CHAPTER 13

RADIONUCLIDES IN OFFSITE DRINKING WATER AND SURFACE WATER

ABSTRACT

This chapter discusses the extent and analytical results of the radiological monitoring program for water supplies of 14 communities surrounding the Savannah River Site (SRS), for one upstream and two downstream drinking water treatment plants supplied by the Savannah River, and for offsite locations from the Savannah River. The sampling locations, collection methods and frequencies, and the analyses performed are discussed.

Routine monitoring of the community water supplies began at the time of plant startup, but it was limited to gross alpha and beta analyses until 1960, when tritium monitoring was initiated. With the exception of tritium measurements, no routine, radionuclide-specific data have been generated for the community water supplies. The downstream water treatment plants were monitored for gross alpha, beta, tritium, and, in later years, for ^{137}Cs. While the Port Wentworth Plant provides most water for an industrial plant, it can also supply some water to the City of Savannah during water shortages. The Beaufort-Jasper Plant was designed to supply domestic water for a population of about 50,000 people. Since plant startup, the SRS has routinely sampled the Savannah River along the Site boundary and downstream of the Site to evaluate the impacts of liquid releases. Routine tritium monitoring began in 1958 to supplement the gross alpha and nonvolatile beta measurements. Beginning in the mid-1960s, other radionuclides, including radiocesium, radiostrontium, ^{51}Cr, ^{60}Co, were routinely monitored.

For dose reconstruction, the potential impacts of SRS operations on both the surrounding community water supplies and the downstream water treatment plants are of greatest concern because the safety of drinking water is of great interest to the public. The Savannah River monitoring data can provide the primary means for evaluating the impact of SRS releases of radionuclides other than tritium on the downstream drinking water supplies. They also may be useful to evaluate other exposure pathways, such as the ingestion of fish and other aquatic organisms and recreational use of the river.

INTRODUCTION

A thorough evaluation of radiological data for any media involves using the most basic types of data that are available. Details on the SRS water monitoring program were compiled through an extensive review of documents—such as weekly and monthly reports, internal memos, and special studies—identified during Phase I of the dose reconstruction. Emphasis was placed on reconstructing and compiling information for the 1950s through the early 1970s, when few details are provided in the semiannual and annual Site monitoring reports. By the mid-1970s, the annual reports had been expanded to include descriptions of the sampling and analytical methods and to provide quality assurance data, such as interlaboratory comparison results.

Until recent years, only summary data (semiannual or annual averages, minimums, and maximums) have been reported in the SRS monitoring reports. To provide the resolution needed for the types of assessments involved in a dose reconstruction, individual measurements or averages calculated over shorter periods of time are needed. Furthermore, individual measurements (preferably raw, handwritten data) are needed to evaluate the reliability of summary data. This verification is needed to ensure the quality of the assessments in which the data are used and to build public confidence in the dose reconstruction process.

Fiche copies of handwritten, individual sample data were identified for a number of environmental media during *Radiological Assessments Corporation*'s (*RAC*'s) comprehensive review of SRS documents. These data, referred to as aperture card data, are available for the community water supplies and the Savannah River from the late 1950s through the early 1970s. Drinking water treatment plant aperture card data are available from the mid-1960s through the early 1970s.

Much of the available aperture card data for the offsite water monitoring programs have been compiled into three Microsoft Excel® workbooks: CWSDATA.xls (community water supply data), WTPDATA.xls (water treatment plant data), and SRDATA.xls (Savannah River data). The CWSDATA and WTPDATA workbooks also contain semiannual and annual averages from the Site monitoring reports for those years in which aperture card data are not available. The sources (e.g., aperture cards, annual monitoring reports, etc.) and their associated *RAC* document database numbers are indicated for each data entry in the offsite water monitoring workbooks.

Another source of individual sample data, covering later years for which no aperture card data are available, has been identified and catalogued in *RAC*'s SRS document database. This source is a series of Health Protection Environmental Monitoring Monthly Reports that are actually computer printouts of laboratory measurements for the various environmental media (e.g., Du Pont 1976). The data reports for 1976 through 1990 have been catalogued in the document database. However, because they were not available until late in Phase II, these data are not included in the Excel workbooks for drinking water or the Savannah River.

DRINKING WATER MONITORING

Routine monitoring of public drinking water by the SRS has consisted of sample collections from 14 communities surrounding the Site (Figure 13-1) and from two drinking water treatment plants located downstream of the SRS on the Savannah River, in Beaufort-Jasper, South Carolina, and Port Wentworth, Georgia (Figure 13-2).

Community Water Supplies

The sources of water used by the 14 communities that were routinely monitored by the SRS are Aiken-stream and well, Allendale-deep well, Augusta-river, Barnwell-deep well, Bath-deep well, Blackville-deep well, Clearwater-lake, Jackson-deep well, Langley-deep well, New Ellenton-deep well, N. Augusta-river, Sardis-deep well, Waynesboro-stream, and Williston-deep well (Arnett et al. 1992).

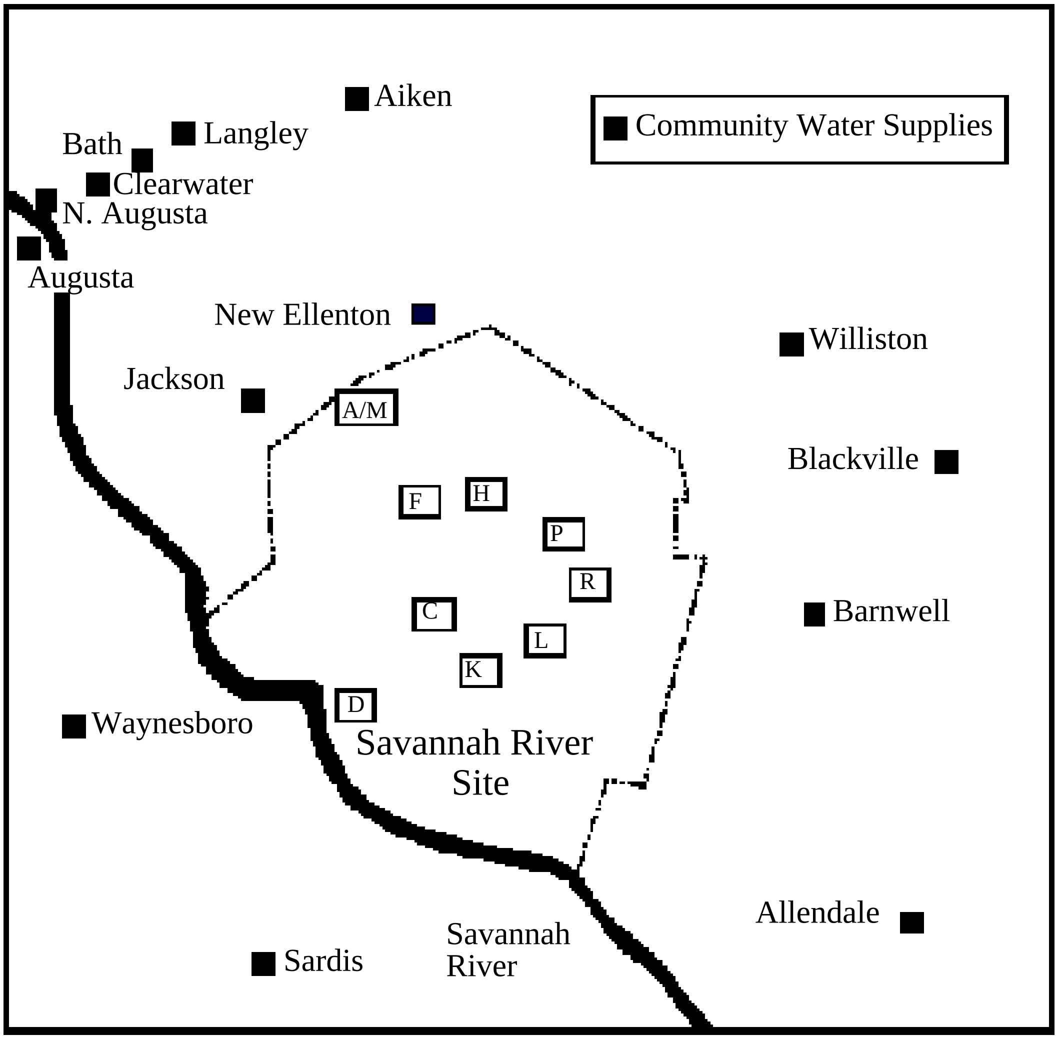


Figure 13-1. Locations of 14 communities surrounding the SRS for which routine radiological monitoring of public drinking water has been conducted.

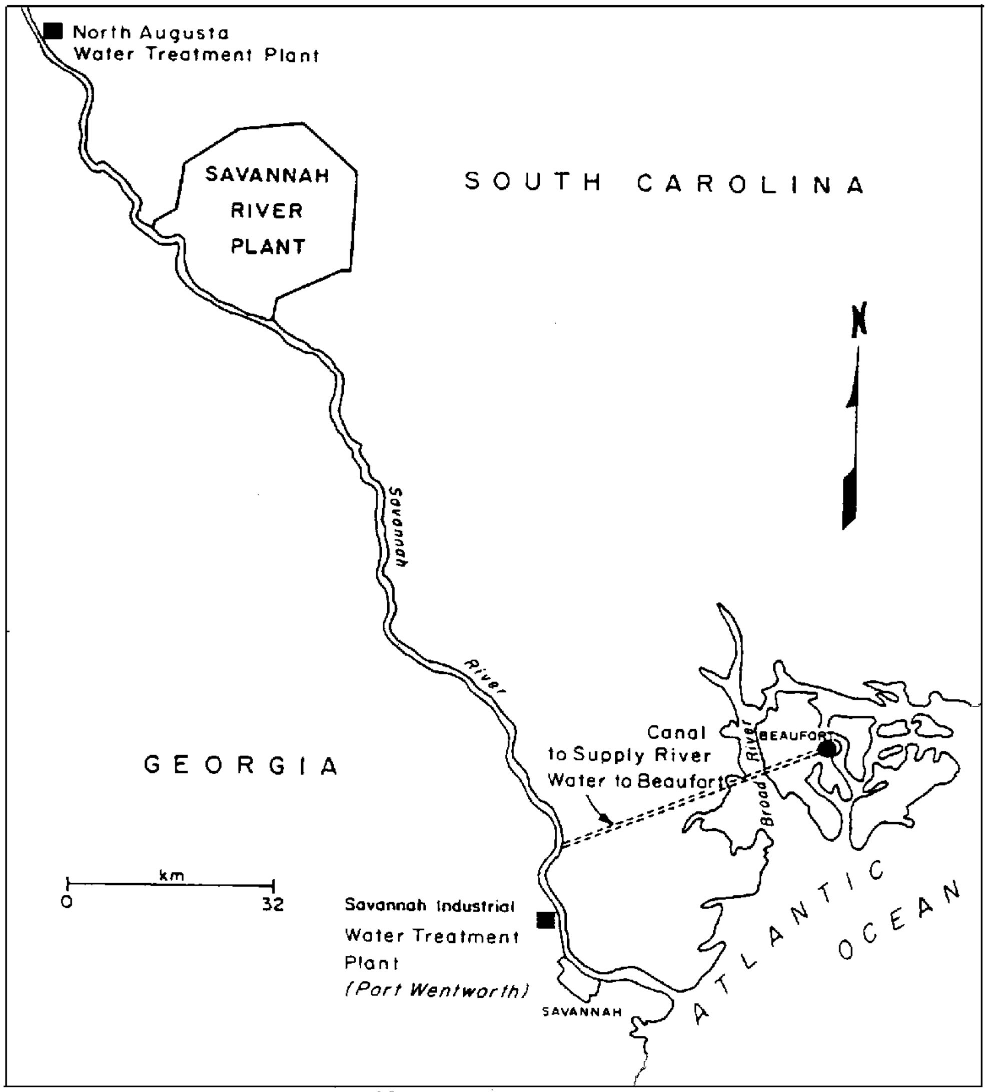


Figure 13-2. Location of drinking water treatment plants using Savannah River water in the vicinity of the SRS. The plant at Port Wentworth, which supplies an industrial complex, was in operation at the time of SRS plant startup. The Beaufort-Jasper plant, which supplies domestic water for a population of approximately 50,000, went into operation in 1965. The North Augusta plant, located upstream of the SRS, was monitored as a control location.

Monitoring History and Available Data

The routine monitoring of the community water supplies is summarized in Table 13-1. Preoperational monitoring was performed on the public water supplies from 12 of the communities shown in Figure 13-1. The New Ellenton and Jackson supplies were not operational until 1955. Samples were analyzed for gross alpha, gross beta, ^{40}K, total potassium, uranium/plutonium alpha, radium, and radon. Based on 16 samples per community, the average beta concentrations in each of the supplies ranged between 5.2 and 6.8 pCi L^{-1} (Reinig et. al 1953).

Table 13-1. History of Routine SRS Radiological Monitoring of the Community Water Supplies[a]

Year	Sampling Frequency	Radiological Analyses
1953 - 1959 [b]	Monthly	gross alpha and beta
1960 – April 1966	Monthly	gross alpha, beta, and tritium
May 1966 – 1991[c]	Semiannually	gross alpha, beta, and tritium

[a] Aiken, Allendale, Augusta, Barnwell, Bath, Blackville, Clearwater, Jackson, Langley, New Ellenton, North August, Sardis, Waynesboro, and Williston
[b] Jackson and New Ellenton not operational until 1955
[c] North Augusta sample four times in 1967 and monthly from April 1968 through 1973.

Routine monitoring of the community water supplies began at the time of plant startup, but it was limited to gross alpha and beta analyses until 1960 when tritium monitoring was initiated. The Jackson and New Ellenton water supplies began to be used in 1955 and were incorporated into the routine monitoring program at that time. Relatively high alpha concentrations were observed in the Jackson water supply (deep well) over the years, prompting periodic investigations by the SRS into the possible sources. In 1961, samples of Jackson well water were analyzed for ^{226}Ra content, and in 1963, drinking water from 11 wells in the central Savannah River area were analyzed for total radium, ^{223}Ra, ^{224}Ra, and ^{226}Ra. Total radium concentrations ranged from 0.3 to 8.9 pCi L^{-1} (Edgar 1961, 1963). In 1981, the SRS analyzed Jackson drinking water for uranium, plutonium, thorium, and gamma emitters. Only naturally occurring radionuclides, principally ^{226}Ra, ^{228}Th, and their radioactive decay products, were identified (Ashley and Zeigler 1984).

From 1953 through April 1966, samples of the community water supplies were collected monthly. After April 1966, the collection frequency was reduced to semiannually for all locations except North Augusta. Sampling of the North Augusta supply was performed four times in 1967 and monthly from April 1968 through 1972. After 1973, North Augusta was sampled semiannually. The community water supply samples have always been grab samples collected from the tap. Historically, the samples were collected at public buildings or service stations (Du Pont 1953). The 1991 SRS annual report (Arnett et al. 1992) lists the community post offices as the sampling locations.

With the exception of tritium measurements, no routine, radionuclide-specific data have been generated for the community water supplies. Furthermore, no special studies, except those related to elevated alpha levels in the Jackson supply, appear to have been performed on the community supplies.

The following individual sample data have been catalogued in *RAC*'s SRS document database:

- Gross alpha, gross beta, and tritium data for monthly samples for the years 1959 through 1966 on aperture cards (handwritten data logs)
- Gross alpha, gross beta, and tritium data for semiannual samples for 1967 through 1973 on aperture cards

- Gross alpha, gross beta, and tritium data for semiannual samples for 1976 through 1990 from the Health Protection Environmental Monitoring Monthly data reports.

No sources of individual sample data have been located for the years before 1959, and the community water supplies monitoring program was rarely mentioned in the Site's early weekly or monthly reports.

As listed above, 9 of the 14 surrounding communities are supplied from deep wells, 4 use surface water sources, and 1, Aiken, South Carolina, uses both well and surface water. Because there is no evidence that contaminated groundwater has moved beyond the Site boundary (Arnett et al. 1993), the communities that use only well water are not expected to be a focus of the dose reconstruction. Continued groundwater monitoring will provide a means of evaluating the importance of this exposure pathway into the future (see appendix J).

Of the five communities supplied by surface water, two get their water from the Savannah River (above the SRS), two from streams, and one from a lake. None of the surface water supplies come into contact with SRS liquid releases. The only pathway for SRS contaminants to enter these supplies would be via deposition following atmospheric releases. The most likely nuclide of interest from SRS releases would be tritium that could enter the surface water sources via rainwater.

All of the surface water-supplied communities are located at least 40 km from the center of the Site. Four of the five are located to the north or northwest of the SRS, and one (Waynesboro) is located to the southwest. There is no strongly prevailing wind direction at the SRS, but a slight prevalence toward the southwest is observed (Arnett et al. 1992). Tritium deposition levels have been shown to steadily decrease with distance from the Site (Murphy et al. 1991). SRS air monitoring performed in these communities during periods of relatively high tritium releases indicates that the tritium levels at these distances are low (see Chapter 8 for a detailed discussion regarding measurements made for air and rainwater samples). Therefore, the contribution of SRS-released tritium to these surface water sources is expected to be small and difficult to detect. In fact, the average tritium measurements reported for the community water supplies are frequently at or below the detection limits (Figure 13-3). For those individual measurements that are substantially above the detection limits, it would be difficult to distinguish between any SRS-contributed tritium and tritium from weapons fallout. This is true especially during the 1960s, when fallout levels were at their peak (Wyerman et al. 1970).

However, it should be noted that the SRS has occasionally reported elevated levels of tritium in these water supplies and attributed these increases to Site operations (e.g., Ashley et al. 1982).

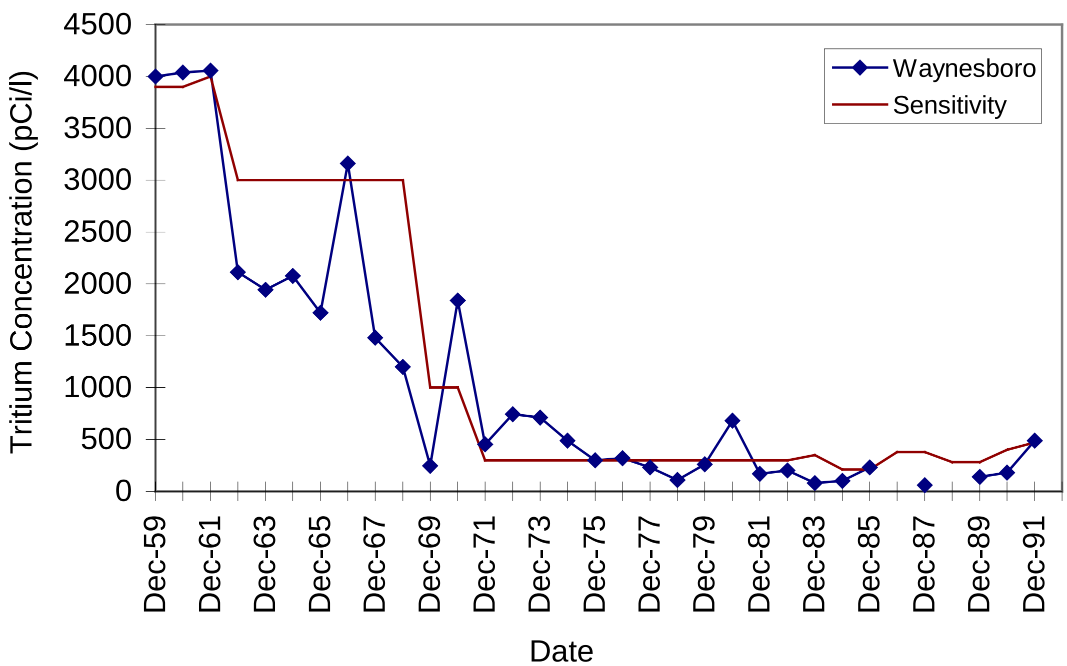


Figure 13-3. Average tritium measurements in Waynesboro, Georgia, drinking water (surface water supplied) from 1959 through 1991. Grab samples of tap water were collected monthly until 1967 when the sampling frequency was decreased to semiannually. Many of the tritium measurements were at or below the sensitivity (detection limit) of the analytical method. The general decrease over time can be attributed to decreases in the levels of fallout tritium from weapons testing and improvements in the detection sensitivities.

Community Water Supplies Data Workbook

The following data for each of the five communities supplied by surface water—taken from aperture cards and the semiannual and annual monitoring reports—have been compiled into a Microsoft Excel workbook, CWSDATA.xls:

- Gross beta and tritium data for monthly samples for 1959 through 1966
- Gross beta and tritium data for semiannual samples for 1966 through 1973
- Gross beta and tritium semiannual or annual averages for 1954 through 1992.

In addition, semiannual and annual average gross beta and tritium values for three of the well water supplied communities (Jackson, Bath, and Langley) have been compiled in the CWSDATA workbook. Annual $^{89,90}Sr$ data that are reported in the annual reports after 1987 have also been entered. In the electronic version, double-clicking on the following hyperlink provides access to this workbook: CWSDATA.xls.

The CWSDATA workbook contains an introductory spreadsheet that provides an overview of the workbook and individual spreadsheets for each of the eight communities for which data have been entered (Aiken, Augusta, Bath, Clearwater, Jackson, Langley, N. Augusta, and Waynesboro). The workbook also contains a "Data Plots" spreadsheet that provides sample plots of the average and individual gross beta and tritium measurements for some of the community supplies. The "USGS" spreadsheet provides a comparison of U.S. Geological Survey (USGS) tritium measurements in southeastern streams during the early 1960s to SRS measurements in three of the surrounding communities.

Downstream Drinking Water Treatment Plants

Two drinking water treatment plants use Savannah River water downstream of the SRS: Beaufort-Jasper and Port Wentworth (also called Cherokee Water Treatment Plant) (Figure 13-2). SRS liquid effluents enter the Savannah River via the Site streams. Therefore, these downstream treatment plants are a source of direct exposure to the public. The following is a discussion of the monitoring information that is available for these two downstream plants. Until 1983, monitoring of an upstream control, the North Augusta Drinking Water Treatment Plant, was limited to the monthly or semiannual grab samples discussed above in the Community Water Supplies section. In late 1983, the SRS began collecting composite samples of raw and finished water from the North Augusta plant for comparison to data generated for the Beaufort-Jasper and Port Wentworth plants.

The treatment processes used by the Port Wentworth, Beaufort-Jasper, and North Augusta treatment plants are similar, consisting of flocculation, settling, and filtration (Figure 13A-1, Addendum 13A).

The monitoring history and available data for the drinking water treatment plants are discussed below. A summary of the data available for individual sample measurements (i.e., not summary data) is provided in Table 13-2.

Monitoring History and Available Data for Port Wentworth

The Port Wentworth Plant is named the Cherokee Hill Water Treatment Plant and is frequently referred to as Savannah or Savannah Industrial in SRS documents. It has been in operation since the time of SRS plant startup. The water plant is supplied via Abercorn Creek. In 1963, it was reported that at least 50% of the water in Abercorn Creek came from the Savannah River (Du Pont 1963a).

The Cherokee Hill Water Treatment Plant provides water for an industrial complex, and can also supply up to 10 million gallons per day to the City of Savannah in times of water shortage (Du Pont 1963a). The City of Savannah is normally supplied by well water. Approximately 15,000 workers in the industrial complex served by the Cherokee Hill plant potentially consume drinking water. Furthermore, there are indications that two soft drink bottling companies may have operated in the industrial complex for some period of time before 1990 (Hamby 1991).

Table 13-2. Available Individual Sample Data from Routine Monitoring of the Drinking Water Treatment Plants Supplied by the Savannah River[a]

Treatment Plant	Dates	Available Data	Data Source
North Augusta (located upstream of SRS, operational at time of SRS startup)	1959 – 1973	Monthly gross alpha, gross beta, and tritium	Aperture cards
	1976 – 1983	Semiannual gross alpha and beta, and tritium	Health Protection Dept. Monthly Data Reports
	1983 – 1990	Monthly gross alpha, gross beta, and tritium	Health Protection Dept. Monthly Data Reports
Port Wentworth (located downstream of SRS, also called the Savannah Industrial WTP, operational at time of SRS startup)	1/65 – 11/66	Monthly tritium	Johnson 1966 (memo)
	4/65 – 10/66	Monthly gross alpha and beta	Johnson 1966 (memo)
	1967 – 1971	Monthly tritium	Aperture cards
	1968 – 1971	Monthly gross alpha and beta	Aperture cards
	1976 – 1990	Monthly gross alpha and beta, and tritium	Health Protection Dept. Monthly Data Reports
Beaufort-Japer (located downstream of SRS, began operation in 1965)	4/65 – 10/66	Monthly tritium	Johnson 1966 (memo)
	1966 – 1973	Monthly tritium	Aperture cards
	1970 – 1973	Monthly gross alpha and beta	Aperture cards
	1976 – 1990	Monthly gross alpha and beta, and tritium	Health Protection Dept. Monthly Data Reports

[a]Does not include summary data reported in semiannual and annual site environmental monitoring reports

No monitoring data for the Port Wentworth treatment plant are included in the SRS semiannual and annual monitoring reports before 1971. However, references to monitoring, as well as some data, for the early to mid-1960s have been identified. No record of monitoring for years before 1963 has been identified. The monthly reports for 1963 and 1964 discuss a sampling program that involved collection and analysis of water at various stages of treatment to determine removal efficiencies for several radionuclides of interest (Du Pont 1963a, 1963b, 1964a, 1964b). A summary of the data collected from May 1963 to March 1964, as reported in Landon (1963) is provided in Table 13A-1, Addendum 13A. The average removal efficiencies observed for the treatment process (coagulation, settling, and filtration) over the 12-month period ranged from 35 to 79%. These averages are said to represent a wide range of treatment conditions because the quality of the raw water varied over the sampling period (Du Pont 1964a).

The monthly reports provide limited information about the removal efficiency study and few interim data are reported. However, based on one set of interim data provided for May 1963, it appears samples were collected daily and composited monthly for analysis (Du Pont 1963b). The removal efficiencies observed during May are reported for the following isotopes: ^{89,90}Sr, ^{144}CdPr, ^{51}Cr, ^{103}Ru, ^{137}Cs, ^{95}Zr/Nb, ^{54}Mn, ^{106}Ru, and ^{140}BaLa. A statement in the January 1964 monthly report indicates that, at least up to that point, sample volumes of 25 L were collected and counted for 10 minutes (Du Pont 1964b).

The sampling effort at the Port Wentworth plant also involved the installation of collection pots in the settling basins for continuous sampling of "river sediment." A similar collection system was installed at the North Augusta Drinking Water Treatment Plant, upstream of the SRS, for background sampling. The first month's sediment data, as reported in Du Pont (1964b), are provided in Table 13A-2, Addendum 13A. Although the data are presented as concentrations in river sediment, they actually represent measurements in the sludge generated during the water treatment process (i.e., flocculation followed by settling). The radionuclide concentrations in these sediments do not depend solely on the concentrations present in the raw water. Other factors that potentially affect the levels include:

- Solids content of the raw water
- Treatment process (especially the type and amount of flocculating chemicals added)
- Frequency and method by which sediments are removed from the settling basins
- Water content of the sediments (Walker 1978).

Therefore, the value of these data to the dose reconstruction would be primarily qualitative. However, in conjunction with river monitoring data, these data could provide useful information. For example, based on the expected removals during water treatment (Table 13A-1, Addendum 13A) and the measured concentrations in the sludge (Table 13A-2, Addendum 13A), it can be estimated that approximately 30 times more ^{51}Cr than ^{137}Cs was present in the raw water treated by the Port Wentworth plant during the time this sludge was generated. This estimate is in good agreement with a statement in a 1963 monthly report that ". . .the Plant has released approximately 30 times as much ^{51}Cr as ^{137}Cs. . . (Du Pont 1963c)." Despite the apparent close agreement, it should be emphasized that the estimate obtained using the sludge data represents only a rough approximation. Several important factors are not considered in this assessment, including

- Differences in the fallout levels of ^{51}Cr and ^{137}Cs present in Savannah River water
- Differences in the losses of ^{51}Cr and ^{137}Cs, primarily to sediments, during transport from the point of release to the drinking water treatment plants

The only other data from the treatment plant sediment sampling program that have been identified to date are gross alpha and beta measurements for samples from the North Augusta and Port Wentworth plants from January 1965 through November 1966 (Johnson 1966).

Water monitoring data for the Port Wentworth plant are reported in the Site semiannual and annual monitoring reports beginning in 1971. The data reported are gross alpha, gross beta, and tritium (averages, maximums, and minimums reported after 1973). Cesium-137 data are reported for the years 1983 through 1985. In addition to these summary data, the following sources of individual water monitoring data have been identified for the Port Wentworth plant and catalogued in *RAC*'s SRS document database:

- Average ^{137}Cs concentration measured in finished water from the plant (0.29 pCi L^{-1}) during a 1-week period in December 1965 from Hayes and Boni (1983)
- Tritium concentrations in monthly grabs samples of water from April 1965 through October 1966 from Johnson (1966)
- Monthly gross beta concentrations in raw and finished water from February 1966 through November 1966 from Johnson (1966)
- Gross alpha and beta data for monthly samples of raw and finished water for 1968 through 1971 from aperture cards
- Tritium data for monthly samples of raw and finished water for 1967 through 1971 from aperture cards
- Gross alpha, gross beta, and tritium data for monthly samples for 1976 through 1990 from the Health Protection Department Monthly data reports.

Special survey data for the Port Wentworth plant (also called the Cherokee Water Treatment Plant) are included in several of the annual reports after 1980. For example, during 1986 the SRS performed a comprehensive survey of Abercorn Creek and the Port Wentworth plant to assess the impact of the restart of L-Reactor in 1985. The study consisted of three quarterly surveys during which water sediment, vegetation, and aquatic specimens were collected (Zeigler et at. 1987). In 1991, another comprehensive survey was performed in support of the proposed K-Reactor restart (Arnett et al. 1993).

Monitoring History and Available Data for Beaufort-Jasper

A second downstream drinking water treatment plant began operation in January 1965. The Beaufort-Jasper plant was constructed to supply domestic water, at a capacity of 8.8 million gallons per day, for a population of approximately 50,000 people represented by the following six major customers: Beaufort, South Carolina; Port Royal, South Carolina; Parris Island Marine Base; Laurel Bay, South Carolina; U.S. Navy Hospital; and Marine Air Base (Marter 1965).

The Beaufort-Jasper plant was designed to receive water via a 21-mi canal from the Savannah River, approximately 90 mi downstream from the SRS, to Mayer's Lake. In addition to Savannah River water, other surface water and groundwater enters the canal and Mayer's Lake. In early 1965, the treatment plant manager reportedly stated that he believed very little of the water they treated originated in the Savannah River. This belief was based on low mineral solids levels and high dissolved organics, which he believed originated in swamps that drain into the supply lake (Marter 1965). In 1985, modifications were made to the Beaufort-Jasper water pumping and transport system that increased the percentage of water supplied by the Savannah River (Hayes and Marter 1991). Before these modifications, the tritium levels reported for Beaufort-Jasper water are consistently lower than those observed in water from the Port Wentworth plant. After the changes were made, the tritium levels in the two downstream plants were essentially the same (Figure 13-4).

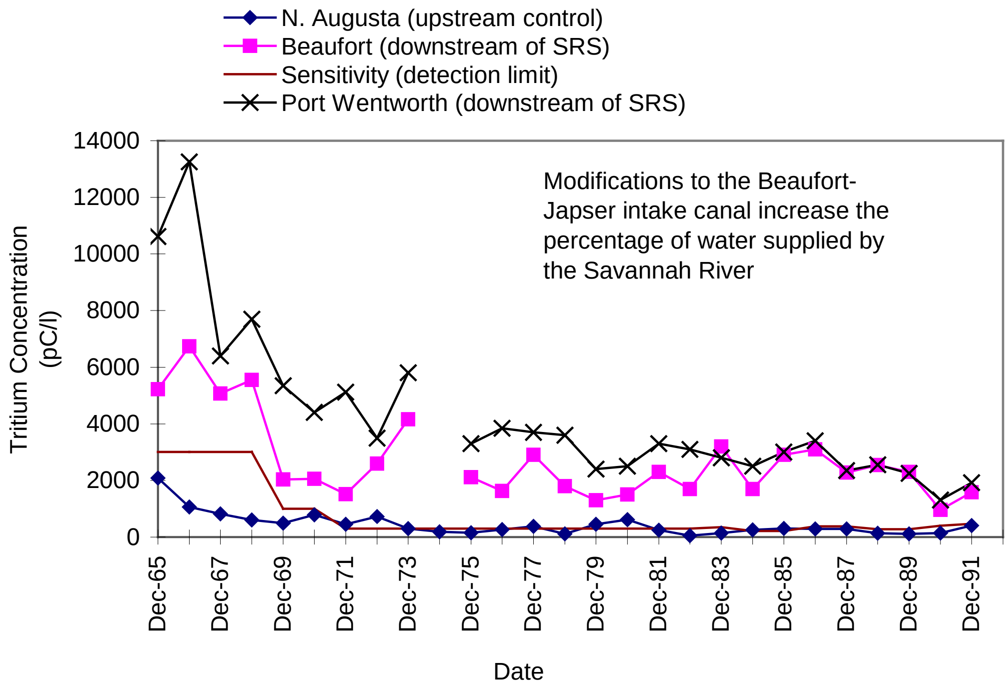


Figure 13-4. Average tritium measurements in treated water from three drinking water treatment plants supplied by the Savannah River: N. Augusta located upstream of the SRS and Beaufort-Jasper and Port Wentworth located downstream of the SRS. Until the mid-1980s when the Beaufort-Jasper supply canal was modified, the tritium levels in Beaufort-Jasper water are lower than those in the Port Wentworth plant because of dilution within the canal resulting from infiltration of surface water and groundwater.

The SRS has monitored water from Beaufort-Jasper for tritium since the treatment plant went online. Monthly data for early 1965 through late 1966 are reported in Johnson (1966). Beginning in 1967, semiannual tritium averages for the Beaufort-Jasper plant are provided in the SRS environmental monitoring report series, *Effect of the Savannah River Plant on Environmental Radioactivity* (identified by report numbers DPST-YY-30-1 and 2*)*. Gross alpha and beta data averages are not included in the Site monitoring reports until 1971.

The following sources of individual sample data for the Beaufort-Jasper plant have been catalogued in the *RAC* document database:

- Average ^{137}Cs concentration measured in finished water from the plant (0.04 pCi L^{-1}) during a 1-week period in December 1965 from Hayes and Boni (1983)
- Tritium data for monthly samples for April 1965 through October 1966 from Johnson (1966)
- Tritium data for monthly samples (specified as raw water after 1968) for January 1966 through 1973 from aperture cards
- Gross alpha and beta data for monthly samples (raw water) for 1970 through 1973 from aperture cards

- Monthly gross alpha, gross beta, and tritium measurements for 1976 through 1990 from the Health Protection Department Monthly data reports (raw water only before 1982, raw and finished water beginning in 1982).

In addition to monitoring water from the Beaufort-Jasper plant for tritium, the SRS arranged (through the South Carolina Board of Health) to obtain urine samples from individuals who consumed the water for tritium analysis. This special sampling was part of an evaluation of the overall impact of SRS-released tritium on the radiation exposure of the surrounding population. The first sampling consisted of 21 samples collected from 14 individuals over a 1-month period. Samples from eight individuals in North Augusta, upstream of the SRS, were analyzed as controls. The average tritium concentration in the urine of the Beaufort-Jasper population was 2.51 ± 0.91 pCi mL^{-1}, and the average in the control population was 1.24 ± 0.21 pCi mL^{-1}. The samples were analyzed by a "new" chromatographic method developed at Savannah River Laboratory (SRL), referenced as DP 65-1-12. From 1967 to 1968, 140 urine samples were analyzed. The results for these samples are not provided. However, they are reported to correspond to an annual radiation dose of 0.4 mrem to the Beaufort-Jasper population as compared to 0.3 mrem for individuals using water from North Augusta (Du Pont 1966, 1968, 1969). No original data or reports relating to this study were located in the SRS records.

Primarily in support of reactor restarts, several extensive surveys of the Beaufort-Jasper plant and canal have been performed by the SRS during the 1980s and 1990s. For example, surveys that included collection of sediment cores, vegetation, water, fish, and turtles and analysis for a variety of specific radionuclides were conducted in 1982, 1986, and 1991 (Ashley et al. 1984; Zeigler et al. 1987; Arnett et al. 1993). Because, virtually no radionuclide-specific data, other than tritium, are available for the downstream drinking water treatment plants, these relatively recent surveys may provide useful data for the dose reconstruction.

Water Treatment Plants Data Workbook

All of the available aperture card and semiannual and annual report data described above for the Port Wentworth (Savannah) and Beaufort-Jasper water treatment plants have been compiled into a Microsoft Excel workbook, WTPDATA.xls. In the electronic version, double-clicking on the following hyperlink provides access to this workbook: WTPDATA.xls.

The tritium data reported in Johnson (1966) also are included. For the North Augusta Drinking Water Treatment Plant (the upstream control location), the community water supply monitoring data for 1965 through 1983 are provided along with the composite sampling data generated for this plant from late 1983 to the present. The WTPDATA workbook contains the following spreadsheets:

- Introduction
- Data plots
- Individual spreadsheets for Beaufort-Jasper, Savannah (Port Wentworth), and N. Augusta.

Water Treatment Plant-related Data

Although radionuclide-specific analyses, other than tritium, were not routinely performed on drinking water from either of the downstream treatment plants, radionuclide-specific data are available for weekly composite samples of Savannah River water from locations upstream and downstream of the SRS beginning in 1963. The downstream monitoring point is located approximately 80 and 90 mi upstream of the Beaufort-Jasper and Port Wentworth intakes, respectively.

If the Savannah River monitoring data are used to evaluate doses from consumption of water from the downstream drinking water treatment plants, additional information will be needed, including

- Transit time from points of discharge, or monitoring locations along the river, to the treatment plant intakes
- Amount of dilution within the Savannah River and within the treatment plant supply systems (canal for Beaufort-Jasper and Abercorn Creek for Port Wentworth) by incoming surface water and groundwater
- Fractions of various radionuclides that would be lost to sediments during transport within the river and within the water intake systems (i.e., in the Beaufort-Jasper supply canal and Abercorn Creek, which supplies the Port Wentworth plant)
- Removal efficiencies for radionuclides of interest during water treatment.

The transit time for contaminants discharged to the Savannah River from the SRS to reach the downstream drinking water treatment plants was estimated from a dye study conducted by the SRL Environmental Technology Section. The dye study was performed in conjunction with a water quality study performed by individuals from the U.S. Environmental Protection Agency (EPA), the South Carolina Department of Health and Environmental Control (SCDHEC), and the Georgia Department of Natural Resources (GDNR) (Hayes 1991). Hayes reports that a more comprehensive study of the river was to be performed in August 1991. Results of this further study have not been located. The dye study was used to determine travel times from or near the mouths of each of the Site effluent streams to the water treatment plants. A plot showing the time of arrival of the leading edge and peak at key locations along the river, including the treatment plant intakes, is provided (reproduced in Figure 13A-1, Addendum 13A). Table 13-3 contains values interpreted from this graph. These data show an approximate travel time from Steel Creek to the Beaufort-Jasper water treatment plant pump station of 76 hours. No information is reported about flow conditions during the time of the dye study, and the dates of the study are not provided.

Additional information on the transport and dilution of SRS-released contaminants in the Savannah River is reported in Hayes and Marter (1991). The information provided includes historical flow rates for the Savannah River at the downstream gauging station at Highway 301, which were compiled for use in retrospective dose calculations. In addition, flow rate data for the Beaufort-Jasper and Port Wentworth water treatment plants are derived by adjusting Highway 301 flow rates. The flow rates are adjusted for dilution from adding water to the river between Highway 301 and the points where the water treatment plants obtain water from the river and "additional dilution in the pumping and transport systems between the river and the water treatment plants." The annual dilution factors reported in Hayes and Marter (1991) for both downstream drinking water plants are provided in Table 13A-3, Addendum 13A. The methodology used to calculate the dilution factors is described in Hayes (1983, cited in Hayes and Marter 1991).

Table 13-3. Results of the Savannah River Laboratory Time of Travel Dye Study on the Savannah River in 1991[a]

Location (approximate river miles above mouth)	Approximate time (hours)
From Steel Creek (142) to Highway 301 (120)	14
From Highway 301 (120) to Clyo, Georgia (63)	37
From Clyo, Georgia, (63) to Beaufort-Jasper pump station (38)	25
From Beaufort-Jasper pump station (38) to Savannah pump station (30)	5

[a] Source: Hayes (1991).

Further insight into transport and dilution of contaminants within the river can be obtained from data generated during special, more extensive, SRS monitoring activities performed following nonroutine releases—such as the December 1991 K-Reactor tritium release. This estimated release of approximately 5700 Ci of tritium, contained in about 150 gal of water from a K-Reactor heat exchanger, occurred over a 3-day period from December 22 through 25. Elevated tritium levels were first detected at the Beaufort-Jasper and Port Wentworth treatment plant intakes on the morning and afternoon of December 28, respectively. Peak concentrations of 52,000 to 56,000 pCi L^{-1} were observed at these locations approximately 30 hours after arrival of the leading edge of the plume (Arnett et al. 1992).

Dilution is not the only means by which radionuclide concentrations are reduced during transport within the river. For some radionuclides, losses to sediments and aquatic vegetation can be significant. A special study conducted in 1965 looked at reductions in discharged ^{137}Cs concentrations from these removal mechanisms. Data from the 1965 study are reported in Hayes and Boni (1983) as part of their evaluation of the potential impacts from the restart of L-Reactor. The data are used to evaluate the expected ^{137}Cs concentrations in finished drinking water from SRS releases. Information is provided on dilution and removals within the river and within the supply systems for the treatment plants. Measurements were made in the Savannah River above the SRS at Augusta, below the SRS at Highway 301, and below the water treatment plant intakes at Highway 17. Port Wentworth is approximately 7 mi upstream and Beaufort-Jasper is approximately 17 mi upstream of the Highway 17 sampling point. The study found a 48% reduction in the ^{137}Cs levels within the river between Highway 301 and Highway 17. Based on the increase in Savannah River flow between these two locations, an approximately 20% reduction from dilution would be expected. Thus, the additional 30% is attributed to the process of deposition/sorption/reequilibration within the river channel and freshwater tidal marshes. The fresh water marshes extend upriver beyond Highway 17 to within the vicinity of Abercorn Creek.

The total reductions observed from Highway 301 to the finished water were 97.5% for Beaufort-Jasper and 79.3% for Port Wentworth. Because the treatment processes are similar, the primary reasons for the difference is attributed to dilution and losses within the Beaufort-Jasper supply canal.

The 1965 study did not include sampling of raw water from the treatment plants. Therefore, the removal efficiencies across the plants cannot be calculated. For their evaluation of potential impacts from L-Reactor releases, the authors assumed that the concentration measured in the river at Highway 17 is representative of the concentration entering the Port Wentworth treatment process (i.e., no reduction within Abercorn Creek). The validity of this assumption—the basis for which is not provided—should be further evaluated. However, if this assumption is used, a 62% removal of ^{137}Cs during water treatment at Port Wentworth is estimated. This estimate is close to the average removal of 60% observed for this radionuclide at Port Wentworth during 1963 to 1964 (Table 13A-1, Addendum 13A).

The removal of plutonium during water treatment at the North Augusta, Beaufort-Jasper, and Port Wentworth plants was investigated by the SRL in the mid-1970s. Removal factors for influent concentrations in the femtocurie range (0.1 to 3.5 fCi L^{-1}) were determined via collection of 50 to 10,000-L samples over a 9-month period. The 10,000-L samples were concentrated using online ion exchange columns at the water treatment plants. Smaller samples were concentrated in the laboratory under more controlled conditions. Following chemical separation samples were counted using an ultra low-level alpha spectrometry system. The findings are reported as removal factors (raw water concentration/treated water concentration). The reported mean removal factors ranged from 5.3 ± 3.4 in the North Augusta plant to 21.0 ± 10.2 in the Port Wentworth plant. The overall mean removal factor was 14 ± 10 (Corey and Boni 1975).

SAVANNAH RIVER MONITORING

The Savannah River forms the southwestern border of the Site and has received SRS effluents via Upper Three Runs, Four Mile Creek, Pen Branch, Steel Creek, Lower Three Runs, Beaver Dam Creek, and up through 1957, the TNX effluent ditch. Members of the public are potentially exposed to these effluents from drinking water supplied by the downstream treatment plants, ingestion of fish and other aquatic organisms taken from the river and estuary, and recreational use of the river.

Monitoring History and Available Data

Preoperational monitoring of the Savannah River was conducted in 1951 and 1952 and is reported in Reinig et al. (1953). Samples from about 15 locations along the river were analyzed for gross alpha, gross beta, uranium/plutonium alpha, radon, radium, and ^{40}K content. The preoperational monitoring report provides plots of the average concentrations for each location. The gross alpha and beta averages represent approximately 20 samples per location. Along with the plotted averages by location, an average value for all locations combined is reported. These values are provided in Table 13A-4, Addendum 13A.

Since the time of plant startup, the SRS has routinely sampled the Savannah River along the Site boundary and downstream of the Site to evaluate the impacts of liquid releases. Three locations have been consistently sampled throughout the Site's operation: (1) #8–below the mouth of Steel Creek, (2) #9–below the mouth of Lower Three Runs, and (3) #10–approximately 10 mi downstream of Lower Three Runs at the Highway 301 bridge (Figure 13-5). Six other river monitoring locations have been used: (1) #3–below the mouth of Upper Three Runs, (2) #4–above the mouth of Four Mile Creek, (3) #5– below the mouth of Four Mile Creek, (4) #6–above the mouth of Steel Creek, (5) #7–above the mouth of Steel Creek, and (6) #11–approximately 60 mi downstream of the SRS, near Clyo, Georgia (Figure 13-5).

The SRS has also consistently collected samples upstream of the Site to assess the levels of fallout and background radionuclides present in the Savannah River. A location near Augusta, Georgia, was used as the upstream control from 1954 through 1960 (#1). In 1958, a second upstream monitoring point (#1A) was added above Upper Three Runs near the Site boundary (Figure 13-5). In 1961, the designation for location #1A was changed to #2, and monitoring at Augusta was discontinued. Since that time, #2 has been consistently used as the upstream control location. The SRS also monitored the Salkehatchie River as a control location for tritium up through mid-1964. In the 1973, the SRS began routine radiological monitoring of the Edisto River for comparison to measurements in the Savannah River.

Since the early 1960s, the SRS has used the results for monitoring points #2 and #10 to evaluate the plant's contribution to radionuclide levels in the river. A summary of the monitoring performed at these locations from 1954 through 1991 is provided in Table 13-4. Location #10 was sampled continuously, using a continuous drip sampler, as early as 1958. All other river locations were grab sampled up through 1960 to 1961. Between April 1960 and August 1961, paddle wheel samplers were installed at #2 and #10 as well as five other locations along the river (Marter and Boulogne 1961). River samples have consistently been collected weekly.

At the time of plant startup, analysis of river water samples was limited primarily to gross alpha and nonvolatile beta measurements. However, some of the monthly and semiannual reports for the early years of operation do provide data from decay studies that were periodically performed on river water samples.

Routine tritium monitoring of the river began as early as 1958, and as early as 1960, samples from locations #2 (#1A) and #10 were routinely analyzed for radioiodine, radiostrontium, and radiocesium. By late 1960, ion exchange media were used to concentrate radiostrontium and radiocesium in river samples resulting in a roughly four-fold decrease in the detection limits, from approximately 4 pCi L^{-1} to 0.8 pCi L^{-1} (Du Pont 1960). Analysis for ^{90}Sr in the upstream and downstream river samples began in September 1959 (Van Wyck 1960). Routine analysis of samples from locations #2 and #10 for specific radionuclides by gamma spectroscopy did not begin until 1963.

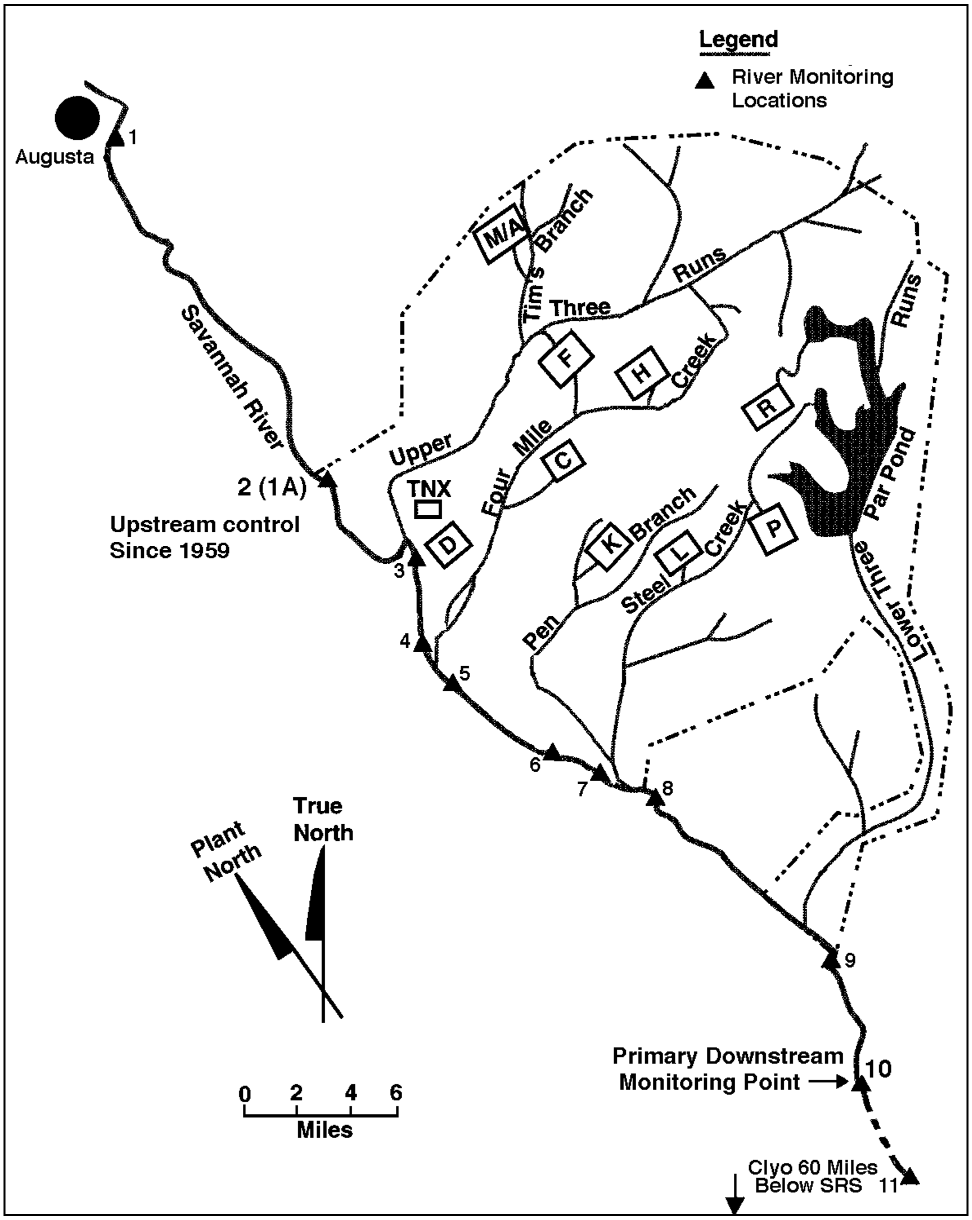


Figure 13-5. Map showing locations of SRS river monitoring points. Three locations on the Savannah River have been monitored by the SRS since the time of plant startup: #8 below the mouth of Steel Creek, #9 below the mouth of Lower Three Runs, and #10 approximately 10 mi downstream of Lower Three Runs at the Highway 301 bridge. Location #1 near Augusta, Georgia, was used as the upstream control from 1954 through 1960. In 1958, a second upstream monitoring point (#1A) was added above Upper Three Runs near the Site boundary. In 1961, the designation for location #1A was changed to #2, and monitoring at Augusta was discontinued. Since that time, #2 has been used as the upstream control location by the SRS.

Table 13-4. History of Monitoring at Upstream (#2) and Downstream (#10) Sampling Locations on the Savannah River

Sampling Point	Dates	Collection Frequency and Sample Type	Radiological Analyses
#2[a] (upstream)	1954 – 1957[a]	weekly, grab	gross alpha and beta
	1958	weekly, grab	gross alpha and beta, and tritium
	1959	weekly, grab	gross alpha and beta, tritium, and Sr-90
	1960 – 1962	weekly, continuous	gross alpha and beta, tritium, Sr-90, radiocesium, radioiodine, and radiostronium
	1963 - 1991	weekly, continuous	gross alpha and beta, tritium, Sr-90, and gamma spectroscopy
#10 (down-stream)	1954 – 1957	weekly, grab	gross alpha and beta
	1958	weekly, continuous	gross alpha and beta, and tritium
	1959	weekly, continuous	gross alpha and beta, tritium, and Sr-90
	1960 – 1962	weekly, continuous	gross alpha and beta, tritium, Sr-90, radiocesium, radioiodine, and radiostronium
	1963 - 1991	weekly, continuous	gross alpha and beta, tritium, Sr-90, and gamma spectroscopy

[a]From 1954 through 1958 the upstream was #1. A new location, #1A, located above Upper Three Runs near the site boundary was added in 1958. The designation for this location was changed to #2 in 1961.

In the spring of 1964, a new type of sampler was installed at locations #2 and #10. This sampler used an ion column to collect radioactive materials from a large volume of river water and was designed to operate continuously without electrical power. (See Appendix A for full description.) A water wheel drove two pistons pumps. One of these pumps passed water through a prefilter and the ion column. The other pump, which was geared much slower, delivered water directly into a 2-gal container. Because each pump had a fixed gear ratio, the volume of water in the container could be used to determine the volume of water that had passed through the ion column. For the first few months of operation (April through October), the volumes of water sampled ranged from 40 to 96 Ls depending on the river flow rate. A comparison of the results obtained at location #10 during this period, using both the ion exchange sampler and the standard paddle wheel sampler (Table 13A-5, Addendum 13A), found that the average concentrations for all radionuclides, except ^{131}I, were consistently higher for the ion exchange sampler. This difference was attributed to possible settling of radionuclides associated with suspended solids within the container of the paddle wheel sampler over the sampling period. Because the volume of water sampled with the ion exchange sampler is two to four times greater than the volume collected by the paddle wheel sampler, the number of positive analyses was also consistently higher for this new sampling technique (Du Pont 1964c).

In June 1964, just after the ion-column samplers were installed at #2 and #10, data for a river sampling location #10B first appear on the river monitoring aperture cards. It is assumed that #10B was initially the collocated, standard paddle wheel sampler used for comparison to the ion exchange sampler. Based on telephone conversations with SRS environmental monitoring program personnel (Manly Grove on November 25, 1997, and Pete Fledderman on December 4, 1997), samplers #10A and #10B were "back-to-back" paddle wheel samplers in more recent years. These co-located samplers were used at the Highway 301 monitoring location up through the early 1990s when ISCO samplers were put into service for river monitoring. At this time, location #10 was moved approximately 0.25 mi downstream so that it could be physically attached to the Highway 301 bridge, and the use of co-located samplers was discontinued. While in operation, the purpose of sampler #10B was solely to provide a backup sample in the event that the #10A sampler did not operate properly. The SRS did not make comparisons of the results for #10A and #10B. Data for sampler #10B were consistently reported from 1964 through 1992. Available data for this sampler include tritium, strontium, gross alpha, and gross beta. These data could provide insight into the sampling uncertainties associated with the river monitoring data.

It is not clear from the available information how long the ion-column equipped samplers, tested in 1964, were used by the SRS. For the first few months of 1965, aperture card data for #2 and #10 are reported as prefilter, ion column, and total, indicating that these samplers were put into routine use. However, by the early 1970s when sampling methods were first described in the annual, offsite monitoring reports, ion-exchange were no longer used as part of the sampling collection process. The 1972 annual report describes continuous sampling of Savannah River water as follows:

> . . . a sampler consisting of a 'Plexiglass' water wheel suspended on two pontoons. As the water wheel is turned by flowing water, a small cup (or cups) on one paddle picks up a sample of water and deposits it into a trough. The sampled water flows by gravity from the trough through connecting tubing into a large polyethylene jug which trails the sampler. The sampled water (up to six gallons) is collected weekly at river locations above and below SRP. Increased analytical sensitivity for water samples (containing insufficient radioactivity for direct processing) is achieved through concentration of radionuclides by ion exchange. The ion exchange column is counted directly for gamma emitting radionuclides (Du Pont 1973).

The sampling equipment used by the SRS does not appear to have been modified from that time up through the early 1990s when the ISCO samplers were installed.

Savannah River Data Workbook

The Savannah River data reported in the semiannual and annual monitoring reports are limited to 6-month or annual averages, maximums, and minimums. Two primary sources of individual sample data for the Savannah River have been identified and catalogued in the *RAC* database: aperture cards (handwritten data for roughly the years 1959 through 1973) and the Health Protection Environmental Monitoring Monthly data reports.

The aperture card data for eight radioactive materials measured at locations #2 and #10 have been compiled into a Microsoft Excel workbook, SRDATA.xls. Data were compiled for those radionuclides that were identified during the Phase I screening as contributing greater than 1% of the dose and for which specific monitoring had been performed (Meyer et al. 1995). These radioactive materials are ^{137}Cs (available data include nonspecific radiocesium and ^{137}Cs), ^{151}Cr, ^{60}Co, ^{131}I (available data include nonspecific radioiodine and ^{131}I), radiostrontium (nonspecific, ^{89,90}Sr, and ^{90}Sr), tritium, ^{65}Zn, and ^{95}Zr/Nb.

In the electronic version, double-clicking on the following hyperlink provides access to this workbook: SRDATA.xls.

The SRDATA.xls workbook contains the following individual spreadsheets:

- Introduction
- Data plots
- Individual spreadsheets forcesium, chromium, cobalt, iodine, tritium, ^{65}Zn, and ^{95}Zr/Nb

The specific data included in SRDATA.xls are as follows:

- Cesium— cesium (nonspecific)-1962 through May 1963 for location #10 only; cesium (ion column, nonspecific)-1962 through May 1963; ^{137}Cs-1963 through 1972 (excluding 1971); ^{137}Cs (low level)-1968 through 1972 (excluding 1971) for #10 only
- Chromium—^{51}Cr-1963 through 1972 (excluding 1971); ^{51}Cr (low level)-1968 through 1970 for #10 only
- Cobalt—^{60}Co-1963 through 1972 (excluding 1971)
- Iodine—radioiodine-1962 through 1967 for #10 only; ^{131}I-1963 through 1972 (excluding 1971); ^{131}I (low level)-1968 through 1970 for #10 only
- Strontium—strontium-1962 through 1964 for #10 only; strontium (ion column)-1962 through 1972 (excluding 1965 and 1971); $^{89/90}$Sr-1963 through 1972 (excluding 1971); ^{90}Sr-1962 through 1972 (excluding 1971)
- Tritium—^{3}H-1963 through 1972 (excluding 1965 and 1971), ^{3}H (sensitive method on monthly composites)-1962, 1966 through 1972 (excluding 1971)
- Zinc—^{65}Zn-1963 through 1972 (excluding 1971); ^{65}Zn (low level)-1968 through 1970 for #10 only
- Zirconium/Niobium—^{95}Zr/Nb-1963 through 1972 (excluding 1971); ^{95}Zr/Nb (low level)-1968 through 1970 for #10 only.

Other Savannah River monitoring aperture card data that are available through the *RAC* SRS Phase II document database but that have not been entered into the SRDATA.xls workbook include:

- 1965 data for tritium and strontium (nonspecific) and ^{90}Sr (not located until late in Phase II)
- 1971 data (original *RAC* copies not legible, new copies obtained late in Phase II)
- 1973 data (data for location #2 not located until late in Phase II)
- 1960 and 1961 ^{90}Sr data for #2 (#1A) and #10
- Tritium data for location #11 (1959 through June 1964 when monitoring at this location was discontinued)

- Cesium (nonspecific) data for #8, #9, #10, and #11 for 1959 through 1964
- 1963 through 1972 data for ^{54}Mn, ^{103}Ru, ^{106}Ru, ^{134}Cs, ^{140}BaLa, ^{144}Ce, and ^{239}Np for #2 and #10
- 1959 through 1973 gross alpha and gross beta data for all river monitoring locations
- 1959 through 1964 tritium data for the Salkahatchie River.

Savannah River Monitoring-related Data

The following provides a brief overview of additional information that may be useful in the evaluation of SRS releases to the Savannah River.

Flow Monitoring on the Savannah River

Weekly flow measurements for the Savannah River, as reported on the data aperture cards, for the year 1963 through 1972 (excluding 1971) are included in the SRDATA.xls workbook.

Flow rate data for four USGS gauging stations (Augusta; near Jackson [SRS Boat Dock]; Highway 301 [Millhaven, Georgia]; and Clyo, Georgia) are summarized in Hayes and Marter (1991). Monthly data (minimum, maximum, and mean) are also provided for these stations. USGS data have been generated for the Augusta and Clyo stations since 1950. Flow monitoring at the Highway 301 station also began in 1950, but it was discontinued from 1971 through 1981. Flows at Highway 301 for this 10-year period are estimated based on the correlation observed between flows at this station and Augusta for other years.

Recreational Use of the River

From December 1980 through December 1982, the GDNR collected data on the recreational use of the Savannah River. The SRL divided the GDNR data into three separate categories (boaters, swimmers, and shoreline activities) for statistical expansion. The data were used to estimate recreational use for the river above, adjacent to, and below the SRS. Estimates of time spent in recreational activity on the Savannah River are reported as person-hours per year. Estimates for boaters, swimmers, and shoreline activities adjacent to the SRS are 35,831 ± 8640, 688 ± 500, and 13283 ± 3386, respectively (Hutto and Turcotte 1983).

River Mile Designations

The river mile designations for locations along the Savannah River have changed over the years of SRS operations as the U.S. Army Corp. of Engineers has updated its navigational charts. A sketch showing mileage numbers for the river below Augusta is provided in Johnson (1968). The memo states that since plant startup, “river bends have been cut out and mileage numbers changed to the extent that Augusta is now about 20 miles closer to Savannah via the River.”

USEFULNESS AND LIMITATIONS OF OFFSITE WATER MONITORING DATA FOR DOSE RECONSTRUCTION

There are a number of factors that impact how the offsite water monitoring data may be used during subsequent phases of the dose reconstruction project. These factors include the availability of sufficient original monitoring data sets to verify reported summary data and to evaluate temporal trends, and the ability to distinguish between Site releases of contaminants and other sources of the same contaminants in the environment (i.e., to establish appropriate background concentrations).

Drinking Water Data

Because the safety of drinking water is of considerable interest to the public, the potential impacts of SRS operations on both the surrounding community water supplies and the downstream water treatment plants should be addressed as part of the dose reconstruction process. The influence of the Site is clearly seen in the data for the downstream drinking water treatment plants; however, this is not the case for the community water supplies.

Tritium is the only radionuclide for which specific monitoring has been performed in the community water supplies. The usefulness of these data for assessing contributions from SRS atmospheric releases is questionable. Tritium monitoring began at the end of 1959, but by the early 1960s, fallout tritium levels in surface waters of the U.S. were at their peak (Wyerman et al. 1970). Thus, for these years, it would be difficult to distinguish between the, presumably, low levels of tritium contributed by the SRS and that introduced from weapons fallout. The absence of a prevailing wind direction and the lack of a control location for the monitoring program would further complicate this task. By the later years, when fallout tritium levels are lower, the community water supply monitoring program is limited to analysis of semiannual grab samples. These infrequent sample collections would reduce the likelihood of identifying increases in tritium concentrations that might occur following a large, short-term release of tritium. In general, the tritium levels observed in the community supplies are low (Figure 13-3) and decreased over time following the downward trend of fallout levels and detection sensitivities.

In the case of the downstream drinking water treatment plants, a considerable amount of useful data—including original handwritten records—exists for quantifying the impacts from SRS releases of tritium to the Savannah River. It should be noted, however, that routine tritium monitoring of the Port Wentworth plant did not begin until the mid-1960s although this treatment plant had been online since before SRS operations began. Therefore, SRS tritium measurements in the Savannah River, which began in 1958, and tritium data from independent sources will be needed to estimate tritium concentrations in Port Wentworth water plant before 1965. Tritium measurements were made in the Savannah River near the downstream treatment plant intakes by the USGS and the U.S. Public Health Service beginning in the early 1960s (Wyerman et al. 1970; Chestnutt et al. 1966).

Although quantitatively distinguishing between background levels and site contribution are beyond the scope of this phase of the dose reconstruction, an effort has been made to assess the potential usefulness of upstream measurements for this purpose. In general, the upstream measurements, both in the drinking water treatment plants and the Savannah River, appear to be reliable indicators of background and fallout contributions. However, before 1983, tritium monitoring in the upstream control for the drinking water treatment plants, North Augusta, was limited to the sampling performed under the community water supply monitoring program. Furthermore, the fact that the North Augusta plant was monitored under the community water supply program may raise concerns that this control location was potentially affected by SRS releases. Therefore, data sets from independent sources, such as the USGS and the U.S. Public Health Service, will be useful as cross-checks in the evaluation of weapons fallout tritium levels in the Savannah River. Because tritium would not be removed by the water treatment process, surface water monitoring data, as well as drinking water data, are of potential value.

The USGS began routine monitoring of surface waters across the U.S. in the early 1960s. Tritium data for 20 streams collected from 1961 to 1968 are reported in Wyerman et al. (1970). Factors affecting fallout tritium levels in streams include local precipitation conditions and the amount of groundwater, relative to runoff, that enters the stream. Because fallout tritium levels in precipitation vary with location, the most appropriate data sets for comparison to SRS monitoring information would be for streams located in the same general area as the Site.

In addition to sampling of the Savannah River near Port Wentworth, the USGS monitored three other rivers located in the Southeast: the Kissimee River near Okeechobee, Florida; the Apalachicola River at Chattahoochee, Florida; and the Neuse River near Vanceboro, North Carolina. The USGS data for the Kissimee and Neuse Rivers for the early 1960s are included in the CWSDATA workbook. A comparison of the data for 1962 through 1964 found the USGS tritium measurements in the Neuse River (Vanceboro, North Carolina) comparable to those made by the SRS in the Augusta and North Augusta Drinking Water Treatment Plants (Figure 13-6). The Apalachicola data were not included in this comparison because the USGS did not begin tritium monitoring in this river until the end of 1964.

Tritium monitoring of surface waters was also initiated by the U.S. Public Health Service in 1964. Reporting of these data began in July 1966 in Chestnutt et al. (1966). In 1969, the U.S. Public Health Service also performed tritium analysis on grab samples of drinking water from communities in at least 14 states across the U.S. Unfortunately, all of the supplies monitored in the southeastern U.S. were groundwater sources (PHS 1970).

With the exception of tritium, few radionuclide-specific data are available for the drinking water treatment plants. For the earlier years, the effect of Site releases is evident in the gross beta concentrations observed in the downstream drinking water treatment plants (Figure 13-7). Therefore, these gross beta data may be of qualitative use to the dose reconstruction.

For quantitative assessments, Savannah River monitoring data will provide the primary means for evaluating the impact of SRS releases of radionuclides other than tritium, such as ^{137}Cs and strontium, on the downstream drinking water supplies. In addition, these data are needed to evaluate the extent to which the public has been exposed to SRS-released contaminants through the ingestion of fish and other aquatic organisms and during recreational use of the river.

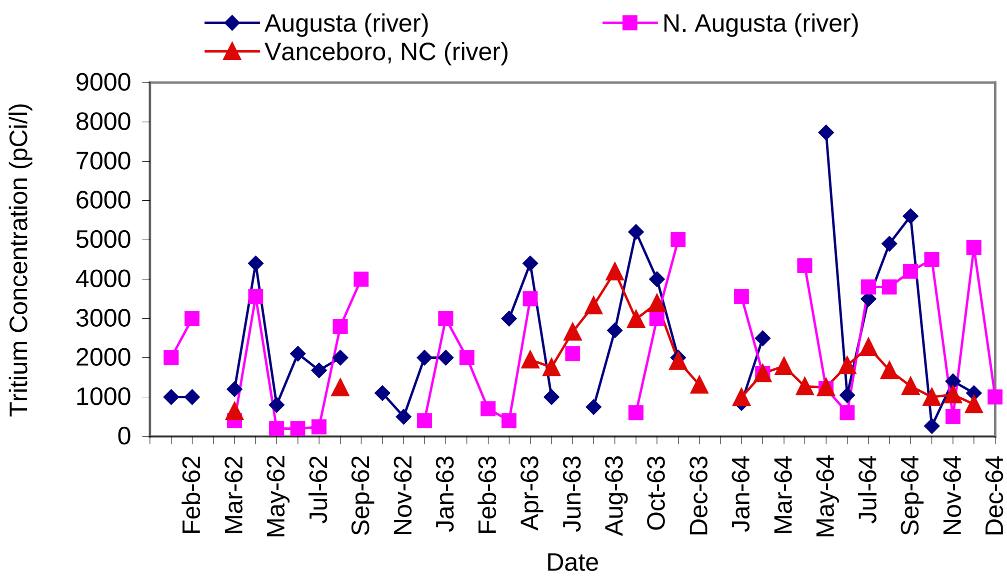
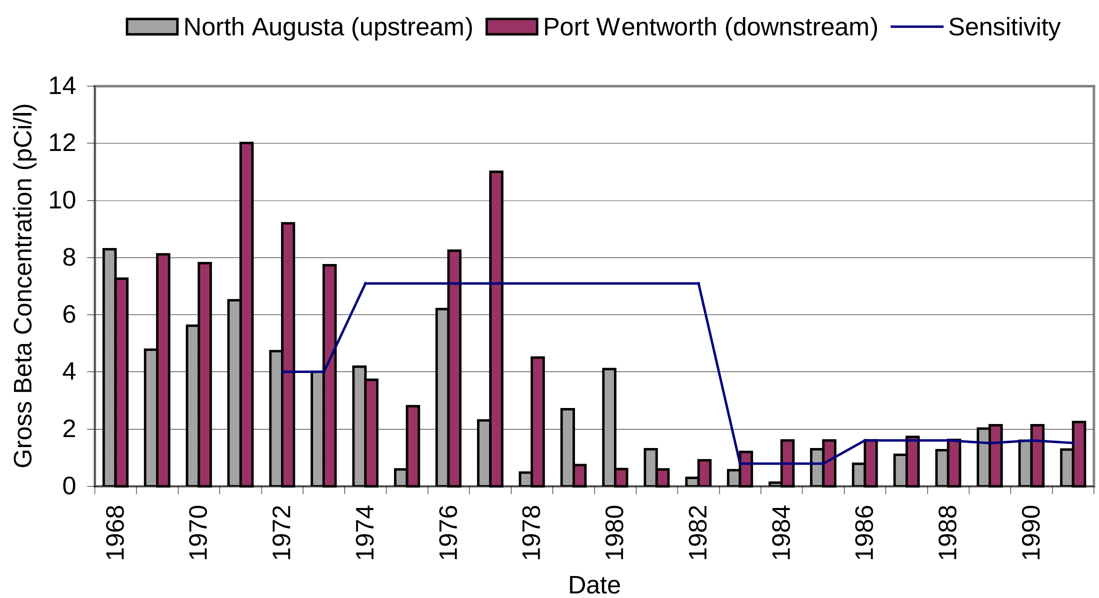


Figure 13-6. A comparison of SRS tritium measurements in drinking water from Augusta and N. Augusta (upstream controls supplied by the Savannah River) to USGS tritium data for the Neuse River in Vanceboro, North Carolina, for 1962 through 1964. Tritium is not removed by the water treatment process; therefore, the treatment plant data are reflective of Savannah River concentrations.



Figures 13-7. Average annual gross beta concentrations measured in finished (treated) water from the North Augusta Drinking Water Treatment Plant, located upstream of the SRS on the Savannah River, and the Port Wentworth plant located downstream of the Site. The influence of Site releases is evident in the gross beta concentrations up through the late 1970s. These data may be of qualitative use to the dose reconstruction.

The SRS began radionuclide-specific monitoring of the Savannah River, upstream and downstream of the Site in the late 1950s and early 1960s and has developed and extensive data set that will be of considerable use to the dose reconstruction process. As seen in a plot of ^{137}Cs concentrations measured in the river in 1963 and 1964, there have been times when the Site's contribution was masked by fallout (Figure 13-8). However, in general the upstream data provide a reliable indicator of fallout levels while the downstream measurements clearly show the influence of Site discharges. In the case of tritium monitoring, even in the early 1960s when fallout levels were at their highest in U.S. surface waters, the downstream tritium measurements are consistently higher than the levels observed upstream (Figure 13-9). Overall, the radionuclide-specific data will be useful for assessment of the Site's contribution of radionuclides to the Savannah River. (i.e., the validating source term estimates) and for directly assessing exposures of individuals who consumed drinking water form the treatment plants downstream of SRS.

The most notable gap in the offsite water monitoring data available for the SRS dose reconstruction is the lack of individual sample measurements for the mid-1950s. Based on the extensive records search performed by *RAC* during Phase I, it appears that no records of these early data have been retained by the Site. The available river monitoring data from the time of plant startup in 1954 through about 1958 are limited to sporadic reports in the weekly and monthly reports and the summary data provided in the semiannual monitoring reports.

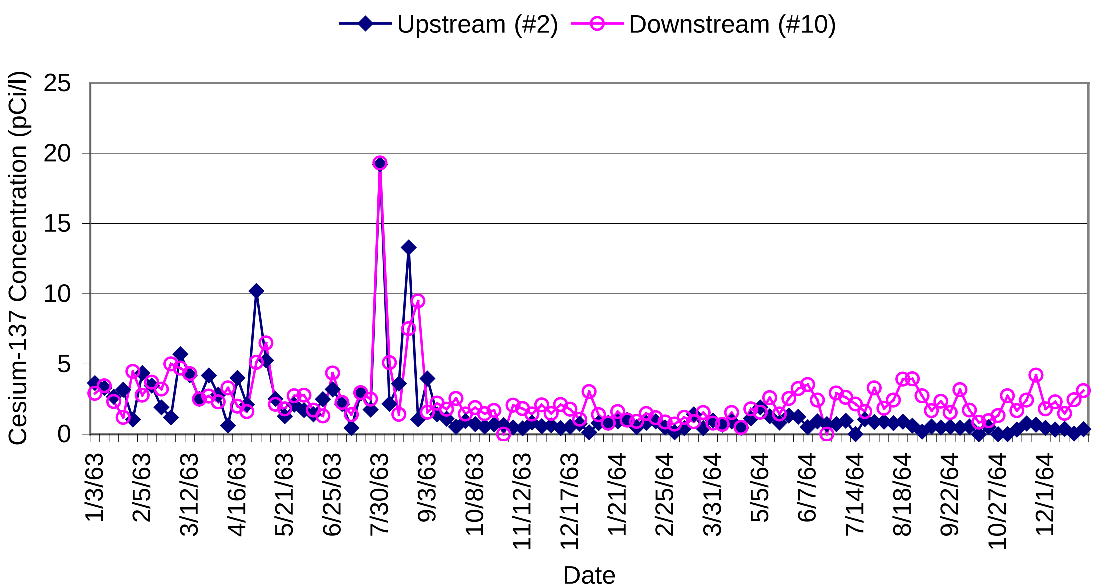


Figure 13-8. Cesium-137 concentrations measured in the Savannah River upstream and downstream of the SRS. The upstream measurements provide a means of quantifying the fallout levels of ^{137}Cs levels present in the Savannah River. There are periods of time—such as the first three quarters of 1963— when the SRS contribution is masked by fallout levels (i.e., the upstream measurements are higher than, or indistinguishable from, the downstream measurements). However, by late 1963, the downstream concentrations are consistently higher than those measured in the upstream control.

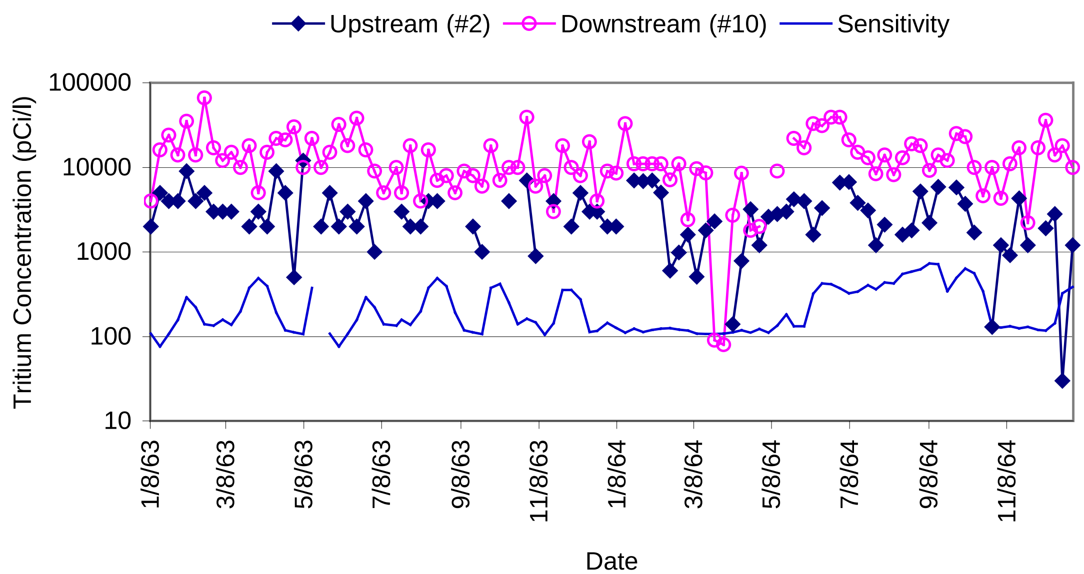


Figure 13-9. Tritium concentrations measured in the Savannah River upstream and downstream of the SRS in 1963 and 1964. The upstream measurements provide a means of quantifying the fallout levels present in the Savannah River. Even in the early 1960s when fallout levels of tritium are at a peak in U.S. surface waters, the influence of SRS releases can be seen in the downstream Savannah River measurements

REFERENCES

Arnett, M.W., L.K. Karapatakis, A.R. Mamatey, and J.L. Todd. 1992. *Savannah River Site Environmental Report for 1991*. WSRC-TR-92-186. Westinghouse Savannah River Company. SRS Phase II Database MOL1993120612.

Arnett, M.W., L.K. Karapatakis, and A.R. Mamatey. 1993. *Savannah River Site Environmental Report for 1992*. WSRC-TR-93-075. Westinghouse Savannah River Company. SRS Phase II Database MOL1993120610.

Ashley, C. and C.C. Zeigler. 1984. *Environmental Monitoring at the Savannah River Plant, Annual Report–1981*. DPSPU-82-302. Health Protection Department, Savannah River Plant, Du Pont. SRS Phase II Database MJC1994051719. April.

Ashley, C., C.C. Zeigler, P.A. Culp, and D.L. Smith. 1982. *Environmental Monitoring at the Savannah River Plant, Annual Report–1979.* DPSPU-80-302. SRS Phase II Database GKH199404148. April.

Ashley, C., P.C. Padezanin, and C.C. Zeigler. 1984. *Environmental Monitoring at the Savannah River Plant, Annual Report–1982*. DPSPU-83-302. Health Protection Department, Savannah River Plant, Du Pont. SRS Phase II Database MJC1994051720. April.

Chesnutt, M.W., J.C. Drobinski, Jr., and R.H. Gorrie. 1966. *Tritium in Surface Waters, 1964–1965*. Radiological Health Data and Reports 7: 377–380. U.S. Dept. of Health, Education, and Welfare, Public Health Service. July. OpenLit.

Corey, J.C. and A.L. Boni. 1975. *Removal of Plutonium from Drinking Water by Community Water Treatment Facilities*. DP-MS-75-26. Savannah River Laboratory, Du Pont. SRS Phase II Database TFW199403289. May 1.

Du Pont. 1953. *Operating Procedure for Regional Survey.* DPSOP-44. Technical Procedures Office, Savannah River Plant, Du Pont. SRS Phase II Database TFW1994110240. May.

Du Pont. 1960. *Control and Methods Weekly Report*. November 7–11, 1960. Savannah River Laboratory. SRS Phase II Database MJC1993051816.

Du Pont. 1963a. *Fate of Radionuclides Released to the Savannah River: Removal of Radioactivity by Savannah, Georgia Water Treatment Plant. February Monthly Report for Radiological Control and Methods, Environmental Monitoring*. 1963 Monthly Reports. Savannah River Plant. SRS Phase II Database MJC1993051819.

Du Pont. 1963b. *Effect of Water Treatment on Removal of Radionuclides. June Monthly Report for Radiological Control and Methods, Environmental Monitoring, Environmental Studies*. 1963 Monthly Reports. Savannah River Plant. SRS Phase II Database MJC1993051819.

Du Pont. 1963c. *Distribution of Radionuclides in Savannah River Sediment Deposits. November Monthly Report for Radiological Control and Methods, Environmental Monitoring, Environmental Studies*. 1963 Monthly Reports. Savannah River Plant. SRS Phase II Database MJC1993051819.

Du Pont. 1964a. *Cherokee Hill Water Treatment Plant. May Monthly Report for Radiological Control and Methods, Environmental Monitoring, Environmental Studies*. 1964 Monthly Reports. Savannah River Plant. SRS Phase II Database MJC1993051820.

Du Pont. 1964b. *Cherokee Hill Water Treatment Plant. January Monthly Report for Radiological Control and Methods, Environmental Monitoring, Environmental Engineering*. 1964 Monthly Reports. Savannah River Plant. SRS Phase II Database MJC1993051820.

Du Pont. 1964c. *Ion Exchange Stream Sampler. November Monthly Report for Radiological Control and Methods, Environmental Monitoring, Environmental Studies*. 1964 Monthly Reports. Savannah River Plant. SRS Phase II Database MJC1993051820.

Du Pont. 1966. *Tritium in Off-Plant Population. June Monthly Report for the Radiological Sciences Division*. 1966 Monthly Reports. Savannah River Plant. SRS Phase II Database MJC199305192.

Du Pont. 1968. *Interlaboratory Comparison of Tritium in River Water. October Monthly Report for the Radiological Sciences Division, Environmental Monitoring Group*. 1968 Monthly Reports. Savannah River Plant. SRS Phase II Database MJC199305194.

Du Pont. 1969. *Potential Exposure from Radionuclides in Savannah River. January Monthly Report for the Radiological Sciences Division, Environmental Monitoring Group*. 1969 Monthly Reports. Savannah River Plant, Aiken, South Carolina. SRS Phase II Database MJC199305195.

Du Pont. 1973. *Environmental Monitoring in the Vicinity of the Savannah River Plant, Annual Report for 1972*. DPSPU-73-30-1. Health Physics Section, Savannah River Plant, Du Pont. SRS Phase II Database MJC1993121335. June.

Du Pont. 1976. Health Protection Environmental Monitoring Monthly Report Printout. Radiological analyses for onsite streams, river, seepage basin water, H-area wells, F-area wells, reactor. SRS Phase II Database KRM1997101311. July–December.

Edgar, W.F. 1961. Savannah River Plant, Du Pont. Inter-office Memorandum to A.R. Boulogne. Subject: Ra^{226} in Drinking Water. SRS Phase II Database HAG1994083170. December 8.

Edgar, W.F. 1963. *Radium Content of Drinking Water in the Central Savannah River Area.* DPSPU-63-30-10B. Savannah River Plant, Du Pont. SRS Phase II Database SKR199310064. April.

Hamby, D.M. 1991. *Land and Water Use Characteristics in the Vicinity of the Savannah River Site (U).* WSRC-RP-91-17. Westinghouse Savannah River Company. SRS Phase II Database HAG1994090239.

Hayes, D.W. 1983. Examples of Savannah River Water Dilution Between the Savannah River Plant and the Beaufort-Jasper and Port Wentworth Water Treatment Plants. DPST-82-1076. Du Pont. SRS Phase II Database KRM199810223. January 12.

Hayes, D.W. 1991. Savannah River Laboratory, Westinghouse Savannah River Company. Inter-office Memorandum to R.P. Addis. Subject: Time of Travel Studies on the Savannah River. SRL-ETS-910191. SRS Phase II Database SKR1994020219. April 25.

Hayes, D.W. and A.L. Boni. 1983. Technical Division, Savannah River Laboratory. Inter-office Memorandum to J.C. Corey. Subject: Cs-137 in the Savannah River and the Beaufort-Jasper and Port Wentworth Water Treatment Plants. SRS Phase II Database DWS1993092213. January 10.

Hayes, D.W. and W.L. Marter. 1991. *Historical River Flow Rates for Dose Calculations*. SRL-ETS-910257. Savannah River Laboratory, Westinghouse Savannah River Company. SRS Phase II Database SKR1994020211. June 10.

Hutto, G.A. and M.D.S. Turcotte. 1983. Technical Division, Savannah River Laboratory. Inter-office memorandum to T.V. Crawford and H.P. Olson. Recreational Use of the Savannah River. DPST-83-622, Rev. 1. SRS Phase II Database MJC1993121416. October 20.

Johnson, J.E. 1966. Technical Division, Savannah River Laboratory. Inter-office memorandum to W.L. Marter. Subject: Water and Sediment Collections, Beaufort-Jasper and Savannah Water Treatment Plants. SRS Phase II Database TFW1994061057. December 2.

Johnson, J.E. 1968. Technical Division, Savannah River Laboratory. Memorandum to Files. Subject: Location of Sampling Stations by River Miles. Contained in SRS Phase II Database TFW1994061055. July 22.

Landon, L.F. 1963. *River and Stream Studies at the Savannah River Plant, Aiken South Carolina*. SRS Phase II Database SKR1994020126. August 1.

Marter, W.L. 1965. Savannah River Plant. Memo to HPMA File. Subject: Beaufort-Jasper Water Authority. SRS Phase II Database JMW1996011134. April 26.

Marter, W.L. and A.R. Boulogne. 1961. Memorandum to W.C. Reinig. Subject: A Review of the Environmental Monitoring Program. SRS Phase II Database SKR1994020138. July 14.

Meyer, K.R., P.D. McGavran, P.G. Voillequé, H.A. Grogan, L.W. Bell, H.R. Meyer, S.K. Rope, and J.E. Till. 1995. *Savannah River Site Dose Reconstruction Project, Task 3, Evaluation of Materials Released from the SRS. RAC* Report #1 CDC-SRS-95-Final. *Radiological Assessments Corporation*, Neeses, South Carolina. June. SRS Phase II Database HRM199901142. OpenLit.

Murphy, C.E., Jr., L.R. Bauer, D.W. Hayes, W.L. Marter, C.C. Zeigler, D.E. Stephenson, D.D. Hoel, and D.H. Hamby. 1991. *Tritium in the Savannah River Site Environment.* WSRC-RP-90-424-1, Rev. 1. Westhinghouse Savannah River Company. SRS Phase II Database MJC1994051310. May.

PHS (U.S. Public Health Service). 1970. "Tritium in Community Water Supplies, 1969." *Radiological Health Data and Reports* 11 (12): 659–724. U.S. Dept. of Health, Education, and Welfare. December. OpenLit.

Reinig, W.C., R.E. Gosline, E.L. Albenesius, and R.C. Williams. 1953. *Natural Radioactive Contents of the Savannah River Plant.* DP-27. Health Physics Section, Savannah River Laboratory. SRS Phase II Database MJC199312101. May 1.

Van Wyck, R.W. 1960. *Radioactivity, Chemical Quality, and General Health of the Savannah River*. DPSPU-60-11-14. Works Technical Department, Savannah River Plant, Du Pont. SRS Phase II Database LWB199403217 and MJC1993121341. June.

Walker, R. 1978. *Water Supply Treatment and Distribution*. ISBN 0-13-946004-7. Englewood Cliffs, New Jersey: Prentice-Hall, Inc. OpenLit.

Wyerman, T.A., R.K. Farnsworth, and G.L. Stewart. 1970. "Tritium in Streams in the United States, 1961–1968." *Radiological Health Data and Reports* 11 (9): 421–439. U.S. Dept. of Health, Education, and Welfare, Public Health Service. SRS Phase II Database SKR1994020426. September.

Zeigler, C.C., E.M. Heath, L.B. Taus, J.L. Todd, and J.E. Till. 1987. *Savannah River Plant Environmental Report for 1986.* DPSPU-87-30-1. Health Protection Department, Savannah River Plant, Du Pont. SRS Phase II Database EIW1993091417. April.

ADDENDUM 13A

ADDITIONAL WATER MONITORING DATA

ADDENDUM 13A—TABLES

Table 13A-1. Radionuclide Removal Data from Cherokee Hill Water Treatment Plant Downstream of SRS[a]

Radionuclide	SRP releases (Ci)	Influent (Ci)	Effluent (Ci)	Removal efficiency (%)	Average effluent conc. (pCi L^{-1})
Tritium	80,000	419	459		11,600
^{144}Ce	50.5	0.100	0.05	50	1.2
^{51}Cr	936	0.520	0.25	52	6.3
^{106}Ru	5.5	0.210	0.09	57	2.3
^{137}Cs	53	0.05	0.02	60	0.6
^{89}Sr	70	0.11	0.07	36	0.9
^{90}Sr	5.7	0.046	0.03	35	0.8
$^{95}Zr/Nb$	11.6	0.14	0.03	79	0.8

[a] Excerpted from SRP (Du Pont 1964a).

Table 13A-2. Comparison of Radionuclide Measurements in Settling Basin Sediment from the North Augusta Drinking Water Treatment Plant (upstream of SRS) and the Port Wentworth Water Treatment Plant (downstream of SRS)[a]

Radionuclide	North Augusta (pCi g^{-1})	Port Wentworth (pCi g^{-1})
^{144}Cd	32	49
^{51}Cr	<51	650
^{106}Ru	110	60
^{137}Cs	9	26
$^{95}ZrNb$	26	24
^{54}Mn	10	7

[a] Excerpted from SRP (Du Pont 1964b).

Table 13A-3. Estimated Annual Dilution of Contaminants in Savannah River Between Highway 301 and the Downstream Drinking Water Plants[a] Based on Tritium Measurements[b]

Year	Percent dilution below Highway 301	
	Beaufort-Jasper plant	Port Wentworth plant
1966	64	
1967	109	
1968	73	
1969	101	
1970	232	
1971	312	
1972	144	
1973	61	15
1974	104	19
1975	101	23
1976	153	20
1977	70	31
1978	131	9
1979	164	32
1980	131	30

[a] Values includes dilution between river and water treatment intakes (i.e., in canal for Beaufort-Jasper and Abercorn Creek for Port Wentworth).

[b] Source: Hayes and Marter (1991).

Table 13A-4. Results of Preoperational Monitoring of the Savannah River Performed by SRS in 1951 and 1952[a]

Analysis	Concentration[b]	Number of samples
Gross alpha	9.3 ± 2.9 (× 10^{-3} d/m mL^{-1})	20
Gross beta	0.6 ± 0.2 (pCi L^{-1})	20
Uranium/plutonium alpha	0.5 ± 0.3 (× 10^{-3} d/m mL^{-1})	3
Radon[c]	15.0 ± 6.0 (pCi L^{-1})	3
Radium	0.4 ± 0.3 (×10^{-3} d/m mL^{-1})	3
^{40}K	2.2 ± 0.4 (pCi L^{-1})	4

[a] Source: Reinig et al. (1953).

[b] Average concentration for approximately 15 locations ± one standard deviation.

[c] Analyzed by precipitation of radon progeny for beta counting.

Table 13A-5. Comparison of Analytical Results of Savannah River Water by Two Sampling Systems-4/14/64–10/27/64[a]

	Average concentration ($pCi\ L^{-1}$)		Total number of positive analyses	
Radionuclide	Ion exchange	Standard	Ion exchange	Standard
^{144}Ce	6.9	5.8	13	5
^{51}Cr	30.4	17.4	16	12
^{131}I	1.4	1.7	4	3
^{106}Ru	5.9	4.6	11	2
^{137}C	3.7	2.3	26	24
$^{95}Zr/Nb$	0.9	0.6	16	3
Nonvolatile beta	18.5	16.4		

[a] Excerpted SRP (Du Pont 1964c).

ADDENDUM 13A—FIGURES

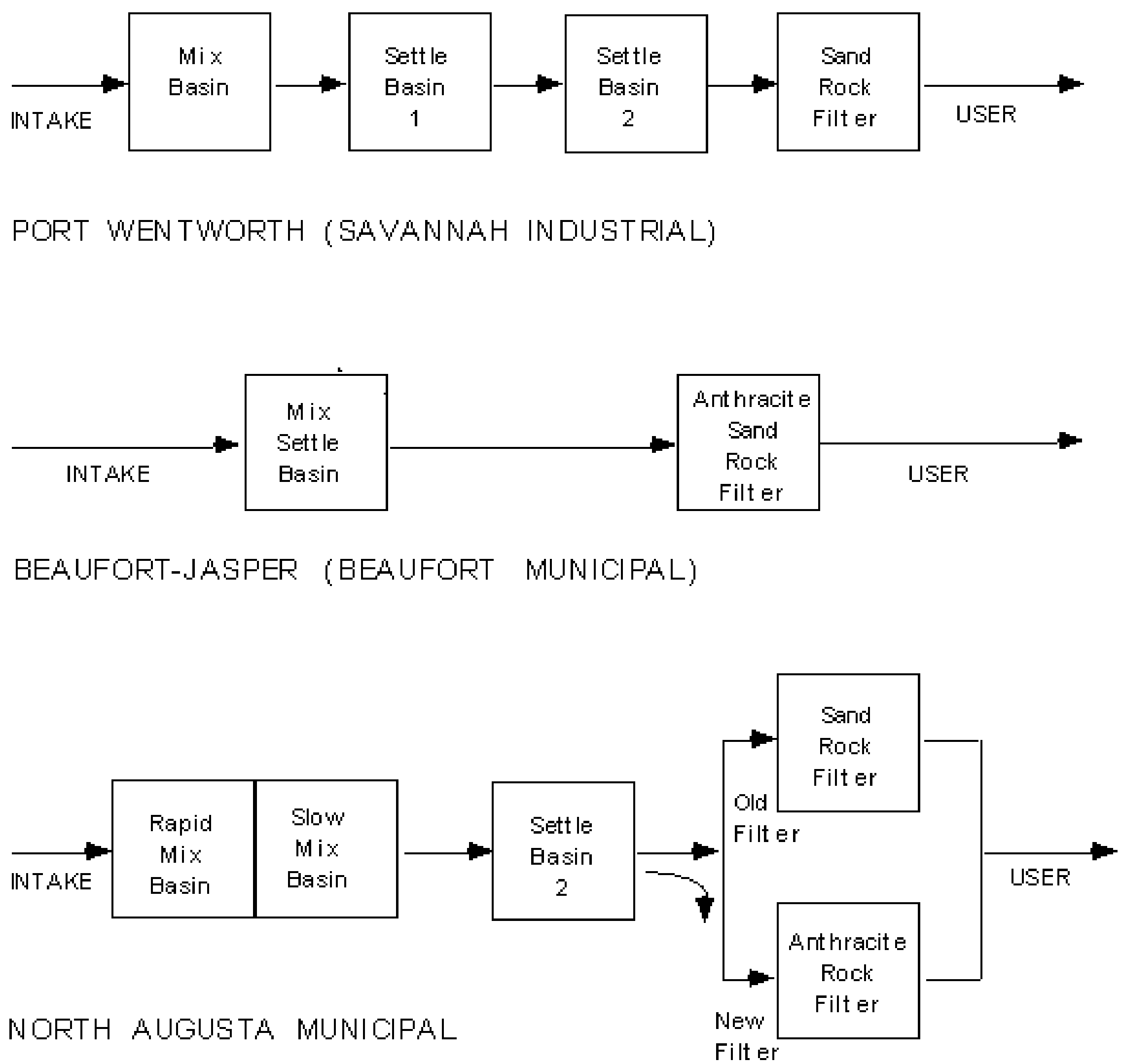


Figure 13A-1. Diagram of treatment processes used in three drinking water treatment plants that use Savannah River water. The Port Wentworth and Beaufort-Jasper water treatment plants are located downstream of SRS. The North Augusta Drinking Water Treatment Plant is upstream of the Site and is used as a monitoring control (reproduced from Figure 2 of Corey and Boni 1975).

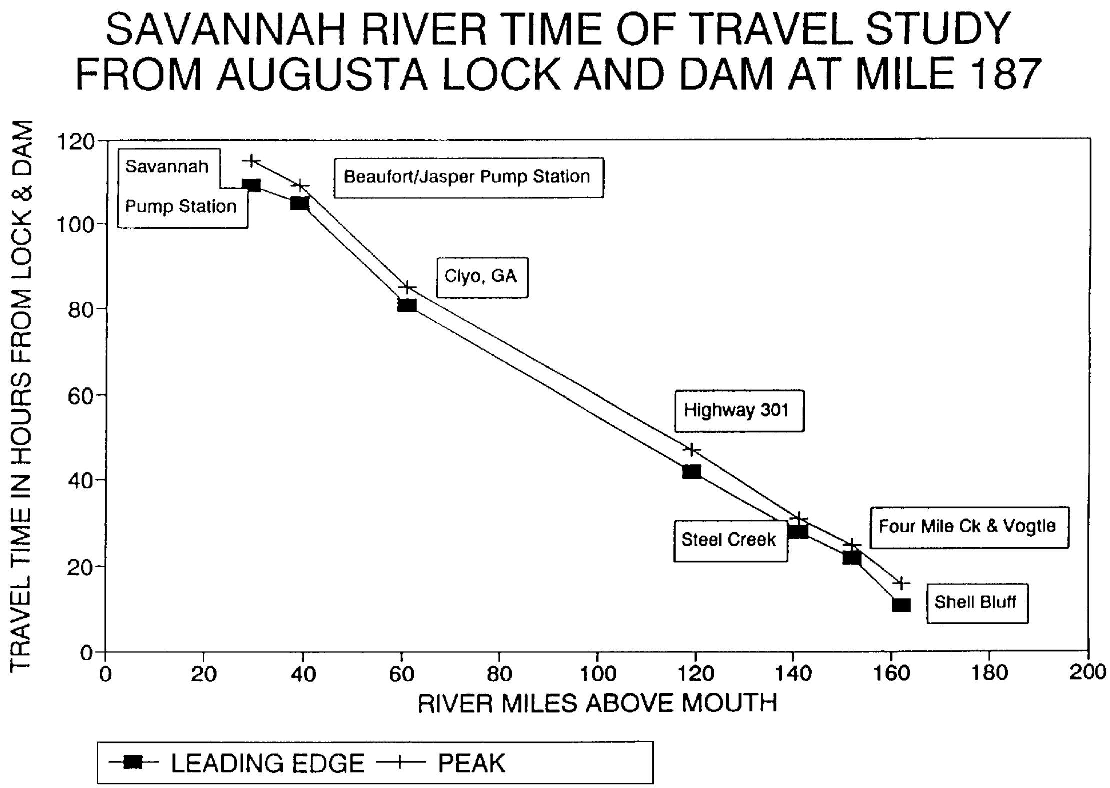


Figure 13A-2. Data obtained during a dye study conducted to determine the time of travel for contaminants discharged to the Savannah River by the SRS (reproduced from Hayes 1991). These data show an approximate travel time from Steel Creek to the Beaufort-Jasper water treatment plant pump station of 76 hours. No information is reported about flow conditions during the time of the dye study, and the dates of the study are not provided.