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BIOLOGICAL ASSESSMENT FOR THE SHORTNOSE STURGEON, *ACIPENSER BREVIROSTRUM* LESUEUR 1818 THE SAVANNAH RIVER PLANT

by

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Executive Summary

The shortnose sturgeon (*Acipenser brevirostrum*) is listed as an endangered species in the United States (48 FR 34182; July 27, 1983). Prior to 1982, the presence of shortnose sturgeon had not been documented in the middle reaches of the Savannah River. However, shortnose sturgeon larvae were collected in 1982-83 near the Savannah River Plant (SRP), a U.S. Department of Energy (DOE) facility, as part of the SRP aquatic ecology program. As a result, DOE notified the National Marine Fisheries Service (NMFS) as required under the Endangered Species Act of 1973. This biological assessment was prepared at the request of the NMFS to evaluate the potential impacts of present and proposed SRP operations on the shortnose sturgeon.

This assessment is based on existing information on the life history and habitat preferences of the shortnose sturgeon, a description of the Savannah River Plant including plant operations which may potentially impact the shortnose sturgeon and consultations with local experts. From this information, it is concluded that the existing and proposed operations (specifically L-Reactor operation) of the Savannah River Plant will not affect the continued existence of the shortnose sturgeon in the Savannah River. This conclusion is based on the following:

- Savannah River ichthyoplankton collections show that shortnose sturgeon are spawning both upriver and downriver of the SRP site. The Savannah River in the vicinity of SRP is not the only site where shortnose sturgeon spawning occurs.

- Spawning activity in the Savannah River above the SRP thermal effluent streams demonstrates that an adequate zone of passage exists for the spawning migration of shortnose sturgeon.

- After L-Reactor startup, areas of the Steel Creek/swamp system will not be suitable for fish spawning and foraging. However, there is no indication that shortnose sturgeon utilize this habitat.

- Entrainment of shortnose sturgeon eggs from the withdrawal of cooling water is not likely because the eggs are demersal, negatively buoyant and adhesive. Although a few shortnose sturgeon larvae have been collected in the cooling water intake canals, larval entrainment losses are expected to be minimal,

- No juvenile or adult shortnose sturgeon have been collected in the SRP cooling water intake canals or have been found in impingement studies. Furthermore, it is unlikely that healthy shortnose sturgeon will be impinged based on a comparison of the cooling water intake velocity at the SRP pumphouses and the reported swimming speeds of shortnose sturgeon.

- It is possible that larval shortnose sturgeon could be adversely affected if they drifted through the SRP thermal plumes; however, this potential impact is considered to be minimal due to the highly localized nature of the thermal plumes.

- Cold shock due to reactor shutdown is another possible effect; however, there is no indication from sampling that shortnose sturgeon are overwintering in the SRP thermal plumes.

1. Introduction

The shortnose sturgeon (*Acipenser brevirostrum*) is listed by the National Marine Fisheries Service (NMFS) as an endangered species in the United States (48 FR 34182; July 27, 1983). 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 shortnose sturgeon larvae were collected near the Savannah River Plant (SRP), a U. S. Department of Energy (DOE) facility, as part of the SRP aquatic ecology program (Appendix A). As a result, DOE initiated a consultation process with the NMFS to comply with Section 7 of the Endangered Species Act of 1973, as amended. The purpose of this document is to assess the biological significance of present and proposed SRP operations on the shortnose sturgeon.

1.1 The Endangered Species Act

Section 7 of the Endangered Species Act (ESA) requires that Federal agencies such as DOE consult with the Department of Interior (DOI) and the Department of Commerce (DOC) to ensure that their actions do not jeopardize the continued existence of endangered or threatened species or result in the destruction or adverse modification of critical habitat. A biological assessment must be prepared by the Federal agency if DOI and/or DOC indicate that an endangered or threatened species or critical habitat may be present in the area of the proposed action. The biological assessment identifies endangered/threatened species likely to be impacted, discusses the potential effects to the species and provides a determination of whether or not populations of endangered/threatened species would be adversely impacted. The content of a biological assessment is based on existing information on the Federally protected species and habitat, observations from site surveys and consultations with local experts on the species. Such an assessment must be completed within 180 days after notification by DOI or DOC or within a mutually agreeable timeframe. DOI and/or DOC will then provide the Federal agency with a written biological opinion within 90 days (or within a mutually agreeable timeframe) stating whether or not it concurs with the findings of the biological assessment.

1.2 Sequence of Events Initiating Compliance Process

During 1982, 15 sturgeon larvae were identified in ichthyoplankton samples collected from the Savannah River (Matthews and Muska 1983). The larvae were very immature and initially could not be identified to species based on available taxonomic keys. The larvae were sent to J. Buckley (University of Massachusetts), an expert on the shortnose sturgeon, and D. E. Snyder (Curator and Technical Director at the Colorado State University Larval Fish Laboratory), a specialist in larval fish taxonomy. Of the 15 sturgeon larvae collected in 1982, two were tentatively identified by Snyder as shortnose sturgeon (Matthews and Muska 1983). Seven of 13 sturgeon larvae found to date from 1983 ichthyoplankton samples have also been tentatively identified as shortnose sturgeon (Matthews and Muska 1983). Since 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.

On May 6, 1983, the Department of Energy - Savannah River Operations Office, in recognition of its responsibilities under the Endangered Species Act to consult with the proper Federal authority, sent a letter to J. T. Brawner, Regional Director of the NMFS, St. Petersburg, Florida, to initiate the consultation process (Sires 1983). A letter dated May 11, 1983 was received by DOE from C. A. Oravetz (1983), Chief of the Protected Species Management Branch at NMFS, St. Petersburg, requesting that DOE conduct a biological assessment. On June 21, DOE submitted for NMFS review a draft outline of the shortnose sturgeon biological assessment (Tseng 1983). On June 23, at the NMFS regional office in St. Petersburg, a meeting was held between representatives of DOE, E. I. du Pont de Nemours & Co. (operating contractor for the SRP) and the NMFS to review the draft outline. Following this meeting, work was initiated to prepare a biological assessment of the potential impacts of SRP operations on the shortnose sturgeon in the Savannah River.

2. SRP Site Description

The Savannah River Plant (SRP) occupies approximately 775 square kilometers and is located in the southwestern portion of South Carolina. It is adjacent to the Savannah River which serves as the border between Georgia and South Carolina and is located about 37 kilometers southeast of the city of Augusta, Georgia (Figure 1).

2.1. Description of Savannah River Drainage Basin

The SRP site is drained almost entirely by the Savannah River which is one of the major drainage basins in the southeastern United States. The Savannah River drainage basin has a total area of about 10,600 square miles (27,400 square kilometers), and extends from the river's headwaters in the Blue Ridge Mountains of North Carolina, South Carolina, and Georgia, to the Atlantic Ocean near Savannah, Georgia. The Savannah River basin is divided into three physiographic regions: the Mountain Province, the Piedmont, and the Coastal Plain (Figure 2).

The Mountain Province is characterized by relatively steep stream gradients, ranging in elevation from 5,500 to 1,000 feet (1,676 to 305 meters). This section of the drainage basin contains most of the major tributaries to the Savannah River, including the Seneca, the Tugaloo, and the Chattooga Rivers. In this region, the Savannah River and its tributaries are typical

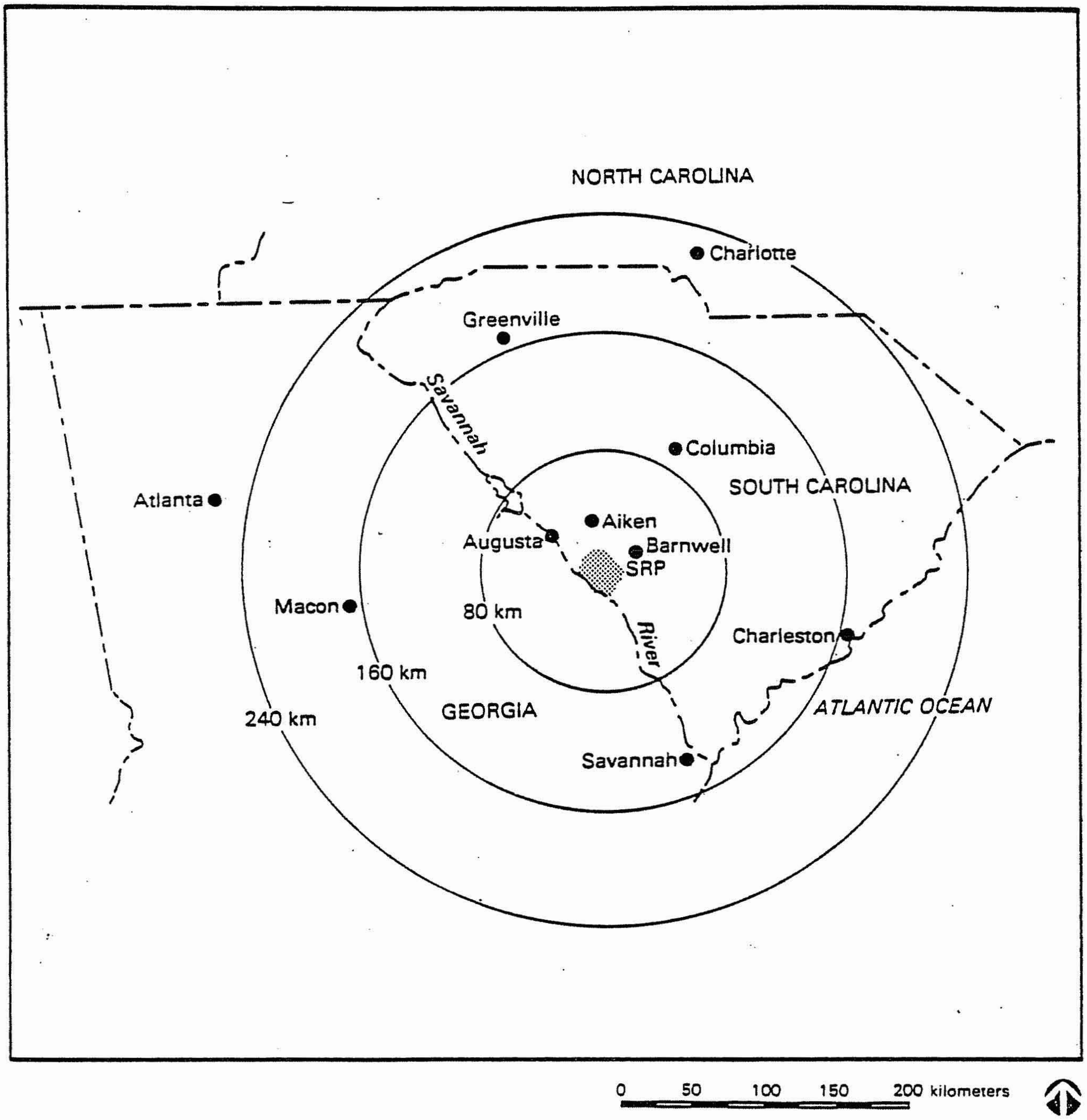


FIGURE 1. Geographic Location of the Savannah River Plant

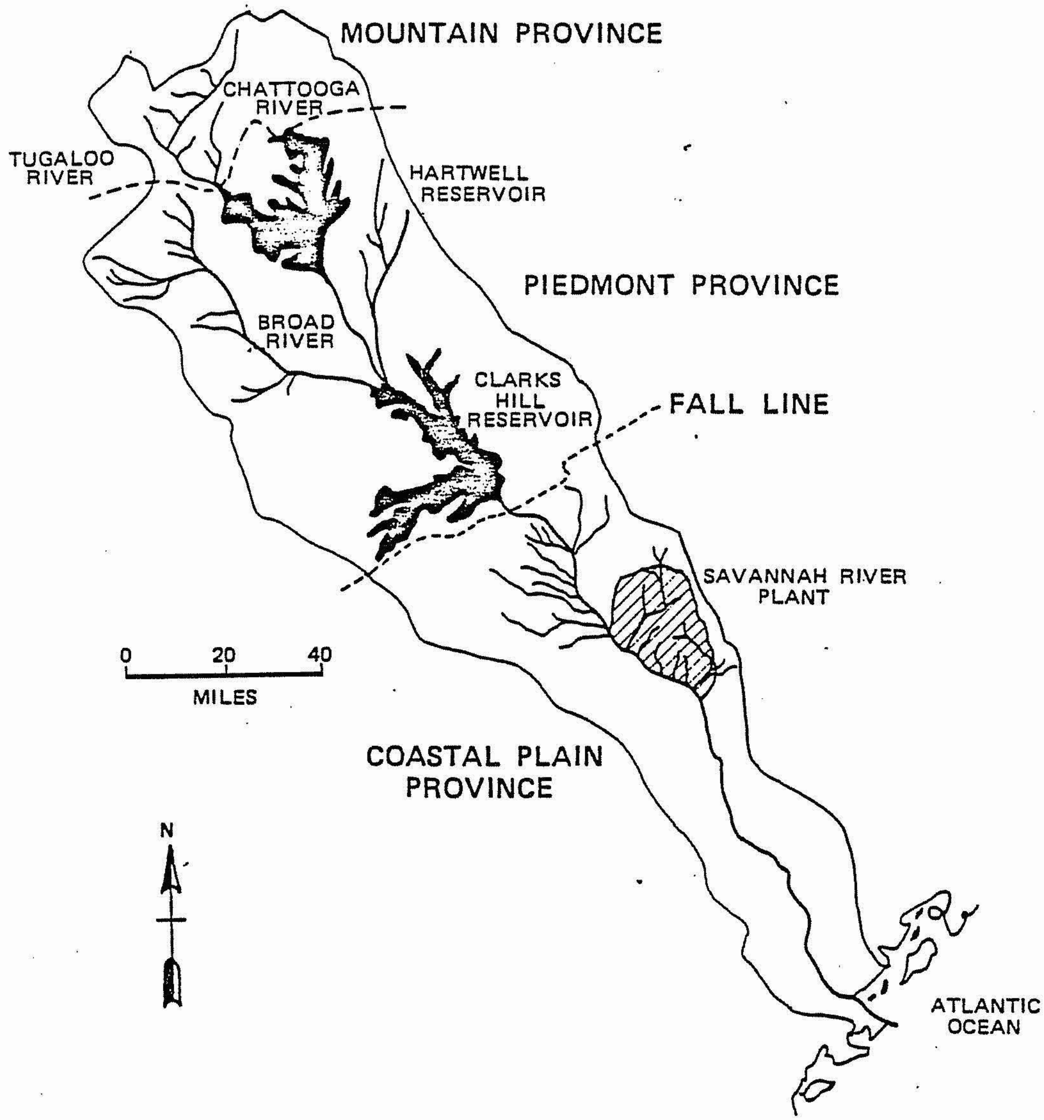


FIGURE 2. The Savannah River Basin

mountain streams, with rocky streambeds containing alternating shallow riffle areas and deep pools (Patrick et al. 1967).

The Piedmont Province extends from just above Hartwell Reservoir to near the city of Augusta, with its southern border located along the Fall Line where the rocky northern terrain meets the sandy coastal soils. The Savannah River becomes considerably more turbid in the Piedmont Province and the river bed is generally unconsolidated silt and sand, although rocky riffles can still be found. The river gradient is intermediate in this region, ranging in elevation from 1,000 to 200 feet (305 to 61 meters) and the river meanders slowly toward the coast.

The Savannah River adjacent to SRP lies in the Coastal Plain Region, which extends from near Augusta, Georgia to the coast. The Coastal Plain has a negligible gradient, ranging from an elevation of 200 feet (61 meters) to sea level. The river in this region is very silty, with an unconsolidated bed and sandy banks. The outer edges of the river bends are often steep and eroding, while silt or sand bars deposit on the inside curves. These river banks are characterized by overhanging vegetation, especially willows, with relatively little emergent or submerged aquatic plants.

There are two major dams and associated reservoirs, Clarks Hill and Hartwell, located above SRP on the Savannah River (Figures 2-3). The Richard B. Russell Dam and Reservoir, which is located between Clarks Hill and Hartwell, is presently being filled. In addition, several small impoundments serve as partial

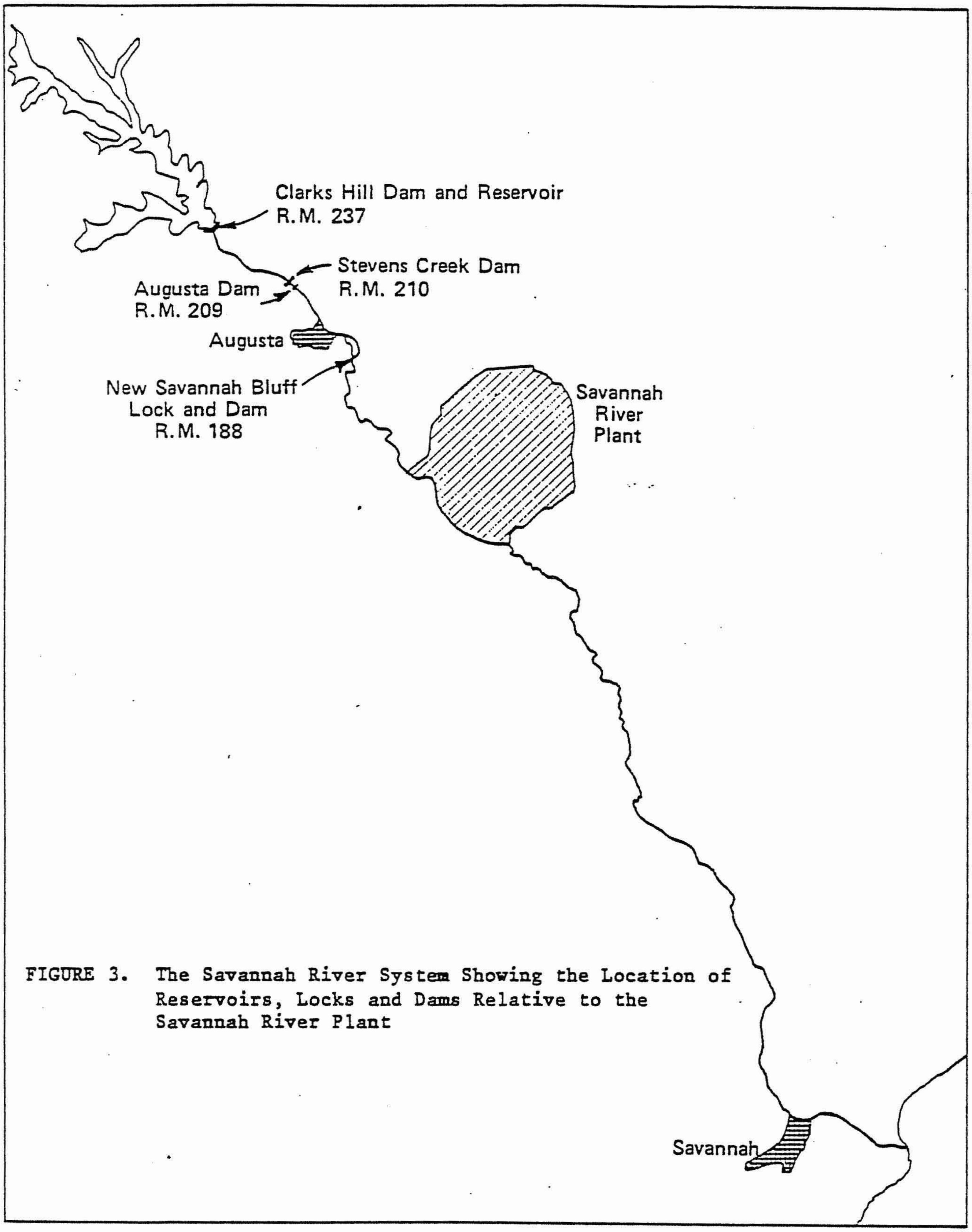


FIGURE 3. The Savannah River System Showing the Location of Reservoirs, Locks and Dams Relative to the Savannah River Plant

barriers to upriver fish migration. The closest of these to SRP is the New Savannah Bluff Lock and Dam, located at river mile 188. Above this dam, but below the Clarks Hill Dam, are the Augusta City Dam (river mile 209) and the Stevens Creek Dam (river mile 210). During flood conditions, the New Savannah Bluff Lock and Dam is open. However, for all practical purposes, the Augusta City Dam prohibits further upriver fish migration.

These reservoirs and the New Savannah Bluff Lock and Dam have stabilized the river flow at the Savannah River Plant to a yearly average of 295 cubic meters per second. Figure 4 shows the mean monthly flow rates for the Savannah River measured at Augusta, Georgia, from January 1964 through September 1981. Highest flows occur in the winter and spring and the lowest flows occur in the summer and fall. Monthly average daily-maximum temperatures at the Savannah River Plant (river mile 156.8) for the period from 1960-1970 (Jacobsen 1972) are presented in Figure 5. During the major Savannah River fish spawning periods, the monthly average daily-maximum temperatures (± standard deviations) were 8.7°±1.0°C for February , 11.0±1.3°C for March, 15.4±1.3°C for April and 18.8±1.6°C for May.

The SRP site has five principal tributaries which discharge to the Savannah River (Figure 6). Upper Three Runs Creek has the largest drainage area with an average flow rate of 6.7 cubic meters per second. It is the only onsite stream that has never received thermal effluent from a reactor. Lower Three Runs Creek

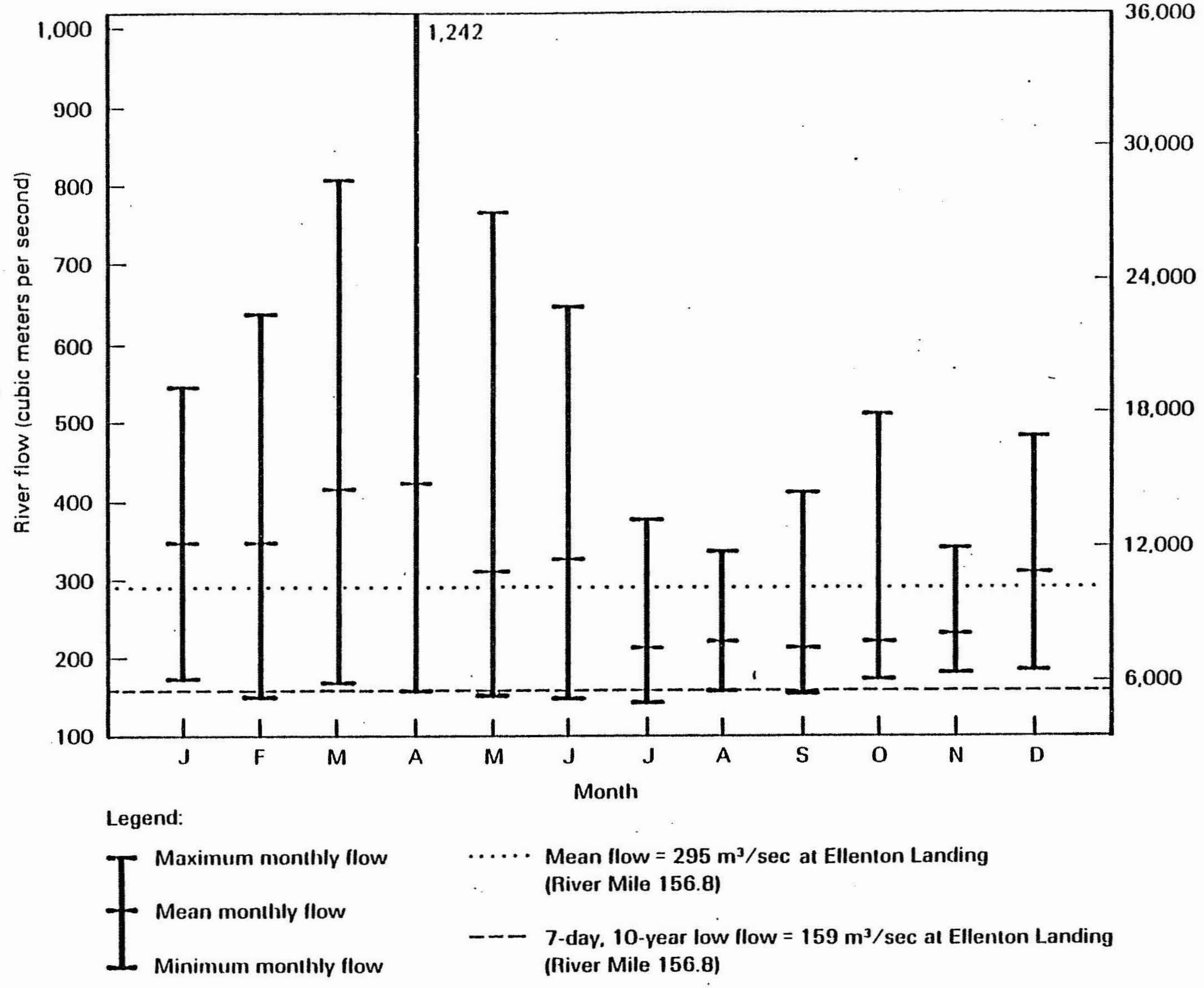


FIGURE 4. Mean Monthly Flow Rates of the Savannah River from 1964-1981 at River Mile 187.5

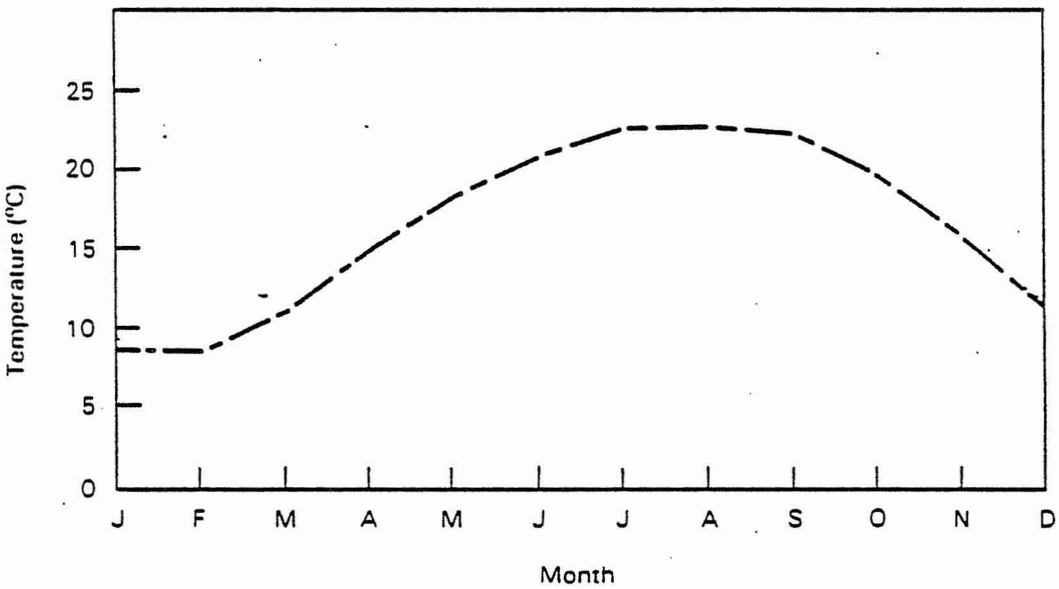
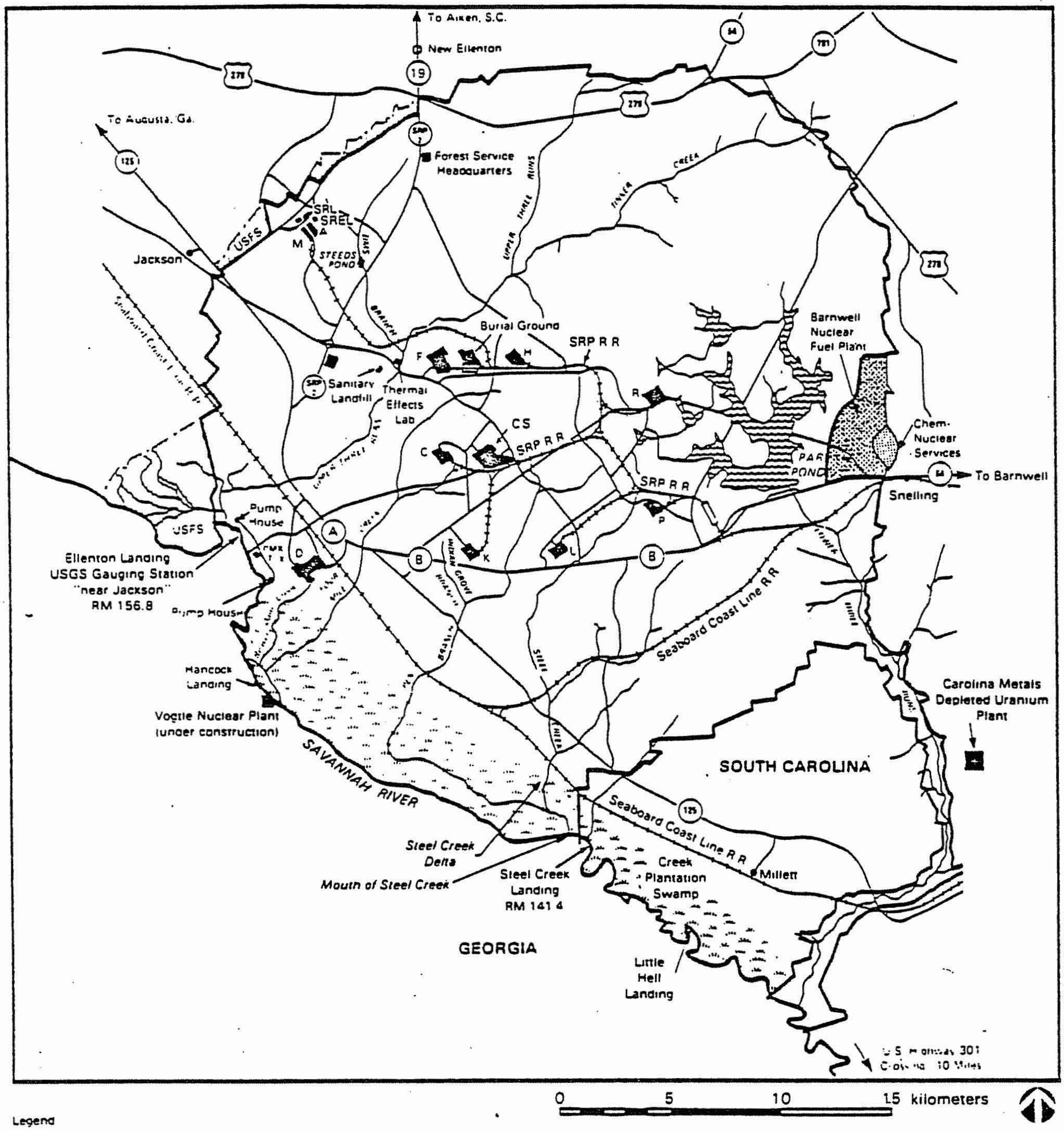


FIGURE 5. Savannah River Monthly Average Daily-Maximum Temperatures for 1960-1970 at the Savannah River Plant (River Mile 156.8)



Legend

C, K, R, L, P	Reactor Areas (C, P, K are operating)
F, H	Separations Areas
M	Fuel and Target Fabrication
D	Heavy Water Production
A	Savannah River Laboratory and Administration Area
CS	Central Shop
RM	River Mile

Road A = Highway 125

FIGURE 6. The Savannah River Plant Site

received R-Reactor thermal effluent from 1953 to 1958, at which time the stream was dammed to form the Par Pond reservoir (Figure 6). Since the formation of Par Pond, Lower Three Runs Creek has received intermittent overflow from Par Pond. The other Savannah River tributaries, Four Mile Creek, Beaver Dam Creek and Steel Creek which is also fed by Pen Branch Creek, will be discussed in Section 2.2.2. The majority of the flow in these creeks comes from reactor thermal effluents. These streams flow into a contiguous swamp (Figure 6) of approximately 10,240 acres (41.4 square kilometers) that is separated from the main flow of the Savannah River by a natural levee along the river bank. These streams generally flow as shallow sheets, and only have well-defined channels where they enter the swamp and where they breach the levee at their mouths.

When the Savannah River is in flood stage (about 27.7 meters adjacent to SRP) with a flow rate of greater than 440 cubic meters per second, the river overflows its banks into the SRP swamp system. At these times there is a reversal of water movement in the tributaries to the river so that river water flows back through the stream channels into the swamp, changing the pattern of thermal discharges to the Savannah River. Water movement during high river levels is complex, with considerable lateral movement through the adjacent swamps. Since the construction of upstream dams, the intensity of flooding has been reduced; however, on the average, the Savannah River reaches flood stage at the Savannah River Plant 79 days or 22 percent of each year, predominantly from January through April.

2.2 Description of the Plant Site

The Savannah River Plant is a nuclear defense materials production site operated by E. I. du Pont de Nemours and Company for the United States Department of Energy. Nuclear materials for national defense are produced at this site in three reactors: C, K, and P Reactors (Figure 6). Two additional reactors, L and R Reactor, are on stand-by. However, L Reactor is scheduled to resume operation in January 1984. Support facilities include a fuel fabrication area (M) and two chemical separations areas (F and H) where the nuclear products are separated from the radioactive by-products and the radioactive wastes are temporarily stored in underground tanks (Figure 6).

2.1.1 Intake Structures

Non-contact cooling water for the C and K Reactors is withdrawn from the Savannah River and used for once-through cooling in the reactor heat exchangers before it is discharged into streams that flow into the Savannah River via the SRP swamp. P Reactor uses recirculated water from a 1012 hectare cooling impoundment, Par Pond, and requires only make-up water from the Savannah River to replace water losses due to evaporation.

The SRP operates three pumping stations on the Savannah River. The relative locations of the pumping stations are shown in Figure 7. The 1G and 3G pumphouses each contain 10 large pumps (2.1 cubic meters per second per pump), while the 5G pumphouse contains 6 smaller pumps (0.8 cubic meters per second per pump). The total pumping rate capacity for all pumphouses is approximately 46 cubic meters per second. Currently, the Savannah River Plant withdraws a maximum of 26 cubic meters per second from the river, primarily for use as non-contact cooling water in production reactors and coal-fired power plants. The operation of L-Reactor with a once-through cooling-water system will require an additional 11 cubic meters per second from the Savannah River. The operation of L Reactor will increase the percentage of Savannah River water used by the SRP for non-contact cooling from the current 9 percent to approximately 13 percent based on the yearly average river flow of 295 cubic meters per second.

A detailed description of the pumphouse intake canals and structures was prepared by McFarlane et al. (1978). The 1G pumphouse is located on a 550 meter long intake canal that varies in width from 30 to 70 meters, depending on river elevation, and has a minimum depth of approximately 2 meters. The 3G pumphouse is located on a 410 meter long intake canal that varies from 27 to more than 90 meters wide, with a minimum depth of 2 meters. The 5G pumphouse is located in a cove that extends 20 meters from the Savannah River and is approximately 12 meters wide with a minimum

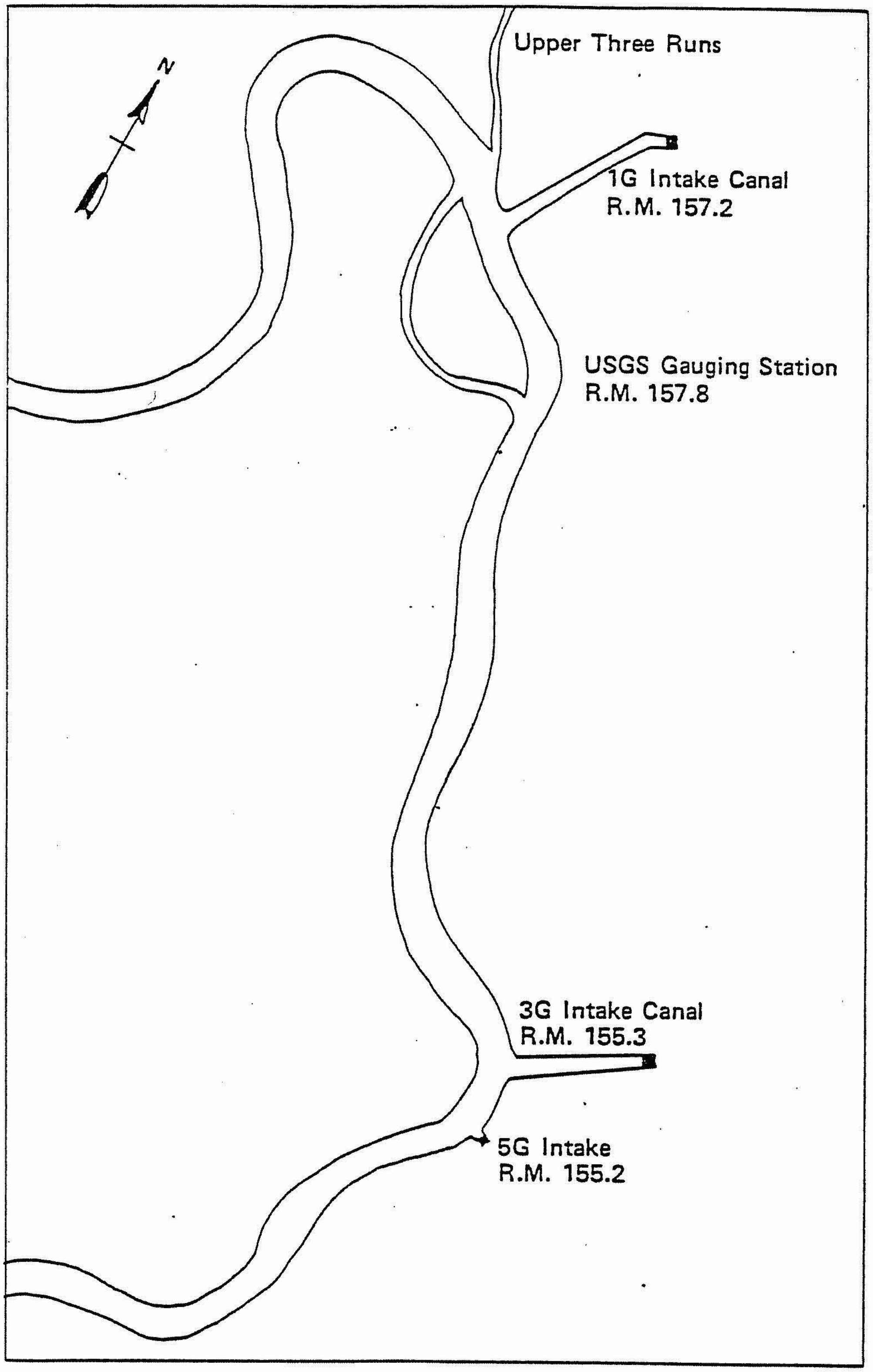


FIGURE 7. Locations of Savannah River Plant Pumphouses and Associated Intake Canals

depth of 2 meters. Water enters the pumphouses through trash racks and vertical traveling screens before entering the bays and conduits to the pumps. The traveling screen panels are 1.82 meters long, 0.59 meters high, with an 11 millimeter square mesh and a 10 centimeter wide trash tray. These screens are normally cleaned three times each day and are cleaned more frequently during the fall when floating leaves accumulate on the screens. The screens are backwashed by high pressure water jets into a shallow trough which empties into the nearby swamp. The backwashing and disposal system results in the mortality of all impinged organisms.

Water velocities in the intake canals vary widely depending upon the number of pumps in operation and the water depth in the canals. Canal water depth is determined by the amount of sediment in the canals and river height. McFarlane et al. (1978) measured the water velocities in the intake canals during periods of high (7 pumps operational) and low (2 pumps operational) water pumping rates. Velocities were measured at low river levels (25.5-25.7 meters) to maximize the velocity measurements and, consequently, represent worst case conditions. At the high pumping rate, mean water velocities ranged from 15 centimeters per second in the middle of the canal to 28 centimeters per second immediately upstream of the 1G and 3G pumphouse training walls. Water velocities ranged from less than 1 centimeter per second to 8 centimeters per second during the low pumping rate. Flow patterns in the 5G pumphouse intake cove are complex, with substantial backflow due to eddy currents. This situation complicates the measurement of water velocities. However, with four pumps in operation and at river elevation of 25.7 meters, water velocities directly in front of the trash rack have been reported to be 5 centimeters per second at a water depth of 0.5 meters and 2 centimeters per second at a depth of 3 meters (McFarlane et al. 1978). These measured flow rates may not be very meaningful due to the complex water flow patterns in the 5G intake cove.

2.2.2 Thermal Effluents

Three onsite streams currently carry thermal effluent from production facilities to the Savannah River (Figure 6). Beaver Dam Creek receives heated effluent from a coal-fired power plant located in D Area and overflow from Four Mile Creek. Four Mile and Pen Branch Creeks receive heated effluent from C and K Reactors, respectively. P Reactor (Figure 6) recirculates cooling water through Par Pond, which overflows into Lower Three Runs Creek at ambient temperature. After reactivation of L Reactor, heated effluent is expected to be discharge into Steel Creek.

Beaver Dam Creek is the smallest of the SRP thermal streams, and has an average flow of about 3.1 to 5.4 cubic meters per second, with about half coming from C Reactor during reactor operation and half from D Area. The temperature at the mouth of

Beaver Dam Creek usually ranges from 5.5 to 11.1°C above the ambient Savannah River temperature during the warmer months of the year. The thermal plume is confined to the South Carolina shore for a relatively short distance before becoming mixed with the Savannah River. The thermal plume is not greater than 2.8°C above river ambient 91 meters downstream of the mouth of Beaver Dam Creek and is limited to less than one-third of the surface area of the Savannah River (Du Pont 1982).

Prior to flowing into a large swampy area adjacent to the Savannah River, Four Mile Creek has a total average flow of about 13.6 cubic meters per second which includes approximately 11 cubic meters per second from C Reactor. In the swamp, water flow is variable and highly influenced by river levels. At river levels above flood stage, Savannah River water flows through the swamp and mixes with Four Mile Creek water. The water mass then moves laterally through the swamp in a southeastern direction until it eventually rejoins the river. At river levels below flood stage, part of the C-Reactor effluent flows into Beaver Dam Creek (1.6 - 2.7 cubic meters per second), part flows through the swamp to eventually join with Pen Branch, and the rest flows out the mouth of Four Mile Creek (1.7-4.0 cubic meters per second). Maximum temperatures observed at the mouth of Four Mile Creek were 16.7 to 19.4°C above river ambient during the late spring and summer months (Du Pont 1982). During low river flow conditions, the mixing zone of the thermal plume, as defined by 2.8°C above river ambient, can extend up to 320 meters downstream and cover as much as 43 percent of the river surface area 90 meters below the mouth of Four Mile Creek (Du Pont 1982). However, these measurements were made during extreme conditions, i.e., at Savannah River flows which were significantly lower than the 7-day, 10-year low flow of 159 cubic meters per second. Thermal plumes from Four Mile Creek normally do not exceed 33% of the river surface area or 25% of the cross sectional area (Du Pont 1982).

Under current operations, Steel Creek has a discharge to the Savannah River of about 15.6 cubic meters per second, of which 11 cubic meters per second comes from K Reactor by way of Pen Branch Creek and the remainder comes from surface runoff. Movement through the swamp has cooled the K-Reactor effluent to near ambient temperatures, so the thermal plume below Steel Creek is small. The temperature of water released from the mouth of Steel Creek is typically less than 5.6°C above river ambient during the spring and summer months (Du Pont 1982). The temperature at the edge of the present mixing zone 91 meters downstream from the mouth does not exceed 2.8°C above river ambient.

Following L-Reactor restart, the discharge from Steel Creek with both K and L Reactors operating is expected to increase to 27.4 cubic meters per second. In general, the monthly average temperature at the mouth of Steel Creek will be 8.3°C above river ambient in the warmer months (Du Pont 1982). Resumption of L-Reactor operations will increase the size of the thermal plume in the Savannah River. However, historical data show that the thermal plume from Steel Creek during L-Reactor operation remains essentially on the South Carolina side of the Savannah River until it becomes completely mixed with river water approximately 2.4 kilometers downstream from the mouth of Steel Creek (Du Pont 1982). Computer models have been used to predict the temperatures within the Steel Creek thermal plume (Du Pont 1982). Assuming a temperature difference of 8.3°C between the river and the Steel Creek discharge at Savannah River flow rates of 172.8 cubic meters per second, a river temperature rise of almost 2.8°C is predicted for a mixing zone comprising 25 percent of the river surface area at a downriver distance of 0.6 kilometers. The thermal plume will not extend across the Savannah River, but remains sufficiently close to the South Carolina shore to permit a zone of passage for anadromous fish (Du Pont 1982).

3. The Species: *Acipenser brevirostrum*, Shortnose Sturgeon

Acipenser brevirostrum was originally described by LeSueur (1818) from the Delaware River. Vladykov and Greeley (1963) have listed the diagnostic characteristics. The standard common name is the shortnose sturgeon (Robins et al. 1980) although local names include little sturgeon (Saint John River, New Brunswick, Canada), pinkster and roundnoser (Hudson River, New York), bottlenose or mammose (Delaware River), salmon sturgeon (Carolinas) and soft-shell or lake sturgeon (Altamaha River, Georgia).

Limited information is available on the shortnose sturgeon in southeastern rivers, including the Savannah River. Except for studies by Marchette and Smiley (MS 1982) in the Winyah Bay system, South Carolina and Heidt and Gilbert (1978) in the Altamaha River, Georgia, no recent fisheries surveys designed to determine the abundance and life history characteristics of the shortnose sturgeon have been conducted in southeastern rivers. The SRP aquatic ecology program in the Savannah River (Appendix A) is providing some information on the shortnose sturgeon; however this program is designed to be a general fisheries survey and does not include the methodologies and specialized sampling gear usually necessary to capture adult shortnose sturgeon. Considerable information is available on northern populations, primarily as a result of the shortnose sturgeon's endangered species status. Consequently, this biological assessment and the resulting conclusions are primarily based on a review of available literature and consultations with shortnose sturgeon experts. Experts who were contacted include D. E. Marchette (South Carolina Wildlife and Marine Resources Research Institute, Charleston, South Carolina), E. K. Dingley (U.S. Fish and Wildlife Service, Orangeburg, South Carolina), R. J. Gilbert (University of Georgia, Athens, Georgia), J. Buckley (University of Massachusetts, Amherst, Massachusetts) and D. E. Snyder (Colorado State University, Fort Collins, Colorado).

3.1. Distribution

The shortnose sturgeon is restricted to the east coast of North America (Vladykov and Greeley 1963) and has been recorded from the Saint John River, New Brunswick, Canada, to the Indian River, Florida. Breeding populations are normally associated with estuary-river complexes that have a strong flow of freshwater. The shortnose sturgeon's endangered species status has stimulated recent investigations which have shown it to be more abundant in some drainage systems than had been previously thought (Brundage and Meadows 1982). Reproducing populations have been recently studied in the Saint John River, New Brunswick, Canada (Dadswell 1979), Montsweag Bay, Maine (McCleave et al. 1977), the Kennebec River, Maine (Squiers and Smith 1978), the Connecticut River, Massachusetts (Taubert and Reed 1978; Taubert 1980b), the Hudson River, New York (Dovel 1978), the Winyah Bay System, South Carolina (Marchette and Smiley MS 1982) and the Altamaha River, Georgia (Heidt and Gilbert 1978).

Shortnose sturgeon have been found in rivers, estuaries and the ocean with their greatest abundance occurring in the estuary of their respective river (Dadswell et al. MS 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) and the Lake Marion-Moultrie system in South Carolina (Marchette and Smiley MS 1982).

3.2. Life History

This section represents a composite life history of the shortnose sturgeon with emphasis on important life stages and habitat requirements which could be potentially impacted by SRP operations.

3.2.1 Spawning Period and Grounds

Spawning of shortnose sturgeon occurs between February and May, depending on the latitude. Ripe and spent females have been collected in the Altamaha River, Georgia, during February (Heidt and Gilbert 1978) and during January to April in the Savannah, Santee, and Pee Dee Rivers, South Carolina (Marchette and Smiley

MS 1982). Newly-hatched larvae were collected in the Savannah River during March in both 1982 and 1983 (Matthews and Muska 1983). In northern rivers, ripe adults occur during the middle two weeks of April in the Delaware (Meehan 1910; Hoff 1965) and until as late as the middle two weeks of May in the Saint John River, New Brunswick, Canada (Dadswell 1979).

The major factor governing spawning appears to be temperature, although other factors include the occurrence of freshets and substrate character (Dadswell et al. MS 1982). Several investigators (Meehan 1910; Heidt and Gilbert 1978; Taubert 1980a; Dadswell 1979; Buckley and Kynard 1981) have reported shortnose sturgeon spawning to occur between 9-12°C. In South Carolina waters, the spawning season is significantly earlier than in northern rivers; however the range of spawning temperatures is similar (Marchette and Smiley MS 1982). In northern rivers, the spawning grounds are located in regions of fast flow (40-60 centimeters per second) with gravel or rubble bottoms (Taubert 1980a; Pekovitch 1979; Buckley 1982). Specific spawning grounds for populations in southeastern rivers have not been described.

Early settlers in South Carolina reported both sturgeon (species not specified) and shad in major rivers above the fall line (Leland 1968). However, since the 1870's, sturgeon have been limited to the lowland sections of the rivers due to the construction of mill dams and water supply dams on the Pee Dee, Wateree, Congaree and Savannah Rivers. More recently, Marchette and Smiley (MS 1982) documented several spawning populations in South Carolina waters. On April 9, 1980, one ripe female specimen was collected 73 miles upstream in the Savannah River. Males and females spilling eggs or dropping milt upon handling have also been reported in the Savannah River at the B&C Landing (river mile 55), Stokes Bluff Landing (river mile 62), Cohens Bluff Landing (river mile 106) and Little Hell Landing (river mile 140) (Marchette pers. comm.). During the 1982-83 spawning seasons, a total of nine shortnose sturgeon larvae were collected at river miles 79.9, 97.5, 155.2, 155.3, 155.4, 157.1 and 157.3 (Table 1) (Matthews and Muska 1983). The Savannah River Plant borders the Savannah River from river mile 129 to 130 and from 141.6 to 157.2.

In the Winyah Bay system, South Carolina, Marchette and Smiley (MS 1982) reported that spawning shortnose sturgeon were only collected in the freshwater portions of the estuary. However, ripe and spent fish were also collected in the 18-30 parts per thousand (ppt) salinity range of the estuary in January and February. From these collections, Marchette and Smiley (MS 1982) speculated that either a segment of the population is capable of spawning in the saltwater regions of the estuary or that this portion of the population spawns much earlier and has already moved downstream to the higher salinity regions. In other river systems, shortnose sturgeon are known to migrate great distances upriver to spawn. Ripe adults have been captured as far upstream as river mile 116 in the Altamaha, Georgia (Heidt and Gilbert

TABLE 1.

Shortnose Sturgeon Larvae Collected in the Savannah River, March-August, 1982 and Spring 1983*

Sampling Date	River Mile	Water Column Location	Water Temperature °C
3/12/82	157.3	top	12.5
3/26/82	157.3	bottom	13.2
3/09/83	79.9	bottom	--
3/22/83	155.4	bottom	12.5
3/23/83	157.1	top	11.5
3/23/83	155.3	top	11.5
3/23/83	155.2	top	11.3
3/23/83	97.5	top	12.6
3/29/83	155.2	top	12.5

* Analysis of 1983 ichthyoplankton data is not complete.

1978), river mile 123 on the Pee Dee River, South Carolina (Marchette and Smiley MS 1982), river mile 138 in the Delaware River (Hoff 1965), river mile 153 in the Hudson River (Dovel 1978) and river mile 118 in the Connecticut River (Taubert 1980a).

3.2.2 Eggs and Embryonic Development

Shortnose sturgeon eggs are dark brown to black with a light grey polar body (Meehan 1910; Dadswell 1979). Ripe eggs have a diameter of 3.0-3.2 millimeters (Dadswell 1979) and size does not change after fertilization or water hardening (Buckley and Kynard 1981). Eggs are fertilized immediately after extrusion. When released the eggs sink to the bottom (Pottle and Dadswell 1979). The fertilized eggs are demersal and become adhesive within twenty minutes after fertilization (Meehan 1910). Meehan (1910) reported that eggs hatched in 13 days after fertilization in water temperatures between 8-12°C. Buckley and Kynard (1981) found that hatching occurred in 8 days at 17°C which agrees with Meehan's observations when both are converted to temperature units (one temperature unit equals 1°C for 24 hours).

3.2.3 Larval Development and Behavior

Little is known regarding shortnose sturgeon larval development and behavior. Extensive ichthyoplankton sampling efforts to collect shortnose sturgeon eggs and larvae have been conducted on the Hudson (Pekovitch 1979), the Connecticut (Taubert and Reed 1978) and the Saint John River systems (Pottle and Dadswell 1979). The paucity of catches from these studies indicate that the larvae are probably benthic in habit and that they may even occupy interstitial spaces in the gravel during early larval stages (Pottle and Dadswell 1979). In artificial propagation studies, Meehan (1910) reported that larvae remained for several days at the bottom of the hatching jar. In contrast, Buckley and Kynard (1981) observed in the laboratory that newly-hatched fry exhibited active swimming on the bottom and within the water column and were photopositive. However, after two days of activity, fry with yolk sacks became strongly photonegative and formed aggregations with other larvae under large gravel or in dense clumps of algae. Pottle and Dadswell (1979) observed that approximately 10 day old larvae, after being collected from the field and then placed in an aquarium, remained on the bottom or placed themselves under any available cover. Of the nine short-nose sturgeon larvae which have been collected in the Savannah River (Matthews and Muska 1983), six were taken in surface tows and three were collected in bottom tows (Table 1). Interpretation of these data for larval distribution is not possible since few fish were collected and the samples were collected under various hydrological conditions. Furthermore, bottom tows were conducted with the net slightly above the substrate to avoid the collection of detrital material. Consequently, fish residing on the bottom were not effectively sampled.

The hatching size of shortnose sturgeon is between 7.3-11.3 millimeters (Dadswell et al. MS 1982). Morphological and meristic characteristics of larvae have been reported by Pekovitch (1979), Taubert and Dadswell (1980), Bath et al. (1981) and Matthews and Muska (1983). Newly-hatched larvae are tadpole-like in body shape, dark grey in overall body color, and have a large yolk sac. At 14 millimeters, approximately 10 days after hatching, barbels appear, the yolk sac is gone and the mouth is large and has teeth (Dadswell et al. MS 1982).

3.2.4. Fry and Juveniles

Little is known about the life history of juvenile shortnose sturgeon, particularly in southeastern rivers. In northern rivers, juveniles are benthic and feed primarily in deep channels over sandy-mud or gravel-mud bottoms (Dadswell 1979; Taubert 1980a). In the Hudson River, young-of-the-year sturgeon were collected in the deep channels between river mile 121 and 137 (Pekovitch 1979). In the Saint John River, juveniles are found in inland riverine sections of the estuary upstream from the salt wedge and apparently move back and forth in response to salt water intrusion (Pottle and Dadswell 1979). In general, the mean length of juveniles in gill net collections is least in upriver portions of the estuary and increases seaward (Dadswell 1979; Pottle and Dadswell 1979). Juveniles probably remain inland of saline waters until attaining a fork length (FL) of 45 centimeters. This length may be attained in two to eight years depending on latitude (Dadswell et al. MS 1982).

3.2.5 Adults

3.2.5.1 Age, Size and Growth

The oldest female and male shortnose sturgeon collected to date, both from the Saint John River, were determined to be 67 and 32 years old, respectively (Dadswell 1979). Although possibly a function of sample size, maximum ages determined to date for other river systems are less. In general, shortnose sturgeon from northern populations have a longer life span than southern populations. Marchette and Smiley (MS 1982) determined a maximum age of 20 years based on 93 shortnose sturgeon collected from South Carolina waters.

To date, the maximum size reported for a shortnose sturgeon is a 122 centimeter (FL), 23.6 kilogram female from the Saint John estuary (Dadswell 1979). The largest male on record is a 97.0 centimeter (FL), 9.4 kilogram shortnose from the Saint John estuary (Dadswell 1979). Maximum size varies from north to south with the largest maximum sizes reported from northern populations. Of 135 specimens collected by Marchette and Smiley (MS 1982) from South Carolina rivers, the largest was 92.7 centimeters (FL) and weighed 4.3 kilograms.

Growth data have been compiled by Dadswell et al. (MS 1982) for populations in the Saint John River, Canada, the Hudson River, New York, the Kennebec River, Maine, Holyoke Pool, Massachusetts, the Pee Dee-Winyah Bay region, South Carolina and the Altamaha River, Georgia. Shortnose sturgeon grow fastest in the southern portion of their range. In the south, specimens attain a length of approximately 50 centimeters after only 2-4 years (Heidt and Gilbert 1978). The Holyoke Pool population has the slowest known growth rate, presumably a result of limited food availability due to its landlocked status (Taubert 1980b). An increase in the growth rate has been observed in Saint John River and South Carolina populations which coincides with juvenile migration to the upper estuary where food is more available.

3.2.5.2 Migratory Movements

The shortnose sturgeon exhibits a migration pattern between spawning grounds, feeding grounds and overwintering areas. Since adults apparently do not spawn every year, a particular population may exhibit several migratory patterns simultaneously.

From tag/recapture studies, shortnose sturgeon are known to move considerable distances in short periods of time. In the Altamaha River, Georgia, a shortnose sturgeon moved 193 kilometers downstream in 11 days (Heidt and Gilbert 1978) and in the Connecticut River a radio tagged fish moved 60 kilometers in 2 days (Buckley, unpub. data). McCleave et al. (1977) reported a mean daily movement of 20 kilometers for shortnose sturgeon in the

Montsweag Bay, Maine; these movements appeared to be non-directed random feeding, often in shallow water.

The migratory behavior of shortnose sturgeon is apparently complex and differs somewhat between northern and southern populations. In the Saint John River, there appears to be a general migration upriver in the spring and summer and downriver in the fall by most of the non-ripening portion of the population (Dadswell 1979). Some portion of the ripening population migrate farther upriver in the fall or remain at upriver locations over winter. However, in the Altamaha River, Georgia, shortnose sturgeon were found upstream during February and March while spawning but during the remainder of the year were captured only in the first few kilometers of the river within the tidal influence (Heidt and Gilbert 1978; Gilbert and Heidt 1979).

A similar pattern was observed in the Winyah Bay system, South Carolina (Marchette and Smiley MS 1982). During February-May, the only fish to move into freshwater portions of the estuary, 0-0.5 parts per thousand (ppt) of salinity, were spawning fish. However ripe and spent fish were also taken in the lower reaches of the estuary (18-30 ppt) in January and February. This suggests that a portion of the population is capable of spawning in saltwater regions of the estuary or this portion of the population spawns much earlier and had already moved back downstream to higher salinity waters. The summer foraging grounds (June-August) in the Winyah Bay system are apparently in the mid-estuary region where salinities averaged 0.5-1.0 ppt. In the fall when water temperature drops 2-3°C, shortnose sturgeon apparently leave the summer foraging grounds and migrate to overwintering sites which were located in the channels of shallow estuarine lakes, at the mouth of Winyah Bay and in the ocean within 5000 meters of the beach. Overwintering sites in the bay had surface temperatures of 5-10°C and salinities of 18-28 ppt, while the ocean had the same temperature range but a higher salinity range between 25-30 ppt (Marchette and Smiley MS 1982).

In contrast to the migratory behavior of the adults, juvenile shortnose sturgeon in the Saint John River are apparently non-migratory and are largely confined to the inland portion of estuaries upstream of the salt wedge (Pottle and Dadswell 1979). Dadswell et al. (MS 1982) suggested that there is a gradual downstream movement of juveniles as they become older. The migratory behavior and foraging grounds of juvenile shortnose sturgeon inhabiting southeastern rivers is not known.

3.2.5.3 Reproduction

The species exhibits little sexual dimorphism. At the same age, adult females are generally larger than males. In the spring, gravid females are readily identifiable due to their swollen abdominal region (Dadswell 1979). Age of maturation increases from south to north. Males mature at age 2 in Georgia, age 3-5 from South Carolina to New York and increase northward to age 10-11 in the Saint John River, Canada. Females mature at age

6 or younger in Georgia, age 6-7 from South Carolina to New York and age 13 in the Saint John River. Length at maturity is between 45 to 55 centimeters (FL) for both females and males throughout their range (Dadswell et al. MS 1982). First spawning occurs 1-2 years after maturity in males but for females is delayed for up to 5 years (Dadswell 1979). Marchette and Smiley (MS 1982) reported that the age of first spawning for males and females in South Carolina ranged between 5-10 years and 7-14 years, respectively.

Although shortnose sturgeon populations spawn once a year, spawning apparently is not a yearly event for each individual. Dadswell (1979) reported that females probably spawn at a maximum of once every 3 years and males every other year in the Saint John River. Marchette and Smiley (MS 1982) noted for shortnose sturgeon in the Pee Dee River, South Carolina, that males require 2-3 years between spawning periods while females require a 3-4 year ripening period.

Fecundity of shortnose sturgeon in the Saint John River, Canada ranged from 27,000 to 208,000 eggs/fish and was directly related to total body weight (Dadswell 1979). In the Altamaha River, Georgia, Heidt and Gilbert (1978) reported egg numbers between 79,000 and 90,000 per fish (75-85 centimeter FL) and Marchette and Smiley (MS 1982) found a 59 centimeter (FL) female from the Pee Dee River, South Carolina, which contained 30,000 eggs. On a per body weight basis, Saint John River females had a mean of 11,568 eggs per kilogram (Dadswell 1979) while Heidt and

Gilbert (1978) and Marchette and Smiley (MS 1982) reported that southern shortnose sturgeon contained 14,000-16,000 eggs per kilogram.

Little is known regarding spawning behavior. Buckley and Kynard (1981) found that when single females were captured in gill nets on the spawning grounds they were often surrounded by numerous males in the same region of the net. Dadswell (1979) reported that sequentially tagged fish had a tendency to be recaptured together.

3.2.6 Food and Feeding Habits

All feeding of shortnose sturgeon seems to be either benthic or from plant surfaces. Dadswell et al. (MS 1982) found shortnose to be most active during the night or on windy days when water turbidity was high. Fish were more readily captured at night and stomach analyses showed full gastrointestinal tracts. Marchette and Smiley (MS 1982) observed shortnose sturgeon grazing at night on molluscs attached to the underside of yellow pond lily pads.

In the freshwater areas of the Saint John estuary in New Brunswick, Canada, adults foraged in weedy backwaters or over mud bottoms at depths of 1-5 meters (Dadswell 1979). During late summer, foraging grounds were located in deeper water (5-10 meters). During the fall and winter, the little feeding that was observed in freshwater took place in deep water (15-25 meters). Juveniles feed primarily in the deep channels (10-20 meters) over sandy-mud or gravel-mud bottoms (Pottle and Dadswell

1979). In the lower Saint John estuary, adults feed during the summer and winter over sandy-mud or mud bottoms in water depths of 5-10 meters. In the Winyah Bay system, South Carolina, Marchette and Smiley (MS 1982) characterized the summer feeding habitat as shallow water with sandy bottoms and emergent macrophytes and the winter feeding habitat as deeper waters with mud bottoms.

Marchette and Smiley (MS 1982) sampled the stomachs from 54 shortnose sturgeon captured in both the freshwater and saltwater portions of the Winyah Bay system. Their work indicates that intensive feeding was initiated in April and May when water temperatures reached 10-11°C in the upper estuary summer foraging area. Between September and November, the population apparently departed the summer feeding grounds for overwintering in the lower estuary. From April through September in the freshwater regions of the estuary (1-3 ppt), shortnose sturgeon were highly selective in feeding with stomachs containing a low percentage of non-food items. The diet was composed primarily of molluscs (90%) which included *Physa*, *Heliosoma* and *Corbicula*. Secondary items included Ephemeroptera, Isopoda, Amphipoda and Diptera. Feeding continued through the colder months with significantly less intensity and selectivity. Stomachs averaged 90% by volume non-food materials. Food items included *Corbicula*, Polychaeta and Amphipoda (Marchette and Smiley MS 1982). In the Saint John River, adult shortnose sturgeon (greater than 50 centimeters) generally feed on whatever molluscs are readily available. Juveniles feed primarily on benthic insects and crustaceans which include <u>Hexagenia</u>, <u>Chaoborus</u>, <u>Chironomus</u>, <u>Gammaris</u>, <u>Asellus</u> and <u>Cyathura</u> (Dadswell 1979). Food items and foraging grounds for juvenile shortnose sturgeon in southern rivers are not known.

3.3 Physical Tolerance

There are no data on the preferred temperature range and upper and lower lethal temperature for this species. In its northern range, spring spawning migrations begin at temperatures of 8-9°C and shortnose sturgeon are rarely collected from shallow waters exceeding 22°C (Dadswell 1975). However, Heidt and Gilbert (1978) collected a shortnose sturgeon in the lower Altamaha River, Georgia, at a water temperature of 34°C. In the Winyah Bay, South Carolina, Marchette and Smiley (MS 1982) observed that a 2-3°C decline in temperature stimulated downstream migration and overwintering sites had a temperature range of 5-10°C.

In northern rivers, juvenile shortnose sturgeon appear to prefer deep channel regions with strong currents (15-40 centimeters per second) (Pottle and Dadswell 1979). Swim speed studies by Pottle and Dadswell (1979) with shortnose sturgeon larger than 19.7 centimeters total length (TL) displayed a minimum recorded speed of 37.0 centimeters per second. The performance and behavior of the sturgeon in these tests suggested that the hydrodynamic features of the sturgeon are well suited to a benthic life style. When in contact with the substrate, the form of the juvenile sturgeon enables them to overcome or resist displacement by high velocity currents (Pottle and Dadswell 1979).

Shortnose sturgeon appear to be more active under lower light conditions. Gilbert and Heidt (1979) observed in the Altamaha River, Georgia, that all shortnose sturgeon were captured at night even though nets were fished during both daylight and darkness. During radio tracking studies, they found that tagged sturgeon remained relatively stationary in deep water during daylight but at night they moved into shallow water and were more active.

The shortnose sturgeon have been reported from freshwater to marine environments. They are apparently able to rapidly acclimate to changes in salinity. MaCleave et al. (1977) observed shortnose sturgeon moving freely through waters of widely varying salinities, sometimes encountering changes of 10 ppt in less than 2 hours.

3.4 Exploitation/Mortality

Besides natural mortality, fishing mortality caused by incidental catches in nets set for other species, particularly shad, is probably the main cause of shortnose sturgeon mortality (Dadswell et al. MS 1982). In the Saint John River, New Brunswick, Canada, many fishermen return sturgeon to the water alive but others do not. Either they are killed and discarded or they are marketed locally. Incidental fishing mortality may be a major reason for its disappearance from the Chesapeake Bay and is suspected to be a major cause of mortality in South Carolina (Dadswell et al. MS 1982). In South Carolina there is no legal commercial exploitation; however, significant numbers are taken incidentally in the various gill net fisheries including shad, sea trout and channel bass (Marchette and Smiley MS 1982). The South Carolina shad fishery uses 14 centimeter stretch mesh monofilament gill nets, the same size nets utilized by Marchette and Smiley (MS 1982) in their study. They determined that the size range of shortnose sturgeon captured by this fishing gear is between 23-93 centimeters (FL).

Natural predators of shortnose sturgeon include yellow perch for young fish and sharks, gar and alligators for adults (Dadswell et al. MS 1982). Impingement of shortnose sturgeon on power plant intake screens may result in some mortality, but the cause of impingement may be from injury elsewhere (Dadswell et al. MS 1982). There are reports of a few shortnose sturgeon impingements at several power plants (Dadswell et al. MS 1982); however, no shortnose sturgeon have been reported during impingement studies at the Savannah River Plant (McFarlane et al. 1978; ECS 1983a, 1983c).

4. Assessment of Potential Impacts

Potential impacts of existing and proposed SRP operations include indirect effects such as loss of habitat and direct effects such as entrainment, impingement and thermal effects.

4.1 Impacts on Habitat

Important habitats in the life history of the shortnose sturgeon include spawning grounds, larval and juvenile foraging grounds and adult winter and summer foraging grounds.

4.1.1 Spawning Grounds

Specific spawning grounds have not been described for shortnose sturgeon in the Savannah River. However, ripe adults spilling eggs or dropping milt upon handling have been taken from river mile 55 to 140 (Marchette pers. comm.) during the spawning season. Also, young larvae have been collected above and below the Savannah River Plant during March 1982-83 at river miles 79.9, 97.5 and 157.3 (Table 1). Shortnose sturgeon larvae have also been collected at sampling stations in the Savannah River adjacent to the SRP. Whether the adults spawned in these areas or the larvae drifted from upriver spawning sites is not known. In other rivers, shortnose sturgeon have been reported to spawn as far upstream as the first migratory obstruction. On the Savannah River, the first obstruction is the New Savannah Bluff Lock and

Dam at river mile 188. However, if the locks are open due to high water, the next obstruction would be the Augusta City Dam at river mile 209.

From the river mile locations of the larval collections, it is apparent that shortnose sturgeon are spawning in the Savannah River below as well as above the SRP. Also, these observations demonstrate that presently a sufficient zone of passage exists to permit upriver spawning migration. When L-Reactor is restarted, a thermal plume will also occur below the mouth of Steel Creek. Historical monitoring data collected before L-Reactor was shut down in 1968 and recent computer simulation models show that the thermal plume will remain sufficiently close to the South Carolina bank to permit a zone of passage.

Furthermore, spawning sites are not limited to a specific reach in the Savannah River (Matthews and Muska 1983). From studies on the Winyah Bay system, South Carolina, Marchette and Smiley (MS 1982) speculated that there may be two shortnose sturgeon spawning populations, one population that spawns early in the main channels of the upper estuary and a second population which spawns in March and April in the riverine segments. Apparently, shortnose sturgeon populations in the Winyah Bay system and in the Savannah River are not restricted to the upper river for spawning sites.

4.1.2 Larval and Juvenile Foraging Grounds

Locations of larval and juvenile foraging grounds are not known for the Savannah River shortnose sturgeon population. In the Saint John River, juveniles are non-migratory and are largely confined to the inland riverine portion of estuaries upstream of the salt wedge (Pottle and Dadswell 1979). In the Winyah Bay estuary of South Carolina, Marchette and Smiley (MS 1982) were not able to collect smaller, younger age classes by trawling. They speculated that the less than 5-year classes did not inhabit the same region of the estuary during the same seasons as the adult or spawning populations.

There is no evidence that juvenile shortnose sturgeon forage in the vicinity of SRP. However, a lack of juvenile captures could be related to the selectivity of commonly used sampling techniques (i.e., electrofishing and hoop nets) and not to their actual absence. Larval and juvenile sturgeon are difficult to sample, presumably due to their close association with the substrate. As discussed earlier, a few shortnose sturgeon larvae have been collected in the Savannah River near SRP. If juveniles are also present, they can probably avoid SRP thermal plumes during the warmer months; but, it is possible that juveniles could be attracted to the thermal plumes during winter months. If a reactor is abruptly shutdown, fish, including juvenile sturgeon, overwintering in the thermal plume areas could experience cold shock.

The Steel Creek swamp could be a possible foraging ground because of its abundant supply of benthic invertebrates and molluscs which are associated with macrophyte beds. However, in the northern rivers, juveniles apparently prefer to feed in deep channels over sandy-mud or gravel-mud bottoms (Pottle and Dadswell 1979). These foraging habitat preferences are consistent with the observation that no juvenile shortnose sturgeon have been collected in the Steel Creek swamp or in any other SRP tributary despite frequent sampling.

4.1.3 Adult Foraging Grounds

Although the adult foraging grounds for shortnose sturgeon in the Savannah River are not known, there is considerable evidence from studies on other populations that adults primarily feed in the estuary. According to Marchette and Smiley (MS 1982), the saltwater-freshwater interface, a relatively small portion of the estuary system, is the area most utilized by adult shortnose sturgeon in South Carolina. Stomach analyses have shown that adults are highly selective in their feeding and habitat preferences. Therefore, habitat availability and productivity within this portion of the estuary appear to be the most important factors affecting the growth and development of adult shortnose sturgeon in South Carolina (Marchette and Smiley MS 1982). Current and proposed SRP operations will have no impact on the Savannah River estuary which is over 100 river miles downstream of Steel Creek.

4.2 Direct Effects

Potential direct effects of existing and proposed SRP operations include entrainment and impingement due to the pumping of Savannah River water for non-contact cooling and thermal discharges to the Savannah River.

4.2.1. Entrainment

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

Little is known about the water column distribution and swimming/foraging behavior of larval shortnose sturgeon. Larval and young-of-the-year sturgeon feed primarily on benthic invertebrates and apparently remain in close contact with the substrate. Early larvae are thought to inhabit interstitial spaces in the substrate (Pottle and Dadswell 1979). The lack of reported larval collections despite extensive sampling efforts provides indirect evidence in support of this hypothesis. Nine shortnose sturgeon larvae have been identified in ichthyoplankton samples collected in the Savannah River (Table 1). Of these, one larva was collected in the 1G pumphouse intake canal, one larva was collected in the 3G pumphouse canal and two larvae were collected just downriver of the 5G pumphouse intake cove. This indicates that some shortnose sturgeon larvae may 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 (Appendix A), it is likely that the number of larvae entrained is small and that their loss does not represent an adverse impact on the Savannah River shortnose sturgeon population.

4.2.2 Impingement

Although several impingement studies have been conducted on SRP cooling water intake structures (McFarlane et al. 1978; ECS 1983a, 1983c), no shortnose sturgeon have been reported. However, in January 1983, one 147 millimeter total length (TL) juvenile Atlantic sturgeon was impinged (ECS 1983c). Thus, it is possible that shortnose sturgeon could be impinged. However, there is no evidence that Atlantic or shortnose sturgeon commonly inhabit the intake canals (ECS 1983a, 1983c).

Shortnose sturgeon, unless injured, should be able to avoid the intake screens because their swim speed exceeds the pumphouse intake velocity. Pottle and Dadswell (1979) reported a minimum critical swimming velocity of 37.0 centimeters per second for shortnose sturgeon greater than 19.7 centimeters TL. Blaxter (1969) has stated that most fish have sustained swimming speeds between 2-3 body lengths per second. During high pumping rates (worst-case conditions), the mean flowrate at the 1G and 3G pumphouses is 28 centimeters per second. Based on a comparison of pumphouse cooling water intake velocity and sturgeon swimming speeds, it is unlikely that healthy shortnose sturgeon will be impinged.

4.2.3 Thermal Effects

Potential direct thermal effects on the shortnose sturgeon are limited to existing (Beaver Dam and Four Mile Creek) and future (Steel Creek) thermal plumes in the Savannah River. Thermal plumes should not impact adults because they can avoid these areas. Eggs are not planktonic and therefore should not drift through the plumes. However, if adults spawned directly upriver of the thermal plumes, 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, it is possible that larvae drifting through the plume near the mouths of Four Mile and Steel Creek would not survive. However, this potential impact is not expected to be significant because it is restricted to adults spawning immediately above the thermal plumes and will only adversely affect larvae drifting through the hottest part of the thermal plumes.

Electrofishing in January 1983 (ECS 1983c) showed a high density of fishes in the heated waters of Four Mile Creek. Although no juvenile shortnose sturgeon were collected, it is possible that the heated water from the SRP creeks provides an overwintering habitat. Cold-shock fish kills could occur to thermally acclimated fish during a sudden reactor shutdown. However, there is no evidence to indicate that this is a problem. In case of reactor shutdown, any impact would be expected to be localized.

5. Summary and Conclusions

The Endangered Species Act of 1973, as amended, requires DOE to determine whether its operations will adversely affect endangered/threatened species or their habitat. Based on this biological assessment, it is concluded that the existing and proposed operations (specifically L Reactor) of the Savannah River Plant will not jeopardize the continued existence of the shortnose sturgeon in the Savannah River. This determination is based on the following:

- No critical habitat has been designated by the NMFS and there is no indication based on known life history characteristics that SRP operations adversely impact shortnose sturgeon spawning, rearing and foraging habitats. Shortnose sturgeon spawn both upriver and downriver from the Savannah River Plant. Spawning activity above the SRP site demonstrates that an adequate zone of passage exists for shortnose sturgeon migration. After L-Reactor startup, large areas of the Steel Creek/swamp system will not be suitable spawning/foraging habitat for fish. However, there is no indication that shortnose sturgeon utilize this habitat.

- Entrainment of shortnose sturgeon eggs in the SRP intake cooling water is not likely due to their demersal and adhesive nature. However, larval entrainment is a possibility since four have been collected in or near the SRP pumphouse intake canals. Given the apparent low density of shortnose sturgeon in the intake canals and their reported or assumed preference for benthic habitats, it is unlikely that larval entrainment is a significant impact.

- From previous impingement studies, no shortnose sturgeon have been found on SRP cooling water intake screens. There is no evidence that shortnose sturgeon juveniles or adults inhabit the cooling water intake canals. Furthermore, it is unlikely that any healthy shortnose sturgeon will be impinged based on a comparison of pumphouse cooling water intake velocities and sturgeon swimming speeds.

- Although temperature effects on shortnose sturgeon larvae are possible due to current and/or future thermal plumes in the Savannah River, the effects are considered minimal because of the localized nature of the plumes. Cold shock is another possible effect; however, there is no indication that juvenile shortnose sturgeon are overwintering in SRP thermal plumes. Adults will not be directly impacted by the thermal plumes because of their ability to avoid them.

APPENDIX A

CURRENT PROGRAMS

A.1 Savannah River Aquatic Ecology Program

The SRP aquatic ecology program in the Savannah River was initiated in March, 1982, to evaluate the impacts of SRP, particularly L-Reactor operation, on the river ecosystem. The program was designed to collect biweekly plankton samples which could contain fish eggs, larvae, and macroinvertebrate drift organisms from the river in the vicinity of the 1G, 3G, and 5G pumphouses (Figure A-1). Additional samples were collected from above, below, and in the mouth of Four Mile Creek, and below and in the mouth of Steel Creek (Figure A-2). Biweekly impingement data were also collected to determine the number of fish trapped on the pumphouse traveling screens. Quarterly adult fish collections were made by electrofishing and hoop netting to provide relative abundance information on fish populations in the SRP area. Data from the first collection year are summarized by Environmental and Chemical Sciences (ECS 1982, 1983a, 1983b, 1983c).

In February, 1983, the original program was expanded into a comprehensive study to evaluate both cooling water intake effects and all SRP thermal effluents to the Savannah River. Sampling stations for ichthyoplankton, macroinvertebrates, and adult fishes were also located at all SRP tributaries to the Savannah River.

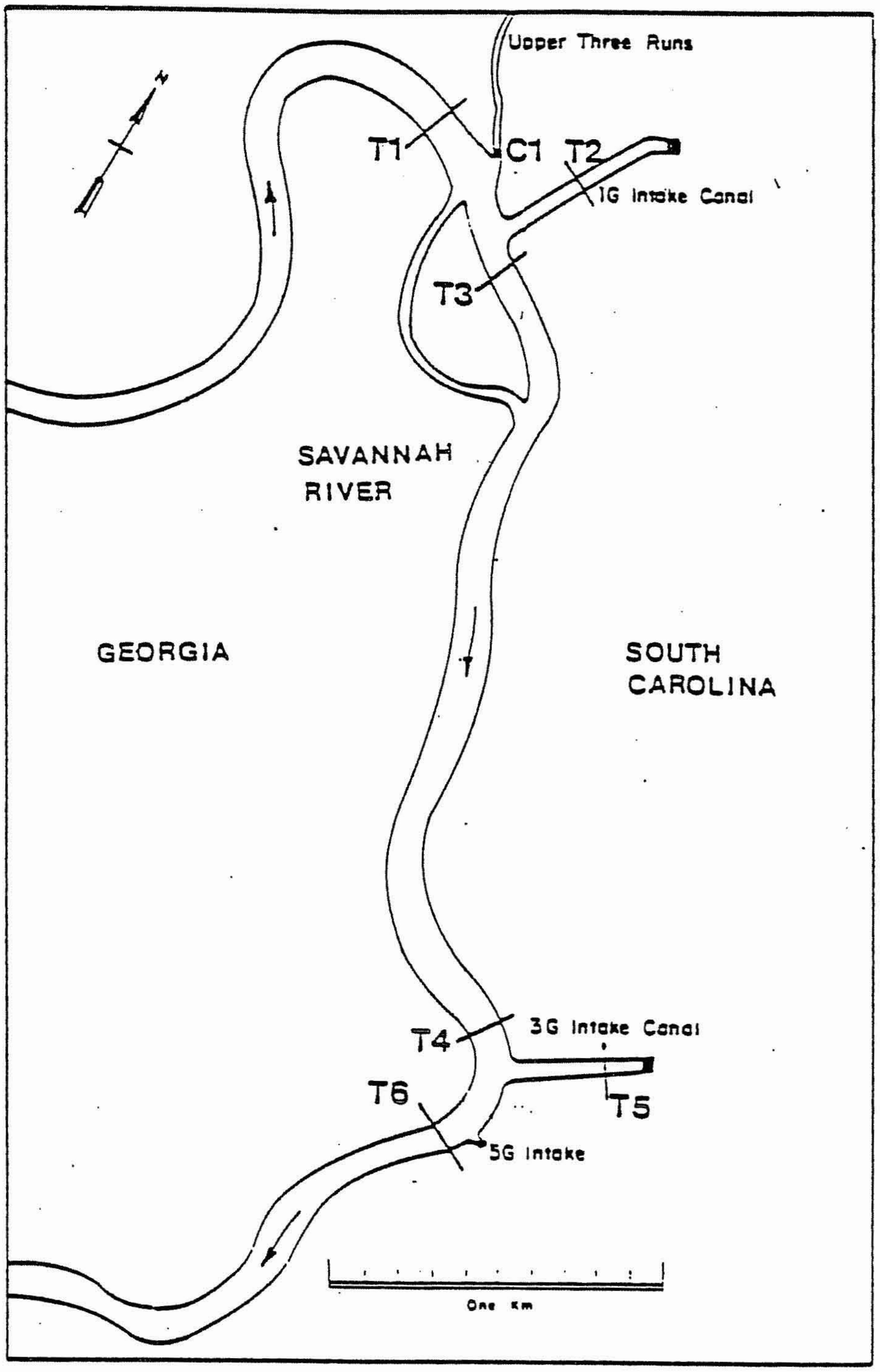


FIGURE A-1. Location of Sampling Transects T1 through T6 and Station C1.

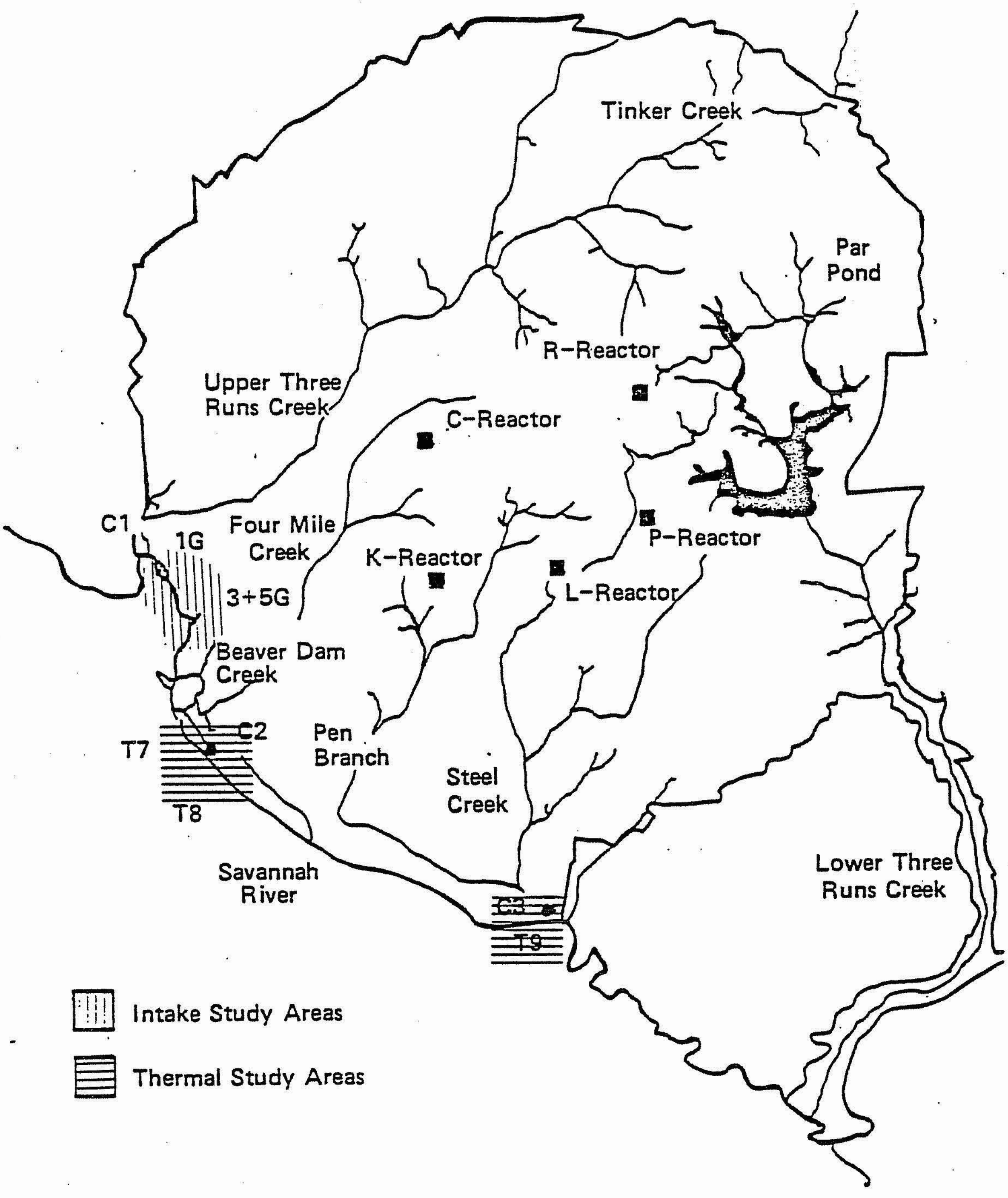


FIGURE A-2. Location of Sampling Transects T7 through T9 and Stations C2 and C3.

In addition, offsite ichthyoplankton stations were located in 28 additional creeks, and at 10 mile intervals in the river from Augusta to Savannah to provide perspective on the relative importance of the SRP area for fish spawning in the Savannah River. Preliminary data analyses from the 1983 collection year are discussed by ECS (1983c). A program summary and listing of the onsite and offsite station locations for the Savannah River aquatic ecology program are given in Tables A-1 and A-2.

A.2 Larval Atlantic and Shortnose Sturgeon Taxonomic Guide

To date, 28 sturgeon larvae have been found in ichthyoplankton samples collected in the Savannah River as part of the 1982-83 SRP aquatic ecology program (Matthews and Muska, 1983). The Savannah River is inhabited by at least two species of sturgeon, the Atlantic and the endangered shortnose. Although nine of the 28 sturgeon larvae collected in 1982-83 have been tentatively identified as shortnose sturgeon by D. E. Snyder, Colorado State University, the existing criteria for larval sturgeon identification, particularly protolarvae and mesolarvae, are largely circumstantial. There are currently no diagnostic keys available to identify shortnose or Atlantic sturgeon larvae. The Savannah River Plant has contracted the services of D. E. Snyder to conduct a comprehensive comparative study of larvae for both species based on currently available specimens. The study will be conducted in cooperation with D. E. Marchette at the South Carolina Wildlife and Marine Resources Research Institute in

Charleston, South Carolina. The final product will be a diagnostic guide for larval sturgeon identification which will be published and made available to other sturgeon investigators.

TABLE A-1.

SRP Aquatic Ecology Program on the Savannah River

I. First Phase Nearfield Monitoring Program

   A. Sample Collection Stations (14)

   - Near or in pumphouse intake canals
   - Mouth of UTRC*, FMC*, SC*
   - Above and below UTRC, FMC, SC

   B. Sample Collection Frequency

   - Ichthyoplankton - biweekly (1982) or weekly (1983) February-July)
   - Adult fish populations - quarterly
   - Macroinvertebrates (fixed samplers) - monthly
   - Impinged fish - 100 times/year

II. 3-Year Monitoring Program

   A. Program in I Above

   B. Additional Nearfield Studies (Phased in Feb. 1, 1983)

   - Ichthyoplankton at BDC* and LTRC*
   - Adult fish at BDC and LTRC
   - Macroinvertebrate (fixed samplers) at UTRC, BDC, and LTRC
   - Sex and breeding condition of impinged fishes
   - Determine periphyton taxa near all tributaries
   - Macroinvertebrate drift (plankton) at all stations

   C. Farfield Studies (Phased in Feb. 1, 1983)

   Weekly ichthyoplankton samples will be collected from February-July between Augusta and Savannah (river mile 30) at stations located in:

   - Savannah River every 10 miles
   - Mouths of all named tributaries (about 30)

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* UTRC: Upper Three Runs Creek
FMC: Four Mile Creek
SC: Steel Creek
BDC: Beaver Dam Creek
LTRC: Lower Three Runs Creek

TABLE A-2.

Sampling Station Locations for the SRP Aquatic Ecology Program (1983) on the Savannah River.

River Mile	Sampling Station Description
River transect	
187.1	Upper farfield River transect at 10-mile interval above Savannah River Plant
176.0	River transect at 10-mile interval above Savannah River Plant
166.6	River transect at 10-mile interval above Savannah River Plant
	Nearfield
157.3	Above 1G canal
157.0	Below 1G canal
155.4	Above 3G canal
155.2	Below 5G pumphouse
152.2	Above Beaver Dam Creek
152.0	Below Beaver Dam Creek
150.8	Above Four Mile Creek
150.4	Below Four Mile Creek
141.7	Above Steel Creek
141.5	Below Steel Creek
137.7	Recovery transect below Steel Creek
129.1	Above Lower Three Runs Creek
128.9	Below Lower Three Runs Creek
	Lower Farfield
120.0	River transect at 10-mile interval below Savannah River Plant

TABLE A-2.

Sampling Station Locations for the SRP Aquatic Ecology Program (1983) on the Savannah River (continued)

River Mile	Sampling Station Description
River transect	
110.0	Lower farfield River transect at 10-mile interval below Savannah River Plant
97.5	River transect at 10-mile interval below Savannah River Plant
89.3	River transect at 10-mile interval below Savannah River Plant
79.9	River transect at 10-mile interval below Savannah River Plant
69.9	River transect at 10-mile interval below Savannah River Plant
60.0	River transect at 10-mile interval below Savannah River Plant
50.2	River transect at 10-mile interval below Savannah River Plant
40.2	River transect at 10-mile interval below Savannah River Plant
29.6	River transect at 10-mile interval below Savannah River Plant
Creek transect	
187.2	Butler Creek
183.3	Spirit Creek
180.1	Pine Creek
176.1	Hollow Creek
171.6	High Bank Creek
164.2	McBean Creek
162.2	Upper Boggy Creek

TABLE A-2.

Sampling Station Locations for the SRP Aquatic Ecology Program (1983) on the Savannah River (continued)

River Mile	Sampling Station Description
Creek transect	
160.2	Newberry Creek
157.2	Upper Three Runs Creek[1]
152.1	Beaver Dam Creek[1]
150.6	Four Mile Creek[1]
141.6	Steel Creek[1]
133.5	Sweet Water Creek
129.0	Lower Three Runs Creek[1]
126.5	Smith Lake Creek
114.5	Swift Creek
109.0	The Gaul
97.6	Briar Creek
92.6	Buck Creek
88.6	Ware Creek
84.1	Pike Creek
78.4	Black Creek
64.2	Lake Parachuchia Outlet
53.2	Tew Lake
51.1	Plank Creek
48.8	Yorkley Creek
47.7	Seines Landing

[1] Located on the Savannah River Plant.

TABLE A-2.

Sampling Station Locations for the SRP Aquatic Ecology Program (1983) on the Savannah River (continued)

River Mile	Sampling Station Description
Creek transect	
44.8	Ebenezer Creek
43.2	Lockners Creek
40.3	Coleman Lake
35.4	Meyer's Lake
30.0	Collin Creek
Intake transect	
157.1	1G Canal[1]
155.3	3G Canal[1]

[1] Located on the Savannah River Plant.

References

Bath, D. W., J. M. O'Conner, J. B. Alber, and G. L. Arvidson. 1981. Development and Identification of Larval Atlantic Sturgeon (*Acipenser oxyrhynchus*) and Shortnose Sturgeon (*A. brevirostrum*) from the Hudson River Estuary, New York. *Copeia 3*, 711-717.

Blaxter, J. H. S. 1969. Swimming Speeds of Fish. *FAO Fish. Rep. 62*, 69-100.

Brundage, H. M. III, and R. E. Meadows, 1982. Occurrence of the Endangered Shortnose Sturgeon, *Acipenser brevirostrum* in the Delaware Estuary. *Estuaries 5*, 203-208.

Buckley, J. L. 1982. *Seasonal Movement, Reproduction, and Artificial Spawning of Shortnose Sturgeon (Acipenser brevirostrum) from the Connecticut River.* M.Sc. Thesis, Univ. of Mass., Amherst, Massachusetts.

Buckley, J. L. and B. Kynard. 1981. Artificial Spawning and Rearing of Shortnose Sturgeon from the Connecticut River. *Prog. Fish Cult. 43*, 74-76.

Dadswell, M. J. 1975. Biology of the Shortnose Sturgeon (*Acipenser brevirostrum*) in the Saint John Estuary, New Brunswick, Canada. p. 75 in *Baseline Survey and Living Resource Potential of the Saint John Estuary Vol. 3*. Huntsman Marine Laboratory, St. Andrews.

Dadswell, M. J. 1979. Biology and Population Characteristics of the Shortnose Sturgeon *Acipenser brevirostrum* LeSueur 1818 (Osteichthyes: Acipenseridae) in the Saint John Estuary, New Brunswick, Canada. *Can. J. Zool. 57*, 2186-2210.

Dadswell, M. J., B. D. Taubert, T. S. Squiers, D. Marchette and J. Buckley. MS 1982. Synopsis of the Biological Data on Shortnose Sturgeon, *Acipenser brevirostrum* LeSueur 1818.

Dovel, W. L. 1978. *Sturgeons of the Hudson River, New York.* Final Performance Report for New York Department of Environmental Conservation.

Du Pont 1982. *Environmental Information Document, L-Reactor Reactivation*. USDOE Report DPST-81-241, Savannah River Laboratory, E. I. du Pont de Nemours & Company, Aiken, South Carolina.

ECS. 1982. Interim Report, Biological Measurement Program in the Savannah River, 1 March through 31 May 1982., ESC-SR-1. Environmental and Chemical Sciences, Inc. USDOE Report DPST-82-990, Savannah River Laboratory, E. I. du Pont Nemours & Company, Aiken, South Carolina.

ECS. 1983a. Final Report on the Preliminary Measurement Program in the Savannah River, 1 March through 31 August 1982., ESC-SR-2. Environmental and Chemical Sciences, Inc. USDOE Report DPST-83-439, Savannah River Laboratory, E. I. du Pont de Nemours & Company, Aiken, South Carolina.

ECS. 1983b. Final Report on the Preliminary Biological Measurement Program in the Savannah River, 1 March through 31 August 1982., ESC-SR-3. Environmental and Chemical Sciences, Inc. USDOE Report DPST-83-736, Savannah River Laboratory, E. I. du Pont de Nemours & Company, Aiken, South Carolina.

ECS. 1983c. Interim Report on Adult Fisheries Study in the Savannah River, September 1982 and February 1983., ESC-SR-4. Environmental and Chemical Sciences, Inc. USDOE Report DPST-83-737, Savannah River Laboratory, E. I. du Pont de Nemours & Company, Aiken, South Carolina.

Gilbert, R. J. and A. R. Heidt. 1979. Movements of Shortnose Sturgeons, *Acipenser brevirostrum*, in the Altamaha River, Georgia. ASB Bull. 26, 35.

Heidt, A. R. and R. J. Gilbert. 1978. The Shortnose Sturgeon in the Altamaha River Drainage. Proceedings of the Rare and Endangered Wildlife Symposium. Georgia Department of Natural Resources, Game and Fish Division. Technical Bulletin WL4, 54-60.

Hoff, J. G. 1965. Two Shortnose Sturgeon, *Acipenser brevirostrum*, from the Delaware River, Scudders Falls, New Jersey. Bull. N. J. Acad. Sci. 10, 23.

Jacobsen, W. R., R. J. Brown, E. W. Rabon and L. J. Tilly. 1972. Thermal Discharges from the Savannah River Plant. DPST-72-428, Savannah River Laboratory, E. I. du Pont de Nemours & Company, Aiken, South Carolina.

Leland, J. G. II. 1968. A Survey of the Sturgeon Fishery of South Carolina. Contributions from Bears Bluff Laboratories 47, Wadmalaw Island, South Carolina.

Marchette, D. E. and R. Smiley. MS 1982. Biology and Life History of Incidentally Captured Shortnose Sturgeon, *Acipenser brevirostrum*, in South Carolina. South Carolina Wildlife and Marine Resources Research Institute, Charleston, South Carolina.

Matthews, R. A. and C. F. Muska. 1983. Shortnose and Atlantic Sturgeon Larvae in the Savannah River. USDOE Report DPST-83-753, Savannah River Laboratory, E. I. du Pont de Nemours & Company, Aiken, South Carolina.

McCleave, J. D., S. M. Fred, and A. K. Towt. 1977. Daily Movements of Shortnose Sturgeon, *Acipenser brevirostrum*, in a Maine Estuary. Copeia 1977, 149-157.

McFarlane, R. W., R. F. Frietsche, and R. D. Miracle. 1978. Impingement and Entrainment of Fishes at the Savannah River Plant, An NPDES 316b Demonstration. USDOE Report DP-1494, Savannah River Laboratory, E. I. du Pont de Nemours & Company, Aiken, South Carolina.

Meehan, W. E. 1910. Experiments in Sturgeon Culture. Trans. Am Fish Soc. 39, 85-91.

Oravetz, C. A. 1983. Letter to M. J. Sires, Assistant Manager for Health, Safety and Environment, Department of Energy, Savannah River Operations Office. 11 May 1983. National Marine Fisheries Service, St. Petersburg, Florida.

Patrick, R., J. Cairns, Jr., and S. S. Roback. 1967. An Ecosystematic Study of the Flora and Fauna of the Savannah River. Proc. Ac. Nat. Sci. Philadelphia 118, 109.

Pekovitch, A. W. 1979. Distribution and Some Life History Aspects of the Shortnose Sturgeon (*Acipenser brevirostrum*) in the Upper Hudson River Estuary. HES No. 550109023. Hazelton Environment Science Corporation. Northbrook, Illinois.

Pottle, R. and M. J. Dadswell. 1979. Studies on Larval and Juvenile Shortnose Sturgeon (*Acipenser brevirostrum*). Report to the Northeast Utilities Service Company, Hartford, Connecticut.

Robins, C. R., R. M. Bailey, C. E. Bond, T. R. Brooker, E. A. Lachner, R. N. Lea, and W. B. Scott. 1980. A List of Common and Scientific Names of Fishes from the United States and Canada. Amer. Fish. Soc. Spec. Publ. 12, 174 p.

Sires, M. J. 1983. Letter to J. T. Brawner, Regional Director of the National Marine Fisheries Service. 6 May 1983. U. S. Department of Energy, Savannah River Operations Office, Aiken, South Carolina.

Squiers, T. S. and M. Smith. 1978. Distribution and Abundance of Shortnose Sturgeon and Atlantic Sturgeon in the Kennebec River Estuary. Prog. Rep. Project #AFC-19-1, Dept. of Marine Resources, Maine.

Taubert, B. D. 1980a. Reproduction of Shortnose Sturgeon (Acipenser brevirostrum) in the Holyoke Pool of the Connecticut River, MA. Copeia 1980, 114-117.

Taubert, B.D. 1980b. Biology of Shortnose Sturgeon (Acipenser brevirostrum) in the Holyoke Pool, Connecticut River, Massachusetts. Ph.D. Thesis, University of Massachusetts, Amherst, Massachusetts.

Taubert, B. D. and M. J. Dadswell. 1980. Description of Some Larval Shortnose Sturgeon (Acipenser brevirostrum) from the Holyoke Pool, Connecticut River, Massachusetts, USA, and the Saint John River, New Brunswick, Canada. Can. J. Zool. 58, 1125-1128.

Taubert, B. D. and R. J. Reed. 1978. Observations of Shortnose Sturgeon (Acipenser brevirostrum) in the Holyoke Pool, Connecticut River, Massachusetts. Rept. to Northeast Utilities Service Co., Hartford, Connecticut.

Tseng, J. C. 1983. Letter to A. Mager, National Marine Fisheries Service, St. Petersburg Florida. 21 June 1983. U.S. Department of Energy, Savannah River Operations Office, Aiken, South Carolina.

Vladykov, V. D. and J. R. Greeley. 1963. Order Aciperseroidei. p. 24-60 in Fishes of the Western North Atlantic. Mem. Sears Found. Mar. Res. 1.