive impact. Spawning conditions for indigenous and migratory fish species would be greatly improved. With discharge temperatures similar to ambient temperature, there would be no potential for cold shock during a winter reactor shutdown. Changes in flow volumes, when they occur, would be smaller than with other alternatives and would tend to minimize changes in stream morphology. This, in turn, would provide a more stable aquatic habitat.

Two of the four endangered species that occur on the Savannah River Plant would be affected by this alternative. The impact on the American alligator should be positive (i.e., increased habitat). The decrease in water flow would allow vegetation to become reestablished over a larger area than the once-through alternative.

Fish and other vertebrates would be able to inhabit the stream channel, providing potential foraging habitat for the wood stork. Fluctuations in water levels would decrease compared to those from the once-through alternative. Consequently, fish populations could not become concentrated in small pools, and potential foraging habitat for the wood stork would decrease.

Vegetative succession should eventually return a large area of the impacted floodplain/wetlands to a closed-canopy forest. A closed-canopy forest is not considered to be good foraging habitat for the wood stork, although it provides food and cover for numerous species of wildlife.

Because the rate of entrainment for fish eggs and larvae is directly proportional to the water intake flow rate, entrainment losses would be proportionally reduced (approximately 85 percent). Estimated impingement losses would also be reduced by a similar amount. Biological impacts are discussed in more detail in Chapter 4.

Implementation of this alternative would result in an estimated total solids deposition of about 23.0 kilograms (50.7 pounds) per acre per year within 0.2 kilometers and about 10 kilograms (22 pounds) per acre per year within

0.8 kilometer of the cooling towers. At 2 kilometers, the predicted solids deposition is calculated to be about 6.0 kilograms (13.2 pounds) per acre per year. Because the deposition rates at 2 kilometers are much less than the critical values reported (see Chapter 4), no significant impacts on vegetation are expected beyond this distance with this alternative.

F.2.3 NO ACTION - EXISTING SYSTEM

F.2.3.1 Operational Impacts

Water Resources

The impacts on water resources of the no-action alternative are mostly negative. The annual average flow in Four Mile Creek below the C-Reactor cooling water discharge point would continue to be about 11.9 cubic meters per second, 11.3 cubic meters per second above natural stream flow. The thermal maximum temperature tolerance for most aquatic and terrestrial species would continue to be exceeded. The dissolved oxygen levels would continue to fall below minimum State of South Carolina water classification standards during the summer. Suspended solids and sedimentation rates for delta expansion would continue. Stream morphology has been permanently altered due to approximately 30 years of discharge at 11.3 cubic meters per second. Because of this alteration, continued operations would have little impact on the ability of the Four Mile Creek floodplain/wetlands to moderate floods. Continued operations would also have little impact on the ability of the swamp floodplain/wetlands adjacent to Four Mile Creek to moderate floods because this is controlled by the Savannah River (483 cubic meters per second of flow during flood stage). Groundwater recharge in this area is primarily controlled by the Savannah River. Water quality and hydrology impacts are discussed in more detail in Chapter 4.

Biological Resources

The impacts on biological resources of the no-action alternative are negative. The flora along the creek would continue to be sparse, reflecting the harsh temperature regime. Most aquatic invertebrates would remain absent from the creek. Fish would not be able to inhabit the creek where their thermal maximum temperature tolerance is exceeded, and the fish fauna above the thermal discharge point would continue to be depauperate in both number and diversity. Limited use by endangered species in Four Mile Creek would continue under existing conditions. Entrainment and impingement rates would remain at the present level. Biological impacts are discussed in more detail in Chapter 4.

F.3 PEN BRANCH (K-REACTOR)

F.3.1 ONCE-THROUGH COOLING TOWER (PREFERRED ALTERNATIVE)

F.3.1.1 Construction Impacts

Water Resources

The types of construction impacts of the once-through cooling tower (either gravity or pump fed and either mechanical or natural draft) for K-Reactor on water resources and biological resources in Pen Branch would be similar to those described for C-Reactor on Four Mile Creek (see Section F.2.1.1 and Chapter 4).

F.3.1.2 Operational Impacts

Water Resources

The operational impacts of the once-through cooling tower for K-Reactor on water resources would be similar to those described for C-Reactor on Four Mile Creek (see Section F.2.1.2 and Chapter 4).

The cooling effect would be the same as that projected for Four Mile Creek in that temperatures would meet the 32.2°C Class B water classification standard, but would be about 15°C above ambient creek temperature during the winter at the point of discharge.

Biological Resources

Operational impacts of the once-through cooling tower for K-Reactor on biological resources would be similar to those described for C-Reactor (see Section F.2.1.2 and Chapter 4). Vegetation would become reestablished on portions of the 680 acres of affected wetlands, and the vegetation loss rate in the swamp of 26 acres per year due to thermal impacts would be reduced, a positive impact. Wood storks have been observed foraging just north of the Pen Branch delta. The implementation of this alternative would further enhance foraging habitat for wood storks, a positive impact. The final cooling tower would be designed and operated to meet the requirements stipulated for MWAT for fish survival during a winter shutdown (EPA, 1977; Muhlbaier, 1986); this would be a positive impact.

Deposition of cooling tower drift would be similar to that projected for the once-through cooling tower alternative for C-Reactor, except higher deposition rates [2.3 kilograms (5.1 pound per acre per year)] would occur within 0.2 kilometer of the tower. However, the rates at 2 kilometers would be the same as those estimated for C-Reactor (2.2 pounds per acre per year). Therefore, there would be no impacts on vegetation with this alternative.

F.3.2 RECIRCULATING COOLING TOWERS

F.3.2.1 Construction Impacts

Water Resources

The construction impacts of recirculating cooling towers for K-Reactor on water resources and biological resources would be similar to those described for C-Reactor on Four Mile Creek (see Section F.2.3.1). Sedimentation runoff impacts should be similar (short-term) because projected disturbances (55 acres) approximate those for the C-Reactor recirculating cooling tower (50 acres).

F.3.2.2 Operational Impacts

The operational impacts of recirculating cooling towers for K-Reactor on water resources and biological resources would be similar to those described for C-Reactor on Four Mile Creek (see Section F.2.2.2 and Chapter 4). It is estimated that approximately 75 percent (500 acres) of the thermally impacted 680 acres of wetland vegetation would become reestablished, a positive impact.

The implementation of this alternative would result in an estimated total solids deposition of 22.7 kilograms (50.1 pounds) per acre per year within 0.8 kilometer and 6 kilograms (13.2 pounds) per acre per year within 2 kilometers of the cooling towers. Because these rates at 2 kilometers are much less than the critical threshold values reported that can cause reduced productivity of plant species (see Section F.2.1.2 and Chapter 4), no significant impacts on vegetation are expected with this alternative.

F.3.3 NO ACTION - EXISTING SYSTEM

F.3.3.1 Operational Impacts

The operational impacts of the no-action alternative on water resources and biological resources are similar to those described for C-Reactor on Four Mile Creek (see Section F.2.4.1 and Chapter 4).

F.4 BEAVER DAM CREEK (D-AREA POWERHOUSE)

F.4.1 INCREASED FLOW WITH MIXING (PREFERRED ALTERNATIVE)

F.4.1.1 Construction Impacts

Existing structures would be used for increasing flow; consequently, there would be no construction or short-term impacts associated with this alternative.

F.4.1.2 Operational Impacts

Water Resources

Water quality monitoring studies have shown that temperature is the only Class B water classification standard not being met and that the thermal limits are exceeded only during the late spring and summer months (Du Pont, 1985). During summer extremes, discharges to the creek are 36°C, 3.8°C above State Class B water classification standards. Implementation of this alternative would reduce the effluent temperature sufficiently to meet State Class B water classification standards. Potential impacts that could occur include small increases in stream suspended solids caused by intermittently increased stream flow (i.e., increases in flow with average increments from 2.6 cubic meters per second to 4.5 cubic meters per second), depending on the number of additional pumps needed to meet temperature requirements (see Chapter 2). Operations under this alternative would have little impact on the ability of the floodplain/wetlands to moderate floods or groundwater recharge, because these activities are dominated by the Savannah River (Du Pont, 1985).

Biological Resources

Water temperatures during the spring and summer would average 2°C above ambient creek temperatures and 7°C above ambient during the winter. Increased flow during the spring and summer months would increase aquatic habitat and should increase the abundance and diversity of fish and macroinvertebrates. However, wildlife habitat would be reduced temporarily during periods of increased pumping.

The increased flow would cause temporary increases in stream channel erosion and consequently would increase siltation. This increased siltation would generally occur after peak spawning in May and June. However, during some years increased flow could be required as early as May or June, a potentially negative impact. Any increase in vegetation loss due to delta growth should be minimal and offset by vegetation reestablishment and succession on previously impacted thermal areas. A reversal in the pattern of the canopy loss is already being observed, and is thought to be due to a reduction in effluent temperatures that began in 1978 and has continued (Du Pont, 1985).

Two of the four endangered species that occur on the Savannah River Plant could be affected by this alternative. The Beaver Dam Creek area supports a large population of alligators, and the mild thermal effluent during the winter probably enhances the survivability of juvenile alligators. Implementation of this alternative would have no impact on winter thermal effluent and, thus, should have no impact on winter alligator populations. Intermittently increased flows during the spring and summer would cause the water level in Beaver Dam Creek to alternately rise and fall 12 to 19 centimeters (see Chapter 4); water-level increases less than or equal to 35 centimeters are not expected to affect alligator nesting sites (Specht, 1985).

Wood storks frequently forage in the Beaver Dam Creek swamp, even though feeding habitat is of marginal quality when compared to other areas on the Savannah River Plant (Du Pont, 1985). An increase in water levels of 12 to 19 centimeters could result in water levels that are too deep at times for foraging activities. Conversely, increased water levels could prevent or delay potential foraging areas from drying up during droughts, because the Beaver Dam Creek foraging sites are not associated with the more permanent wetlands found along primary and secondary creeks.

Entrainment losses would increase by about three percent or 0.1×10^6 if this alternative were implemented. Entrainment of the eggs and larvae of the shortnose sturgeon, an endangered species, should not occur. This is due to the demersal and adhesive nature of their eggs, as well as to the time of year shortnose sturgeon spawn (February-March). Fish impingement on the 5G intake screens would continue to average about 1 to 13 per day based on data from 1982 through 1984. Biological impacts are discussed in greater detail in Chapter 4 and Appendix C.

F.4.2 DIRECT DISCHARGE TO SAVANNAH RIVER

F.4.2.1 Direct Impacts to Floodplains/Wetlands and Practicable Alternatives

Implementation of this alternative would temporarily disturb approximately 1 acre of floodplain/wetlands during construction. The overall operational impact of this alternative would be to return Beaver Dam Creek to its approximate original status as an intermittent stream. Implementing this action would reduce floodplain/wetland values because current operations enhance certain wildlife values (see Section F.4.3.1 and Chapter 4).

An alternative action that would achieve the intended thermal performance standards but would minimize harm to or within the floodplain/wetlands is described in Section F.4.1; the no-action alternative is described in Section F.4.3. Because public access to and use of the Savannah River Plant are strictly controlled, no individual or private property would be affected by this alternative. In addition, no impact would directly or indirectly support floodplain development, nor would there be an impact on cultural resources, agriculture, aquaculture, or forestry resources as they relate to floodplain values.

F.4.2.2 Construction Impacts

Water Resources

The principal direct impact to water resources in the Beaver Dam Creek floodplain/wetlands during construction would be on water quality. A pipeline would be constructed parallel to the existing intake pipe. This pipeline would run from the D-Area powerhouse across the Beaver Dam Creek swamp to a discharge point on the Savannah River below the cooling water intake structure. The pipeline would cross approximately 1 acre of floodplain/wetlands.

The construction activities would result in a temporary increase in turbidity and suspended solids. Construction impacts would have no measurable effect on groundwater recharge or on the ability of floodplain/wetlands to moderate floods.

Biological Resources

The principal indirect impact would be from sediment loading on fish and microinvertebrates in Beaver Dam Creek. After construction activities cease, suspended solids levels should return quickly to ambient conditions. Wildlife might also be disturbed by the construction activities and the noise associated with the activity. This disturbance is also short-term and noncumulative.

F.4.2.3 Operational Impacts

Water Resources

The principal direct impact to water resources in the Beaver Dam Creek floodplain/wetlands would be to stream flow, which would decrease from the present average of 2.6 cubic meters per second to only 0.2 cubic meter per second. Beaver Dam Creek and the adjacent swamp would essentially return to their approximate original condition, a wetland with an intermittent stream. Periodic flooding would depend entirely on natural flooding from the Savannah River and storm runoff after rains. Based on pump test data (Specht, 1985), any flooding that occurred on Beaver Dam Creek due to storm runoff would be of short duration, and the water level in Beaver Dam Creek swamp would return to its original level approximately 24 hours after the rainfall stopped.

Thermal effluent that occasionally exceeded State Class B water classification standards would be discharged directly to the Savannah River. Because of the small volumes of discharge water in relation to the volume of the river, there would be little thermal impact.

Biological Resources

The most significant ecological impact would be a loss of nesting and foraging habitat for wildlife. The implementation of this alternative would decrease or eliminate nesting habitat for the American alligator and any thermal refugia that might have existed during the winter months. Foraging habitat for the wood stork would be decreased significantly or eliminated. Beaver Dam Creek would essentially return to approximately its original condition as an intermittent stream (Moyer, 1985). This would also cause aquatic organisms to receive negative impacts.

Because the thermal effluent would be pumped directly to the Savannah River, there would be a small thermal plume at the outfall structure. Because of the small volume of mildly thermal effluent and the large volume of ambient river water, there would be little thermal impact. There would be a large zone of

passage for all fish species, including the shortnose sturgeon. There would be no impact on the shortnose sturgeon from entrainment and impingement with implementation of this alternative.

F.4.3 NO ACTION - EXISTING SYSTEM

F.4.3.1 Operational Impacts

Water Resources

The flow of 2.6 cubic meters per second would continue. Water temperatures in the creek and delta could reach 36°C under extreme summer conditions and would not comply with State Class B water classification standards. Concentrations of dissolved oxygen would be somewhat lower than those in unimpacted streams where ambient temperatures sometimes reach 33°C. Continued operations would have no measurable impact on the ability of the floodplain wetlands to moderate floods or groundwater recharge. Water resource impacts are discussed in more detail in Chapter 4.

Biological Resources

The aquatic and terrestrial ecology of the creek would continue to be affected by the thermal effluent but to a much lesser extent than that of Pen Branch or Four Mile Creek. Portions of Beaver Dam Creek would continue to show evidence of revegetation and succession due to a slight decline in water temperatures that began in the 1970s.

This area around the creek would continue to provide habitat for a dense population of alligators and foraging habitat for the wood stork.

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APPENDIX G

RADIATION DOSE CALCULATION METHODS AND ASSUMPTIONS

The operation of alternative cooling water systems for the C- and K-Reactors at the Savannah River Plant (SRP) would change the amount of radioactive materials released to the environment. Cooling alternatives associated with the D-Area would not cause any changes in radioactive releases to the environment. This appendix describes the methods and assumptions used to (1) determine the change in radiological impacts expected to result from the operation of the cooling alternatives, and (2) determine the doses expected from the operation of facilities on or within 80 kilometers of the Savannah River Plant without the implementation of cooling alternatives (no action - existing conditions).

The cooling water alternatives for C- and K-Reactors that are considered in this EIS are existing operation (no action), recirculating cooling towers, and once-through cooling towers (either pumped or gravity feed, and either mechanical or natural draft). For the once-through alternative, atmospheric doses were analyzed for the pumped-feed, mechanical-draft cooling towers. Atmospheric doses would be slightly different for the maximally exposed individual at the Plant boundary if a natural-draft, rather than a mechanical-draft, cooling tower is implemented. This is due to the higher release height for the natural-draft tower. This difference in doses, however, is negligible.

A once-through, gravity-feed cooling tower (either mechanical draft or natural draft) would cause a slightly higher dose to the maximally exposed individual at the Plant boundary than a once-through, pumped-feed tower, because a gravity-feed tower would be somewhat closer to the individual. The changes in dose, however, are negligible.

For liquid releases from C-Reactor, doses would be the same for either a gravity-feed or a pumped-feed once-through cooling tower because the discharge rate and creek bed area remain the same. For K-Reactor, a once-through, gravity-feed (either mechanical- or natural-draft) cooling tower could result in a slight decrease in doses from remobilization because a small percentage of the Indian Grave Branch and Pen Branch beds would no longer receive cooling water discharges. The decrease in dose, however, is negligible.

The implementation of a once-through or recirculating cooling-tower alternative for C- and K-Reactors would change the amount of radionuclides released to the environment. Because of an increase in evaporation from cooling towers, a greater amount of tritium would be released to the atmosphere, resulting in a positive tritium source term. However, for liquid releases the tritium source term would decrease by the same amount and, therefore, would be considered a negative value. Also, the implementation of alternative cooling water systems might cause a change in the rate of remobilization of radionuclides present in creek beds. Remobilization is discussed in Section G.2 and Appendix D.

Radioactive materials released to the environment generally become involved in a complex series of physical, chemical, and biological processes. The principal pathways by which radioactivity released from a facility can reach people are (1) exposure to nuclides in the air, in the water, or on the ground, (2) inhalation of radioactivity, and (3) ingestion of radioactivity in food and water. Figure G-1 shows these pathways.

The calculations of radiological doses to members of the public from these various pathways are based on methods recommended by the U.S. Nuclear Regulatory Commission (NRC) for licensing power reactors. However, the dose-conversion factors were taken from ICRP Publication 30 (ICRP, 1979). Estimates of doses are based on detailed analyses of the sources and rates of radioactive releases and the pathways by which people can be exposed to dispersed radioactive materials. The NRC methods are adapted to specific SRP conditions.

In the calculation of doses, the dose-conversion factors for adults presented in ICRP-30 were used. Dose factors for other age groups have not yet been published by the ICRP. However, age-specific usage factors were used to calculate doses. The age groups considered were infant (0 to 1 year old), child (1 to 11 years old), teen (11-17 years old), and adult (17 years old and older).

Dose-conversion factors are provided in ICRP-30 for many organs. These factors depend on the physical and chemical nature of the radionuclide. The oral- and inhalation-dose conversion factors chosen for tritium presume it to be in the form of tritiated water. Also, to account for tritium absorption through the skin, the inhalation-dose conversion factor is increased by a factor of 0.5. For all radionuclides released to the environment, an effective-whole-body-dose conversion factor was obtained by multiplying the individual-organ-dose conversion factors by the health-risk weighting factors presented in ICRP-30 and summing the results.

Radiation doses are calculated for the maximally exposed individual, collective doses for the population within 80 kilometers of the Savannah River Plant and that population served by the Beaufort-Jasper County and Cherokee Hill (Port Wentworth) water-treatment plants.

G.1 ATMOSPHERIC RELEASES

For airborne releases, annual average air concentration and ground deposition per unit release (X/Q and D/Q) were calculated for each of 160 segments (16 wind-direction sectors at 10 distances) within an 80-kilometer radius of the site and for the site boundaries, using the methods implemented in the NRC computer program XOQDOQ (Sagendorf and Gall, 1976). Site-specific meteorological data were used to generate joint-frequency distributions (JFDs) of wind speed, stability, and direction for input to XOQDOQ (Table G-1). These

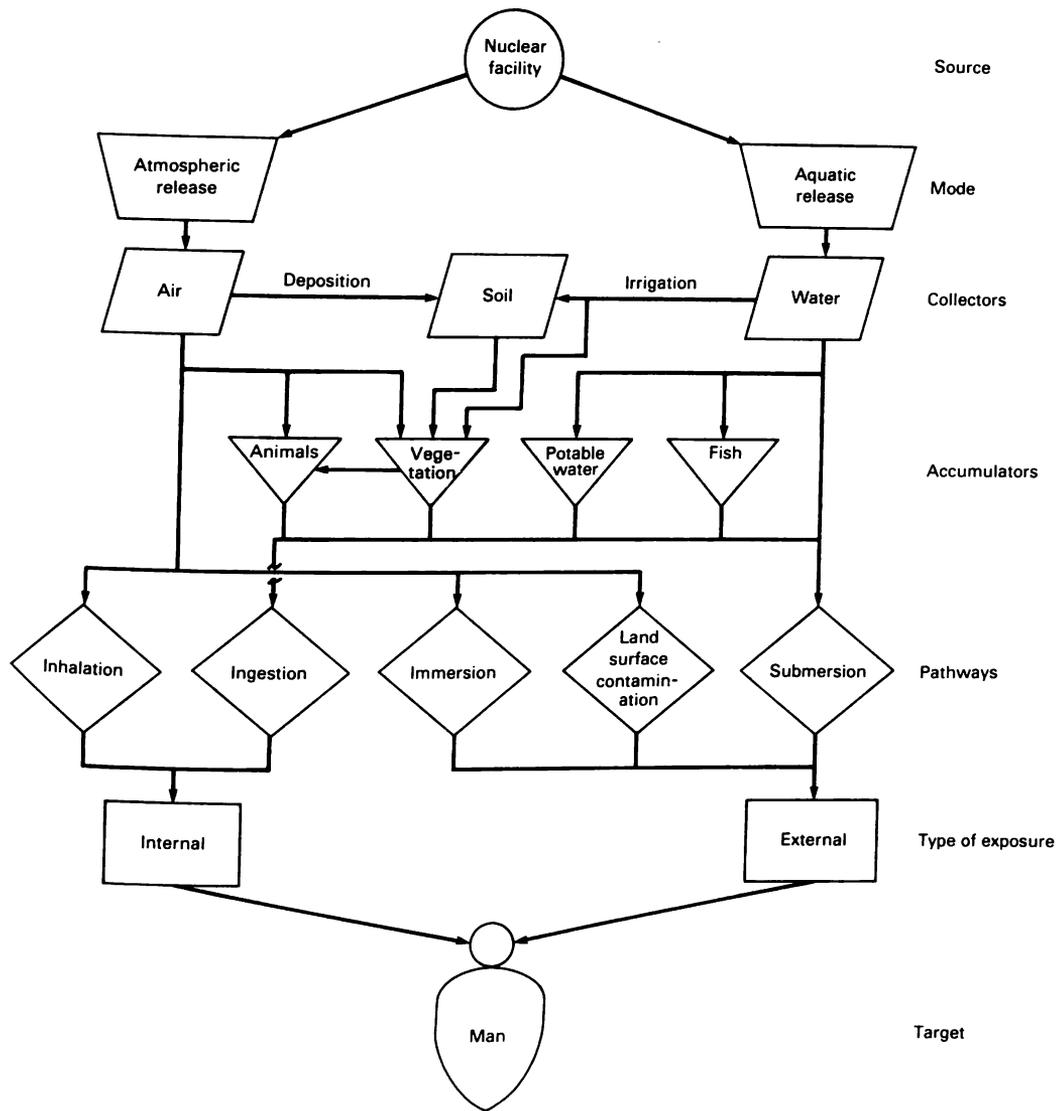


Figure G-1. Exposure Pathways Considered in Radiological Impact Assessments

Table 6-1. Joint-Frequency Distribution of Wind: H-Area Tower, 1975-1979

Wind speed class (m/sec)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL	
ATMOSPHERIC STABILITY CLASS A (VERY UNSTABLE)																		
0.0-2.0	0.39	0.32	0.39	0.33	0.32	0.38	0.41	0.40	0.37	0.36	0.40	0.40	0.56	0.61	0.46	0.39	6.49	
2.1-4.0	0.31	0.28	0.31	0.42	0.59	0.64	0.68	0.48	0.48	0.45	0.49	0.44	0.56	0.63	0.53	0.34	7.62	
4.1-6.0	0.04	0.05	0.05	0.08	0.18	0.15	0.08	0.08	0.09	0.13	0.17	0.12	0.09	0.09	0.14	0.08	1.64	
6.1-8.0	0.01	0.00	0.01	0.03	0.01	0.01	0.00	0.06	0.06	0.01	0.02	0.03	0.02	0.03	0.03	0.01	0.31	
8.1-12.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.09	
>12.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
ATMOSPHERIC STABILITY CLASS B (UNSTABLE)																		
0.0-2.0	0.09	0.10	0.17	0.13	0.17	0.18	0.14	0.11	0.15	0.11	0.11	0.22	0.22	0.23	0.19	0.13	2.46	
2.1-4.0	0.19	0.14	0.27	0.39	0.38	0.41	0.36	0.26	0.29	0.26	0.29	0.29	0.37	0.44	0.31	0.28	4.92	
4.1-6.0	0.05	0.05	0.07	0.26	0.27	0.21	0.13	0.12	0.21	0.24	0.18	0.17	0.16	0.28	0.27	0.18	2.85	
6.1-8.0	0.02	0.02	0.01	0.04	0.03	0.02	0.00	0.03	0.06	0.05	0.03	0.04	0.05	0.02	0.07	0.03	0.53	
8.1-12.0	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.02	0.02	0.01	0.08	
>12.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
ATMOSPHERIC STABILITY CLASS C (SLIGHTLY UNSTABLE)																		
0.0-2.0	0.12	0.11	0.21	0.19	0.18	0.17	0.16	0.13	0.14	0.16	0.16	0.13	0.25	0.29	0.15	0.18	2.75	
2.1-4.0	0.20	0.19	0.39	0.62	0.69	0.58	0.45	0.47	0.29	0.36	0.40	0.38	0.66	0.60	0.49	0.35	7.11	
4.1-6.0	0.11	0.10	0.18	0.50	0.55	0.46	0.23	0.24	0.37	0.44	0.32	0.42	0.47	0.49	0.46	0.23	5.58	
6.1-8.0	0.01	0.02	0.04	0.18	0.14	0.02	0.06	0.08	0.07	0.11	0.11	0.15	0.18	0.18	0.37	0.19	1.92	
8.1-12.0	0.01	0.01	0.01	0.01	0.02	0.00	0.00	0.03	0.01	0.02	0.05	0.03	0.10	0.11	0.26	0.09	0.76	
>12.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.02	
ATMOSPHERIC STABILITY CLASS D (NEUTRAL)																		
0.0-2.0	0.11	0.10	0.17	0.18	0.17	0.14	0.18	0.18	0.17	0.17	0.16	0.23	0.31	0.32	0.22	0.15	2.98	
2.1-4.0	0.31	0.34	0.58	0.79	1.02	0.98	0.66	0.70	0.51	0.49	0.82	0.68	0.79	0.88	0.77	0.54	10.87	
4.1-6.0	0.16	0.16	0.33	0.82	0.78	0.68	0.57	0.62	0.62	0.93	0.73	0.83	1.14	1.22	0.41	10.73		
6.1-8.0	0.06	0.04	0.06	0.15	0.08	0.06	0.12	0.17	0.20	0.23	0.23	0.27	0.36	0.50	0.83	0.21	3.56	
8.1-12.0	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.02	0.04	0.05	0.08	0.08	0.24	0.37	0.47	0.15	1.53	
>12.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.05	0.02	0.00	0.11	

Table 6-1. Joint-Frequency Distribution of Wind: H-Area Tower, 1975-1979 (continued)

Wind speed class (m/sec)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	MNW	TOTAL
ATMOSPHERIC STABILITY CLASS E (SLIGHTLY STABLE)																	
0.0-2.0	0.05	0.10	0.16	0.06	0.09	0.06	0.15	0.08	0.19	0.08	0.12	0.16	0.18	0.14	0.11	0.09	1.81
2.1-4.0	0.26	0.28	0.43	0.27	0.56	0.38	0.67	0.45	0.41	0.27	0.63	0.63	0.58	0.43	0.51	0.38	7.13
4.1-6.0	0.21	0.19	0.37	0.69	0.58	0.55	0.65	0.64	0.65	0.80	0.92	0.74	0.86	0.84	0.57	0.37	9.64
6.1-8.0	0.01	0.01	0.09	0.06	0.03	0.05	0.10	0.03	0.08	0.15	0.14	0.13	0.14	0.08	0.03	0.02	1.16
8.1-12.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.03
>12.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ATMOSPHERIC STABILITY CLASS F (STABLE)																	
0.0-2.0	0.03	0.01	0.03	0.02	0.02	0.03	0.03	0.02	0.03	0.02	0.02	0.01	0.02	0.01	0.00	0.01	0.30
2.1-4.0	0.15	0.08	0.11	0.02	0.10	0.03	0.22	0.09	0.08	0.05	0.09	0.09	0.10	0.12	0.03	0.07	1.44
4.1-6.0	0.13	0.15	0.24	0.30	0.22	0.08	0.23	0.13	0.14	0.06	0.16	0.14	0.16	0.18	0.05	0.05	2.42
6.1-8.0	0.01	0.00	0.03	0.03	0.01	0.01	0.03	0.02	0.02	0.02	0.04	0.00	0.03	0.02	0.00	0.01	0.29
8.1-12.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
>12.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ATMOSPHERIC STABILITY CLASS G (VERY STABLE)																	
0.0-2.0	0.00	0.01	0.01	0.00	0.01	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.14
2.1-4.0	0.00	0.07	0.26	0.01	0.01	0.01	0.10	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.50
4.1-6.0	0.00	0.00	0.07	0.01	0.00	0.01	0.03	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.18
6.1-8.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
8.1-12.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>12.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ALL CLASSES																	
All classes	3.06	2.94	5.08	6.57	7.23	6.31	6.52	5.62	5.77	6.08	6.90	6.76	8.42	9.15	8.59	4.97	4.97

stability windrose statistics were derived by 1-hour averaging of data collected at the 61-meter level of the SRP H-Area meteorological tower during the 5-year period from 1975 to 1979. Stability class was determined from the observed azimuthal and vertical standard deviations (σ_θ and σ_ρ). Values of X/Q and D/Q by compass sector and radial increment for ground-level and elevated releases (using the windspeed measured at a height of 61 meters) are presented in Tables G-2 and G-3, respectively. Flat terrain was assumed; no credit was taken for plume rise induced by momentum or thermal effects.

The meteorological dispersion parameters obtained by running the XQDOQ code are used as input to the NRC GASPAR code (Eckerman et al., 1980), which implements the radiological exposure models of Regulatory Guide 1.109, Revision 1 (NRC, 1977), to estimate doses from atmospheric exposure pathways to the effective whole body and various organs. Dose-conversion factors presented in ICRP-30 were input to the GASPAR code. Population distribution data and milk-, meat-, and vegetable-production distribution data (Table G-4) for the 16 wind-direction sectors are also used as input to GASPAR for calculating the collective dose to the regional population; the term "regional population" refers to those individuals residing within 80 kilometers of the Plant. Population data for the year 2000 are used in this analysis.

Source terms that are input to the GASPAR code and used in the calculation of doses to the maximally exposed individual and the regional population are given in Chapter 4 for each of the cooling alternatives. For facilities on, or within 80 kilometers of the Savannah River Plant, the source terms were taken from supporting documentation referenced in Section G.3.

To calculate collective doses to the regional population within 80 kilometers, compass-sector average values of X/Q and D/Q are used. All atmospheric releases are assumed to occur at the center of the site; the population and agricultural production distributions were centered at the same points. These are reasonable assumptions, given the absence of high population densities near the release points. Collective doses for each year, plus residual doses for the next 100 years from radioactivity released during that same year. The calculated collective dose is referred to as a 100-year environmental dose commitment (EDC) per year of operation. (The EDC concept is discussed later in this appendix.) The collective dose received by the exposed offsite population is calculated by adding the individual dose commitments in the population. Parameters used in calculating the collective dose to the 80-kilometer radius population are summarized in Table G-5.

The maximally exposed individual is assumed to reside continuously at the location on the Plant boundary with the highest potential exposure. This is true for both current operating conditions and operations associated with the implementation of cooling alternatives. For the latter, the reference release points of radioactivity to the atmosphere are at the midpoint between the two cooling alternative locations selected for each reactor (C and K). The shortest distance from each of the reference release points to the Plant boundary was calculated for each of the 16 cardinal directions. This method was used to determine the highest boundary X/Q value, thus identifying the location at which a member of the public would receive the highest dose.

Table G-2. Annual Average Meteorological Dispersion/Deposition Parameters Within 80 Kilometers of SRP Center for Ground-Level Releases

Direction from site	Distance (km)									
	0-2	2-3	3-5	5-6	6-8	8-16	16-32	32-48	48-64	64-80
	ANNUAL AVERAGE X/Q, UNDECAYED AND UNDEPLETED (sec/m ³)									
N	8.254 x 10 ⁻⁷	2.524 x 10 ⁻⁷	1.084 x 10 ⁻⁷	6.403 x 10 ⁻⁸	4.365 x 10 ⁻⁸	2.117 x 10 ⁻⁸	7.908 x 10 ⁻⁹	3.881 x 10 ⁻⁹	2.468 x 10 ⁻⁹	1.769 x 10 ⁻⁹
NNE	7.390 x 10 ⁻⁷	2.245 x 10 ⁻⁷	9.554 x 10 ⁻⁸	5.606 x 10 ⁻⁸	3.802 x 10 ⁻⁸	1.827 x 10 ⁻⁸	6.741 x 10 ⁻⁹	3.291 x 10 ⁻⁹	2.089 x 10 ⁻⁹	1.495 x 10 ⁻⁹
NE	9.494 x 10 ⁻⁷	2.912 x 10 ⁻⁷	1.251 x 10 ⁻⁷	7.389 x 10 ⁻⁸	5.035 x 10 ⁻⁸	2.434 x 10 ⁻⁸	9.042 x 10 ⁻⁹	4.417 x 10 ⁻⁹	2.800 x 10 ⁻⁹	2.002 x 10 ⁻⁹
ENE	9.499 x 10 ⁻⁷	2.902 x 10 ⁻⁷	1.241 x 10 ⁻⁷	7.304 x 10 ⁻⁸	4.966 x 10 ⁻⁸	2.397 x 10 ⁻⁸	8.882 x 10 ⁻⁹	4.330 x 10 ⁻⁹	2.742 x 10 ⁻⁹	1.959 x 10 ⁻⁹
E	1.227 x 10 ⁻⁶	3.746 x 10 ⁻⁷	1.605 x 10 ⁻⁷	9.473 x 10 ⁻⁸	6.453 x 10 ⁻⁸	3.125 x 10 ⁻⁸	1.167 x 10 ⁻⁸	5.747 x 10 ⁻⁹	3.666 x 10 ⁻⁹	2.634 x 10 ⁻⁹
ESE	1.156 x 10 ⁻⁶	3.503 x 10 ⁻⁷	1.486 x 10 ⁻⁷	8.699 x 10 ⁻⁸	5.889 x 10 ⁻⁸	2.824 x 10 ⁻⁸	1.039 x 10 ⁻⁸	5.068 x 10 ⁻⁹	3.216 x 10 ⁻⁹	2.302 x 10 ⁻⁹
SE	9.465 x 10 ⁻⁷	2.866 x 10 ⁻⁷	1.213 x 10 ⁻⁷	7.079 x 10 ⁻⁸	4.781 x 10 ⁻⁸	2.282 x 10 ⁻⁸	8.327 x 10 ⁻⁹	4.029 x 10 ⁻⁹	2.544 x 10 ⁻⁹	1.814 x 10 ⁻⁹
SSE	6.359 x 10 ⁻⁷	1.918 x 10 ⁻⁷	8.127 x 10 ⁻⁸	4.757 x 10 ⁻⁸	3.221 x 10 ⁻⁸	1.548 x 10 ⁻⁸	5.727 x 10 ⁻⁹	2.813 x 10 ⁻⁹	1.793 x 10 ⁻⁹	1.288 x 10 ⁻⁹
S	4.705 x 10 ⁻⁷	1.433 x 10 ⁻⁷	6.196 x 10 ⁻⁸	3.681 x 10 ⁻⁸	2.522 x 10 ⁻⁸	1.236 x 10 ⁻⁸	4.709 x 10 ⁻⁹	2.353 x 10 ⁻⁹	1.515 x 10 ⁻⁹	1.095 x 10 ⁻⁹
SSW	5.057 x 10 ⁻⁷	1.551 x 10 ⁻⁷	6.730 x 10 ⁻⁸	4.009 x 10 ⁻⁸	2.752 x 10 ⁻⁸	1.351 x 10 ⁻⁸	5.156 x 10 ⁻⁹	2.576 x 10 ⁻⁹	1.656 x 10 ⁻⁹	1.197 x 10 ⁻⁹
SW	9.776 x 10 ⁻⁷	3.013 x 10 ⁻⁷	1.313 x 10 ⁻⁷	7.850 x 10 ⁻⁸	5.404 x 10 ⁻⁸	2.666 x 10 ⁻⁸	1.025 x 10 ⁻⁸	5.149 x 10 ⁻⁹	3.322 x 10 ⁻⁹	2.407 x 10 ⁻⁹
WSW	8.207 x 10 ⁻⁷	2.479 x 10 ⁻⁷	1.048 x 10 ⁻⁷	6.127 x 10 ⁻⁸	4.144 x 10 ⁻⁸	1.984 x 10 ⁻⁸	7.307 x 10 ⁻⁹	3.576 x 10 ⁻⁹	2.276 x 10 ⁻⁹	1.632 x 10 ⁻⁹
W	9.536 x 10 ⁻⁷	2.893 x 10 ⁻⁷	1.230 x 10 ⁻⁷	7.213 x 10 ⁻⁸	4.892 x 10 ⁻⁸	2.354 x 10 ⁻⁸	8.718 x 10 ⁻⁹	4.276 x 10 ⁻⁹	2.722 x 10 ⁻⁹	1.953 x 10 ⁻⁹
WNW	7.890 x 10 ⁻⁷	2.378 x 10 ⁻⁷	1.007 x 10 ⁻⁷	5.889 x 10 ⁻⁸	3.987 x 10 ⁻⁸	1.917 x 10 ⁻⁸	7.106 x 10 ⁻⁹	3.494 x 10 ⁻⁹	2.229 x 10 ⁻⁹	1.603 x 10 ⁻⁹
NW	1.103 x 10 ⁻⁶	3.407 x 10 ⁻⁷	1.484 x 10 ⁻⁷	8.866 x 10 ⁻⁸	6.096 x 10 ⁻⁸	2.997 x 10 ⁻⁸	1.144 x 10 ⁻⁸	5.699 x 10 ⁻⁹	3.657 x 10 ⁻⁹	2.638 x 10 ⁻⁹
NNW	7.672 x 10 ⁻⁷	2.342 x 10 ⁻⁷	1.003 x 10 ⁻⁷	5.907 x 10 ⁻⁸	4.019 x 10 ⁻⁸	1.939 x 10 ⁻⁸	7.193 x 10 ⁻⁹	3.517 x 10 ⁻⁹	2.233 x 10 ⁻⁹	1.598 x 10 ⁻⁹
	ANNUAL AVERAGE X/Q, DECAYED AND UNDEPLETED (sec/m ³)									
N	8.235 x 10 ⁻⁷	2.513 x 10 ⁻⁷	1.076 x 10 ⁻⁷	6.334 x 10 ⁻⁸	4.304 x 10 ⁻⁸	2.070 x 10 ⁻⁸	7.557 x 10 ⁻⁹	3.592 x 10 ⁻⁹	2.214 x 10 ⁻⁹	1.538 x 10 ⁻⁹
NNE	7.375 x 10 ⁻⁷	2.236 x 10 ⁻⁷	9.490 x 10 ⁻⁸	5.553 x 10 ⁻⁸	3.756 x 10 ⁻⁸	1.791 x 10 ⁻⁸	6.477 x 10 ⁻⁹	3.073 x 10 ⁻⁹	1.896 x 10 ⁻⁹	1.320 x 10 ⁻⁹
NE	9.476 x 10 ⁻⁷	2.901 x 10 ⁻⁷	1.243 x 10 ⁻⁷	7.322 x 10 ⁻⁸	4.976 x 10 ⁻⁸	2.388 x 10 ⁻⁸	8.701 x 10 ⁻⁹	4.135 x 10 ⁻⁹	2.552 x 10 ⁻⁹	1.776 x 10 ⁻⁹
ENE	9.479 x 10 ⁻⁷	2.890 x 10 ⁻⁷	1.232 x 10 ⁻⁷	7.231 x 10 ⁻⁸	4.902 x 10 ⁻⁸	2.347 x 10 ⁻⁸	8.514 x 10 ⁻⁹	4.028 x 10 ⁻⁹	2.477 x 10 ⁻⁹	1.719 x 10 ⁻⁹
E	1.224 x 10 ⁻⁶	3.729 x 10 ⁻⁷	1.593 x 10 ⁻⁷	9.367 x 10 ⁻⁸	6.361 x 10 ⁻⁸	3.052 x 10 ⁻⁸	1.113 x 10 ⁻⁸	5.297 x 10 ⁻⁹	3.268 x 10 ⁻⁹	2.271 x 10 ⁻⁹
ESE	1.154 x 10 ⁻⁶	3.488 x 10 ⁻⁷	1.476 x 10 ⁻⁷	8.613 x 10 ⁻⁸	5.815 x 10 ⁻⁸	2.766 x 10 ⁻⁸	9.970 x 10 ⁻⁹	4.721 x 10 ⁻⁹	2.909 x 10 ⁻⁹	2.023 x 10 ⁻⁹
SE	9.447 x 10 ⁻⁷	2.856 x 10 ⁻⁷	1.205 x 10 ⁻⁷	7.014 x 10 ⁻⁸	4.725 x 10 ⁻⁸	2.238 x 10 ⁻⁸	8.005 x 10 ⁻⁹	3.764 x 10 ⁻⁹	2.310 x 10 ⁻⁹	1.602 x 10 ⁻⁹

Table 6.2. Annual Average Meteorological Dispersion/Deposition Parameters Within 80 Kilometers of SRP Center for Ground-Level Releases (continued)

Direction from site	Distance (km)									
	0-2	2-3	3-5	5-6	6-8	8-16	16-32	32-48	48-64	64-80
	ANNUAL AVERAGE X/Q, DECAYED AND UNDEPLETED (sec/m ³) (continued)									
SSE	6.345 x 10 ⁻⁷	1.910 x 10 ⁻⁷	8.068 x 10 ⁻⁸	4.708 x 10 ⁻⁸	3.179 x 10 ⁻⁸	1.515 x 10 ⁻⁸	5.484 x 10 ⁻⁹	2.611 x 10 ⁻⁹	1.615 x 10 ⁻⁹	1.125 x 10 ⁻⁹
S	4.694 x 10 ⁻⁷	1.427 x 10 ⁻⁷	6.148 x 10 ⁻⁸	3.641 x 10 ⁻⁸	2.487 x 10 ⁻⁸	1.208 x 10 ⁻⁸	4.497 x 10 ⁻⁹	2.175 x 10 ⁻⁹	1.355 x 10 ⁻⁹	9.491 x 10 ⁻¹⁰
SSW	5.045 x 10 ⁻⁷	1.544 x 10 ⁻⁷	6.677 x 10 ⁻⁸	3.965 x 10 ⁻⁸	2.713 x 10 ⁻⁸	1.321 x 10 ⁻⁸	4.925 x 10 ⁻⁹	2.382 x 10 ⁻⁹	1.484 x 10 ⁻⁹	1.039 x 10 ⁻⁹
SW	9.755 x 10 ⁻⁷	2.999 x 10 ⁻⁷	1.303 x 10 ⁻⁷	7.768 x 10 ⁻⁸	5.332 x 10 ⁻⁸	2.609 x 10 ⁻⁸	9.816 x 10 ⁻⁹	4.786 x 10 ⁻⁹	2.999 x 10 ⁻⁹	2.110 x 10 ⁻⁹
WSW	8.191 x 10 ⁻⁷	2.470 x 10 ⁻⁷	1.042 x 10 ⁻⁷	6.072 x 10 ⁻⁸	4.096 x 10 ⁻⁸	1.948 x 10 ⁻⁸	7.038 x 10 ⁻⁹	3.355 x 10 ⁻⁹	2.080 x 10 ⁻⁹	1.454 x 10 ⁻⁹
W	9.518 x 10 ⁻⁷	2.882 x 10 ⁻⁷	1.221 x 10 ⁻⁷	7.145 x 10 ⁻⁸	4.833 x 10 ⁻⁸	2.308 x 10 ⁻⁸	8.379 x 10 ⁻⁹	3.996 x 10 ⁻⁹	2.475 x 10 ⁻⁹	1.727 x 10 ⁻⁹
WNW	7.874 x 10 ⁻⁷	2.368 x 10 ⁻⁷	9.997 x 10 ⁻⁸	5.832 x 10 ⁻⁸	3.937 x 10 ⁻⁸	1.879 x 10 ⁻⁸	6.819 x 10 ⁻⁹	3.255 x 10 ⁻⁹	2.017 x 10 ⁻⁹	1.408 x 10 ⁻⁹
W	1.101 x 10 ⁻⁶	3.392 x 10 ⁻⁷	1.474 x 10 ⁻⁷	8.774 x 10 ⁻⁸	6.015 x 10 ⁻⁸	2.932 x 10 ⁻⁸	1.094 x 10 ⁻⁸	5.287 x 10 ⁻⁹	3.291 x 10 ⁻⁹	2.303 x 10 ⁻⁹
WNW	7.657 x 10 ⁻⁷	2.332 x 10 ⁻⁷	9.959 x 10 ⁻⁸	5.851 x 10 ⁻⁸	3.969 x 10 ⁻⁸	1.901 x 10 ⁻⁸	6.910 x 10 ⁻⁹	3.283 x 10 ⁻⁹	2.027 x 10 ⁻⁹	1.411 x 10 ⁻⁹
	ANNUAL AVERAGE X/Q, DECAYED AND DEPLETED (sec/m ³)									
N	7.396 x 10 ⁻⁷	2.154 x 10 ⁻⁷	8.784 x 10 ⁻⁸	4.988 x 10 ⁻⁸	3.290 x 10 ⁻⁸	1.496 x 10 ⁻⁸	4.918 x 10 ⁻⁹	2.112 x 10 ⁻⁹	1.212 x 10 ⁻⁹	7.949 x 10 ⁻¹⁰
NNE	6.623 x 10 ⁻⁷	1.916 x 10 ⁻⁷	7.745 x 10 ⁻⁸	4.369 x 10 ⁻⁸	2.868 x 10 ⁻⁸	1.293 x 10 ⁻⁸	4.200 x 10 ⁻⁹	1.795 x 10 ⁻⁹	1.029 x 10 ⁻⁹	6.749 x 10 ⁻¹⁰
NE	8.508 x 10 ⁻⁷	2.465 x 10 ⁻⁷	1.014 x 10 ⁻⁷	5.759 x 10 ⁻⁸	3.798 x 10 ⁻⁸	1.723 x 10 ⁻⁸	5.635 x 10 ⁻⁹	2.411 x 10 ⁻⁹	1.381 x 10 ⁻⁹	9.050 x 10 ⁻¹⁰
ENE	8.512 x 10 ⁻⁷	2.476 x 10 ⁻⁷	1.006 x 10 ⁻⁷	5.692 x 10 ⁻⁸	3.744 x 10 ⁻⁸	1.695 x 10 ⁻⁸	5.530 x 10 ⁻⁹	2.360 x 10 ⁻⁹	1.349 x 10 ⁻⁹	8.827 x 10 ⁻¹⁰
E	1.100 x 10 ⁻⁶	3.196 x 10 ⁻⁷	1.301 x 10 ⁻⁷	7.379 x 10 ⁻⁸	4.864 x 10 ⁻⁸	2.208 x 10 ⁻⁸	7.253 x 10 ⁻⁹	3.124 x 10 ⁻⁹	1.796 x 10 ⁻⁹	1.181 x 10 ⁻⁹
ESE	1.036 x 10 ⁻⁶	2.990 x 10 ⁻⁷	1.204 x 10 ⁻⁷	6.779 x 10 ⁻⁸	4.441 x 10 ⁻⁸	1.997 x 10 ⁻⁸	6.472 x 10 ⁻⁹	2.763 x 10 ⁻⁹	1.583 x 10 ⁻⁹	1.038 x 10 ⁻⁹
SE	8.483 x 10 ⁻⁷	2.447 x 10 ⁻⁷	9.830 x 10 ⁻⁸	5.518 x 10 ⁻⁸	3.607 x 10 ⁻⁸	1.615 x 10 ⁻⁸	5.190 x 10 ⁻⁹	2.199 x 10 ⁻⁹	1.253 x 10 ⁻⁹	8.190 x 10 ⁻¹⁰
SSE	5.699 x 10 ⁻⁷	1.637 x 10 ⁻⁷	6.587 x 10 ⁻⁸	3.706 x 10 ⁻⁸	2.429 x 10 ⁻⁸	1.094 x 10 ⁻⁸	3.564 x 10 ⁻⁹	1.532 x 10 ⁻⁹	8.813 x 10 ⁻¹⁰	5.798 x 10 ⁻¹⁰
S	4.216 x 10 ⁻⁷	1.223 x 10 ⁻⁷	5.021 x 10 ⁻⁸	2.868 x 10 ⁻⁸	1.901 x 10 ⁻⁸	8.734 x 10 ⁻⁹	2.926 x 10 ⁻⁹	1.280 x 10 ⁻⁹	7.429 x 10 ⁻¹⁰	4.918 x 10 ⁻¹⁰
SSW	4.532 x 10 ⁻⁷	1.323 x 10 ⁻⁷	5.453 x 10 ⁻⁸	3.123 x 10 ⁻⁸	2.074 x 10 ⁻⁸	9.548 x 10 ⁻⁹	3.205 x 10 ⁻⁹	1.401 x 10 ⁻⁹	8.128 x 10 ⁻¹⁰	5.378 x 10 ⁻¹⁰
SW	8.761 x 10 ⁻⁷	2.570 x 10 ⁻⁷	1.064 x 10 ⁻⁷	6.115 x 10 ⁻⁸	4.074 x 10 ⁻⁸	1.884 x 10 ⁻⁸	6.374 x 10 ⁻⁹	2.805 x 10 ⁻⁹	1.634 x 10 ⁻⁹	1.084 x 10 ⁻⁹
WSW	7.355 x 10 ⁻⁷	2.116 x 10 ⁻⁷	8.499 x 10 ⁻⁸	4.776 x 10 ⁻⁸	3.126 x 10 ⁻⁸	1.405 x 10 ⁻⁸	4.555 x 10 ⁻⁹	1.953 x 10 ⁻⁹	1.123 x 10 ⁻⁹	7.387 x 10 ⁻¹⁰
W	8.547 x 10 ⁻⁷	2.469 x 10 ⁻⁷	9.967 x 10 ⁻⁸	5.621 x 10 ⁻⁸	3.690 x 10 ⁻⁸	1.665 x 10 ⁻⁸	5.431 x 10 ⁻⁹	2.333 x 10 ⁻⁹	1.341 x 10 ⁻⁹	8.821 x 10 ⁻¹⁰
WNW	7.071 x 10 ⁻⁷	2.030 x 10 ⁻⁷	8.159 x 10 ⁻⁸	4.589 x 10 ⁻⁸	3.007 x 10 ⁻⁸	1.356 x 10 ⁻⁸	4.425 x 10 ⁻⁹	1.905 x 10 ⁻⁹	1.097 x 10 ⁻⁹	7.225 x 10 ⁻¹⁰
W	9.889 x 10 ⁻⁷	2.907 x 10 ⁻⁷	1.203 x 10 ⁻⁷	6.907 x 10 ⁻⁸	4.596 x 10 ⁻⁸	2.118 x 10 ⁻⁸	7.111 x 10 ⁻⁹	3.103 x 10 ⁻⁹	1.797 x 10 ⁻⁹	1.187 x 10 ⁻⁹
WNW	6.876 x 10 ⁻⁷	1.999 x 10 ⁻⁷	8.127 x 10 ⁻⁸	4.604 x 10 ⁻⁸	3.031 x 10 ⁻⁸	1.372 x 10 ⁻⁸	4.481 x 10 ⁻⁹	1.919 x 10 ⁻⁹	1.100 x 10 ⁻⁹	7.215 x 10 ⁻¹⁰

Table G-2. Annual Average Meteorological Dispersion/Deposition Parameters Within 80 Kilometers of SRP Center for Ground-Level Releases (continued)

Direction from site 64-80	Distance (km)										ANNUAL AVERAGE D/Q (m ⁻²)
	0-2	2-3	3-5	5-6	6-8	8-16	16-32	32-48	48-64	64-80	
N	6.024 x 10 ⁻⁹	1.861 x 10 ⁻⁹	7.406 x 10 ⁻¹⁰	4.047 x 10 ⁻¹⁰	2.572 x 10 ⁻¹⁰	1.105 x 10 ⁻¹⁰	3.426 x 10 ⁻¹¹	1.358 x 10 ⁻¹¹	7.251 x 10 ⁻¹²	4.488 x 10 ⁻¹²	
NNE	6.351 x 10 ⁻⁹	1.962 x 10 ⁻⁹	7.808 x 10 ⁻¹⁰	4.267 x 10 ⁻¹⁰	2.712 x 10 ⁻¹⁰	1.165 x 10 ⁻¹⁰	3.612 x 10 ⁻¹¹	1.432 x 10 ⁻¹¹	7.645 x 10 ⁻¹²	4.732 x 10 ⁻¹²	
NE	7.209 x 10 ⁻⁹	2.227 x 10 ⁻⁹	8.863 x 10 ⁻¹⁰	4.843 x 10 ⁻¹⁰	3.078 x 10 ⁻¹⁰	1.322 x 10 ⁻¹⁰	4.100 x 10 ⁻¹¹	1.625 x 10 ⁻¹¹	8.678 x 10 ⁻¹²	5.371 x 10 ⁻¹²	
ENE	7.064 x 10 ⁻⁹	2.182 x 10 ⁻⁹	8.684 x 10 ⁻¹⁰	4.746 x 10 ⁻¹⁰	3.016 x 10 ⁻¹⁰	1.296 x 10 ⁻¹⁰	4.017 x 10 ⁻¹¹	1.592 x 10 ⁻¹¹	8.503 x 10 ⁻¹²	5.263 x 10 ⁻¹²	
E	8.791 x 10 ⁻⁹	2.716 x 10 ⁻⁹	1.081 x 10 ⁻⁹	5.906 x 10 ⁻¹⁰	3.754 x 10 ⁻¹⁰	1.612 x 10 ⁻¹⁰	5.000 x 10 ⁻¹¹	1.982 x 10 ⁻¹¹	1.058 x 10 ⁻¹¹	6.550 x 10 ⁻¹²	
ESE	9.561 x 10 ⁻⁹	2.954 x 10 ⁻⁹	1.175 x 10 ⁻⁹	6.423 x 10 ⁻¹⁰	4.083 x 10 ⁻¹⁰	1.754 x 10 ⁻¹⁰	5.438 x 10 ⁻¹¹	2.155 x 10 ⁻¹¹	1.151 x 10 ⁻¹¹	7.124 x 10 ⁻¹²	
SE	8.976 x 10 ⁻⁹	2.773 x 10 ⁻⁹	1.104 x 10 ⁻⁹	6.030 x 10 ⁻¹⁰	3.833 x 10 ⁻¹⁰	1.646 x 10 ⁻¹⁰	5.105 x 10 ⁻¹¹	2.023 x 10 ⁻¹¹	1.080 x 10 ⁻¹¹	6.688 x 10 ⁻¹²	
SSE	5.195 x 10 ⁻⁹	1.605 x 10 ⁻⁹	6.387 x 10 ⁻¹⁰	3.490 x 10 ⁻¹⁰	2.218 x 10 ⁻¹⁰	9.528 x 10 ⁻¹¹	2.955 x 10 ⁻¹¹	1.171 x 10 ⁻¹¹	6.254 x 10 ⁻¹²	3.871 x 10 ⁻¹²	
S	3.199 x 10 ⁻⁹	9.884 x 10 ⁻¹⁰	3.933 x 10 ⁻¹⁰	2.149 x 10 ⁻¹⁰	1.366 x 10 ⁻¹⁰	5.868 x 10 ⁻¹¹	1.820 x 10 ⁻¹¹	7.212 x 10 ⁻¹²	3.851 x 10 ⁻¹²	2.384 x 10 ⁻¹²	
SSW	3.072 x 10 ⁻⁹	9.491 x 10 ⁻¹⁰	3.777 x 10 ⁻¹⁰	2.064 x 10 ⁻¹⁰	1.312 x 10 ⁻¹⁰	5.634 x 10 ⁻¹¹	1.747 x 10 ⁻¹¹	6.925 x 10 ⁻¹²	3.698 x 10 ⁻¹²	2.289 x 10 ⁻¹²	
SW	5.308 x 10 ⁻⁹	1.640 x 10 ⁻⁹	6.525 x 10 ⁻¹⁰	3.566 x 10 ⁻¹⁰	2.266 x 10 ⁻¹⁰	9.735 x 10 ⁻¹¹	3.019 x 10 ⁻¹¹	1.196 x 10 ⁻¹¹	6.389 x 10 ⁻¹²	3.955 x 10 ⁻¹²	
WSW	6.867 x 10 ⁻⁹	2.122 x 10 ⁻⁹	8.443 x 10 ⁻¹⁰	4.614 x 10 ⁻¹⁰	2.932 x 10 ⁻¹⁰	1.260 x 10 ⁻¹⁰	3.906 x 10 ⁻¹¹	1.548 x 10 ⁻¹¹	8.267 x 10 ⁻¹²	5.117 x 10 ⁻¹²	
W	7.555 x 10 ⁻⁹	2.334 x 10 ⁻⁹	9.288 x 10 ⁻¹⁰	5.075 x 10 ⁻¹⁰	3.226 x 10 ⁻¹⁰	1.386 x 10 ⁻¹⁰	4.297 x 10 ⁻¹¹	1.703 x 10 ⁻¹¹	9.094 x 10 ⁻¹²	5.629 x 10 ⁻¹²	
WNW	6.595 x 10 ⁻⁹	2.037 x 10 ⁻⁹	8.108 x 10 ⁻¹⁰	4.430 x 10 ⁻¹⁰	2.816 x 10 ⁻¹⁰	1.210 x 10 ⁻¹⁰	3.751 x 10 ⁻¹¹	1.487 x 10 ⁻¹¹	7.938 x 10 ⁻¹²	4.914 x 10 ⁻¹²	
NW	6.813 x 10 ⁻⁹	2.105 x 10 ⁻⁹	8.376 x 10 ⁻¹⁰	4.577 x 10 ⁻¹⁰	2.909 x 10 ⁻¹⁰	1.250 x 10 ⁻¹⁰	3.875 x 10 ⁻¹¹	1.536 x 10 ⁻¹¹	8.201 x 10 ⁻¹²	5.076 x 10 ⁻¹²	
NWN	5.875 x 10 ⁻⁹	1.815 x 10 ⁻⁹	7.223 x 10 ⁻¹⁰	3.947 x 10 ⁻¹⁰	2.509 x 10 ⁻¹⁰	1.078 x 10 ⁻¹⁰	3.341 x 10 ⁻¹¹	1.324 x 10 ⁻¹¹	7.072 x 10 ⁻¹²	4.377 x 10 ⁻¹²	

Table G-3. Annual Average Meteorological Dispersion/Deposition Parameters Within 80 Kilometers of SRP Center for Elevated Releases

Direction from site	Distance (km)									
	0-2	2-3	3-5	5-6	6-8	8-16	16-32	32-48	48-64	64-80
	ANNUAL AVERAGE X/Q, UNDECAYED AND UNDEPLETED (sec/m ³)									
N	1.657 x 10 ⁻⁷	9.830 x 10 ⁻⁸	6.035 x 10 ⁻⁸	4.110 x 10 ⁻⁸	3.030 x 10 ⁻⁸	1.617 x 10 ⁻⁸	6.688 x 10 ⁻⁹	3.455 x 10 ⁻⁹	2.246 x 10 ⁻⁹	1.630 x 10 ⁻⁹
NNE	1.715 x 10 ⁻⁷	9.824 x 10 ⁻⁸	5.792 x 10 ⁻⁸	3.855 x 10 ⁻⁸	2.800 x 10 ⁻⁸	1.461 x 10 ⁻⁸	5.878 x 10 ⁻⁹	2.997 x 10 ⁻⁹	1.938 x 10 ⁻⁹	1.402 x 10 ⁻⁹
NE	1.851 x 10 ⁻⁷	1.140 x 10 ⁻⁷	7.034 x 10 ⁻⁸	4.786 x 10 ⁻⁸	3.523 x 10 ⁻⁸	1.870 x 10 ⁻⁸	7.660 x 10 ⁻⁹	3.931 x 10 ⁻⁹	2.546 x 10 ⁻⁹	1.843 x 10 ⁻⁹
ENE	1.979 x 10 ⁻⁷	1.186 x 10 ⁻⁷	7.223 x 10 ⁻⁸	4.881 x 10 ⁻⁸	3.578 x 10 ⁻⁸	1.891 x 10 ⁻⁸	7.703 x 10 ⁻⁹	3.936 x 10 ⁻⁹	2.542 x 10 ⁻⁹	1.837 x 10 ⁻⁹
E	2.592 x 10 ⁻⁷	1.492 x 10 ⁻⁷	8.848 x 10 ⁻⁸	5.922 x 10 ⁻⁸	4.323 x 10 ⁻⁸	2.278 x 10 ⁻⁸	9.331 x 10 ⁻⁸	4.829 x 10 ⁻⁹	3.150 x 10 ⁻⁹	2.294 x 10 ⁻⁹
ESE	2.821 x 10 ⁻⁷	1.583 x 10 ⁻⁷	9.177 x 10 ⁻⁸	6.061 x 10 ⁻⁸	4.382 x 10 ⁻⁸	2.274 x 10 ⁻⁸	9.098 x 10 ⁻⁸	4.628 x 10 ⁻⁹	2.990 x 10 ⁻⁹	2.162 x 10 ⁻⁹
SE	2.365 x 10 ⁻⁷	1.357 x 10 ⁻⁷	7.860 x 10 ⁻⁸	5.161 x 10 ⁻⁸	3.711 x 10 ⁻⁸	1.904 x 10 ⁻⁸	7.490 x 10 ⁻⁹	3.757 x 10 ⁻⁹	2.407 x 10 ⁻⁹	1.731 x 10 ⁻⁹
SSE	1.609 x 10 ⁻⁷	8.715 x 10 ⁻⁸	5.018 x 10 ⁻⁸	3.311 x 10 ⁻⁸	2.394 x 10 ⁻⁸	1.246 x 10 ⁻⁸	5.017 x 10 ⁻⁹	2.571 x 10 ⁻⁹	1.669 x 10 ⁻⁹	1.212 x 10 ⁻⁹
S	9.942 x 10 ⁻⁸	5.287 x 10 ⁻⁸	3.174 x 10 ⁻⁸	2.172 x 10 ⁻⁸	1.615 x 10 ⁻⁸	8.804 x 10 ⁻⁸	3.772 x 10 ⁻⁹	2.007 x 10 ⁻⁹	1.329 x 10 ⁻⁹	9.773 x 10 ⁻¹⁰
SSW	9.513 x 10 ⁻⁸	5.374 x 10 ⁻⁸	3.282 x 10 ⁻⁸	2.247 x 10 ⁻⁸	1.669 x 10 ⁻⁸	9.063 x 10 ⁻⁸	3.867 x 10 ⁻⁹	2.055 x 10 ⁻⁹	1.360 x 10 ⁻⁹	1.000 x 10 ⁻⁹
SW	1.629 x 10 ⁻⁷	9.250 x 10 ⁻⁸	5.601 x 10 ⁻⁸	3.832 x 10 ⁻⁸	2.850 x 10 ⁻⁸	1.560 x 10 ⁻⁸	6.776 x 10 ⁻⁹	3.661 x 10 ⁻⁹	2.449 x 10 ⁻⁹	1.815 x 10 ⁻⁹
WSW	2.038 x 10 ⁻⁷	1.107 x 10 ⁻⁷	6.305 x 10 ⁻⁸	4.144 x 10 ⁻⁸	2.991 x 10 ⁻⁸	1.553 x 10 ⁻⁸	6.242 x 10 ⁻⁹	3.200 x 10 ⁻⁹	2.078 x 10 ⁻⁹	1.508 x 10 ⁻⁹
W	2.212 x 10 ⁻⁷	1.229 x 10 ⁻⁷	7.136 x 10 ⁻⁸	4.735 x 10 ⁻⁸	3.438 x 10 ⁻⁸	1.800 x 10 ⁻⁸	7.305 x 10 ⁻⁹	3.760 x 10 ⁻⁹	2.445 x 10 ⁻⁹	1.777 x 10 ⁻⁹
WNW	2.032 x 10 ⁻⁷	1.085 x 10 ⁻⁷	6.167 x 10 ⁻⁸	4.047 x 10 ⁻⁸	2.918 x 10 ⁻⁸	1.515 x 10 ⁻⁸	6.103 x 10 ⁻⁹	3.132 x 10 ⁻⁹	2.036 x 10 ⁻⁹	1.480 x 10 ⁻⁹
NW	1.796 x 10 ⁻⁷	1.080 x 10 ⁻⁷	6.754 x 10 ⁻⁸	4.674 x 10 ⁻⁸	3.492 x 10 ⁻⁸	1.911 x 10 ⁻⁸	8.213 x 10 ⁻⁸	4.375 x 10 ⁻⁹	2.897 x 10 ⁻⁹	2.131 x 10 ⁻⁹
NNW	1.648 x 10 ⁻⁷	9.680 x 10 ⁻⁸	5.825 x 10 ⁻⁸	3.922 x 10 ⁻⁸	2.870 x 10 ⁻⁸	1.513 x 10 ⁻⁸	6.167 x 10 ⁻⁹	3.163 x 10 ⁻⁹	2.049 x 10 ⁻⁹	1.485 x 10 ⁻⁹
	ANNUAL AVERAGE X/Q, DECAYED AND UNDEPLETED (sec/m ³)									
N	1.653 x 10 ⁻⁷	9.782 x 10 ⁻⁸	5.987 x 10 ⁻⁸	4.064 x 10 ⁻⁸	2.987 x 10 ⁻⁸	1.580 x 10 ⁻⁸	6.384 x 10 ⁻⁹	3.194 x 10 ⁻⁹	2.012 x 10 ⁻⁹	1.416 x 10 ⁻⁹
NNE	1.711 x 10 ⁻⁷	9.781 x 10 ⁻⁸	5.751 x 10 ⁻⁸	3.818 x 10 ⁻⁸	2.765 x 10 ⁻⁸	1.431 x 10 ⁻⁸	5.644 x 10 ⁻⁹	2.797 x 10 ⁻⁹	1.758 x 10 ⁻⁹	1.237 x 10 ⁻⁹
NE	1.846 x 10 ⁻⁷	1.135 x 10 ⁻⁷	6.986 x 10 ⁻⁸	4.741 x 10 ⁻⁸	3.481 x 10 ⁻⁸	1.833 x 10 ⁻⁸	7.366 x 10 ⁻⁹	3.679 x 10 ⁻⁹	2.319 x 10 ⁻⁹	1.634 x 10 ⁻⁹
ENE	1.974 x 10 ⁻⁷	1.181 x 10 ⁻⁷	7.168 x 10 ⁻⁸	4.831 x 10 ⁻⁸	3.530 x 10 ⁻⁸	1.850 x 10 ⁻⁸	7.377 x 10 ⁻⁹	3.658 x 10 ⁻⁹	2.294 x 10 ⁻⁹	1.610 x 10 ⁻⁹
E	2.586 x 10 ⁻⁷	1.484 x 10 ⁻⁷	8.779 x 10 ⁻⁸	5.858 x 10 ⁻⁸	4.263 x 10 ⁻⁸	2.227 x 10 ⁻⁸	8.914 x 10 ⁻⁹	4.466 x 10 ⁻⁹	2.822 x 10 ⁻⁹	1.990 x 10 ⁻⁹
ESE	2.813 x 10 ⁻⁷	1.575 x 10 ⁻⁷	9.108 x 10 ⁻⁸	5.998 x 10 ⁻⁸	4.324 x 10 ⁻⁸	2.225 x 10 ⁻⁸	8.716 x 10 ⁻⁹	4.304 x 10 ⁻⁹	2.700 x 10 ⁻⁹	1.896 x 10 ⁻⁹
SE	2.359 x 10 ⁻⁷	1.351 x 10 ⁻⁷	7.808 x 10 ⁻⁸	5.113 x 10 ⁻⁸	3.666 x 10 ⁻⁸	1.868 x 10 ⁻⁸	7.199 x 10 ⁻⁹	3.511 x 10 ⁻⁹	2.187 x 10 ⁻⁹	1.529 x 10 ⁻⁹

Table G-3. Annual Average Meteorological Dispersion/Deposition Parameters Within 80 Kilometers of SRP Center for Elevated Releases (continued)

Direction from site	Distance (km)									
	0-2	2-3	3-5	5-6	6-8	8-16	16-32	32-48	48-64	64-80
	ANNUAL AVERAGE X/Q, DECAYED AND UNDEPLETED (sec/m ³) (continued)									
SSE	1.604 x 10 ⁻⁷	8.673 x 10 ⁻⁸	4.979 x 10 ⁻⁸	3.276 x 10 ⁻⁸	2.362 x 10 ⁻⁸	1.218 x 10 ⁻⁸	4.799 x 10 ⁻⁹	2.384 x 10 ⁻⁹	1.501 x 10 ⁻⁹	1.057 x 10 ⁻⁹
S	9.914 x 10 ⁻⁸	5.259 x 10 ⁻⁸	3.148 x 10 ⁻⁸	2.147 x 10 ⁻⁸	1.591 x 10 ⁻⁸	8.596 x 10 ⁻⁹	3.597 x 10 ⁻⁹	1.853 x 10 ⁻⁹	1.188 x 10 ⁻⁹	8.459 x 10 ⁻¹⁰
SSW	9.486 x 10 ⁻⁸	5.345 x 10 ⁻⁸	3.254 x 10 ⁻⁸	2.221 x 10 ⁻⁸	1.643 x 10 ⁻⁸	8.841 x 10 ⁻⁹	3.683 x 10 ⁻⁹	1.894 x 10 ⁻⁹	1.213 x 10 ⁻⁹	8.643 x 10 ⁻¹⁰
SW	1.624 x 10 ⁻⁷	9.201 x 10 ⁻⁸	5.553 x 10 ⁻⁸	3.787 x 10 ⁻⁸	2.807 x 10 ⁻⁸	1.523 x 10 ⁻⁸	6.462 x 10 ⁻⁹	3.384 x 10 ⁻⁹	2.195 x 10 ⁻⁹	1.578 x 10 ⁻⁹
WSW	2.033 x 10 ⁻⁷	1.103 x 10 ⁻⁷	6.261 x 10 ⁻⁸	4.105 x 10 ⁻⁸	2.955 x 10 ⁻⁸	1.523 x 10 ⁻⁸	6.004 x 10 ⁻⁹	2.997 x 10 ⁻⁹	1.895 x 10 ⁻⁹	1.340 x 10 ⁻⁹
W	2.207 x 10 ⁻⁷	1.224 x 10 ⁻⁷	7.087 x 10 ⁻⁸	4.690 x 10 ⁻⁸	3.397 x 10 ⁻⁸	1.765 x 10 ⁻⁸	7.021 x 10 ⁻⁹	3.515 x 10 ⁻⁹	2.225 x 10 ⁻⁹	1.573 x 10 ⁻⁹
WNW	2.027 x 10 ⁻⁷	1.080 x 10 ⁻⁷	6.124 x 10 ⁻⁸	4.008 x 10 ⁻⁸	2.882 x 10 ⁻⁸	1.485 x 10 ⁻⁸	5.856 x 10 ⁻⁹	2.918 x 10 ⁻⁹	1.843 x 10 ⁻⁹	1.301 x 10 ⁻⁹
NW	1.791 x 10 ⁻⁷	1.075 x 10 ⁻⁷	6.703 x 10 ⁻⁸	4.625 x 10 ⁻⁸	3.445 x 10 ⁻⁸	1.869 x 10 ⁻⁸	7.863 x 10 ⁻⁹	4.064 x 10 ⁻⁹	2.612 x 10 ⁻⁹	1.865 x 10 ⁻⁹
N	1.644 x 10 ⁻⁷	9.637 x 10 ⁻⁸	5.783 x 10 ⁻⁸	3.883 x 10 ⁻⁸	2.833 x 10 ⁻⁸	1.482 x 10 ⁻⁸	5.917 x 10 ⁻⁹	2.949 x 10 ⁻⁹	1.857 x 10 ⁻⁹	1.308 x 10 ⁻⁹
	ANNUAL AVERAGE X/Q, DECAYED AND DEPLETED (sec/m ³)									
N	1.617 x 10 ⁻⁷	9.484 x 10 ⁻⁸	5.757 x 10 ⁻⁸	3.886 x 10 ⁻⁸	2.845 x 10 ⁻⁸	1.493 x 10 ⁻⁸	5.959 x 10 ⁻⁹	2.962 x 10 ⁻⁹	1.857 x 10 ⁻⁹	1.294 x 10 ⁻⁹
NNE	1.673 x 10 ⁻⁷	9.451 x 10 ⁻⁸	5.490 x 10 ⁻⁸	3.613 x 10 ⁻⁸	2.600 x 10 ⁻⁸	1.328 x 10 ⁻⁸	5.120 x 10 ⁻⁹	2.494 x 10 ⁻⁹	1.546 x 10 ⁻⁹	1.069 x 10 ⁻⁹
NE	1.807 x 10 ⁻⁷	1.100 x 10 ⁻⁷	6.711 x 10 ⁻⁸	4.524 x 10 ⁻⁸	3.305 x 10 ⁻⁸	1.724 x 10 ⁻⁸	6.824 x 10 ⁻⁹	3.375 x 10 ⁻⁹	2.112 x 10 ⁻⁹	1.472 x 10 ⁻⁹
ENE	1.931 x 10 ⁻⁷	1.145 x 10 ⁻⁷	6.882 x 10 ⁻⁸	4.606 x 10 ⁻⁸	3.349 x 10 ⁻⁸	1.738 x 10 ⁻⁸	6.820 x 10 ⁻⁹	3.348 x 10 ⁻⁹	2.084 x 10 ⁻⁹	1.446 x 10 ⁻⁹
E	2.528 x 10 ⁻⁷	1.435 x 10 ⁻⁷	8.396 x 10 ⁻⁸	5.561 x 10 ⁻⁸	4.024 x 10 ⁻⁸	2.080 x 10 ⁻⁸	8.195 x 10 ⁻⁹	4.068 x 10 ⁻⁹	2.554 x 10 ⁻⁹	1.783 x 10 ⁻⁹
ESE	2.750 x 10 ⁻⁷	1.520 x 10 ⁻⁷	8.673 x 10 ⁻⁸	5.655 x 10 ⁻⁸	4.046 x 10 ⁻⁸	2.051 x 10 ⁻⁸	7.833 x 10 ⁻⁹	3.791 x 10 ⁻⁹	2.342 x 10 ⁻⁹	1.615 x 10 ⁻⁹
SE	2.308 x 10 ⁻⁷	1.304 x 10 ⁻⁷	7.426 x 10 ⁻⁸	4.809 x 10 ⁻⁸	3.418 x 10 ⁻⁸	1.711 x 10 ⁻⁸	6.955 x 10 ⁻⁹	3.040 x 10 ⁻⁹	1.857 x 10 ⁻⁹	1.270 x 10 ⁻⁹
S	1.567 x 10 ⁻⁷	8.367 x 10 ⁻⁸	4.746 x 10 ⁻⁸	3.095 x 10 ⁻⁸	2.217 x 10 ⁻⁸	1.129 x 10 ⁻⁸	4.344 x 10 ⁻⁹	2.119 x 10 ⁻⁹	1.314 x 10 ⁻⁹	9.085 x 10 ⁻¹⁰
SSW	9.680 x 10 ⁻⁸	5.077 x 10 ⁻⁸	3.010 x 10 ⁻⁸	2.041 x 10 ⁻⁸	1.506 x 10 ⁻⁸	8.068 x 10 ⁻⁹	3.330 x 10 ⁻⁹	1.702 x 10 ⁻⁹	1.084 x 10 ⁻⁹	7.636 x 10 ⁻¹⁰
SW	1.587 x 10 ⁻⁷	8.906 x 10 ⁻⁸	5.332 x 10 ⁻⁸	3.619 x 10 ⁻⁸	2.674 x 10 ⁻⁸	1.444 x 10 ⁻⁸	6.092 x 10 ⁻⁹	3.193 x 10 ⁻⁹	2.075 x 10 ⁻⁹	1.487 x 10 ⁻⁹
WSW	1.985 x 10 ⁻⁷	1.082 x 10 ⁻⁷	5.949 x 10 ⁻⁸	3.882 x 10 ⁻⁸	2.760 x 10 ⁻⁸	1.402 x 10 ⁻⁸	5.379 x 10 ⁻⁹	2.638 x 10 ⁻⁹	1.642 x 10 ⁻⁹	1.139 x 10 ⁻⁹
W	2.156 x 10 ⁻⁷	1.181 x 10 ⁻⁷	6.755 x 10 ⁻⁸	4.433 x 10 ⁻⁸	3.190 x 10 ⁻⁸	1.637 x 10 ⁻⁸	6.392 x 10 ⁻⁹	3.144 x 10 ⁻⁹	1.965 x 10 ⁻⁹	1.368 x 10 ⁻⁹
WNW	1.990 x 10 ⁻⁷	1.041 x 10 ⁻⁷	5.819 x 10 ⁻⁸	3.770 x 10 ⁻⁸	2.690 x 10 ⁻⁸	1.365 x 10 ⁻⁸	5.239 x 10 ⁻⁹	2.555 x 10 ⁻⁹	1.585 x 10 ⁻⁹	1.096 x 10 ⁻⁹
NW	1.752 x 10 ⁻⁷	1.042 x 10 ⁻⁷	6.453 x 10 ⁻⁸	4.431 x 10 ⁻⁸	3.290 x 10 ⁻⁸	1.775 x 10 ⁻⁸	7.415 x 10 ⁻⁹	3.830 x 10 ⁻⁹	2.463 x 10 ⁻⁹	1.751 x 10 ⁻⁹
N	1.608 x 10 ⁻⁷	9.323 x 10 ⁻⁸	5.532 x 10 ⁻⁸	3.684 x 10 ⁻⁸	2.673 x 10 ⁻⁸	1.382 x 10 ⁻⁸	5.410 x 10 ⁻⁹	2.659 x 10 ⁻⁹	1.658 x 10 ⁻⁹	1.151 x 10 ⁻⁹

Table G-3. Annual Average Meteorological Dispersion/Deposition Parameters Within 80 Kilometers of SRP Center for Elevated Releases (continued)

Direction from site	Distance (km)									
	0-2	2-3	3-5	5-6	6-8	8-16	16-32	32-48	48-64	64-80
	ANNUAL AVERAGE D/Q (m ⁻²)									
N	2.473 x 10 ⁻⁹	9.109 x 10 ⁻¹⁰	4.045 x 10 ⁻¹⁰	2.331 x 10 ⁻¹⁰	1.539 x 10 ⁻¹⁰	6.845 x 10 ⁻¹¹	2.264 x 10 ⁻¹¹	1.049 x 10 ⁻¹¹	6.614 x 10 ⁻¹²	4.729 x 10 ⁻¹²
NNE	2.697 x 10 ⁻⁹	1.011 x 10 ⁻⁹	4.511 x 10 ⁻¹⁰	2.602 x 10 ⁻¹⁰	1.717 x 10 ⁻¹⁰	7.626 x 10 ⁻¹¹	2.506 x 10 ⁻¹¹	1.151 x 10 ⁻¹¹	7.194 x 10 ⁻¹²	5.100 x 10 ⁻¹²
NE	2.740 x 10 ⁻⁹	1.038 x 10 ⁻⁹	4.647 x 10 ⁻¹⁰	2.682 x 10 ⁻¹⁰	1.770 x 10 ⁻¹⁰	7.851 x 10 ⁻¹¹	2.569 x 10 ⁻¹¹	1.179 x 10 ⁻¹¹	7.421 x 10 ⁻¹²	5.323 x 10 ⁻¹²
ENE	2.811 x 10 ⁻⁹	1.059 x 10 ⁻⁹	4.737 x 10 ⁻¹⁰	2.733 x 10 ⁻¹⁰	1.804 x 10 ⁻¹⁰	8.005 x 10 ⁻¹¹	2.625 x 10 ⁻¹¹	1.205 x 10 ⁻¹¹	7.565 x 10 ⁻¹²	5.399 x 10 ⁻¹²
E	3.650 x 10 ⁻⁹	1.369 x 10 ⁻⁹	6.114 x 10 ⁻¹⁰	3.527 x 10 ⁻¹⁰	2.327 x 10 ⁻¹⁰	1.033 x 10 ⁻¹⁰	3.394 x 10 ⁻¹¹	1.559 x 10 ⁻¹¹	9.764 x 10 ⁻¹²	6.939 x 10 ⁻¹²
ESE	4.124 x 10 ⁻⁹	1.582 x 10 ⁻⁹	7.110 x 10 ⁻¹⁰	4.104 x 10 ⁻¹⁰	2.708 x 10 ⁻¹⁰	1.200 x 10 ⁻¹⁰	3.908 x 10 ⁻¹¹	1.776 x 10 ⁻¹¹	1.100 x 10 ⁻¹¹	7.739 x 10 ⁻¹²
SE	4.028 x 10 ⁻⁹	1.575 x 10 ⁻⁹	7.119 x 10 ⁻¹⁰	4.113 x 10 ⁻¹⁰	2.714 x 10 ⁻¹⁰	1.200 x 10 ⁻¹⁰	3.880 x 10 ⁻¹¹	1.747 x 10 ⁻¹¹	1.072 x 10 ⁻¹¹	7.461 x 10 ⁻¹²
SSE	2.366 x 10 ⁻⁹	8.707 x 10 ⁻¹⁰	3.865 x 10 ⁻¹⁰	2.228 x 10 ⁻¹⁰	1.470 x 10 ⁻¹⁰	6.541 x 10 ⁻¹¹	2.164 x 10 ⁻¹¹	9.996 x 10 ⁻¹²	6.248 x 10 ⁻¹²	4.412 x 10 ⁻¹²
S	1.385 x 10 ⁻⁹	4.897 x 10 ⁻¹⁰	2.146 x 10 ⁻¹⁰	1.235 x 10 ⁻¹⁰	8.152 x 10 ⁻¹¹	3.642 x 10 ⁻¹¹	1.224 x 10 ⁻¹¹	5.765 x 10 ⁻¹²	3.666 x 10 ⁻¹²	2.621 x 10 ⁻¹²
SSW	1.251 x 10 ⁻⁹	4.481 x 10 ⁻¹⁰	1.972 x 10 ⁻¹⁰	1.136 x 10 ⁻¹⁰	7.496 x 10 ⁻¹¹	3.344 x 10 ⁻¹¹	1.118 x 10 ⁻¹¹	5.246 x 10 ⁻¹²	3.340 x 10 ⁻¹²	2.407 x 10 ⁻¹²
SW	1.979 x 10 ⁻⁹	7.211 x 10 ⁻¹⁰	3.191 x 10 ⁻¹⁰	1.839 x 10 ⁻¹⁰	1.213 x 10 ⁻¹⁰	5.404 x 10 ⁻¹¹	1.796 x 10 ⁻¹¹	8.384 x 10 ⁻¹²	5.355 x 10 ⁻¹²	3.888 x 10 ⁻¹²
WSW	3.024 x 10 ⁻⁹	1.120 x 10 ⁻⁹	4.979 x 10 ⁻¹⁰	2.870 x 10 ⁻¹⁰	1.894 x 10 ⁻¹⁰	8.423 x 10 ⁻¹¹	2.780 x 10 ⁻¹¹	1.282 x 10 ⁻¹¹	8.021 x 10 ⁻¹²	5.678 x 10 ⁻¹²
W	3.342 x 10 ⁻⁹	1.228 x 10 ⁻⁹	5.447 x 10 ⁻¹⁰	3.139 x 10 ⁻¹⁰	2.072 x 10 ⁻¹⁰	9.220 x 10 ⁻¹¹	3.052 x 10 ⁻¹¹	1.412 x 10 ⁻¹¹	8.852 x 10 ⁻¹²	6.275 x 10 ⁻¹²
WNW	3.053 x 10 ⁻⁹	1.120 x 10 ⁻⁹	4.969 x 10 ⁻¹⁰	2.864 x 10 ⁻¹⁰	1.890 x 10 ⁻¹⁰	8.411 x 10 ⁻¹¹	2.785 x 10 ⁻¹¹	1.288 x 10 ⁻¹¹	8.043 x 10 ⁻¹²	5.673 x 10 ⁻¹²
NW	2.555 x 10 ⁻⁹	9.364 x 10 ⁻¹⁰	4.152 x 10 ⁻¹⁰	2.393 x 10 ⁻¹⁰	1.579 x 10 ⁻¹⁰	7.028 x 10 ⁻¹¹	2.330 x 10 ⁻¹¹	1.085 x 10 ⁻¹¹	6.912 x 10 ⁻¹²	5.008 x 10 ⁻¹²
NNW	2.415 x 10 ⁻⁹	9.062 x 10 ⁻¹⁰	4.047 x 10 ⁻¹⁰	2.334 x 10 ⁻¹⁰	1.540 x 10 ⁻¹⁰	6.840 x 10 ⁻¹¹	2.246 x 10 ⁻¹¹	1.032 x 10 ⁻¹¹	6.468 x 10 ⁻¹²	4.602 x 10 ⁻¹²

Table 6-4. Population and Annual Food Production Within 80 Kilometers of the SRP Center^a

Direction	Distance (km)						
	0-8	8-16	16-32	32-48	48-64	64-80	0-80
	POPULATION						
N	0	1,507	5,589	7,411	8,541	20,725	43,774
NNE	0	70	1,118	2,952	4,899	17,585	26,623
NE	0	283	1,218	5,213	9,295	12,435	28,443
ENE	0	25	6,783	5,150	8,039	44,590	64,586
E	0	0	3,203	11,430	6,029	9,672	30,334
ESE	0	0	5,778	4,899	4,208	4,333	19,218
SE	0	0	452	7,285	5,652	9,797	23,187
SSE	0	0	766	1,143	565	5,087	7,561
S	0	0	1,080	1,570	7,034	3,957	13,641
SSW	0	0	264	2,387	6,908	3,454	13,013
SW	0	0	553	3,894	2,261	3,140	9,847
WSW	0	0	496	5,652	1,821	7,662	15,632
W	0	440	2,575	9,420	3,705	12,435	28,575
WNW	0	4,019	5,778	247,443	84,156	15,701	357,096
NW	0	1,118	15,701	64,059	5,778	2,512	89,167
NWN	0	4,208	40,822	16,957	14,445	4,899	81,330
Total ^b	0	11,670	92,176	396,863	173,336	177,983	852,027

		MILK PRODUCTION (liters/yr)						
N	0	1.64 x 10 ⁴	1.03 x 10 ⁵	1.72 x 10 ⁵	1.41 x 10 ⁶	5.57 x 10 ⁶	7.28 x 10 ⁶	
NNE	0	1.31 x 10 ⁴	1.03 x 10 ⁵	1.72 x 10 ⁵	3.68 x 10 ⁵	6.06 x 10 ⁵	1.26 x 10 ⁶	
NE	0	5.73 x 10 ³	1.22 x 10 ⁵	1.33 x 10 ⁶	2.15 x 10 ⁶	1.39 x 10 ⁶	4.99 x 10 ⁶	
ENE	0	1.58 x 10 ³	1.80 x 10 ⁵	1.92 x 10 ⁶	4.82 x 10 ⁶	5.46 x 10 ⁶	1.24 x 10 ⁷	
E	0	1.85 x 10 ³	1.80 x 10 ⁵	1.74 x 10 ⁶	4.15 x 10 ⁶	5.76 x 10 ⁶	1.18 x 10 ⁷	
ESE	0	4.51 x 10 ³	1.80 x 10 ⁵	9.31 x 10 ⁵	2.84 x 10 ⁶	1.46 x 10 ⁶	5.41 x 10 ⁶	
SE	0	--	1.21 x 10 ⁵	4.52 x 10 ⁴	1.80 x 10 ⁵	4.00 x 10 ⁵	7.46 x 10 ⁵	
SSE	0	--	9.38 x 10 ⁴	2.41 x 10 ⁵	3.52 x 10 ⁵	5.64 x 10 ⁵	1.25 x 10 ⁶	

Table G-4. Population and Annual Food Production Within 80 Kilometers of the SRP Center^a (continued)

Direction	Distance (km)						
	0-8	8-16	16-32	32-48	48-64	64-80	0-80
MILK PRODUCTION (liters/yr) (continued)							
S	0	--	3.31 x 10 ⁵	5.74 x 10 ⁵	7.70 x 10 ⁵	9.97 x 10 ⁵	2.67 x 10 ⁶
SSW	0	--	3.58 x 10 ⁵	1.89 x 10 ⁵	6.40 x 10 ⁵	7.61 x 10 ⁵	1.63 x 10 ⁷
SW	0	7.65 x 10 ³	3.87 x 10 ⁵	6.71 x 10 ⁵	3.07 x 10 ⁶	2.84 x 10 ⁶	6.97 x 10 ⁶
WSW	0	2.47 x 10 ³	3.53 x 10 ⁵	6.68 x 10 ⁵	1.05 x 10 ⁶	2.40 x 10 ⁶	4.47 x 10 ⁶
W	0	1.16 x 10 ⁴	1.81 x 10 ⁵	3.79 x 10 ⁵	1.01 x 10 ⁶	1.77 x 10 ⁶	3.36 x 10 ⁶
WNW	0	1.38 x 10 ⁴	1.79 x 10 ⁵	3.46 x 10 ⁵	6.13 x 10 ⁵	8.55 x 10 ⁵	2.01 x 10 ⁶
NW	0	1.75 x 10 ⁴	1.03 x 10 ⁵	4.24 x 10 ⁵	1.16 x 10 ⁶	7.81 x 10 ⁵	2.49 x 10 ⁶
NNW	0	1.79 x 10 ⁴	1.03 x 10 ⁵	2.95 x 10 ⁵	1.48 x 10 ⁶	3.14 x 10 ⁶	5.04 x 10 ⁶
Total ^b	0	1.10 x 10 ⁵	3.08 x 10 ⁶	1.18 x 10 ⁷	3.18 x 10 ⁷	4.16 x 10 ⁷	8.84 x 10 ⁷
MEAT PRODUCTION (kg/yr)							
N	0	8.32 x 10 ⁴	5.24 x 10 ⁵	8.73 x 10 ⁵	1.41 x 10 ⁶	3.15 x 10 ⁶	6.05 x 10 ⁶
NNE	0	6.63 x 10 ⁴	5.24 x 10 ⁵	8.73 x 10 ⁵	2.29 x 10 ⁶	4.06 x 10 ⁶	7.81 x 10 ⁶
NE	0	2.37 x 10 ⁴	4.71 x 10 ⁵	7.80 x 10 ⁵	1.71 x 10 ⁶	3.01 x 10 ⁶	5.99 x 10 ⁶
ENE	0	2.65 x 10 ⁴	3.02 x 10 ⁵	5.50 x 10 ⁵	8.87 x 10 ⁵	1.06 x 10 ⁶	2.80 x 10 ⁶
E	0	3.10 x 10 ³	3.02 x 10 ⁵	4.74 x 10 ⁵	6.89 x 10 ⁵	1.03 x 10 ⁶	2.50 x 10 ⁶
ESE	0	7.56 x 10 ¹	3.02 x 10 ⁵	4.66 x 10 ⁵	6.14 x 10 ⁵	7.10 x 10 ⁵	2.09 x 10 ⁶
SE	0	--	2.74 x 10 ⁵	3.82 x 10 ⁵	6.56 x 10 ⁵	1.00 x 10 ⁶	2.31 x 10 ⁶
SSE	0	--	2.35 x 10 ⁵	4.35 x 10 ⁵	6.19 x 10 ⁵	9.88 x 10 ⁵	2.28 x 10 ⁶
S	0	--	1.75 x 10 ⁵	4.58 x 10 ⁵	7.32 x 10 ⁵	1.02 x 10 ⁶	2.39 x 10 ⁶
SSW	0	--	1.57 x 10 ⁵	3.93 x 10 ⁵	1.13 x 10 ⁶	1.58 x 10 ⁶	3.26 x 10 ⁶
SW	0	2.29 x 10 ³	1.33 x 10 ⁵	2.01 x 10 ⁵	5.76 x 10 ⁵	7.57 x 10 ⁵	1.67 x 10 ⁶
WSW	0	1.06 x 10 ⁴	1.75 x 10 ⁵	2.00 x 10 ⁵	3.09 x 10 ⁵	6.65 x 10 ⁵	1.36 x 10 ⁶
W	0	5.90 x 10 ⁴	1.66 x 10 ⁵	1.19 x 10 ⁵	2.91 x 10 ⁵	5.11 x 10 ⁵	1.15 x 10 ⁶
WNW	0	7.01 x 10 ⁴	1.75 x 10 ⁵	1.09 x 10 ⁵	1.76 x 10 ⁵	2.45 x 10 ⁵	7.75 x 10 ⁵

Table 6-4. Population and Annual Food Production Within 80 Kilometers of the SRP Center^a (continued)

Direction	Distance (km)						
	0-8	8-16	16-32	32-48	48-64	64-80	0-80
MEAT PRODUCTION (kg/yr) (continued)							
NW	0	8.86 x 10 ⁴	5.24 x 10 ⁵	6.98 x 10 ⁵	5.83 x 10 ⁵	7.01 x 10 ⁵	2.60 x 10 ⁶
NNW	0	9.11 x 10 ⁴	5.24 x 10 ⁵	8.20 x 10 ⁵	7.14 x 10 ⁵	1.45 x 10 ⁵	3.60 x 10 ⁶
Total ^b	0	5.01 x 10 ⁵	4.96 x 10 ⁶	7.83 x 10 ⁶	1.34 x 10 ⁷	2.20 x 10 ⁷	4.86 x 10 ⁷
VEGETABLE PRODUCTION (kg/yr)							
N	0	7.39 x 10 ⁴	4.65 x 10 ⁵	7.75 x 10 ⁵	2.16 x 10 ⁶	3.11 x 10 ⁶	6.58 x 10 ⁶
NNE	0	5.89 x 10 ⁴	4.65 x 10 ⁵	7.75 x 10 ⁵	1.18 x 10 ⁶	1.61 x 10 ⁶	4.09 x 10 ⁶
NE	0	4.13 x 10 ⁴	9.71 x 10 ⁵	1.08 x 10 ⁶	1.59 x 10 ⁶	1.93 x 10 ⁶	5.61 x 10 ⁶
ENE	0	2.25 x 10 ⁴	2.57 x 10 ⁶	2.89 x 10 ⁶	2.21 x 10 ⁶	2.78 x 10 ⁶	1.05 x 10 ⁷
E	0	2.64 x 10 ⁴	2.57 x 10 ⁶	3.01 x 10 ⁶	2.72 x 10 ⁶	3.03 x 10 ⁶	1.14 x 10 ⁷
ESE	0	6.44 x 10 ²	2.57 x 10 ⁶	3.82 x 10 ⁶	3.44 x 10 ⁶	9.66 x 10 ⁵	1.08 x 10 ⁷
SE	0	--	2.73 x 10 ⁶	4.97 x 10 ⁶	4.70 x 10 ⁶	2.89 x 10 ⁶	1.53 x 10 ⁷
SSE	0	--	2.65 x 10 ⁶	3.71 x 10 ⁶	5.01 x 10 ⁶	3.16 x 10 ⁶	1.45 x 10 ⁷
S	0	--	1.36 x 10 ⁶	1.69 x 10 ⁶	2.50 x 10 ⁶	3.27 x 10 ⁶	8.82 x 10 ⁶
SSW	0	--	1.15 x 10 ⁶	1.33 x 10 ⁶	1.86 x 10 ⁶	2.55 x 10 ⁶	6.89 x 10 ⁶
SW	0	1.51 x 10 ⁴	9.20 x 10 ⁵	1.33 x 10 ⁶	1.81 x 10 ⁶	1.97 x 10 ⁶	6.04 x 10 ⁶
WSW	0	1.01 x 10 ⁴	7.21 x 10 ⁵	1.31 x 10 ⁶	1.86 x 10 ⁶	2.41 x 10 ⁶	6.31 x 10 ⁶
W	0	5.23 x 10 ⁴	1.86 x 10 ⁵	3.17 x 10 ⁵	1.18 x 10 ⁶	2.77 x 10 ⁶	4.51 x 10 ⁶
WNW	0	6.22 x 10 ⁴	1.94 x 10 ⁵	1.70 x 10 ⁵	4.89 x 10 ⁴	1.36 x 10 ⁶	1.83 x 10 ⁶
NW	0	7.86 x 10 ⁴	4.65 x 10 ⁵	1.59 x 10 ⁶	4.20 x 10 ⁶	2.27 x 10 ⁶	8.59 x 10 ⁶
NNW	0	8.08 x 10 ⁴	4.65 x 10 ⁵	1.25 x 10 ⁶	5.70 x 10 ⁶	6.38 x 10 ⁶	1.39 x 10 ⁷
Total ^b	0	5.23 x 10 ⁵	2.05 x 10 ⁷	3.00 x 10 ⁷	4.22 x 10 ⁷	4.24 x 10 ⁷	1.36 x 10 ⁸

^aAdapted from Du Pont, 1981, 1982.
^bReflects rounding.

Table G-5. Parameters and Demographic Data Used in Calculating Collective Dose to the 80-Kilometer Population

Average individual parameters ^a	Child	Teen	Adult
Inhalation (m ³ /yr)	3700	8000	8000
Ingestion ^b			
Cow's milk (liter/yr)	170	200	110
Meat (kg/yr)	37	59	95
Leafy vegetables (kg/yr) ^c	10	20	30
Fruits, vegetables, and grains (kg/yr)	200	240	190
External exposure			
Transmission factor for shielding by residential structures	0.5	0.5	0.5
Demographic data, CY 2000 ^d			
80-kilometer residential population (852,000) age-group distribution	20.8	11.8	67.4

^aData are recommended values from Regulatory Guide 1.109 (NRC, 1977).

^bFoodstuff obtained at large from the 80-kilometer agricultural production of man's foods; any insufficiency is assumed to be imported (uncontaminated). Crop yield and animal feeding data for the 80-kilometer vicinity are presented in Du Pont (1981).

^cData from Eckerman et al. (1980).

^d1970 census data projected to the assumed midpoint of operations.

All individual doses are 50-year dose commitments. Parameters used in calculating doses to maximally exposed individuals are summarized in Table G-6.

The following exposure pathways were considered for the atmospheric dose assessment:

1. Plume - External dose from radioactive materials transported through the atmosphere.
2. Ground - External dose from radioactive materials deposited on the ground.
3. Inhalation - Internal dose from inhalation of radioactive materials transported through the atmosphere.

Table G-6. Parameters Used in Calculating Dose to Maximally Exposed Individuals^a

Parameter	Infant	Child	Teen	Adult
Inhalation (m ³ /yr)	1400	3700	8000	8000
Ingestion ^b				
Cow's milk (liter/yr)	330	330	400	310
Meat (kg/yr)	0	41	65	110
Leafy vegetables (kg/yr) ^c	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

^aData are recommended values from Regulatory Guide 1.109 (NRC, 1977).

^bFoodstuff 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 are presented in Du Pont (1981).

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

^dSeventy-six percent taken from reference family's crops (Regulatory Guide 1.109 recommended value) (NRC, 1977); remainder imported (uncontaminated).

4. Vegetation - Internal dose from consumption of crops that have been contaminated by radioactive deposits from the atmosphere.
5. Milk - Internal dose from consumption of milk from cows that consume vegetation contaminated by radioactive deposits from the atmosphere.
6. Meat - Internal dose from consumption of meat products from beef cattle that consume vegetation contaminated by radioactive deposits from the atmosphere.

The dose to the maximally exposed individual and collective doses to the population within 80 kilometers of the Savannah River Plant from atmospheric radioactive releases from once-through and recirculating cooling towers for C- and K-Reactors are presented in Tables G-7 through G-14. Section G.3 discusses doses from facilities on or within 80 kilometers of the Plant.

Table G-7. Increase in Annual Dose to Maximally Exposed Individual from Increased Release of Tritium to the Atmosphere, Millirem per (Once-Through Cooling Tower for C-Reactor)

Pathway	All soft tissues	Effective whole body
ADULT		
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	5.44×10^{-5}	4.62×10^{-5}
Meat ingestion	8.10×10^{-6}	6.89×10^{-6}
Milk ingestion	1.90×10^{-5}	1.62×10^{-5}
Inhalation	4.56×10^{-5}	3.87×10^{-5}
Total	1.27×10^{-4}	1.08×10^{-4}
TEEN		
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	6.26×10^{-5}	5.32×10^{-5}
Meat ingestion	4.78×10^{-6}	4.06×10^{-6}
Milk ingestion	2.45×10^{-5}	2.08×10^{-5}
Inhalation	4.56×10^{-5}	3.87×10^{-5}
Total	1.37×10^{-4}	1.17×10^{-4}
CHILD		
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	5.09×10^{-5}	4.33×10^{-5}
Meat ingestion	3.02×10^{-6}	2.57×10^{-6}
Milk ingestion	2.02×10^{-5}	1.72×10^{-5}
Inhalation	2.10×10^{-5}	1.79×10^{-5}
Total	9.51×10^{-5}	8.09×10^{-5}
INFANT		
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	0.0	0.0
Meat ingestion	0.0	0.0
Milk ingestion	2.02×10^{-5}	1.72×10^{-5}
Inhalation	7.97×10^{-6}	6.77×10^{-6}
Total	2.82×10^{-5}	2.40×10^{-5}

Table G-8. Increase in Annual Dose to Maximally Exposed Individual from Increased Release of Tritium to the Atmosphere, Millirem per Year (Once-Through Cooling Tower for K-Reactor)

Pathway	All soft tissues	Effective whole body
ADULT		
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	5.28×10^{-5}	4.49×10^{-5}
Meat ingestion	7.86×10^{-6}	6.68×10^{-6}
Milk ingestion	1.85×10^{-5}	1.57×10^{-5}
Inhalation	4.43×10^{-5}	3.77×10^{-5}
Total	1.23×10^{-4}	1.05×10^{-4}
TEEN		
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	6.08×10^{-5}	5.17×10^{-5}
Meat ingestion	4.65×10^{-6}	3.95×10^{-6}
Milk ingestion	2.38×10^{-5}	2.02×10^{-5}
Inhalation	4.43×10^{-5}	3.77×10^{-5}
Total	1.34×10^{-4}	1.14×10^{-4}
CHILD		
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	4.94×10^{-5}	4.20×10^{-5}
Meat ingestion	2.93×10^{-6}	2.49×10^{-6}
Milk ingestion	1.97×10^{-5}	1.67×10^{-5}
Inhalation	2.04×10^{-5}	1.74×10^{-5}
Total	9.24×10^{-5}	7.86×10^{-5}
INFANT		
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	0.0	0.0
Meat ingestion	1.97×10^{-5}	1.67×10^{-5}
Milk ingestion	7.74×10^{-6}	6.59×10^{-6}
Inhalation		
Total	2.74×10^{-5}	2.33×10^{-5}

Table G-9. Increase in Annual Dose to Maximally Exposed Individual from Increased Release of Tritium to the Atmosphere, Millirem per Year (Recirculating Cooling Towers for C-Reactor)

Pathway	All soft tissues	Effective whole body
ADULT		
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	4.62×10^{-4}	3.93×10^{-4}
Meat ingestion	6.88×10^{-5}	5.84×10^{-5}
Milk ingestion	1.62×10^{-4}	1.37×10^{-4}
Inhalation	3.86×10^{-4}	3.27×10^{-4}
Total	1.08×10^{-3}	9.15×10^{-4}
TEEN		
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	5.33×10^{-4}	4.51×10^{-4}
Meat ingestion	4.06×10^{-5}	3.46×10^{-5}
Milk ingestion	2.09×10^{-4}	1.78×10^{-4}
Inhalation	3.86×10^{-4}	3.27×10^{-4}
Total	1.17×10^{-3}	9.91×10^{-4}
CHILD		
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	4.33×10^{-4}	3.68×10^{-4}
Meat ingestion	2.57×10^{-5}	2.17×10^{-5}
Milk ingestion	1.72×10^{-4}	1.46×10^{-4}
Inhalation	1.79×10^{-4}	1.52×10^{-4}
Total	8.09×10^{-4}	6.87×10^{-4}
INFANT		
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	0.0	0.0
Meat ingestion	0.0	0.0
Milk ingestion	1.72×10^{-4}	1.46×10^{-4}
Inhalation	6.77×10^{-5}	5.75×10^{-5}
Total	2.40×10^{-4}	2.03×10^{-4}

Table G-10. Increase in Annual Dose to Maximally Exposed Individual from Increased Release of Tritium to the Atmosphere, Millirem per Year (Recirculating Cooling Towers for K-Reactor)

Pathway	All soft tissues	Effective whole body
ADULT		
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	4.48×10^{-4}	3.80×10^{-4}
Meat ingestion	6.68×10^{-5}	5.67×10^{-5}
Milk ingestion	1.57×10^{-4}	1.33×10^{-4}
Inhalation	3.77×10^{-3}	8.92×10^{-4}
Total	1.05×10^{-3}	8.92×10^{-4}
TEEN		
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	5.15×10^{-4}	4.39×10^{-4}
Meat ingestion	3.93×10^{-5}	3.35×10^{-5}
Milk ingestion	2.02×10^{-4}	1.72×10^{-4}
Inhalation	3.77×10^{-4}	3.21×10^{-4}
Total	1.13×10^{-3}	9.65×10^{-4}
CHILD		
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	4.20×10^{-4}	3.58×10^{-4}
Meat ingestion	2.48×10^{-5}	2.11×10^{-5}
Milk ingestion	1.67×10^{-4}	1.42×10^{-4}
Inhalation	1.74×10^{-4}	1.48×10^{-4}
Total	7.87×10^{-4}	6.69×10^{-4}
INFANT		
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	0.0	0.0
Meat ingestion	0.0	0.0
Milk ingestion	1.67×10^{-4}	1.42×10^{-4}
Inhalation	6.56×10^{-5}	5.57×10^{-5}
Total	2.32×10^{-4}	1.97×10^{-4}

Table G-11. Increase in 80-Kilometer Collective Dose from Increased Release of Tritium to the Atmosphere, Person-Rem per Year (Once-Through Cooling Tower for C-Reactor)

Pathway	All soft tissues	Effective whole body
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	1.59×10^{-3}	1.35×10^{-3}
Meat ingestion	3.03×10^{-4}	2.58×10^{-4}
Milk ingestion	3.85×10^{-4}	3.27×10^{-4}
Inhalation	3.57×10^{-3}	3.03×10^{-3}
Total	5.85×10^{-3}	4.97×10^{-3}

Table G-12. Increase in 80-Kilometer Collective Dose from Increased Release of Tritium to the Atmosphere, Person-Rem per Year (Once-Through Cooling Tower for K-Reactor)

Pathway	All soft tissues	Effective whole body
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	1.59×10^{-3}	1.35×10^{-3}
Meat ingestion	3.03×10^{-4}	2.58×10^{-4}
Milk ingestion	3.85×10^{-4}	3.27×10^{-4}
Inhalation	3.57×10^{-3}	3.03×10^{-3}
Total	5.85×10^{-3}	4.97×10^{-3}

G.2 LIQUID RELEASES

The LADTAP II computer code (Simpson and McGill, 1980) was used to calculate radiation exposures due to liquid releases; LADTAP II implements the dose models recommended in NRC Regulatory Guide 1.109, Revision 1 (NRC, 1977). Both maximum-individual and collective doses were calculated as functions of age group and pathway for various body organs. An effective whole-body dose was also calculated.

Table G-13. Increase in 80-Kilometer Collective Dose from Increased Release of Tritium to the Atmosphere, Person-Rem per Year (Recirculating Cooling Towers for C-Reactor)

Pathway	All soft tissues	Effective whole body
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	1.35×10^{-2}	1.15×10^{-2}
Meat ingestion	2.57×10^{-3}	2.18×10^{-2}
Milk ingestion	3.28×10^{-3}	2.78×10^{-2}
Inhalation	3.03×10^{-2}	2.59×10^{-2}
Total	4.98×10^{-2}	4.22×10^{-2}

Table G-14. Increase in 80-Kilometer Collective Dose from Increased Release of Tritium to the Atmosphere, Person-Rem per Year (Recirculating Cooling Towers for K-Reactor)

Pathway	All soft tissues	Effective whole body
Plume immersion	0.0	0.0
Ground plane	0.0	0.0
Vegetation ingestion	1.35×10^{-2}	1.15×10^{-2}
Meat ingestion	2.57×10^{-3}	2.18×10^{-3}
Milk ingestion	3.28×10^{-3}	2.78×10^{-3}
Inhalation	3.03×10^{-2}	2.59×10^{-2}
Total	4.98×10^{-2}	4.22×10^{-2}

During operation of the reactors and associated facilities at the Savannah River Plant (existing operations), liquids are released that ultimately discharge into the Savannah River. Included in these releases are radionuclides from reactors and support facilities, and from remobilization from stream beds. The primary radionuclides remobilized are cesium-134 and cesium-137 (DOE, 1984b).

In determining the number of curies of radionuclides remobilized from stream beds that eventually reach the Savannah River, it was assumed that each once-through reactor cooling water system discharges 8.6 cubic meters per second

averaged over the entire year, based on cooling water flowing 80 percent of the time. Flow emanating from other sources is added to this amount. For Pen Branch the additional flow annually averages about 2.2 cubic meters per second, and for Four Mile Creek about 0.9 cubic meter per second.

The routine operation of cooling water systems for C- and K-Reactors would result in either no change or a decrease in the remobilization of radionuclides to the Savannah River. This is because flow rates in Four Mile Creek and Indian Grave/Pen Branch would remain essentially unchanged if once-through cooling towers were implemented, and would decrease if recirculating cooling towers were implemented. The routine operation of the cooling water alternative systems for D-Area would produce an insignificant increase in remobilization of radionuclides from Beaver Dam Creek because the creek bed contains insignificant amounts of radionuclides.

The following exposure pathways were considered in the liquid-dose assessments:

1. Drinking water - Internal dose from consumption of drinking water from the Savannah River containing radioactive materials transported by the river
2. Sport and commercial fish - Internal dose from consumption of fish from Savannah River
3. Salt-water invertebrates - Internal dose from consumption of shellfish from estuaries of the Savannah River
4. Recreation - External dose from recreational activities on or along the Savannah River shoreline

All individual and collective doses were based on the assumption that liquids discharged are mixed completely in the river before reaching the potential exposure pathways. This assumption is supported by measurements that indicate complete mixing of the liquids before they reach the Highway 301 bridge. A dilution factor of 3 was applied to the shellfish dose calculation because a significant portion of the harvest would be from estuarine or ocean waters.

Individual and site parameters used in the calculations are summarized in Tables G-15 and G-16. The data on fish consumption are based on data from the region.

The individual who would receive the maximum potential dose from liquid releases is assumed to live near the Savannah River downstream from the Savannah River Plant. This individual is assumed to use river water regularly for drinking, to consume river fish, and to receive external exposure from shoreline activities.

The collective doses received by the offsite population as a result of liquid releases is estimated by summing the doses to the individuals in the population. The population within an 80-kilometer radius uses no river water for

Table G-15. Individual Parameters Used in Dose Calculations

Parameters	Child	Teen	Adult
AVERAGE INDIVIDUAL			
Water consumption (liter/year)	260	260	370
Fish consumption (kg/yr)	3.6	8.5	11.3
Other seafood consumption (kg/yr)	0.33	0.75	1.0
Shoreline recreation (hr/yr)	9.5	47	8.3
Shoreline recreation (person-hours) ^a	--	--	200,000
MAXIMUM INDIVIDUAL			
Water consumption (liter/yr) ^b	510	510	730
Fish consumption (kg/yr)	11.2	25.9	34
Other seafood consumption (kg/yr)	1.7	3.8	5
Shoreline recreation (hr/yr)	14	67	20

^aFor collective dose calculations.

^bDrinking-water consumption for an infant equals 330 liters per year.

Table G-16. Site Parameters Used in Dose Calculations

Parameters	Values
River flow rate (m ³ /s)	
Average (m ³ /s)	294
Low flow (m ³ /s)	173
River dilution in estuary	3
Transit time 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 in year 2000 ^a	
Beaufort-Jasper water consumers	117,000
Port Wentworth water consumers	200,000
80-kilometer-radius population	852,000

^aAge distribution of population: Beaufort-Jasper--21 percent child, 10 percent teen, 69 percent adult; Port Wentworth--100 percent adult; 80-kilometer radius--21 percent child, 11 percent teen, 68 percent adult.

domestic purposes downstream from the Savannah River Plant; this population is assumed to use the river for recreational purposes and to consume fish and shellfish from the river and its estuary.

There is no known use of Savannah River water for human consumption up to a distance of about 80 kilometers downstream from the Savannah River Plant. At this distance, Beaufort and Jasper Counties, South Carolina, will pump water from the river for treatment and service to a population of about 117,000 people in the year 2000. Several kilometers farther downstream, the Cherokee Hill water-treatment plant draws water from the river to supply a business-industrial complex near Savannah, Georgia. This water is not used for normal domestic service, but it is assumed that about 200,000 people will use this water during the year 2000 (DOE, 1984a). Although these population groups are beyond the 80-kilometer radius, collective doses from drinking-water for these groups have been included in this document. All population doses are 100-year environmental dose commitments.

The doses to the maximally exposed individual and collective dose from liquid radioactive releases from once-through and recirculating cooling-towers for C- and K-Reactors are presented in Tables G-17 through G-28. Section G.3 discusses doses from facilities on or within 80 kilometers of the Savannah River Plant.

G.3 CUMULATIVE EFFECTS

The evaluation of the radiological impacts associated with the implementation of the alternative cooling water systems has also considered the cumulative effects of the operation of all other nuclear facilities in the affected region. This region includes the Savannah River Plant and the area within 80 kilometers of the Plant. These cumulative effects are summarized in Section 4.4.

Impacts for the following nuclear facilities, which represent existing operations, have been considered in the calculation of cumulative effects:

- Four onsite production reactors (L, P, K, and C) using current cooling water systems, and associated support facilities.
- The Defense Waste Processing Facility (DWPF) under construction at S-Area on the Plant.
- The Fuel Materials Facility (FMF) under construction at F-Area on the Plant.
- The Fuel Production Facility (FPF) to be constructed at H-Area on the Plant.
- The Vogtle Electric Generating Station (VEGS) under construction across the Savannah River from the southwestern boundary of the site.

The maximum individual dose and population doses associated with each of these facilities are presented in Tables G-29, G-30, G-31, and G-32. As indicated above, these represent basecase doses. Information necessary for these dose calculations was derived from supporting environmental documentation available for each facility (DOE, 1982a,b; 1984a; Du Pont, 1983; Georgia Power Company, 1985).

To obtain the cumulative impact of the operation of nuclear facilities in the region, including the alternative cooling water systems, the changes in doses associated with operation of the cooling water systems (Tables G-7 through G-14 and G-17 through G-28) must be combined with the existing doses. These cumulative doses are presented in Tables G-33 through G-38.

Table G-17. Decrease in Annual Dose to Maximally Exposed Individual from Reduced Release of Tritium to Four Mile Creek, Millirem per Year (Once-Through Cooling Tower for C-Reactor)

Pathway	All soft tissues	Effective whole body
ADULT		
Fish	1.04×10^{-5}	8.84×10^{-6}
Drinking	2.47×10^{-4}	2.10×10^{-4}
Total	2.58×10^{-4}	2.19×10^{-4}
TEEN		
Fish	7.90×10^{-6}	6.72×10^{-6}
Drinking	1.73×10^{-4}	1.47×10^{-4}
Total	1.81×10^{-4}	1.54×10^{-4}
CHILD		
Fish	3.42×10^{-6}	2.91×10^{-6}
Drinking	1.73×10^{-4}	1.47×10^{-4}
Total	1.76×10^{-4}	1.50×10^{-4}
INFANT		
Drinking	1.12×10^{-4}	9.52×10^{-5}
Total	1.12×10^{-4}	9.52×10^{-5}

Table G-18. Decrease in Annual Dose to Maximally Exposed Individual from Reduced Release of Tritium to Indian Grave/Pen Branch, Millirem per Year (Once-Through Cooling Tower for K-Reactor)

Pathway	All soft tissues	Effective whole body
ADULT		
Fish	1.04×10^{-5}	8.84×10^{-6}
Drinking	2.47×10^{-4}	2.10×10^{-4}
Total	2.58×10^{-4}	2.19×10^{-4}
TEEN		
Fish	7.90×10^{-6}	6.72×10^{-6}
Drinking	1.73×10^{-4}	1.47×10^{-4}
Total	1.81×10^{-4}	1.54×10^{-4}
CHILD		
Fish	3.42×10^{-6}	2.91×10^{-6}
Drinking	1.73×10^{-4}	1.47×10^{-4}
Total	1.76×10^{-4}	1.50×10^{-4}
INFANT		
Drinking	1.12×10^{-4}	9.52×10^{-5}
Total	1.12×10^{-4}	9.52×10^{-5}

G.4 ENVIRONMENTAL DOSE COMMITMENT CONCEPT

Man can receive doses externally from radioactive materials outside the body or internally from the intake of radioactive material by inhalation or ingestion. Radionuclides that enter the body are distributed to various organs and are removed by normal biological processes and radioactive decay. The rate at which each radionuclide is removed from the body depends on its chemical, physical, and radiological properties. Historically, dose calculations have included an accounting of doses that are the fraction of radionuclides retained in the body for 50 years following the year of intake. This 50-year "integrating period" is included in the dose-commitment factors used in these dose calculations.

Table G-19. Decrease in Annual Dose to Maximally Exposed Individual from Reduced Release of Tritium to Four Mile Creek, Millirem per Year (Recirculating Cooling Towers for C-Reactor)

Pathway	All soft tissues	Effective whole body
ADULT		
Fish	8.81×10^{-5}	7.48×10^{-5}
Drinking	2.09×10^{-3}	1.78×10^{-3}
Total	2.18×10^{-3}	1.85×10^{-3}
TEEN		
Fish	6.72×10^{-5}	5.70×10^{-5}
Drinking	1.47×10^{-3}	1.25×10^{-3}
Total	1.53×10^{-3}	1.31×10^{-3}
CHILD		
Fish	2.90×10^{-5}	2.47×10^{-5}
Drinking	1.47×10^{-3}	1.25×10^{-3}
Total	1.50×10^{-3}	1.27×10^{-3}
INFANT		
Drinking	9.48×10^{-4}	8.06×10^{-4}
Total	9.48×10^{-4}	8.06×10^{-4}

Similarly, radioactive material released in any year remains in the environment for varying lengths of time, depending on many environmental factors and on the decay rate of each radionuclide. The environmental-dose-commitment (EDC) concept is employed to account for this residual activity.

The EDC concept has been developed by the U.S. Environmental Protection Agency (EPA, 1974). The EPA has defined the environmental dose commitment as "the sum of all doses to individuals over the entire time period the material persists in the environment in a state available for interaction with humans." The EPA report describes how this concept is implemented and presents some sample calculations. These calculations integrate doses for 100 years following radionuclide release rather than "the entire time period." This 100-year integrating period is distinct from the 50-year integrating period discussed above because it deals with the accumulation of doses from residual radioactivity in the environment rather than in the body.

Table G-20. Decrease in Annual Dose to Maximally Exposed Individual from Reduced Release of Tritium to Indian Grave/Pen Branch, Millirem per Year (Recirculating Cooling Towers for K-Reactor)

Pathway	All soft tissues	Effective whole body
ADULT		
Fish	8.81×10^{-5}	7.48×10^{-5}
Drinking	2.09×10^{-3}	1.78×10^{-3}
Total	2.18×10^{-3}	1.85×10^{-3}
TEEN		
Fish	6.72×10^{-5}	5.70×10^{-5}
Drinking	1.47×10^{-3}	1.25×10^{-3}
Total	1.53×10^{-3}	1.31×10^{-3}
CHILD		
Fish	2.90×10^{-5}	2.47×10^{-5}
Drinking	1.47×10^{-3}	1.25×10^{-3}
Total	1.50×10^{-3}	1.27×10^{-3}
INFANT		
Drinking	9.48×10^{-4}	8.06×10^{-4}
Total	9.48×10^{-4}	8.06×10^{-4}

This analysis uses the 100-year integrating period. All collective dose calculations include an accounting of collective dose resulting from environmental radioactivity levels for 100 years following each year's release. The 100-year period provides meaningful results by accounting for impacts over a period of time about equal to the maximum lifetime of an individual; thus, it provides a measure of risk to an individual. Longer integrating periods or an infinite time integral would require extremely speculative predictions.

For all EDC calculations, no attempt was made to predict changes in environmental characteristics. Population size and distribution were based on estimates for the year 2000. Historical meteorological patterns and conditions were assumed to continue, and food production and consumption patterns were assumed to be static.

Table G-21. Decrease in Annual Dose to Maximally Exposed Individual from Reduced Remobilization of Radiocesium from Four Mile Creek Stream Bed, Millirem per Year (Recirculating Cooling Towers for C-Reactor)

Pathway	Gonads	Breast	R. Marrow	Lung	Thyroid	Bone Surface	SI Wall	ULI Wall	LLI Wall	Remainder	Effective whole body
ADULT											
Fish	3.11×10^{-1}	2.57×10^{-1}	2.84×10^{-1}	2.74×10^{-1}	2.74×10^{-1}	2.64×10^{-1}	3.21×10^{-1}	1.05×10^{-1}	3.21×10^{-1}	3.28×10^{-1}	3.01×10^{-1}
Drinking	2.23×10^{-3}	1.84×10^{-3}	2.03×10^{-3}	1.96×10^{-3}	1.96×10^{-3}	1.89×10^{-3}	2.30×10^{-3}	7.53×10^{-4}	2.30×10^{-3}	2.42×10^{-3}	2.16×10^{-3}
Total	3.13×10^{-1}	2.59×10^{-1}	2.86×10^{-1}	2.76×10^{-1}	2.76×10^{-1}	2.66×10^{-1}	3.23×10^{-1}	1.06×10^{-1}	3.23×10^{-1}	3.40×10^{-1}	3.03×10^{-1}
TEEN											
Fish	2.37×10^{-1}	1.96×10^{-1}	2.16×10^{-1}	2.09×10^{-1}	2.09×10^{-1}	2.01×10^{-1}	2.44×10^{-1}	8.01×10^{-2}	2.44×10^{-1}	2.58×10^{-1}	2.30×10^{-1}
Drinking	1.56×10^{-3}	1.28×10^{-3}	1.42×10^{-3}	1.37×10^{-3}	1.37×10^{-3}	1.32×10^{-3}	1.61×10^{-3}	5.26×10^{-4}	1.61×10^{-3}	1.69×10^{-3}	1.51×10^{-3}
Total	2.39×10^{-1}	1.97×10^{-1}	2.17×10^{-1}	2.10×10^{-1}	2.10×10^{-1}	2.02×10^{-1}	2.46×10^{-1}	8.06×10^{-2}	2.46×10^{-1}	2.60×10^{-1}	2.32×10^{-1}
CHILD											
Fish	1.02×10^{-1}	8.46×10^{-2}	9.36×10^{-2}	9.03×10^{-2}	9.03×10^{-2}	8.71×10^{-2}	1.06×10^{-1}	3.46×10^{-2}	1.06×10^{-1}	1.11×10^{-1}	9.93×10^{-2}
Drinking	1.56×10^{-3}	1.28×10^{-3}	1.42×10^{-3}	1.37×10^{-3}	1.37×10^{-3}	1.32×10^{-3}	1.61×10^{-3}	5.26×10^{-4}	1.61×10^{-3}	1.69×10^{-3}	1.51×10^{-3}
Total	1.04×10^{-1}	8.59×10^{-2}	9.50×10^{-2}	9.17×10^{-2}	9.17×10^{-2}	8.84×10^{-2}	1.08×10^{-1}	3.51×10^{-2}	1.08×10^{-1}	1.13×10^{-1}	1.01×10^{-1}
INFANT											
Drinking	1.01×10^{-3}	8.31×10^{-4}	9.19×10^{-4}	8.87×10^{-4}	8.87×10^{-4}	8.56×10^{-4}	1.04×10^{-3}	3.40×10^{-4}	1.04×10^{-3}	1.09×10^{-3}	9.75×10^{-4}
Total	1.01×10^{-3}	8.31×10^{-4}	9.19×10^{-4}	8.87×10^{-4}	8.87×10^{-4}	8.56×10^{-4}	1.04×10^{-3}	3.40×10^{-4}	1.04×10^{-3}	1.09×10^{-3}	9.75×10^{-4}

Table G-22. Decrease in Annual Dose to Maximally Exposed Individual from Reduced Remobilization of Radionuclides from Indian Grave/Pen Branch Stream Bed, Millirem per Year (Recirculating Cooling Towers for K-Reactor)

Pathway	Gonads	Breast	R. Marrow	Lung	Thyroid	Bone Surface	SI Mail	ULI Mail	LLI Mail	Remainder	Effective whole body
ADULT											
Fish Drinking	4.66 x 10 ⁻¹	3.82 x 10 ⁻¹	4.24 x 10 ⁻¹	4.06 x 10 ⁻¹	4.06 x 10 ⁻¹	3.89 x 10 ⁻¹	4.83 x 10 ⁻¹	1.01 x 10 ⁻¹	4.83 x 10 ⁻¹	5.08 x 10 ⁻¹	4.48 x 10 ⁻¹
	3.33 x 10 ⁻³	2.73 x 10 ⁻³	3.03 x 10 ⁻³	2.91 x 10 ⁻³	2.91 x 10 ⁻³	2.79 x 10 ⁻³	3.46 x 10 ⁻³	7.20 x 10 ⁻⁴	3.46 x 10 ⁻³	3.63 x 10 ⁻³	3.21 x 10 ⁻³
Total	4.69 x 10 ⁻¹	3.85 x 10 ⁻¹	4.27 x 10 ⁻¹	4.09 x 10 ⁻¹	4.09 x 10 ⁻¹	3.92 x 10 ⁻¹	4.86 x 10 ⁻¹	1.02 x 10 ⁻¹	4.86 x 10 ⁻¹	5.12 x 10 ⁻¹	4.51 x 10 ⁻¹
TEEN											
Fish Drinking	3.55 x 10 ⁻¹	2.91 x 10 ⁻¹	3.23 x 10 ⁻¹	3.10 x 10 ⁻¹	3.10 x 10 ⁻¹	2.96 x 10 ⁻¹	3.68 x 10 ⁻¹	7.66 x 10 ⁻²	3.68 x 10 ⁻¹	3.87 x 10 ⁻¹	3.42 x 10 ⁻¹
	2.33 x 10 ⁻³	1.91 x 10 ⁻³	2.12 x 10 ⁻³	2.03 x 10 ⁻³	2.03 x 10 ⁻³	1.95 x 10 ⁻³	2.42 x 10 ⁻³	5.03 x 10 ⁻⁴	2.42 x 10 ⁻³	2.54 x 10 ⁻³	2.24 x 10 ⁻³
Total	3.57 x 10 ⁻¹	2.93 x 10 ⁻¹	3.25 x 10 ⁻¹	3.12 x 10 ⁻¹	3.12 x 10 ⁻¹	2.98 x 10 ⁻¹	3.70 x 10 ⁻¹	7.71 x 10 ⁻²	3.70 x 10 ⁻¹	3.90 x 10 ⁻¹	3.44 x 10 ⁻¹
CHILD											
Fish Drinking	1.53 x 10 ⁻¹	1.26 x 10 ⁻¹	1.40 x 10 ⁻¹	1.34 x 10 ⁻¹	1.34 x 10 ⁻¹	1.28 x 10 ⁻¹	1.59 x 10 ⁻¹	3.31 x 10 ⁻²	1.59 x 10 ⁻¹	1.67 x 10 ⁻¹	1.48 x 10 ⁻¹
	2.33 x 10 ⁻³	1.91 x 10 ⁻³	2.12 x 10 ⁻³	2.03 x 10 ⁻³	2.03 x 10 ⁻³	1.95 x 10 ⁻³	2.42 x 10 ⁻³	5.03 x 10 ⁻⁴	2.42 x 10 ⁻³	2.54 x 10 ⁻³	2.24 x 10 ⁻³
Total	1.55 x 10 ⁻¹	1.28 x 10 ⁻¹	1.42 x 10 ⁻¹	1.36 x 10 ⁻¹	1.36 x 10 ⁻¹	1.30 x 10 ⁻¹	1.61 x 10 ⁻¹	3.36 x 10 ⁻²	1.61 x 10 ⁻¹	1.70 x 10 ⁻¹	1.50 x 10 ⁻¹
INFANT											
Drinking	1.51 x 10 ⁻³	1.24 x 10 ⁻³	1.37 x 10 ⁻³	1.32 x 10 ⁻³	1.32 x 10 ⁻³	1.26 x 10 ⁻³	1.56 x 10 ⁻³	3.26 x 10 ⁻⁴	1.56 x 10 ⁻³	1.64 x 10 ⁻³	1.45 x 10 ⁻³
Total	1.51 x 10 ⁻³	1.24 x 10 ⁻³	1.37 x 10 ⁻³	1.32 x 10 ⁻³	1.32 x 10 ⁻³	1.26 x 10 ⁻³	1.56 x 10 ⁻³	3.26 x 10 ⁻⁴	1.56 x 10 ⁻³	1.64 x 10 ⁻³	1.45 x 10 ⁻³

Table G-23. Decrease in Collective Dose from Reduced Tritium Release to Four Mile Creek, Person-Rem per Year (Once-Through Cooling Tower for C-Reactor)

Pathway	All soft tissues	Effective whole body
Drinking water		
Beaufort-Jasper	1.33×10^{-2}	1.13×10^{-2}
Port Wentworth	2.51×10^{-2}	2.13×10^{-2}
Total	3.84×10^{-2}	3.26×10^{-2}
Sport fish		
Commercial fish	1.73×10^{-6}	1.47×10^{-6}
Shellfish	5.32×10^{-8}	4.52×10^{-8}
Total	2.90×10^{-5}	2.46×10^{-5}
Grand total	3.84×10^{-2}	3.26×10^{-2}

Table G-24. Decrease in Collective Dose from Reduced Tritium Release to Indian Grave/Pen Branch, Person-Rem per Year (Once-Through Cooling Tower for K-Reactor)

Pathway	All soft tissues	Effective whole body
Drinking water		
Beaufort-Jasper	1.33×10^{-2}	1.13×10^{-2}
Port Wentworth	2.51×10^{-2}	2.13×10^{-2}
Total	3.84×10^{-2}	3.26×10^{-2}
Sport fish		
Commercial fish	1.73×10^{-6}	1.47×10^{-6}
Shellfish	5.32×10^{-8}	4.52×10^{-8}
Total	2.90×10^{-5}	2.46×10^{-5}
Grand total	3.84×10^{-2}	3.26×10^{-2}

Table G-25. Decrease in Collective Dose from Reduced Tritium Release to Four Mile Creek, Person-Rem per Year (Recirculating Cooling Towers for C-Reactor)

Pathway	All soft tissues	Effective whole body
Drinking water		9.58×10^{-2}
Beaufort-Jasper	1.13×10^{-1}	1.82×10^{-1}
Port Wentworth	2.14×10^{-1}	2.78×10^{-1}
Total	3.27×10^{-1}	
Sport fish	2.30×10^{-4}	1.96×10^{-4}
Commercial fish	1.47×10^{-5}	1.25×10^{-5}
Shellfish	4.52×10^{-7}	3.84×10^{-7}
Total	2.45×10^{-4}	2.09×10^{-4}
Grand total	3.27×10^{-1}	2.78×10^{-1}

Table G-26. Decrease in Collective Dose from Reduced Tritium Release to Indian Grave/Pen Branch, Person-Rem per Year (Recirculating Cooling Towers for K-Reactor)

Pathway	All soft tissues	Effective whole body
Drinking water		9.58×10^{-2}
Beaufort-Jasper	1.13×10^{-1}	1.82×10^{-1}
Port Wentworth	2.14×10^{-1}	2.78×10^{-1}
Total	3.27×10^{-1}	
Sport fish	2.30×10^{-4}	1.96×10^{-4}
Commercial fish	1.47×10^{-5}	1.25×10^{-5}
Shellfish	4.52×10^{-7}	3.84×10^{-7}
Total	2.45×10^{-4}	2.09×10^{-4}
Grand total	3.27×10^{-1}	2.78×10^{-1}

Table 6-27. Decrease in Collective Dose from Reduced Remobilization of Radiocesium from Four Mile Creek, Person-Rem Per Year (Recirculating Cooling Towers for C-Reactor)

Pathway	Gonads	Breast	R. Marrow	Lung	Thyroid	Bone Surface	SI Mail	ULI Mail	LLI Mail	Remainder	Effective whole body
Drinking water											
Beaufort-Jasper	2.35×10^{-2}	1.94×10^{-2}	2.15×10^{-2}	2.07×10^{-2}	2.07×10^{-2}	2.00×10^{-2}	2.43×10^{-3}	7.95×10^{-3}	2.43×10^{-2}	2.56×10^{-2}	2.28×10^{-2}
Port											
Wentworth	4.44×10^{-2}	3.67×10^{-2}	4.05×10^{-2}	3.91×10^{-2}	3.91×10^{-2}	3.77×10^{-2}	4.58×10^{-2}	1.50×10^{-2}	4.58×10^{-2}	4.83×10^{-2}	4.30×10^{-2}
Total	6.79×10^{-2}	5.61×10^{-2}	6.20×10^{-2}	5.98×10^{-2}	5.98×10^{-2}	5.77×10^{-2}	7.01×10^{-2}	2.30×10^{-2}	7.01×10^{-2}	7.39×10^{-2}	6.58×10^{-2}
Sport fish	8.12×10^{-1}	6.70×10^{-1}	7.41×10^{-1}	7.15×10^{-1}	7.15×10^{-1}	6.90×10^{-1}	8.37×10^{-1}	2.76×10^{-1}	8.37×10^{-1}	8.82×10^{-1}	7.86×10^{-1}
Commercial fish	5.15×10^{-2}	4.25×10^{-1}	4.70×10^{-2}	4.54×10^{-2}	4.54×10^{-2}	4.38×10^{-2}	5.31×10^{-2}	1.75×10^{-2}	5.31×10^{-2}	5.60×10^{-2}	4.99×10^{-2}
Shellfish	1.28×10^{-5}	1.06×10^{-5}	1.17×10^{-5}	1.13×10^{-5}	1.13×10^{-5}	1.09×10^{-5}	1.32×10^{-5}	4.36×10^{-6}	1.32×10^{-5}	1.39×10^{-5}	1.24×10^{-5}
Total	8.64×10^{-1}	7.13×10^{-1}	7.88×10^{-1}	7.60×10^{-1}	7.60×10^{-1}	7.34×10^{-1}	8.90×10^{-1}	2.94×10^{-1}	8.90×10^{-1}	9.38×10^{-1}	8.36×10^{-1}
Grand Total	9.31×10^{-1}	7.69×10^{-1}	8.50×10^{-1}	8.20×10^{-1}	8.20×10^{-1}	7.92×10^{-1}	9.60×10^{-1}	3.16×10^{-1}	9.60×10^{-1}	1.01	9.02×10^{-1}

Table G-28. Decrease in Collective Dose from Reduced Remobilization of Radocesium from Indian Grave/Pen Branch Stream Bed, Person-Rem

Pathway	Gonads	Breast	R. Marrow	Lung	Thyroid	Bone Surface	SI Wall	ULI Wall	LLI Wall	Remainder	Effective whole body
Drinking water											
Beaufort-Jasper	3.52×10^{-2}	2.88×10^{-2}	3.20×10^{-2}	3.07×10^{-2}	3.07×10^{-2}	2.94×10^{-2}	3.65×10^{-2}	7.61×10^{-3}	3.65×10^{-2}	3.84×10^{-2}	3.39×10^{-2}
Port Wentworth	6.65×10^{-2}	5.45×10^{-2}	6.05×10^{-2}	5.80×10^{-2}	5.80×10^{-2}	5.55×10^{-2}	6.89×10^{-2}	1.44×10^{-2}	6.89×10^{-2}	7.24×10^{-2}	6.40×10^{-2}
Total	1.02×10^{-1}	8.33×10^{-2}	9.25×10^{-2}	8.87×10^{-2}	8.87×10^{-2}	8.49×10^{-2}	1.05×10^{-1}	2.20×10^{-2}	1.05×10^{-1}	1.11×10^{-1}	9.97×10^{-2}
Sport fish	1.21	9.95 x 10 ⁻¹	1.10	1.06	1.06	1.01	1.26	2.64	1.26	1.32	1.17
Commercial fish	7.70×10^{-2}	6.32×10^{-2}	7.01×10^{-2}	6.72×10^{-2}	6.72×10^{-2}	6.44×10^{-2}	7.99×10^{-2}	1.68×10^{-2}	7.99×10^{-2}	8.40×10^{-2}	7.42×10^{-2}
Shellfish	1.92×10^{-5}	1.57×10^{-5}	1.74×10^{-5}	1.67×10^{-5}	1.67×10^{-5}	1.60×10^{-5}	1.99×10^{-5}	4.17×10^{-6}	1.99×10^{-5}	2.09×10^{-5}	1.24
Total	1.29	1.06	1.17	1.13	1.13	1.07	1.34	2.81 x 10 ⁻¹	1.34	1.40	1.34
Grand Total	1.39	1.14	1.26	1.22	1.22	1.16	1.45	3.03×10^{-1}	1.45	1.51	1.34

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Table 6-29. Annual Maximum Individual Doses from Atmospheric Releases; Cumulative Impact Without the Cooling Alternatives, in Year 2000 (Millirem Per Year) (continued)

Receptor organ	Facilities				Total from all facilities
	SRP	DMPF	FNF	Vogtle ^a	
Pancreas	1.97 x 10 ⁻¹	5.91 x 10 ⁻⁵	8.50 x 10 ⁻⁸	5.48 x 10 ⁻⁹	1.97 x 10 ⁻¹
Spleen	2.11 x 10 ⁻¹	6.68 x 10 ⁻⁵	8.39 x 10 ⁻⁸	6.39 x 10 ⁻⁹	2.11 x 10 ⁻¹
Thymus	1.11 x 10 ⁻¹	7.57 x 10 ⁻⁵	9.04 x 10 ⁻⁸	7.43 x 10 ⁻⁹	1.11 x 10 ⁻¹
Uterus	9.91 x 10 ⁻²	6.01 x 10 ⁻⁵	5.38 x 10 ⁻⁸	5.58 x 10 ⁻⁹	9.92 x 10 ⁻²
Adrenals	1.06 x 10 ⁻¹	7.15 x 10 ⁻⁵	1.28 x 10 ⁻⁷	7.17 x 10 ⁻⁹	1.06 x 10 ⁻¹
Bladder Wall	1.97 x 10 ⁻¹	6.90 x 10 ⁻⁵	7.06 x 10 ⁻⁸	6.39 x 10 ⁻⁹	1.97 x 10 ⁻¹
Sk in	2.90 x 10 ⁻¹	1.11 x 10 ⁻⁴	4.87 x 10 ⁻⁶	3.05 x 10 ⁻⁸	6.87 x 10 ⁻¹
Remainder	1.28 x 10 ⁻²	2.31 x 10 ⁻⁵	0.00	0.00	1.28 x 10 ⁻²
E.M.B.D.	2.22 x 10 ⁻¹	2.27 x 10 ⁻⁴	9.55 x 10 ⁻⁴	4.01 x 10 ⁻⁶	6.15 x 10 ⁻¹

INFANT (continued)

^aDoses from Georgia Power Company, 1985.

Table 6-30. Maximum Individual Doses from Liquid Releases; Cumulative Impact Without the Cooling Alternatives, in Year 2000 (Millirem Per Year) (continued)

Receptor organ	Facilities				Total from all facilities
	SRP	DMPF	FPMF	Vogtleb	
Thymus	9.47 x 10 ⁻²	1.90 x 10 ⁻³			9.66 x 10 ⁻²
Uterus	9.47 x 10 ⁻²	1.90 x 10 ⁻³			9.66 x 10 ⁻²
Adrenals	9.47 x 10 ⁻²	1.90 x 10 ⁻³			9.66 x 10 ⁻²
Bladder Wall	9.47 x 10 ⁻²	1.90 x 10 ⁻³			9.66 x 10 ⁻²
Skin	3.19 x 10 ⁻³	1.01 x 10 ⁻¹¹			3.19 x 10 ⁻³
Remainder E.M.B.D.	8.51 x 10 ⁻²	1.58 x 10 ⁻³	2.66 x 10 ⁻⁴	2.42 x 10 ⁻¹	3.29 x 10 ⁻¹

^aThere are no radioactive liquid releases during normal PPF operations.
^bDoses from Georgia Power Company, 1985; liquid dose is "negligible."

Table G-31. Annual Maximum Individual Doses from Combined Atmospheric and Liquid Releases; Cumulative Impact Without the Cooling Alternatives, in Year 2000 (Millirem Per Year)

Receptor organ	Total from all facilities			
	Adult	Teen	Child	Infant
Gonads	1.72	1.48	9.39 x 10 ⁻¹	3.11 x 10 ⁻¹
Breast	1.57	1.37	9.01 x 10 ⁻¹	3.25 x 10 ⁻¹
R. Marrow	2.29	2.30	3.21	1.25
Lungs	2.35	2.15	1.74	9.94 x 10 ⁻¹
Thyroid	6.48	6.95	7.19	6.32
Bone Surface	1.35	1.12	6.40 x 10 ⁻¹	2.12 x 10 ⁻¹
ST Wall	7.12 x 10 ⁻¹	6.91 x 10 ⁻¹	5.42 x 10 ⁻¹	2.13 x 10 ⁻¹
SI Wall	1.65	1.40	8.50 x 10 ⁻¹	2.12 x 10 ⁻¹
ULI Wall	1.11	1.02	7.52 x 10 ⁻¹	3.21 x 10 ⁻¹
LLI Wall	2.42	2.08	1.61	7.99 x 10 ⁻¹
Kidneys	1.66	1.68	1.76	1.00
Liver	2.62	2.78	3.01	1.59
Pancreas	7.53 x 10 ⁻¹	7.29 x 10 ⁻¹	5.93 x 10 ⁻¹	2.94 x 10 ⁻¹
Spleen	7.67 x 10 ⁻¹	7.44 x 10 ⁻¹	6.07 x 10 ⁻¹	3.08 x 10 ⁻¹
Thymus	6.67 x 10 ⁻¹	6.44 x 10 ⁻¹	5.07 x 10 ⁻¹	2.08 x 10 ⁻¹
Uterus	6.55 x 10 ⁻¹	6.31 x 10 ⁻¹	4.95 x 10 ⁻¹	1.96 x 10 ⁻¹
Adrenals	6.62 x 10 ⁻¹	6.38 x 10 ⁻¹	5.01 x 10 ⁻¹	2.03 x 10 ⁻¹
Bladder Wall	7.53 x 10 ⁻¹	7.29 x 10 ⁻¹	5.92 x 10 ⁻¹	2.94 x 10 ⁻¹
Skin	1.25	1.26	1.16	7.84 x 10 ⁻¹
Remainder	1.04	8.06 x 10 ⁻¹	3.72 x 10 ⁻¹	1.60 x 10 ⁻²
E.W.B.D.	3.25	2.64	1.94	9.44 x 10 ⁻¹

Table G-32. Annual Collective Doses from Atmospheric and Liquid Releases; Cumulative Impact Without the Cooling Alternative, In Year 2000 (Person-Rem Per Year)

Receptor organ	Facilities					Total from all facilities
	SRP	DMPF	FWF	FPPA	Vogtle ^b	
ATMOSPHERIC						
Gonads	4.12 x 10 ¹	3.52 x 10 ⁻²	3.77 x 10 ⁻⁴	7.98 x 10 ⁻⁶		4.12 x 10 ¹
Breast	4.12 x 10 ¹	3.22 x 10 ⁻²	1.91 x 10 ⁻³	1.50 x 10 ⁻⁵		4.12 x 10 ¹
R. Marrow	1.04 x 10 ¹	8.03 x 10 ⁻²	3.02 x 10 ⁻³	1.68 x 10 ⁻⁵	3.24 x 10 ⁻¹	1.08 x 10 ¹
Lungs	4.87 x 10 ¹	6.41 x 10 ⁻²	6.14	2.57 x 10 ⁻²	4.82 x 10 ⁻¹	5.54 x 10 ¹
Thyroid	3.58 x 10 ²	6.64 x 10 ⁻¹	1.23 x 10 ⁻⁴	6.75 x 10 ⁻⁶	6.12 x 10 ⁻¹	3.59 x 10 ²
Bone Surface	3.02 x 10 ¹	2.26 x 10 ⁻¹	4.63 x 10 ⁻²	1.96 x 10 ⁻⁴		3.05 x 10 ¹
ST Wall	3.67 x 10 ¹	2.16 x 10 ⁻²	5.94 x 10 ⁻⁵	4.43 x 10 ⁻⁶		3.67 x 10 ¹
SI Wall	3.62 x 10 ¹	2.34 x 10 ⁻²	3.89 x 10 ⁻⁵	4.15 x 10 ⁻³		3.62 x 10 ¹
LLI Wall	4.25 x 10 ¹	3.28 x 10 ⁻²	1.65 x 10 ⁻²	1.18 x 10 ⁻²		4.26 x 10 ¹
LLI Wall	4.07 x 10 ¹	4.25 x 10 ⁻²	5.03 x 10 ⁻²	8.42 x 10 ⁻⁵	4.76 x 10 ⁻¹	4.13 x 10 ¹
Kidneys	3.41 x 10 ¹	2.30 x 10 ⁻²	1.95 x 10 ⁻²	4.44 x 10 ⁻⁶	4.79 x 10 ⁻¹	3.46 x 10 ¹
Liver	3.91 x 10 ¹	4.21 x 10 ⁻²	4.97 x 10 ⁻⁵	4.44 x 10 ⁻⁶	4.83 x 10 ⁻¹	3.96 x 10 ¹
Pancreas	3.77 x 10 ¹	1.88 x 10 ⁻²	5.92 x 10 ⁻⁵	3.81 x 10 ⁻⁶		3.77 x 10 ¹
Spleen	3.86 x 10 ¹	2.13 x 10 ⁻²	5.84 x 10 ⁻⁵	4.45 x 10 ⁻⁶		3.86 x 10 ¹
Thymus	3.42 x 10 ¹	2.42 x 10 ⁻²	6.29 x 10 ⁻⁵	5.17 x 10 ⁻⁶		3.42 x 10 ¹
Uterus	3.34 x 10 ¹	1.91 x 10 ⁻²	3.75 x 10 ⁻⁵	3.89 x 10 ⁻⁶		3.34 x 10 ¹
Adrenals	3.41 x 10 ¹	2.28 x 10 ⁻²	8.88 x 10 ⁻⁵	4.99 x 10 ⁻⁶		3.41 x 10 ¹
Bladder Wall	3.77 x 10 ¹	2.20 x 10 ⁻²	4.91 x 10 ⁻⁵	4.45 x 10 ⁻⁶		3.77 x 10 ¹
Sk In	4.27 x 10 ¹	3.63 x 10 ⁻²	3.39 x 10 ⁻³	2.13 x 10 ⁻⁵	7.58 x 10 ¹	4.35 x 10 ¹
RemaInder	2.77	4.22 x 10 ⁻³				2.77
E.W.B.D.	4.78 x 10 ¹	9.37 x 10 ⁻²	7.44 x 10 ⁻¹	4.07 x 10 ⁻³	4.80 x 10 ¹	4.91 x 10 ¹
LIQUID						
Gonads	3.52 x 10 ¹	6.50 x 10 ⁻¹	3.88 x 10 ⁻⁶			3.59 x 10 ¹
Breast	3.47 x 10 ¹	6.50 x 10 ⁻¹	1.97 x 10 ⁻⁵			3.53 x 10 ¹
R. Marrow	9.02	2.47 x 10 ⁻⁴	3.93 x 10 ⁻²			9.06
Lungs	3.48 x 10 ¹	6.50 x 10 ⁻¹	9.54 x 10 ⁻⁷			3.55 x 10 ¹
Thyroid	3.48 x 10 ¹	7.60 x 10 ⁻¹	1.27 x 10 ⁻⁶			3.56 x 10 ¹
Bone Surface	1.71 x 10 ¹	5.28 x 10 ⁻⁴	6.10 x 10 ⁻¹			1.77 x 10 ¹

Table G-33. Effective Whole-Body Doses to the Maximally Exposed Individual from Cumulative Atmospheric Releases, Comparison of Cooling Alternatives (Millirem per Year)

Cooling alternative	Adult	Teen	Child	Infant
Present cooling system	1.18	1.22	1.08	6.15×10^{-1}
Once-through cooling towers (C- and K-Reactors)	1.18	1.22	1.08	6.15×10^{-1}
Recirculating cooling towers (C- and K-Reactors)	1.18	1.22	1.08	6.15×10^{-1}

Table G-34. Effective Whole-Body Doses to the Maximally Exposed Individual from Cumulative Liquid Releases to Savannah River, Comparison of Cooling Alternatives (Millirem per Year)

Cooling alternative	Adult	Teen	Child	Infant
Present cooling system	2.07	1.42	8.60×10^{-1}	3.29×10^{-1}
Once-through cooling towers (C- and K-Reactors)	2.07	1.42	8.60×10^{-1}	3.29×10^{-1}
Recirculating cooling towers (C- and K-Reactors)	1.3	18.4×10^{-1}	6.06×10^{-1}	3.24×10^{-1}

Table G-35. Effective Whole-Body Doses to the Maximally Exposed Individual from Cumulative Atmospheric and Liquid Releases, Comparison of Cooling Alternatives (Millirem per Year)

Cooling alternative	Adult	Teen	Child	Infant
Present cooling system	3.25	2.64	1.94	9.44×10^{-1}
Once-through cooling towers (C- and K-Reactors)	3.25	2.64	1.94	9.44×10^{-1}
Recirculating cooling towers (C- and K-Reactors)	2.49	2.06	1.69	9.39×10^{-1}

Table G-36. Comparison of 80-Kilometer Collective Dose from Increased Release of Tritium to the Atmosphere with Present Cooling Systems: Once-Through Cooling Towers for C- and K-Reactors and Recirculating Cooling Towers for C- and K-Reactors; Person-Rem per Year

Cooling alternative	Effective whole body
Present cooling systems (no action)	4.91×10^1
Once-through cooling towers	4.91×10^1
Recirculating cooling towers	4.92×10^1

Table G-37. Comparison of Collective Dose from Reduced Liquid Releases to Savannah River with Present Cooling Systems: Once-Through Cooling Towers for C- and K-Reactors and Recirculating Cooling Towers for C- and K-Reactors; Person-Rem per Year

Cooling alternative	Effective whole body
Present cooling systems (no action)	3.15×10^1
Once-through cooling towers	3.14×10^1
Recirculating cooling towers	2.87×10^1

G.5 RADIATION-INDUCED HEALTH EFFECTS

Radiation can affect human health by causing cancer, genetic disorders, and other health problems. The Committee on the Biological Effects of Ionizing Radiation (BEIR) of the National Academy of Sciences has published a detailed review of available data on radiation-induced health effects (BEIR, 1980). This report (BEIR III) uses a variety of methods and data to quantify the health impacts of low levels of radiation. Its estimates of health risk associated with radiation exposure have been used to quantify the possible changes in radiation-induced health effects that might be caused by operation of the cooling water systems; these potential health effects are discussed in Chapter 4.

Table G-38. Comparison of Collective Dose from Increased Atmospheric Releases and Reduced Liquid Releases with Present Cooling Systems: Once-Through Cooling Towers for C- and K-Reactors and Recirculating Cooling Towers for C- and K-Reactors; Person-Rem per Year

Cooling alternative	Effective whole body
Present cooling systems (no action)	8.07×10^1
Once-through cooling towers	8.05×10^1
Recirculating cooling towers	7.79×10^1

The International Commission on Radiological Protection also provides risk estimates for radiation exposure in ICRP Publication 26 (ICRP, 1977). These risk estimates for cancer mortality are generally consistent with BEIR III. The total cancer risk for all organs reported in ICRP-26 is 1.25×10^{-4} per rem, compared to 1.20×10^{-4} reported in BEIR III. However, the genetic risk estimate reported in ICRP-26 is about three times lower than that of BEIR III. BEIR III risk estimates were used in this analysis because (1) BEIR III is a more recent and comprehensive evaluation of radiation-induced health effects and (2) BEIR III results in higher estimates of total risk.

The BEIR III report identifies three categories of radiation-induced human health effects: (1) cancer, (2) genetic disorders, and (3) somatic effects other than cancer. The committee believes cancer induction is the most important effect of low-dose radiation. In this context, "low dose" refers to doses as high as a few rads per person per year. Natural background radiation ranges from 0.1 to 0.2 rad per person per year. Genetic effects of low-level radiation have been well documented and are addressed in detail in the BEIR III report. Somatic effects other than cancer include cataract induction and fertility impairment. The BEIR III report concludes that low-dose exposure of human populations does not increase the risk of somatic effects other than cancer and developmental changes in unborn children. The report also indicates that developmental changes in unborn children are probably not caused by radiation at or below natural background levels. For these reasons, only cancer and genetic disorders are considered in this analysis.

Cancer data from the Japanese survivors of atomic bomb blasts are used in most of the analyses in the BEIR III report. A major question addressed by the BEIR III report is how to extrapolate the cancer risks observed at the relatively high dose rates down to the lower dose rates caused by most nuclear facilities. The BEIR III report adopted a parametric family of functions to accomplish this extrapolation. The linear model represents an upper limit or maximum risk; the linear-quadratic model, an intermediate or probable risk;

and the quadratic model, a low-limit or minimum risk. These functions have been suggested by the report for low linear energy transfer (LET) radiation. This type of radiation includes gamma and X-radiation and electrons (beta particles). High-LET radiation includes alpha particles encountered in the decay of radionuclides in the natural uranium decay chain. The BEIR III report states that for High-LET radiation, "the linear hypothesis is less likely to lead to over estimates of risk and may, in fact, lead to underestimates." The linear model would, therefore, represent the best estimate for probable risk from this type of radiation.

One characteristic of radiation-induced cancer is that it takes a long time to develop, a period referred to as the "latent period." Leukemia has a characteristically short latent period (less than 25 years), while other cancers can have latent periods as long as the life span of an individual. Because only about 35 years of cancer data have been collected on the survivors of atomic bomb blasts, the data do not account for all the cancers that might develop because of the bombs' radiation. Two projection models have been developed to account for these future cancer deaths: (1) the absolute risk projection model, which assumes that the cancer rate (risk per year) observed since the atomic bomb blasts will continue throughout the life spans of those exposed; and (2) the relative-risk model, which assumes the excess radiation-induced risk is proportional to the natural incidence of cancer with age. The relative-risk model results in cancer-risk estimates greater than those predicted by the absolute model. However, the BEIR III report states that the absolute model is generally more applicable to most forms of cancer. The cancer-risk estimates used represent an average of those calculated using the absolute- and relative-risk models.

Only low-LET radiation is associated with the changes of radioactivity released to the environment resulting from the implementation of the alternative cooling water systems. For existing operations, the contribution of High-LET radiation has been found to be much less than that from low-LET radiation.

Health-effects estimators for low-LET radiation were derived for use in estimating health effects based on an evaluation of the data presented in the BEIR III report. The resulting health-effects estimators used in this document are summarized in Table G-39. They total 120 fatalities per million person-rem. The health-effects estimate for genetic effects used in this document is 257 genetic effects per million person-rem of radiation, received by the gonads.

These health-effects estimators are the best estimate of risk based on present data. The estimators could vary widely, depending on the models used. The low-LET estimators could range from near 0 to as high as 400 person-rem. For genetic effects, the risk estimator could range from 60 to 1100.

Table G-39. Health Effects Estimators Used in the Evaluation of Radiation Health Effects

Organ/cancer	Cancer fatalities per millirem person-rem Low-LET radiation ^{a, b}
Leukemia and bone cancer ^c	20
Lung	28
Liver	6.5
Kidney and bladder ^c	3.2
Intestinal tract ^c	5.3
Thyroid	6.9
Breast	9.8
Pancreas	7.9
Stomach	11
Other	<u>19</u>
Total	120

^aLET = linear energy transfer.

^bThe arithmetic average of the absolute and relative model values has been used. In addition, the linear-quadratic model has been assumed.

^cFor multiple organs, the health effects estimators are multiplied by the organ that produces the highest collective organ dose.

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APPENDIX H
SCOPING COMMENTS AND RESPONSES

Pursuant to the National Environmental Policy Act of 1969, the Department of Energy announced its intent to prepare an environmental impact statement on cooling-water systems for C- and K-Reactors and the D-Area coal-fired powerhouse at the Savannah River Plant in the Federal Register on July 29, 1985 (50 FR 145). The Notice of Intent solicited comments and suggestions from interested agencies, organizations, and the general public for consideration in preparing the environmental impact statement. Comments were received by mail and at a scoping meeting held in Aiken, South Carolina, on August 19, 1985. Written comments were received until August 31, 1985.

During the public comment period, 12 individuals, agencies, and organizations presented written or oral comments--two individuals provided written comments at one of the public scoping meetings and more detailed written comments following the scoping meetings. Individuals, agencies, and organizations providing comments are listed on Table H-1.

The comments received at the public scoping meeting or in writing during the public comment period are presented in Table H-2. Table H-2 also provides responses to the comments raised by individuals, agencies, and organizations on the scope of the EIS.

Table H-3 provides a summary listing of the topics contained in the comments with references to the appropriate chapters and sections of the proposed environmental impact statement outline.

Copies of the oral statements and scoping letters are available for public inspection at the DOE Public Reading Room located at the University Library, 2nd Floor, University of South Carolina, Aiken Campus, University Parkway, Aiken, South Carolina, and the Freedom of Information Reading Room, Room 1E-190, Forrestal Building, 1000 Independence Avenue, SW, Washington, DC.

Table H-1. Index of Agencies, Organizations, and Individuals Submitting Scoping Comments

Designation	Agency, organization, or individual	Page
A	Sheppard N. Moore, Chief of NEPA Review Staff for Region IV, U.S. Environmental Protection Agency	H-3
B	Bart Ruitter, representing the South Carolina Department of Health and Environmental Control	H-5
C	Mr. W. P. Bebbington	H-6
D	Frances Hart, representing the Energy Research Foundation	H-10
E	Mr. Karl Herde	H-12
F	Ms. Dorcas Elledge	H-15
G	Jean Robinson, on behalf of W. F. Lawless	H-16
H	Mr. Sam Schillaci	H-19
I	Mr. William McDaniel	H-20
J	Zoe G. Tsagos, representing the League of Women Voters in Northern Beaufort County	H-24
K	Roger L. Banks, representing the South Carolina Office of the U.S. Department of the Interior, Fish and Wildlife Service	H-26
L	J. W. Morris	H-28

Table H-2. Scoping Comments and DOE Responses

Comment number	Comments	Responses
	<p>STATEMENT OF MR. SHEPPARD MOORE Chief, NEPA Review Staff Environmental Protection Agency Region IV Atlanta, Georgia</p>	
A-1	<p>My name is Sheppard N. Moore. I'm chief of the NEPA Review Staff at Region IV, U.S. Environmental Protection Agency, Atlanta, Georgia. We at EPA are pleased to see that the Department of Energy is preparing an environmental impact statement as part of the decision-making process concerning cooling water systems at the Savannah River plant. EPA has a long history of involvement with environmental matters at SRP, and we look forward to working with DOE and the State of South Carolina during the preparation of this EIS.</p>	<p>A discussion of impacts associated with floodplain/wetlands, groundwater, and noise will be presented in Chapter 4 of the EIS. Appendix F will present a wetlands/floodplains assessment pursuant to Executive Orders 11988 and 11990, and DOE's regulations for compliance with floodplain/wetlands environmental review requirements (10 CFR 1022).</p>
A-2	<p>Relevant to the proposed EIS, EPA believes that the environmental and nonenvironmental issues identified by DOE in their news announcement dated July 29th, 1985 for this EIS are important. Of the issues listed by DOE, EPA is particularly concerned with potential wetland impacts, water quality issues, and radionuclide effects as well as fishery implications, air quality, drinking water quality, and the cumulative effects. Recommended additions to the DOE list are possible floodplain, groundwater, and noise impacts.</p>	<p>Wetland acreage that will be gained or lost will be quantified and characterized for each cooling water alternative in Chapter 4 and Appendix F of the EIS.</p>
A-3	<p>Since one of our major concerns at EPA is the protection of wetlands, we wish to emphasize that any wetland acreage that may be lost should be quantified and characterized for each action alternative. Avoidance of impacts and mitigation for unavoidable impacts should be addressed for wetlands as well as other areas.</p>	<p>Chapter 4 of the EIS will discuss the environmental impacts of the reasonable cooling water alternatives for the C-Reactor, K-Reactor, and the D-Area coal-fired powerhouse. In addition, the no-action alternative will also be addressed.</p>
	<p>We appreciate the numerous alternatives considered by DOE for the cooling effluent of C- and K-Reactors and the D-Area coal-fired power plant. In our view, at least two and preferably three feasible action alternatives should be addressed in the EIS in similar detail for each facility so that the EIS will be a decisionmaking document and a final preferred alternative can be selected. Similarly, the no-action alternative should be thoroughly addressed.</p>	
	<p>I appreciate the opportunity to be here. I guess my main purpose is to hear what you and the others have to say. Thank you.</p>	

Table H-2. Scoping Comments and DOE Responses

Responses

Comments

Comment
number

ADDITIONAL STATEMENTS OF MR. MOORE
EVENING PUBLIC SCOPING MEETING

Since I spoke this morning and gave you a copy of my written statement, I won't repeat that. I do want to say for the people that are here this evening that were not here this morning that I appreciate the opportunity to be here. I want to thank you for inviting EPA and the State to participate in this meeting.

I would like to add one thing to what Pat had to say about the slide on NEPA. It's true that NEPA requires that the Federal decisionmakers factor the environment into their decision-making process, but I think the really important benefit from NEPA is the public involvement.

I'm a little disappointed at the number of people here tonight, and I would like to encourage anyone that is here that has something to say that from experience, I can say that government does listen to what people say. That's what NEPA has done for us is provided the mechanism for public involvement and how we, the government, carry out their business.

Table H-2. Scoping Comments and DOE Responses

Comment number	Comments	Responses
	<p style="text-align: center;">STATEMENT OF MR. BART RUITER SOUTH CAROLINA DEPARTMENT OF HEALTH AND ENVIRONMENTAL CONTROL</p> <p>My name is Bart Ruitter. I am with the Department of Health and Environmental Control.</p> <p>On January 3, 1984, the South Carolina Department of Health and Environmental Control entered into a Consent Order with the United States Department of Energy Savannah River Plant. This Consent Order allowed the Savannah River Plant Temperature Requirements in the National Pollutant Discharge Elimination System (NPDES) permit to be temporarily superseded by those requirements contained in the Order. Outfalls affected by this Order are specifically C-Reactor, P-Reactor, K-Reactor, and D-Area powerhouse.</p> <p>In this Consent Order, SRP agreed to, one, complete comprehensive studies on the thermal effects of all operations at the Savannah River Plant upon the waters of the State of South Carolina; two, complete and submit the thermal mitigation studies to DHEC within nine months of the signing of the Consent Order; three, implement the alternative approved by DHEC under a schedule to be established by DHEC in a subsequent order; and four, submit and actively support appropriate funding requests to accomplish any actions resulting from the thermal studies.</p> <p>To date, we are currently near completion in establishing an implementation schedule under an amendment to the Consent Order with SRP which takes into account the National Environmental Policy Act process.</p>	
B-1	<p>As SRP proceeds through this NEPA process and eventually selects a final alternative for the mitigation of thermal restrictions on the above outfalls, the selected alternatives for C-Reactor, K-Reactor, P-Reactor, and D-Area powerhouse must meet the specified limitations of the NPDES permit and/or temperature limits that are consistent with the requirements or intent of the Clean Water Act and the South Carolina Water Classifications and Standards.</p>	<p>The ability of each of the cooling water alternatives considered in the EIS to meet applicable regulatory requirements will be discussed in Chapters 2 and 4.</p>

Thank you for allowing the Department to express its comments.

Table H-2. Scoping Comments and DOE Responses

Responses

Comment number

Comments

STATEMENT OF MR. W. M. P. BEBBINGTON

Comments noted.

I have submitted a letter containing more specific comments than I intend to make here. I wish, now, to direct the attention of the audience and the other participants to some important general facts regarding the Savannah River Plant and its history.

The 200,000-acre site was purchased with taxpayers' money in 1950 to ensure that the public would be adequately protected from possible harm from the nuclear operations within the site and that there would be adequate protection of the operations against incursions.

It was recognized at the outset that, while the operators could and would be expected to hold releases of radioactive and other undesirable wastes to levels that were as low as practical, very large amounts of heat would necessarily be discharged from the reactors. The heat would be released as heated water, and the Savannah River had to be protected against biological damage from it. By placing the reactors near the center of the site and allowing the water to flow to the river through the beds of existing small streams, the temperature of the water, when it entered the river, would be low enough to preclude damage.

To verify that there was no thermal damage to the river, Dr. Ruth Patrick and her team of limnologists from the Academy of Natural Sciences of Philadelphia were commissioned to determine exactly and comprehensively the condition of the river before plant startup and to monitor it carefully for changes while the plant operated. Dr. Patrick has stated repeatedly and unequivocally that thermal effluents from SRP have had no adverse effects on the river.

The streams that carry reactor cooling water to the river are small, rise on the site, and have no significant economic, recreational, or unique ecological values. The hot water has destroyed vegetation and discouraged animal life; but, as was demonstrated in Steel Creek after L-Reactor was shut down, the damage is not permanent.

Most of the land of the site is outside the restricted production areas. This land has not been neglected and allowed to deteriorate. Hundreds of millions of trees were planted and

Table H-2. Scoping Comments and DOE Responses

Comment number	Comments	Responses
	<p>managed as a productive forest. The University of Georgia established there a field laboratory of ecology under the overall direction of Dr. Eugene P. Odum, one of the nation's most revered ecologists. Later, the site was designated as the first National Environmental Research Park. It has attracted students and faculty from many universities for summer and longer residences. A former director of the Savannah River Ecology Laboratory said, "If it hadn't been for AEC support, there wouldn't be a science of ecology." The well-protected site has become an important wildlife refuge.</p>	
	<p>After three decades of plant operation without public harm and with great ecological benefit, the State of South Carolina has intruded with costly, unnecessary, and indeed environmentally detrimental demands that can be met only at great public expense at a time when there is a terribly urgent need to reduce the federal deficit.</p>	
	<p>The cost of the L-Reactor lake project will not be 25 or 40 million dollars but, when delay times and productivity losses are taken into account, in the hundreds of millions of dollars. The reactor will never again operate as efficiently as it once did because the State has demanded that the cooling lake not be treated as such but as a natural recreational lake. This hearing is the beginning of proceedings aimed at applying to C- and K-Reactors and to the D-Area coal-fired powerhouse similarly costly and unnecessary changes.</p>	
		<p>I ask the State of South Carolina, in the interest of responsible concern for the American people, to withdraw its demands and allow SRP to continue its efficient, safe and environmentally benign operations. Failing this, I ask the Department of Energy to take no action as its decision and defend it vigorously up through the courts, if necessary.</p> <p>Thank you very much.</p>

Table H-2. Scoping Comments and DOE Responses

Responses

Comment number

Comments

Responses

LETTER FROM MR. W. B. BEBBINGTON
Thank you for the opportunity to comment on the "Scoping of an Environmental Impact Statement on cooling-water systems at the Savannah River Plant."

It should be recognized at the outset that the important issues under consideration, here, are political and bureaucratic not environmental. There is, in the document [6450-01] that defines the purpose of the August 19 public meeting, no reference to past, present or potential future harm to the environment surrounding SRP caused by operations within it. The absence of such harmful effects has been documented in public reports of comprehensive routine and special scientific monitoring over the past quarter century of the plant's existence.

In 1950 about 200,000 acres of land was purchased by the United States government on which to build the Savannah River Plant. The large site was acquired to provide isolation of the production facilities and to ensure that those facilities would not harmfully affect surrounding private lands, and most importantly, not damage biologically the Savannah River. Accordingly, the facilities of greatest environmental concern, the reactors and separations plants, were sited near the center of the plant, several miles from the river and the boundary fences. The channels of insignificant streams that rise within the plant, streams that were not then, are not now, will not be in the future of any economic, recreational or unique ecological importance, were used to convey reactor cooling water to the river. The river was seen to be the most important natural resource that might be vulnerable to harm, and the Academy of Natural Sciences of Philadelphia under the direction of eminent Limnologist, Dr. Ruth Patrick, was commissioned in 1951, years before plant startup, to monitor comprehensively the biological condition of the river. The work of ANSP continues, today, and Dr. Patrick has repeatedly and unequivocally stated that there has been no biological damage from the thermal effluents of SRP. Vegetation in the streambeds was damaged, to be sure, but not irrevocably as was shown by the recovery of Steele Creek during the years that L-Reactor was shut down.

The matters with which we are now concerned stem from the actions taken to refurbish and restart L-Reactor at SRP as au-

Table H-2. Scoping Comments and DOE Responses

Comment number	Comments	Responses
	<p>thorized by Congress in 1980. Operation of the reactor was declared necessary by October 1983 to meet the needs of national defense. The Department of Energy was obliged to meet this goal. The reactor was rehabilitated and brought up to the technological state of the other operating reactors with the intent to operate it as it had operated for fourteen years, previously, and as two other reactors, K and C, were continuing to operate. Near the end of 1982, anti-nuclear activist groups abetted by State officials instigated a succession of delays and ultimately, through a bit of Congressional trickery, the requirement that the cooling water from L-Reactor be passed through a new 1000-acre lake enroute to the Savannah River. Ostensibly, this lake was to forestall damage to "wetlands;" in fact it will permanently inundate most of the area of concern and destroy much productive forest in addition. The direct cost of the lake was to have been \$25 million, but has risen to \$40 million. The overall addition to the national deficit and cost to the taxpayers, taking into account delays, interest charges and permanent productivity losses will be in the hundreds of millions of dollars, with, on balance, a detrimental environmental effect. If the reactor starts up in October, as <u>TS now hopes, it will have been delayed two years.</u></p>	
	<p>With regard to C and K reactors and the D-Area coal-fired power house, we are now at the point where the L-Reactor fiasco began more than three years ago. No existing environmental harm is alleged, only the need to comply with a "Consent Order" dated January 3, 1984, three decades after the beginning of safe, efficient and environmentally harmless operation of safe, efficient and environmentally harmless operation of SRP. We taxpayers need to be protected against the squandering of more hundreds of millions of dollars merely to enhance the egos or further the special interests of politicians and activists.</p>	
	<p>It is stated on page 7 of the notice of this meeting that, "As required by the Council on Environmental Quality regulations for implementing the National Environmental Policy Act, the EIS will also consider 'no action.'" I urge that "no action" be given first consideration and that the matter be shelved without even the preparation of another redundant, unnecessary and costly Environmental Impact Statement.</p>	

Table H-2. Scoping Comments and DOE Responses

Responses

Comments

Comment number

STATEMENT OF MS. FRANCES HART
ENERGY RESEARCH FOUNDATION

I am Frances Hart, and I represent the Energy Research Foundation. We appreciate the opportunity to address this hearing on the subject of the scope of the proposed environmental impact statement concerning cooling water systems for thermal discharges from the C- and K-Reactors and from the D-Area coal-fired power plant.

The issue of environmental impacts of cooling water systems at SRP was discussed and analyzed at length as part of this NPDES permit reissuance process which began in 1982 and during the L-Reactor EIS process.

A permit demanding compliance of the Clean Water Act requirements was issued by DHEC for SRP's operating reactors in January of 1984, along with the Consent Order allowing the continuation of direct discharge of cooling water for an unspecified time. DOE was required to prepare a comprehensive study of the impacts of thermal discharges and recommend alternative systems which would comply with the Clean Water Act.

Nearly a year ago, in October of 1984, DOE published this report called "Thermal Mitigation Study, Compliance with the Federal and South Carolina Water Quality Standards," which analyzed various cooling water options. We reviewed that report and believe that recirculating mechanical draft cooling towers and once-through mechanical draft cooling towers with holding pond systems -- these are alternatives C-4, C-5, K-5, and K-6 -- would be acceptable for C- and K-Reactors. Although DOE is required to analyze all reasonable options during the EIS process, we would urge that any option chosen provide at least as much environmental protection as do these options.

It may not have been clear as early as 1981, when these original NPDES permits for the operating reactors at SRP expired, that new cooling water systems would have to be installed. When this necessity must have become obvious soon thereafter when negotiations with DHEC over new permits began, and South Carolina's Attorney General ruled that SRP's streams were part of the state.

Table H-2. Scoping Comments and DOE Responses

Comment number	Comments	Responses
D-1	<p>It is unfortunate that the EIS process was not begun at that time and that these years have passed without implementation of some sort of mitigation. Beginning the EIS process now has the obvious side effect of delaying still further the long-awaited cooling systems. We believe that complying with the National Environmental Policy Act is a valuable objective and, therefore, that the delay is perhaps warranted, even at this late date.</p> <p>However, because it seems unlikely that substantive new information will be generated during further study of possible alternatives beyond that already offered in the L-Reactor EIS and NPDIS comments, we would urge that the preparation of this particular environmental impact statement be expedited as much as is possible within the law, given the substantial information and public comments already generated in these other related processes.</p>	<p>The Department of Energy will expedite the preparation of the EIS to the extent permitted by its regulations for implementing the procedural provisions of the National Environmental Policy Act.</p>
D-2	<p>The EIS is designed to play an integral role in the decision-making process, a role which cannot be very meaningful after the fact. Hopefully, DOE will initiate the EIS process at the beginning of future projects as the law requires, rather than after extensive study has taken place and time has elapsed, to ensure that the process itself can be meaningful and that timely compliance with other legal requirements will be possible.</p>	<p>The preparation and completion of the Thermal Mitigation Study and Comprehensive Cooling Water Study were undertaken by the Department of Energy in fulfillment and compliance with the Memorandum of Understanding and Consent Order with the State of South Carolina. The Department of Energy is currently undertaking the preparation of the environmental impact statement to fulfill its requirements pursuant to the National Environmental Policy Act--as identified in the current Consent Order with the South Carolina Department of Health and Environmental Control--in attaining compliance with South Carolina's Class B water classification standards.</p>

Thank you.

Table H-2. Scoping Comments and DOE Responses

Responses

Comment number	Comments	Responses
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STATEMENT OF MR. KARL HERDE

I am retired from the Atomic Energy Commission. I retired five years ago. I came here in 1951 as the first environmentalist for the Atomic Energy Commission. I served 23 years in that capacity; and, during that time, the emphasis always with the Atomic Energy Commission was with regard to the taxpayers' dollars.

As a guardian of the taxpayers' dollars and a taxpayer myself, along with the few hundred million other taxpayers, I would like to say that we have had enough. The costs are just unjustified.

I am also a member of the Antique Automobile Association of America. We have a motto there for antique cars: If they are not broke, don't fix them.

Experience has proven that there is nothing wrong with the way the reactors have been operated out there at the Savannah River Plant. I want to completely endorse my friend Mr. Bebbington on what he just said in the second talk ahead of this one.

I'm an environmental biologist by training and experience. I started my biological work with the Atomic Energy Commission back actually with Du Pont at the Hanford plant in the State of Washington. There, I was a group leader in environmental biology for five years before coming here. When I came here, I came by way of Washington, in which they very definitely gave me the indoctrination that we are guardians of the taxpayers' dollars.

We are to see that every dollar spent of government money is to get just as much value out of it as if it were our own dollars. That theory still should exist. I'm afraid it doesn't. We are willing to help build up the deficit by requiring costs that are unjustified.

Earlier, we built nine big plants and completed the plants roughly in a square-mile area for less than 3 billion dollars. We have not come close to that now. Our liaison negotiations with the contractor, the Du Pont Company, were every thousand dollars that we could save was a thousand dollars earned for the government. Every \$100,000 was that much more.

Table H-2. Scoping Comments and DOE Responses

Comment number	Comments	Responses
	<p>As an environmentalist, we look toward saving dollars. I still think that that should be the utmost concern in the plan and method of our Department of Energy.</p>	
	<p>I have my reservations, but I think I should make this statement. I actually hope that our Congressmen are smart enough that they won't allow this expenditure. I know that the plant needs to go on and I know, from a biology standpoint, we need to be safe; but I'm an environmentalist. I am not a lobbyist. I am not an activist, but I certainly want the environment to be kept intact.</p>	
	<p>Our authority back in the early days was respected authority. The three main authorities we had were the Reactor Safeguard Committee, the National Academy of Science, and the International Commission on Radiation Protection. We met the standards of those three organizations. We were doing a good job. Those three organizations are all made up of men of prestige. There were not would-be environmentalists, self-made environmentalists, in the group. They were all college-trained and college-experienced people, and those three organizations guided our destiny and guided well.</p>	
	<p>Using our minor tributaries and streams was regarded by people who were looking after the taxpayers' dollars as good business, as good logic, as good empirical use of the streams. Our empirical experience over the past 30 years has proven that theory to be right. It's just as right now as it ever was.</p>	
	<p>The streams have adjusted to the higher temperature, and so change them now is rather futile. One thing about the stream, though, a stream has its own capacity to restore itself.</p>	
	<p>It doesn't need the restoration, the decontamination, and so forth that a cooling tower is going to take. A cooling tower can become a sight in the environment.</p>	
	<p>I would like for some of you to take a trip up on the upper part of the Ohio River up in the region of West Virginia and Pennsylvania. Look along that river. There are a bunch of old, rusty monsters, towers, cooling towers, that have been completely abandoned and have been left there to become a part of the environment. I don't like that kind of an environment. I don't want to see that kind of environment on our Savannah River.</p>	

Table H-2. Scoping Comments and DOE Responses

Comment number	Comments	Responses
E-1	<p>I think we know that our streams will clean up themselves and will become fertile and productive biological streams within two or three years. In a very few years, a stream will produce good fishing again without any effort on the part of man. All he has to do is let mother nature take over.</p> <p>I want to say the pond costs us 40 million dollars and is killing off every species, every plant and animal species, of that thousand acres of land to save or maybe better the environment of one or two individual species. If that makes sense, I'm crazy.</p>	<p>Chapter 2 and Chapter 4 of the EIS will present and discuss both adverse and beneficial impacts of the cooling water alternatives considered.</p>

Table H-2. Scoping Comments and DOE Responses

Comment number	Comments	Responses
	STATEMENT OF MS. DORCAS ELLEDGE	
	<p>I appreciate the opportunity to say a few words to you. I have been to many of the meetings concerning the L-Reactor and read as much as I could understand of the books relating to that.</p>	
	<p>I still compliment the Department of Energy for doing something about the L-Reactor, a better way than putting scalding water in a stream that would have destroyed life. I don't know the best way. I'm not an engineer, as I've said before.</p>	
	<p>I don't know the best way to cool the water and to restore life to these streams that have been killed by the scalding waters from the reactors now in operation. But I do feel that it is an obligation of the Department of Energy and any governmental agency to protect life as we know it on earth.</p>	
	<p>To do less and to do nothing in this case will eventually affect our life, and it might well put South Carolinians and Georgians and anyone else visiting this state on the endangered species list.</p>	
	<p>I do feel that South Carolina citizens and Georgians and all those affected by the operation of the Savannah River Plant deserve protection, equal protection, with all citizens in the United States.</p>	
	<p>I believe we make nuclear weapons to protect our safety. I believe the obligation also in the making of them is paramount with the United States Government.</p>	
F-1	<p>And I do urge you to pick the best solution to the problem that DHEC has required of you. To do nothing doesn't sound like a solution to me, and that is one of the alternatives.</p>	<p>The consideration in the EIS of "No Action" is required pursuant to regulations of the Council on Environmental Quality for Implementing the procedural provisions of the National Environmental Policy Act (40 CFR 1500-1508).</p>
	<p>And I thank you very much.</p>	

Table H-2. Scoping Comments and DOE Responses

Comment number	Comments	Responses
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STATEMENT OF MS. JEAN ROBINSON
ON BEHALF OF M. F. LAWLESS

My name is Jean Robinson. I'm presenting a statement for Professor M. F. Lawless who had to be out of town at this time. Professor Lawless is at Paine College in Augusta, SRP Georgia. The statement is entitled Scoping Comments on SRP Cooling Water Systems EIS.

General Comments

To proceed with some general comments, the Department of Energy should be commended for asking for public scoping comments on the proposed Savannah River Plant cooling water systems environmental impact statement. Compared to the recent public environmental impact statement, Carolina DHEC and SRP, where in DHEC had cited SRP for groundwater violations, and as well to past coverups of SRP reports by the Department of Energy, it's always refreshing to have government business conducted in the open. However, as important as this is, it can be significantly improved.

G-1

H-16

As required by the regulations of the Council on Environmental Quality (40 CFR 1502.19), copies of the draft EIS will be provided to Federal and State agencies having special expertise with respect to any environmental impact that may be involved.

The public does not have the technical capability nor the time to adequately explore nor keep track of the rather abstruse scientific studies of the environmental interactions and alternatives explored in this new environmental impact statement. That the public knows of, there are two such SRP environmental impact statements now underway.

A publicly funded peer review committee should be created, using regional scientific and political talent, as a means of safeguarding the public's interest. Both DHEC and DOE, by their nature as political bureaucratic institutions, have more than enough administrative chores to worry about as it is, and an independent peer review panel would appropriately monitor scientific reports and construction projects with the rigor that escapes bureaucracies. If a peer review panel prevents the necessity of another 60-million-dollar clean-up basin that now being spent to clean up the M-Area seepage basin in Lasco, such a peer review panel could easily afford to attract talented participants.

The public deserves more than playing DHEC against DOE to protect its interests and the environment. As the technological advances increase, an independent scientific peer review panel

Table H-2. Scoping Comments and DOE Responses

Comment number	Comments	Responses
	<p>for the Savannah River Plant will add flexibility, improve technological solutions, and reduce the opportunity for environmental impacts, mistakes, and ineptitude. This technique has worked well with the NASA bureaucracy, and landed Americans on the moon. On the other hand, without peer review panels, the SRP has given us not only the M-Area seepage basin, but 67 other seepage basins at the Plant at well.</p>	
	<p><u>Specific Comments</u></p>	
G-2	<p>1. The DOE has not yet responded to information provided at the last Public Scoping Meeting on the reported statistically significant differences between strontium-90 concentrations found in milk around the SRP plant compared to the Southeastern average concentration of strontium-90 in milk.</p>	<p>Responses to comments received during the scoping period for the preparation of the environmental impact statement on waste management activities for groundwater protection will be included in that environmental impact statement.</p>
G-3	<p>2. The new EIS should consider treatment of the cooling water before it is released back to the environment.</p>	<p>The effluent from the cooling systems considered in the EIS will meet the State of South Carolina's Class B water classification standards. The effluent is expected to be similar to the water quality of the Savannah River, and other than for reduction of temperature, treatment of the cooling water will not be required. Water quality impacts of the alternatives will be assessed in Chapter 4 of the EIS.</p>
G-4	<p>3. Water quality analyses of water released into the environment from C- and K-Reactors and the D-Area coal-fired power plant should be published and compared to EPA drinking water standards. The D-Area basin overflow and outfall water quality characteristics should also be provided.</p>	
G-5	<p>4. The D-Area power plant air quality at the release point from its cooling tower should be included in the new EIS.</p>	<p>Air quality impacts of the alternatives for the D-Area powerhouse will be described in Chapter 4 of the EIS.</p>
G-6	<p>5. P-Reactor effluent, that is, thermal, water quality, air stream quality characteristics should be included in the new EIS. Also, a biological community comparison to Par Pond with a comparable sized pond to Par Pond should be made and included. An aquifer water quality analysis of water under Par Pond should be made and included in the proposed EIS.</p>	<p>A discussion of P-Reactor effluent and Par Pond is not within the scope of this EIS as discussed in the <u>Federal Register</u> notice announcing the preparation of the EIS.</p>
G-7	<p>6. The South Carolina DHEC and DOE March 1985 agreement suggests the continued use of a raw water basin at the D-Area power plant. The advantages of having a lined basin and an unlined basin, as well as RCRA compliance, should be discussed in the new EIS for this basin and for the ponds at C- and K-Reactors.</p>	<p>The use of the raw water basin at the D-Area powerhouse does not involve hazardous waste; therefore, a discussion of having lined basins and compliance with RCRA is not an appropriate topic for inclusion in the EIS.</p>

Table H-2. Scoping Comments and DOE Responses

Comment number	Comments	Responses
G-8	7. Water quality characteristics of the cooling water at its source should be provided. Coolant waste system diagrams and effluent system diagrams should be provided. Well construction and closure information as necessary should be provided.	Chapter 3 of the EIS will describe the existing surface water hydrology and water quality of the streams that would be affected by the alternative cooling water systems. Also see the response to comment G-3. If well closures should be required due to construction of the alternative cooling-water systems, the closure wells will be discussed in the EIS.
G-9	8. Cooling water tower effluent characteristics at the release point should be provided.	See the response to comment G-3.
G-10	9. All mathematical models should be detailed, statistical techniques discussed, and validation of all models, equations, or techniques discussed. Thank you very much. That concludes his statement. And he wanted to let you know that he would be glad to submit a final copy by the 31st but wishes to make you copies of this because of some typographical errors.	Appendix B of the EIS and its referenced documents will discuss the models, assumptions, and validation of models used in the preparation of the EIS.
G-11	10. Airborne releases, including levels of dioxin, from the Beta-Gamma Incinerator (BGI) at the point of release should be quantified and reported. Provide calculated and actual release data, from the point of release, for each waste category, matching the BGI INCINERATOR burn loads to normalize the predicted with actual data.	A discussion of airborne releases from the Beta-Gamma Incinerator is outside the scope of this EIS.
G-12	11. The two high level radioactive waste (HLW) corrosion pitting reports (L-Reactor EIS, P. M 113-114) did not discuss corrosion pitting in HLW tanks 25-28. These 4 HLW tanks were not treated for corrosion pitting as were HLW tanks 38-51 since HLW tanks 25-28 were already radioactive when the corrosion pitting was discovered in the 14 HLW tanks completed later. Provide a corrosion pitting status report on HLW tanks 25-28 performance, and compare to the last 14 HLW tanks at SRP (tanks 38-51) that went into radioactive waste service after remedial action for corrosion pitting.	A discussion of high-level waste is outside the scope of this EIS.

Table H-2. Scoping Comments and DOE Responses

Comment number	Comments	Responses
	<p>STATEMENT OF MR. SAM SCHILLACI</p> <p>I've been studying the Savannah River Plant for a long time, and I've got a good plan for its survival. I'm a former employee also with ten years of service with the Department of Energy. I had some mental problems because of stress, so the government "retired me." The stress was brought on because I didn't like all the waste, fraud, and abuse out there. But they dumped me in a hurry. For six months after they dumped me I went without a salary or any means of support. I had a lot of time to think, do things I've never done before, drink a lot, write, which I thoroughly enjoy, even though my grammar ain't so hot.</p> <p>Now, my plan for DOE is simple. It's the same (expletive deleted) plan I had. Set all the DOE employees, and hopefully all the government employees, free at a certain, hopefully surprise, moment. They all go home for five months without leave or salary. They could think, read, do anything they want to. They could grind and gnash their teeth if they want to. And at the end of the five-month period -- notice that I give them a little less time than I had; I'm lenient -- the ones that haven't done themselves in could come back and determine if those cooling ponds or whatever is needed out there at SRP. Let them think a little more. Now, if the government employees do that, I think the whole public sector would probably do the same thing. Just think of all the fun that we could have. 1929 all over again.</p> <p>Mr. Herde, you probably remember him. That's probably why he has grayer hair and his voice has a little more common sense in his tone of voice. And just think of all the neat movie stuff of 1929. Back to the future.</p> <p>Anyway, I'm not anti or pro nuclear or anything; I'm just pro myself, pro my God, which is different from your God, and a survivor. I hope more become self-reliant, learn to fight rather than this (expletive deleted) love we have now, and learn that the best plan is no plan. I will also shut up my mouth for a half million dollars, passage to New Zealand, and permanent silence to the Will Rogers Institute.</p> <p>After five months I hope the hot water is used for enemas for anybody who wants it. Thank you.</p>	<p>Comments noted.</p>

Table H-2. Scoping Comments and DOE Responses

Responses

Comment number

Comments

STATEMENT OF MR. WILLIAM McDANIEL

I have no written speech with me, but I do have a part of a tape that I would like to play. Of course, you can have a copy of the tape.

I think you are escalating out of control as far as reactors are concerned. This has very little bearing, I realize this, on the coolant system that you have here as far as water going back into the creeks and rivers and so on. I would like to play as much of this tape as I can. I appreciate this opportunity.

(Mr. McDaniel began playing the tape.)

Forbes, the magazine that calls itself a capitalist tool, last month proclaimed on its cover the failure of the U.S. Nuclear Power program ranked as the largest managerial disaster in business history. Forbes pointed out that we spent more on nuclear power than we did on the space program or the Vietnam War, and the magazine says, "Only the blind or the biased can now think that most of the money has been well spent."

Well, that's something that Amory and Hunter Lovins have been saying for years. They are husband and wife who put their energies together to create a vision of a non-nuclear energy future.

"Who would have guessed that a beer-drinking, country-music-loving cowboy would team up with a scrawny, four-eyed, physicist?"

The physicist and the cowboy, she is also a lawyer and political scientist, were married in 1979. They began traveling around the world, as Amory says, "Cross-pollinating the energy grapevine." They wrote books and consulted for governments and businesses in 15 countries.

They contend that the new nuclear plants will turn out more electricity than we really need at a cost no one can afford and that the money the utility companies spend on those plants would be better spent on helping the country become more energy-efficient. In other words, use the money to help make homes, factories, and office buildings do the same work with less energy. Then everybody is a winner. The answer can be as

Table H-2. Scoping Comments and DOE Responses

Comment number	Comments	Responses
	<p>simple as installing better windows, designing better buildings and appliances.</p>	
	<p>At their home and research institute in Old Snowmass, Colorado, Amory and Hunter Lovins live their state-of-the-art ideas for saving energy. They built a 4,000-square-foot home, office, and indoor farm that takes the simple idea of a solar greenhouse and makes use of it on a grand scale. The 16-inch-thick curving walls provide more insulation than most people's roofs. The Lovins moved into the still-unfinished structure in January 1984. Soon after, they published a visitors' guide. More than 2600 people from around the world have to come to see their house.</p>	
	<p>"This is the space we donate as the headquarters of our non-profit group, Rocky Mountain Institute, where we and about a dozen colleagues try to foster the official use of resources."</p>	
	<p>Amory and Hunter Lovins use electricity for those things it does best. "Using nuclear power to heat a house," Amory Lovins has said, "is like cutting butter with a chain saw." Passive solar design, even at an altitude of 7100 feet in the Rocky Mountains, allows the Lovins to heat with sunlight year-round.</p>	
	<p>"This is the greenhouse?"</p>	
	<p>"No. This is basically the furnace of the house. These windows are, I think, the most advanced in commercial use anywhere. They insulate twice as well as typical shades and cost less. There is an invisibly thin film of plastic with special high-tech coatings on it which let the light in but don't let the heat get out, and then we fill up the space around that heat-mirror form with argon gas which insulates better than air."</p>	
	<p>"Design with nature," say the Lovins, who would have built differently in a different climate; but some of their basic design elements are just common sense. If you insulate more, you have to heat or cool less.</p>	
	<p>"There is about yea much polyurethane foam up on the roof, and there is 4 inches of it in the middle of the walls. Just (knocking sound) like that, and the house is also darn near airtight. We then laid it through what are called air-to-air heat exchangers."</p>	

Table H-2. Scoping Comments and DOE Responses

Comment number	Comments	Responses
	<p>In all over the house, they have energy-efficient light bulbs.</p> <p>"It's an 18-watt bulb that screws into a regular socket and gives the same amount of light as a regular 75-watt bulb, so it's four times as efficient, lasts about thirteen times as long, and I think gives better light. It isn't a fluorescent folded up in there."</p> <p>The bulbs currently retail for \$18 to \$25 each. They are just coming onto the American market. Lovins, critics say that the bulbs are too expensive, won't fit in many home lighting fixtures, and are better for commercial lighting because they don't give full light instantly. Lovins also sees the benefits of commercial use, but he is not bothered by the warm-up time. He believes the price will come down and that the fixture problems will be solved.</p> <p>(Mr. McDaniel stopped playing the tape)</p> <p>I'm a member of two different groups, ecology groups. Of course, I'm a public citizen. The point I'm trying to get across is that, as I have stated here when I first came up here, things, in my opinion, are escalating out of proportion. Sometimes I think we should try to go back and erase the board and start all over, but then that cannot be done.</p> <p>I am still opposed to any type of radiation in regards to how high a level or how low a level it is, and I know we have certain amounts of radiation naturally. I think we have 82 percent of the oxygen that comes out of the Amazon Rivers in the New Guinea. But you add radiation onto x-rays that a person has had and nature itself, and then you are doubling and tripling it.</p> <p>The thing that bothers me most, which I see from research, is it's a mortality. You know the group I'm with. This is a research committee. It's a citizens committee, and now we have taken a survey on mortality and cancer. I was so shocked when it went through my neighborhood. At least one or both people have died from cancer of some sort or the other, and the people around us are dying. I live on 2910 Carolina Avenue. Other members of this same group --</p>	<p>A discussion of the existing radiation environment at and in the Savannah River Plant Region will be presented in Chapter 3 of the EIS. Chapter 4 of the EIS will discuss the radiological impacts the cooling water alternatives considered.</p>

Table H-2. Scoping Comments and DOE Responses

Comment number	Comments	Responses
	<p>(Mr. McDaniel's time for making his presentation expired)</p> <p>Thank you. I appreciate it very much. I will see that you get a copy of the tape.</p>	

Comment number	Comments	Responses
J-1	<p>STATEMENT OF ZOE G. ISAGOS LEAGUE OF WOMEN VOTERS OF NOTRHERN BEAUFORT COUNTY</p> <p>The League of Women Voters of Northern Beaufort County appreciates this opportunity to participate, by our comments, in the preparation of an EIS on the type of cooling-water systems to be used for the C- and K- Reactors and the D-Area coal-fired power plant at the SRP.</p> <p>It is our understanding that a conditional National Pollutant Discharge Elimination System (NPDES) permit was issued to DOE for SRP by SCDHEC in January 1984. Compliance with NPDES provisions rests upon the issuance of an EIS which will note the environmental impact of thermal discharges from the above mentioned reactors and power plant and will outline the means proposed to mitigate the high temperature flow by the use of cooling systems so that the 90°F required by law can be attained before it reaches the Savannah River.</p> <p>Inasmuch as SCDHEC, according to the DOE statement on page 5 of the "Intent to Prepare an Environmental Impact Statement" document [6450-01] which we have received, has accepted either a cooling water system of "once-through cooling towers for C- and K-Reactors" or "recirculating cooling towers" as satisfying NPDES provisions, we support this SCDHEC position. We hope that DOE and SCDHEC will work towards whatever method is environmentally safest in thermal effluent management. An expedited EIS will help to bring this about with the least loss of time.</p>	See the response to comment D-1.
J-2	<p>We agree with Ms. Frances Hart in her presentation for the Energy Research Foundation at the August 19 DOE hearing in Aiken where she stated that if an alternative method is chosen, it should provide "at least as much environmental protection" as the SCDHEC acceptable cooling methods as presented above.</p> <p>We in Beaufort are as concerned as we have ever been about the quality of our drinking water which has as its source the Savannah River. We shall read with great interest the EIS analysis of "Environmental Issues" (p. 9) numbers: 6. "Radio-nuclide remobilization" and 9. "Cumulative thermal effects." Both changes can have an impact on the quality of downstream drinking water.</p> <p>In conclusion, we urge DOE to continue holding hearings in Beaufort as well as Aiken. The number of people attending any</p>	Radionuclide remobilization and cumulative thermal effects will be assessed in Chapter 4 of the EIS for the cooling water alternatives.

Table H-2. Scoping Comments and DOE Responses

Comment number	Comments	Responses
	<p>one hearing has varied; this is perhaps also true of Aiken. Because the decisions reached and changes made at SRP are of great environmental importance to us here, we must continue to be involved and to actively participate in hearings held in Beaufort.</p>	<p>Please include this submission in the Scoping Record.</p>

Table H-2. Scoping Comments and DOE Responses

Comment number	Comments	Responses
K-1	<p>STATEMENT OF ROGER L. BANKS U.S. DEPARTMENT OF THE INTERIOR FISH AND WILDLIFE SERVICE</p> <p>We have reviewed the above-referenced notice as presented in the Federal Register on July 29, 1985. The following comments are provided to you in accordance with the Fish and Wildlife Coordination Act and are intended to assist you during the preparation of the EIS.</p> <p>The environmental issues identified in the Register that you intend to analyze during the preparation of the EIS appear generally inclusive of the fish and wildlife resource issues of concern to the Service. It appears likely at this early stage in project planning that significant beneficial effects on wetland fish and wildlife resources will likely result from installation of the proposed cooling water alternatives. It also appears probable that significant adverse effects may result from siting of the cooling towers, holding ponds, and ancillary facilities.</p>	<p>The potential environmental effects resulting from the location of cooling water systems and ancillary facilities will be discussed in Chapter 4 of the EIS.</p>
K-2	<p>We would like to see the following issues emphasized and the extent of their probable effects quantified during subsequent studies:</p> <ol style="list-style-type: none">1. The effects of reduced thermal effluents on fish and wildlife resources in the receiving streams and contiguous wetland habitats.2. A comparison of habitat impacts resultant from alternative facilities siting plans.3. Impingement and entrainment effects on fishery resources resultant from alternative plans.	<p>Chapter 4 of the EIS will present the environmental consequences of the construction and operation of alternative cooling water systems including the beneficial and adverse impacts to fish and wildlife resources, wetland habitats, and impingement and entrainment. Also see the response to comment K-1.</p>
K-3	<p>We recommend that the Habitat Evaluation Procedures (HEP) be considered as a means of comparing and quantifying the habitat effects of alternative plans considered in the EIS. Use of the HEP in this case could make economical use of the basic frame-</p>	<p>A HEP study is being conducted to identify the value of habitat to be gained or lost for use in assessing further mitigation. The EIS will discuss the HEP study in Chapter 5.</p>

Table H-2. Scoping Comments and DOE Responses

Comment number	Comments	Responses
	<p>work of the ongoing L-Reactor HEP Mitigation Study. As a result of the L-Reactor HEP Study you have trained and experienced staff members capable of conducting a study within the time constraints of the EIS. In addition should the need for habitat mitigation be indicated after selection of the preferred alternative, HEP provides a means of mitigation cost-benefit analysis. Finally, the primary benefit of the HEP is in promoting interagency cooperation resulting in balanced planning decisions.</p>	<p>If you have any questions regarding our comments contact me at your convenience.</p>

Table H-2. Scoping Comments and DOE Responses

Comment number	Comments	Responses
	STATEMENT OF J. W. MORRIS	
	<p>Thank you for the opportunity to comment on the scope of the Planned Environmental Impact Statement (EIS) on the Savannah River Plant (SRP) Cooling Water Systems.</p> <p>I urge that the EIS deal carefully and thoroughly with a cost-benefit analysis of the construction and operation of the proposed cooling-water systems. Specifically, the following aspects should be considered:</p>	
L-1	<ol style="list-style-type: none">1. The complete and continuing cost to the taxpayers of increasing the national debt to pay for<ol style="list-style-type: none">a. the proposed construction,b. the operational costs,and c. the increased production costs that will result from the proposed operating limits.2. The benefits, if any, that can be expected from the proposed changes.	<p>Chapter 2 of the EIS will present the estimated costs associated with the cooling water alternatives considered. Chapter 2 of the EIS will summarize and Chapter 4 will discuss the adverse and beneficial impacts of the construction and operation of the cooling water alternatives.</p>
L-2	<p>I urge also that the EIS review the overall environmental productivity of the SRP site, as a whole, and compare that productivity with the productivity that might have been expected from the SRP area had the project been located elsewhere, and with the incremental effects that may be expected from the proposed cooling-water systems. Such a review will show that the environmental productivity of the SRP site now is very high, and that the incremental benefits of the proposed actions are very low.</p> <p>The long-term costs of the proposed action will be very high to the nation's taxpayers, the benefits will be very small, and none of these benefits will accrue to the public since the SRP site is necessarily closed to the public.</p> <p>The basic intent of the Clean Water Act and of Water Quality Standards is to protect the public and to preserve environmental productivity. At SRP overall the public is presently well protected and environmental productivity is very high.</p>	<p>Chapter 3 of the EIS will discuss the existing environment at the SRP site that will be affected by alternative cooling water systems, and Chapter 4 will discuss the environmental consequences of constructing and operating the systems. Since the cooling water systems will neither affect the entire SRP site nor can the systems be located elsewhere, the comparison of overall productivity as cited is considered outside the scope of the EIS.</p>

Table H-2. Scoping Comments and DOE Responses

Comment number	Comments	Responses
	I urge the Federal government to exercise its responsibility to the total spectrum of U.S. taxpayers, and to pursue all possible means to implement "No Action" in the matter at hand.	

Table H-3. Scoping Topics and EIS Sections

Comment number	Scoping topic	EIS section
A-1	Environmental impacts	Ch. 4, App. F
A-2	Environmental impacts	Ch. 4, App. F
A-3	Cooling water alternatives	Ch. 4
B-1	Regulatory requirements	Ch. 2, Ch. 4
D-1	Regulatory requirements	Ch. 1, Ch. 5
D-2	Regulatory requirements	Ch. 1, Ch. 5
E-1	Environmental impacts	Ch. 2, Ch. 4
F-1	Cooling water alternatives, No-action alternative	Ch. 2, Ch. 4
G-1	Regulatory requirements	Ch. 1
G-2	Scoping comments	Ch. 1
G-3	Water quality impacts	Ch. 4
G-4	Water quality impacts	Ch. 4
G-5	Air quality impacts	Ch. 4
G-6	Regulatory requirements	Ch. 1
G-7	Raw water basin usage - RCRA compliance	Outside the scope of the EIS
G-8	Surface water hydrology and water quality, well closures	Ch. 3, Ch. 4
G-9	Water quality impacts	Ch. 4
G-10	Mathematical models	App. B, App.
G-11	Beta-Gamma incinerator	Outside the scope of the EIS
G-12	High-level waste	Outside the scope of the EIS

Table H-3. Scoping Topics and EIS Sections (continued)

Comment number	Scoping topic	EIS section
I-1	Radiological releases	Ch. 3, Ch. 4
J-1	Regulatory requirements	Ch. 1, Ch. 5
J-2	Radionuclide remobilization, cumulative thermal effects	Ch. 4
K-1	Facility siting impacts	Ch. 4
K-2	Fish and wildlife resource impacts	Ch. 4
K-3	Habitat impacts	Ch. 4
L-1	Cost of alternatives, impacts of alternatives	Ch. 2, Ch. 4
L-2	Affected environment, impacts of alternatives	Ch. 3, Ch. 4

