Chapter 5

Streams, Reservoirs, and the Savannah River

The southeastern United States has abundant freshwater resources, which provide diverse ecosystems. There are five main drainage basins on SRS. The five streams that originate on, or pass through SRS before entering the Savannah River are Upper Three Runs, Beaver Dam Creek, Fourmile Branch, Steel Creek, and Lower Three Runs. A sixth stream, Pen Branch, does not flow directly into the Savannah River but joins Steel Creek in the Savannah River floodplain swamp. The upper reaches of Lower Three Runs were impounded in 1958 to form Par Pond. L Lake was formed in 1985 by damming Steel Creek. The purpose of Chapter 5 is to describe and define the physical and biological characteristics of these systems and provide a synopsis from the many aquatic studies conducted through the years at SRS.

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5.1 Upper Three Runs

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Drainage Description and Surface Hydrology

General Description

Upper Three Runs is a large, cool (annual maximum temperature of 26.1°C [79°F]), blackwater stream in the northern part of SRS (Figure 5-1). With headwaters arising offsite, near Aiken, Upper Three Runs drains an area of approximately 545 km^2 (209 mi^2) and discharges directly into the Savannah River. Upper Three Runs is approximately 40 km (25 mi) long, with the lower 28 km (17 mi) within the boundaries of SRS. Upper Three Runs receives more water from underground sources (Dublin-Midville aquifer system) than the other SRS streams; hence, it has low conductivity, low hardness, and low pH values (Specht 1987).

Effluent Contribution

Upper Three Runs is the only major tributary on SRS that never has received major thermal discharges. Its two significant tributaries are Tinker Creek, the largest, and Tims Branch. Above its confluence with Tims Branch, Upper Three Runs is relatively unimpacted. Beginning in late 1988, Upper Three Runs began receiving effluents from the F-/H-Area Effluent Treatment Facility, which discharges into the creek just downstream of the Road C bridge. Tims Branch receives industrial wastes from the fuel fabrication facilities (300-M Area) and the Savannah River Technology Center (700-A Area) including nonprocess cooling water, steam condensates, process effluents, and treated groundwater effluents. Three smaller tributaries of Upper Three Runs originating from the 200-F and the 200-H Separations Areas

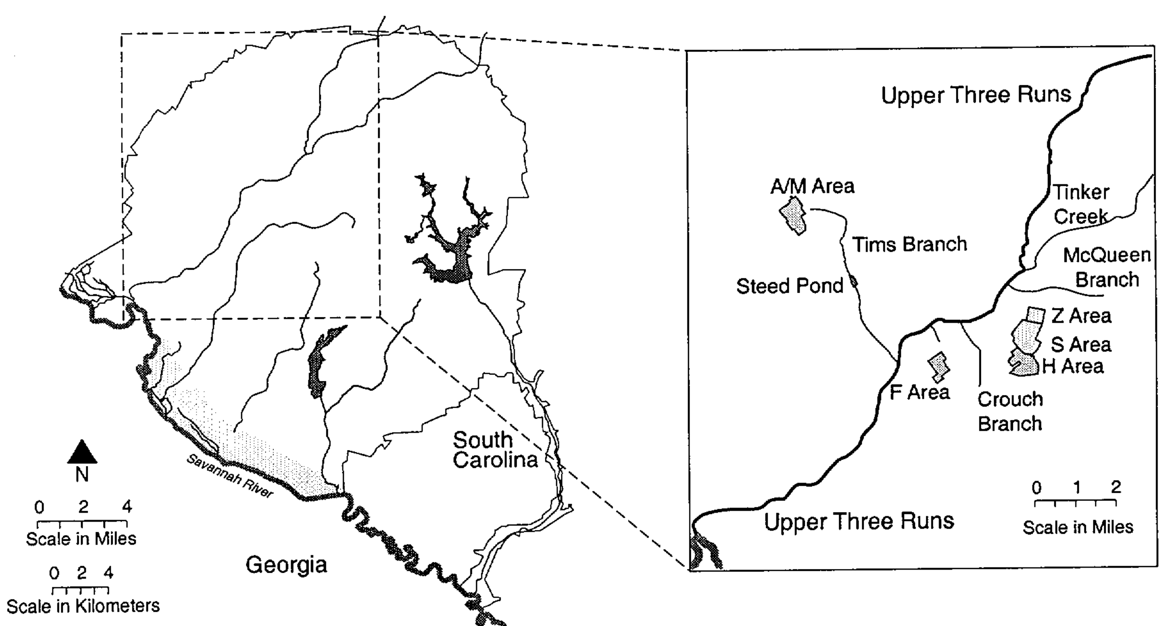

Figure 5-1. Location of Upper Three Runs on SRS

and S-Area carry ambient temperature cooling water, steam condensates, powerhouse wash-down waters, and ash disposal basin effluents.

Upper Three Runs, either directly or via tributaries, receives the following NPDES-permitted discharges: cooling water, blowdown, stormwater, lab drains, air stripper discharge, steam condensate, M-Area wastes, process-water, Consolidated Incineration Facility wastewater, neutralization wastewater, and F/H Effluent Treatment Facility wastewater.

Flow Measurements

The U.S. Geological Survey measures flow at several locations on Upper Three Runs. Flow statistics of Upper Three Runs at SRS Road A, above SRS Road C, and near New Ellenton (Highway 278) (Figure 5-2) are summarized in Table 5-1. Records for the most downstream station (Upper Three Runs at Road A) date back to June 1974 (no records from February 1978 through September 1978). In water year 1995, the mean flow of Upper Three Runs at Road A was 8.0 m^3/s (284 ft^3/s). Over the period of record (water years 1974-1995) at Road A, the mean flow was 6.9 m^3/s (245 ft^3/s), the 7-day low flow was 2.4 m^3/s (84 ft^3/s), and the 7Q10 was 2.8 m^3/s (100 ft^3/s). The maximum, minimum, and mean daily flows from October 1982 to September 1995 at the three stations are shown in Figure 5-3 through Figure 5-5.

	Station Name
01	near New Ellenton (Hwy 278)
02	above Road C at SRS
03	at Road A at SRS

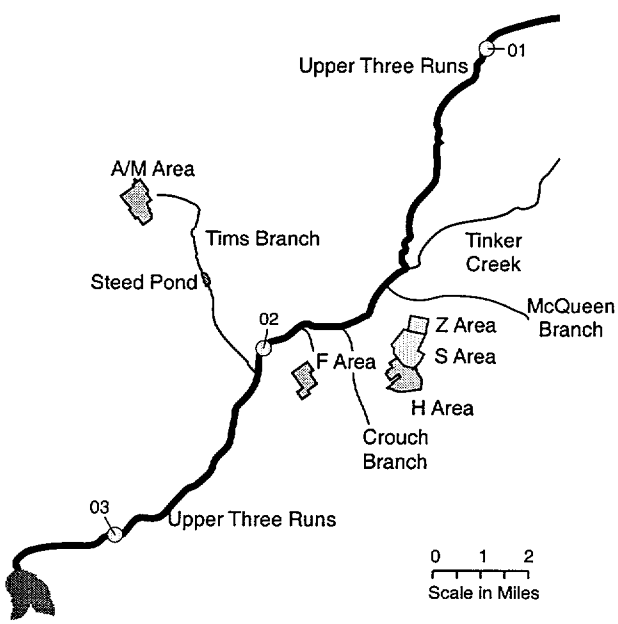

Figure 5-2. Flow Measurement Sampling Stations for Upper Three Runs

Table 5-1. Flow Summary for Upper Three Runs

			Range									
			Mean		Low		High		7Q10		7-Day Low Flow	
Station Location	**Station Number**	**Period of Record**	**cms**	**cfs**	**cms**	**cfs**	**cms**	**cfs**	**cms**	**cfs**	**cms**	**cfs**
near New Ellenton (Hwy 278)	02197300	1966-1995	3.0	105	1.5	53	14.4	509	1.6	56	1.6	55
above Road C at SRS	02197310	1974-1995	5.9	211	2.4	85	49.3	1740	2.8	100	2.4	86
at Road A at SRS	02197315	1974-1995	6.9	245	2.4	83	56.6	2000	2.8	100	2.4	84

cms = cubic meters per second.
cfs = cubic feet per second.

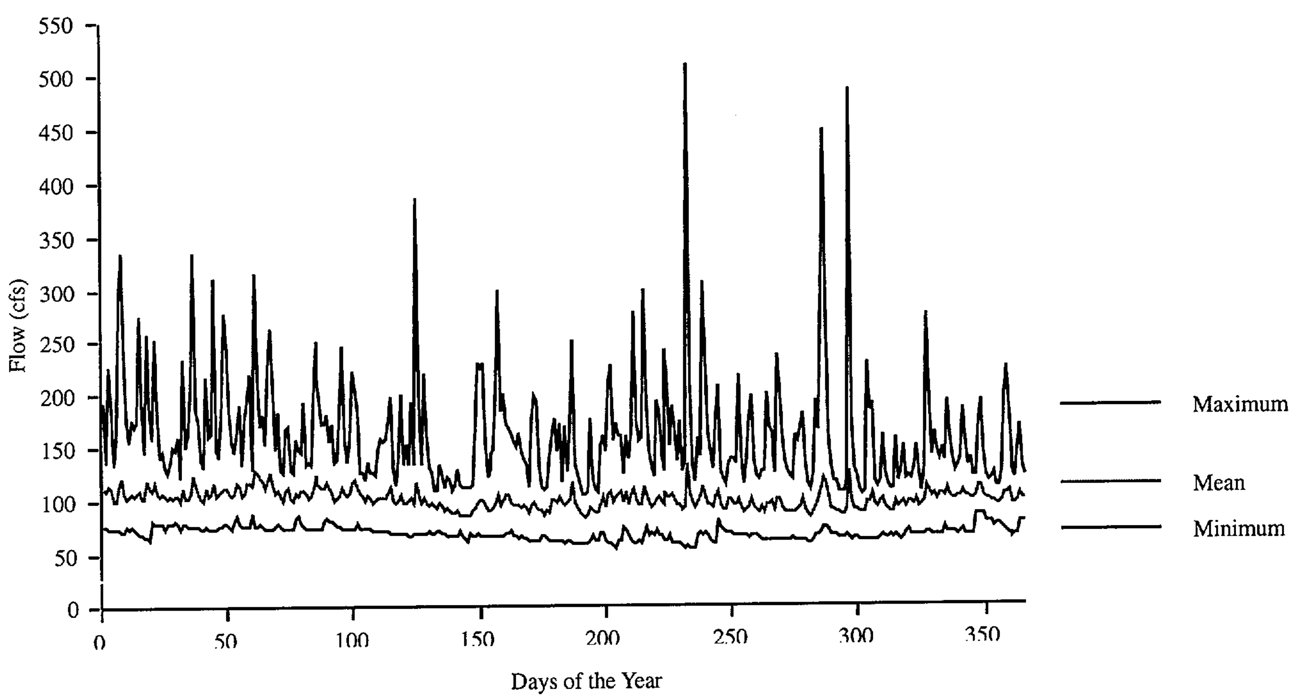

Figure 5-3. Maximum, Mean, and Minimum Flow Measurements for Upper Three Runs at U.S. Highway 278, October 1982-September 1995.

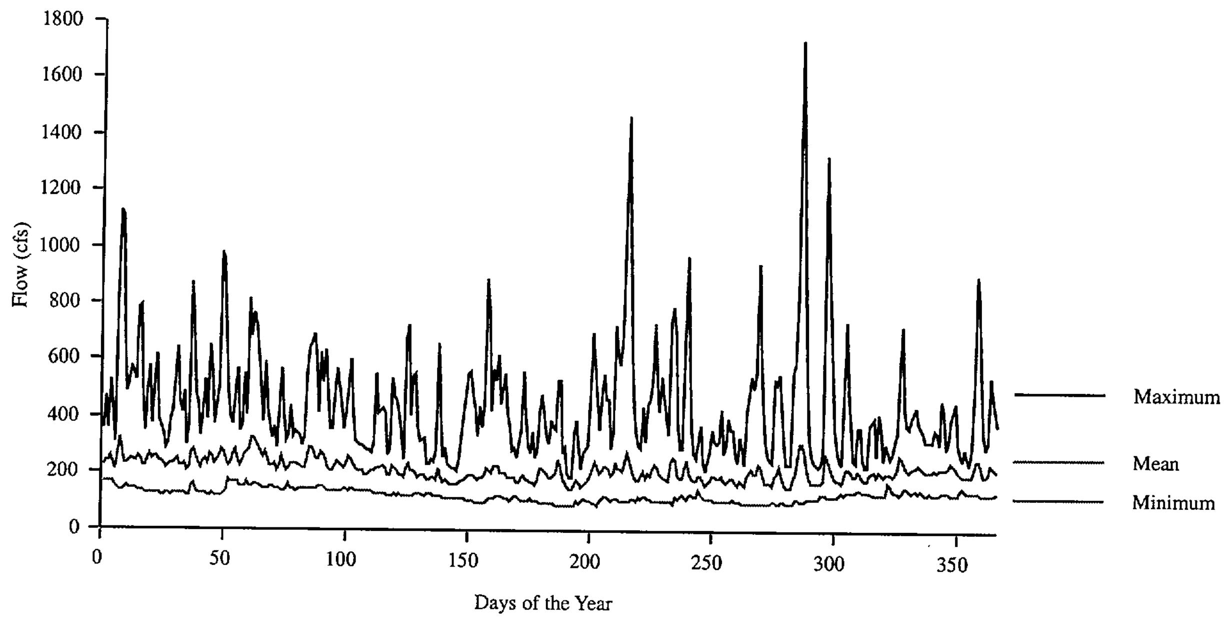

Figure 5-4. Maximum, Mean, and Minimum Flow Measurements for Upper Three Runs above Road C on SRS, October 1982-September 1995.

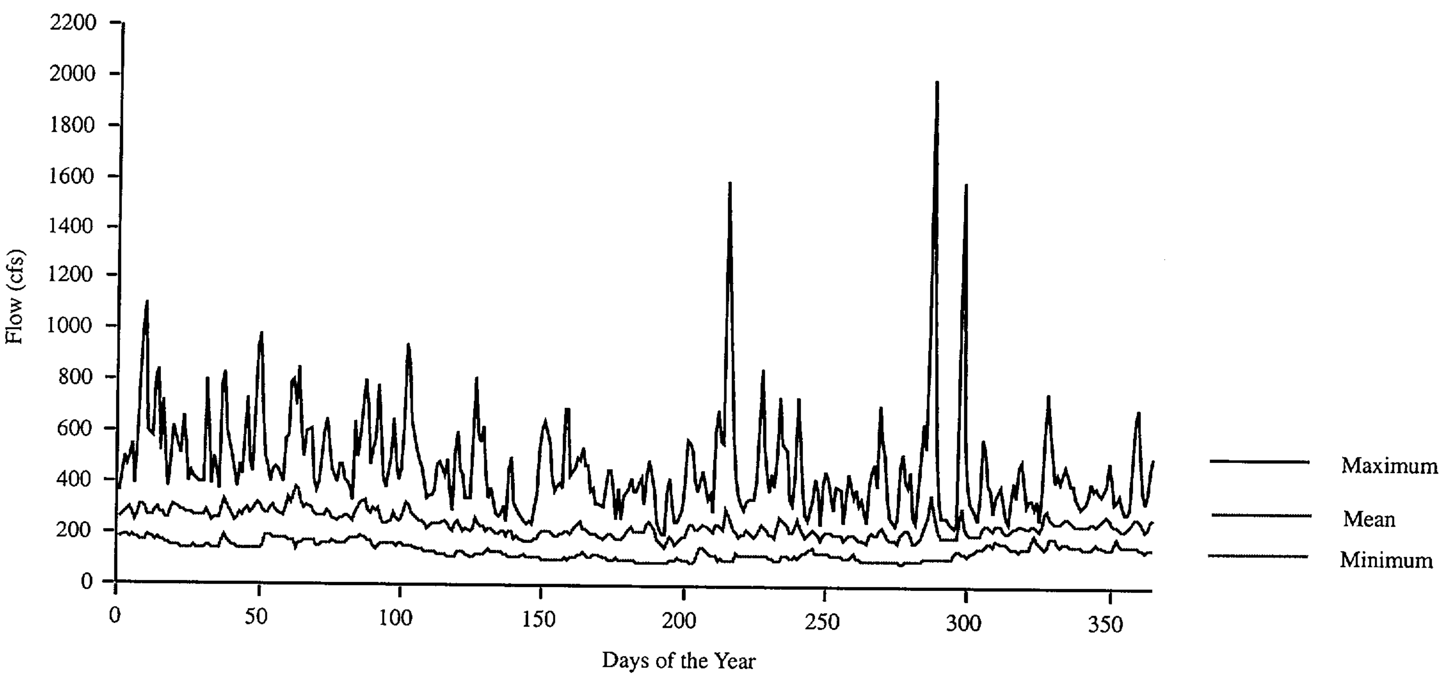

Figure 5-5. Maximum, Mean, and Minimum Flow Measurements for Upper Three Runs at Road A at SRS, October 1982-September 1995.

Water Chemistry and Quality

Studies and Monitoring

Water-Quality Monitoring

Westinghouse Savannah River Company Environmental Monitoring Section has monitored the water quality of Upper Three Runs since 1973. During routine monitoring, three sampling locations have been established on Upper Three Runs. These locations — Upper Three Runs at U.S. Highway 278, Tims Branch 5, and Upper Three Runs at Road A — are sampled monthly for physical and biological water quality parameters and for metals (Figure 5-6). Samples also are collected annually and analyzed for pesticides, herbicides, and PCBs. In 1990, the Upper Three Runs at Highway 278 sampling location was moved approximately 1.6 km (1 mi) downstream and closer to the SRS boundary to provide a better indication of contaminants originating above SRS; this new sampling location is designated Upper Three Runs 1A.

All routine water quality monitoring data reported in the following sections can be found in the annual SRS Environmental Reports.

	Station Name
01	Upper Three Runs (U3R) at U.S. Highway 278
02	U3R at Road 8-1
03	U3R-1A
04	upstream Road C, Tims Branch (TB)-5, Site 1 (F/H)
05	A-014
06	A-015
07	M-out
08	TB-2
09	TB-0
10	TB-1
11	TB-3
12	TB-4, Tim Branch upstream of Upper Three Runs, Tims Branch (F/H), and Tims Branch 5 (water quality monitoring)
13	TB-6, Site 2 (F/H)
14	Site 3 (F/H)
15	Site 4 (F/H)
16	Site 5 (F/H)
17	U3R at Road A
18	confluence with Savannah River

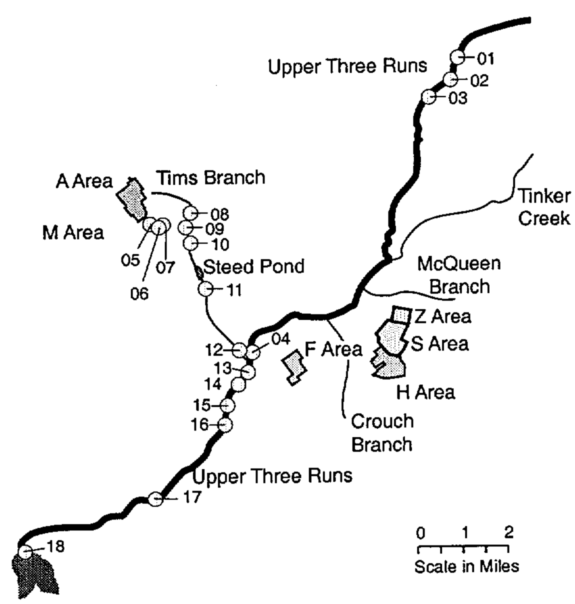

Figure 5-6. Water Chemistry and Quality Sampling Stations for Upper Three Runs

Comprehensive Cooling Water Study

From 1983 to 1985, Upper Three Runs and Tims Branch were studied as part of the Comprehensive Cooling Water Study (CCWS). This study was designed to assess the impact of current and proposed SRS activities on water quality. The CCWS included the following four locations on Upper Three Runs and Tims Branch (Figure 5-6):

- Upper Three Runs at Road 8-1 - upstream of SRS point source effluents and upstream of Tinker Creek (02 on map)
- Upper Three Runs at Road C - primarily consists of headwater conditions, but also reflects point-source effluents to tributaries of Upper Three Runs from 200-F and 200-H Separations Areas, as well as construction impacts from 200-S Area (13 on map).
- Upper Three Runs upstream of confluence with Savannah River - consists of all upstream point-source and runoff conditions, as well as temporal flooding from high water conditions of the Savannah River (18 on map).
- Tims Branch - cumulative effects of point-source effluents discharged to this stream from 300-M Area, the Savannah River Technology Center, and the Savannah River Ecology Laboratory (12 on map).

Comprehensive results and discussion of CCWS data can be found in Newman et al. (1986) and Lower (1987). Gladden et al. (1985) present a synopsis of Upper Three Runs and Tims Branch water quality data prior to the CCWS.

Priority Pollutants Survey

In 1984, an instream survey of priority pollutants was conducted to determine the levels of volatile, acid, base and neutral compounds in Upper Three Runs. This study sampled four locations: Upper Three Runs at Highway 278 (01), Tims Branch near Road C (12), Upper Three Runs upstream of Road C (04), and Upper Three Runs at Road A (17). Potential sources for organics in Upper Three Runs included process sewer outfalls, local outcropping of groundwater, and the M-Area settling basin. The results of this study are presented in the sections that follow and in Lower (1987).

Chemical Assessment Studies

From 1985 to 1993, four studies were conducted on the waters of Tims Branch and Upper Three Runs to determine impacts from specific SRS operations. In addition, a toxicity study was done on Upper Three Runs waters upstream of all SRS discharges. These studies, which are summarized later in this chapter included:

- Effect of changes in M-Area effluent on Tims Branch (June 1985-December 1986)
- Effect of M-Area Liquid Effluent Treatment Facility on Tims Branch (September 1988-March 1990)
- Effect of F/H-Area Effluent Treatment Facility on Upper Three Runs (July 1987-February 1990)
- Effect of contaminants from Mixed Waste Management Facility on Upper Three Runs wetlands (1993)
- Effect of Upper Three Runs water on *Ceriodaphnia dubia* (1994)

Field Data

Water Temperature

The mean water temperature at sampling locations on Tims Branch and Upper Three Runs ranged from 15.2 to 17.3°C (59 to 63°F) during the CCWS and routine monitoring program (Table 5-2). These temperatures are reflective of the nonthermal nature of this stream.

pH Measurements

The mean pH in the Upper Three Runs watershed is slightly acidic, with means ranging from 6.03 near Road 8-1 to 6.65 at the stream confluence with the Savannah River (Table 5-2). Throughout the CCWS and during routine monitoring, waters at all Upper Three Runs and tributary sites displayed wide pH variations (3.1-8.3).

Physical Characteristics and General Chemistry

Dissolved Oxygen

Mean dissolved oxygen concentrations ranged from 7.80 to 8.10 mg/l throughout Upper Three Runs during the CCWS (Table 5-3). Dissolved oxygen concentrations measured since the CCWS have been slightly higher, with ranges from 5.0 to 15.1 mg/l. Dissolved oxygen in McQueen Branch and Crouch Branch fluctuates from 1.2 to 13.5 mg/l (Table 5-3).

Suspended Solids and Turbidity

Mean concentrations of suspended solids and turbidity were highest and most variable during the CCWS (Table 5-3). The range in maximum suspended solids concentrations varied considerably (46.8 mg/l - 892 mg/l) throughout the watershed. Maximum turbidities ranged from 32 to 352 NTU (Nephelometric Turbidity Units). Suspended solids and turbidity concentrations have been lower since the CCWS. From 1987 to 1991, maximum suspended solids concentrations ranged from 6.0 to 97 mg/l, and turbidities have ranged from 3.9 to 120 NTU. From 1992 to 1995, maximum suspended solids concentrations ranged from 31 to 89 mg/l and turbidities ranged from 1.02 to 200 NTU in Upper Three Runs and its tributaries (Table 5-3).

Water quality in tributaries to Upper Three Runs that drain the Defense Waste Processing Facility (DWPF) site was monitored from 1983 to 1995 to determine the effect of construction activities on the tributaries and Upper Three Runs. In both McQueen Branch and Crouch Branch, total suspended solids and turbidity increased over baseline and reference stream concentrations. During the period of construction mean total suspended solids ranged from 18.26 to 182.33 mg/l in McQueen Branch and from 50.12 to 99.62 mg/l in Crouch Branch. After construction means ranged from 5.63 to 135.83 mg/l and 26.13 to 156.99 mg/l in McQueen and Crouch Branch, respectively (Bodie and Scott 1995).

Turbidity ranged from 25.62 to 236.13 NTUs in McQueen Branch during construction and from 1.86 to 158.89 NTUs since construction. In Crouch Branch the values were 98.67 to 187.33 NTUs during construction and 30.62 to 237.44 NTUs after construction.

The higher suspended solid loads and turbidity values occurred after periods of heavy rain and may be the result of poorly functioning sedimentation basins (Bodie and Scott 1995).

Table 5-2. Upper Three Runs Field Data

	Water Temperature (°C)	pH	Stream Maximum Depth (cm)	Stream Velocity (cm/sec)
Upper Three Runs at Road 8-1 (CCWS)[a]				
Mean	16.5	6.03	181	42
Range	5.2 - 23.0	4.70 - 8.10	165 - 209	20 - 74
Samples	45	44	41	41
Upper Three Runs upstream of Road C (CCWS)[a]				
Mean	16.0	6.34	69	51
Range	2.0 - 24.0	4.60 - 7.60	11 - 166	16 - 100
Samples	46	46	27	41
Upper Three Runs at confluence with Savannah River (CCWS)[a]				
Mean	15.2	6.64	135	27
Range	0.8 - 23.5	4.90 - 8.00	83 - 338	5 - 52
Samples	46	46	26	39
Tims Branch just upstream of Upper Three Runs (CCWS)[a]				
Mean	16.3	6.65	35	28
Range	3.3 - 23.0	5.30 - 7.80	6 - 126	2 - 82
Samples	46	46	36	41
Upper Three Runs at Highway 278[b]				
Mean	17.3			
Range	9.5 - 26	3.1 - 7.6	NA	NA
Samples	41	41		
Upper Three Runs 1A[b]				
Mean	17.3			
Range	10 - 22.6	5.2 - 8.2	NA	NA
Samples	19	19		
Tims Branch 5[b]				
Mean	15.9			
Range	6.2 - 25	4.9 - 8.3	NA	NA
Samples	60	60		
Upper Three Runs at Road A, 1992-1995[b]				
Mean	17.0	6.3		
Range	7.1 - 24.4	5.2 - 8.0	NA	NA
Samples	48	48		
Upper Three Runs at Road 8-1, 1992-1995[c]				
Mean	16.8	6.3	NA	NA
Range	8.0 - 24.0	4.3 - 8.0		
Samples	48	48		
Tims Branch-5, 1992-1995[c]				
Mean	16.3	6.6	NA	NA
Range	6.2 - 23.0	5.8 - 7.6		
Samples	48	48		
Crouch Branch, 1992-1995[c]				
Mean	16.6	NA	NA	NA
Range	4.0 -26.6			
Samples	48			
McQueen Branch, 1992-1995[c]				
Mean	16.5	NA	NA	NA
Range	6.0 - 24.8			
Samples	48			

NA = Not analyzed.
Blank Spaces = Mean not calculated due to insufficient data in report.
[a]CCWS = Comprehensive Cooling Water Study (Newman et al. 1986).
[b]1987-1991 = Data taken from Arnett et al. 1992; Cummins et al. 1990, 1991; Davis et al. 1989; Mikol et al. 1988.
[c]1992-1995 = Data taken from Arnett et al. 1993, 1994, 1995, and 1996.

Table 5-3. Upper Three Runs Physical Characteristics and General Chemistry

	Dissolved Oxygen (mg/l)	Specific Conductivity (µS/cm)	Turbidity (NTU)[a]	Total Suspended Solids (mg/l)
Upper Three Runs at Road 8-1 (CCWS)[b]				
Mean	8.07	14.7	5.7	9.89
Range	5.60 - 11.0	1.4 - 20.1	0.2 - 30.0	0.25 - 55.2
Samples	46	38	43	44
Upper Three Runs upstream of Road C (CCWS)[b]				
Mean	8.00	19.9	24.7	18.5
Range	5.10 - 11.6	10.5 - 22.9	1.9 - 352	0.25 - 333
Samples	46	38	43	45
Upper Three Runs at confluence with Savannah River (CCWS)[b]				
Mean	7.80	28.2	13.0	26.9
Range	4.40 - 11.9	20.6 - 68.9	2.5 - 75.0	0.25 - 892
Samples	45	38	43	
Tims Branch just upstream of Upper Three Runs (CCWS)[b]				
Mean	8.10	25.0	8.0	7.21
Range	4.80 - 11.1	13.8 - 67.2	2.3 - 32.0	0.25 - 46.8
Samples	46	38	43	44
Upper Three Runs at Highway 278, 1987-1991[c]				
Mean	8.33	22.5	5.73	4.63
Range	6.2 - 10	7.0 - 76	<1.0 - 120	2.0 - 19
Samples	41	41	41	41
Upper Three Runs at Road 8-1, 1987-1991[c]				
Mean	8.60	21.5	1.75	3.85
Range	7.4 - 9.8	15 - 30	0.82 - 3.9	1.0 - 6.0
Samples	19	19	19	19
Tims Branch 5, 1987-1991[c]				
Mean	8.98	51.2	7.52	9.02
Range	6.0 - 13	12 - 165	3.0 - 25	2.0 - 32
Samples	60	60	60	60
Upper Three Runs at Road A[c]				
Mean	8.36	24.5	5.24	10.2
Range	4.9 - 12	3.0 - 41	1.0 - 22	2.0 - 97
Samples	60	60	60	60
Upper Three Runs at Road 8-1, 1992-1995[d]				
Mean	8.64	24	3.00	5.5
Range	6.3 - 15.1	14 - 61	1.02 - 9.0	1 - 31
Samples	48	48	48	48
Tims Branch 5, 1992-1995[d]				
Mean	9.54	64.5	12.24	12.75
Range	6.7 - 13.4	25 - 134	4.6 - 38	4 - 43
Samples	48	48	48	48
Upper Three Runs at Road A, 1992-1995[d]				
Mean	8.5	26.25	7.78	10.2
Range	5.0 - 12.5	17 - 40	2.4 - 45	1 - 69
Samples	48	48	48	48

[a]NTU = Nephelometric Turbidity Units.
[b]CCWS = Comprehensive Cooling Water Study (Newman et al. 1986).
[c]1987-1991 = Data taken from Arnett et al. 1992; Cummins et al. 1990, 1991; Davis et al. 1989; Mikol et al. 1988.
[d]1992-1995 = Data taken from Arnett 1993, 1994, 1995, and 1996.

Statistically there appears to have been no significant adverse impact to Upper Three Runs from the construction activities.

Conductivity

During the CCWS, specific conductance in Upper Three Runs and Tims Branch was low compared to other onsite streams and the Savannah River (Newman et al. 1986). Specific conductance ranged from 1.4 to 20.1 μS/cm at the headmost waters of Upper Three Runs and increased in range from 20.6 to 68.9 μS/cm near the confluence with the Savannah River (Table 5-3). Specific conductances measured from 1987 to 1991 were highest at Tims Branch 5 (mean 51.2 μS/cm) and lowest at the upstream location, Upper Three Runs 1A (mean 21.5 μS/cm). Between 1992 and 1995, mean conductivity at Tims Branch was 64.5 μS/cm, 76.75 μS/cm at Crouch Branch, 45.5 μS/cm at McQueen Branch, and 26.25 μS/cm and 24 at the two Upper Three Runs locations (Table 5-3).

Conductivity values were monitored in McQueen Branch, Crouch Branch, and Upper Three Runs during and since construction of DWPF to determine the impact of construction activities on the tributaries' water quality and the effects of tributary water quality on Upper Three Runs water quality. During construction, mean conductivity ranged from 55.93 to 66.80 μS/cm in McQueen Branch and from 90.02 to 108.27 μS/cm in Crouch Branch. After construction conductivity ranged from 28.31 to 60.55 μS/cm in McQueen Branch and from 87.27 to 95.02 μS/cm in Crouch Branch (Bodie and Scott 1995).

Major Anions and Cations

Alkalinity, Chloride, and Sulfate

Alkalinity, chloride, and sulfate concentrations in Upper Three Runs increased with distance downstream during the CCWS (Table 5-4). The waters near the confluence with the Savannah River had mean alkalinity and sulfate concentrations of 5.09 mg $CaCO_3$/l, chloride concentrations of 2.05 mg/l, and sulfate concentrations of 1.18 mg/l. Except for alkalinity and sulfate in Tims Branch, similar concentrations of alkalinity, chloride, and sulfate have been measured in Upper Three Runs in the years following the CCWS. Alkalinity in Tims Branch has averaged 14.3 mg $CaCO_3$/l since the study.

Calcium, Magnesium, Sodium, and Potassium

Concentrations of total calcium, magnesium, sodium, and potassium in Upper Three Runs waters during the CCWS and as part of routine monitoring are given in Table 5-5. The CCWS determined that most of the calcium, magnesium, and sodium was in the dissolved phase (Newman et al. 1986). Mean potassium concentrations were below detection limits during CCWS and were not measured during routine monitoring. All monitoring data indicate that concentrations of these cations are low, but increase with distance downstream. Tims Branch tended to have slightly higher concentrations of these cations relative to the mainstream Upper Three Runs.

Aluminum, Iron, and Manganese

Table 5-5 gives concentrations of total aluminum, manganese, and iron measured during the CCWS and routine monitoring. The highest concentrations of these cations were mea-

Table 5-4. Upper Three Runs Major Anions

	Alkalinity (mg $CaCO_3$/l)	Chloride (mg/l)	Sulfate (mg/l)
Upper Three Runs at Road 8-1 (CCWS)[a]			
Mean	0.93	1.63	0.34
Range	0.16 - 6.70	0.20 - 2.00	0.01 - 1.92
Samples	45	46	26
Upper Three Runs upstream of Road C (CCWS)[a]			
Mean	2.69	1.73	0.63
Range	0.49 - 4.48	0.20 - 2.20	0.06 - 2.24
Samples	45	46	26
Upper Three Runs at confluence with Savannah River (CCWS)[a]			
Mean	5.09	2.05	1.18
Range	1.99 - 18.1	0.20 - 3.90	0.13 - 6.93
Samples	45	46	27
Tims Branch just upstream of Upper Three Runs (CCWS)[a]			
Mean	5.22	1.85	0.60
Range	1.10 - 8.90	0.20 - 3.40	0.06 - 8.46
Samples	45	46	25
Upper Three Runs at Highway 278, 1987-1991[b]			
Mean	3.13	1.9	2.83
Range	1.0 - 37	0.05 - 4.5	0.05 - 1.1
Samples	41	41	41
Upper Three Runs 1A, 1987-1991[b]			
Mean	2.15	2.2	2.7
Range	<1.0 - 2.0	1.1 - 3.6	1.0 - 5.0
Samples	19	19	19
Tims Branch 5, 1987-1991[b]			
Mean	14.2	2.98	4.1
Range	9.0 - 29	0.54 - 7.3	<1.0 - 31
Samples	60	60	60
Upper Three Runs at Road A, 1987-1991[b]			
Mean	4.9	1.94	2.96
Range	1.0 - 19	0.31 - 8.8	0.50 - 7.0
Samples	60	60	60
Upper Three Runs 1A at Road 8-1, 1992-1995[c]			
Mean	<2.52	2.18	<1.15
Range	<1 - 24	<1 - 7.37	<1 - 5.04
Samples	48	48	48
Tims Branch, 1992-1995[c]			
Mean	14.4	3.8	5.8
Range	8 - 23	1.35 - 11.65	1 - 18
Samples	48	48	48
Upper Three Runs at Road A, 1992-1995[c]			
Mean	2.12	2.5	2.25
Range	2 - 6	<1 - 13.84	1 - 5.63
Samples	48	48	48

[a]CCWS = Comprehensive Cooling Water Study (Newman et al. 1986).
[b]1987-1991 = Data taken from Arnett et al. 1992; Cummins et al. 1990, 1991; Davis et al. 1989; Mikol et al. 1988.
[c]1992-1995 = Data taken from Arnett 1993, 1994, 1995, and 1996.

Table 5-5. Upper Three Runs Major Cations (Total)

	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Potassium (mg/l)	Aluminum (mg/l)	Iron (mg/l)	Manganese (mg/l)
Upper Three Runs at Road 8-1 (CCWS)[a]							
Mean	0.512	0.333	1.06	<0.368	0.514	0.593	0.033
Range	0.245 - 1.45	0.179 - 0.443	0.535 - 1.90	<0.368 - 0.719	0.099 - 1.36	0.192 - 1.48	<0.0004 - 0.092
Samples	39	39	39	39	39	39	17
Upper Three Runs upstream of Road C (CCWS)[a]							
Mean	1.89	0.397	1.48	<0.368	1.32	0.903	0.039
Range	0.265 - 13.5	0.286 - 1.3639	0.842 - 8.95	<0.368 - 1.54	0.134 - 21.4	0.218 - 5.72	<0.0004 - 0.108
Samples	39	39	39	39	39	39	17
Upper Three Runs at confluence with Savannah River (CCWS)[a]							
Mean	1.90	0.527	1.69	<0.368	0.685	0.921	0.075
Range	1.45 - 4.13	0.341 - 1.57	0.778 - 7.82	<0.368 - 1.53	0.132 - 4.07	0.287 - 3.14	<0.0004 - 0.331
Samples	38	38	38	38	38	38	17
Tims Branch just upstream of Upper Three Runs (CCWS)[a]							
Mean	1.40	0.429	1.82	<0.368	0.473	1.31	0.100
Range	0.45 - 2.28	0.348 - 0.561	1.16 - 4.78	<0.368 - 0.890	0.108 - 2.99	0.588 - 3.08	<0.0004 - 0.198
Samples	39	39	39	39	39	39	17
Upper Three Runs at Highway 278, 1987-1991[b]							
Mean							
Range	0.22 - 0.69	0.17 - 0.37	0.29 - 1.5	NA	<0.01 - 0.10	<0.01 - 0.71	<0.01 - 0.02
Samples	13	13	12		12	13	13
Upper Three Runs 1A, 1987-1991[b]							
Mean							
Range	0.39 - 0.49	0.26 - 0.36	1.02 - 1.5	NA	0.07 - 0.15	0.19 - 0.59	<0.005 - 0.01
Samples	5	5	7		7	7	5
Tims Branch 5, 1987-1991[b]							
Mean							
Range	0.67 - 2.6	0.37 - 0.70	6.0 - 18	NA	0.02 - 1.9	0.11 - 2.6	<0.01 - 0.40
Samples	16	16	15		15	16	16
Upper Three Runs at Road A, 1987-1991[b]							
Mean							
Range	0.69 - 2.3	0.17 - 0.40	0.69 - 2.2	NA	<0.05 - 0.23	0.07 - 0.71	<0.01 - 0.03
Samples	16	16	15		15	16	16
Upper Three Runs at Road 8-1, 1992-1995[c]							
Mean	0.49	0.33	1.56		0.114	0.28	0.034
Range	0.22 - 0.905	0.211 - 0.42	0.606 - 4.92	NA	0.036 - 0.25	0.197 - 0.48	0.005 - 0.14
Samples	16	15	12		15	16	14
Tims Branch 5, 1992-1995[c]							
Mean	1.18	0.82	9.8		0.41	1.82	0.06
Range	0.953 - 1.395	0.383 - 5.17	5.54 - 19.2	NA	0.105 - 0.765	1.06 - 3.48	0.038 - 0.794
Samples	16	15	16		16	16	15
Upper Three Runs at Road A, 1992-1995[c]							
Mean	1.62	0.33	1.73		0.20	0.583	0.02
Range	1.32 - 2.234	0.034 - 0.44	0.29 - 5.57	NA	0.018 - 0.30	0.36 - 0.90	0.008 - 0.05
Samples	16	15	16		14	16	13

NA = Not analyzed.
Blank Spaces = Mean not calculated due to insufficient data in report.
[a]CCWS = Comprehensive Cooling Water Study (Newman et al. 1986).
[b]1987-1991 = Data taken from Arnett et al. 1992; Cummins et al. 1990, 1991; Davis et al. 1989; Mikol et al. 1988.
[c]1992-1995 = Data taken from Arnett 1993, 1994, 1995, and 1996.

sured during the CCWS. It was determined during the CCWS that most of the aluminum (91%) and iron (90%) was transported in the solid phase. Solid phase-associated manganese accounted for 34% of the concentrations measured at the farthest upstream site and increased to 47% near the stream mouth (Newman et al. 1986). Concentrations of aluminum, manganese, and iron have been lower since the CCWS (Table 5-5).

Nutrients

Phosphorus

Concentrations of nutrients in Upper Three Runs were low relative to the Savannah River despite the influx of nutrients from offsite agricultural areas (Lower 1987). Mean total phosphorus ranged from 0.034 mg/l to 0.052 mg/l during the CCWS. Since 1987, mean total phosphorus has ranged from not detected to 0.072 mg /l (Table 5-6).

Nitrogen

The major nitrogen species in Upper Three Runs waters during the CCWS were nitrate-nitrogen (40%) and total Kjeldahl nitrogen (50%). Concentrations of nitrogen (as NO_2-NO_3) measured during routine monitoring have been higher than concentrations measured during the CCWS; this difference is probably the result of changes in 300-M Area effluent (see Chemical Assessment Studies Section). The maximum mean nitrogen concentration measured during routine monitoring (1.04 mg NO_3/l) was in Tims Branch (Table 5-6).

Trace Elements

The CCWS measured relatively low levels of trace elements. Routine monitoring report detection limits that were higher than the concentrations measured during the CCWS; therefore, only CCWS data is discussed in this section (Table 5-7). Mean total concentrations of arsenic, cadmium, chromium, copper, lead, nickel, and zinc in Upper Three Runs and Tims Branch during the CCWS reflected the ambient and largely undisturbed nature of these waters and the lack of significant quantities of these materials discharged from SRS operations. Mean concentrations ranged between the watershed headwaters and the creek mouth as follows: arsenic 1.4-1.3 µg/l; cadmium, 0.54-0.32 µg/l; chromium, 8.1-6.1 µg/l; copper, 1.9-2.1 µg/l; lead, 2.2-2.1 µg/l; nickel, 2.7-3.8 µg/l; and zinc, 4.5-4.6 µg/l. CCWS did not detect mercury or uranium in Upper Three Runs or Tims Branch.

Organic Carbon

During the CCWS, mean total organic carbon concentrations ranged from 5.56 to 6.59 mg/l, with approximately 55-75% of the organic carbon present in the dissolved phase. Total organic carbon was routinely measured only at Tims Branch 5 and at Upper Three Runs near Road A during routine monitoring. Total organic concentrations at these locations ranged from <1.0 to 12 mg/l.

Table 5-6. Upper Three Runs Nutrients

	Total Phosphorus (mg/l)	Total Ortho-phosphate (mg/l)	Organic Nitrogen (mg/l)	Total Kjeldahl Nitrogen (mg/l)	Ammonia (mg/l)	Nitrite (mg/l)	Nitrate (mg/l)
Upper Three Runs at Road 8-1 (CCWS)[a]							
Mean	0.034	0.009		0.227	0.024	0.002	0.186
Range	<0.010 - 0.162	<0.001 - 0.061		0.022 - 0.930	0.005 - 0.220	<0.001 - 0.006	0.024 - 0.321
Samples	46	41		46	46	44	42
Upper Three Runs upstream of Road C (CCWS)[a]							
Mean	0.052	0.015		0.221	0.024	0.002	0.136
Range	0.014 - 0.693	0.003 - 0.048		0.015 - 0. 750	0.005 - 0.220	<0.001 - 0.007	0.026 - 0.278
Samples	46	41		46	46	44	43
Upper Three Runs at confluence with Savannah River (CCWS)[a]							
Mean	0.045	0.021		0.211	0.030	0.003	0.118
Range	<0.010 - 0.258	0.010 - 0.063		0.030 - 0.900	0.005 - 0.180	<0.001 - 0.010	0.023 - 0.239
Samples	46	41		46	46	44	43
Tims Branch just upstream of Upper Three Runs (CCWS)[a]							
Mean	0.042	0.023		0.217	0.029	0.003	0.159
Range	<0.010 - 0.148	0.005 - 0.092		0.026 - 0.585	0.005 - 0.180	<0.001 - 0.012	0.004 - 0.293
Samples	46	41		46	46	42	41
Upper Three Runs at Highway 278, 1987-1991[b]							
Mean	0.016				0.023		0.24
Range	<0.01 - 0.07	NA	NA	NA	<0.01 - 0.08	NA	0.05 - 1.1
Samples	41				41		41
Upper Three Runs 1A, 1987-1991[b]							
Mean	0.03				0.14		0.31
Range	ND - 0.07	NA	NA	NA	ND - 0.79	NA	0.15 - 0.38
Samples	12				36		24
Tims Branch 5, 1987-1991[b]							
Mean	0.08		0.27	0.45	<0.075	1.8	1.8
Range	ND - 0.15	NA	<0.01 - 1.6	ND - 0.95	ND - 0.3	0.01 - 7.31	0.01 - 7.31
Samples	12		60	27	28	24	24
Upper Three Runs at Road A, 1987-1991[b]							
Mean	0.026		0.31		0.038		0.15
Range	0.01-0.12	NA	<0.10-2.8	NA	<0.01-0.14	NA	0.04-0.91
Samples	60		60		60		60
Upper Three Runs at Road 8-1, 1992 - 1995[c]							
Mean[d]	0.06		0.31	0.31[e]	0.036	NA	0.24
Range	ND - 0.16	NA	<0.01 - 2.8	ND - 0.47	ND - 0.66		0.02 - 0.34
Samples	12		60	19	26		24
Upper Three Runs at Road A, 1992-1995[c]							
Mean[d]	0.06			0.31[e]	0.036	0.155[f]	0.24[g]
Range	ND-0.16	NA	NA	ND-0.47	ND - 0.66	0.05 - 0.44	0.02 - 0.34
Samples	12			19	26	24	24
Tims Branch 5, 1992-1995[c]							
Mean[d]	0.08			0.45[e]	<0.075	1.8[f]	1.04[g]
Range	ND - 0.15	NA	NA	ND - 0.95	ND - 0.3	0.01 - 7.31	0.23 - 6.09
Samples	12			27	28	24	24

NA = Not analyzed.
ND = None detected.
Blank Spaces = Mean not calculated due to insufficient data in report.
[a]CCWS = Comprehensive Cooling Water Study (Newman et al. 1986).
[b]1987-1991 = Data taken from Arnett et al. 1992; Cummins et al. 1990, 1991; Davis et al. 1989; Mikol et al. 1988.
[c]1992-1995 = Data taken from Arnett 1993, 1994, 1995, 1996.
[d]All nondetectable quantities were excluded from the calculation of means.
[e]1992-1993.
[f]1993-1995.
[g]1994-1995.

Table 5-7. Upper Three Runs Trace Elements (Total)

	Arsenic (µg/l)	Cadmium (µg/l)	Chromium (µg/l)	Copper (µg/l)	Lead (µg/l)	Nickel (µg/l)	Zinc (µg/l)
Upper Three Runs at Road 8-1 (CCWS)[a]							
Mean	1.4	0.54	8.1	1.9	2.2	2.7	4.5
Range	<0.4 - 5.7	<0.04 - 4.30	<0.4 - 67.0	<0.4 - 4.1	<0.4 - 9.3	<0.4 - 10.9	<0.4 - 18.2
Samples	17	17	17	17	17	17	17
Upper Three Runs upstream of Road C (CCWS)[a]							
Mean	1.0	0.36	14.1	2.1	2.8	2.7	5.1
Range	<0.4 - 5.0	<0.04 - 1.41	<0.4 - 71.0	<0.4 - 5.1	<0.4 - 16.5	<.4 - 14.0	<0.4 - 17.4
Samples	17	17	17	17	17	17	17
Upper Three Runs at confluence with Savannah River (CCWS)[a]							
Mean	1.3	0.32	6.1	2.1	2.1	3.8	4.6
Range	<0.4 - 5.4	<0.04 - 1.50	<0.4 - 47.0	<0.4 - 7.8	<0.4 - 3.7	<0.4 - 17.3	<0.4 - 18.1
Samples	17	17	17	17	17	17	17
Tims Branch just upstream of Upper Three Runs (CCWS)[a]							
Mean	1.7	0.30	8.1	2.0	1.7	5.1	3.6
Range	<0.4 - 8.6	<0.04 - 1.55	<0.4 - 50.0	<0.4 - 4.1	<0.4 - 8.7	<0.4 - 15.0	<0.4 - 11.2
Samples	17	17	17	17	17	17	17
Upper Three Runs at Highway 278[b]							
Mean							
Range	NA	<10	<10 - <50	<10 - <50	<3 - 60	<10 - <20	<10 - <20
Samples		13	13	13	13	13	13
Upper Three Runs 1A, 1987-1991[b]							
Mean							
Range	NA	<10	<20	<10 - 20	<3 - 70	<50	<10
Samples		7	7	7	7	7	7
Tims Branch 5, 1987 - 1991[b]							
Mean							
Range	NA	<10	<10-30	<10-<50	<3 - 190	<10 - 70	<10 - 20
Samples		16	16	16	16	14	16
Upper Three Runs at Road A, 1987-1991[b]							
Mean							
Range	NA	<10	<10 - <50	<10 - <50	<3 - 100	<10 - 80	<10 - <20
Samples		16	16	16	16	15	16
Upper Three Runs 1A, 1992-1995[c]							
Mean[d]		<10	<15	<30	<6	<30	18
Range	NA	ND - <10	ND <20	ND - 190	ND - 300	ND - <50	ND - 61
Samples		4	4	6	5	4	10
Tims Branch at Road C, 1992 - 1995[c]							
Mean[d]		<10	<17	<18	<6	<19	20
Range	NA	ND - <10	ND - <20	ND - 230	ND - 20	ND - 20	ND - 42
Samples		4	5	8	6	8	8
Upper Three Runs at Road A, 1992 - 1995[c]							
Mean[d]		<10	<15	<15	<4	<30	14
Range	NA	ND <10	ND <20	ND 900	ND - 4	ND <50	ND - 210
Samples		4	4	7	2	4	4

NA = Not analyzed.
ND = None detected.
Blank Spaces = Mean not calculated due to insufficient data in report.
[a]CCWS = Comprehensive Cooling Water Study (Newman et al. 1986).
[b]1987-1991 = Data taken from Arnett et al. 1992; Cummins et al. 1990, 1991; Davis et al. 1989; Mikol et al. 1988.
[c]1992-1995 = Data taken from Arnett 1993, 1994, 1995, 1996.
[d]All nondetectable quantities were excluded from the calculation of means.

Priority Pollutants

Concentrations of all 88 tested volatile, acid, and base/neutral organics were below detection limits in waters in Upper Three Runs at each of the sampling locations. The 1984 study indicated that the natural quality of these streams was low in detectable synthetic organics and that potential groundwater outcropping of chlorinated hydrocarbons from the 300-M Area to the Upper Three Runs watershed was not occurring in detectable quantities at the time of the study (Lower 1987).

Pesticides, Herbicides, PCBs, and Volatile Organic Compounds

Water samples also are collected annually from Tims Branch and Upper Three Runs during routine monitoring and analyzed for pesticides, herbicides, PCBs, and volatile organic compounds (VOCs). From 1987 to 1994, no analytes were detected in Upper Three Runs or Tims Branch. In 1995, pesticides and VOCs were detected in Tims Branch. VOCs and herbicides also were detected in Upper Three Runs (Table 5-8) (Arnett and Mamatey 1996).

Lower (1987) reports the results of analyses for pesticides, herbicides, and PCBs from 1982 to 1985, and results from 1967 to 1981 can be found in Gladden et al. (1985). During these periods, concentrations were also near or below detection limits at all locations.

Chemical, Including Radionuclide, and Toxicity Assessment Studies

Changes in M-Area Effluent

A chemical and biological study was conducted in Tims Branch from September 1988 to March 1990 to determine if changes to the discharges of the A-014 and A-015 outfalls had an adverse effect on communities in Tims Branch. Seven locations (Figure 5-6; 05 and 06) were sampled semimonthly for chemical parameters. ECS (1990) documented the results. Table 5-9 summarizes the data obtained in this study.

Table 5-8. Pesticides, Herbicides, and Volatile Organic Compounds Detected in Water Samples from SRS Streams in 1995. All Other Pesticides, Herbicides and Volatile Organic Compounds at all Other Sample Locations were Not Detected

Pesticide	Practical Quantification Limit (μg/l)	Tims Branch-5	Upper Three Runs at Road-4	Steel Creek
Heptachlor	0.05	0.052		
Heptachlor epoxide	0.05	0.052		
Methoxyclor	0.20	0.52		
Toxaphene	5.00	5.2		4.8
Herbicides				
2, 4, 5-TP (Silvex)	0.10		0.28	
Volatile Organic Compounds				
Tetrachloroethene	2.0	3.4	3.7	

Source: Arnett 1996.

Table 5-9. Water Quality Parameters for Biological and Chemical Assessment of M-Area Discharge on Tims Branch, September 1988-September 1990

Site		Total Suspended Solids (mg/l)	Ammonia (mg/l)	Nitrite (mg/l)	Total Kjeldahl Nitrogen (mg/l)	Nitrate (mg/l)	Ortho-phosphate (mg/l)	Total Phosphate (mg/l)
A-014 (05)[a]	Mean	<4	NA	0.03	<1	6.85	0.34	0.26
	Pre-Op.							
A-015 (06)	Mean	13.7	0.82	0.03	0.44	6.40	0.43	0.48
	Pre-Op.	2.6		0.05	0.07	9.44		0.45
TB-0 (09)	Mean	45.8	NA	0.06	0.41	5.89	0.42	0.57
	Pre-Op.	12.6		0.020	0.13	5.88		0.41
TB-1 (10)	Mean	27.5	NA	0.10	0.28	4.33	0.25	0.32
	Pre-Op.	9.7		0.020	0.11	5.85		0.03
TB-2 (08)	Mean	15.7	NA	<0.01	0.44	0.45	0.05	0.06
	Pre-Op.	13.5		0.002	0.46	0.05		0.04
TB-3 (11)	Mean	9.9	NA	0.03	0.37	1.39	0.11	0.15
	Pre-Op.	2.9		0.002	0.17	1.42		0.05
TB-4 (12)	Mean	11.2	NA	<0.01	0.20	0.85	0.05	0.07
	Pre-Op.	7.2		0.002	0.18	0.63		0.04

Site		Sodium (mg/l)	Dissolved Oxygen (mg/l)	pH	Specific Conductivity (μS/cm)	Temperature (°C)
A-014 (05)	Mean	22.64	8.61	6.85	108	20
	Pre-Op.					
A-015 (06)	Mean	43.74	8.50	7.29	135	20
	Pre-Op.		8.52	6.76	123	21.2
TB-0 (09)	Mean	25.44	8.18	6.94	131	20
	Pre-Op.		4.4	6.13		21.2
TB-1 (10)	Mean	20.01	7.23	6.21	98	18
	Pre-Op.		5.78	6.26	95	21
TB-2 (08)	Mean	3.84	5.26	5.71	33	16
	Pre-Op.		2.95	5.55	36	20.2
TB-3 (11)	Mean	17.29	7.96	6.39	76	17
	Pre-Op.		7.91	6.45	59	20.4
TB-4(12)	Mean	10.77	8.23	6.51	43	16
	Pre-Op.		8.11	6.30	35	18.4

[a] See Figure 5-6.

During the study, a noticeable difference in water chemistry was observed along Tims Branch at TB-1 and TB-11. With the exception of total Kjeldahl nitrogen at Site 1 and temperature at Site 3, all other chemical parameters at the sites were significantly higher than the control site. The A-015 discharge increased the phosphate content of Tims Branch; however, the phosphate value for Site 4 had recovered to the level of control Site 2. The A-014 discharge was the primary source for nitrates in Tims Branch. The most noticeable effect of nitrates was at Site 4, which was significantly different from the control site only during release of the effluent.

Overall, the discharge from M-Area did appear to impact the water quality of Tims Branch. A comparison of preoperational and postoperational data for Tims Branch and the outfall channels indicated that total suspended solids, phosphate, dissolved oxygen, and temperature were significantly higher during 1988-1990. The nitrate values for Site 1 and Site 3 were lower than in 1985-1986, due to the modifications of effluents discharged to A-014 and A-015. Post-operational phosphate values increased for all sites along Tims Branch.

M-Area Liquid Effluent Treatment Facility

A chemical and biological assessment was conducted to address the effects of the M-Area Liquid Effluent Treatment Facility on the chemistry and biota of Tims Branch and Upper Three Runs. The discharge point and eight locations (Figure 5-6) along Tims Branch and Upper Three Runs were sampled monthly for chemical parameters. The results of this study are documented in ECS (1987) and are summarized in Table 5-10.

The study indicated that a beaver pond immediately upstream greatly influenced the water chemistry at site TB-2 (Figure 5-6). High organic-matter concentrations in the waters of upstream sites TB-2, TB-0, and TB-1 created low dissolved oxygen conditions. Sites TB-3, TB-4, TB-5, and TB-6 had much higher mean dissolved oxygen concentrations.

Nitrate concentrations were highest at M-Out (maximum 47 mg/l), and decreased as the discharge peak moved downstream to TB-4 (maximum 2.7 mg/l). Background nitrate concentrations at Tims Branch sites increased by a factor of three between 1985 and 1986. Nitrite concentrations had trends similar to the nitrate, but were one or two orders of magnitude lower. Ammonium and total Kjeldahl nitrogen levels did not appear to be related to the M-Area Liquid Effluent Treatment Facility discharges.

Uranium was detected two times in water samples at M-Out and at some upstream Tims Branch sites, and once in Upper Three Runs (TB-6). Zinc levels originally were elevated at M-Out and TB-1.

Traces of trichloroethylene were observed frequently at M-Out, with an overall mean concentration of 2.9 µg/l. No detectable levels of tetrachloroethene or 1,1,1-trichloroethylene were measured.

F-/H-Area Effluent Treatment Facility

In June 1987, a 4-year biological study was initiated in anticipation of the fall 1988 startup of effluent discharges into Upper Three Runs by SRS F-/H-Area Effluent Treatment Facility (ETF). Using Hester-Dendy multiplate samplers, six sites were sampled quarterly for macroinvertebrates. Sampling locations included one site upstream of the Road C bridge, four sites downstream of the Road C bridge, and one site on Tims Branch (Figure 5-6). The dis-

Table 5-10. Water Quality Parameters for Biological and Chemical Assessment of M-Area Discharge

Site		Temperature (°C)	Dissolved Oxygen (mg/l)	pH	Alkalinity (mg/l)	Hardness (mg/l)	Specific Conductivity (µS/cm)	Total Suspended Solids (mg/l)
TB-2 (08)[a]	Mean	20.22	2.95	5.55	5.62	13.4	36.2	13.52
	Standard Error	1.17	0.34	0.06	0.33	1.4	6.4	1.37
	No. Samples	31	31	31	31	31	31	31
TB-0 (09)	Mean	21.18	4.40	6.13	16.63	13.42	111.33	12.56
	Standard Error	1.22	0.74	0.18	2.61	2.00	22.88	2.93
	No. Samples	39	39	39	39	39	39	39
M-Out	Mean	22.52	8.52	6.76	13.88	17.2	122.8	2.62
	Standard Error	0.33	0.06	0.12	1.75	1.5	18.2	0.54
	No. Samples	31	31	31	31	31	31	31
TB-1 (10)	Mean	21.04	5.78	6.26	16.19	14.7	95.2	9.68
	Standard Error	0.58	0.37	0.07	1.48	0.9	10.2	1.21
	No. Samples	31	31	31	31	31	31	31
TB-3 (11)	Mean	20.40	7.91	6.45	17.69	12.3	58.5	2.94
	Standard Error	0.86	0.27	0.06	1.35	1.0	3.3	0.55
	No. Samples	31	31	31	31	31	31	31
TB-4 (12)	Mean	18.39	8.11	6.30	10.17	10.4	34.7	7.23
	Standard Error	0.77	0.21	0.07	1.01	0.9	2.1	0.78
	No. Samples	31	31	31	31	31	31	31
TB-5 (04)	Mean	18.64	7.79	5.95	2.91	9.9	20.0	7.13
	Standard Error	0.75	0.19	0.06	0.33	0.8	0.6	0.98
	No. Samples	31	31	31	31	31	31	31
TB-6(13)	Mean	18.66	7.86	6.09	3.39	10.8	21.3	6.97
	Standard Error	0.75	0.21	0.06	0.17	1.0	0.7	0.80
	No. Samples	31	31	31	31	31	31	31
Road A (17)	Mean	19.29	8.20	6.08	NA	NA	20.27	NA
	Standard Error	0.93	0.19	0.08			0.68	
	No. Samples	22	22	22			22	

NA = Not analyzed.
[a]See Figure 5-6.

Table 5-10. (cont)

Site		Total Organic Carbon (mg/l)	Nitrate (mg/l)	Nitrite (mg/l)	Ammonia (mg/l)	Total Kjeldahl Nitrogen (mg/l)	Total Phosphorus (mg/l)	Trichloroethylene (mg/l)
TB-2 (08)	Mean	9.81	0.055	0.0022	0.063	0.460	0.0358	<0.00012
	Standard Error	0.60	0.006	0.0004	0.016	0.045	0.0036	
	No. Samples	31	31	31	31	31	31	16
TB-0 (09)	Mean	4.49	5.88	0.0242	0.038	0.129	0.0412	NA
	Standard Error	1.10	2.25	0.0120	0.005	0.035	0.0071	
	No. Samples	9	9	9	9	9	9	
M-Out	Mean	0.94	9.44	0.0501	0.019	0.070	0.0451	0.00292
	Standard Error	0.12	1.78	0.0236	0.003	0.009	0.0221	0.00074
	No. Samples	31	30	31	31	31	31	25
TB-1 (10)	Mean	3.15	5.86	0.0229	0.056	0.111	0.0296	<0.00012
	Standard Error	0.54	0.99	0.0091	0.008	0.028	0.0031	
	No. Samples	31	31	31	31	31	31	16
TB-3 (11)	Mean	2.69	1.43	0.0024	0.041	0.165	0.0546	<0.00012
	Standard Error	0.21	0.24	0.0003	0.004	0.020	0.043	
	No. Samples	31	31	31	31	31	31	16
TB-4 (12)	Mean	3.03	0.634	0.0026	0.029	0.176	0.0443	<0.00012
	Standard Error	0.24	0.112	0.0003	0.003	0.021	0.0033	
	No. Samples	31	31	31	31	31	31	16
TB-5 (04)	Mean	3.59	0.146	0.0015	0.025	0.172	0.0367	<0.00012
	Standard Error	0.30	0.009	0.0001	0.004	0.020	0.0023	
	No. Samples	31	31	31	31	31	31	16
TB-6 (13)	Mean	3.69	0.188	0.0016	0.023	0.176	0.0377	<0.00012
	Standard Error	0.26	0.016	0.0001	0.003	0.023	0.0021	
	No. Samples	31	31	31	31	31	31	16
Road A (17)	Mean	4.74	0.149	0.0017	0.020	0.205	NA	NA
	Standard Error	0.37	0.009	0.0002	0.005	0.026		
	No. Samples	25	22	21	22	21		

NA = Not analyzed.

Table 5-10. (cont)

Site		Total Iron (mg/l)	Dissolved Iron (mg/l)	Total Aluminum (mg/l)	Dissolved Aluminum (mg/l)	Total Zinc (mg/l)	Dissolved Zinc (mg/l)	Total Mercury (mg/l)	Dissolved Mercury (mg/l)
TB-2 (08)	Mean	4.74	0.78	0.118	<0.1	0.111	0.128	0.00004	0.0022
	Standard Error	0.37	0.13	0.016		0.031	0.064	0.00001	0.0008
	No. Samples	25	25	25	25	25	16	15	25
TB-0 (09)	Mean	2.30	0.31	0.247	<0.1	0.045	NA	NA	0.0030
	Standard Error	0.70	0.09	0.040		0.009			0.0011
	No. Samples	9	9	9	9	9			9
M-Out	Mean	0.15	0.02	0.262	0.117	1.162	2.175	<0.00004	0.0027
	Standard Error	0.03	0.00	0.033	0.036	0.725	1.444		0.0007
	No. Samples	25	25	25	25	25	16	15	25
TB-1 (10)	Mean	2.30	0.31	0.236	<0.1	0.839	0.765	<0.00004	0.0031
	Standard Error	0.51	0.05	0.040		0.365	0.375		0.0011
	No. Samples	25	25	25	25	25	16	15	25
TB-3 (11)	Mean	1.28	0.64	0.097	<0.1	0.073	0.111	<0.00004	<0.002
	Standard Error	0.14	0.07	0.014		0.056	0.047		
	No. Samples	25	25	25	25	25	16	15	25
TB-4 (12)	Mean	1.39	0.25	0.149	<0.1	0.174	0.210	0.00004	<0.002
	Standard Error	0.10	0.03	0.021		0.071	0.118	0.00002	
	No. Samples	25	25	25	25	25	16	15	25
TB-5 (04)	Mean	0.59	0.14	0.262	<0.1	0.049	0.066	0.00005	0.0026
	Standard Error	0.08	0.01	0.071		0.013	0.029	0.00002	0.0007
	No. Samples	25	25	25	25	25	16	15	25
TB-6 (13)	Mean	0.69	0.16	0.280	<0.1	0.039	0.019	<0.00004	<0.002
	Standard Error	0.07	0.02	0.070		0.008	0.006		
	No. Samples	25	25	25	25	25	16	15	25
Road A (17)	Mean	NA	NA	NA	NA	NA	NA	NA	NA
	Standard Error								
	No. Samples								

NA = Not analyzed.

charge point for the ETF effluent (H-016) is at Road C. The results of this study are documented in Enwright Environmental (1990) and Chem-Nuclear Laboratory Services (1991) and Table 5-11.

Thirty-one parameters were analyzed monthly on water samples collected from the five sites on Upper Three Runs. Six parameters were analyzed monthly on water samples from the mouth of Tims Branch. Of the 31 water chemistry parameters analyzed, only two parameters were measured at higher levels at downstream sites than at the control site: nitrate-nitrogen and uranium. Nitrate-nitrogen levels also were found to be elevated in Tims Branch, which suggests that tributary, as being the source of elevated nitrate at downstream Upper Three Runs sites, not the F-/H-Area ETF. Uranium was not sampled in Tims Branch. All other measured parameters exhibited similar concentrations upstream and downstream, with no observed impact by the F-/H-Area ETF.

Table 5-11. Water Quality Parameters for Stream Assessments for F-/H-Area ETF Effluent Discharge, July 1987-February 1990

Location	Temperature (°C)	pH	Dissolved Oxygen (mg/l)	Specific Conductivity (μS/cm)	Alkalinity (mg $CaCO_3$/l)	Residual Chlorine (mg/l)	Total Suspended Solids (mg/l)
TB-5 (04)[a]							
Mean	15.6	5.93	8.95	23.13	4.18		4.67
Std. Dev.	5.0	0.41	1.2	5.03	1.21		3.46
Range	6.0 - 23.0	5.2 - 6.9	7.0 - 11.3	11 - 31	3 - 8	<0.05 - <0.01	<4 - 11
TB-6 (13)							
Mean	15.7	6.05	9.03	22.73	5.15		6.14
Std. Dev.	5.0	0.62	1.5	4.73	5.33		7.31
Range	6.0 - 23.0	5.0 - 7.5	7.0 - 12.6	11 - 32	2 - 24	<0.5	<4 - 28
Site 3 (F/H) (14)							
Mean	15.8	6.23	9.12	23.4	4.77		4.93
Std. Dev.	5.1	0.51	1.5	5.49	1.58		3.73
Range	6.0 - 22.5	5.2 - 7.2	6.9 - 12.0	12 - 32	2 - 8	<0.05 - <0.1	<4 - 11
Site 4 (F/H) (15)							
Mean	15.6	6.14	9.45	23.1	4.24		6.73
Std. Dev.	5.1	0.57	1.6	4.73	1.10		4.18
Range	6.0 - 22.5	5.0 - 7.3	7.8 - 11.4	12 - 30	1 - 5.4	<0.05 - <0.1	<5 - 14
Site 5 (F/H) (16)							
Mean	15.4	6.20	9.4	20.6	4.45		9.93
Std. Dev.	5.0	0.64	1.7	8.78	0.716		5.99
Range	6.0 - 22.0	5.2 - 7.6	7.5 - 13.8	19 - 30	3 - 6	<0.05 - <0.2	<5 - 22
TB-4 (12)							
Mean	15.6	6.42	9.4	NA	NA	NA	NA
Std. Dev.	5.5	0.46	1.3				
Range	5.0 - 24	5.6 - 7.5	7.5 - 12.1				

NA = Not analyzed.
[a]See Figure 5-6.

Table 5-11. (cont)

Location	Ortho-Phosphate (mg/l)	Total Phosphate (mg/l)	Nitrate (mg N/l)	Nitrite (mg N/l)	Ammonia (mg/l)
TB-5 (04)[a]					
Mean	0.0186	0.0587	0.22		
Std. Dev.	0.0083	0.122	0.69		
Range	<0.01 - 0.03	0.01 - 0.05	<0.2 - 2.7	<0.01	<0.1 - <1
TB-6 (13)					
Mean	0.034	0.038	0.227		
Std. Dev.	0.049	0.025	0.743		
Range	<0.01 - 0.2	0.02 - 0.11	<0.1 - 2.9	<0.01	<0.1 - <1
Site 3 (F/H) (14)					
Mean	0.0177	0.0323	0.32		
Std. Dev.	0.0094	0.0132	0.947		
Range	<0.01 - 0.03	0.02 - 0.06	<0.2 - 0.5	<0.01	<0.1 - <1
Site 4 (F/H) (15)					
Mean	0.020	0.0356	0.207		
Std. Dev.	0.0113	0.0184	0.534		
Range	<0.01 - 0.04	<0.25 - 0.07	<0.2 - 0.3	<0.01	<0.1 - <1
Site 5 (F/H) (16)					
Mean	0.023	0.042	0.24		
Std. Dev.	0.016	0.016	0.689		
Range	<0.01 - 0.06	0.02 - 0.07	<0.2 - 2.7	<0.01	<0.1 - <1
TB-4 (12)					
Mean	NA	0.066	1.01	NA	NA
Std. Dev.		0.042	1.49		
Range		0.03 - 0.18	0.3 - 6.1		

NA = Not analyzed.
[a]See Figure 5-6.

Table 5-11. (cont)

	Total Chromium (mg/l)	Total Copper (mg/l)	Total Lead (mg/l)	Total Manganese (mg/l)	Total Mercury (μg/l)	Total Sodium (mg/l)	Total Uranium (mg/l)	Total Zinc (mg/l)
TB-5 (04)								
Mean	<0.005			0.022		1.34		0.0204
Std. Dev.				0.017		0.15		0.056
Range	<0.005 - 0.005	<0.05 - <0.005	<0.001 - <0.01	<0.005 - 0.071	<0.5 - <0.8	1.1 - 1.6	<0.001	<0.005 - 0.220
TB-6 (13)								
Mean	<0.005			0.0264		1.34	<0.001	0.0233
Std. Dev.				0.0355		0.184		0.061
Range	<0.005 - 0.005	<0.05 - <0.005	<0.001 - <0.01	<0.001 - 0.074	<0.5	1.1 - 1.8	<0.001 - 0.002	<0.005 - 0.299
Site 3 (F/H) (14)								
Mean	<0.005			0.0249		1.613	<0.001	0.0219
Std. Dev.				0.0180		0.290		0.0517
Range	<0.005 - 0.005	<0.05 - <0.005	<0.001 - <0.01	<0.005 - 0.069	<0.5	1.1 - 2.4	<0.001 - 0.003	<0.005 - 0.207
Site 4 (F/H) (15)								
Mean	0.0004	0.001		0.0271		1.64	<0.001	0.0321
Std. Dev.	0.0126	0.0026		0.019		0.206	0.0705	0.0705
Range	<0.005 - 0.049	<0.005 - 0.008	<0.001 - <0.01	<0.005 - 0.077	<0.5	1.2 - 2.0	<0.005 - 0.261	<0.005 - 0.261
Site 5 (F/H) (16)								
Mean	<0.005	<0.005		0.0295		1.55	<0.001	0.0404
Std. Dev.				0.0187		0.245		0.097
Range	<0.005 - 0.017	<0.005 - 0.005	<0.001 - <0.01	<0.005 - 0.079	<0.5 - <1	1.1 - 2.1	<0.001 - 0.001	<0.005 - 0.380
TB-4 (12)								
Mean	<0.005	<0.005	NA	NA		NA	NA	0.0263
Std. Dev.								<0.005 - 0.245
Range	<0.005 - 0.015	<0.005 - 0.006			<0.5			

NA = Not analyzed.
[a]See Figure 5-6.

Impact of the Mixed Waste Management Facility Groundwater Contamination

In 1993, sampling was conducted to characterize Upper Three Runs wetland waters near the Mixed Waste Management Facility to determine if contaminants from the facility were outcropping into the Upper Three Runs floodplain, and to determine if cesium from beneath the H-Area Tank Farm had migrated to the Upper Three Runs outcrops.

The results indicate that tritium, but not cesium, is outcropping into the Upper Three Runs wetlands. In the spring and fall, tritium was detected in concentrations above the maximum contaminant level at 13 (9 wetland and 4 stream) and 18 (13 wetland and 5 stream) locations, respectively.

During spring, cadmium, gross alpha, nonvolatile beta, potassium-40, ruthenium-106, and trichloroethylene also were detected above the maximum contaminant levels from at least one location. Cadmium was detected above the maximum contaminant levels at four wetland locations. Gross alpha was detected above the maximum contaminant levels at two wetland locations, one of which was a background location. Nonvolatile beta was detected above the maximum contaminant level at three wetland locations, two of which were background locations. Trichloroethylene was detected at one wetland location at 5.09 µg/l, which is slightly above the method detection limit and maximum contaminant levels of 5 µg/l. None of these contaminants was detected above the maximum contaminant levels in the fall.

Results did not suggest that the wetlands were being impacted by leaks from Tank 16 in the H-Area tank farm. (Dixon and Cummins 1994).

Toxicity Study

In 1994, a study was done to determine if Upper Three Runs water could support the cladoceran *Ceriodaphnia dubia*. The objectives of the study were to determine if *Ceriodaphnia dubia* is adversely affected by the Upper Three Runs water that does not receive National Pollutant Discharge Eliminations System (NPDES) discharges; if *Ceriodaphnia* can be cultured for extended times in Upper Three Runs water; and if *Ceriodaphnia* cultured in Upper Three Runs water are sensitive to a reference toxicant. SRS surface waters are extremely soft, with hardnesses ranging from approximately 2 to 30 mg/l. Waters this soft may not have adequate calcium or trace minerals to support long-term survival of *Ceriodaphnia* (Specht 1994a).

Upper Three Runs water was acutely toxic (measured as percent survival) to *Ceriodaphnia dubia* in 6 of 11 monthly tests and was chronically toxic (measured as reproductive success) in 10 of 10 monthly tests. Reference toxicant (sodium chloride) tests on Upper Three Runs water indicated that the test organisms in that water were severely stressed and extremely sensitive to the reference toxicant (See Chapter 7 for detail). Additional studies are needed to determine if the toxicity is due to low pH, the presence of toxicants introduced upstream of the SRS boundary, or the lack of essential trace minerals.

Algae

Although the type locality for several diatom species have their origin in Upper Three Runs (Patrick and Reimer 1966), the algae of this stream have not been quantitatively sampled except for three sampling stations that were sampled for periphyton ash-free dry weight and chlorophyll content between 1983 and 1985 (Specht 1987). These measurements were primarily used for pooled data comparisons of thermal versus nonthermal streams on SRS. When extracted from this context, the data revealed limited descriptive information about the periphyton community of Upper Three Runs.

Macrophytes

Introduction

Aquatic macrophytes provide stream structure, substrate for periphyton development, cover and substrate for smaller animals, and a source of carbon for the stream system. Although aquatic macrophytes are an important component to the function of many aquatic systems, they tend to be less important in flowing waters. Streams such as Upper Three Runs tend to have little macrophyte colonization because of the closed canopy above the stream channel. The reduction in available sunlight falling directly upon the water limits macrophyte colonization to the few open areas of the channel such as those found at road bridges and power-line crossings.

Comprehensive Cooling Water Study

The only data dealing with aquatic macrophytes in Upper Three Runs comes from the Comprehensive Cooling Water Study (Specht 1987) and was collected during 1984-1985. The data are from one sample at one station in the creek near a bridge and show limited macrophyte development. A survey of the entire stream to document the extent of this important component of the lower food chain would provide valuable information on the structure and condition of this SRS watershed.

Zooplankton

No studies have been conducted on the zooplankton in Upper Three Runs.

Macroinvertebrates

Sampling Locations and Methods

Aquatic Insects Survey

From September 1976 through August 1977, Morse et al. (1980) conducted an extensive sampling program for aquatic insects at six locations adjacent in the Upper Three Runs drainage basin. Sampling was conducted at Upper Three Runs at Roads 8-1 and F, Tinker Creek at Road 8-1, Mill Creek at Road E-2, Mill Creek at an unnamed fork 2.75 km (1.75 mi) upstream from Road E-2, and Boggy Gut at U.S. Forest Service at Road 781-4 (Figure 5-7). At each station, aquatic insects were collected biweekly from natural substrates and by light trapping. Details of sampling methods can be found in Morse et al. (1980).

Comprehensive Cooling Water Study

During the Comprehensive Cooling Water Study, macroinvertebrates were collected monthly from November 1984 through September 1985 at two locations in Upper Three Runs (just above Road C and in the creek mouth) using Hester-Dendy multiplate samplers and drift nets (Chimney and Cody 1986; Firth et al. 1986). In the creek mouth, macroinvertebrates also were sampled quarterly from March 1982 through September 1984 using drift nets and Hester-Dendy multiplate samplers (Specht et al. 1984; O'Hop et al. 1985). Details of sampling methods can be found in Specht et al. (1984) and Firth et al. (1986). These results are summarized in Specht (1987).

	Station Name
01[a]	TB-2
02	TB-0
03	TB-1
04	TB-3
05	CCWS1, F/H1, TB-5
06	TB-4
07	F/H2, TB-6
08	F/H3
09	F/H4
10	F/H5
11	CCWS3

[a]Sampling locations for Morse et al. (1980) indicated with a rectangle.

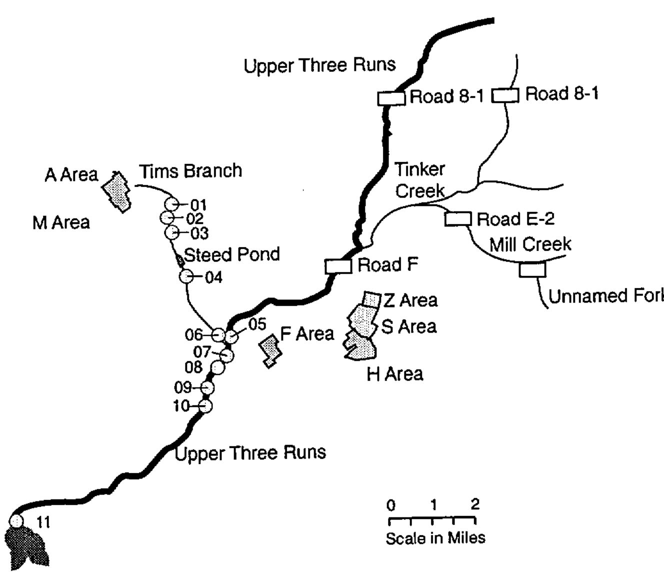

Figure 5-7. Macroinvertebrate Sampling Stations for Upper Three Runs

F-/H-Area Effluent Treatment Facility Monitoring Program

Macroinvertebrates were sampled quarterly from July 1987 through July 1991 using Hester-Dendy multiplate samplers and semiannually by qualitative sampling of natural substrates at five locations in Upper Three Runs in the vicinity of Road C. These samples were taken to determine if the F-/H-Area Effluent Treatment Facility effluent was adversely impacting the macroinvertebrate community of the stream. Beginning in March 1990 and continuing through July 1991, this sampling program was continued at three of the five stations.

Tims Branch Monitoring Program

Macroinvertebrates were sampled from June 1985 through December 1986 at five stations in the Tims Branch tributary of Upper Three Runs and at two locations in Upper Three Runs to determine if effluents from M Area and the A-/M-Area sanitary wastewater treatment plant were adversely affecting the Tims Branch macroinvertebrate community. Additional sampling was conducted at four locations in Tims Branch from September 1988 through March 1990 using Hester-Dendy multiplate samplers.

Other Sampling Programs

Macroinvertebrates were sampled during the summer of 1993 at six locations in Upper Three Runs and in eight tributaries: Cedar Creek, Boggy Gut, Tinker Creek, Reedy Branch, Mill Creek, McQueen Branch, Crouch Branch, and Tims Branch. This one-month sample identified streams with great variability in populations among locations as a first step in developing a long-term sampling program. Hester-Dendy muliplate samplers were used to collect macroinvertebrates. Parameters measured included total number of taxa collected at each station, mean number of taxa per sampler, density of organisms, biomass, relative abundance of functional feeding groups, and relative abundance of major taxonomic groups (Specht 1994b).

Macroinvertebrates also were sampled in September 1994 to develop a biotic index for southeastern streams using Hester-Dendy multiplate samplers. While not specifically designed to characterize SRS streams, these data contribute to a better understanding of the streams. Upper Three Runs at Road C and its tributaries, Tinker Creek and Mill Creek, were 3 of the 16 sampled locations (Specht and Paller 1995).

Past investigators collected from SRS locations and described "peculiar" species of a bivalve in the genus *Elliptio* (Britton and Fuller 1979). In 1989, *Elliptio* specimens were collected from seven locations on the SRS: the Savannah River, Upper Three Runs drainage (four sites), Pen Branch, and Lower Three Runs. The clams' morphology was described and compared with known specimens. In addition, electrophoresis was used to elicit differences in enzyme structures.

Results

Aquatic Insects Survey

A total of 34,206 aquatic insects were collected during the one-year study (Morse et al. 1980, 1983). The study identified at least 551 species of aquatic insects, including at least 52 species and 2 genera new to science. Several other species were collected from Upper Three Runs that are either rarely collected or were not reported in South Carolina before this study.

The species list that Morse et al. (1980, 1983) compiled for Upper Three Runs contains more species than have been reported for any other North American streams of comparable size.

Morse et al. (1980) concluded: "It is clear that the aquatic insect fauna of the Upper Three Runs drainage is unusual. It not only includes many rare species, but also, because of its special combination of ecological characteristics, contains species not often found living together in the same freshwater system. This spring-fed stream is colder and generally clearer than most surface waters at its low elevation, reminiscent of unpolluted streams in northern North America or high in the Appalachian Mountains. On the other hand, its shifting sandy bottom and somewhat tea-colored water are visibly indistinguishable from those of other lowland southeastern streams. As a result, many typically northern and mountain species co-exist here with southern lowland species. In consideration of the many rare insect species in the Upper Three Runs drainage and of the several "typically northern" species co-existing here with an endemic southern fauna, it is probably safe to say that this stream has persisted for a very long time without appreciable alteration. It is therefore appropriate to regard the system as an outstanding example of an unpolluted, spring-fed, Sandhills waterway."

More recent studies of the aquatic insects in Upper Three Runs identified more than 650 species, including 104 species of caddisflies (Trichoptera) (Floyd et al. 1993). Ninety-three species of caddisflies, representing 14 families, were identified during biweekly collections over a one-year period at two locations on Upper Three Runs downstream of all SRS discharges. Three species (*Oxyethira setosa, Triaenodes smithi, and Nyctiophylax seratus*) are new distributional records for South Carolina. Two species of *Triaenodes* are new to science. Other species considered endemic to the Upper Three Runs drainage, rare outside the drainage, or of limited distribution included *Cheumatopsyche richardsoni, Oxyethira dunbartonensis, Protoptila morettii, Hydrophysche elissoma, Triaenodes ochraceus, Neotrichia falca, Oecetis morsei, and Pycnopsyche virginica* (Floyd et al. 1993).

Comprehensive Cooling Water Study

Introduction

Macroinvertebrate drift and Hester-Dendy multiplate data are summarized in this section. More detailed information can be found in Specht et al. (1984), O'Hop et al. (1985), Firth et al. (1986), Chimney and Cody (1986), and Specht (1987).

Taxa Collected

Sixty-two macroinvertebrate taxa (Table 5-12) were collected from multiplate samplers near Road C during the 1984-1985 program. However, these data are not directly comparable to the data collected by Morse et al. (1980, 1983) or to data from the F-/H-Area Effluent Treatment Facility monitoring program since there were differences in the level of taxonomic resolution among the studies.

Table 5-12. Summary Statistics for Macroinvertebrate Data from Hester Dendy Multiplate Samplers, Upper Three Runs, October 1984-September 1985

Parameter	Road C	Creek Mouth
Density (no./m^2)	582.7	2,839.5
Biomass (gAFDW/m^2)	0.500	0.190
Number of Taxa/Sampler	15.1	16.1
Total Number of Taxa	62	72

AFDW = ash-free dry weight.

Densities

The mean density of organisms on the multiplate samplers near Road C was 582.7 organisms/m^2 in 1984-1985, while densities in the creek mouth were much higher, averaging 2839.5 organisms/m^2 (Table 5-12). However, biomass was higher at Road C (0.500 g/m^2) than in the creek mouth (0.190 g/m^2; Table 5-12) The number of taxa collected per sampler was similar at the two stations, averaging 15.1 taxa/sampler at Road C and 16.1 taxa/sampler in the creek mouth (Table 5-12). The macroinvertebrate collections from multiplate samplers at Road C were overwhelmingly dominated by tanytarsine chironomids (70.1%; Firth et al. 1986). Other abundant taxa included unidentified chironomids (21.6%) and the mayfly, *Stenonema modestum* (1.6%). Dominant taxa in the creek mouth were orthoclad chironomids (28.0%), chironomini chironomids (16.7%), tanytarsine chironomids (8.5%), brachycentrid and hydropsychid caddisflies (3.1% for each taxa; Chimney and Cody 1986).

Macroinvertebrate drift densities were much higher at Road C (6848.9 organisms/1000 m^3; Firth et al. 1986) than in the creek mouth (377.6 organisms/1000 m^3; Chimney and Cody 1986). Abundant taxa in the drift at Road C included chironomids (21.0%), hydropsychid caddisflies (10.5%), baetid mayflies (8.7%), blackfly larvae (6.7%), and the stonefly *Taeniopteryx longicera* (6.5%; Firth et al. 1986). The composition of drift in the creek mouth was dominated more by chironomids (52.9%) but also included relatively high abundances of baetid mayflies (12.3%), hydropsychid caddisflies (3.4%) and blackfly larvae (7.4%; Chimney and Cody 1986).

Effluent Treatment Facility Monitoring Program

Taxa Collected

During the five-year monitoring program, 292 macroinvertebrate taxa were collected from Upper Three Runs from quantitative sampling (Hester-Dendy multiplate samplers) and sampling of natural substrates combined (Table 5-13). Of these taxa, 96 were collected exclusively from natural substrates.

Dominant Taxa

Introduction

Table 5-14 presents the relative abundance of major taxonomic groups of macroinvertebrates at each sampling station.

Table 5-13. Macroinvertebrate Taxa Collected from Hester Dendy Multiplate Samplers and by Qualitative Sampling, Upper Three Runs, July 1987-July 1991

Taxon	Quantitative	Qualitative
Ephemeroptera		
Acerpenna pygmaeus	X	X
Baetis ephippiatus	X	X
Baetis frondalis		X
Baetis intercalaris	X	X
Baetis propinquus		X
Caenis sp.	X	X
Callibaetis sp.	X	X
Centroptilum sp.		X
Dannella simplex	X	X
Dolania americana		X
Ephemerella argo	X	X
Ephemerella catawba sp.		X
Ephemerella dorothea	X	X
Ephemerella inconstans	X	X
Ephemerella invaria/rotunda	X	X
Eurylophella doris	X	X
Eurolophella nr. *bicolor*	X	X
Eurolophella prudentalis		X
Eurolophella temporalis		X
Heptagenia flavescens	X	X
Hexagenia limbata		X
Hexagenia munda	X	X
Isonychia sp.	X	X
Leptophlepia sp.	X	X
Neoephemera youngi	X	X
Paraleptophlebia guttata		X
Pseudocloeon bimaculatus	X	X
Pseudocloeon dubium	X	X
Pseudocloeon punctiventris	X	X
Serratella serratoides	X	
Stenonema modestum/smithae	X	X
Tricorythodes sp.	X	X
Odonata		
Argia sp.	X	X
Boyeria vinosa	X	X
Calopteryx dimidiata		X
Calopteryx maculata	X	X
Enallagma sp.		X
Gomphus lividus		X
Hagenius brevistylus		
Helocordulia selysii	X	
Neurocordulia sp.		X
Perithemis sp.	X	X
Progomphus sp.		X
Tetragoneuria costalis/cynosura		X
Tetragoneuria semiaquea		X
Tetragoneuria sp.	X	X

Table 5-13. (cont)

Taxon	Quantitative	Qualitative
Plecoptera		
Acroneuria abnormis	X	X
Acroneuria mela	X	X
Agnetina capitata	X	
Allocapnia sp.		X
Alloperla sp.	X	
Amphinemura delosa		X
Haploperla brevis	X	X
Helopicus subvarians	X	X
Isoperla bilineata	X	X
Isoperla decala	X	X
Isoperla holochlora/lata	X	X
Isoperla nr. *nana*	X	X
Isoperla orata/dicala	X	X
Leuctra sp.	X	X
Neoperla prob. carlsoni	X	
Paragnetina fumosa	X	X
Paragnetina kansensis	X	X
Perlesta placida	X	X
Perlinella drymo	X	X
Perlinella ephyre	X	X
Pteronarcys dorsata	X	X
Taeniopteryx nr. *lita*	X	X
Hemiptera		
Gerris remigis		X
Hesperocorixa minor		X
Metrobates hesperius		X
Ochterus sp.		X
Rhagovelia obesa		X
Megaloptera		
Chauliodes rasticornis		X
Corydalus cornutus	X	X
Nigronia serricornis	X	X
Sialis prob. *vagans*	X	X
Trichoptera		
Agarodes libalis	X	X
Anisocentropus pyraloides	X	X
Brachycentrus nigrosoma	X	
Brachycentrus numerosus	X	X
Ceraclea resurgens		X
Cheumatopsyche spp.	X	X
Chimarra sp.	X	X
Cyrnellus fraternus	X	
Diplectrona modesta	X	X
Hydropsyche elissoma	X	X
Hydropsyche sp.	X	
Hydroptila sp.	X	X
Lepidistoma sp.	X	X

Table 5-13. (cont)

Taxon	Quantitative	Qualitative
Lype diversa	X	X
Macrostemum carolina		X
Mayatrichia ayama	X	
Micrasema rusticum	X	X
Micrasema wataga	X	X
Nectopsyche pavida		X
Neureclipsis sp.	X	X
Nyctiophylax sp.	X	
Oecetis sp.	X	X
Oxyethira sp.	X	
Phylocentropus sp.	X	X
Polycentropus sp.	X	X
Psilotreta sp.	X	X
Pycnopsyche sp.	X	X
Triaenodes nr. injusta		X
Triaenodes nr. taenia		X
Triaenodes sp. 2	X	X
Lepidoptera		
Parapoynx obscuralis	X	X
Coleoptera		
Anchytarsus bicolor	X	X
Ancyronyx variegatus	X	X
Copelatus glyphicus		X
Cyphon sp.		X
Dineutus assimilis		X
Dineutus ciliatus		X
Dineutis discolor		X
Dineutis larvae	X	X
Dubiraphia quadrinotata	X	X
Ectopria nervosa	X	X
Enochrus cinctus	X	
Enochrus ochraceus		X
Gonielmis dietrichi	X	X
Gyrinus aenolus	X	X
Hydaticus sp.		X
Hydroporus pilatei		X
Macronychus glabratus	X	X
Microcylloepus pusillus	X	X
Optioservus sp.	X	X
Oulimnius latisculus		X
Peltodytes sp.		X
Sperchopsis tessellatus	X	X
Stenelmis antennalis	X	
Stenelmis convexula	X	
Stenelmis crenata	X	
Stenelmis markeli	X	X
Stenelmis sinuata	X	X
Stenelmis sp. 3	X	

Table 5-13. (cont)

Taxon	Quantitative	Qualitative
Diptera		
Antocha sp.	X	X
Atherix lantha	X	X
Atrichopogon sp.	X	X
Bezzia sp. 2	X	X
Bezzia sp. 6		X
Bezzia sp. 7	X	X
Chelifera sp.	X	
Clinocera sp.	X	
Chrysops sp.	X	X
Culicoides sp.		X
Culex sp.		X
Dixa sp.	X	
Dolichopodidae		X
Ectemnia invenusta	X	X
Empididae	X	X
Erioptera/Ormosia sp.		X
Forcipomyia sp.	X	X
Hemerodromia sp. 1	X	X
Hemerodromia sp. 2		X
Hexatoma (Eriocera) cinerea	X	X
Limonia sp.	X	
Palpomyia sp. 1	X	X
Palpomyia sp. 3		X
Palpomyia sp. 4		X
Palpomyia sp. 5	X	X
Pilaria sp.		X
Probezzia sp.		X
Sciomyzidae		X
Simulium jonesi	X	X
Simulium slossonae	X	X
Simulium snowi		X
Simulium tuberosum	X	X
Simulium verecundum	X	X
Stilobezzia sp.		X
Telmatoscopus sp.	X	
Tipula sp. A		X
Tipula sp. 1		X
Tipula (Yamato.) sp. 7		X
Tipula (Yamato.) nr *strepens*		X
Wiedemannis sp.		X
Tanypodinae		
Ablabesmyia janta/parajanta		X
Ablabesmyia mallochi	X	X
Apsectrotanypus johnsoni		X
Clinotanypus pinguis		X
Conchapelopia sp.	X	X
Labrundinia pilosella		X
Meropelopia sp.	X	X
Nilotanypus fimbriatus	X	X
Paramerina sp.	X	X

Table 5-13. (cont)

Taxon	Quantitative	Qualitative
Procladius sp.	X	X
Zavrelimyia sp.		X
Orthocladiini		
Brillia flavifrons	X	X
Brillia parva	X	X
Corynoneura nr. *coronata*	X	X
Corynoneura nr. *taris*	X	X
Corynoneura sp. 3	X	X
Corynoneura sp. 4	X	X
Cricotopus bicinctus	X	X
Cricotopus sp. 5 *pupa*	X	
Cricotopus trifasciatus gp.	X	
Cricotopus vierriensis	X	X
Euliefferiella sp.	X	
Gymnometriocnemus sp.		X
Heterotrissocladius marcidus		X
Limnophyes sp.	X	
Lopescladius sp.		X
Metriocnemus fuscipes	X	
Nanocladius distinctus	X	
Nanocladius nr. alternantherae	X	X
Nanocladius rectinervis	X	X
Orthocladius annectens	X	
Orthocladius carlatus		X
Orthocladius curtiseta	X	X
Orthocladius dentifer	X	X
Orthocladius lignicola	X	X
Orthocladius obumbratus	X	
Orthocladius (Eudactylocladius) sp.	X	
Paracricotopus sp.		X
Parakiefferiella sp. A	X	X
Parakiefferiella sp. B	X	X
Parakiefferiella sp. 4	X	X
Parametriocnemus lunbecki	X	X
Parametriocnemus sp. C	X	X
Parametriocnemus sp. D		X
Psectrocladius (Mesopsectro.) sp.		X
Pseudorthocladius sp.		X
Rheocricotopus robacki	X	X
Rheocricotopus tuberculatus	X	
Rheosmittia sp.	X	X
Symposiocladius lignicola	X	X
Synorthocladius semivirens	X	X
Thienemanniella fusca gp.	X	X
Thienemanniella xena gp.	X	X
Tvetenia discoloripes gp.	X	X
Tvetenia paucunca/vitracies	X	X
Unniella multivirga	X	X
Diamesinae		
Odontomesa fulva		X
Potthastia longimana	X	X

Table 5-13. (cont)

Taxon	Quantitative	Qualitative
Tanytarsini		
Cladotanytarsus sp. A	X	X
Cladotanytarsus sp. B		X
Micropsectra sp.	X	X
Paratanytarsus sp.	X	
Rheotanytarus distinctissimus gp.	X	X
Rheotanytarsus exiguus gp.	X	X
Stempellinella sp.	X	X
Tanytarsus chinyensis gp. *(pupa)*	X	
Tanytarsus glabrescens gp.	X	X
Tanytarsus sp. I *Cantrell*		X
Tanytarsus sp. IX *Rutter*	X	X
Tanytarsus sp. XI *Rutter*	X	X
Tanytarsus sp. XII *Rutter*		X
Tanytarsus sp. XIII *Rutter*	X	X
Tanytarsus sp. XIV *Rutter*	X	X
Tanytarsus sp. XVI *Rutter*	X	X
Tanytarsus sp. XVII *Rutter*	X	X
Tanytarsus sp. XVIII *Rutter*		X
Chironomini		
Cryptochironomus blarina		X
Cryptochironomus fulvus gp.	X	X
Demicryptochironomus cuneatus		X
Einfeldia sp. A	X	
Kloosia dorsenna		X
Lauterborniella agrayloides		X
Microtendipes pedellus	X	X
Microtendipes nr. *rydalensis*	X	X
Nilothauma babiyi	X	X
Pagastiella ostansa	X	X
Paracladopelma doris		X
Paracladopelma loganae		X
Paracladopelma undine		X
Paralauterborniella nigrohalteralis	X	X
Paratendipes nr. nudisquama		X
Phaenopsectra flavipes	X	X
Polypedilium aviceps	X	
Polypedilum braseniae		X
Polypedilum convictum	X	X
Polypedilum fallax	X	X
Polypedilum halterale	X	X
Polypedilum illinoense	X	X
Polypedilum scalaenum	X	X
Pseudochironomus sp.	X	
Robackia claviger		X
Robackia demeijerei	X	X
Stelechomyia perpulchra	X	X
Stenochironomus hilaris	X	X
Tribelos jucundus	X	X

Table 5-13. (cont)

Taxon	Quantitative	Qualitative
Crustacea		
Asellus		X
Caecidotea sp.		X
Cambarinae		X
Crangonyx serratus		X
Palaemonetes paludosus		X
Acari		
Hydracarina	X	X
Annelida		
Lumbriculidae		X
Naididae[a]	X	X
Nais sp.	X	
Pristina/Stephensoniana sp.	X	X
Spirosperma sp.		X
Tubificidae	X	X
Mollusca		
Campeloma sp.		X
Elliptio sp.		X
Ferrissia sp.	X	
Gillia altilis	X	X
Sphaerium sp.		X
Viviparus subpurpureus		X

[a]Specimen not identifiable to genus.

Table 5-14. Relative Abundance (Percent Composition) of Major Taxonomic Groups of Macroinvertebrates Collected from Hester-Dendy Multiplate Samplers, Upper Three Runs, July 1987-July 1991

	Station				
Taxon	**1 (05)**	**2 (07)**	**3 (08)**	**4 (09)**	**5 (10)**
Ephemeroptera	7.9	7.7	9.4	7.5	7.2
Plecoptera	11.4	11.4	12.7	12.2	13.2
Trichoptera	13.4	11.5	11.0	12.5	13.2
Coleoptera	5.6	10.7	7.4	6.2	7.7
Diptera (Non Chir.)	6.4	5.0	3.8	11.3	7.9
Chironomidae	54.7	53.0	55.3	49.9	50.3
Other	0.6	0.7	0.4	0.4	0.5
Total	100.0	100.0	100.0	100.0	100.0

Chironomids

At all stations, chironomids were the most common group of macroinvertebrates collected, ranging from 49.9 to 55.3% of the total number of organisms collected from the multiplate samplers. Most of the chironomids were in the subfamilies Orthocladiinae and Chironominae. Dominant species of chironomids collected from the multiplate samplers included *Rheocricotopus robacki*, *Polypedilum convictum*, *Tvetenia discoloripes*, and *Corynoneura* sp.. *Rheotanytarsus* sp., *Conchopelopia* sp., *Cladotanytarsus* sp., and *Rheosmittia* sp., and *Parametriocnemus lunbecki* also were abundant on natural substrates. The most common nonchironomid species of dipteran was the blackfly, *Simulium jonesi*.

Trichoptera

Trichoptera (caddisflies) composed 11.0-13.4% of the organisms collected from the multiplate samplers. The most abundant caddisflies on the multiplates were *Hydropsyche elissoma* and *Cheumatopsyche* sp. These two taxa and *Brachycentrus numerosus* were the most commonly collected caddisflies on natural substrates.

Plecoptera

Plecoptera (stoneflies) were much more common in Upper Three Runs than in any other SRS streams, where they made up 11.4-13.2% of the macroinvertebrates collected from the multiplate samplers. Stoneflies prefer cool water, which is provided in Upper Three Runs by naturally occurring flows of groundwater into the stream. The most common stoneflies were *Perlesta placida*, *Acroneuria abnormis*, and *Isoperla* sp.

Ephemeroptera and Coleoptera

Ephemeroptera (mayflies; 7.2-9.4%) and Coleoptera (beetles; 5.6-10.7%) accounted for most of the remaining organisms collected from the multiplate samplers. *Stenonema modestum/smithae*, *Heptagenia flavescens*, and *Paraleptophlebia guttata* were the dominant mayflies, while *Stenelmis crenata* and several other elmid beetles were the most common beetles in the stream.

Mean Number of Taxa and Density of Organisms

The mean number of taxa collected from multiplate samplers at a given station (all multiplates combined) ranged from 27.0 to 45.0 during the five year study (Table 5-15), while the mean number of taxa per sampler ranged from 12.3 to 22.9 (Table 5-16). Mean densities of organisms ranged from 213.9 to 799.2 organisms/m^2 (Table 5-17), which is lower than the densities reported for most other SRS streams. However, macroinvertebrate biomass (ash-free dry weight) was comparable to most other streams, ranging from 0.1399 to 0.6860 g/m^2 (Table 5-18). Distinct seasonal variations in biomass were observed, with biomass peaking in the spring as organisms reached their maximum size and declining over summer, just after the period of peak emergence.

Macroinvertebrate diversity, as calculated by the Shannon-Weaver diversity index was high at all stations, ranging from 3.90 to 4.59 (Table 5-19). Generally, diversity values above 3 are indicative of unimpacted streams.

Table 5-15. Mean Number of Taxa Collected During Each Sampling Period from Hester-Dendy Multiplate Samplers, Upper Three Runs, July 1987-July 1991

	Station				
Year	**1 (05)**	**2 (07)**	**3 (08)**	**4 (09)**	**5 (10)**
1987	37.5	44.0	45.0	40.5	42.0
1988	39.5	45.0	43.2	44.5	42.0
1989	35.2	37.8	34.2	32.8	33.0
1990	30.2	31.5	33.0	27.0	30.0
1991	31.0	34.3	-	-	33.7

Table 5-16. Mean Number of Taxa Collected Per Hester-Dendy Multiplate Sampler, Upper Three Runs, July 1987-July 1991

	Station				
Year	**1 (05)**	**2 (07)**	**3 (08)**	**4 (09)**	**5 (10)**
1987	18.9	21.9	22.9	20.8	21.1
1988	18.0	21.4	19.6	21.6	20.4
1989	15.8	16.6	15.8	15.4	14.8
1990	12.3	13.8	17.0	13.5	12.8
1991	14.8	16.6	-	-	16.2

Table 5-17. Mean Density of Macroinvertebrates (no./m^2) Collected from Hester-Dendy Multiplate Samplers, Upper Three Runs, July 1987-July 1991

	Station				
Year	**1 (05)**	**2 (07)**	**3 (08)**	**4 (09)**	**5 (10)**
1987	779.2	799.2	629.6	522.4	607.2
1988	2.4	566.6	538.4	648.0	540.4
1989	356.3	414.1	432.6	366.3	312.9
1990	213.9	238.8	336.8	331.2	246.2
1991	374.3	500.3	-	-	406.3

Table 5-18. Mean Biomass (g/m^2) of Macroinvertebrates Collected from Hester-Dendy Multiplate Samplers, Upper Three Runs, July 1987-July 1991

	Station				
Year	**1 (05)**	**2 (07)**	**3 (08)**	**4 (09)**	**5 (10)**
1987	0.1763	0.3925	0.2288	0.1399	0.2142
1988	0.4873	0.4023	0.6942	0.3696	0.5014
1989	0.4228	0.4982	0.3554	0.2904	0.2987
1990	0.4501	0.6066	0.6025	0.3865	0.4594
1991	0.4482	0.3781			0.6860

Table 5-19. Shannon-Weaver Diversity of Macroinvertebrates Collected from Hester-Dendy Multiplate Samplers, Upper Three Runs, July 1987-July 1991

	Station				
Year	**1 (05)**	**2 (07)**	**3 (08)**	**4 (09)**	**5 (10)**
1987	4.22	4.42	4.50	4.56	4.48
1988	4.38	4.59	4.56	4.46	4.38
1989	4.42	4.35	4.08	4.15	4.22
1990	4.16	4.31	4.31	3.90	4.28
1991	4.08	4.17			4.12

Temporal Trends

During the course of the five-year study, declines in the mean number of taxa per station, mean number of taxa per sampler, mean density of organisms, and diversity were observed at all stations (Table 5-15, Table 5-16, Table 5-17, and Table 5-19). The decline in density of organisms was the most dramatic, with mean density for all stations combined declining from 667.5 organisms/m^2 in 1987 to 273.8 organisms/m^2 in 1990. In 1991, densities increased somewhat to an average of 427.0 organisms/m^2. Taxa that exhibited the greatest declines in abundance were primarily chironomids, such as the orthoclads, *Rheocricotopus robacki, Thienemanniella* spp., *Tvetenia discoloripes, Orthocladius* spp., and *Cricotopus* spp.; the Chironomini midge, *Polypedilum convictum*; and the tanytarsine midge, *Rheotanytarsus* spp. Species richness among Ephemeroptera, Plecoptera, and Trichoptera, which are generally considered to be pollution-intolerant organisms, did not decrease significantly, and the relative abundance of Plecoptera and Trichoptera actually increased, although overall densities of these orders remained relatively constant. Although the densities declined, the total biomass of the macroinvertebrate community did not decrease over time (Table 5-18), which indicates that larger organisms were being collected.

The observed changes in the macroinvertebrate community are not attributable to effects from the F-/H-Area Effluent Treatment Facility effluent since they occurred at the upstream reference station (Station 1 [05]) as well as the stations located downstream from the F-/H-Area Effluent Treatment Facility. At this time, there is no explanation for the observed changes, but data from 1991 indicate that the stream appears to be recovering somewhat from the unknown perturbation. Possible perturbations included increased siltation from the Defense Waste Processing Facility construction area and/or toxic inputs to the stream from areas upstream from SRS.

Tims Branch Monitoring Program

1985-1986 Sampling Program

The 1985-1986 sampling program collected 147 macroinvertebrate taxa in Tims Branch, including 97 taxa from multiplate samplers and 50 taxa collected exclusively from natural substrates during qualitative sampling efforts (Table 5-20). The fewest total number of taxa (23) was collected from multiplate samplers at Station TB-2, which was upstream from the M-Area effluent discharge but just downstream from a stagnant pond. Outflow from the

Table 5-20. Macroinvertebrate Taxa Collected from Hester-Dendy Multiplate Samplers and by Qualitative Sampling, Tims Branch, 1985-1986

Taxon	Quantitative	Qualtitative
Collembola	X	
Ephemeroptera		
Baetis	X	X
Caenis	X	X
Callibaetis	X	
Habrophlebiodes		X
Heptagenia	X	X
Leptophlebia	X	
Paraleptophlebia debilis		X
Stenonema modestum	X	X
Tricorythodes	X	
Plecoptera		
Acroneuria abnormis	X	X
Allocapnia sp.		X
Clioperla clio	X	
Isoperla spp.		X
Leuctra	X	
Nemocapnia carolina	X	X
Neoperla	X	
Paragnetina fumosa	X	
Paragnetina sp.	X	
Perlesta placida	X	X
Taetiopteryx robinae	X	
Taeniopteryx sp.	X	
Megaloptera		
Chauliodes	X	
Corydalus cornutus	X	
Nigronia sp.	X	
Sialis	X	
Trichoptera		
Agrypnia vestita		X
Aniscentropus	X	X
Cernotina	X	
Cheumatopsyche spp.	X	X
Chimarra	X	
Diplectrona modesta	X	
Hydropsyche betteni		X
Hydropsyche rossi		X
Hydropsyche spp.	X	X
Hydroptila	X	X
Lepidistoma	X	X
Lype diversa	X	X
Macrostemum carolina	X	
Mayatrichia	X	

Table 5-20. (cont)

Taxon	Quantitative	Qualtitative
Micrasema	X	X
Nectopsyche sp.		X
Oecetis	X	X
Oxyethira	X	X
Phylocentropus sp.		X
Polycentropus spp.	X	
Pycnopsyche scabripennis		X
Triaenodes marginatus		X
Trianodes tardus		X
Odonata		
Argia spp.	X	X
Boyeria vinosa		X
Calopteryx dimidiata	X	X
Cordulegaster maculata		X
Dromogomphus spinosus		X
Enallagma spp.	X	X
Epicordulia regina	X	
Erythemis simplicicollis	X	X
Haegenius brevistylus		X
Hetaerina spp.	X	
Ischnura prognatha		X
Libellula cyanea		X
Pachydiplax longipennis	X	X
Progomphus obscurus		X
Somatochlora		X
Stylurus		X
Lepidoptera		
Munroessa	X	
Parapoynx	X	
Coleoptera		
Ancyronyx variegatus	X	X
Berosus sp.		X
Celina sp.		X
Cyphon		X
Dineutus	X	
Dubiraphia	X	
Ectopria nervosa		X
Gonielmis dietrichi	X	X
Gyrinus	X	
Haliplus fasciatus		X
Haliplus pantherinus		X
Haliplus triopsis		X
Helobata striata		X
Helochares	X	
Hydrocanthus oblongus	X	
Hydrochus inaequalis		X
Hydroporus aulicus		X

Table 5-20. (cont)

Taxon	Quantitative	Qualtitative
Hydroporus mixtus		X
Hydroporus sp.	X	X
Hygrotus		X
Macronychus glabratus	X	X
Peltodytes bradleyi		X
Peltopytes shermani		X
Pyrrhalta nymphaeae	X	X
Stenelmis	X	X
Suphisellus puncticollis	X	
Heteroptera		
Belostoma	X	X
Corixidae	X	
Hesperocorixa semilucida		X
Merragata brunnea	X	X
Mesovelia mulsanti	X	
Microvelia americana		X
Neoplea striola	X	X
Ochterus	X	
Pelocoris femoratus		X
Trichocorixa sexcinta		X
Diptera		
Nonchironomids		
Anopheles	X	
Antocha	X	
Atherix	X	
Ceratopogoninae	X	X
Chaoborus punctipennis	X	X
Chrysops sp.	X	X
Dixa sp.		X
Empididae	X	X
Ephydridae		X
Erioptera		X
Forcipomyiinae	X	
Hexatoma	X	
Pericoma sp.	X	
Pilaria sp.		X
Pseudolimnophlia sp.		X
Simulium decorum		X
Simulium venustrum		X
Simulium vittatum		X
Simulium sp.	X	X
Tabanus sp.		X
Tipula		X
Chironomidae		
Chironomini	X	X
Stenochironomus	X	X
Diamesinae	X	
Orthocladiinae	X	X
Tanypodiinae	X	X

Table 5-20. (cont)

Taxon	Quantitative	Qualtitative
Tanytarnsini	X	X
Crustacea		
Procambarus	X	X
Crangonyx sp.		X
Gammarus fasciatus	X	X
Hyalella azteca	X	X
Palaemonetes paludosus	X	X
Acari		
Arrenurus sp.		X
Hydracarina	X	X
Oligochaeta	X	X
Hirudinea	X	X
Nematoda	X	X
Turbellaria	X	
Dugesia tigrina		X
Gastropoda		
Amnicola	X	X
Ancylidae	X	
Elmia (=Goniobasis)	X	
Ferrissia rivularis		X
Gyraulus parvus	X	
Helisoma trivolvis	X	X
Menetus dilitatus	X	
Physella spp.	X	X
Pseudosuccinea columnella	X	X
Succinea spp.	X	
Pelecypoda		
Corbicula fluminea	X	
Sphaeriidae	X	X

pond often had no detectable levels of dissolved oxygen, and the macroinvertebrate community of this station was typical of streams with high organic loading. The mean number of taxa collected per sampler was also lowest at Station TB-2 (5 taxa/sampler; Table 5-21) and increased in a downstream direction to 12.8 taxa per sampler in the mouth of the creek (Station TB-4). Dominant groups of macroinvertebrates at Station TB-2 included oligochaetes (66.4%) and chironomids from the tribe Chironomini (23.1%; Table 5-22). The macroinvertebrate community downstream from the M-Area effluent discharge gradually improved to a community more typical of less impacted streams, with the oligochaetes and Chironomini being replaced by orthoclad and tanytarsine chironomids, as well as Coleoptera (beetles), Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). At Station TB-4, 57 taxa were collected from multiplate samplers. Mayflies composed 19.5% of the total organisms collected; stoneflies 3.6%; caddisflies, 4.8%; beetles, 5.5%; orthoclads, 30.9%; and tanytarsine chironomids 16.6% (Table 5-22).

The total density of organisms in 1985-1986 was highest at Station TB-2 (3679.1 organisms/m^2) and generally declined in a downstream direction to 584.0 organisms/m^2 at Station TB-4 (Table 5-21). Total biomass was also highest at Station TB-2 (0.253 g/m^2), declined to 0.072 g/m^2 at Station TB-1, and then increased to 0.123 and 0.207 g/m^2 at Stations TB-3 and TB-4, respectively (Table 5-21).

1988-1990 Sampling Program

Macroinvertebrate identification during the 1988-1990 study generally was performed only to the family level; therefore direct comparisons of taxa richness with the 1985-1986 study are not possible. Also, no taxa list is presented for the 1988-1990 program since all of the families identified were present in the 1985-1986 study.

The macroinvertebrate community in Tims Branch in 1988-1990 differed somewhat from that of 1985-1986. Station TB-2 still was dominated by pollution-tolerant taxa, but had shifted from a community dominated by oligochaetes to one dominated by pollution-tolerant chironomids of the tribe Chironomini, which constituted 90.7% of the organisms collected from multiplate samplers at this station (Table 5-23). At the most downstream station (Station TB-4), mayflies and caddisflies were less abundant than in 1985-1986, composing 14.5% and 1.2%, respectively, of the macroinvertebrates on the multiplate samplers, while stoneflies were more abundant, making up 14.3% of the organisms collected in 1988-1990 (Table 5-23), as compared to just 3.6% in 1985-1986.

The density of organisms was much lower at Station TB-2 in 1988-1990 (421.1 organisms/m^2 as compared to 3679.1 in 1985-1986). Densities at Stations 1 and 3 were also somewhat lower, while mean densities at Station 4 were higher (763.5 organisms/m^2 as compared to 584.0 in 1985-1986; Table 5-21). At present, there is no explanation for the observed declines. The decline in density of organisms is of particular concern since densities were observed to decline steadily during the last year of the sampling program (Figure 5-8).

In contrast to the decline in macroinvertebrate densities, macroinvertebrate biomass was higher at three of the four sampling stations in 1988-1990 than in 1985-1986 (Table 5-21). The increased biomass with decreased densities indicates that the relative size of the organisms has increased, possibly due to shifts in species composition.

Table 5-21. Summary Statistics for Macroinvertebrate Data from Hester-Dendy Multiplate Samplers, Tims Branch, 1985-1990

	Station				
Parameter	**TB-2 (01)**	**TB-0 (02)**	**TB-1 (03)**	**TB-3 (04)**	**TB-4 (06)**
Taxa richness (no./sampler)					
1985-1986	5	8.4	10.6	9.7	12.8
1988-1990	3.6	-	7.3	7.5	9.0
Density of Organisms (no./m^2)					
1985-1986	3,679.1	1,387.6	1,754.7	1,116.4	584.0
1988-1990	421.1	-	1,147.1	1,094.6	763.5
Biomass (gAFDW/m^2)					
1985-1986	0.253	0.045	0.072	0.123	0.207
1988-1990	0.042	-	0.267	0.280	0.251

Table 5-22. Relative Abundance (Percent Composition) of Major Taxonomic Groups of Macroinvertebrates, Tims Branch, June 1985-December 1986

	Station						
Taxon	**TB-2 (01)**	**TB-0 (02)**	**TB-1 (03)**	**TB-3 (04)**	**TB-4 (06)**	**TB-5 (05)**	**TB-6 (07)**
Ephemeroptera	<0.1	0.6	0.3	0.1	19.5	5.3	6.7
Plecoptera	<0.1	<0.1	<0.1	0.1	3.6	7.1	6.5
Trichoptera	0.1	0.2	3.5	10.4	4.8	8.1	7.0
Coleoptera	0.1	<0.1	0.1	0.2	5.5	2.4	2.6
Odonata	0.3	1.0	0.3	0.1	0.2	<0.1	0.0
Diptera[a]	32.2	34.0	75.4	83.7	63.8	75.5	75.5
Chironomini	(23.1)	(12.9)	(14.0)	(14.0)	(12.2)	(12.2)	(13.2)
Orthocladiinae	(0.5)	(1.5)	(20.3)	(17.8)	(30.9)	(37.3)	(37.4)
Tanytarsini	(1.5)	(13.1)	(29.2)	(21.2)	(16.6)	(12.6)	(13.8)
Tanypodinae	(1.8)	(5.4)	(7.9)	(4.3)	(1.7)	(4.4)	(3.3)
Simuliidae	(5.1)	(<0.1)	(2.4)	(22.5)	(0.8)	(7.3)	(5.6)
Turbellaria	0.1	1.3	<0.1	0.2	<0.1	<0.1	0.0
Oligochaeta	66.4	60.0	15.9	3.6	1.3	0.8	0.8
Gastropoda	0.5	2.0	2.7	<0.1	0.0	<0.1	0.1
Other	0.2	0.8	1.7	1.6	1.3	0.7	0.8
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[a]Includes subtaxa values in parentheses.

Table 5-23. Relative Abundance (Percent Composition) of Major Taxonomic Groups of Macroinvertebrates, Tim's Branch, September 1988-March 1990

	Station			
Taxon	**1**	**2**	**3**	**4**
Ephemeroptera	0.1	<0.1	1.4	14.5
Plecoptera	0.1	0.0	1.0	14.3
Trichoptera	14.7	<0.1	5.6	1.2
Coleoptera	0.4	0.7	2.5	4.8
Odonata	0.3	0.3	0.3	<0.1
Diptera[a]	82.6	97.6	88.9	64.2
Chironomini	(15.9)	(90.7)	(7.6)	(13.9)
Orthocladiinae	(17.6)	(1.2)	(22.6)	(38.9)
Tanytarsini	(15.6)	(2.5)	(22.6)	(5.4)
Tanypodinae	(16.9)	(2.6)	(11.1)	(3.5)
Simuliidae	(15.1)	(0.3)	(23.7)	(1.4)
Turbellaria	0.0	0.0	0.0	0.0
Oligochaeta	0.7	1.0	0.1	0.1
Gastropoda	0.2	<0.1	0.0	0.0
Other	0.9	0.4	0.2	0.9
Total	100.0	100.0	100.0	100.0

[a]Includes subtaxa values in parentheses.

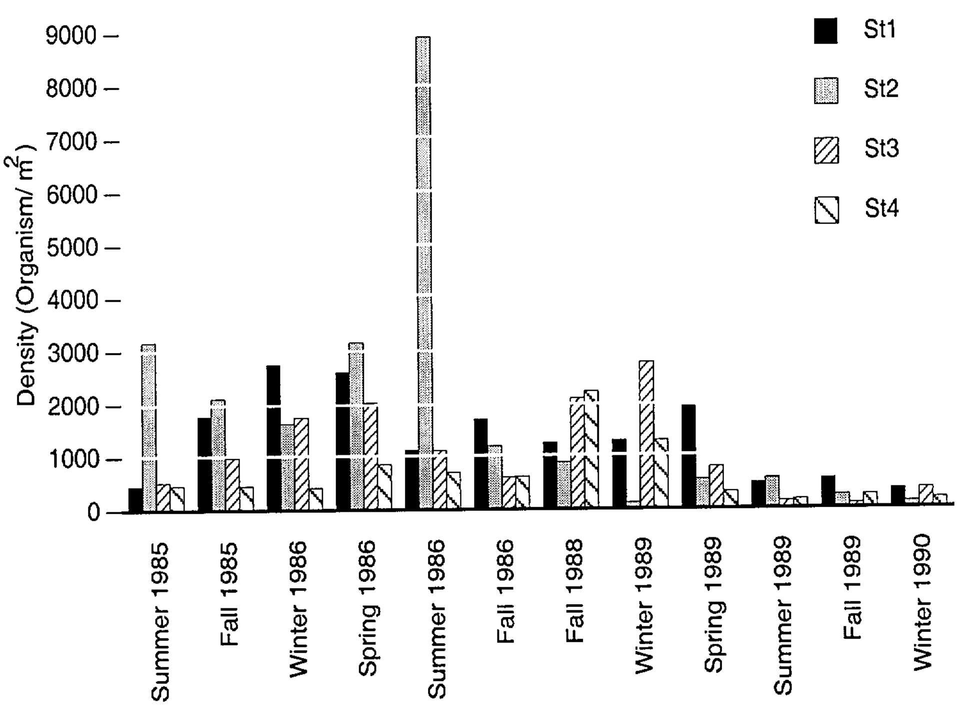

Figure 5-8. Density of Macroinvertebrates in Tims Branch, 1985-1990

1993-1994 Sampling Program

Upper Three Runs and three of its tributaries (Tims Branch, McQueen Branch, and Crouch Branch) received effluent from 25 National Pollutant Discharge Elimination System (NPDES) outfalls in A, B, F, H, M, and S Areas and the Flowing Streams Facility at Road C. The new NPDES permit issued in 1996, eliminated 10 of theses outfalls by deletion or consolidation of several outfalls into one. Upper Three Runs supports a reasonably rich macroinvertebrate community. Total number of taxa collected per station in 1993 ranged from 42 at Road F to 52 at Road C (Table 5-24). Thirty-six taxa were collected at Road C in 1994. The mean number of taxa per sampler in 1993 ranged from 20.0 at Banks Mill Road (offsite) to 26.8 at Road C. In 1994, the mean number of taxa per sampler at Road C was 20.8. Density ranged from 444.7 organisms/m^2 at Road F to 1378.8 organisms/m^2 at the railroad bridge upstream of Road C in the 1993 study and was 765.4 organisms/m^2 in 1994 at Road C. Biomass in 1993 ranged from 0.0296 g/m^2 at Road A to 0.8470 g/m^2 at Road 8-1. Biomass was 0.0390 g/m^2 at Road C in 1994 (Table 5-24). The most abundant group of macroinvertebrates collected at all of the stations in 1993 were the orthoclad chironomids (33.7-57.0%). In 1994, the most abundant group was the Chironomini (31.4%). Other abundant groups were Tanytarsini chironomids, Chironomini chironomids, Trichoptera, and Coleoptera in 1993 and Orthocladiinae, Tanytarsini, other Diptera, and Ephemeroptera in 1994 (Table 5-25). Collector-gatherers was the most abundant functional feeding group at any station in either year (Table 5-26). No longitudinal trends were observed for any measured population parameter.

Sampled tributaries of Upper Three Runs included Cedar Creek and Boggy Gut (both upstream of the SRS boundary), Tinker Creek, Reedy Branch, Mill Creek, McQueen Branch, Tims Branch, and Crouch Branch. The data indicate that the three tributaries that receive NPDES discharges (Tims Branch, McQueen Branch, and Crouch Branch) are perturbed to some extent as evidenced by fewer total taxa, fewer mean taxa per sampler, and lower densities (Table 5-27).

Crouch Branch was the most disturbed of the tributaries sampled in 1993 with only 19 taxa collected, none of which was the more sensitive Ephemeroptera-Plecoptera-Trichorptera taxa. Chironomini chironomids dominated its community (Table 5-28), generally an indication of perturbed conditions. Crouch Branch had relatively low oxygen concentrations, which may be responsible, at least in part, for the observed perturbation. In addition, Crouch and McQueen Branches had high suspended solids loads during the construction of the Defense Waste Processing Facility which also may have had some effect on the streams' macroinvertebrate communities. Crouch Branch was also the most disturbed stream sampled in 1994. It had 25 taxa and was dominated by Chironomini and oligochaetes (Table 5-27 and Table 5-28).

The remainder of the sampled tributaries showed no evidence of perturbation in 1993. Mill Creek had the highest number of taxa (63), and Tinker Creek had the fewest (46). Dominant taxa in most streams included the orthoclad chironomids, the Tanytarsine chironomids, a Tanypodinae chironomid, and a Chironomini chironomid (Table 5-27 and Table 5-28). As in Upper Three Runs proper, the most abundant functional group was the collector-gatherers (Table 5-29). Based on the Hester-Dendy data from 1994, Tims Branch showed evidence of some disturbance (Specht 1994b; Specht and Paller 1995).

Table 5-24. Mean Number of Taxa, Density, and Biomass For Macroinvertebrates collected on Hester-Dendy Multiplate Samplers in Upper Three Runs, July-August 1993 and September 1994

	1993						1994
	Banks Mill Rd.	**Road 8-1**	**Road F**	**RR Bridge**	**Road C**	**Road A**	**Road C**
Taxa/Sampler	20.0	23.8	22.2	24.0	26.8	22.4	20.8
Mean Density (no./m^2)	658.1	812.3	444.7	1378.8	1160.9	576.5	765.4
Mean Biomass (g/m^2)	0.1321	0.8470	0.1022	0.1789	0.2867	0.0296	0.3090
Total Number of Taxa collected	43	45	42	44	52	43	36

Source: Specht 1994b; Specht and Paller 1995.

Table 5-25. Percent Composition of Macroinvertebrate Taxa Collected on Hester-Dendy Multiplate Samplers in Upper Three Runs, July-August 1993 and September 1994

	1993						1994
Taxa	**Banks Mill Rd.**	**Road 8-1**	**Road F**	**RR Bridge**	**Road C**	**Road A**	**Road C**
Nematoda	0.00	0.00	0.00	0.00	0.00	0.00	0.18
Ephemeroptera	4.41	1.65	8.29	4.3	1.73	3.88	9.31
Plecoptera	2.89	9.22	4.27	2.43	3.46	4.65	4.01
Trichoptera	8.66	6.74	7.54	6.81	4.62	4.07	4.01
Coleoptera	1.7	1.93	15.58	2.27	2.31	8.53	1.09
Odonata	0.00	0.28	0.00	0.00	0.00	0.00	0.00
Megaloptera	0.34	0.14	0.50	0.08	0.48	0.58	0.55
Lepidoptera	0.00	0.00	0.00	0.16	0.10	0.19	0.00
Other Diptera	9.85	4.68	6.78	8.02	4.52	5.43	15.51
Tanypodinae	1.53	6.05	3.77	1.70	4.81	3.10	2.37
Tanytarsini	25.98	19.53	8.79	6.89	12.03	9.11	8.39
Orthocladiinae	40.75	37.00	33.67	56.97	47.55	50.19	22.29
Chironomini	3.40	12.79	10.80	10.29	18.38	9.88	31.59
Oligochaeta	0.00	0.00	0.00	0.00	0.00	0.00	0.18
Gastropoda	0.00	0.00	0.00	0.00	0.00	0.19	0.00
Hydracarina	0.51	0.00	0.00	0.08	0.00	0.19	0.00
Total	100.02	100.01	99.99	100.00	99.99	99.99	99.48

Source: Specht 1994b; Specht and Paller 1995.

Table 5-26. Relative Abundance (Percent Composition) of Macroinvertebrate Functional Groups in Upper Three Runs, July-August 1993 and September 1994.

	1993						1994
Functional Group	**Banks Mill Rd.**	**Road 8-1**	**Road F**	**RR Bridge**	**Road C**	**Road A**	**Road C**
Collector-Gatherers	71.31	67.95	68.84	76.09	77.09	73.64	62.77
Collector-Filterers	19.69	10.45	11.31	15.48	11.36	13.18	22.26
Predators	4.93	16.37	10.05	4.54	8.85	8.14	7.48
Scrapers	2.72	1.10	8.04	2.76	1.15	2.91	6.02
Shredders	1.36	4.13	1.76	0.81	1.35	1.74	1.46
Piercer-Herbivores	0.00	0.00	0.00	0.32	0.19	0.39	0.00
Total	100.01	100.00	100.00	100.00	99.99	100.00	99.99

Source: Specht 1994b; Specht and Paller 1995.

Table 5-27. Mean Number of Taxa, Density, and Biomass For Macroinvertebrates collected on Hester-Dendy Multi-plate Samplers in Tributaries of Upper Three Runs, July-August 1993 and September 1994).

	1993										1994			
	Cedar Creek	**Boggy Gut**	**Tinker Creek at Kennedy Pond Road**	**Tinker Creek at Road 2-1**	**Reedy Branch**	**Mill Creek at Road E-2**	**McQueen Branch at Road F**	**Tims Branch at Road 2**	**Tims Branch at Road C**	**Crouch Branch at Road 4**	**Tinker Creek at Kennedy Pond Road**	**Mill Creek at Road E-2**	**Tims Branch at Road 2**	**Crouch Branch at Road 4**
Taxa/Sampler	25.2	26.8	24.0	27.2	28.4	33.2	17.0	20.2	27.0	5.6	29.6	26.2	22.4	11.8
Mean Density (no./m^2)	1076	729.6	1032.4	1150.8	1048	1763.1	326.3	1207.8	806.7	202.2	1792.2	1728.5	1715.1	2492
Mean Biomass (g/m^2)	0.0293	0.1751	0.5209	0.2716	0.0713	0.0904	0.0374	0.1360	0.1578	0.0207	0.9056	0.0986	0.0327	0.0409
Total number of Taxa Collected	47	57	53	46	52	63	35	38	48	19	55	56	39	25

Source: Specht 1994b; Specht and Paller 1995.

Table 5-28. Percent Composition of Macroinvertebrate Taxa Collected on Hester-Dendy Multiplate Samplers in Tributaries of Upper Three Runs, July-August 1993 and September 1994.

	1993										**1994**			
	Cedar Creek	**Boggy Gut**	**Tinker Creek at Kennedy Pond Road**	**Tinker Creek at 2-1**	**Reedy Branch**	**Mill Creek at Road E-2**	**McQueen Branch at Road F**	**Tims Branch at Road 2**	**Tims Branch at Road C**	**Crouch Branch at Road 4**	**Tinker Creek at Kennedy Pond Road**	**Mill Creek at Road E-2**	**Tims Branch at Road 2**	**Crouch Branch at Road 4**
Hydra	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00
Ephemeroptera	3.22	2.76	13.42	2.91	4.9	6.46	0.68	0.00	4.57	0.00	19.95	9.95	0.39	2.24
Plecoptera	0.31	3.37	0.00	3.4	0.75	0.00	7.19	0.00	3.05	0.00	0.00	0.00	0.33	0.00
Trichoptera	9.03	2.14	6.28	0.97	4.26	3.99	1.71	8.05	2.49	0.00	2.99	2.20	0.07	0.00
Coleoptera	1.35	12.25	2.71	18.84	6.08	1.08	1.02	17.30	11.91	1.10	1.00	0.52	2.08	0.00
Odonata	0.21	0.31	0.11	0.00	0.21	0.38	3.08	0.18	0.28	1.10	0.31	0.13	0.13	3.59
Megaloptera	0.10	1.07	1.19	0.10	0.21	0.00	0.68	0.00	0.69	0.00	0.06	0.13	0.00	0.00
Hemiptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.55	0.00	0.00	0.00	0.00
Other Diptera	5.19	3.68	0.76	4.66	1.71	2.22	4.11	2.78	1.25	1.66	0.50	0.19	1.69	0.90
Tanypodinae	1.35	5.36	1.52	4.76	9.49	12.29	18.84	6.57	9.28	2.21	2.00	4.85	3.65	9.87
Tanytarsini	20.67	24.96	24.89	10.10	42.96	33.02	24.66	31.36	17.31	5.52	51.81	46.86	57.20	4.48
Orthocladiinae	48.29	23.58	19.81	46.21	6.50	17.87	8.56	26.83	38.23	0.55	4.74	7.24	17.72	0.45
Chironomini	7.68	20.37	28.03	6.99	21.54	22.56	29.10	4.81	10.66	86.19	11.97	23.79	11.92	56.05
Pseudochiromomini	0.00	0.00	0.00	0.10	0.11	0.00	0.00	0.00	0.00	0.55	0.00	0.00	0.00	0.00
Oligochaeta	2.60	0.15	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.94	3.88	3.65	17.94
Gastropoda	0.00	0.00	0.22	0.00	1.07	0.06	0.34	0.00	0.00	0.00	0.19	0.00	0.07	1.35
Pelecypoda	0.00	0.00	0.22	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Amphipoda	0.00	0.00	0.00	0.00	0.11	0.06	0.00	2.04	0.00	0.00	0.00	0.00	0.00	0.00
Hydracarina	0.00	0.00	0.54	0.97	0.00	0.00	0.00	0.09	0.14	0.55	0.00	0.00	0.00	0.00
Decapoda	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.06	0.06	0.45
Nemertea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.13	0.00
Turbellaria	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.12	0.06	0.00	1.79
Bivalva	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00
Hydracarina	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.06	0.00	0.98
Total	100.00	100.00	100.03	100.01	100.01	99.99	99.97	100.01	100.00	99.98	99.95	99.98	99.03	100.09

Source: Specht 1994b; Specht and Paller 1995.

Table 5-29. Relative Abundance (Percent Composition) of Macroinvertebrate Functional Groups in Tributaries of Upper Three Runs, July-August 1993 and September 1994

	1993										1994			
	Cedar Creek	**Boggy Gut**	**Tinker Creek at Kennedy Pond Road**	**Tinker Creek at Road 2-1**	**Reedy Branch**	**Mill Creek at Road E-2**	**McQueen Branch at Road F**	**Tims Branch at Road 2**	**Tims Branch at Road C**	**Crouch Branch at Road 4**	**Tinker Creek at Kennedy Pond Road**	**Mill Creek at Road E-2**	**Tims Branch at Road 2**	**Crouch Branch at Road 4**
Collector-Gatherers	65.94	75.19	70.88	82.62	76.33	72.43	54.45	79.93	72.58	93.37	43.20	78.54	62.93	78.48
Collector-Filterers	24.09	7.04	14.07	4.95	4.26	9.19	0.34	11.19	8.17	1.10	37.66	9.31	25.54	1.35
Predators	2.28	10.26	4.33	9.13	12.05	15.15	25.34	8.33	12.60	5.52	6.17	5.43	6.71	16.59
Scrapers	1.45	1.84	9.85	0.97	3.52	1.96	2.40	0.00	2.22	0.00	11.91	4.91	0.33	2.69
Shredders	4.57	5.67	0.87	2.33	3.73	1.08	17.47	0.56	4.43	0.00	0.81	1.36	4.50	0.00
Piercer-Herbivores	1.66	0.00	0.00	0.00	0.11	0.19	0.00	0.00	0.00	0.00	0.25	0.45	0.00	0.90
Total	99.99	100.00	100.00	100.00	100.00	100.00	100.00	100.01	100.00	99.99	100.00	100.00	100.01	100.01

Source: Specht 1994b; Specht and Paller 1995.

Bivalve Mollusks

Mill Creek is a tributary of Upper Three Runs. Recent research indicates that the taxonomy of the bivalve population in the Upper Three Runs' drainage is more complex than was previously suspected.

Based on conchology and electrophoresis it is apparent that while mollusks in the Savannah River are *Elloptio icterina*, the traditional classification scheme for Upper Three Runs *Elliptio* needs to be modified. The Mill Creek *Elliptio* population, formerly considered *E. icterina*, contains two discrete species, *E. compeanata* and one whose shells match the holotype of *E. hepatica* (Davis and Mulvey 1993).

Fish

Introduction

Upper Three Runs was sampled in 1984-1985, 1992, and 1993. The 1984-1985 samples were taken as part of the CCWS. These samples included ichthyoplankton collections from the lower reaches of the stream. The 1992 samples were taken as a dual effort to characterize stream fish assemblages on SRS and assess possible impacts from the outcropping of contaminated groundwater from F and H Areas into Upper Three Runs.

Comprehensive Cooling Water Study

Introduction

Most of the sampling in Upper Three Runs during the CCWS was devoted to the collection of ichthyoplankton from sample stations at Road C, Road A, and in the creek mouth (Figure 5-9). Samples were collected with 0.505-mm mesh nets weekly during daylight from February through July during 1984 and 1985 (Paller 1985; Paller et al. 1986).

Ichthyoplankton Taxa Collected

Paller (1985) collected 358 ichthyoplanktons from Upper Three Runs during 1984, and Paller et al. (1986) collected 217 during 1985 (Table 5-30 and Table 5-31). The dominant taxa during both years was spotted sucker (*Minytrema melanops*). Other relatively abundant taxa were darters (*Etheostoma* spp.), crappie (*Pomoxis nigromaculatus*), minnows (primarily *Notropis* spp.), blueback herring (*Alosa aestivalis*), and American shad (*Alosa sapidissima*). The occurrence of American shad in Upper Three Runs reflects the relatively large size and substantial flow of this creek that make it a suitable spawning area for this species. Perhaps the most unusual feature of the ichthyoplankton assemblage in Upper Three Runs was the relatively high abundance of spotted sucker larvae. Larvae of this species were not

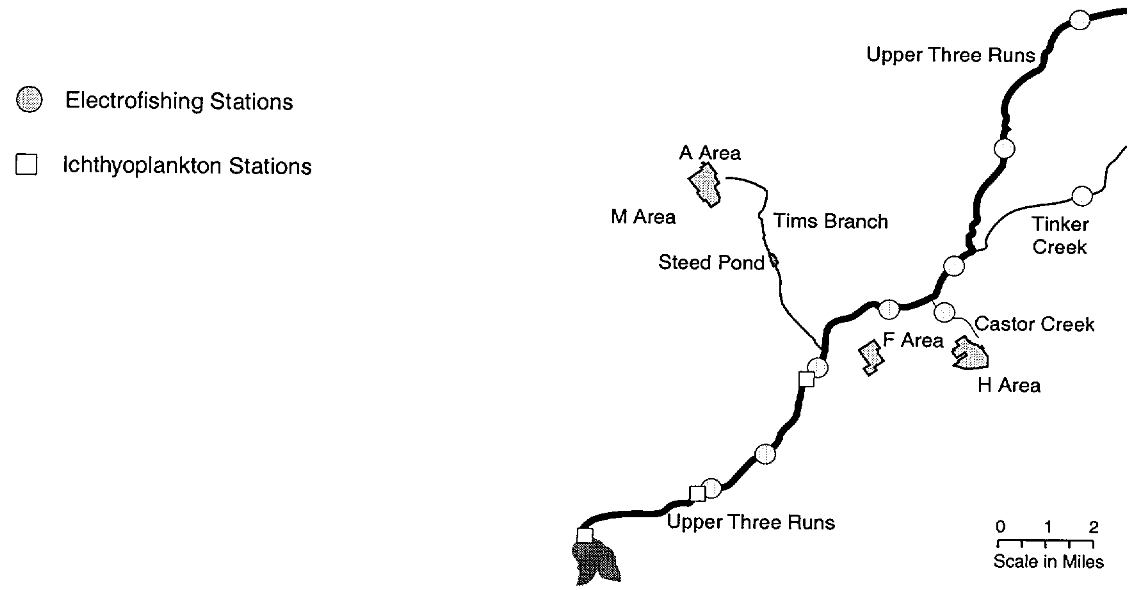

Figure 5-9. Fish Sampling Stations in Upper Three Runs

Table 5-30. Number and Percent Composition of Ichthyoplankton Collected from Upper Three Runs, March 14-June 3, 1984

Taxa	Number	Percent
gizzard and/or threadfin shad	12	3.4
blueback herring	4	1.1
unidentified herring or shad	4	1.1
spotted sucker	234	65.4
unidentified suckers	3	0.8
sunfish and/or bass	4	1.1
crappie	51	14.2
yellow perch	2	0.6
darters	20	5.6
minnows	17	4.7
carp	2	0.6
unidentified ichthyoplankton	5	1.4
total	358	100.0

Table 5-31. Number and Percent Composition of Ichthyoplankton Collected from Upper Three Runs, February-July 1985

Taxa	Number	Percent
blueback herring	11	5.1
American shad	9	4.1
unidentified clupeid	2	0.9
minnows	4	1.8
spotted sucker	116	53.5
sucker	6	2.8
sunfish and/or bass	3	1.4
crappie	2	0.9
darters	48	22.1
unidentified ichthyoplankton	16	7.4
total	217	100.0

found in such numbers in any of the other SRS creeks, suggesting that Upper Three Runs is an important spawning site for spotted sucker.

Ichthyoplankton Densities

Mean ichthyoplankton densities at the three sample stations in Upper Three Runs ranged from 29/1000 m^3 to 69/1000 m^3 during 1984 (Figure 5-10). Mean densities during 1985 ranged from 21/1000 m^3 to 41/1000 m^3. These densities were low to moderate compared with densities in the other unimpacted creeks sampled during the CCWS (Paller 1985; Paller et al. 1986). There were few consistent differences among sample stations except that the sample station in the creek mouth supported more taxa, partly because of the accessibility of this sample station to riverine taxa such as the anadromous American shad and blueback herring.

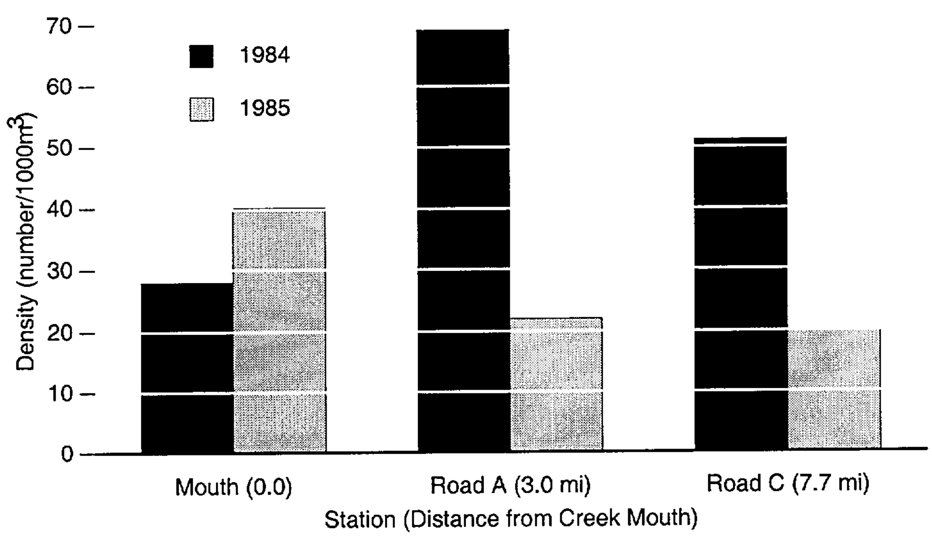

Figure 5-10. Mean Ichthyoplankton Density at Three Stations in Upper Three Runs, 1984 and 1985

Studies to Assess Impacts from F and H Areas

Introduction

Paller (1993) electrofished sample sites on Upper Three Runs, several tributary streams, and a control stream, Hollow Creek, to assess possible impacts of the F- and H- Area seepage basins on fish assemblages in Upper Three Runs. The tributaries include two third-order streams: Cedar Creek, north of the SRS; and Tinker Creek, which joins Upper Three Runs upstream from the F- and H- Area seepage basins. The third tributary was Crouch Branch, a small first-order tributary of Upper Three Runs that drains F and H Areas. The control stream, Hollow Creek, was selected because of its proximity to Upper Three Runs and its generally similar size, bottom substrate, channel morphometry, and water quality.

There were eight sample stations on Upper Three Runs (Figure 5-9), four (Stations 4-8) downstream from and four upstream from F and H Areas. There was one sample station on Cedar Creek (Station 9), one sample station on Tinker Creek (Station 10), one sample station on Crouch Branch (Station 11), and three sample stations (Stations 12-14) on Hollow Creek. Each sample station consisted of three 100-m stream reaches. Repeated electrofishing passes (usually seven) were made through each reach until no or few fish were collected. Habitat data also were collected, consisting of stream width, and depth, current velocity, number of logs and stumps, substrate type, dissolved oxygen concentration, pH, temperature, and conductivity. Percentages of stream bottom area covered or overhung by submerged debris (leaves, twigs, and wood fragments), submerged brush/snags, submerged root masses, and aquatic macrophytes. Low-growing riparian vegetation were estimated visually.

Comparison to Other SRS Streams

In general, the fish assemblages in Upper Three Runs were typical of those in third- and higher-order streams on SRS (Paller 1992). Shiners (Cyprinidae) and sunfishes (Centrarchidae) numerically dominated the fish assemblages at most Upper Three Runs sample stations. Larger predatory and benthic insectivorous species were present, as is typically the case in larger streams. The smaller tributary sample stations were strongly dominated by shiners, followed by pirate perch, madtoms, and darters. This pattern, too, is typical of unimpacted streams on the SRS (Paller 1992).

Differences Among Sample Stations

Differences in number of species and number of individuals among sample stations did not indicate degradation of the fish assemblages downstream from the waste management areas. Three of the five highest mean species numbers were observed at sample stations that were downstream from F and H Areas (Table 5-32). The lowest mean species numbers were observed upstream from the confluence of Upper Three Runs and Tinker Creek, possibly reflecting smaller stream size, other habitat factors, or offsite impacts. There were no significant differences in total number of fish per sample station; densities at the stations downstream from F and H Areas were within the range or higher than numbers at the stations upstream of F and H Areas.

Canonical discriminant analysis was used to assess differences among sample stations based on the numbers of the 10 most abundant species. Sample stations were divided into three groups: Upper Three Runs upstream from the waste management areas, Upper Three Runs downstream from the waste management areas, and Hollow Creek. Differences among the three station groups were significant at $P<0.05$. Upper Three Runs stations downstream from

Table 5-32. Fishes Collected by Electrofishing from Sample Stations in Upper Three Runs, Hollow Creek, and Several Tributaries

Species	UTR-114	UTR-8.1	UTR-TB	UTR-F.5	UTR-F.4	UTR-C	UTR-Ca	UTR-A	HOL-PJ	HOL-125	HOL-?	Tinker	Cedar	Crouch
dusky shiner	0	13	83	39	67	47	71	20	2	8	38	106	0	0
yellowfin shiner	0	14	21	35	10	60	17	14	12	2	0	276	103	249
sailfin shiner	0	19	84	9	0	2	1	1	1	1	29	12	10	0
American eel	3	10	8	10	16	4	16	12	3	7	10	1	13	4
redbreast sunfish	2	1	1	25	21	22	15	10	5	3	2	17	0	0
pirate perch	2	2	0	17	12	3	7	3	19	3	4	28	25	7
spotted sucker	0	7	0	0	17	9	0	13	0	3	30	0	0	0
bluegill	0	3	0	24	18	9	4	2	13	2	7	0	0	0
spotted sunfish	0	1	0	10	14	3	2	4	16	2	20	5	1	0
speckled madtom	1	1	0	2	3	2	2	1	15	1	11	19	13	4
coastal shiner	7	0	4	3	17	13	9	6	0	0	0	0	0	0
chain pickerel	2	5	0	4	3	5	5	7	7	1	7	0	0	0
redfin pickerel	0	0	1	4	3	0	0	1	5	3	8	16	5	0
largemouth bass	1	3	2	1	0	5	2	2	3	0	10	2	0	0
tesselated darter	0	0	0	0	2	2	0	0	5	0	2	5	13	7
lake chubsucker	1	5	2	2	0	1	0	0	1	0	2	0	9	0
blackbanded darter	0	1	0	2	0	2	1	2	2	1	11	14	0	0
ironcolor shiner	0	1	0	8	5	1	0	0	0	0	0	3	6	0
redear sunfish	1	2	0	0	11	0	0	0	0	1	2	1	3	1
bluehead chub	0	0	0	3	0	2	1	2	0	0	0	5	13	104
warmouth	0	2	0	3	1	1	1	2	3	0	3	0	4	0
northern hogsucker	1	1	0	1	0	1	0	3	0	2	4	2	0	0
yellow bullhead	1	0	0	2	1	0	0	0	3	0	0	5	6	9
silver redhorse	0	0	4	0	4	0	1	2	0	2	0	1	0	0
christmas darter	1	0	0	0	0	0	0	0	3	0	6	2	2	0
dollar sunfish	0	0	0	0	0	0	0	0	2	0	0	0	10	0
bowfin	0	1	1	0	1	1	3	2	1	1	2	0	0	0
brown bullhead	0	1	0	2	0	1	2	1	1	0	2	5	0	0
yellow perch	0	2	1	0	0	0	0	4	0	0	0	0	0	0
savannah darter	0	0	1	1	0	1	0	0	1	0	0	1	3	0
tadpole madtom	1	0	0	1	1	0	0	0	3	0	0	3	1	8
mosquitofish	0	0	0	0	6	1	1	0	0	0	0	0	0	0
brook silverside	0	0	0	2	0	1	1	3	0	0	0	0	0	0
golden shiner	0	1	1	0	2	0	0	0	0	0	0	0	0	0
creek chub	0	0	0	0	0	0	0	0	0	0	0	1	4	0
black crappie	0	0	2	0	0	1	0	0	0	0	0	0	0	0
longnose gar	0	0	0	0	0	0	0	3	0	0	0	0	0	0
blackbanded sunfish	0	1	0	0	0	0	0	0	1	0	0	0	0	0
creek chubsucker	0	2	0	0	0	0	0	0	0	0	0	6	0	45
shiner (*Notropis* spp.)	0	0	1	0	0	1	0	0	0	0	0	0	0	0
channel catfish	0	0	0	1	0	0	1	1	0	0	0	0	0	0
white crappie	0	0	0	1	0	1	0	0	0	0	0	0	0	0
spottail shiner	0	0	0	0	2	0	0	0	0	0	0	0	0	0
banded pygmy sunfish	0	1	0	0	0	0	0	0	0	0	0	0	0	0
white catfish	0	0	0	0	0	0	0	1	0	0	0	0	0	0
American shad	0	0	0	0	0	0	0	1	0	0	0	0	0	0
madtom (*Noturus* spp.)	0	0	0	0	1	0	0	0	0	0	0	0	0	0
margined madtom	0	0	0	0	0	0	0	0	0	0	0	1	0	0
flier	0	0	0	0	0	0	0	0	0	0	0	1	0	0
total no. fish	24	100	217	212	238	202	163	123	127	43	210	538	244	438
total no. species	13	25	16	26	24	28	21	27	24	17	21	26	19	10

the waste management areas differed from Upper Three Runs sample stations upstream from the waste management areas in that they had higher numbers of many species and from Hollow Creek sample stations in that they had lower densities of coastal shiner (*Notropis petersoni*), dusky shiner (*Notropis cummingsae*) and redbreast sunfish (*Lepomis auritis*).

Differences Among Different Habitats

Canonical discriminant analysis was used to assess habitat differences that could be responsible for the observed differences in fish assemblage structure among station groups. Habitat differences among the three station groups were significant at $P<0.05$. Upper Three Runs stations downstream from the waste management area were wider, deeper, and had faster currents than both Upper Three Runs sample stations upstream from the waste management area and Hollow Creek sample stations. The sample station groups also differed in macrophyte coverage, coverage by brush, and other factors. These and related habitat differences can exert strong influences on fish assemblage structure and fish-capture probability and were probably responsible for the observed differences among station groups.

Effects of F- and H-Area Operations

Paller (1993) observed that natural changes in species composition resulting from increases in stream size and other longitudinal habitat changes would be expected to be gradual and continuous. In contrast, changes caused by the introduction of toxicants from a point source could be abrupt, with the greatest change occurring near the discharge point. However, indices of similarity in species composition between adjacent station pairs indicated less differences between the sample station just upstream from the F and H Areas and the sample station just downstream from F and H Areas than between the putatively unimpacted sample stations farther upstream. Thus, this analysis also supported the conclusion of no measurable community level impacts associated with contaminants outcropping from F and H Areas. Further conclusions about the impacts of F and H Areas on fish in Upper Three Runs must remain tentative until additional data are available, including the analyses of contaminant levels in fish from potentially polluted sites.

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5.2 Beaver Dam Creek

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Drainage Description and Surface Hydrology

General Description

Beaver Dam Creek, which is approximately 5 km (3 mi) long and drains an area of approximately 2.2 km^2 (0.85 mi^2), originates at the effluent outfall canal of D Area and flows south, parallel to Fourmile Branch, to the Savannah River (Figure 5-11). The discharge of Beaver Dam Creek mixes with a portion of Fourmile Branch discharge in the Savannah River floodplain swamp before entering the Savannah River. Beaver Dam Creek is deep, narrow, and channelized in its headwaters and near its mouth and opens into a slough-like channel in its midreaches (Firth et al. 1986).

Effluents Contribution

Before SRS operations, Beaver Dam Creek probably had only intermittent or very low flow. Beaver Dam Creek has received thermal effluents since 1952 as a result of cooling water discharges from combined heavy water production (shut down in 1982) and operation of a coal-fired power plant in 400-D Area. In fall 1988, extended reactor outages decreased site electrical and steam demands, thus reducing the operations and thermal effluent of 400-D Area. Currently, Beaver Dam Creek receives condenser cooling water from the coal-fired power plant, neutralization waste water, sanitary waste water, ash basin effluent waters, and various laboratory waste waters.

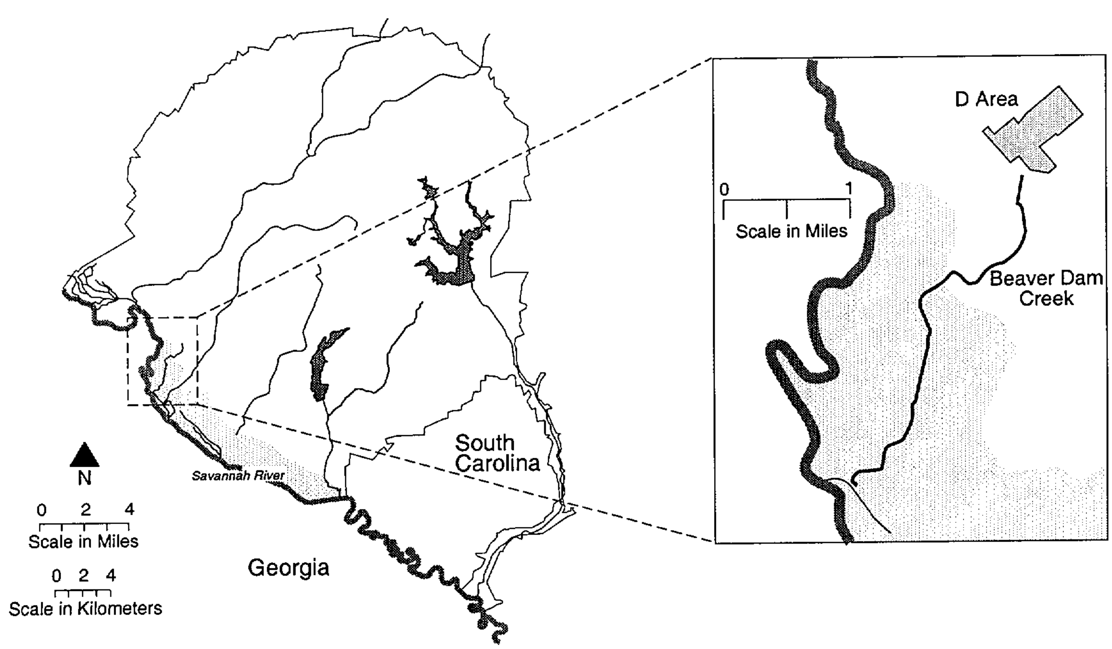

Figure 5-11. Location of Beaver Dam Creek on SRS

Flow Measurements

The U. S. Geological Survey measures flow at 400-D (Figure 5-12). Table 5-33 summarizes flow statistics of Beaver Dam Creek at 400-D. Records for the station at 400-D begin in June 1974. In water year 1995, the mean flow of Beaver Dam Creek at 400-D was 2.0 m^3/s (92 ft^3/s). Over the period of record (water years 1974-1995) at 400-D, the mean flow was 2.3 m^3/s (82 ft^3/s), the 7-day low flow was 0.45 m^3/s (16 ft^3/s), and the 7Q10 was 0.0003 m^3/s (0.01 ft^3/s). The maximum, minimum, and mean daily flows from October 1982 to September 1995 at 400-D are shown in Figure 5-13.

	Station Name
01	at 400-D

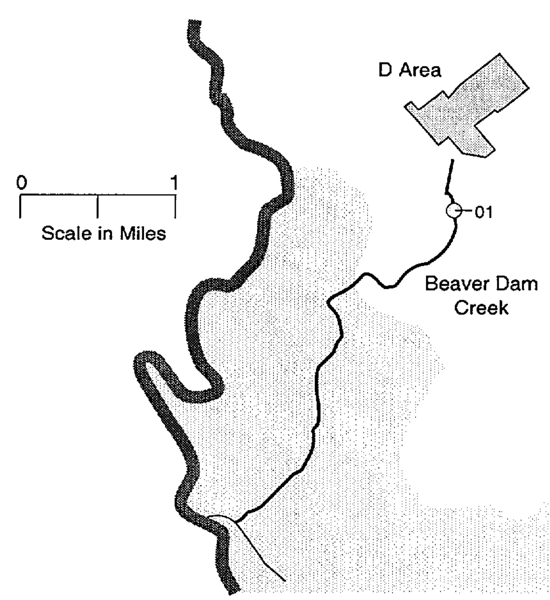

Figure 5-12. Flow Sampling Station on Beaver Dam Creek

Table 5-33. Flow Summary for Beaver Dam Creek

			Mean		Range				7Q10		7-day low flow	
					Low		High					
Station Name	**Station Number**	**Period of Record**	**cms[a]**	**cfs[b]**	**cms**	**cfs**	**cms**	**cfs**	**cms**	**cfs**	**cms**	**cfs**
at 400-D	02197326	1974-1995	2.3	81.5	0.40	14	3.7	130	0.0003	0.01	0.45	16

[a]cms = Cubic meters per second.
[b]cfs = Cubic feet per second.

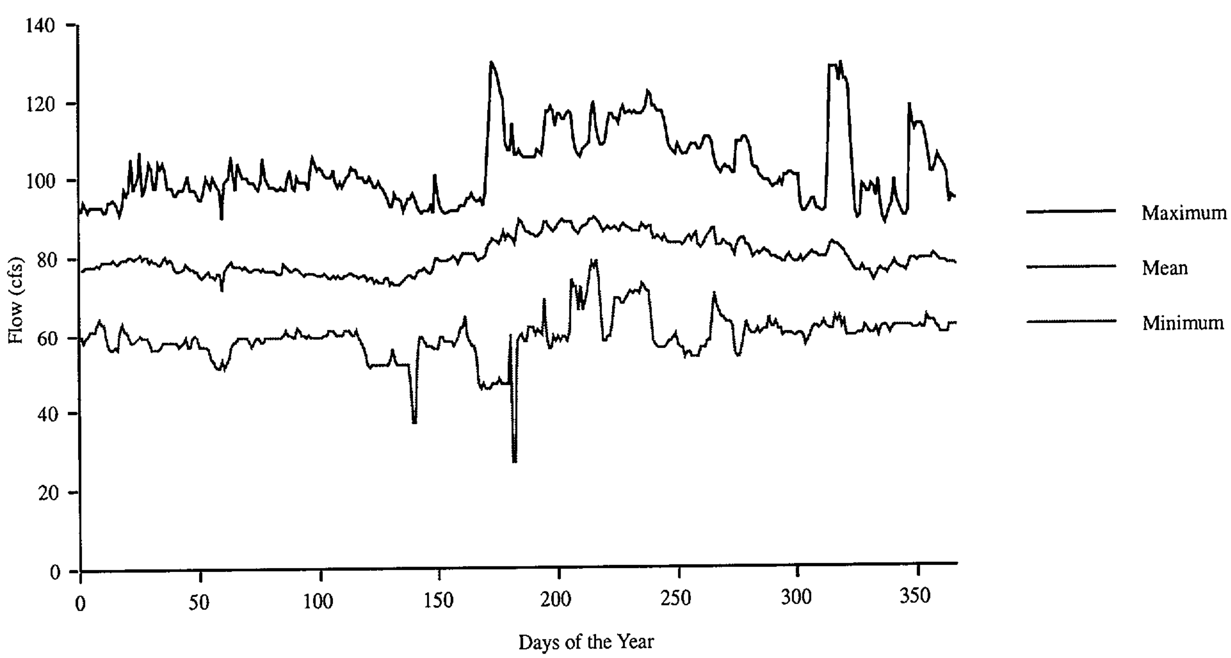

Figure 5-13. Maximum, Mean, and Minimum Flow Measurements from October 1982 to September 1995 for Beaver Dam Creek at 400-D, October 1982-September 1995

Water Chemistry and Quality

Studies and Monitoring

Water-Quality Monitoring

Westinghouse Savannah River Company Environmental Monitoring Section (EMS) conducted routine water-quality monitoring of Beaver Dam Creek from 1973 to 1986. EMS monitored one location on Beaver Dam Creek near the Savannah River Swamp (Figure 5-14; location 08 on map) monthly for physical and biological water quality indicators and quarterly for metals. Since 1986, water-quality measurements consisting of water temperature, pH, dissolved oxygen concentration, conductivity, and oxidation/reduction potential have been taken hourly downstream of D-Area discharge. Lower (1987) summarizes water quality monitoring results for Beaver Dam Creek from 1983-1985. All routine water quality monitoring data reported in the following sections can be found in the annual SRS Environmental Reports.

Comprehensive Cooling-Water Study

From 1983 to 1985, three locations on Beaver Dam Creek were studied as part of the Comprehensive Cooling Water Study (CCWS). This study was designed to assess the impact of current and proposed SRS activities on water quality. The Beaver Dam Creek sampling locations, which are shown in Figure 5-14, included:

- Beaver Dam Creek at 400-D outfall prior to ash basin effluent (01 on map)
- Beaver Dam Creek downstream of 400-D ash basin effluent (02 on map)
- Beaver Dam Creek near confluence with Savannah River (09 on map)

	Station Name
01	Prior to ash basin effluent
02	Downstream of ash basin effluent; downstream of outfall
03	1A - 316(a) Demonstration
04	1 - 316(a) Demonstration
05	2 - 316(a) Demonstration
06	3 - 316(a) Demonstration
07	4 - 316(a) Demonstration
08	5 - 316(a) Demonstration
09	6 - confluence with Savannah River

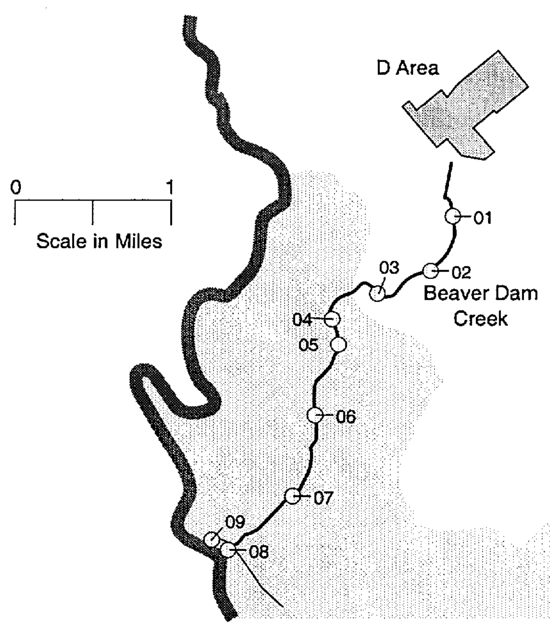

Figure 5-14 Water Chemistry and Quality Sampling Stations for Beaver Dam Creek

A synopsis of historical water quality monitoring of Beaver Dam Creek prior to the CCWS can be found in Gladden et al. (1985).

Comprehensive results and discussion of CCWS data can be found in Lower (1987).

Priority Pollutants Survey

In 1984, a special instream survey of priority pollutants was conducted to determine the levels of volatile, acid, and base/neutral organic compounds in Beaver Dam Creek. One location in Beaver Dam Creek, downstream of 400-D effluent, was sampled (Figure 5-14; 02 on map). The "Comprehensive Cooling Water Study Final Report, Volume II: Water Quality" (Lower 1987) documented these results. This document also reports the results of analyses for pesticides and PCBs in Beaver Dam Creek.

Chemical Assessment Studies

A Clean Water Act Section 316(a) Demonstration special study was conducted in 1988 on the waters of Beaver Dam Creek to determine impacts from specific SRS operations. The data collected during the 316(a) Demonstration are reflective of the thermal flow regimes that exist when D Area is operating at a reduced power level and are most reflective of current conditions in Beaver Dam Creek. This study, documented in "Compliance of the Savannah River Site D-Area Cooling System with Environmental Regulations" (Specht et al. 1990), is discussed later in this chapter. Stations 03 to 09 on Figure 5-14 correspond to the stations sampled during this monitoring program (1A-6).

Field Data

Water Temperature

Stream water temperatures at the mainstream Beaver Dam Creek sites during the CCWS ranged from 11.2 to 34°C (52.2 to 93.2°F), with an average temperature of 25.5°C (Table 5-34). These temperatures reflected the moderate thermal effluent associated with the stream. In Beaver Dam Creek near the confluence with the Savannah River, the temperatures were slightly lower than at the upstream sites. However, the range of temperatures was greater, reflecting river water inputs during high water conditions in the winter and the input of thermal effluents from Four Mile Creek during the spring and summer (Lower 1987). Routine monitoring on Beaver Dam Creek near the Savannah River Swamp from 1987 to 1991 indicated temperatures were comparable to those measured during the CCWS at the same location (Table 5-35). Hourly temperature measurements ranged from 5 to 32°C (41 to 89.6°F), with a mean temperature of 22°C (71.6°F).

pH Measurements

The pH measurements at all locations during the CCWS ranged from 6.0 to 7.7, with an average near 7.0 (Table 5-34). These values reflected Savannah River source water concentrations. From 1987 to 1991, hourly pH measurements ranged from 4.9 to 10.9 (Table 5-35).

Table 5-34. Beaver Dam Creek Field Data

	Water Temperature (°C)	pH	Stream Maximum Depth (cm)	Stream Velocity (cm/sec)
Beaver Dam Creek at 400-D outfall upstream of ash basin effluent (CCWS)[a]				
Mean	26.1	7.02	109	67
Range	14.5-34	6.20-7.60	96-132	23-106
Samples	46	46	35	41
Beaver Dam Creek downstream of 400-D ash basin effluent (CCWS)[a]				
Mean	25.2	6.90	132	65
Range	11.2-33.3	6.20-7.60	113-159	17-92
Samples	45	46	39	41
Beaver Dam Creek near confluence with Savannah River (CCWS)[a]				
Mean	22.1	6.81	213	44
Range	8.3-38.0	6.0-7.70	157-409	-45-118
Samples	46	46	26	39

[a]CCWS = Comprehensive Cooling Water Study, Newman et al. (1986).

Table 5-35. Water Quality Measurements in Beaver Dam Creek, 1987-1991

	Temperature (°C)	pH	Dissolved Oxygen (mg/l)	Specific Conductivity (µS/cm)	Oxidation/ Reduction Potential (mV)
Quarter 1 (January 1-March 31)					
Hourly Maximum	28	10.9	11.9	195	446
Hourly Minimum	5	4.9	5.0	59	229
Hourly Average	16.6		9.02	112	311
Quarter 2 (April 1-June 30)					
Hourly Maximum	32	8.8	9.9	176	456
Hourly Minimum	13.9	5.7	4.5	44	173
Hourly Average	24.4		7.36	109	324
Quarter 3 (July 1-September 30)					
Hourly Maximum	31.7	8.4	9.3	302	465
Hourly Minimum	21.7	5.3	5.1	54	260
Hourly Average	26.9		6.68	105	327
Quarter 4 (October 1-December 31)					
Hourly Maximum	29.4	9.0	13	239	513
Hourly Minimum	7.7	5.4	2.6	54	244
Hourly Average	18.8		8.35	103	324

Blank Spaces = Mean not calculated due to insufficient data in report.
Data taken from Arnett et al. 1992; Cummins et al. 1991, 1990; Davis et al. 1989; Mikol et al. 1988.

Physical Characteristics and General Chemistry

Dissolved Oxygen

The mean dissolved oxygen concentration in the mainstream waters of Beaver Dam Creek was 7.25 mg O_2/l, with ranges of 5.40 to 10.0 mg O_2/l during the CCWS (Table 5-36). Near the confluence with the Savannah River (swamp), the mean dissolved oxygen concentration was much lower (5.53 mg O_2/l). The lower dissolved oxygen concentration in the swamp was likely the result of thermal input from Fourmile Branch. From 1987 to 1991, concentrations of dissolved oxygen (mean 7.85 mg O_2/l) have continued to reflect concentrations measured during the CCWS (Table 5-35).

Suspended Solids and Turbidity

Mean turbidity and total suspended solids concentrations measured during the CCWS were elevated compared to Savannah River source water concentrations (Newman et al. 1986). Newman et al. (1986) documented that the source water contributions and the mainstream velocity regime contributed to the conditions in Beaver Dam Creek. The routine monitoring program does not measure suspended solids and turbidity.

Conductivity

Mean specific conductance in Beaver Dam Creek ranged from 79.1 to 91.1 µS/cm during the CCWS (Table 5-36). These values are reflective of the specific conductance of Savannah River source water. Hourly specific conductance measurements from 1987 to 1991 ranged from 44 to 302 µS/cm, with a mean of 107 µS/cm (Table 5-36).

Table 5-36. Beaver Dam Creek Physical Characteristics and General Chemistry, 1987-1991

	Dissolved Oxygen (mg/l)	Specific Conductivity (µS/cm)	Turbidity (NTU)[a]	Total Suspended Solids (mg/l)
Beaver Dam Creek at 400-D outfall prior to ash basin effluent (CCWS)[b]				
Mean	7.35	79.1	19.8	10.5
Range	5.80 - 10.0	53.0 - 96.8	6.6 - 82.3	1.0 - 31.8
Samples	46	38	43	45
Beaver Dam Creek downstream of 400-D ash basin effluent (CCWS)[b]				
Mean	7.15	91.1	20.3	13.0
Range	5.40 - 9.80	20.2 - 126.0	4.7 - 78.9	0.25 - 50.0
Samples	46	38	43	45
Beaver Dam Creek near confluence with Savannah River (CCWS)[b]				
Mean	5.53	79.5	21.3	16.0
Range	2.90 - 10.2	50.2 - 103.7	7.8 - 67.0	2.00 - 60.8
Samples	46	38	43	44

[a]NTU = Nephelometric turbidity units.
[b]CCWS = Comprehensive Cooling Water Study (Newman et al. 1986).

Major Anions and Cations

Alkalinity, Chloride and Sulfate

Table 5-37 gives alkalinity, chloride, and sulfate concentrations in Beaver Dam Creek during the CCWS. Total alkalinity and chloride concentrations measured during the CCWS reflected concentrations of Savannah River water. Mean total alkalinity concentrations in Beaver Dam Creek ranged from 16.7 to 18.1 mg $CaCO_3$/l; Savannah River concentrations ranged from 16.5 to 19.6 mg $CaCO_3$/l (Lower 1987). Mean chloride concentrations in Beaver Dam Creek ranged from 5.70 to 6.38 mg/l; while Savannah River concentrations ranged from 5.53 to 6.29 mg/l (Lower 1987). Sulfate concentrations during the CCWS were higher downstream (mean 11.3 mg/l) than at the upstream location (mean 6.77 mg/l). Sulfate concentrations in the Beaver Dam Creek swamp waters (mean 8.40 mg/l) were slightly reduced from the downstream location, but were elevated compared to the upstream location and were attributed to ash basin effluent entering Beaver Dam Creek. The routine monitoring program does not measure total alkalinity, chloride, and sulfate.

Calcium, Magnesium, Sodium, and Potassium

Concentrations of total calcium, magnesium, sodium, and potassium in Beaver Dam Creek waters during the CCWS are given in Table 5-38. Data collected during the CCWS indicated that the transport of these cations in Beaver Dam Creek was almost entirely in the dissolved phase (Newman et al. 1986). Calcium, magnesium, sodium, and potassium are not measured during routine monitoring.

Aluminum, Iron, and Manganese

Table 5-38 gives concentrations of total aluminum, manganese, and iron measured during the CCWS. Approximately 94% of the aluminum was associated with the solid phase, 86% of the iron was in the solid phase, and about 25-40% of the manganese was in the solid phase (Newman et al. 1986). The concentrations of these elements were reflective of Savannah River source water. The routine monitoring program does not measure aluminum, manganese, and iron.

Table 5-37. Beaver Dam Creek Major Anions

	Alkalinity (mg $CaCO_3$/l)	**Chloride (mg/l)**	**Sulfate (mg/l)**
Beaver Dam Creek at 400-D upstream of ash basin effluent (CCWS)[a]			
Mean	18.1	6.27	6.77
Range	10.3 - 24.6	2.40 - 8.60	3.98 - 13.1
Samples	45	46	28
Beaver Dam Creek downstream of 400-D ash basin effluent (CCWS)[a]			
Mean	17.0	6.38	11.3
Range	5.5 - 25.4	2.90 - 8.60	5.82 - 23.7
Samples	45	46	28
Beaver Dam Creek near confluence with Savannah River (CCWS)[a]			
Mean	16.7	5.70	8.40
Range	10.5 - 21.8	2.90 - 7.90	2.88 - 19.0
Samples	44	46	27

[a]CCWS = Comprehensive Cooling Water Study (Newman et al. 1986).

Table 5-38. Beaver Dam Creek Major Cations (Total)

	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Potassium (mg/l)	Aluminum (mg/l)	Iron (mg/l)	Manganese (mg/l)
Beaver Dam Creek at 400-D outfall upstream of ash basin effluent (CCWS)[a]							
Mean	3.37	1.35	7.66	1.04	1.09	1.16	0.113
Range	2.68 - 4.41	1.02 - 1.82	3.83 - 10.6	<0.368 - 1.73	0.359 - 4.14	0.567 - 3.81	<0.0004 - 0.412
Samples	39	39	39	39	39	39	16
Beaver Dam Creek downstream of 400-D ash basin effluent (CCWS)[a]							
Mean	3.80	1.42	8.65	1.27	1.17	1.18	0.105
Range	1.34 - 4.92	0.494 - 1.92	1.83 - 12.3	<0.368 - 2.51	0.442 - 4.07	0.607 - 3.76	<0.0004 - 0.352
Samples	38	38	38	39	38	38	17
Beaver Dam Creek near confluence with Savannah River (CCWS)[a]							
Mean	3.79	1.34	7.73	1.10	1.25	1.400	0.106
Range	2.70 - 12.7	0.562 - 1.66	2.58 - 11.5	<0.368 - 2.23	0.341 - 5.09	0.601 - 3.59	<0.0004 - 0.240
Samples	39	39	39	39	39	39	17

[a]CCWS = Comprehensive Cooling Water Study (Newman et al. 1986).

Nutrients

Phosphorus

During the CCWS, all phosphorus species in Beaver Dam Creek waters were found in concentrations similar to those of its source water, the Savannah River (Table 5-39). Mean concentrations of total phosphorus and total orthophosphate in the mainstream waters during the CCWS were 0.13 mg P/l and 0.10 mg P/l, respectively. In the Beaver Dam Creek swamp waters, mean concentrations of total phosphorus (0.092 mg P/l) and total orthophosphate (0.064 mg P/l) were slightly lower than at the mainstream locations. The routine monitoring program does not measure phosphorus species.

Nitrogen

During the CCWS, all nitrogen species in Beaver Dam Creek waters were found in concentrations similar to those of its source water, the Savannah River (Table 5-39). Concentrations of nitrite and ammonia were lowest at the Beaver Dam Creek swamp location. Mean concentrations of nitrate were similar at all three locations, with a range of 0.310-0.325mg/l (Table 5-39). Newman et al. (1986) documented that at the mainstream locations, mean percentages of total nitrogen and nitrate, ammonia, and organic nitrogen were 40%, 20%, and 40%, respectively. The routine monitoring program does not measure nitrogen species.

Trace Elements

Total trace elemental concentrations measured in Beaver Dam Creek during the CCWS largely reflected Savannah River source water concentrations (Table 5-40). During the CCWS, mean total arsenic concentrations ranged from 2.7 to 3.7 µg/l; total cadmium ranged from 0.55 to 0.77 µg/l; total chromium ranged from 7.7 to 11.8 µg/l; total copper ranged from 2.8 to 5.4 µg/l; total lead ranged from 2.1 to 3.1 µg/l; and total zinc ranged from 4.8 to 5.3 µg/l.

Table 5-39. Beaver Dam Creek Nutrients

	Total Phosphorus (mg/l)	Total Ortho-phosphate (mg l)	Organic Nitrogen (mg/l)	Total Kjeldahl Nitrogen (mg/l)	Ammonia (mg/l)	Nitrite (mg/l)	Nitrate (mg/l)
Beaver Dam Creek at 400-D outfall upstream of ash basin effluent (CCWS)[a]							
Mean	0.133	0.113	0.232	0.374	0.163	0.017	0.314
Range	<0.010 - 1.50	0.025 - 1.40	0.010 - 0.810	0.130 - 0.950	0.048 - 0.400	0.002 - 0.054	0.107 - 0.467
Samples	46	41	45	45	45	44	43
Beaver Dam Creek downstream of 400-D ash basin effluent (CCWS)[a]							
Mean	0.127	0.096	0.204	0.330	0.133	0.018	0.325
Range	0.045 - 0.739	0.032 - 0.591	0.015 - 0.685	0.100 - 0.850	0.042 - 0.310	0.002 - 0.052	0.049 - 0.484
Samples	45	41	44	45	45	44	43
Beaver Dam Creek near confluence with Savannah River (CCWS)[a]							
Mean	0.092	0.064	0.220	0.263	0.064	0.007	0.310
Range	<0.010 - 0.205	0.017 - 0.127	0.016 - 0.968	0.035 - 0.990	0.015 - 0.320	0.001 - 0.021	0.005 - 0.728
Samples	45	41	41	45	45	44	43

[a]CCWS = Comprehensive Cooling Water Study (Newman et al. 1986).

Table 5-40. Beaver Dam Creek Trace Elements (Total)

	Arsenic (μg/l)	Cadmium (μg/l)	Chromium (μg/l)	Copper (μg/l)	Lead (μg/l)	Nickel (μg/l)	Zinc (μg/l)
Beaver Dam Creek at 400-D outfall upstream of ash basin effluent (CCWS)[a]							
Mean	2.7	0.77	10.5	5.4	3.1	4.6	5.3
Range	<0.4 - 15.1	<0.04 - 2.52	<0.4 - 68.0	<0.4 - 14.0	<0.4 - 15.3	<0.4 - 15.4	<0.4 - 17.2
Samples	16	16	16	16	16	16	16
Beaver Dam Creek downstream of 400-D ash basin effluent (CCWS)[a]							
Mean	3.7	0.55	7.7	5.4	2.1	4.6	4.8
Range	<0.4 - 21.3	<0.04 - 2.50	<0.4 - 38.0	<0.4 - 37.3	<0.4 - 5.7	<0.4 - 15.0	<0.4 - 15.0
Samples	17	17	17	17	17	17	17
Beaver Dam Creek near confluence with Savannah River (CCWS)[a]							
Mean	3.2	0.57	11.8	2.8	2.4	3.2	5.2
Range	<0.4 - 23.9	<0.04 - 4.60	<0.04 - 69.0	<0.4 - 7.3	<0.4 - 10.1	<0.4 - 14.0	<0.4 - 18.0
Samples	17	17	17	17	17	17	17

[a]CCWS = Comprehensive Cooling Water Study (Newman et al. 1986).

Total nickel concentrations sometimes were elevated during the CCWS, with ranges from 3.2 to 4.6 μg/l. The elevated nickel concentrations may have been the result of the 400-D Area powerhouse and ash sluicing operations (Lower 1987).

Total mercury and uranium concentrations were consistently below the analytical detection limits for those elements during the CCWS. The routine monitoring program does not measure trace elements.

Organic Carbon

Total organic carbon concentrations in Beaver Dam Creek were similar to concentrations in the Savannah River. Mean total organic carbon concentrations ranged from 5.65 to 6.75 mg/l in Beaver Dam Creek, while the Savannah River average was 6.10 mg/l. Approximately 72-84% of the organic carbon was present in the dissolved phase (Newman et al. 1986).

Priority Pollutants

Concentrations of all 88 volatile, acid, and base/neutral organics tested in Beaver Dam Creek during the 1984 instream survey were below the associated analytical detection limits (Lower 1987). These results confirmed the 1981 point source data for outfall D-001 and indicated that the input of Savannah River water for various operations in 400-D Area had no adverse impact on levels of organics in Beaver Dam Creek.

Pesticides, Herbicides, and PCBs

Pesticides, herbicides, and PCBs are not measured in Beaver Dam Creek during routine water quality monitoring.

Lower (1987) reports the results of analyses for pesticides, herbicides, and PCBs from 1982 to 1985; results from 1967 to 1981 can be found in Gladden et al. (1985). During these periods, concentrations were also near or below detection limits at all locations.

Chemical, Including Radionuclide, and Toxicity Assessment Studies

In 1988, a Clean Water Act Section 316(a) Demonstration was initiated to determine whether Beaver Dam Creek could support a balanced indigenous biological community because water temperature during D-Area operations exceeded limits set forth in the National Pollutant Discharge Elimination System (NPDES) permit. Seven sampling locations were selected on Beaver Dam Creek to represent different habitats of the stream (Figure 5-14; locations 03-09).

Forty water quality parameters were assessed monthly at the sampling stations in Beaver Dam Creek (Table 5-41). The data show that 400-D Area operations greatly influence the water quality of Beaver Dam Creek. Generally, water quality parameters at Station 1A (03) were consistently different from all other stations on Beaver Dam Creek. Station 1A was in the original intermittent stream channel of the creek, upstream of the confluence of

Table 5-41. Mean Values for Water Chemistry Parameters at Stations Sampled in Beaver Dam Creek, 1988-1990

	Station						
Parameter	**1A[a] (03)**	**1 (04)**	**2 (05)**	**3 (06)**	**4 (07)**	**5 (08)**	**6 (09)**
Temperature (°C)	13.2	19.9	19.8	19.4	19.1	18.8	18.7
pH	4.42	6.76	6.68	6.60	6.58	6.50	6.51
Dissolved oxygen (mg/l)	6.21	8.43	8.34	8.00	7.76	7.70	7.92
Conductivity (µS/cm)	57	129	131	128	127	128	124
Turbidity (NTU)	98.1	16.7	13.6	13.8	12.8	13.4	17.0
Total suspended solids (mg/l)	105	17	14	19	14	16	22
Total hardness (mg $CaCO_3$/l)	25.6	22.1	22.4	23.1	22.7	23.4	22.4
Sulfate (mg/l)	9.7	19.8	19.1	18.7	18.4	17.8	17.0
Total aluminum (µg/l)	1,776	611	596	630	641	710	802
Total iron (µg/l)	2,362	906	982	1,129	1,039	1,094	1,286
Total manganese (µg/l)	421	96	97	108	104	108	131
Total phosphorus (mg/l)	0.060	0.137	0.134	0.136	0.130	0.127	0.135
Orthophosphate (mg/l)	0.007	0.076	0.077	0.075	0.072	0.069	0.069
Nitrate (mg/l)	0.04	0.41	0.42	0.43	0.42	0.42	0.40
Total arsenic (µg/l)	0.8	3.4	3.9	3.3	3.1	2.9	2.7
Total barium (µg/l)	56.9	26.9	27.8	28.3	28.4	27.7	28.3
Total cadmium (µg/l)	1	1	0.1	1	1	1	0
Total chromium (µg/l)	4	3	5	3	4	3	3
Total copper (µg/l)	3	1	3	3	3	3	4
Total lead (µg/l)	6.1	3.8	3.0	1.7	1.9	2.8	2.1
Total mercury (µg/l)	0.05	0.04	0.05	0.05	0.05	0.20	0.03
Total selenium (µg/l)	0.8	1.2	1.0	1.0	1.1	0.9	0.8
Total silver (µg/l)	0.05	0.06	0.12	0.10	0.82	0.06	0.05
Total strontium (µg/l)	19.9	45.9	46.9	46.1	46.7	45.2	43.7
Total zinc (µg/l)	21	1.0	10	10	11	8	9

Source: Specht et al. 1990.
[a]Five sampling dates; all others were sampled monthly for 18 months.

the 400-D Area discharge canal. However, this station was usually dry, except after periods of heavy rainfall, and the water collected was reflective of rainwater runoff.

Station 1A had the lowest mean values for pH, conductivity, dissolved oxygen, temperature, orthophosphorus, sulfate, nitrate, total phosphorus, and dissolved and total strontium. Means for total hardness, total suspended solids, turbidity, dissolved and total aluminum, dissolved and total barium, dissolved and total iron, total lead, dissolved and total manganese, and total zinc were higher at Station 1A than at the other stations. Excluding Station 1A, means for the study period were generally similar among stations on Beaver Dam Creek (Table 5-41).

This study indicated that there were no characteristics of the Beaver Dam Creek water quality measurements that represented obvious indicators of stress to the biological communities. Water temperatures never exceeded the maximum NPDES limit of 32.2°C (90°F). However, the water temperatures below the thermal discharge from the D-Area power plant were often more than 2.8°C (5°F) higher than the water temperatures at the 5G pumphouse at the Savannah River or the upstream station (1A).

No radionuclide or toxicity data have been collected from Beaver Dam Creek.

Algae

There have been no studies of the algae of Beaver Dam Creek with the exception of three stations that were sampled for periphyton from 1983 to 1985 (Specht 1987) as part of the CCWS. Periphyton biomass values for the Beaver Dam Creek sampling stations were statistically similar to each other and to the values of the other SRS streams. There was no evidence that pollutants discharged to Beaver Dam Creek via D-Area effluents had an adverse impact on the periphyton community of this stream system.

Macrophytes

Introduction

Aquatic macrophytes provide stream structure, substrate for periphyton development, cover and substrate for smaller animals, and a source of carbon for the stream system. Although aquatic macrophytes are an important component of the function of many aquatic systems, they tend to be less important in flowing than still waters.

Comprehensive Cooling Water Study

The CCWS examined the Beaver Dam Creek aquatic macrophyte community (Specht 1987). Data from the single station sampled for macrophytes in 1983-1984 show a total of 28 taxa; of the 28 taxa, only 4 were found growing in the stream channel, and the remainder were found growing in the riparian area. Macrophyte data from a different single station were collected from October 1984-September 1985. Eight taxa were found in measurable quantities (Table 5-42). Differences were found between spring-summer values and those of fall-winter sampling periods. Most aquatic macrophyte growth was in backwaters and along the creek margins (Specht 1987). The number of taxa and population parameters compare favorably with those for at least one nonthermal stream location surveyed during the same sampling period.

Effects of Reduced Power Plant Operation

Normal successional patterns and development of macrophyte beds would be expected to continue in suitable sections of Beaver Dam Creek with the reduced operation of the D-Area power plant.

Table 5-42. The Annual Mean Macrophyte Area, Volume, Biomass, Percent Cover and Standard Deviation (s), October 1984-September 1985

	Station 7[a]							
	Area/m^2		Volume/m^2 of Surface Area		Biomass (g/m^2)		Percent Cover of Stream	
Species	**Mean**	**s**	**Mean**	**s**	**Mean**	**s**	**Mean**	**s**
Alternanthera philoxeroides	0.0133	0.0310	0.0015	0.0035	1.437	3.269	1.333	3.097
Callitriche heterophytlla	0.0008	0.0015	0.0002	0.0003	0.0905	0.1731	0.1048	0.1905
Ceratophyllum demersum	0.0849	0.0464	0.0220	0.0167	11.62	9.322	8.824	6.067
Hydrocotyle ranunculoides	0.0001	0.0002	<0.0001	<0.0001	0.0015	0.0058	0.0062	0.2444
Leersia sp.	0.0026	0.0063	0.0002	0.0007	0.3085	0.7610	0.2643	0.6326
Lemna spp. (and occasional *Spirodela* fronds)	0.0038	0.0062	-	-	0.5661	1.113	0.4621	0.7724
Unidentified	0.0033	0.0060	-	-	-	-	0.3305	0.6017
Polygonum spp.	0.0078	0.0161	-	-	3.486	7.210	0.8340	1.696

Source: Firth et al. 1986.
[a]Twenty reaches were sampled.

Zooplankton

Comprehensive Cooling Water Study

Chimney and Cody (1986a) studied the zooplankton in Beaver Dam Creek for regulatory compliance issues covered by the Clean Water Act Section 316(a). The study documented the temporal and spatial characteristics of zooplankton species based on quarterly sampling from December 1984 to August 1985. Surface-water grab samples were collected at two stations approximately one-third of the distance down the channel. Species richness comprised 7 Protozoa, 15 Rotifera, 14 Cladocera, 4 Copepoda, and 1 Ostracoda; Steel Creek was the only SRS stream with a higher species richness. Figure 5-15 indicates that the greatest densities occurred during March 1985 and May 1985. During March 1985, Cladocera dominated the assemblage; during May 1985, Protozoa and Copepods were most abundant.

Regulatory Compliance Study

Specht et al. (1990) performed a study in Beaver Dam Creek from September 1988 to February 1990 to meet regulatory compliance of the D-Area cooling system. Results were based on seven sampling stations distributed throughout the length of the stream at approximately equal intervals. Species richness during these years averaged 26 Protozoa, 27 Rotifera, 7 Cladocera, 8 Copepoda, and 1 Ostracoda. Figure 5-16 illustrates the mean monthly zooplankton densities. Seasonal patterns were different from the results in 1985, probably due to sampling differences and large natural variability in abundances. Large and typical standard errors are associated with this variation. These results are representative of most zooplankton populations in flowing water habitats.

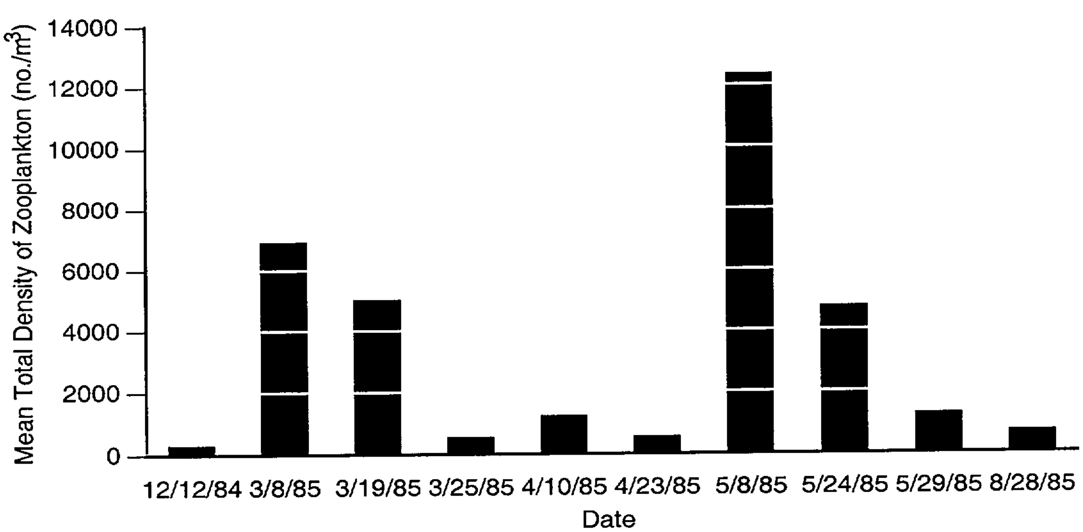

Figure 5-15. Mean Total Density of Zooplankton in Beaver Dam Creek, 1984-1985

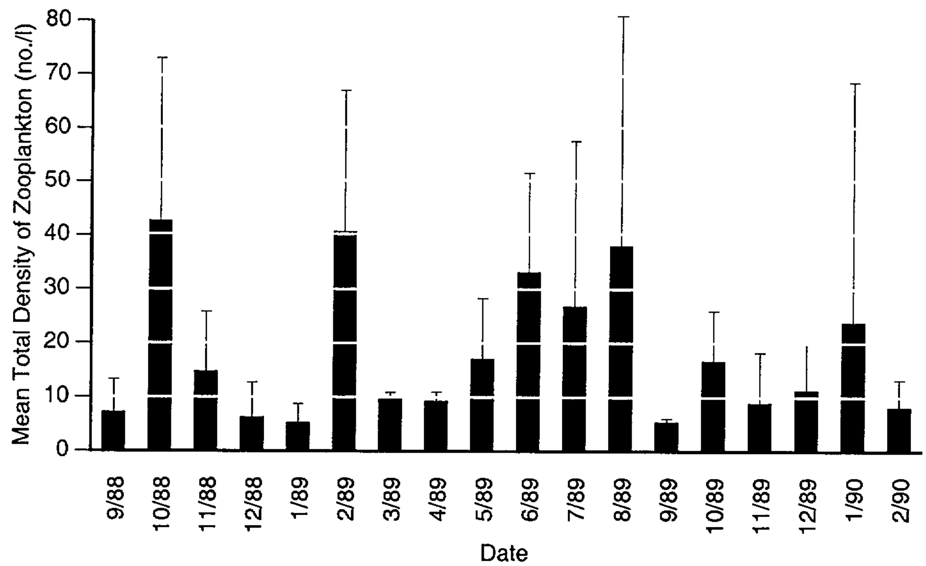

Figure 5-16. Mean Total Density of Zooplankton in Beaver Dam Creek, 1988-1990

Macroinvertebrates

Sampling Locations and Methods

Comprehensive Cooling Water Study

From September 1982 through August 1983, macroinvertebrates were sampled quarterly in the mouth of Beaver Dam Creek using Hester-Dendy multiplate samplers and drift nets (Specht and Painter 1983).

From November 1983 through September 1985, as part of the CCWS, macroinvertebrates were sampled monthly at five stations in Beaver Dam Creek (Figure 5-17) using Hester-Dendy multiplate samplers, leaf bags, and drift nets; at three of these five stations, macroinvertebrates also were collected from aquatic macrophytes (Kondratieff and Kondratieff 1984, 1985; Firth et al. 1986). The CCWS macroinvertebrate data were summarized by Specht (1987).

Clean Water Act Compliance Study

In support of a Clean Water Act Section 316(a) Demonstration, macroinvertebrate sampling also was conducted monthly at six stations in Beaver Dam Creek (Figure 5-17) from September 1988 through February 1990 using Hester-Dendy multiplate samplers and quarterly using drift nets and dip nets (Specht et al. 1990). Detailed sampling methods for the 1988-1990 program can be found in Nagle et al. (1990). Stream temperatures in Beaver Dam Creek averaged several degrees cooler during the 1988-1990 study than during the 1983-1985 study, due to reduced power production at the D-Area power house.

Sample Stations (moving downstream)

1983-1985 (CCWS)	1988-1990 (316[a])	1994
/5		/5
/6	01	
	02	
	03	
/7	04	
	05	
/8		
/9	06	

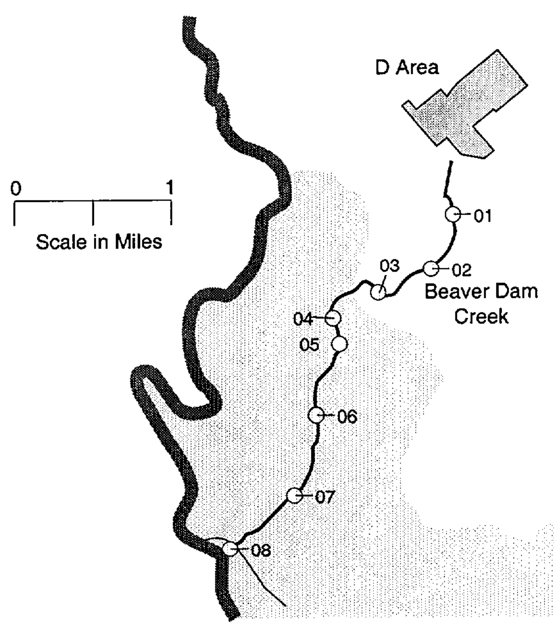

Figure 5-17. Macroinvertebrate Sampling Stations for Beaver Dam Creek

Additional Study

A program to develop a biotic index for southeastern streams using Hester-Dendy multiplate samplers sampled macroinvertebrates in the upstream portion of Beaver Dam Creek in September 1994. While not specifically designed to characterize SRS streams, these data contribute to a better understanding of the streams (Specht and Paller 1995).

Results

Introduction

The thermal regime in 1988-1990 is similar to present (1997) conditions; therefore, the macroinvertebrate data from 1988-1990 should be representative of present conditions. Most of the data presented and discussed in this section are Hester-Dendy data from the 1984-1985 and 1988-1990 sampling programs because these are the most comparable data sets, with respect to sampling methods and stations.

Number of Taxa

In 1984-1985, the total number of macroinvertebrate taxa collected on Hester-Dendy multiplate samplers at each of the five sampling stations ranged from 36 to 61, while in 1988-1990, excluding chironomid genera, the number of taxa collected at the six sampling stations was slightly higher, ranging from 41 to 64 (Table 5-43). In both sampling programs, the most upstream station had the fewest taxa, while the slough-like area (Station 7 in 1984-1985; Station 04 in 1988-1990) had the most taxa. Total number of taxa collected in September 1994 at one station was 27 (Table 5-44).

The 1988-1990 sampling program including all sampling methods, collected 163 macroinvertebrate taxa from Beaver Dam Creek (Table 5-45). Of these taxa, 124 were collected on the multiplate samplers, and 39 were collected exclusively by the supplemental sampling methods. Taxa that were most likely to be missed or under-represented by the multiplate samplers included some species of mollusks (Gastropoda and Pelecypoda), dragonflies and damselflies (Odonata), most aquatic bugs (Hemiptera), and many aquatic beetles (Coleoptera). Many of these taxa are exclusively benthic and do not readily colonize artificial substrates that are above the stream bottom. Taxa that are likely to be over-represented on the multiplate samplers include many species of chironomids, at least one of which (*Stenochironomus*) actively burrowed into the plates of the multiplate samplers in large numbers but was rarely collected on natural substrates in Beaver Dam Creek.

Densities

The mean density of macroinvertebrates collected on multiplate samplers ranged from 921.2 to 1776.5 organisms/m^2 in 1984-1985 and from 773.7 to 2348.0 organisms/m^2 in 1988-1990 (Table 5-46). Mean density in September 1994 at Station 5 was 502.8 organisms/m^2. Densities at upstream stations (01, 02, and 03) were generally higher than at downstream stations (04, 05, and 06) throughout the sampling programs. Densities were fairly comparable between studies for any given station. The mean biomass of macroinvertebrates ranged from 0.076 to 0.220 g ash-free dry-weight (AFDW)/m^2 in 1984-1985, while biomass in 1988-1990 was substantially higher at most stations, ranging from 0.185 to 0.394 g AFDW/m^2 (Table 5-46). Biomass in September 1994 was 0.442 g AFDW/m^2.

Table 5-43. Total Number of Macroinvertebrate Taxa Collected on Multiplate Samplers in Beaver Dam Creek, October 1984-September 1985 and September 1988-February 1990

Beaver Dam Creek Station			All Taxa			Taxa Richness Less Chironomidae
1984–1985[a]	1988–1990[b]	1994[c]	1984–1985[a]	1988–1990[b]	1994[c]	1988–1990[b]
5[d]	—	5	36	—	27	—
—	01	—	—	67	—	41
—	02	—	—	69	—	47
6	03	—	42	71	—	44
7	04	—	61	92	—	64
—	05		—	68		46
8	—	—	50	—	—	—
9[e]	06	—	47[d]	82	—	57

[a]Specht 1987.
[b]Specht et al. 1990.
[c]Specht and Paller 1995.
[d]Station 5 was approximately 0.8 km (0.5 mi) upstream from Station 01 (1988-1990), in the D-Area discharge canal.
[e]Chimney and Cody 1986b.

Table 5-44. Mean Number of Taxa, Density and Biomass of Macroinvertebrate Taxa and of Percent Composition of Functional Groups Collected on Hester-Dendy Multiplate Samplers in Beaver Dam Creek, September 1994

Parameter		Functional Group	Percent Composition
Taxa/Sampler	14.4	collector-gatherer	54.67
Density/m^2	502.8	collector-filterer	11.78
Biomass (g/m^2)	0.4422	predator	2.44
Total taxa collected	27	scraper	29.78
		shredder	1.11
		herbivore	0.22
		Total	100.00

Source: Specht and Paller 1995.

Table 5-45. Macroinvertebrate Taxa Found in Beaver Dam Creek, All Sampling Methods Combined. "X" Denotes Quantitative (Multiplate) Sampling and "*" Denotes Qualitative Sampling (Dip Nets and Drift) Only, September 1988-February 1990

		Station					
Class/Order	**Taxon**	**01**	**02**	**03**	**04**	**05**	**06**
Coelenterata	*Hydra*	X	*	X	*	X	
Platyhelminthe	Class Turbellaria	X	X	X	X	X	X
Nematoda	Phylum Nematoda	X	X	X	X	X	X
Polychaeta	*Manayunkia* sp.	*	X	X	X	*	
Oligochaeta	Class Oligochaeta (unid.)	X	X	X	X	X	X
Hirudinea	Class Hirudinea	X	X	X	X	*	X
Gastropoda	Class Gastropoda (unid.)	X	X	X	X	X	X
Gastropoda	Family Ancylidae (unid.)	X	X	X	X	X	X
Gastropoda	*Amnicola* spp.		X		X	X	X
Gastropoda	*Pseudosuccinea columella*		*	*	*	*	X
Gastropoda	*Physella heterostropha*	X	X	X	X	X	X
Gastropoda	Family Planorbidae (unid).	*				*	*
Gastropoda	*Helisoma* spp				*		
Gastropoda	*Helisoma trivolvis*				X		
Gastropoda	*Menetus dilatatus*		*	X	X		X
Gastropoda	*Campeloma decisum*				*		*
Gastropoda	*Succinea* sp.		*		*		
Pelecypoda	Class Pelecypoda (unid.)	X		X	X		
Pelecypoda	*Corbicula fluminea*	*	*	*	*		*
Pelecypoda	Family Sphaeriidae				X		
Isopoda	Order Isopoda (unid.)			X			
Isopoda	*Asellus* sp.			X	X	X	
Amphipoda	Order Amphipoda (unid.)	X	X	X	X	X	X
Amphipoda	*Gammarus fasciatus*	X	X	X	X	X	X
Amphipoda	*Hyalella azteca*	*	*	X	X	X	X
Decapoda	*Palaemonetes paludosus*	*	*	*	X	*	*
Decapoda	Family Cambaridae (unid.)		*		X		
Decapoda	*Procambarus* sp.	*	*	*	X	*	*
Collembola	Order Collembola	*	X	*	X	X	*
Hydracarina	Order Hydracarina	X	X	X	X	X	X
Ephemeroptera	Order Ephemeroptera (unid.)	X	X	X	X	X	X
Ephemeroptera	Family Baetidae (unid.)	X	X	X	X	X	X
Ephemeroptera	*Baetis* sp.	X	X	X	X	X	X
Ephemeroptera	*Pseudocloeon* sp.				*		
Ephemeroptera	*Caenis* sp.	X	X	X	X	*	X
Ephemeroptera	Family Ephemerellidae (unid.)	X	X	*			
Ephemeroptera	*Ephemerella* sp.						X
Ephemeroptera	*Eurylophella* spp.		X	*	X	*	X
Ephemeroptera	*Eurylophella temporalis*				X		X
Ephemeroptera	Family Heptageniidae (unid.)	X	X	X	X	X	X
Ephemeroptera	*Heptagenia* sp.					X	X
Ephemeroptera	*Pseudiron* sp.						X
Ephemeroptera	*Stenacron* sp.					X	X
Ephemeroptera	*Stenonema* sp.	X	X	X	X	X	X
Ephemeroptera	*Tricorythodes* sp.	X	X	X	X	X	X
Odonata	Order Odonata (unid.)	X		X	X		

Table 5-45. (cont)

		Station					
Class/Order	**Taxon**	**01**	**02**	**03**	**04**	**05**	**06**
Odonata	Suborder Anisoptera (unid.)	*	X	X	X	X	X
Odonata	*Boyeria* spp.	X		X		*	
Odonata	*Boyeria vinosa*					*	X
Odonata	*Neurocordulia molesta*	X					
Odonata	*Tetragoneuria* sp.				X		
Odonata	Family Gomphidae (unid.)	*			X		*
Odonata	*Dromogomphus* sp.	*	*		*		
Odonata	*Dromogomphus spinosus*						*
Odonata	*Gomphus* spp.	*	*	*	*		*
Odonata	*Progomphus* sp.	*					
Odonata	Family Libellulidae (unid.)			X	X		
Odonata	*Erythemis simplicicollis*			*	X		
Odonata	*Erythrodiplax* spp.				X		
Odonata	*Libellula* spp.		*		*		
Odonata	*Didymops transversa*		X	X			X
Odonata	*Macromia* spp.	*		*	X		X
Odonata	Suborder Zygoptera (unid.)	X	X	X	X	X	X
Odonata	Family Calopterygidae (unid.)	X	X	X	X	X	X
Odonata	*Calopteryx augustipennis*		*				
Odonata	*Hetaerina* spp.	*	X	X	X	X	X
Odonata	*Hetaerina titia*	X	X	X	X	X	
Odonata	Family Coenagrionidae (unid.)	*	X	X	X	X	X
Odonata	*Argia* spp.	X	X	X	X	X	X
Odonata	*Enallagma* spp.	*	*	*	X	X	X
Odonata	*Ischnura* spp.			*	X		
Odonata	*Nehalennia* spp.			*	*		
Plecoptera	Order Plecoptera (unid.)			X			X
Plecoptera	Family Nemouridae						X
Plecoptera	Family Perlidae (unid.)						X
Plecoptera	*Acroneuria abnormis*					X	
Plecoptera	*Perlesta* spp.						X
Hemiptera	Order Hemiptera (unid.)			*			*
Hemiptera	*Belostoma* sp.		*	*	*		
Hemiptera	Family Corixidae (unid.)		X	*	*	*	*
Hemiptera	*Trichocorixa* spp.						*
Hemiptera	Family Gerridae (unid.)		*			*	*
Hemiptera	*Merragata* sp.			*			*
Hemiptera	*Hydrometra* sp.	*					*
Hemiptera	*Mesovelia* sp.				*		
Hemiptera	*Paravelia* sp.				*		
Coleoptera	Order Coleoptera (unid.)		*		X		
Coleoptera	Family Chrysomelidae		*				
Coleoptera	Family Curculionidae		X	X	*	X	X
Coleoptera	Family Dytiscidae (unid.)		X	*	*	*	
Coleoptera	*Agabetes acuductus*			*			
Coleoptera	*Hydroporus* sp.		*		X		X
Coleoptera	*Laccophilus* sp.						*
Coleoptera	Family Elmidae (unid.)	X	X	X	X	X	X

Table 5-45. (cont)

		Station					
Class/Order	Taxon	01	02	03	04	05	06
Coleoptera	*Ancyronyx variegatus*	X	X	X	X	X	X
Coleoptera	*Macronychus glabratus*	X	X	X	X	X	X
Coleoptera	*Microcylloepus pusillus*	X	X	X	X	X	X
Coleoptera	*Stenelmis* sp.	X	X	X	X	X	X
Coleoptera	*Ectopria nervosa*					*	
Coleoptera	Family Gyrinidae (unid.)				X		X
Coleoptera	*Dineutus* sp.	X	X	X	X	X	X
Coleoptera	*Gyrinus* sp.			*		*	X
Coleoptera	*Haliplus* spp.						*
Coleoptera	*Peltodytes* spp.		*	*	X	*	*
Coleoptera	Family Helodidae (unid.)		*				
Coleoptera	*Hydrochus* spp.			*	X		
Coleoptera	Family Hydrophilidae (unid.)		X	*			
Coleoptera	*Berosus* sp.		*		X		*
Coleoptera	*Enochrus* spp.					*	
Coleoptera	*Sperchopsis* sp.					*	
Coleoptera	Family Noteridae (unid.)		X				
Coleoptera	*Hydrocanthus* sp.				*	X	
Coleoptera	*Notomicrus* sp.	*					
Coleoptera	*Suphisellus* sp.	*	*	*	*		
Megaloptera	Family Corydalidae (unid.)	X	X	X	X	X	X
Megaloptera	*Chauliodes* sp.	*		*	X	*	
Megaloptera	*Corydalus cornutus*	X	X	X	X	X	X
Neuroptera	*Climacia areolaris*						X
Trichoptera	Order Trichoptera (unid.)	X	X	X	X	X	X
Trichoptera	Family Hydropsychidae (unid.)	X	X	X	X	X	X
Trichoptera	*Cheumatopsyche* spp.	X	X	X	X	X	X
Trichoptera	*Hydropsyche* spp.	X	X	X	X	X	X
Trichoptera	*Macrostemum carolina*				X		
Trichoptera	Family Hydroptilidae (unid.)	X	X	X	X	X	X
Trichoptera	*Hydroptila* sp.	X	X	X	X	X	X
Trichoptera	*Mayatrichia* sp.		X				
Trichoptera	*Orthotrichia* sp.		*				
Trichoptera	*Oxyethira* sp.		X	*	X		*
Trichoptera	Family Leptoceridae (unid.)		X	X	X		X
Trichoptera	*Ceraclea* sp.				X		
Trichoptera	*Nectopsyche* sp.	X	X	X	X	X	X
Trichoptera	*Nectopsyche candida*	*	*	*	*	*	
Trichoptera	*Oecetis* sp.	X	X	X	X	X	X
Trichoptera	*Triaenodes* spp.	X	X	X	X	*	X
Trichoptera	*Pycnopsyche* sp.		*	*			
Trichoptera	Family Philopotamidae (unid.)					X	
Trichoptera	*Chimarra* sp.	X	X	X	X	X	X
Trichoptera	Family Polycentropodidae	X	X	X	X	X	X
Trichoptera	*Cernotina* sp.	*			X		X
Trichoptera	*Cyrnellus* sp.						X
Trichoptera	*Neureclipsis* sp.	X	X	X	X	X	X
Trichoptera	*Polycentropus* sp.				X		

Table 5-45. (cont)

Class/Order	Taxon	Station 01	02	03	04	05	06
Lepidoptera	Order Lepidoptera (unid.)		X	X	X		
Lepidoptera	Family Pyralidae (unid.)	X	X	X	X	X	
Lepidoptera	*Munroessa* sp.				X		
Lepidoptera	*Neargyractis* sp.		*	*	X		
Lepidoptera	*Parapoynx* sp.		X	X	X	X	X
Lepidoptera	*Synclita* sp.		*	*	*	*	
Diptera	Order Diptera (unid.)		*	X	*	X	*
Diptera	Family Tipulidae (unid.)						*
Diptera	*Helius* sp.					*	
Diptera	*Limonia* sp.	X					
Diptera	*Tipula* sp.		X			X	
Diptera	*Telmatoscopus* sp.	X	X			X	
Diptera	*Chaoborus punctipennis*	X	X	X	X	X	*
Diptera	Family Culicidae (unid.)			*	*		*
Diptera	*Aedes* sp.			*			
Diptera	*Anopheles* sp.			*	*		*
Diptera	*Simulium* sp.	X	X	X	X	X	X
Diptera	Family Ceratopogonidae (unid.)	*	X		X		*
Diptera	Subfamily Ceratopogoniinae	X	X	X	X	X	X
Diptera	Subfamily Forcipomyiinae	X	X	X	X	X	X
Diptera	Family Chironomidae (unid.)	X	X	X	X	X	X
Diptera	Subfamily Tanypodinae (unid.)	X	X	X	X	X	X
Diptera	*Clinotanypus* sp.		*	*	X		*
Diptera	*Coelotanypus* sp.		*				
Diptera	*Nilotanypus* sp.		X				X
Diptera	*Procladius* sp.		*	*	X		*
Diptera	Tribe Pentaneuriini (unid.)		*				
Diptera	*Ablabesmyia* sp.	X	X	X	X	X	X
Diptera	*Conchapelopia* gr.	X		X		X	
Diptera	*Labrundinia* sp.	X	X	X	X	X	X
Diptera	*Larsia* sp.	X	X				
Diptera	*Monopelopia* sp.	X	X	X	X	X	X
Diptera	*Potthastia* sp.	X	X	X	X	X	X
Diptera	Subfamily Orthocladiinae	X	X	X	X	X	X
Diptera	*Brillia* sp.	X	X	X	X	X	X
Diptera	*Cardiocladius* sp.	X					
Diptera	*Cricotopus* sp.	X	X	X	X	X	X
Diptera	*Cricotopus bicinctus* gr.	X	X	X	X		X
Diptera	*Nanocladius* sp.	X	X	X	X	X	X
Diptera	*Parakiefferiella* sp.	*		X			
Diptera	*Parametriocnemus* sp.	X	X	X	X	X	X
Diptera	*Rheocricotopus* sp.	X	X	X	X	X	X
Diptera	*Symposiocladius* sp.	X	X	X	X	X	X
Diptera	*Tvetenia* sp.	X	X	X	X	X	X
Diptera	*Corynoneura* sp.	X	X	X	X	X	X
Diptera	*Thienemanniella* sp.	X	X	X	X	X	X
Diptera	Tribe Chironomini (unid.)	X	X	X	X	X	X
Diptera	*Chironomus* sp.	X	X	X	X	X	X

Table 5-45. (cont)

		Station					
Class/Order	**Taxon**	**01**	**02**	**03**	**04**	**05**	**06**
Diptera	*Cladopelma* sp.			X	*		
Diptera	*Cryptochironomus* sp.	X	X	X	X		X
Diptera	*Dicrotendipes* sp.	X	X	X	X	X	X
Diptera	*Glyptotendipes* sp.			X			
Diptera	*Microtendipes* sp.				X		
Diptera	*Nilothauma* sp.			X			
Diptera	*Parachironomus* sp.						X
Diptera	*Phaenopsectra* sp.	X	X	X	X	X	X
Diptera	*Polypedilum* sp.	X	X	X	X	X	X
Diptera	*Saetheria* sp.				X		
Diptera	*Stelechomyia* app.	X			X	X	X
Diptera	*Stelechomyia perpulchra*				X	X	X
Diptera	*Stenochironomus* sp.	X	X	X	X	X	X
Diptera	*Stictochironomus*					*	
Diptera	*Tribelos* sp.	X	X	X	X	X	X
Diptera	*Pseudochironomus* sp.	X				X	
Diptera	Tribe Tanytarsini (unid.)	X	X	X	X	X	X
Diptera	*Nimbocera* sp.			X	X		
Diptera	*Rheotanytarsus* sp.	X	X	X	X	X	X
Diptera	*Tanytarsus* (T.) spp.	X	X	X	X	X	X
Diptera	Family Tabanidae (unid.)						X
Diptera	*Chrysops* sp.			*	*	*	
Diptera	*Tabanus* sp.		*	*			
Diptera	*Odontomyia* sp.	*	*	*	*		
Diptera	Family Empididae (unid.)	X	X	X	X	X	X
Diptera	*Chelifera* sp.	X	X	X	X	X	X
Diptera	*Dolichocephala* sp.	X	X				
Diptera	*Hemerodromia* sp.	X	X	X	X	X	X
Diptera	Family Sciomyzidae		*	*	*		
Diptera	Family Ephydridae	*	*			X	
Total taxa/station (all sampling methods combined)[a]		88	102	106	116	92	102
Percent taxa collected by qualitative sampling		21	32	35	24	24	21
Total taxa/study[a]		163					

Source: Specht et al. 1990.
[a]Higher level taxa not included in count if a lower level taxon was present.

Table 5-46. Mean Density and Biomass of Macroinvertebrates Collected on Multiplate Samplers in Beaver Dam Creek, October 1984-September 1985 and September 1988-February 1990

Beaver Dam Creek Station			Mean Density (No./m^2)			Mean Biomass (g AFDW/m^2)		
1984-1985[a,d]	1988-1990[b]	1994[c]	1984-1985[a,d]	1988-1990[b]	1994[c]	1984-1985[a,d]	1988-1990[b]	1994[c]
5[e]	—	5	1626.9	—	502.8	0.118	—	0.4422
—	01		—	1636.0		—	0.185	
—	02		—	2348.0		—	0.273	
6	03		1776.5	1867.2		0.076	0.225	
7	04		1131.9	1451.8		0.173	0.394	
	05			773.8			0.215	
8			921.2			0.170		
9	06		1253.6	1295		0.220	0.222	

Sources: [a]Specht 1987; [b]Specht et al. 1990; [c]Specht and Paller 1995.
[d]Station numbers used in the 1984-1985 study differ from those used in the 1988-1990 study.
[e]Station 5 was approximately 0.8 km (0.5 mi) upstream from Station 01 (1988-1990) in the D-Area discharge canal.
AFDW = ash-free dry weight.

Dominant Species

As a group, Chironomidae were by far the most common macroinvertebrates in Beaver Dam Creek in 1988-1990, comprising from 51.8% (Station 05) to 75.9% (Station 01) of the organisms collected from the multiplate samplers (Table 5-47). At Stations 01 through 04, the chironomid subfamily Orthocladiinae was the most abundant macroinvertebrate taxon, accounting for 22.4-29.6% of the organisms collected, while at Stations 05 and 06, chironomids of the tribe Chironomini were most abundant (20.6 and 25.0%, respectively). Tanytarsini chironomids were also abundant at all stations, comprising 8.4-19.9% of the organisms collected. Other groups of macroinvertebrates that contributed at least 5% to the total density at one or more stations included mayflies (Ephemeroptera; 0.8-26.5%), caddisflies (Trichoptera; 2.1-11.8%), beetles (Coleoptera; 1.0-11.9%), oligochaete worms (1.4- 6.6%), and non-chironomid dipterans (0.8-5.6%; Table 5-47). Groups that contributed at least 5% to the total density at Station 5 in 1994 were Ephemeroptera (73%) and Trichoptera (12%).

Differences Among Sampling Stations

In 1988-1990, Station 01 had fewer macroinvertebrate taxa and slightly lower biomass than the other sampling stations (Table 5-43 and Table 5-46) but was similar to the other sampling stations with respect to densities of organisms and mean number of taxa (Table 5-46 and Table 5-48). There were some indications of longitudinal changes in the relative abundances of macroinvertebrate taxonomic groups in Beaver Dam Creek. Station 01 had the lowest relative abundance of mayflies (0.8%) and the highest relative abundance of chironomids (75.9%; Table 5-47) of all of the stations. In general, the relative abundance of mayflies increased in a downstream direction and beetles (Coleoptera) were much more abundant at Stations 05 and 06 (11.9% and 5.1%, respectively) than at the four upstream stations (1.0- 2.1%; Table 5-47). Conversely, trichopterans were more abundant at the three upstream stations (5.9-11.8%) than at the three downstream stations (2.1-4.8%; Table 5-47).

Table 5-47. Mean Relative Abundance (Percent Composition) of Higher Order Taxonomic Groups of Macroinvertebrates from Quantitative Sampling in Beaver Dam Creek, September 1988-February 1990 and September 1994

	1988-1990						1994
Taxon	**Sta 01**	**Sta 02**	**Sta 03**	**Sta 04**	**Sta 05**	**Sta 06**	**Sta 05**
Coelenterata	<0.01	0.00	<0.01	0.00	0.01	0.00	0.00
Turbellaria	0.08	0.09	0.20	0.34	0.33	0.06	0.00
Nematoda	0.40	0.52	0.24	0.20	0.08	0.17	0.00
Polychaeta	0.00	<0.01	<0.01	<0.01	0.00	0.00	0.00
Oligochaeta	5.30	6.55	4.68	4.59	1.35	3.26	3.56
Hirudinea	0.01	0.01	0.01	0.05	0.00	0.02	0.00
Gastropoda	3.93	3.20	1.78	1.85	3.33	1.49	1.11
Pelecypoda	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Hydracarina	0.25	0.62	0.47	0.45	0.43	0.44	0.00
Isopoda	0.00	0.00	0.06	0.18	0.02	0.00	0.00
Amphipoda	0.03	0.01	0.06	0.53	0.08	0.16	0.22
Decapoda	0.00	0.00	0.00	0.28	0.00	0.00	0.00
Collembola	0.00	0.04	0.00	0.01	0.03	0.00	0.00
Ephemeroptera	0.75	9.06	12.42	12.14	26.52	18.72	73.33
Odonata	0.08	0.17	0.24	1.28	0.18	0.30	0.00
Plecoptera	0.00	0.00	0.01	0.00	0.01	0.10	0.22
Hemiptera	0.00	<0.01	0.00	0.00	0.00	0.00	0.00
Coleoptera	1.72	1.04	2.09	1.29	11.87	5.09	1.56
Megaloptera	0.17	0.20	0.16	0.25	0.24	0.12	1.56
Neuroptera	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Trichoptera	5.86	11.80	6.02	4.83	2.09	4.03	11.78
Lepidoptera	<0.01	0.03	0.05	0.18	0.07	0.01	0.00
Non-chir. Diptera	5.55	3.94	2.35	0.82	2.25	1.92	0.00
Chironomidae (unid.)	8.51	4.05	4.24	6.62	3.02	6.53	0.00
Orthocladiinae	27.54	28.99	29.64	22.43	18.12	15.87	2.00
Tanypodinae	1.35	1.30	1.73	2.81	0.90	1.65	0.67
Tanytarsini	14.43	15.01	19.93	19.72	8.43	15.02	1.78
Chirononini	24.01	13.24	13.53	18.87	20.64	25.00	2.22
Diamesiinae	0.02	0.16	0.08	0.25	0.01	0.05	0.00
Totals[a]	100.00	100.00	100.00	100.00	100.00	100.00	100.01

Source: Specht et al. 1990: Specht and Paller 1995.

[a]Some totals may not equal 100.00 due to rounding.

Table 5-48. Descriptive Statistics for Total Macroinvertebrate Densities (Organisms/m^2) and Mean Number of Taxa from Quantitative (Multiplate) Sampling in Beaver Dam Creek, September 1988-February 1990

Station	N[a]	Mean	Med[a]	SD[a]	CV[a]	Min[a]	Max[a]	Mean No. of Taxa
01	90	1636.0	1273.7	1179.4	72.1	5.6	6463.7	16.2
02	90	2348.0	2069.8	1272.3	54.2	597.8	6257.0	22.2
03	89[b]	1867.3	1379.9	1392.2	74.6	162.0	6011.2	19.6
04	90	1451.8	1125.7	1241.8	85.5	44.7	6430.2	21.2
05	90	773.8	698.3	534.4	69.1	50.3	2910.6	14.3
06	85[c]	1295.8	1167.6	707.9	54.6	273.7	3804.5	18.4

Source: Specht et al. 1990.
[a]Abbreviations:N=Total number of samples analyzed; Med=Median; SD=Standard Deviation; CV=Coefficient of Variation; Min=Minimum; Max=Maximum.
[b]Only four samples were collected at Station 03 in January 1989.
[c]Samples were not retrieved from Station 06 in February 1990 due to high water levels.

Taxonomic Composition Changes Since 1984-1985

The taxonomic composition of Beaver Dam Creek has changed substantially between 1984-1985 and 1988-1990, with most stations exhibiting increases in the relative abundance of mayflies (Ephemeroptera), snails (Gastropoda), beetles (Coleoptera), caddisflies (Trichoptera) and Tanytarsini chironomids, and an overall decline in the relative abundance of Chironomini chironomids (Table 5-45, Table 5-47, and Table 5-49). Many species of Chironomini generally are considered to be pollution-tolerant (Beck 1977), while most species of mayflies and caddisflies are intolerant of poor water quality (Hynes 1970). Although Ephemeroptera were common in 1994 (73% of the total number of macroinvertebrates), the group comprised almost exclusively *Baetis*. Some species of this genus have been reported to be very tolerant of heavy metals (Heliovaara and Vaisanen 1993), which are present in the coal ash, the ash basins, and the run-off to the creek from these areas. However, it appears that, with respect to taxonomic composition, the macroinvertebrate community of Beaver Dam Creek has undergone substantial improvement since 1984-1985.

Table 5-49. Mean Relative Abundance (Percent Composition) of Higher Order Taxonomic Groups of Macroinvertebrates Collected on Hester Dendy Multiplate Samplers, October 1984-September 1985

	Station				
Taxon	**05**[c]	**06**[c]	**07**[c]	**08**[c]	**09**[d]
Coelenterata	0.00	0.00	0.00	0.00	0.0
Turbellaria	0.02	0.33	3.98	1.63	0.2
Nematoda	0.56	0.39	0.30	0.60	0.2
Polychaeta	0.00	0.00	0.00	0.00	0.0
Oligochaeta	7.60	4.69	16.64	6.44	2.0
Hirudinea	0.00	0.00	0.07	0.06	<0.1
Gastropoda	0.74	1.86	1.14	1.20	<0.1
Pelecypoda	0.00	0.00	0.02	0.02	<0.1
Hydracarina	0.10	0.64	0.80	0.52	0.7
Isopoda	0.00	0.05	0.12	0.16	<0.1
Amphipoda	0.02	0.24	0.89	0.30	<0.1
Decapoda	0.00	0.00	0.00	0.00	0.0
Collembola	0.00	0.00	0.00	0.00	0.0
Ephemeroptera	0.64	3.47	10.28	18.62	12.4
Odonata	0.09	0.14	1.07	0.14	<0.1
Plecoptera	0.00	0.00	0.02	0.05	0.2
Hemiptera	0.00	0.00	0.00	0.00	0.0
Coleoptera	0.15	0.04	0.54	3.02	5.5
Megaloptera	0.07	0.02	0.16	0.22	2.2
Neuroptera	0.00	0.00	0.00	0.00	0.0
Trichoptera	0.31	0.59	3.43	9.81	3.2
Lepidoptera	0.00	0.01	0.14	0.05	0.0
Non-chir. Diptera	2.13	4.50	1.64	1.58	2.7
Chironomidae (unid.)	7.36	6.47	3.29	2.91	48.5
Orthocladiinae	8.58	27.60	6.45	15.27	a
Tanypodinae	0.67	1.68	4.73	1.53	1.3
Tanytarsini	4.91	9.06	7.07	10.19	20.7
Chironomini	66.05	38.23	37.20	25.65	a
Diamesiinae	0.00	0.00	0.02	0.02	a
Total[b]	100.00	100.01	100.00	99.99	99.8

Source: Specht et al. 1990.
[a]Taxa were grouped in "Chironomidae."
[b]Some totals may not equal 100.00 due to rounding.
[c]Stations 05, 06, 07, 08 calculated from Firth et al. 1986.
[d]Station 09 calculated from Chimney and Cody 1986b.

Fish

Introduction

Three fisheries sampling programs have been conducted on Beaver Dam Creek. The most extensive was the D-Area Clean Water Act Section 316(a) Demonstration, which was conducted from September 1988 through February 1990 to evaluate the effects of heated cooling water discharged to Beaver Dam Creek from the D-Area power plant. Fisheries sampling in Beaver Dam Creek also was conducted in conjunction with the CCWS (1983-1985) and the Comprehensive Cooling Water Quarterly Study (1984-1985). The results of all three programs will be presented in this discussion, although the 316(a) study will be emphasized because it is more recent and comprehensive than the earlier studies.

D-Area 316(a) Demonstration

Introduction

Six stations from the upper reaches to the mouth of Beaver Dam Creek were electrofished monthly from September 1988 through February 1990 (Figure 5-18) (Specht et al. 1990). These stations encompassed a range of habitats from wide, deep, slow-flowing areas near the creek mouth (Station 06) to narrower, more swiftly flowing channels (Stations 01, 02, and 03). Some portions of the creek were heavily overgrown with aquatic vegetation, particularly the slough-like habitat represented by Station 04. Initially, all stations also were sampled monthly by hoopnetting. However, hoopnet sampling was discontinued at Stations 02, 03, and 04 to prevent the accidental trapping of alligators. Hoopnet sampling also

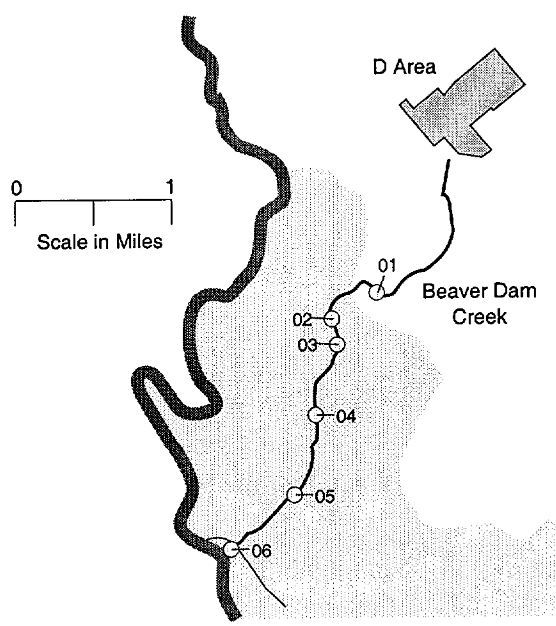

Figure 5-18. Fish Sampling Stations for Beaver Dam Creek.

was suspended at all sample stations during April and May, the months of maximum alligator movement.

Adult Fish

Forty-five species were collected by electrofishing and hoopnetting during the 18-month study (Specht et al. 1990). The number of fish collected by electrofishing ranged from 561 at Station 02 and 532 at Station 05 to 167 at Station 01 (Table 5-50). The number of species collected from each station was less variable, ranging from 25-32. Electrofishing catches varied monthly, and long-term patterns were not evident.

Fewer fish were collected at Station 01 than at the other stations (Table 5-50). Station 01 was closest to the D-Area outfall and had higher flow rates than the other sample stations. A major portion of the sample area at Station 01 was strongly channelized with little vegetation or instream structure to serve as foraging or refuge areas for fish. Stations 02, 04, and 05, in contrast, generally had open canopies with abundant aquatic and shoreline vegetation.

The electrofishing data were converted to catch per unit effort (CPUE, expressed as number caught per 100 m [328 ft]) by dividing the number caught in each transect by the transect length. Total (all species) mean CPUE ranged from approximately 10.4 fish/100 m at Station 02 to approximately 3.1 fish/100 m at Station 01 (Table 5-51). CPUE fluctuated widely monthly. Low CPUE occurred when Savannah River flood waters inundated Stations 03, 04, 05, and 06. Flooding greatly increased water depth at these stations and allowed fish to disperse into the surrounding floodplain.

Statistical testing indicated that CPUE was significantly lower at Station 01 than at the other stations. The low CPUE at Station 01 was probably a result of high current velocities and relatively poor habitat. Other differences were likely the result of local variations in instream structure, vegetation, substrate, current velocity, flooding, and other factors that influenced habitat quality and sampling efficiency.

The most abundant species (by number) collected by electrofishing were spotted sucker (*Minytrema melanops*), coastal shiner (*Notropis petersoni*), redbreast sunfish (*Lepomis auritus*), largemouth bass (*Micropterus salmoides*), and spotted sunfish (*Lepomis punctatus*) (Table 5-50). Sunfish (Centrarchidae) were the most abundant family, composing nearly 40% of the fish collected from Beaver Dam Creek. Minnows and shiners (Cyprinidae) (26%) and suckers (Catostomidae) (17.3%) were also abundant (Table 5-52). Several taxa, including the bannerfin shiner (*Cyprinella leedsi*), blackbanded darter (*Percina nigrofasciata*), and channel catfish (*Ictalurus punctatus*), exhibited a distinct longitudinal zonation, being more abundant either towards the headwaters or towards the stream mouth. Most of the more common species, however, were abundant throughout the stream.

Seventeen species were collected by hoopnetting (Table 5-53). The greatest number of fish (96) and greatest number of species (13) were collected from Station 06, at the mouth of Beaver Dam Creek. While Stations 02, 03, and 04 were sampled for only four months due to the high potential for alligator mortality by drowning in the hoopnets, they yielded a total of 11 species and 99 individuals, indicating that fish were abundant at these stations.

For further analysis, the hoopnetting data were converted to CPUE (expressed as number caught per net per day; Table 5-54). Mean CPUE was highly variable. However, catch rates

Table 5-50. Total Number of Fish and Species Collected by Electrofishing in Beaver Dam Creek, September 1988-February 1990

	Stations						All Stations
Species	**01**	**02**	**03**	**04**	**05**	**06**	**Combined**
longnose gar		1	8	9	10	13	41
Florida gar		7	3	18	3		31
bowfin	4	19	2	16		2	43
American eel	1	2	1	2	5	3	14
American shad				3		12	15
gizzard shad	2		3	16	5	7	33
threadfin shad		3			4	3	10
redfin pickerel	1				2		3
chain pickerel	2	5			1		8
unidentified Cyprinidae[a]					1		1
common carp					1	1	2
golden shiner		2			2		4
bannerfin shiner	4	1	5		37	53	100
dusky shiner			1	1	16		18
spottail shiner	2	2	3		12	16	35
whitefin shiner	1	13	18	1	28	24	85
yellowfin shiner	1				4		5
coastal shiner	20	77	58	27	131	34	347
creek chubsucker		2					2
lake chubsucker	3	15			2		20
northern hogsucker	2						2
spotted sucker	38	102	56	76	31	64	367
silver redhorse		1		1	1	4	7
white catfish				1	1		2
yellow bullhead	1	6	1	1			9
flat bullhead		1	1		5	5	12
channel catfish	1	3	1	2	4	19	30
tadpole madtom							1
speckled madtom							1
lined topminnow		2		3			5
mosquitofish	1			1			2
brook silverside	1		2	4	2		9
stripped bass						1	1
redbreast sunfish	32	69	87	29	87	23	327
warmouth	1	11	7	11	1		31
bluegill	5	11	1	22	8	3	50
dollar sunfish	1	15	4	5			25
redear sunfish	3	5	2	15	7	6	38
spotted sunfish	14	102	11	34	48	5	214
largemouth bass	7	56	35	62	36	18	214
black crappie		1	2	5	2	1	11
yellow perch	1					1	2
blackbanded darter	8	22	7	5	10	2	54
striped mullet	10	5	8	8	24	8	63
total number	167	561	327	378	532	329	2294
total number of species	27	29	25	27	32	26	43

[a]Not included in taxa count.

Table 5-51. Electrofishing CPUE (No./100 m) at Stations 01-06 in Beaver Dam Creek, September 1988-February 1990

Species	Stations 01	02	03	04	05	06	All Stations Combined
longnose gar		0.02	0.15	0.17	0.19	0.24	0.13
Florida gar		0.13	0.06	0.33	0.06		0.10
bowfin	0.07	0.35	0.04	0.30		0.04	0.13
American eel	0.02	0.04	0.02	0.04	0.09	0.06	0.04
American shad				0.06		0.22	0.05
gizzard shad	0.04		0.06	0.30	0.09	0.13	0.10
threadfin shad		0.06			0.07	0.06	0.03
redfin pickerel	0.02				0.04		0.01
chain pickerel	0.04	0.09			0.02		0.02
unidentified Cyprinidae					0.02		<0.01
common carp					0.02	0.02	0.01
golden shiner		0.04			0.04		0.01
bannerfin shiner	0.07	0.02	0.09		0.69	0.98	0.31
dusky shiner			0.02	0.02	0.30		0.06
spottail shiner	0.04	0.04	0.06		0.22	0.30	0.11
whitefin shiner	0.02	0.24	0.33	0.02	0.52	0.44	0.26
yellowfin shiner	0.02				0.07		0.02
coastal shiner	0.37	1.43	1.07	0.50	2.43	0.63	1.07
creek chubsucker		0.04					0.01
lake chubsucker	0.06	0.28			0.04		0.06
northern hogsucker	0.04						0.01
spotted sucker	0.70	1.89	1.04	1.41	0.57	1.19	1.13
silver redhorse		0.02		0.02	0.02	0.07	0.02
white catfish				0.02	0.02		0.01
yellow bullhead	0.02	0.11	0.02	0.02			0.03
flat bullhead		0.02	0.02		0.09	0.09	0.04
channel catfish	0.02	0.06	0.02	0.04	0.07	0.35	0.09
tadpole madtom					0.02		<0.01
speckled madtom						0.02	<0.01
lined topminnow		0.04		0.06			0.02
mosquitofish	0.02			0.02			0.01
brook silverside	0.02		0.04	0.07	0.04		0.03
striped bass						0.02	<0.01
redbreast sunfish	0.59	1.28	1.61	0.54	1.61	0.43	1.01
warmouth	0.02	0.20	0.13	0.20	0.02		0.10
bluegill	0.09	0.20	0.02	0.41	0.16	0.06	0.15
dollar sunfish	0.02	0.28	0.07	0.09			0.08
redear sunfish	0.06	0.09	0.04	0.28	0.13	0.11	0.12
spotted sunfish	0.26	1.89	0.20	0.63	0.89	0.09	0.66
largemouth bass	0.13	1.04	0.65	1.15	0.67	0.33	0.66
black crappie		0.02	0.04	0.09	0.04	0.02	0.03
yellow perch	0.02					0.02	0.01
blackbanded darter	0.15	0.41	0.13	0.09	0.19	0.04	0.17
striped mullet	0.19	0.09	0.15	0.15	0.4	0.15	0.19
total no. fish/100 m	3.09	10.39	6.05	7.00	9.85	6.09	7.08

Table 5-52. Relative Abundance (Percent Composition) of Species Collected by Electrofishing at Stations 01-06 in Beaver Dam Creek, September 1988-February 1990

	Stations						All Stations
Species	01	02	03	04	05	06	Combined
longnose gar		0.18	2.45	2.38	1.88	3.95	1.79
Florida gar		1.25	0.92	4.76	0.56		1.35
bowfin	2.40	3.39	0.61	4.23		0.61	1.87
American eel	0.60	0.36	0.31	0.53	0.94	0.91	0.61
American shad				0.79		3.65	0.65
gizzard shad	1.20		0.92	4.23	0.94	2.13	1.44
threadfin shad		0.53			0.75	0.91	0.44
redfin pickerel	0.60				0.38		0.13
chain pickerel	1.20	0.89			0.19		0.35
unidentified Cyprinidae					0.19		0.04
common carp					0.19	0.30	0.09
golden shiner		0.36			0.38		0.17
bannerfin shiner	2.40	0.18	1.53		6.95	16.11	4.36
dusky shiner			0.31	0.26	3.01		0.78
spottail shiner	1.20	0.36	0.92		2.26	4.86	1.53
whitefin shiner	0.60	2.32	5.5	0.26	5.26	7.29	3.71
yellowfin shiner	0.60				0.75		0.22
coastal shiner	11.98	13.73	17.74	7.14	24.62	10.33	15.13
creek chubsucker		0.36					0.09
lake chubsucker	1.80	2.67			0.38		0.87
northern hogsucker	1.20						0.09
spotted sucker	22.75	18.18	17.13	20.11	5.83	19.45	16.00
silver redhorse		0.18		0.26	0.19	1.22	0.31
white catfish				0.26	0.19		0.09
yellow bullhead	0.60	1.07	0.31	0.26			0.39
flat bullhead		0.18	0.31		0.94	1.52	0.52
channel catfish	0.60	0.53	0.31	0.53	0.75	5.78	1.31
tadpole madtom					0.19		0.04
speckled madtom						0.30	0.04
lined topminnow		0.36		0.79			0.22
mosquitofish	0.60			0.26			0.09
brook silverside	0.60		0.61	1.06	0.38		0.39
striped bass						0.30	0.04
redbreast sunfish	19.16	12.30	26.61	7.67	16.35	6.99	14.25
warmouth	0.60	1.96	2.14	2.91	0.19		1.35
bluegill	2.99	1.96	0.31	5.82	1.50	0.91	2.18
dollar sunfish	0.60	2.67	1.22	1.32			1.09
redear sunfish	1.80	0.89	0.61	3.97	1.32	1.82	1.66
spotted sunfish	8.38	18.18	3.36	8.99	9.02	1.52	9.33
largemouth bass	4.19	9.98	10.70	16.40	6.77	5.47	9.33
black crappie		0.18	0.61	1.32	0.38	0.30	0.48
yellow perch	0.60					0.30	0.09
blackbanded darter	4.79	3.92	2.14	1.32	1.88	0.61	2.35
striped mullet	5.99	0.89	2.45	2.12	4.51	2.43	2.75
total percent	100.03	100.01	100.03	99.95	100.02	99.97	100.01
total number	167	561	327	378	532	329	2294

Table 5-53. Total Number of Fish and Species Collected by Hoopnetting in Beaver Dam Creek (Hoopnets were not Set During March and April 1989), September 1988-February 1990

	Stations						
Species	**01**	**02**[a]	**03**[a]	**04**[a]	**05**	**06**	**All Stations Combined**
longnose gar					1	3	4
Florida gar	1		1	1		1	4
gizzard shad						1	1
chain pickerel						1	1
spotted sucker				1			1
snail bullhead	1					7	8
white catfish	1				3	7	11
yellow bullhead	1	4		1		1	7
flat bullhead		3		1	4	6	14
channel catfish	54	20	14	6	50	56	200
hybrid *Morone*						1	1
flier				1			1
Lepomis sp.[b]	1			1			2
redbreast sunfish	3	20		1	5	6	35
bluegill	1	4	1	4	3	4	17
redear sunfish	1	3		1	1	2	8
spotted sunfish	3			1	2		6
Pomoxis sp.[b]		1					1
black crappie	1	4		5	1		11
total number	68	59	16	24	70	96	333
total no. species	10	7	3	11	9	13	17

[a]Sampling at these stations was discontinued after December due to the danger hoopnets presented to the alligator population.
[b]Not included in taxa count.

Table 5-54. Hoopnetting CPUE (No./Net Day) at Stations 01-06 in Beaver Dam Creek, September 1988-February 1990[a]

	Stations					
Species	**01**	**02[a]**	**03[a]**	**04[a]**	**05**	**06**
longnose gar					0.01	0.03
Florida gar	0.01		0.04	0.04		0.01
gizzard shad						0.01
chain pickerel						0.01
spotted sucker				0.04		
snail bullhead	0.01					0.07
white catfish	0.01				0.03	0.07
yellow bullhead	0.01	0.17		0.04		0.01
flat bullhead		0.13		0.04	0.04	0.06
channel catfish	0.56	0.83	0.58	0.25	0.52	0.58
hybrid *Morone*						0.01
flier				0.04		
Lepomis sp.	0.01			0.04		
redbreast sunfish	0.03	0.83		0.04	0.05	0.06
bluegill	0.01	0.17	0.04	0.17	0.03	0.04
redear sunfish	0.01	0.13		0.04	0.01	0.02
spotted sunfish	0.03			0.04	0.02	
Pomoxis sp.		0.04				
black crappie	0.01	0.17		0.21	0.01	
total CPUE	0.71	246	0.67	1.00	0.73	1.00

[a]Stations 02, 03, and 04 discontinued after four months. No nets were set in March or April 1989.

were generally higher during the warmer months. Zero catch rates occurred most often during the fall and winter of 1988-1989 (Figure 5-19), especially at Station 01, probably because of seasonal reductions in fish activity and movement.

Channel catfish constituted 60% of the total hoopnetting catch, followed by redbreast sunfish (10.5%), bluegill (*Lepomis macrochirus*) (5.1%), and flat bullhead (*Ictalurus platycephalus*) (4.2%) (Table 5-55). In addition, white catfish (*Ictalurus catus*) were abundant at Stations 05 and 06, perhaps because this species entered the lower reaches of Beaver Dam Creek from the Savannah River.

One objective of the 316 (a) Demonstration was to determine the health of the Beaver Dam Creek fish community. This was done by comparing fish communities in Beaver Dam Creek to fish communities in relatively unimpacted streams. These included several nonthermal streams on the SRS and several other southeastern streams described in the literature (summarized in Paller et al. 1988) (Table 5-56).

Total number of species ranged from 21 in Upper Three Runs Creek to 59 in Steel Creek. The total in Beaver Dam Creek, 46, was near the maximum. The high species number in Beaver Dam Creek was partly a function of sampling effort, but it also reflects the habitat diversity of this stream, which contains swamp, slough, and stream environments.

Sunfishes and black bass dominated the fish assemblage in Beaver Dam Creek (38% of the collections), followed by minnows (23%), suckers (15%), and catfishes (11%) (Table 5-56). The relative abundance of minnows and sunfishes was within the range of the other southeastern streams, but the relative abundance of suckers and catfishes was greater. The high relative abundance of catfishes in Beaver Dam Creek was partly due to the intensive hoop-

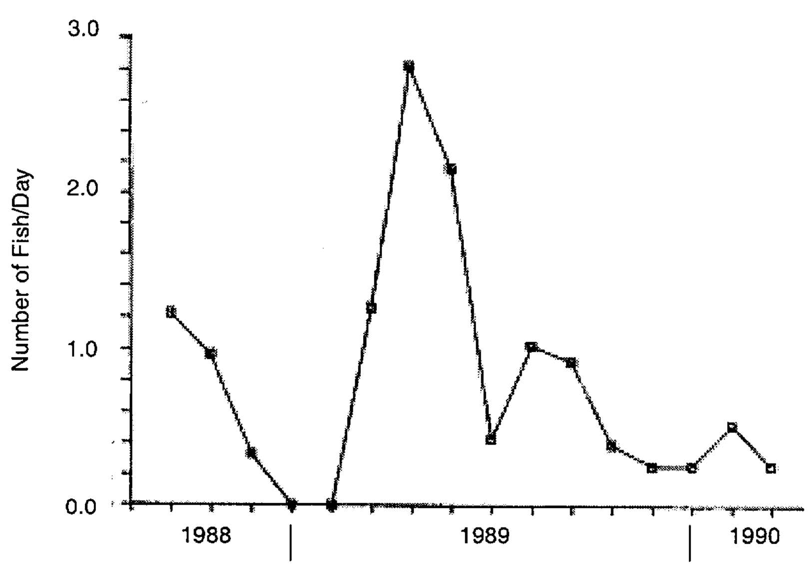

Figure 5-19. Monthly Mean Hoopnetting Catch Per Unit Effort (No./Net Day) in Beaver Dam Creek, September 1988-February 1990

Table 5-55. Relative Abundance (Percent Composition) of Species Collected by Hoopnetting at Stations 01-06 in Beaver Dam Creek, September 1988-February 1990[a]

	Stations						
Species	**01**	**02**[a]	**03**[a]	**04**[a]	**05**	**06**	**All Stations Combined**
longnose gar					1.43	3.13	1.20
Florida gar	1.47		6.25	4.17		1.04	1.20
gizzard shad						1.04	0.30
chain pickerel						1.04	0.30
spotted sucker				4.17			0.30
snail bullhead	1.47					7.29	2.40
white catfish	1.47				4.29	7.29	3.30
yellow bullhead	1.47	6.78		4.17		1.04	2.10
flat bullhead		5.08		4.17	5.71	6.25	4.20
channel catfish	79.41	33.90	87.50	25.00	71.43	58.33	60.06
hybrid *Morone*						1.04	0.30
flier				4.17			0.30
Lepomis sp.	1.47			4.17			0.60
redbreast	4.41	33.90		4.17	7.14	6.25	10.51
bluegill	1.47	6.78	6.25	16.66	4.29	4.17	5.10
redear sunfish	1.47	5.08		4.17	1.43	2.08	2.40
spotted sunfish	4.41			4.17	2.86		1.80
Pomoxis sp.		1.69					0.30
black crappie	1.47	6.78		20.83	1.43		3.30
total percent	99.99	99.99	100.00	100.02	100.01	99.99	99.97
total number	68	59	16	24	70	96	333

[a]Stations 02, 03, and 04 discontinued after four months. No nets were set in March or April 1989.

Table 5-56. Species Number and Relative Abundance (Percent Composition) of Fishes in Nine Southeastern Streams. Relative Abundances are Based on the Number of Individual Fish in Each Family

	Beaver Dam Creek[a]		Shoal Creek, AL[b]		Barbaree Creek, AL[c]		Tombigbee Waterway, TN[d]		Duke Swamp, NC[e]	
Family	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
bowfin	1	2							1	1
gars	2	3					1	<1	1	<1
freshwater eels	1	<1					1	<1	1	2
herrings	3	2	1	<1			1	<1		
mudminnow									1	4
pikes	2	<1	1	<1					2	28
suckers	5	15	3	7	2	3	4	2	1	10
minnows	8	23	14	55	10	81	18	72	1	3
catfishes	7	11	2	1	1	<1	4	4	3	10
needlefishes										
killifishes	1	<1	1	<1			2	2		
livebearers	1	<1					1	5	1	<1
pirate perch									1	21
cavefishes									1	2
silversides	1	<1								
temperate basses	2	<1								
sunfishes and black basses	9	38	11	23	6	2	6	7	9	18
perches	2	2	7	9	5	11	11	6	1	<1
drums							1	2		
mullets	1	2								
sculpins			1	5	1	3				
total	46		41		25		49		24	

[a]Specht et al. 1990, electrofishing and hoopnetting combined.
[b]Kelly et al. 1981.
[c]Boschung and O'Neil 1981.
[d]Mundy and Boschung 1981.
[e]Pardue and Huish 1981.

Table 5-56. (cont)

Family	Haggard Mill Creek[f]		Steel Creek[g]		Lower Three Runs[h]		Upper Three Runs[h]	
	No.	%	No.	%	No.	%	No.	%
bowfin	1	<1	1	1	1	1	1	3
gars			2	1	1	<1		
freshwater eels	1	6	1	1	1	6	1	10
herrings	1	1	2	<1			1	2
mudminnow	1	10	1	<1	1	<1		
pikes	2	11	1	1	1	1	1	2
suckers	1	3	4	6	3	8	3	13
minnows	2	1	10	40	5	1	2	16
catfishes	3	4	9	2	5	2	2	2
needlefishes			1	<1	1	<1		
killifishes			2	<1			1	2
livebearers	1	8	1	2	1	1		
pirate perch	1	24	1	2	1	4	1	4
cavefishes	1	8	1	<1				
silversides			1	1	1	<1	1	1
temperate basses			1	<1				
sunfishes and black basses	11	22	13	39	9	69	7	46
perches	2	4	6	3	4	6		
drums								
mullets			1	<1				
sculpins			1	<1				
total	28		59		35		21	

[f]Pardue and Huish 1981.
[g]Paller et al. 1988.
[h]Paller and Saul 1986.

net sampling effort in this stream but also indicates the abundance of these fish. Catfishes and spotted sucker may enter Beaver Dam Creek from the Savannah River, where both are common (Paller and Saul 1986).Comparisons of CPUE were restricted to the onsite streams where sampling methods were relatively consistent and similar to those in the 316(a) Demonstration. Electrofishing CPUE in Upper Three Runs Creek, Steel Creek, and Lower Three Runs Creek ranged from 0.3–26.7/100 m. CPUE in Beaver Dam Creek (0.7-16.6 fish/100 m) fell within this range. Mean quarterly hoopnetting CPUE ranged from 0.43 fish/net day in Upper Three Runs to 0.75 fish/net day in Lower Three Runs. Mean hoopnetting CPUE in Beaver Dam Creek was somewhat higher (1.38 fish/net day), reflecting the abundance of catfishes in Beaver Dam Creek.

In summary, the fish assemblage in Beaver Dam Creek compared favorably with the fish assemblages in other southeastern streams. Taxa richness, relative abundance of major taxa, densities, and catch rates in Beaver Dam Creek were within the ranges measured in the other streams.

Ichthyoplankton

Plankton nets (0.505-mm mesh) were used to collect ichthyoplankton (drifting fish larvae and eggs) weekly. Only one complete spawning season (February through July 1989) was surveyed.

A total of 82 larval fish and 15 fish eggs, representing at least 9 taxa, were collected from Beaver Dam Creek during February through July 1989 (Table 5-57). Station 06 had the most ichthyoplankton and the most taxa, followed by Station 05. Stations 01 and 03 had only five specimens each. The greatest ichthyoplankton catches were in April (55 specimens) and May (17 specimens) (Table 5-58). Centrarchids (primarily *Lepomis* spp., bluegill, and pygmy sunfish [*Elassoma* spp.]) were the most abundant group, composing approximately 53% of the total number of larvae and eggs. Other relatively abundant taxa were percids (19.0%) and suckers (12.4%).

Mean ichthyoplankton densities ranged from 1.7/1000 m^3 at Station 03 to 15.8/1000 m^3 at Station 06 (Table 5-59). The highest average monthly density for the creek as a whole was in April (21.4/1000 m^3). Average densities for the other months ranged from 1.6/1000 m^3 in July to 6.4/1000 m^3 in May.

As with the adult fish, the ichthyoplankton assemblage in Beaver Dam Creek was compared to ichthyoplankton assemblages in other creeks. The nonthermal streams included in this comparison were Steel Creek, Upper Three Runs, and Lower Three Runs. The number of taxa collected from these streams during 1984 and 1985 ranged from 8-15 compared with the 9 taxa collected from Beaver Dam Creek in 1989 (Table 5-60). Relative abundance in Beaver Dam Creek during 1989 was similar to relative abundance in the other streams during 1984 (dominant taxa were sunfishes, darters, and suckers) but not 1985. However, all streams exhibited high interannual variability in species composition and numbers (Table 5-60), making it difficult to evaluate the significance of differences among streams.

Table 5-57. Total Number of Ichthyoplankton Collected from Stations 01-06 in Beaver Dam Creek, February-July 1989

		Stations						
Taxon	**Stage**	01	02	03	04	0	06	**Total No.**
Clupeidae	Larva						1	1
Catostomidae	Larva		1		1		2	4
Erimyzon	Larva					1		1
spotted sucker	Larva			1	2	3	1	7
Cyprinidae	Larva		1					1
common carp	Larva	1						1
ironcolor shiner	Larva		1				1	2
Centrarchidae	Larva					1	19	20
Elassoma	Larva						11	11
Lepomis	Larva	1	5	1		2		9
bluegill	Larva	1	1	1	3	2	1	9
Pomoxis	Larva						2	2
Percidae	Larva						1	1
Percina	Larva			1	3	2	1	7
darter[a]	Egg		4	1		6		11
unknown	Larva	2	1			2	1	6
unknown	Egg				1	2	1	4
total number		5	14	5	10	21	42	97
total taxa[b]		2	4	3	3	4	7	9

[a]Darter = *Percina* sp. or *Etheostoma* sp.
[b]Higher taxon not counted in total if lower taxon present.

Table 5-58. Monthly Ichthyoplankton Collections from Beaver Dam Creek, February-July 1989

Taxa	**February**	**March**	**April**	**May**	**June**	**July**
darters	6	3	5	3	2	0
sunfish	0	0	31	11	3	4
minnow	0	0	1	0	2	0
sucker	0	0	11	1	0	0
other	0	5	7	2	0	0
total no.	6	8	55	17	7	4

Table 5-59. Average Densities (Organisms/1000m^3) of Ichthyoplankton Collected from Stations 01-06 in Beaver Dam Creek, February-July 1989

		Station						
Species	**Stage**	**01**	**02**	**03**	**04**	**05**	**06**	**Total Density**
Clupeidae	Larva						0.38	0.06
Catostomidae	Larva		0.36		0.31		0.78	0.24
Erimyzon	Larva					0.37		0.06
spotted sucker	Larva			0.38	0.76	1.02	0.41	0.43
Cyprinidae	Larva		0.50					0.08
common carp	Larva	0.37						0.06
ironcolor shiner	Larva		0.34				0.35	0.11
Centrarchidae	Larva					0.34	6.86	1.20
Elassoma	Larva						4.45	0.74
Lepomis	Larva	0.32	1.75	0.37		0.64		0.51
bluegill	Larva	0.37	0.34	0.35	1.06	0.63	0.40	0.52
Pomoxis	Larva						0.73	0.12
Percidae	Larva						0.28	0.05
Percina	Larva			0.27	1.06	0.67	0.43	0.40
darter	Egg		1.16	0.32		1.83		0.55
unknown	Larva	0.76	0.34			0.72	0.35	0.36
unknown	Egg				0.32	0.71	0.41	0.24
mean total density[a]		1.82	4.79	1.70	3.52	6.93	15.84	5.73
standard deviation		5.6	11.34	5.30	8.99	13.39	53.81	

[a]Differences are due to rounding error.

Table 5-60. Number and Percent Composition of Ichthyoplankton Collected from Steel Creek, Upper Three Runs, and Lower Three Runs, 1984-1985

	Steel Creek				Upper Three Runs				Lower Three Runs			
	1984		1985		1984		1985		1984		1985	
Taxa	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
Clupeidae												
American shad	15	1.0	103	15.1			9	4.7	1	0.1	2	0.4
gizzard shad and/ or threadfin shad	12	0.8			12	3.4			23	1.6		
blueback herring	65	4.3	116	17.1	4	1.1	10	5.2	20	1.3	5	1.1
unidentified herring or shad	14	0.9	6	0.9	4	1.1	2	1.0	16	1.1		
Catostomidae												
spotted sucker	14	0.9	7	1.0	234	65.4	101	52.3	7	0.5	5	1.1
unidentified suckers	57	3.8	2	0.3	3	0.8	2	1.0	15	1.0	1	0.2
Aphredoderidae												
pirate perch	42	2.8	1	0.1								
Centrarchidae												
sunfish and bass	449	29.6	79	11.6	4	1.1	2	1.0	671	45.2	57	12.8
crappie	34	2.2	7	1.0	51	14.2	2	1.0	266	17.9	46	10.3
Percidae												
yellow perch	14	0.9	11	1.6	2	0.6			29	2.0	7	1.6
darters	186	12.2	170	25.0	20	5.6	47	24.4	160	10.8	84	18.9
Umbridae												
mudminnow	5	0.3										
Amblyopsidae												
swampfish	8	0.5	1	0.1								
Cyprinidae												
minnows	420	25.7	105	15.4	17	4.7	4	2.1	24	1.6	26	5.8
topminnow			1	0.1								
carp			2	0.3	2	0.6						
Esocidae												
pickerel	2	0.1	1	0.1								
Atherinidae												
brook silverside	32	2.1	11	1.6					78	5.3	96	21.6
Ictaluridae												
catfish and bull-head	4	0.3	1	0.1								

Table 5-60. (cont)

	Steel Creek				Upper Three Runs				Lower Three Runs			
	1984		1985		1984		1985		1984		1985	
Taxa	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Belonidae												
needlefish	2	0.1										
Percichthyidae												
striped bass			1	0.1								
unidentified ichthyoplankton[a]	138	9.1	55	8.1	5	1.4	14	7.3	172	11.6	115	25.8
total	1519[b]	99.5	680	100.00	358	100.00	193	100.00	1483	100.1	446	100.00
total taxa[c]	15		15		8		8		11		11	

Source: Specht (1987).
[a]principally eggs.
[b]total incorrect in original table; actual total is 1,513.
[c]higher taxon not counted if lower taxa were present.

Comprehensive Cooling Water Study

Adult and Juvenile fish

The CCWS involved two adult/juvenile fish sampling programs on Beaver Dam Creek: one quarterly and one reporting on the distribution of fish during the winter (Paller and Osteen 1985; Paller and Saul 1986). For the quarterly study, two hoopnets were placed in the mouth of Beaver Dam Creek and five sites were electrofished four times a year. Four of the electrofishing sites corresponded to Stations 03-06 of the 316(a) Demonstration. The overwintering study included one electrofishing sample station in the mouth of Beaver Dam Creek during 1984 and three during 1985 in the mouth (Station 06), lower reaches of the floodplain swamp (roughly analogous to Station 05), and upper reaches of the floodplain (roughly analogous to Station 02). In addition, hoopnets were set in the mouth of the creek during the 1985 overwintering study.

Electrofishing CPUE near the mouth of Beaver Dam Creek was considerably lower during the quarterly (1.6/100 m) and overwintering (1.4/100 m) studies than during the 316(a) Demonstration (7.1/100 m). Similar trends also were observed at Stations 02, 03, 04, 05, and 06. The studies used the same sampling methods and equipment, suggesting that differences in sampling efficiency were not responsible for the differences in CPUE.

Electrofishing data from the overwintering study indicated that the dominant species, in rank order, at Stations 02, 05, and 06 were spotted sunfish, redbreast sunfish, largemouth bass, bowfin, (*Amia calva*) gizzard shad (*Dorosoma cepedianum*) and bluegill (Table 5-61). Dominant species at the same stations during the 316(a) Demonstration were spotted sucker, redbreast sunfish, largemouth bass, spotted sunfish, striped mullet (*Mugil cephalus*), and bluegill. Definite reasons for these differences are unknown, but interannual

Table 5-61. Dominant Species[a] Collected from Beaver Dam Creek by Electrofishing at Stations 02, 05, and 06 during the Overwintering Study (1984-1985), and at Each Station during the 316(a) Demonstration

Species	
November 1984–April 1985[b]	**September 1988–February 1990[c]**
spotted sunfish (21.5%)	spotted sucker (16.0%)
redbreast sunfish (19.7%)	redbreast sunfish (14.3%)
largemouth bass (9.0%)	largemouth bass (9.3%)
bowfin (7.4%)	spotted sunfish (9.3%)
gizzard shad (6.9%)	striped mullet (2.8%)
bluegill[d] (2.7%)	bluegill (2.2%)

[a]Excluding minnows and other small fishes.
[b]Paller and Saul 1986.
[c]Specht et al. 1990.
[d]Bluegill ranked eighth.

variations in recruitment and changes in habitat between studies (e.g., aquatic plant growth) are possible causes for sampling variation.

Mean overall hoopnetting CPUE for the overwintering study (1.2 fish/net day) was approximately the same as for the 316(a) Demonstration (1.0 fish/net day); CPUE during both studies was higher than during the quarterly study (0.6 fish/net day). Channel catfish were dominant during the overwintering program, but flat bullhead (*Ameiurus platycephalus*), black crappie (*Pomoxis nigromaculatus*), redear sunfish (*Lepomis microlophus*), and blueback herring (*Alosa aestivalis*) constituted substantial proportions of the catch (Table 5-62). Channel catfish were also strongly dominant during the 316(a) Demonstration. In general, all these studies revealed the presence of diverse fish assemblages in Beaver Dam Creek over time.

Ichthyoplankton

Larval fish and fish eggs were collected from five sample stations in Beaver Dam Creek during the 1984-1985 Comprehensive Cooling Water Study. Four of these sample stations were analogous to the stations sampled in the 316(a) demonstration in 1989 (Stations 03, 04, 05, and 06). Sampling methodology and effort was similar for both studies.

More ichthyoplankton were collected in 1984 (334 individuals) (Table 5-63) and 1985 (253 individuals) (Table 5-64) than in 1989 (97 individuals). This may be an effect of low water levels during the 1989 spawning season since many species spawn most successfully when floodwaters inundate terrestrial areas (Martin et al. 1981). Relative abundance also differed among years. While sunfishes (Centrarchidae) were dominant during 1984 and 1989 (Table 5-57 and Table 5-63), they constituted a comparatively small proportion of the total catch in 1985 (11.4%, Table 5-64). Similarly, the relative abundance of clupeids (herring and shad), suckers, darters, and brook silversides varied substantially among years.

Table 5-62. Dominant Species Collected from Hoopnets at Station 06 during the CCWS Overwintering Study (1984-1985) and the 316(a) Demonstration

	Relative Abundance (%)	
Species	**Nov 1984-Apr 1985[a]**	**Sept 1988-Feb 1990[b]**
channel catfish	23.3	58.3
snail bullhead		7.3
white catfish		7.3
flat bullhead	17.8	6.2
black crappie	13.7	
redear sunfish	8.2	
redbreast sunfish		6.2
blueback herring	8.2	
bluegill[c]	(2.7)	4.2

[a]Paller and Saul 1986.
[b]Specht et al. 1990.
[c]Bluegill ranked tenth in abundance for November 1984-April 1985 and sixth for September 1988-February 1990.

Table 5-63. Number and Percent Composition of Ichthyoplankton Collected from Beaver Dam Creek, 1984

Taxa	Number	Percent	Percent by Family[a]
Clupeidae			10.2
American shad	1	0.3	
gizzard shad and threadfin shad	19	5.7	
blueback herring	9	2.7	
unid. herring or shad	5	1.5	
Catostomidae			1.2
spotted sucker	4	1.2	
Aphredoderidae			
pirate perch	3	0.9	
Centrarchidae			60.5
sunfish and bass	177	53.0	
crappie	25	7.5	
Percidae			6.6
yellow perch	1	0.3	
darters	21	6.3	
Cyprinidae			6.6
minnows	19	5.7	
topminnow	2	0.6	
carp	1	0.3	
Atherinidae			
brook silverside	11	3.3	
Percichthyidae			
striped bass	1	0.3	
unidentified ichthyoplankton[b]	35	10.5	
total	334	100.0	

Source: Specht et al. 1987.
[a]Calculated to compare with current program.
[b]Principally eggs.

Table 5-64. Number and Percent Composition of Ichthyoplankton Collected from Beaver Dam Creek, 1985

Taxa	Number	Percent	Percent by Family[a]
Clupeidae			33.2
American shad	7	2.8	
blueback herring	74	29.2	
unid. herring or shad	3	1.2	
Catostomidae			2.0
spotted sucker	5	2.0	
unid. suckers			
Centrarchidae			11.4
sunfish and bass	13	5.1	
crappie	16	6.3	
Percidae			4.0
yellow perch	1	0.4	
darter	9	3.6	
Cyprinidae			1.6
minnows	2	0.8	
topminnow	1	0.4	
carp	1	0.4	
Esocidae			
pickerel	1	0.4	
Ictaluridae			
catfish and bullhead	1	0.4	
unidentified ichthyoplankton[b]	118	46.6	
total	253	100.0	

Source: Specht et al. 1987.
[a]Calculated to compare with current program.
[b]principally eggs.

Mean ichthyoplankton densities in 1984, 1985, and 1989 were highest in the creek mouth and the stations (04 and 05) in the lower reaches of Beaver Dam Creek (1989 data in Table 5-59). The lowest densities occurred in the upper reaches of Beaver Dam Creek during all years.

The preceding comparisons indicate considerable annual variability in ichthyoplankton density and species composition. Some of this variability stems from sampling error, but some probably reflects real differences in ichthyoplankton abundance. Water level is known to strongly influence the attractiveness of tributary streams to spawning anadromous fish such as blueback herring (Frankensteen 1976) and the spawning success of other species that require coves, backwaters, shallows, and inundated vegetation where larvae and eggs are sheltered and protected from currents (Martin et al. 1981). A noteworthy trend that was consistent across all years was greater densities and species richness in the lower reaches of Beaver Dam Creek reflecting the relative importance of this portion of the stream as a spawning area for some species.

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5.3 Fourmile Branch

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Drainage Description and Surface Hydrology

General Description

Fourmile Branch originates near the center of SRS and flows southwesterly for approximately 24 km (15 mi) (Figure 5-20). The watershed, which drains about 57 km^2 (22 mi^2), includes several SRS facilities: C Area (reactor), F and H Areas (separations facilities, tank farms, and seepage basins), and the Solid Waste Disposal Facility (SWDF). At its headwaters, Fourmile Branch is a small blackwater stream that is relatively unimpacted by SRS operations (Specht 1987).

In its lower reaches, Fourmile Branch broadens and flows through a delta that has been formed by the deposition of sediments. Although most of the flow through the delta is in one main channel, the delta has numerous standing dead trees, logs, stumps, and cypress trees, which provide structure and reduce water velocity in some areas. Downstream of the delta the creek flows in one main channel; the majority of the flow discharges into the Savannah River at river kilometer 244.7 (river mile 152.1), while a small portion of the creek flows west and enters Beaver Dam Creek. When the Savannah River floods, water from Fourmile Branch flows along the northern boundary of the floodplain swamp and joins with Pen Branch and Steel Creek instead of flowing directly into the river (Specht 1987).

Effluent Contributions

Fourmile Branch receives effluents from F, H, and C Areas. Before C-Reactor shutdown in 1985 the reactor discharged heated Savannah River water (as hot as 70°C [158°F]) into Fourmile Branch via Castor Creek. Resulting water temperatures were in excess of 60°C

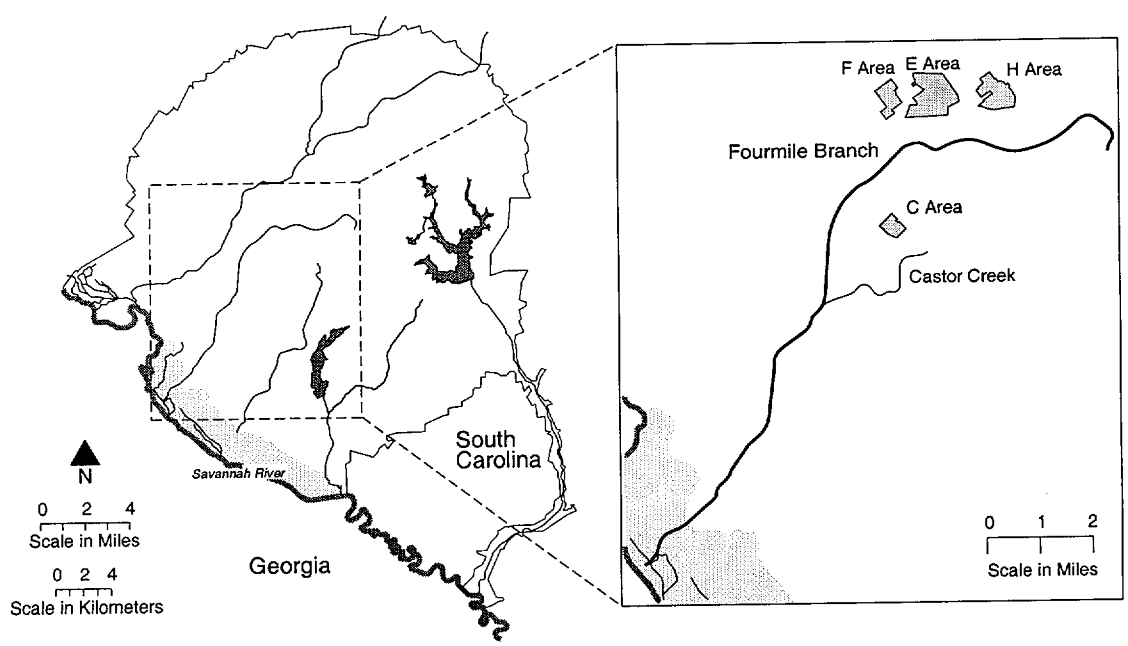

Figure 5-20. Location of Fourmile Branch on SRS

(140°F) in Fourmile Branch just downstream of its confluence with Castor Creek. With the contribution of C-Reactor cooling water, the flow in Fourmile Branch measured about 11.3 m^3/s (400 ft^3/s) (Murphy et al. 1991). The flows and temperatures associated with C-Reactor operations no longer occur.

Prior to 1996, Fourmile Branch received effluents from 16 National Pollutant Discharge Elimination System (NPDES) outfalls in C, F, and H Areas, and Central Shops as well as groundwater from beneath F and H Areas. Until 1985, Fourmile Branch also received thermal effluents from C Reactor. With the new NPDES permit issued in 1996, outfalls were reduced from 16 to 5 due to deletions of waste streams and the consolidation of the outfalls. Effluent from the new 1.05-million gallon per day Centralized Sanitary Wastewater Treatment Facility began discharging to Fourmile Branch in 1995.

Fourmile Branch, either directly or via tributaries, receives the following NPDES-permitted discharges: 186 basin overflows, cooling water, floor drains, steam condensate, process wastewater, laundry effluent, stormwater, sanitary treatment wastewater, ash basin runoff, and lab drains.

Flow Measurements

The U.S. Geological Survey measures flow at several locations on Fourmile Branch. Table 5-65 summarizes flow statistics of Fourmile Branch at Site No. 7 and at SRS Road A-13.2 (Figure 5-21). Records for the most downstream station (Fourmile Branch at Road A-13.2) date back to November 1976. In water year 1995, the mean flow of Fourmile Branch at Road A-13.2 was 1.1 m^3/s (37.3 ft^3/s). Over the period of record (water years 1977-1995) at Road A-13.2, the mean flow was 3.2 m^3/s (113 ft^3/s), the 7-day low flow was 0.22m^3/s (7.6 ft^3/s), and the 7Q10 was 0.23 m^3/s (8.2 ft^3/s). Figure 5-22 and Figure 5-23 show the maximum, minimum, and mean daily flows from October 1982 to September 1995.

Table 5-65. Flow Summary for Fourmile Branch

					Range							
			Mean		Low		High		7Q10		7-Day Low Flow	
Station Name	**Station Number**	**Period of Record**	**cms**	**cfs**	**cms**	**cfs**	**cms**	**cfs**	**cms**	**cfs**	**cms**	**cfs**
Site No. 7	02197342	1972-1995	0.50	17.8	0.08	2.7	23.5	830	0.02	0.58	0.09	3.2
Road A-13.2	02197344	1976-1995	3.2	113	0.19	6.7	34.0	1200	0.23	8.2	0.22	7.6

cms = cubic meters per second.
cfs = cubic feet per second.

	Station Name
01	Site No. 7 at SRS
02	at Road A-13.2 at SRS

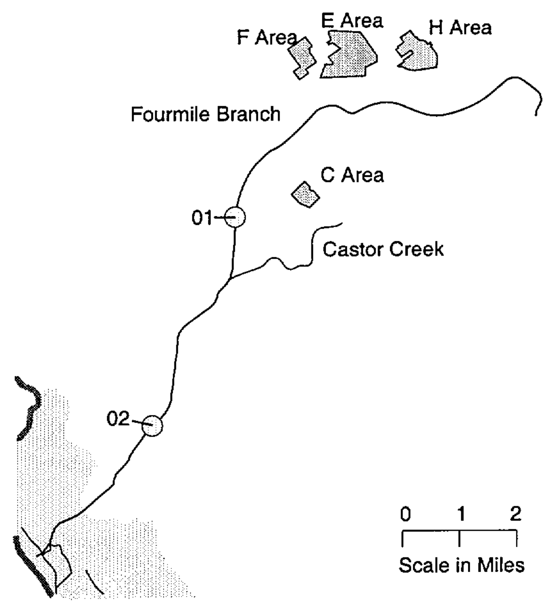

Figure 5-21. Flow Measurement Sampling Stations for Fourmile Branch

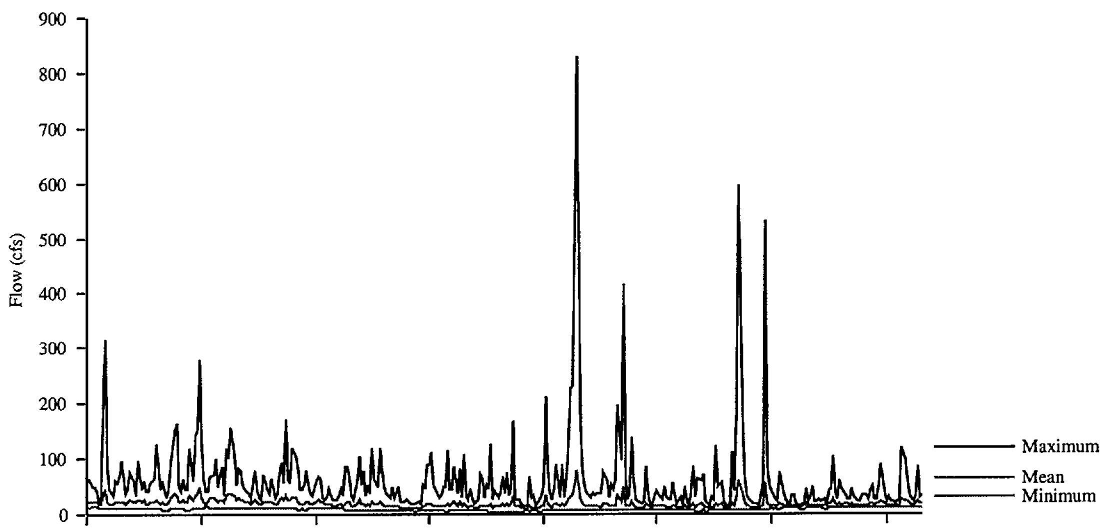

Figure 5-22. Maximum, Mean, and Minimum Flow Measurements for Fourmile Branch at Site No. 7, October 1982-September 1995

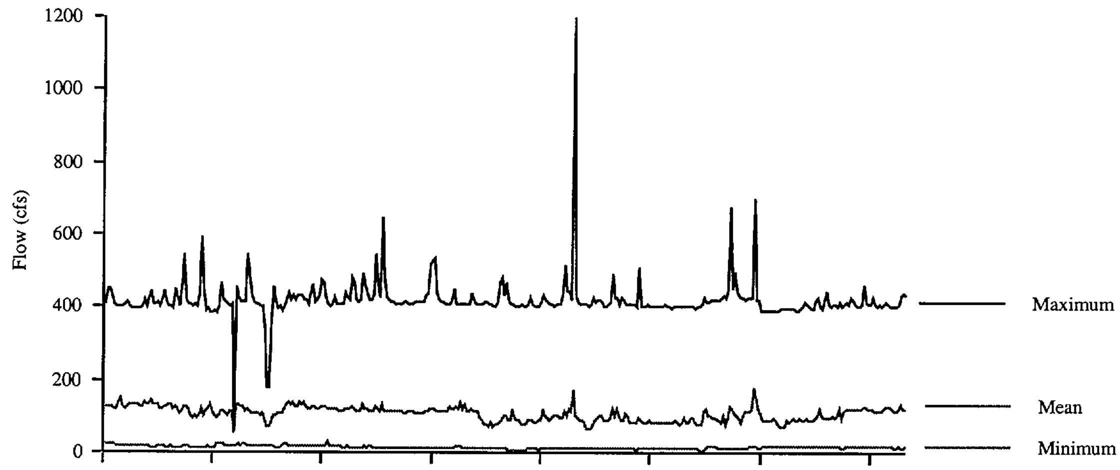

Figure 5-23. Maximum, Mean, and Minimum Flow Measurements for Fourmile Branch at Road A-13.2, October 1982-September 1995

Water Chemistry and Quality

Studies and Monitoring

Water-Quality Monitoring

Westinghouse Savannah River Company's Environmental Monitoring Section has conducted routine water-quality monitoring in Fourmile Branch since 1973. It samples locations on Fourmile Branch—near Road A-7 and near Road A-13.2 — monthly for physical and biological parameters and quarterly for metals (Figure 5-24; 08 and 10). The Environmental Monitoring Section also collects a sample annually from the same locations and analyzes it for pesticides, herbicides, and PCBs. All routine water quality monitoring data reported in the following sections can be found in the annual SRS Environmental Reports.

Comprehensive Cooling Water Study

From 1983 to 1985, the Savannah River Ecology Laboratory (SREL) studied Fourmile Branch as part of the Comprehensive Cooling Water Study (CCWS). The study was to provide "an assessment of the potential effects of present and proposed SRS activities on the quality of waters used for cooling at the SRS" (Newman et al. 1986). The study included sampling the following four locations on Fourmile Branch (Figure 5-24):

1. Fourmile Branch at Road E-1 (02)
2. Fourmile Branch at Road 3, near Fourmile Branch at Road A-7 (08)
3. Fourmile Branch at Castor Creek (09)
4. Fourmile Branch at Road A-13.2, near Fourmile Branch at Road A (11)

	Station Name
01	Upstream H(I)
02	Road E-1, CW3, HW7
03	Road C1
04	Downstream H (III)
05	Road C
06	Upstream F (IV), CW2 & HW2
07	115 TransLine and Downstream F (VI) and CW1, FW4
08	Road A-7
09	Road 3
10	Road A
11	Road A-13.2

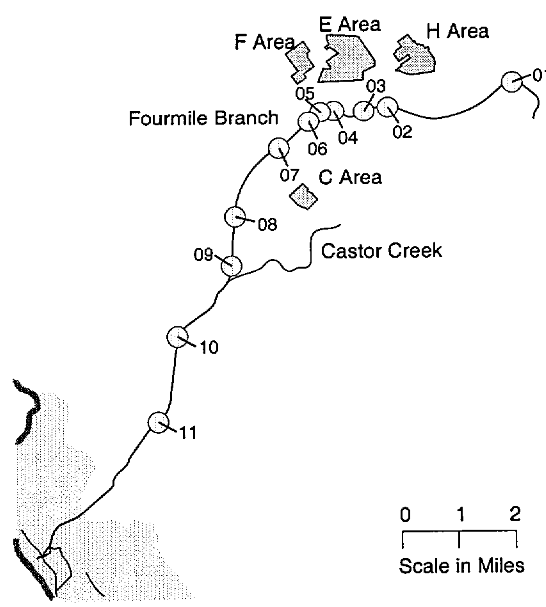

Figure 5-24. Water Quality Monitoring Stations on Fourmile Branch

The data collected from the thermal portions of Fourmile Branch reflect impacts associated with reactor operation and are not relevant to the current conditions of Fourmile Branch. However, because a limited amount of monitoring data are available, portions of the CCWS data will be presented.

Gladden et al. (1985) presented a synopsis of historical water quality monitoring of the Fourmile Branch system prior to the CCWS. Comprehensive results and discussion of CCWS data can be found in Lower (1987).

Priority Pollutant Study

In 1984, a special instream survey of priority pollutants was conducted to determine the levels of volatile, acid, and base/neutral compounds in Fourmile Branch. The sample locations were Fourmile Branch at Road C (05 on map), Road A-7 (08 on map), and Road A (10 on map). Potential sources for organics into Fourmile Branch were discharges from F and H Areas, shallow groundwater outcropping, runoff from precipitation, and input of Savannah River water. The results of this study are in the following sections and in Lower (1987).

Chemical Assessment Studies

Since 1985, three special studies have been conducted on Fourmile Branch to determine the impacts of groundwater contamination on Fourmile Branch. The Savannah River Technology Center (SRTC) conducted two studies in 1988 and 1989 aimed at characterizing the shallow groundwater outcropping into Fourmile Branch and its associated seepline (Looney et al. 1988; Haselow et al. 1990). The third study, (Dixon et al. 1994) which began in 1991, is a continuation of the 1988 and 1989 studies and is aimed at determining whether annual rainfall and natural groundwater flow will dilute and flush the remaining contaminant plume out of the shallow groundwater and Fourmile Branch wetland. The Chemical Assessment Studies later in this section summarize the results of the SRTC studies.

Field Data

Water Temperature

When C-Reactor was operating (from the 1950s to 1985), temperatures in Castor Creek reached in excess of 70°C (158°F), while temperatures in the nonthermal portions of Fourmile Branch averaged 16.9°C (62.4°F) at Fourmile Branch near Road 3 (Table 5-66). After the thermal and nonthermal waters of this system blended, the mean temperature was 39.4°C (102.9°F) (Fourmile Branch at Road A-13.2), and then dropped to 28°C (82.4°F) near the confluence with the Savannah River.

Between C-Reactor's shutdown in 1985 and 1991, temperatures in Fourmile Branch at Road A ranged from 4.2°C to 31°C (39.5 to 87.8°F) with means ranging from 16.8 to 18.5°C (62.2 to 65.3°F) and averaged 18.5°C (65.3°F) (Table 5-66). Since 1992, the temperatures have ranged from 4.5°C to 25.5°C (40.1 to 77.9°F) and averaged 17°C (62.6°F) (Table 5-66). The wide fluctuations in temperature reflect seasonal temperature differences. Temperatures upstream at Road A-7 reflect a similar range of 6.4°C to 27°C (43.5 to 80.6°F) and an average of 17°C (62°F).

Table 5-66. Fourmile Branch Field Data

Sampling Location	Water Temperature (C)	pH	Stream Maximum Depth (cm)	Stream Velocity (cm/sec)
Fourmile Branch at Road E-1 (CCWS)				
Mean	16.8	6.32	48	73
Range	1.3 - 28.5	5.10 - 8.10	19 - 199	7 - 250
Samples	46	46	33	41
Fourmile Branch at Road 3 (CCWS)				
Mean	16.9	6.81	147	9
Range	0.1 - 27.0	5.30 - 8.30	121 - 193	1 - 45
Samples	46	46	36	37
Fourmile Branch at Road A-7, 1987-1991				
Mean	17			
Range	6.4 - 26	5.4 - 8.1	NA	NA
Samples	60	60		
Fourmile Branch at Road A-13.2 (CCWS)				
Mean	39.4	7.42		73
Range	9.6 - 52.0	5.90 - 9.05	NA	14 - 100
Samples	46	46		41
Fourmile Branch at Road A, 1987-1991				
Mean	18.5			
Range	6.2 - 31	3.1 - 8.5		
Samples	60	60	NA	NA
Fourmile Branch at Road A-7, 1992-1995				
Mean	17	6.5	NA	NA
Range	4.5 - 25.5	5.4 - 7.7		
Samples	48	48		
Fourmile Branch at Road A-13.2, 1992-1995				
Mean	17.4	6.5	NA	NA
Range	4.2 - 26.6	5.2 - 7.7		
Samples	48	48		

Source: Newman et al. 1986; Arnett et al. 1992; Cummins et al. 1990, 1991; Davis et al. 1989; Mikol et al. 1988; Arnett 1993, 1994, 1995, 1996.

Blank spaces = mean not calculated due to insufficient data in report.

NA = not analyzed.

pH Measurements

Since 1987, the pH in Fourmile Branch has varied from 5.4 to 8.1 at Road A-7 and from 3.1 to 8.5 at Road A (Table 5-66). The pH measurements from the CCWS also fell within these ranges. The change in the ionization constant ($K_w = [H^+][OH^-]$) associated with the change in water temperature is responsible, in part, for the changes in pH (Newman et al. 1986).

Physical Characteristics and General Chemistry

Dissolved Oxygen

Concentrations of dissolved oxygen are strongly correlated to water temperature. Because there was no thermal input near Road A-7, dissolved oxygen concentrations measured between 1987 and 1991 (mean 8.4 mg/l) were similar to those measured during the CCWS (mean 7.8 mg/l) (Table 5-67). During the CCWS, the mean dissolved oxygen concentration

Table 5-67. Fourmile Branch Physical Characteristics and General Chemistry

	Dissolved Oxygen (mg/l)	Specific Conductivity (μS/cm)	Turbidity (NTU)	Total Suspended Solids (mg/l)
Fourmile Branch at Road E-1 (CCWS)				
Mean	6.79	24.3	10.1	13.8
Range	2.30 - 11.6	12.5 - 40.7	1.3 - 60	0.25 - 270
Samples	46	38	43	45
Fourmile Branch at Road 3 (CCWS)				
Mean	7.81	70.0	20.8	7.82
Range	5.20 - 12.40	31.5 - 96.9	0.3 - 394.0	0.25 - 152.10
Samples	46	38	43	44
Fourmile Branch at Road A-7, 1987-1991				
Mean	8.4	56.5	8.2	5.1
Range	5.0 - 12	0.15 - 112	1.0 - 42	0.0 - 27
Samples	60	60	60	60
Fourmile Branch at Road A-13.2 (CCWS)				
Mean	5.99	87.0	18.5	9.31
Range	3.50 - 11.8	59.3 - 108.2	4.3 - 118.0	0.25 - 109.70
Samples	46	45	43	45
Fourmile Branch at Road A, 1987-1991				
Mean	7.9	44.3	5.2	3.1
Range	6.5 - 12	11 - 103	1.0 - 23	1.0 - 47
Samples	60	60	60	60
Fourmile Branch at Road A-7, 1992-1995				
Mean	8.22	70.8	7.5	6.4
Range	5.1 - 15.9	35 - 116	1.2 - 19	1 - 40
Samples	48	48	48	48
Fourmile Branch at Road A-13.2, 1992-1995				
Mean	8.9	60	4.5	5
Range	6.4 -12.7	30 -135	1.8 -13	<1 - 23
Samples	48	48	48	46

Sources: Newman et al. 1986; Arnett et al. 1992; Cummins et al. 1990, 1991; Davis et al. 1989; Mikol et al. 1988; Arnett 1993, 1994, 1995, 1996.
NTU = Nephelometric Turbidity Units.

upstream of Road 3 at the swampy headwater pool (Road E-1) was 6.8 mg/l. Dissolved oxygen concentrations near Road A-13.2 (mean 6.0 mg/l) were lower during the CCWS than during the period following cessation of reactor operations (mean 7.9 mg/l; at Road A), due to the thermal input to the system. Mean dissolved oxygen concentrations between 1992 and 1995 were 8.9 mg O_2/l at Road A and 8.22 mg O_2/l at Road A-7 (Table 5-67).

Turbidity and Suspended Solids

Turbidity and suspended solids have been lower in Fourmile Branch since the cessation of C Reactor operations (Table 5-67). Mean turbidities and suspended solids near Road A-7 between 1987 and 1991 were 8.2 NTU and 5.1 mg/l, respectively. However, during the CCWS, the mean turbidity near Road 3 was 20.8 NTU, and the mean suspended solids concentration was 7.82 mg/l. Between 1987 and 1991, mean turbidities and suspended solids have been 5.2 NTU and 3.1 mg/l, respectively, near Road A. During the CCWS, the mean turbidity near Road A-13.2 was 18.5 NTU, and the mean suspended solids concentration was 9.31 mg/l. Between 1992 and 1995, mean turbidity was 4.5 NTU and Road A and 7.5 NTU at Road A-7 (Table 5-67).

Conductivity

Specific conductivity in Fourmile Branch between 1987 and 1991 averaged 56.5 µS/cm at Fourmile Branch near Road A-7 and 44.3 µS/cm at Fourmile Branch near Road A (Table 5-67). Between 1992 and 1995, specific conductivity averaged 60 µS/cm at Road A and 70.75 µS/cm at Road A-7 (Table 5-67). During the CCWS, mean conductivity in Fourmile Branch near Road A-13.2 was 66 µS/cm. Discharging Savannah River water to Fourmile Branch resulted in this higher conductivity.

Major Anions and Cations

Alkalinity, Chloride, and Sulfate

Monitoring data from 1987-1991 indicate that mean concentrations of total alkalinity are similar in waters near Road A-7 (9.7 mg $CaCO_3$/l) and near Road A (10.3 mg $CaCO_3$/l) (Table 5-68). These mean concentrations are also similar to those measured during the CCWS (8.52 mg $CaCO_3$/l at Road 3 and 14.14 mg $CaCO_3$/l near Road A-13.2). Mean chloride concentrations between 1987 and 1991 were higher at Road A-7 (5.7 mg/l) than at Road A (3.2 mg/l), which may reflect groundwater outcroppings from the F- and H-Area seepage basins. Mean sulfate concentrations were highest near Road A-7, also reflecting groundwater input from the F- and H-Area seepage basins. Higher sulfate and chloride concentrations also were observed during the CCWS. Between 1992 and 1995, mean chloride concentrations in Fourmile Branch ranged from 3.58 to 4.22 mg/l; mean sulfate concentrations ranged from 4.75 to 6.5 mg/l; and mean alkalinity ranged from 8.25 to 11.75 mg $CaCO_3$/l (Table 5-68).

Calcium, Magnesium, Sodium, and Potassium

Concentrations of calcium, magnesium, sodium, and potassium near Road A-7 and Road A remain similar to the concentrations measured during the CCWS (Table 5-69). As in other onsite aquatic systems, calcium, magnesium, and sodium are transported almost entirely in the dissolved phase throughout Fourmile Branch (Newman et al. 1986). Mean concentrations of potassium were generally below the detection limits in the nonthermal portion of Fourmile Branch, but increased to about 1 mg/l in downstream thermal waters, reflecting Savannah River source waters. Potassium is not measured during routine SRS water-quality monitoring.

Aluminum, Iron, and Manganese

Concentrations of aluminum, manganese, and iron are in Table 5-69. During the CCWS, concentrations of aluminum were highest near Road A-13.2, reflecting concentrations in the Savannah River. Concentrations of manganese and iron were highest at the upstream location (Road E-1). The high concentrations of iron (mean 3.59 mg/l) measured at the upstream Fourmile Branch location were attributed to a large amount of iron oxide deposition in the marshy area.

Table 5-68. Fourmile Branch Major Anions

Sampling Location	Alkalinity (mg $CaCO_3$/l)	Chloride (mg/l)	Sulfate (mg/l)
Fourmile Branch at Road E-1 (CCWS)			
Mean	4.28	2.60	1.16
Range	0.49 - 11.9	1.40 - 3.40	0.03 - 11.5
Samples	45	46	27
Fourmile Branch at Road 3 (CCWS)			
Mean	8.52	2.91	7.66
Range	3.24 - 16.62	0.20 - 4.70	1.83 - 18.97
Samples	44	46	28
Fourmile Branch at Road A-7, 1987-1991			
Mean	9.7	5.7	7.2
Range	5.0 - 24	1.2 - 15	3.0 - 17
Samples	60	60	60
Fourmile Branch at Road A-13.2 (CCWS)			
Mean	14.14	5.10	5.09
Range	5.70 - 21.4	2.10 - 7.60	0.25 - 8.92
Samples	45	46	28
Fourmile Branch at Road A, 1987-1991			
Mean	10.3	3.2	5.9
Range	2.0 - 32	1.2 - 6	3.0 - 22
Samples	60	60	60
Fourmile Branch at Road A-7, 1992-1995			
Mean	8.2	3.6	6.5
Range	5 - 24	2 - 10.07	3 - 11
Samples	48	48	48
Fourmile Branch at Road A-13.2, 1992-1995			
Mean	11.8	4.22	4.8
Range	6 - 17	2.44 - 10.65	3 - 8.08
Samples	48	48	39

Source: Newman et al. 1986; Arnett et al. 1992; Cummins et al. 1990, 1991; Davis et al. 1989; Mikol et al. 1988; Arnett 1993, 1994, 1995, 1996.

Table 5-69. Fourmile Branch Major Cations (Total)

	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Potassium (mg/l)	Aluminum (mg/l)	Iron (mg/l)	Manganese (mg/l)
Fourmile Branch at Road E-1(CCWS)							
Mean	1.60	0.52	1.89	<0.368	0.49	3.59	0.23
Range	0.69 - 8.82	0.21 - 0.82	1.09 - 6.56	<0.368 - 1.09	0.076 - 2.09	0.46 - 14.5	<0.0004 - 1.10
Samples	39	39	39	39	39	39	17
Fourmile Branch at Road 3 (CCWS)							
Mean	2.87	0.68	7.60	0.51	0.74	0.784	0.092
Range	2.03 - 4.16	0.53 - 1.23	3.72 - 10.3	<0.368 - 1.77	0.057 - 4.97	0.195 - 4.81	<0.0004 - 0.183
Samples	38	38	38	38	38	38	17
Fourmile Branch at Road A-7, 1987-1991							
Mean							
Range	2.1 - 3.9	0.27 - 0.78	6.6 - 15	NA	0.01 - 0.37	0.04 - 1.7	<0.01 - 0.21
Samples	18	18	20	NA	20	20	18
Fourmile Branch at Road A-13.2 (CCWS)							
Mean	2.99	1.08	6.11	0.92	0.91	1.03	0.11
Range	0.89 - 4.21	0.49 - 1.35	1.32 - 8.73	<0.368 - 2.57	0.248	0.11 - 3.42	<0.0004 - 0.299
Samples	38	38	38	38	38	38	17
Fourmile Branch at Road A, 1987-1991							
Mean							
Range	1.8 - 4.1	0.51 - 0.73	4.8 - 10	NA	<0.01 - 0.20	<0.003 - 0.66	<0.01 - 0.04
Samples	18	18	19	NA	20	20	18
Fourmile Branch at Road A-7, 1992-1995							
Mean	2.92	0.68	8.38	NA	0.32	0.86	0.09
Range	2.24 - 3.56	0.48 - 1.59	6.05 - 14.30	NA	0.080 - 0.865	0.364 - 1.51	0.05 - 0.16
Samples	16	16	16		14	16	15
Fourmile Branch at Road A-13.2, 1992-1995							
Mean	3.08	0.97	4.59	NA	0.156	0.573	0.038
Range	2.56 - 4.15	0.28 - 6.08	4.67 - 11.00	NA	0.031 - 0.29	0.289 - 1.23	0.013 - 0.096
Samples	16	16	16		12	16	14

Source: Newman et al. 1986; Arnett et al. 1992; Cummins et al. 1990, 1991; Davis et al. 1989; Mikol et al. 1988; Arnett 1993, 1994, 1995, 1996.

Blank spaces = mean not calculated due to insufficient data in report.

NA = not analyzed.

From 1987-1991, the maximum aluminum (0.37 mg/l) and manganese (0.21 mg/l) concentrations were measured near Road A-7. The maximum iron concentration, 1.7 mg/l, was measured near Road A. From 1992 to 1995, the maximum aluminum (0.865 mg/l), iron (1.51 mg/l), and manganese (0.16 mg/l) concentrations were all at Road A-7 (Table 5-69).

Nutrients

Phosphorus

Phosphorus concentrations are in Table 5-70. The mean concentrations of phosphorus species in Fourmile Branch waters during the CCWS were higher near Road-A 13.2 (0.089 mg/l) than the concentrations near Road 3 (0.023 mg/l). Analyses determined that the larger percentage of the phosphorus was dissolved orthophosphate. From 1987-1991, mean concentrations of phosphorus have been lower near Road A than near Road A-7 (0.075 mg/l near Road A-7 and 0.028 mg/l near Road A). Between 1992 and 1995, the concentrations were almost the same (mean of 0.038 mg/l at Road A and 0.03 mg/l at Road A-7).

Nitrogen

Organic nitrogen and nitrite concentrations during the CCWS were similar at all Fourmile Branch sites (Table 5-70). Nitrite is not measured in routine water-quality monitoring, and organic nitrogen was measured only near Road A-7 between 1987 and 1995. The concentrations of organic nitrogen measured near Road A-7 were similar to those measured in the CCWS. Ammonia concentrations were highest in the most upstream location (Road E-1) and decreased with distance downstream.

The CCWS measured extremely high concentrations of nitrate (2.3 mg NO_3/l) near Road 3 during the CCWS. These elevated concentrations can be attributed to the outcropping of water from the F-and H-Area seepage basins (Fenimore and Horton 1973). Nitric acid was added to the seepage basins during that time. Ammonia and nitrate concentrations measured since 1992 are similar to prior measurements (Table 5-70).

Trace Elements

SREL measured low levels of trace elements in Fourmile Branch during the CCWS. The detection limits reported for routine monitoring are higher than the concentrations measured during the CCWS; therefore, only the CCWS data is discussed below. All data are in Table 5-71. The CCWS measured the highest mean concentrations of arsenic (2.5 µg/l), cadmium (0.45 µg/l), copper (3.8 µg/l), and nickel (3.6 µg/l) in Fourmile Branch at Road A. Fourmile Branch near Road A-7 had the highest mean concentration of chromium (9.1 µg/l), while the most upstream location, Road E-1, had the highest mean concentrations of lead (2.2 µg/l) and zinc (8.2 µg/l).

Table 5-70. Fourmile Branch Nutrients

	Total Phosphorus (mg/l)	Total Orthophosphate (mg/l)	Organic Nitrogen (mg/l)	Total Kjeldahl Nitrogen (mg/l)	Ammonia (mg/l)	Nitrite (mg/l)	Nitrate (mg/l)
Fourmile Branch at Road E-1 (CCWS)							
Mean	0.023	0.006	0.248	0.264	0.031	0.002	0.019
Range	<0.010 - 0.195	<0.001 - 0.033	0.030 - 0.862	0.017 - 0.890	0.005 - 0.180	<0.001 - 0.009	<0.001 - 0.082
Samples	46	40	44	46	46	44	43
Fourmile Branch at Road 3 (CCWS)							
Mean	0.023	0.010	0.246	0.265	0.027	0.003	2.325
Range	<0.010 - 0.144	0.002 - 0.104	0.020 - 0.681	0.019 - 0.700	<0.005 - 0.110	<0.001 - 0.006	0.589 - 3.870
Samples	46	41	45	46	46	44	43
Fourmile Branch at Road A-7, 1987-1991							
Mean	0.075	NA	0.27	NA	0.13	NA	2.3
Range	<0.02 - 0.14	NA	<0.01 - 2.7	NA	<0.01 - 0.42	NA	0.47 - 8.2
Samples	60	NA	60	NA	60	NA	60
Fourmile Branch at Road A-13.2 (CCWS)							
Mean	0.089	0.066	0.230	0.258	0.047	0.011	0.441
Range	0.024 - 0.170	0.005 - 0.178	0.045 - 0.756	0.012 - 0.800	<0.005 - 0.420	<0.001 - 0.045	0.146 - 0.774
Samples	46	41	44	46	46	44	42
Fourmile Branch at Road A, 1987-1991							
Mean	0.028	NA	NA	NA	0.059	NA	0.24
Range	0.0 - 0.11	NA	NA	NA	0.0 - 0.29	NA	0.04 - 5.1
Samples	60	NA	NA	NA	60	NA	60
Fourmile Branch at Road A-7, 1992-1995							
Mean[a]	0.03	NA	2.36[b]	0.47[c]	0.1	NA	2.21[d]
Range	ND - 0.06	NA	1.1 - 4.06	ND - 2.30	ND - 0.33		1.07 - 4.59
Samples	12	NA	24	22	27		48
Fourmile Branch at Road A-13.2, 1992-1995							
Mean[a]	0.038	NA	0.92[b]	NA	0.128	NA	1.01[d]
Range	ND - 0.13	NA	0.14 - 1.47	NA	ND - 0.48	NA	0.37 - 1.46
Samples	12	NA	24	NA	31	NA	24

Source: Newman et al. 1986; Arnett et al. 1992; Cummins et al. 1990, 1991; Davis et al. 1989; Mikol et al. 1988; Arnett 1993, 1994, 1995, and 1996.
NA= not analyzed.
ND = none detected.
[a]All nondetectable quantities were excluded from the calculation of means.
[b]1992-1993; nitrate + nitrite.
[c]1993-1995.
[d]1994-1995.

Table 5-71. Fourmile Branch Trace Elements (Total)

	Arsenic (µg/l)	Cadmium (µg/l)	Chromium (µg/l)	Copper (µg/l)	Lead (µg/l)	Nickel (µg/l)	Zinc (µg/l)
Fourmile Branch at Road E-1(CCWS)							
Mean	1.2	0.34	7.1	2.0	2.2	2.7	8.2
Range	<0.4 - 9.1	<0.04 - 2.48	<0.4 - 46.0	<0.4 - 6.0	<0.4 - 9.0	<0.4 - 8.3	<0.4 - 53.0
Samples	17	17	17	17	17	17	17
Fourmile Branch at Road A-7 (CCWS)							
Mean	1.5	0.44	9.1	2.6	1.5	3.4	5.3
Range	<0.4 - 7.3	<0.04 - 2.41	<0.4 - 77	<0.4 - 5.7	<0.4 - 6.0	<0.4 - 15	<0.4 - 23
Samples	17	17	17	17	17	17	17
Fourmile Branch at Road A-7, 1987-1991							
Mean							
Range	NA	<10	<10 - 10	<10 - <50	<3 - 110	<10 - 50	<10 - 20
Samples	NA	20	20	20	20	20	20
Fourmile Branch at Road A (CCWS)							
Mean	2.5	0.45	8.0	3.8	2.0	3.6	5.0
Range	<0.4 - 17.3	<0.04 - 2.45	<0.4 - 49	<0.4 - 10	<0.4 - 9.3	<0.4 - 10.7	<0.4 - 16.8
Samples	17	17	17	17	17	17	17
Fourmile Branch at Road A, 1987-1991							
Mean							
Range	NA	<10	<10 - 10	<10 - 300	<3 - 60	<10 - 70	<10 - 20
Samples	NA	20	20	20	20	19	20
Fourmile Branch at Road A-7, 1992-1995							
Mean[a]	NA	<10	19	13	<4	<30	<20
Range		ND -37	ND - 110	ND - 10	ND - <50	ND - <50	ND - 0.73
Samples		4	4	8	5	4	11
Fourmile Branch at Road A-13.2, 1992-1995							
Mean[a]	NA	<10	<15	40	<4	<30	10
Range		ND - <10	ND - <20	ND - 270	ND - <10	ND - <50	ND - 17
Samples		4	4	8	5	4	9

Source: Newman et al. 1986, Arnett et al. 1992; Cummins et al. 1990, 1991; Davis et al. 1989; Mikol et al. 1988; Arnett 1993, 1994, 1995, and 1996.
Blank spaces = mean not calculated due to insufficient data in report.
NA = not analyzed.
ND = none detected.
[a]All nondetectable quantities were excluded from the calculation of means.

Organic Carbon

During the CCWS, mean total organic carbon concentrations in nonthermal waters ranged from 4.3 to 8.0 mg/l, while the thermal waters had total organic carbon concentrations of 6.4-7.3 mg/l. Between 1987 and 1991, total organic carbon concentrations ranged from 0.06 to 9.04 mg/l.

Priority Pollutants

Lower (1987) reports the results of an instream study to determine the levels of volatile, acid, and base/neutral organics in Fourmile Branch. Concentrations of all 88 tested organics were below the detection limits at each of the three sampling locations.

In 1984, an instream survey of priority pollutants was conducted to determine the levels of volatile, acid, and base/neutral compounds in Fourmile Branch. Three locations—Fourmile Branch at Road C, Road A-7, and Road A—were sampled for this study. Potential sources for organics into Fourmile Branch were discharges from F and H Areas, shallow groundwater outcropping, runoff from precipitation, and input of Savannah River water. The results of this study are in the sections that follow and in Lower (1987).

Pesticides, Herbicides, PCBs, and Volatile Organic Compounds

Pesticides, herbicides, PCBs, and volatile organic compounds also are measured during routine water-quality monitoring. No pesticides, herbicides, PCBs, or volatile organic compounds have been detected in Fourmile Branch.

Lower (1987) reports the results of analyses for pesticides, herbicides, and PCBs from 1982 to 1985; results from 1967 to 1981 can be found in Gladden et al. (1985). During these periods, concentrations were also near or below detection limits at all locations.

Chemical, Including Radionuclide, and Toxicity Assessment Studies

Seepline Metals

In 1987, SRTC initiated a sampling and analysis program in the vicinity of the F- and H-Area seepage basins because observations of the basins suggested that water outcropping along the seepline was impacting a small area of the terrestrial/wetlands environment along Fourmile Branch. SRTC collected samples upstream and downstream from both F and H Areas (Figure 5-24) and analyzed for selected metals, inorganic constituents, pH, conductivity, nitrate, and nitrite. The results of this study are presented in Table 5-72.

Results from the analysis of the water from Fourmile Branch suggested that the input of sodium nitrate from the seep areas or area outfalls was measurable in the stream. The remaining constituents did not measurably impact the stream (Looney et al. 1988).

Haselow et al. (1990) collected soil cores, stream, and seepline water samples from Fourmile Branch in 1988 and 1989 as a follow-up to the Looney et al. (1988) study. These samples also were analyzed for selected metals, inorganic constituents, pH, conductivity, nitrate, and nitrite. The results of this study are in Table 5-72.

Metals analyses showed that all concentrations in Fourmile Branch were below the proposed drinking water standards for those analytes. Aluminum and sodium concentrations were elevated, but no standards exist for these constituents. The high sodium concentrations are probably from the caustic discharged to the basins, and the aluminum is probably being leached from the soil matrix. Nitrate was elevated at both the F- and H-Area seeplines but

Table 5-72. Results from Seepline Sampling Study of Fourmile Branch

	88CW-1[a]	88CW-2	88CW-3	88CW-4	89HW-9	89HW-4	89HW-7	89HW-8
pH	NA	NA	NA	NA	6.30	7.21	6.37	5.34
Conductivity (mV/cm)	NA	NA	NA	NA	93.5	320	91.6	35.9
Alkalinity (mg/l)	NA	NA	NA	NA	ND	148	8.0	ND
Total Hardness	NA	NA	NA	NA	139	73.3	196	196
Chloride mg/l)	NA	NA	NA	NA	4.6	1.2	5.5	5.7
Nitrate (mg/l)	NA	NA	NA	NA	1.4	8.9	5.7	0.15
Silver (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.004	<0.004	<0.004	<0.004
Aluminum(mg/l)	<0.2	<0.2	<0.2	<0.2	0.05	0.08	0.47	0.07
Arsenic(mg/l)	NA	NA	NA	NA	<0.003	<0.003	<0.003	<0.003
Cadmium (mg/l)	<0.005	<0.005	<0.005	<0.005	<0.006	<0.006	<0.006	<0.006
Chromium (mg/l)	<0.01	<0.01	<0.01	0.018	<0.003	<0.003	0.021	<0.003
Copper (mg/l)	<0.025	<0.025	<0.025	<0.025	<0.007	<0.007	<0.007	<0.007
Mercury (mg/l)	<0.0002	<0.0002	0.0003	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Sodium (mg/l)	14	14	12	2.9	11.7	63.3	10.2	25.9
Nickel (mg/l)	<0.04	<0.04	<0.04	<0.04	<0.034	<0.034	<0.034	<0.034
Lead (mg/l)	<0.005	<0.005	<0.005	<0.005	<0.003	<0.003	<0.003	<0.003
Selenium (mg/l)	NA	NA	NA	NA	<0.002	<0.002	<0.002	<0.002
Zinc (mg/l)	<0.02	<0.02	0.059	0.029	<0.009	<0.009	0.028	0.009

Source: Haselow et al. 1990.
NA = not analyzed.
ND = not detected.
[a]Refer to Haselow et al. (1990) for description of these sampling locations.

was no more than half the concentration in the stream at all sampling locations. The concentration of chloride apparently was unaffected by the basins because upstream samples were about the same as the concentrations along the seepline and in Fourmile Branch.

Discharges to the seepage basins were discontinued in 1988, and the basins were capped and sealed in 1990 to minimize the release of contaminants to the environment. Scientists hypothesized that after eliminating the contaminant source, annual rainfall and natural groundwater flow would dilute and flush the remaining contaminant plume out of the shallow groundwater and Fourmile Branch wetland system. After the contaminant plume in the shallow groundwater is diluted and flushed, the Fourmile Branch wetland systems below the basins will begin to recover.

To investigate this hypothesis and to monitor the postbasin-closure temporal changes in the contaminant levels outcropping along the Fourmile Branch seepline, a semiannual program was initiated to monitor Title 40 CFR Part 264 Appendix IX metals and various inorganics. Samples were collected from five seepline locations in F Area, five seepline locations in H Area, and three stream locations on Fourmile Branch. Analytical results for the seepline sampling locations are in Dixon and Rogers (1994), Chappell et al. (1995), Koch and Dixon (1997) and in Table 5-73 and Table 5-74. The sampling indicates that as of 1996 the seepline and Fourmile Branch still were influenced by contaminants migrating from the F- and H-Area seepage basins. However, when compared to 1989 concentrations (Haselow et al. 1990), the concentrations of most constituents have declined.

Table 5-73. Average Tritium, Conductivity, and pH values for F- and H-Area Seeplines, March 1989-September 1996

	F Area Seepline - Average Values			H Area Seepline - Average Values		
Sampling Event Date	**Tritium (pCi/ml)**	**Conductivity (μS/cm)**	**pH**	**Tritium (pCi/ml)**	**Conductivity (μS/cm)**	**pH**
Mar 1989	3357	438	4.8	8402	297	5.2
May 1992	1934	335	4.7	4131	183	5.9
Sep 1992	1990	352	5.2	2904	182	6.0
Dec 1992	1823	300	5.3	3001	165	6.0
Mar 1993	1398	293	5.0	2063	124	5.9
Jun 1993	1936	330	5.1	2885	157	6.0
Sep 1993	2384	404	5.0	2876	205	5.7
Dec 1993	1920	415	5.1	2749	181	5.7
Mar 1994	1525	371	5.0	1818	140	5.6
Jun 1994	1688	344	5.0	2053	153	5.8
Sep 1994	1806	381	5.1	1953	159	6.0
Dec 1994	1698	366	4.9	2836	179	5.8
May 1995	1634	311	5.0	1547	131	5.6
Mar 1996	1424	331	4.7	1082	113	5.9
Sep 1996	1545	328	4.8	880	142	6.1

Source: Koch and Dixon 1997.

Table 5-74. Average Tritium and Conductivity Values for Seepline below 643-E, March 1993-September 1996

Sampling Event Date	Tritium (all) (pCi/ml)	Tritium (East) (pCi/ml)	Tritium (West) (pCi/ml)	Conductivity (All) (μS/cm)	Conductivity (East) (μS/cm)	Conductivity (West) (μS/cm)
Mar 1993	4808	242	8999	62	43	88
Jun 1993	7617	389	14779	82	53	122
Sep 1993	10924	445	22017	92	57	140
Dec 1993	8182	435	15527	68	56	86
Jun 1994	8557	324	14557	58	53	68
Sep 1994	8065	303	15469	57	53	65
Dec 1994	no data	no data	no data	no data	no data	no data
May 1995	4323	270	6630	69	64	79
Mar 1996	4069	143	7483	43	36	53
Sep 1996	4260	183	7121	44	37	54

Source: Koch and Dixon 1997.

Seepline Tritium

The Savannah River Technology Center established a monitoring program to track changes in tritium, pH, and specific conductivity at the Fourmile Branch seepline downgradient from the F- and H-Area seepage basins.

Measurements from the September 1993 survey indicated higher tritium concentrations, conductivity measurements, and pH values than in recent previous surveys, but lower than measurements recorded in 1990. Decreased rainfall prior to the sampling event contributed to the increased tritium concentrations and conductivity values during this survey.

September 1993 tritium values in the F-Area seepline ranged from 12 to 17,800 pCi/ml (Figure 5-25). Six of twenty-one locations sampled had above-background tritium activities that exceeded 1989 measurements by 10%. The tritium activity of 17,800 pCi/ml exceeded the maximum value recorded in 1989 (14,000 pCi/ml [Dixon et al. 1994])

Tritium values in the H-Area seepline ranged from 124 to 15,500 pCi/ml (Figure 5-26). Four of twenty-one sampling locations had above-background tritium activities that exceeded 1989 measurements by more than 10%. No tritium activity exceeded the maximum activity of 24,000 pCi/ml measured in 1989.

Below-average rainfall prior to the September 1993 sampling event caused the tritium plume to move upward through the soil profile, while the toe of the plume moved back toward the seepage basins and the seepline intercept. Therefore, tritium concentrations at most locations increased considerably. With increased rainfall, the plume should move deeper into the soil profile and outcrop closer to Fourmile Branch. Tritium concentrations at the seepline should return to levels typically measured in the past. It is important to note that total tritium fluxes to the wetlands and Fourmile Branch have steadily declined since basin closure. Overall results suggest that the tritium plume is flushing from the Fourmile Branch system (Dixon et al. 1994).

In September 1996, tritium concentrations ranged from 7-7150 pCi/ml at the F-Area seepline, from 20-1980 pCi/ml at the H-Area seepline and from 16-19,100 pCi/ml in the drainage below 643-E (a decommissioned area of the Solid Waste Management Facility).

The following conclusions are based on trends in measured concentrations from 1986 to 1996:

- tritium concentrations measured at most locations in September 1996 are relatively unchanged compared to the previous sampling events, but are significantly lower than the 1986 baseline tritium concentration
- total tritium fluxes to Fourmile Branch and its associated wetlands have steadily declined since basin closure, supporting the hypothesis that the tritium plumes are being flushed from shallow groundwater
- most of the tritium detected along the F-Area seepline is localized in two areas (8 of 22 sample locations)
- most of the tritium detected along the seepline below 643-E (a decommissioned area of the Solid Waste Management Facility) is on the west side of the drainage
- differences in tritium concentrations measured from one sampling event to the next represent seasonal variability and the effects of rainfall

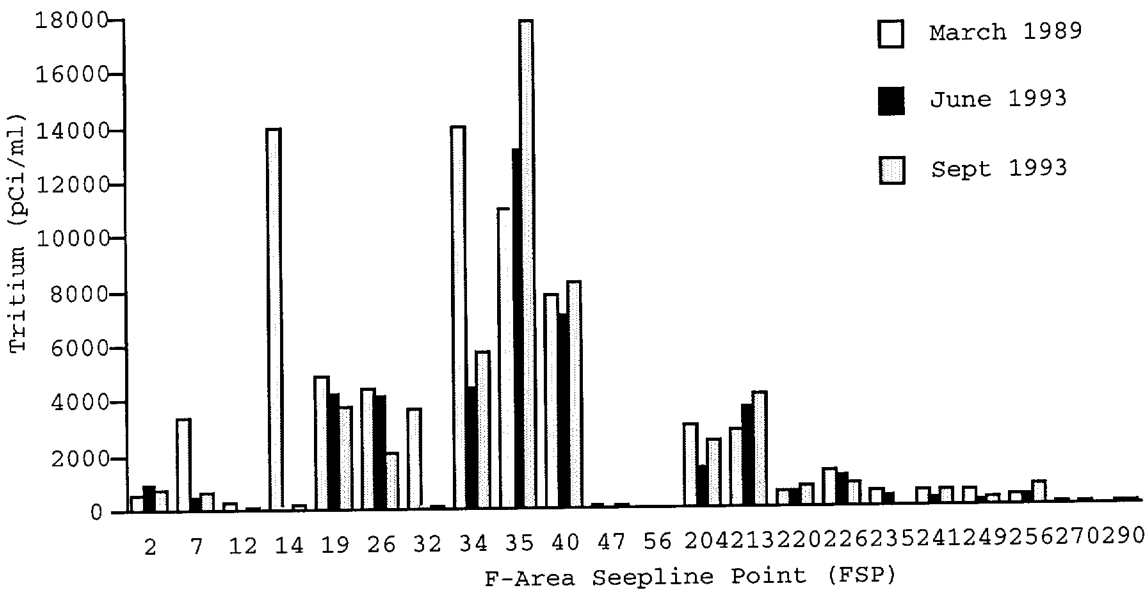

Figure 5-25. Comparison of March 1989, June 1993, and September 1993 Tritium Concentrations for Selected F-Area Seepline Locations

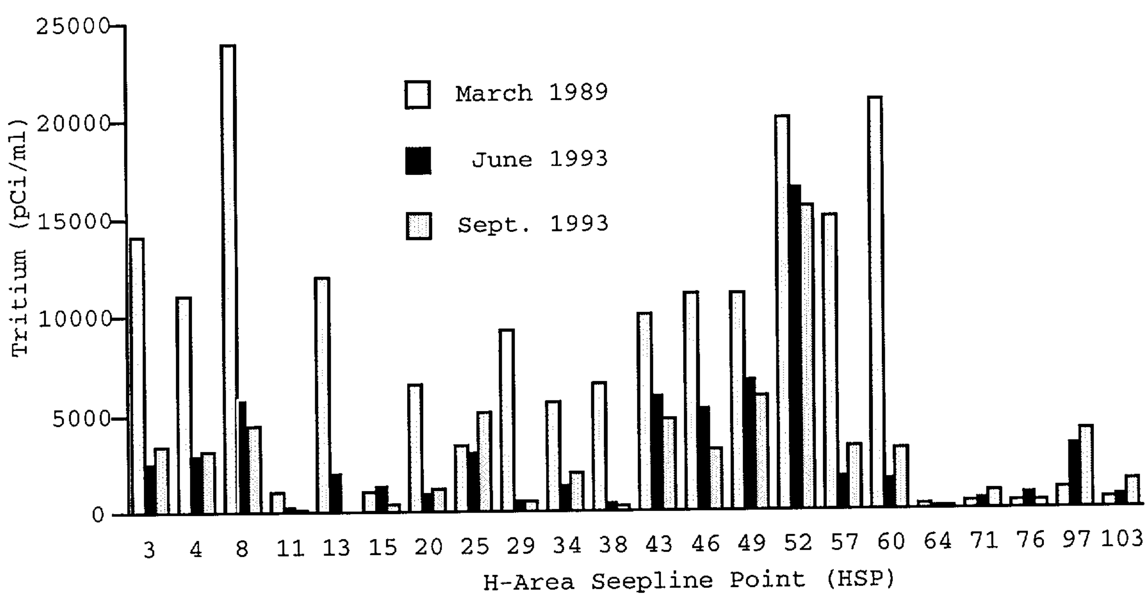

Figure 5-26. Comparison of March 1989, June 1993, and September 1993 Tritium Concentrations for Selected H-Area Seepline Locations

Toxicity

In 1994, a study was done to determine if the cladoceran *Ceriodaphnia dubia* is adversely affected by Fourmile Branch water that does not receive NPDES discharges, if *Ceriodaphnia* can be cultured for extended times in Fourmile Branch water, and if *Ceriodaphnia* cultured in Fourmile Branch water are sensitive to a reference toxicant. SRS surface waters are extremely soft, with hardnesses ranging from approximately 2 to 30 mg/l. Waters this soft may not have adequate calcium or trace minerals to support long-term survival of *Ceriodaphnia*. Detailed results of this study are presented in Specht (1994a).

Fourmile Branch water was acutely toxic (measured as percent survival) to *Ceriodaphnia dubia* in three of five monthly tests and was chronically toxic (measured as reproductive success) in five of five monthly tests.The reference toxicant (sodium chloride) tests on Fourmile Branch water indicated test organisms in that water were severely stressed and extremely sensitive to the reference toxicant. Water from Fourmile Branch above any SRS NPDES outfall is not capable of sustaining cultures of *Ceriodaphnia dubia*.

In order to determine the source of the observed toxicity in Fourmile Branch, a Toxicity Identification Evaluation (TIE) was performed in 1995 on water collected from Fourmile Branch at Road F following U.S. Environmental Protection Agency protocols (Durhan et al. 1993; Norberg-King et al. 1991). The results of the TIE indicate that naturally occurring iron is responsible for the toxicity to *Ceriodaphnia dubia* (ETT Environmental 1995a, b).

Algae

Phytoplankton

The former C-Reactor cooling water effluent system, which includes Fourmile Branch and its principal tributary Castor Creek, is a low-potential impact area for phytoplankton. The food base throughout this system is composed of detrital material and attached algae (periphyton), rather than phytoplankton, as is typical in lotic systems (Wetzel 1983). Primary producers in the Fourmile Branch system consist mainly of periphyton and macrophytes (Specht 1987).

Periphyton

The periphyton of Fourmile Branch were studied from 1983-1985 as part of the CCWS. Methods and sampling locations can be found in Specht (1987).

Macrophytes

Aquatic macrophytes provide stream structure, substrate for periphyton development, cover and substrate for smaller animals, and a source of carbon for the stream system. Although aquatic macrophytes are an important component of the function of many aquatic systems, they tend to be less important in flowing waters. Macrophytes could not colonize the channels of systems such as Fourmile Branch during the large thermal and flow impacts from reactor operations. Colonization of the stream has occurred since the cessation of C-Reactor operations in 1985; unfortunately, there are no data dealing with the invasion of submerged macrophytes in Fourmile Branch. However, there is some research, started in 1987 (Sharitz et al. 1993), addressing vegetational succession in the Fourmile Branch corridor that does deal with the emergent and wetland species colonizing the stream banks.

Comprehensive Cooling Water Study

The 1984-1985 data collected during the CCWS (Specht 1987) were the only data dealing with aquatic macrophytes in Fourmile Branch. The CCWS data are not representative of the current status of aquatic macrophytes in the Fourmile Branch system because they were collected at only two stations, both of which had been impacted by reactor operations. The data showed fewer total number of taxa than post-thermal and reference streams and had no taxa growing in the stream channel. Area, volume, biomass, and percent cover for aquatic macrophytes at the two stations are in Table 5-75.

Table 5-75. Annual Mean, N, and Standard Deviation for the Following Aquatic Vascular Plant Parameters at Each Mapped Station: Area, Volume, Biomass and Percent Cover, October 1984-September 1985

Area (m^2/m^2)		Volume (m^3/m2)		Biomass (g/m^2)		Percent Cover of Stream Reaches		
Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	N
0.0010	0.0031	—	—	0.0047	0.0189	0.0189	0.3070	16
0.0127	0.0288	0.0055	0.0156	4.107	13.04	1.268	2.880	15

Source: Firth et al. (1986).

Expectations Since the Cessation of C-Reactor Operation

Normal successional patterns and development of macrophyte beds would likely have occurred in suitable sections of Fourmile Branch since the cessation of C-Reactor operation. This probability cannot, however, be supported or refuted because of the lack of observations and data. There may be adequate justification for either resampling of the areas studied during the CCWS, or a survey of the entire stream to document the invasion of this important component of the lower food chain.

Zooplankton

Chimney and Cody (1986) performed the only systematic study of the zooplankton in Fourmile Branch which documented the temporal and spatial characteristics of zooplankton species based on quarterly sampling from December 1984 to August 1985. Surface water grab samples were collected adjacent to macrophyte beds at a single station where the stream enters the Savannah River swamp. Due to thermal discharges, mean temperature was greater than 32°(89.6 F). Species richness consisted of 8 Protozoa, 21 Rotifera, 6 Cladocera, 2 Copepoda, and 1 Ostracoda.

The data in Figure 5-27 indicate that the greatest densities occurred during March 1985. With the exception of December 1984, Protozoa and Rotifera made up more than 80% of the monthly total densities. This result is typical of zooplankton populations, which are warm-water, summer species (Hutchinson 1967).

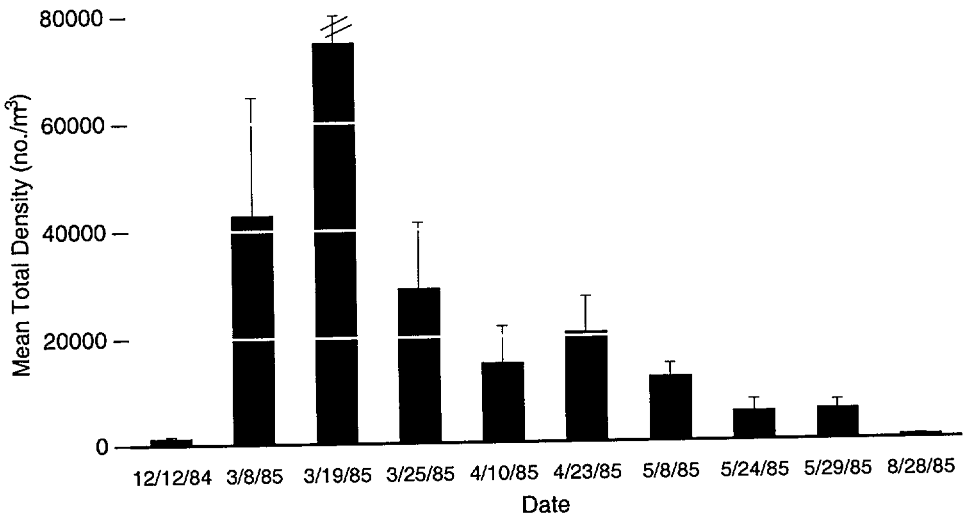

Figure 5-27. Mean Total Zooplankton Density in Fourmile Branch

Macroinvertebrates

Sampling Locations and Methods

Locations

Macroinvertebrates were sampled monthly from September 1982 to August 1983 in the mouth of Fourmile Branch (Specht et al. 1984), monthly from November 1983 through September 1984 at three locations in Fourmile Branch (Kondratieff and Kondratieff 1984, 1985; O'Hop et al. 1985), and monthly from October 1984 through September 1985 at six locations in Fourmile Branch (Figure 5-28) (Specht 1987). Because C Reactor, which discharged to Fourmile Branch, was placed on cold standby in June 1985, these data primarily represent the macroinvertebrate community that existed when C Reactor was operating at full power; however, the data also document early recovery of thermal stations between June and September 1985. After C Reactor shut down in June 1985, Lauritsen and Starkel (1989) collected macroinvertebrate samples at one location in Fourmile Branch from June 1985 to September 1987 to document macroinvertebrate recolonization. During the recolonization study, they collected samples at time intervals ranging from one day to two weeks from June through August 1985 and monthly from October 1985 to September 1987.

	Station Name
01	12 (Road A-7)
02	14 (Road A-13.2)
03	15
04	16
05	17
06	18

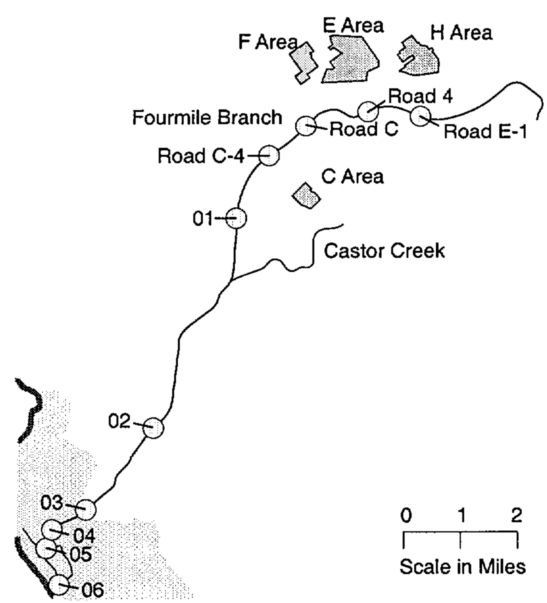

Figure 5-28. Location of the Fourmile Branch Macroinvertebrate Sampling Stations

Macroinvertebrates were sampled during the summer of 1993 at six locations in Fourmile Branch using Hester-Dendy multiplate macroinvertebrate samplers (Specht 1994b). Macroinvertebrates also were sampled in September 1994 using Hester-Dendy multiplate samplers to develop a biotic index for southeastern streams.While not specifically designed to characterize SRS streams, these data contribute to a better understanding of them. Fourmile Branch was sampled at Road C and Road A-13.2 (Table 5-76) (Specht and Paller 1995).

Methods

A majority of the Fourmile Branch macroinvertebrate sampling was conducted with Hester-Dendy multiplate samplers. However, macroinvertebrates also were collected from leaf bags, artificial snags, macrophytes, natural substrates, and drift at some stations. Details of sampling methods can be found in Specht et al. (1984), Kondratieff and Kondratieff (1984, 1985), Firth et al. (1986), Lauritsen and Starkel (1989), Specht (1994b) and Specht and Paller (1995). Most of the data in this summary is from the 1984-1985 sampling period because fewer stations were sampled in the other years. Table 5-76 identifies the locations of all sampling stations and the sampling methods employed in each study.

Results

Introduction

From the onset of macroinvertebrate sampling in 1982 until C-Reactor was shut down in June 1985, Fourmile Branch was subject to severe thermal stress, with temperatures as high as 51.7°C (125°F) recorded at some macroinvertebrate sampling stations. However, during reactor outages, which sometimes lasted for several weeks or longer, stream temperatures were near ambient. Many species of macroinvertebrates were able to colonize the stream quickly during reactor outages. In addition, it is likely that some of the organisms collected in the severely thermal areas drifted downstream from portions of the stream where temperatures were ambient and that the organisms were no longer alive when collected. Therefore, the macroinvertebrate data collected from Fourmile Branch between 1982 and June 1985 must be interpreted cautiously to prevent erroneous conclusions.

Macroinvertebrate Community During Operation of C-Reactor

Nonthermal Areas

Station 12 was located at Road A-7 upstream from the discharge of thermal effluent into Fourmile Branch. Macroinvertebrate data collected from Hester-Dendy multiplate samplers (Table 5-77) indicate that this station was similar to other nonthermal SRS streams with respect to density of organisms, biomass, average number of taxa, and total number of taxa collected. Dominant taxa at Road A-7 included leeches (Hirudinea), the mayfly *Stenonema modestum*, blackflies, tanytarsine and orthoclad chironomids, and several species of hydropsychid caddisflies (Table 5-78 and Table 5-79). The taxonomic composition of the Station at Road A-7 differed from most other nonthermal stream stations sampled during the CCWS in that it was overwhelmingly dominated by filter-feeders (Table 5-80). The domination of filter-feeders makes Station 12 most similar to the macroinvertebrate communities found downstream from L Lake and Par Pond. Fourmile Branch receives nutrient inputs from several small sanitary wastewater treatment plants and nitrogen inputs from the F -and H-Area seeplines. The creek also supports numerous beavers, which dam the creek.

Table 5-76. Locations of Macroinvertebrate Sampling Stations and Sampling Methods in Fourmile Branch, 1982-1987

1982–1983	1983–1984	1984–1985	1985–1987	1993	1994
Creek mouth (HD, D)	Road A-13.2 (St. 2) (HD, LB, SN, SB, M)	Road A-7 (St. 12) (HD, D, LB)	Road A-13.2 (HD)	Road A-13.2 (HD) Road A-7 (HD) Road C (HD) Road C-4 (HD) Road 4 (HD) Road E-1 (HD)	Road A-13.2 (HD) Road C (HD)
	SREL Boardwalk off Road A-13 (St. 3) (HD, LB, SN, SB, M)	SREL Boardwalk off Road A-13 (St. 14) (HD, LB, D)			
	Creek mouth (HD, D) (St. C150.6)	Delta (St. 15, 16, 17) (HD, LB, D)			
		Creek mouth (St. 18) (HD, D)			

HD = Hester-Dendy multiplate samplers.
D = Drift.
LB =Leaf bags.
SN = Artificial snags.
SB = Substrate.
M = Macrophyte.

Table 5-77. Mean Number of Taxa, Density, and Biomass for Macroinvertebrates Collected on Hester-Dendy Multiplate Samplers in Fourmile Branch, October 1984-September 1985

	Station					
Parameter	**12**	**14**	**15**	**16**	**17**	**18**
Mean number of taxa/sampler	19.0	6.3	8.2	8.5	8.7	9.8
Mean density/m^2	2109.3	1012.1	1532.8	1517.7	1230.0	1433.7
Mean biomass g/m^2	0.351	0.191	0.097	0.121	0.097	0.100
Mean biomass/ individual (mg)	0.166	0.189	0.063	0.080	0.079	0.070
Total number of taxa collected	67	45	35	38	41	38

Source: Firth et al. 1986.

Table 5-78. Percent Composition of Macroinvertebrate Taxa Collected on Hester-Dendy Multiplate Samplers in Fourmile Branch, October 1984-September 1985

	Station					
Taxa	**12**	**14**	**15**	**16**	**17**	**18**
Turbellaria	0.73	0.00	0.01	0.02	0.00	0.01
Nematoda	0.57	0.49	16.78	3.75	11.36	0.62
Oligochaeta	4.61	13.49	21.84	27.42	32.40	12.11
Gastropoda	0.14	1.02	0.49	0.04	2.58	1.19
Arachnida	1.42	0.06	0.14	0.09	0.04	0.10
Ephemeroptera	5.80	4.65	7.45	4.79	5.11	8.76
Coleoptera	1.28	0.21	0.03	0.07	0.05	0.12
Trichoptera	39.40	20.08	2.50	4.05	1.48	2.21
Diptera[a]	44.67	59.77	50.62	59.56	46.55	74.69
Chironomini	(2.59)	(28.74)	(26.90)	(35.50)	(30.57)	b
Tanytarsini	(18.60)	(7.54)	(7.53)	(8.72)	(2.18)	(5.01)
Orthocladiinae	(9.83)	(7.36)	(4.30)	(3.60)	(1.59)	b
Tanypodinae	(1.73)	(11.36)	(7.00)	(5.18)	(7.88)	b
Other	1.38	0.23	0.14	0.21	0.43	0.19
Total	100.00	100.00	100.00	100.00	100.00	100.00

Source: Firth et al. 1986.
[a]Includes subtaxa in parentheses.
[b]Subtaxa not differentiated.

Table 5-79. Mean Invertebrate Density (no./m^2) on Hester-Dendy Multiplate Samplers Collected at Each Station in Fourmile Branch, October 1984-September 1985

			Delta Stations			
Taxa	**Road A-7 (12)**	**Boardwalk of Road A-13 (14)**	**(15)**	**(16)**	**(17)**	**Creek Mouth (18)**
Turbellaria	15.3		0.2	0.3		0.2
Nematoda	12.1	5.0	257.3	58.6	139.8	8.6
Oligochaeta	97.2	136.6	334.9	428.1	398.8	165.5
Hirudinea						0.2
Gastropoda	0.5	0.3	1.0	0.2	5.0	2.1
Family Ancylidae						9.4
Ferrissia rivularis	0.3				0.3	
Family Hydrobiidae						
Amnicola sp.	0.3		0.2			0.3
Family Lymnaeidae						
Pseudosuccinea columella	0.2	0.2				
Family Physidae						
Physella heterostropha	1.0	9.8	6.3	0.5	26.5	4.9

Table 5-79. (cont)

			Delta Stations			
Taxa	**Road A-7 (12)**	**Boardwalk of Road A-13 (14)**	**(15)**	**(16)**	**(17)**	**Creek Mouth (18)**
Family Planorbidae						
Gyraulus parvus	0.2					
Helisoma trivolvis	0.5					
Amphipoda						
Family Gammaridae						
Gammarus fasciatus				0.3	0.2	
Family Talitridae						
Hyalella azteca	1.1		0.3	0.2	0.2	0.3
Arachnida						
Hydracarina	30.0	0.6	2.2	1.4	0.5	1.4
Insecta						
Collembola						0.2
Family Entomobryidae						
Entomobrya sp.					0.2	
Family Isotomidae	0.2					
Family Poduridae						
Podura aquatica	2.4					
Ephemeroptera						
Family Baetidae						
Baetis sp.	16.4	29.0	71.1	48.8	14.6	21.7
Family Caenidae						
Caenis sp.	0.6	8.4	27.6	4.8	40.0	40.7
Family Ephemerellidae	0.3					
Dannella simplex		0.2				
Ephemerella invaria	0.2					1.9
Eurylophella temporalis	30.6	0.2	0.2			0.8
Family Heptageniidae		0.5	0.5	1.0	0.8	
Heptagenia sp.						5.9
Stenacron interpunctatum	0.2	0.9	1.9	3.0	2.3	28.3
Stenonema modestum	73.4	3.9	8.0	10.4	4.7	21.7
Family Neoephemeridae						
Neoephemera youngi	0.2		0.2			
Family Oligoneuriidae						
Isonychia sp.	0.2	0.6		6.2	0.5	
Family Tricorythidae						
Tricorythodes sp.	0.3	3.4	4.7	0.6		0.5
Ononata						
Anisoptera	0.5		0.2			
Family Aeshnidae						
Boyeria vinosa	0.2		0.7	0.2	0.2	
Nasiaeschna pentacantha	0.2					
Family Corduliidae						
Epicordulia regina		1.2				
Neurocordulia sp.			0.2			

Table 5-79. (cont)

Taxa	Road A-7 (12)	Boardwalk of Road A-13 (14)	Delta Stations (15)	Delta Stations (16)	Delta Stations (17)	Creek Mouth (18)
Family Libellulidae						
Erythemis simplicicollis					0.8	
Pachydiplax longipennis					0.6	
Family Macromiidae						
Macromia spp.		0.2			0.2	
Zygoptera	0.2					
Family Calopterygidae						
Hetaerina sp.	0.3					
Family Coenagrionidae			0.2			
Argia sp.	1.0					0.2
Enallagma sp.	1.0		0.2		1.1	
Ischnura sp.					1.4	
Plecoptera						0.5
Family Perlidae	0.6			0.3	0.2	0.2
Acroneuria abnormis		0.3	0.2			
Paragnetina fumosa				0.2		
Perlesta placida	2.2	0.2		0.3		0.5
Family Perlodidae						
Helopicus bogaloosa	0.2	0.2				
Isoperla sp.	0.5					
Family Pteronarcyidae						
Pteronarcys dorsata	0.5					
Family Taeniopterygidae						0.2
Taeniopteryx longicera	2.2					
Taeniopteryx robinae	1.8					
Hemiptera						
Family Corixidae				0.2		
Coleoptera						
Family Elmidae	0.2				0.2	
Ancyronyx variegatus	2.6	0.5	0.2	0.2		0.5
Dubiraphia sp.	0.6					
Macronychus glabratus	20.4	1.2			0.2	
Microcylloepus pusillus	0.2					
Stenelmis sp.	1.6					
Family Gyrinidae						
Dineutes sp.			0.3	0.6		1.3
Gyrinus sp.	1.0					
Family Hydrophilidae						
Berosus sp.		0.2				
Hydrobius sp.	0.3					
Parachymus sp.					0.2	
Tropisternus sp.		0.2		0.3		
Megaloptera						
Family Corydalidae						
Corydalus cornutus	1.9	0.2		1.3	0.2	0.3

Table 5-79. (cont)

			Delta Stations			
Taxa	**Road A-7 (12)**	**Boardwalk of Road A-13 (14)**	**(15)**	**(16)**	**(17)**	**Creek Mouth (18)**
Trichoptera						
Family Hydropsychidae	0.8	0.6	3.6	1.4		0.3
Cheumatopsyche spp.	357.5	15.5	5.2	4.6	2.9	10.5
Hydropsyche sp.	110.0	147.1	19.0	39.1	2.5	6.1
Macrostemum carolina	255.9	0.2				
Family Hydroptilidae		0.2				
Hydroptila sp.	1.0	1.7			0.2	
Orthotrichia sp.						0.3
Oxyethira sp.	2.7	0.6	3.2	1.0	1.1	0.2
Family Leptroceridae						
Ceraclea sp.					0.3	0.2
Nectopsyche candida	0.3		0.2			
Oecetis sp.	12.6	0.3	0.8	1.6	0.8	4.6
Triaenodes sp.	0.3					
Family Philopotamidae						
Chimarra sp.	100.2	21.9	4.1	13.7	9.9	6.4
Family Polycentropodidae						
Cernotina sp.	0.2					
Cyrnellus sp.		0.2				
Neureclipsis sp.	0.2	14.9	2.2	1.6	0.5	4.5
Polycentropus sp.	0.3					
Family Psychomyiidae						
Lype diversa	0.2	0.2		0.2		
Lepidoptera						
Family Pyralidae						
Neargyractis sp.	0.3					
Parapoynx sp.	0.3					
Diptera						
Family Ceratopogonidae	4.0	3.7	7.4	7.3	4.3	4.3
Ceratopogonidae pupae	0.3				0.2	
Subfamily Forcipomyiinae	0.2	2.6	2.2	2.9	0.8	
Atrichopogon sp.					0.2	
Family Chaoboridae						
Chaoborus punctipennis		0.3				
Family Chironomidae						1033.5
Chironomidae pupae	44.4	40.5	65.2	91.3	46.4	
Subfamily Chironominae						
Tribe Chironomini	54.7	291.1	412.4	554.2	376.3	
Robackia claviger		0.2				

Table 5-79. (cont)

Taxa	Road A-7 (12)	Boardwalk of Road A-13 (14)	Delta Stations (15)	(16)	(17)	Creek Mouth (18)
Tribe Tanytarsini	392.3	76.4	115.5	136.2	26.8	71.8
Subfamily Diamesinae						
Potthastia sp.		0.2				
Subfamily Orthocladiinae	207.2	74.5	65.9	56.2	19.6	
Subfamily Tanypodinae	36.4	115.0	107.3	80.9	97.0	54.1
Family Empididae	14.0	0.5		0.6	1.1	3.8
Family Simulidae	3.5					
Simulium sp.	184.7	0.3		0.2	0.3	4.8
Family Tipulidae			0.2			
Tipula sp.	0.2					

Source: Firth et al. 1986.

Table 5-80. Relative Abundance (Percent Composition) of Macroinvertebrate Functional Groups in Fourmile Branch, October 1984-September 1985

Functional Group	Station 12	14	15	16	17	18
Collector-gatherers	25.53	57.69	80.94	79.61	84.41	65.76
Collector-filterers	67.91	28.37	10.17	13.79	3.65	28.66
Scrapers	0.23	1.06	0.51	0.04	2.69	0.15
Predators	5.92	12.67	8.16	6.48	9.15	5.33
Piercer-herbivores	0.13	0.21	0.22	0.07	0.09	0.05
Shredders	0.28	0.00	0.01	0.00	0.00	0.05
Total [a]	100.00	100.00	100.01	99.99	99.99	100.00

Source: Firth et al. 1986.
[a]Totals not equalling 100.00% are due to rounding error.

It is likely that ponding from beaver activity occurred upstream from Station 12 and that the nutrient inputs from SRS sources stimulated algal production, which resulted in an abundant source of food for filter-feeding macroinvertebrates.

Thermal Areas

During reactor operation, few macroinvertebrates were found in the water column of Fourmile Branch. Only a few species of oligochaetes, nematodes, and chironomids survived deep in the sediments. During reactor outages, the thermal portion of the stream quickly was colonized by several species of mayflies, caddisflies, and beetles. Gastropods also were collected at the thermal stations during reactor outages. The gastropods probably moved into the main channels of the creek from cooler side channels. Thus, the resident number of taxa, density of organisms, and biomass during reactor operation were much lower than suggested by the data in Table 5-77 and Table 5-79, which include data collected during reactor outages.

Creek Mouth

During reactor operation, water temperatures in the mouth of Fourmile Branch were always at least several degrees warmer than the Savannah River, except when the creek was flooded by high river levels. During reactor operation, water temperatures in the creek mouth exceeded 35°C (95°F) beginning in May and approached 40°C (104°F) in July. The macroinvertebrate community in the mouth of Fourmile Branch was far more diverse than that of the delta, but still exhibited strong evidence of thermal perturbation. The community was dominated by dipterans (primarily chironomids; Table 5-78). Some species, such as *Hyalella azteca* (Amphipoda) and *Caenis* spp. (Ephemeroptera), were abundant during the winter and spring. *Physella heterostropha* (Gastropoda) was abundant from January to April, especially on the multiplate samplers positioned near the creek bottom. From June to October, densities of all macroinvertebrates were low and the fauna consisted mostly of *Cheumatopsyche* spp. (Trichoptera), *Simulium* spp. (Diptera), and Nematoda. When river levels were high and the Savannah River swamp was flooded, the number of taxa and densities increased on multiplate samplers in the mouth of Fourmile Branch. When compared to the mouths of the other four creeks that drain SRS, Fourmile Branch had far lower mean densities, taxa richness, and biomass.

Recovery of Macroinvertebrate Community After Shutdown of C Reactor

Introduction

A smaller mesh size (#106) was used in the recovery study than in the CCWS (#600 mesh size). Therefore, density estimates from the recovery study are not directly comparable to density estimates from the CCWS. The smaller mesh size was used to collect very early instars of macroinvertebrates that might otherwise be missed by conventional sampling.

Recolonization

Following the shutdown of C Reactor in June 1985, macroinvertebrates rapidly colonized the stream. Within two months of shutdown, macroinvertebrate taxa richness in Fourmile Branch (mean of 20 taxa/sampler) was comparable to that of nonthermal SRS streams sampled during the CCWS (19.7-25.9 taxa/sampler). In subsequent months, the number of taxa collected was variable, but increased slightly over time, to about 23 taxa/sampler when sampling ended in September 1987 (Figure 5-29). Mean densities of macroinvertebrates were low during the first few weeks after reactor shutdown. However, in July 1985 densities increased sharply and peaked at 23,631 organisms/m^2 (Figure 5-30), which was the highest density reported during the recolonization study.

Taxa Collected

Table 5-81 lists all macroinvertebrate taxa collected during the recolonization study. The dominant organisms found during the first months of recovery were Orthocladiinae, Tanytarsini, and other chironomid early instar larvae, which accounted for up to 98.8% of the macroinvertebrates collected. Chironomids are often among the first colonizers of aquatic habitats that have been severely stressed. These data indicate that recolonization of Fourmile Branch following reactor shutdown was rapid for certain groups of aquatic insects. Other insects, such as caddisflies and mayflies, were somewhat slower to colonize, but still were present in relatively large numbers within two months of reactor shutdown. Mean macroinvertebrate biomass was similar to nonthermal streams within a month of reactor shutdown, and the distribution of biomass in functional groups was similar to most nonthermal streams at SRS.

Macroinvertebrate Community After Long-Term Shutdown of C Reactor

1993

Three of the six stations sampled in 1993, (at Roads 4, A-7, and A-13.2) had relatively high numbers of taxa (ranging from 46 to 52) and high mean numbers of taxa per sampler (ranging from 20.2 to 32.2; Table 5-82). Two of the remaining stations (at Road E-1 and C-4) had somewhat lower values for these parameters, while the macroinvertebrate community at Road C was extremely depauperate with only five taxa collected. The macroinvertebrate community was dominated by chironomids at most stations. Ephemeroptera (mayflies) were the most abundant group at the Road A-13.2 station, which is downstream of all the outfalls and in the section of the stream that received thermal effluent (Table 5-83). Collector-filterers, which feed on suspended organic matter were common at both Road A-13.2 (29.7% of the functional groups) and Road A-7 (35.7%) stations (Table 5-83). The source of perturbation at Road C appears to be low dissolved oxygen concentrations. Dissolved oxygen levels at that station were extremely low at the time of sample collection (0.8mg/l) and are probably responsible for the poor macroinvertebrate community at this location. Contrast these data with data from 1994, when dissolved oxygen concentration at the time of collection was 4.7 mg/l, still the lowest from all the creeks sampled, but not so low as to preclude the survival of macroinvertebrates. The macroinvertebrate data from 1993 indicate that the quality of the stream appears to improve with downstream distance (Specht 1994b).

1994

In 1994, there were 55 taxa collected in Fourmile Branch at Road C and 48 taxa at Road A-13.2. Mean number of taxa per sampler was 27.6 at Road C and 30.6 at Road A-13.2 (Table 5-82). Biomass was 0.0904 g/m^2 at Road C and 0.3176 g/m^2 at Road A-13.2. Tanytarsii (41%), oligochaetes (13%), Tanypodinae (14%), and Chironomini (11%) dominated

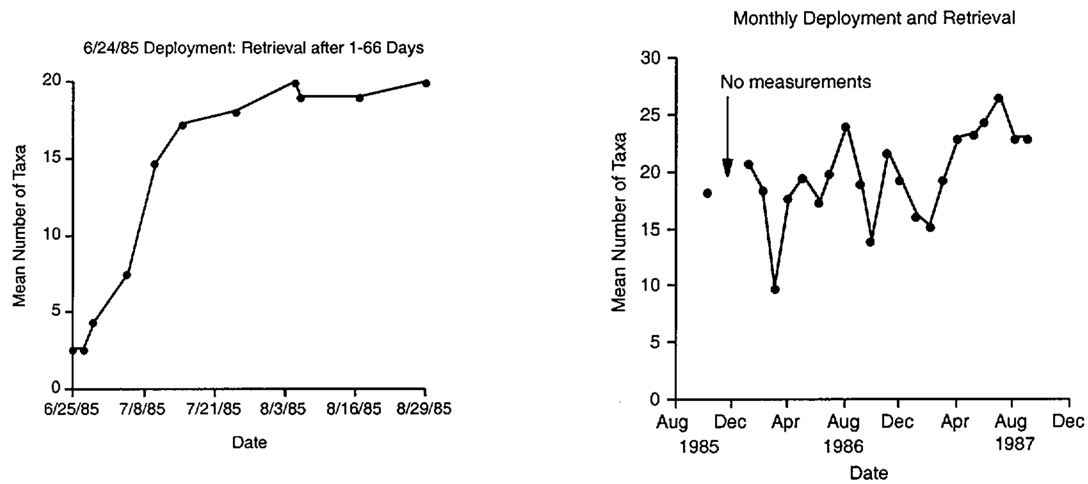

Figure 5-29. Macroinvertebrate Taxa Richness in Fourmile Branch at Road A-13.2 following C-Reactor Shutdown (Scale on y-axes are different).

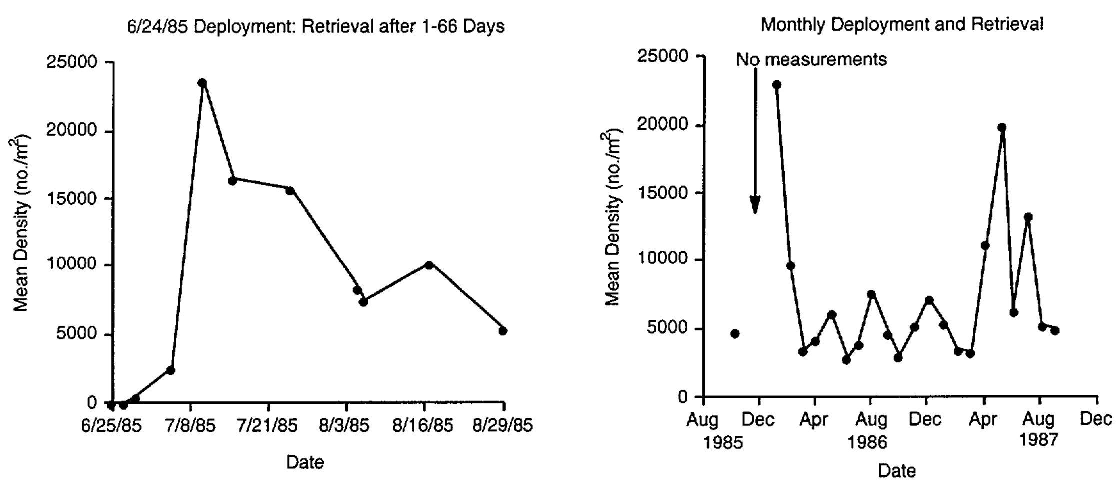

Figure 5-30. Total Macroinvertebrate Mean Density (no./m^2) in Fourmile Branch at Road A-13.2 following C-Reactor Shutdown

Table 5-81. Macroinvertebrate Taxa Found on Artificial Substrates in Fourmile Branch, June 1985-September 1987

Taxon
Class Turbellaria
Phylum Nematoda
Class Polychaeta
Manayunkia speciosa
Class Oligochaeta
Class Hirudinea
Class Gastropoda
Family Ancylidae
Family Physidae
Physella heterostropha
Family Planorbidae
Gyraulus parvus
Helisoma anceps
Helisoma trivolvis
Menetus dilatatus
Class Pelecypoda
Family Corbiculidae
Corbicula fluminea
Order Hydracarina
Order Amphipoda
Family Talitridae
Hyalella azteca
Order Ephemeroptera
Family Baetidae
Baetis
Callibaetis
Pseudocloeon parvulum
Family Caenidae
Caenis
Family Ephemerellidae
Ephemerella
Eurylophella temporalis
Serratella
Family Heptageniidae
Heptagenia
Stenacron interpunctatum
Stenonema modestum
Family Oligoneuriidae
Isonychia
Family Tricorythidae
Leptohyphes
Leptohyphes dolani
Tricorythodes
Order Odonata
Suborder Anisoptera
Family Aeshnidae
Boyeria
Boyeria vinosa
Family Corduliidae
Neurocordulia
Neurocordulia molesta
Family Gomphidae
Hagenius brevistylus
Family Macromiidae
Didymops transversa
Macromia
Suborder Zygoptera
Family Calopterygidae
Calopteryx
Hetaerina
Family Coenagrionidae
Argia
Enallagma
Order Plecoptera
Family Perlidae
Paragnetina fumosa
Paragnetina kansensis
Perlesta
Order Hemiptera
Family Corixidae
Order Coleoptera
Family Chrysomelidae
Pyrrhalta nymphaeae
Family Dytiscidae
Coptotomus
Family Elmidae
Ancyronyx variegatus
Dubiraphia
Macronychus glabratus
Microcylloepus pusillus
Stenelmis
Family Gyrinidae
Dineutus
Family Hydrophilidae
Family Ptilodactylidae
Order Megaloptera
Family Corydalidae
Corydalus cornutus
Order Trichoptera
Family Hydropsychidae
Cheumatopsyche
Hydropsyche
Macrostemum carolina
Family Hydroptilidae
Hydroptila
Oxyethira
Family Leptoceridae
Ceraclea
Nectopsyche
Nectopsyche candida
Oecetis
Triaenodes
Triaenodes tardus
Family Philopotamidae
Chimarra
Family Polycentropodidae
Cernotina
Neureclipsis
Order Lepidoptera
Family Pyralidae
Neargyractis
Parapoynx
Synclita
Order Diptera
Family Tipulidae
Antocha
Tipula
Family Chaoboridae
Chaoborus punctipennis
Family Simuliidae
Simulium
Family Ceratopogonidae
Subfamily Ceratopogoniinae
Subfamily Forcipomyiinae
Family Chironomidae
Subfamily Tanypodinae
Subfamily Diamesiinae
Potthastia
Subfamily Orthocladiinae
Subfamily Chironominae
Tribe Chironomini
Stenochironomus
Tribe Tanytarsini
Family Empididae
Chelifera
Hemerodromia

Table 5-82. Mean Number of Taxa, Density and Biomass for Macroinvertebrates Collected on Hester-Dendy Multiplate Samplers in Fourmile Branch, July - August 1993 and September 1994

	1993						1994	
	Road E-1	Road 4	Road C	Road C-4	Road A-7	Road A-13.2	Road C	Road A-13.2
Number of Taxa/Sampler	16.2	20.2	1.6	17.6	32.2	27.8	27.6	30.6
Density (no./m^2)	503.9	588.8	22.3	435.8	1909.5	1272.6	1959.8	1928.5
Mean Biomass (g/m^2)	0.0145	0.0253	0.0013	0.1955	0.0278	0.6950	0.0904	0.3176
Total Number of Taxa Collected	30	46	5	36	49	52	55	48

Source: Specht 1994b; Specht and Paller 1995.
Station designations between the years are not comparable.

Table 5-83. Percent Composition of Macroinvertebrate Taxa Collected on Hester-Dendy Multiplate Samplers in Fourmile Branch, July - August 1993 and September 1994

	Stations							
	1993						1994	
Taxa	Rd E-1	Rd 4	Rd C	Rd C-4	Rd A-7	Rd A-13.2	Rd C	Rd A-13.2
Hydra	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06
Ephemeroptera	9.76	3.23	0.00	1.54	13.17	55.75	1.37	44.67
Plecoptera	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.17
Trichoptera	0.89	2.85	0.00	4.87	11.88	7.55	0.91	12.63
Coleoptera	1.33	7.78	0.00	26.15	8.31	7.99	0.91	1.97
Odonata	3.33	4.17	5.00	0.77	0.23	0.44	0.46	0.29
Megaloptera	0.44	0.76	0.00	1.03	0.47	0.18	0.00	0.06
Other Diptera	2.22	3.80	0.00	4.36	3.04	4.04	0.74	0.52
Tanypodinate	31.04	5.69	0.00	8.21	2.11	3.69	14.42	5.45
Tanytarsini	23.95	10.25	0.00	1.79	31.30	2.63	41.28	19.93
Orthocladiinae	1.11	33.78	0.00	34.62	25.57	4.83	3.19	4.00
Chironomini	25.94	25.05	15.00	15.64	0.94	12.73	11.29	3.88
Pseudochiromomini	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00
Diamesinae	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00
Oligochaeta	0.00	0.38	0.00	0.00	0.23	0.00	13.00	4.69
Hirudinea	0.00	0.19	5.00	0.00	0.00	0.00	0.00	0.00
Gastropoda	0.00	1.90	75.00	0.26	0.35	0.00	0.11	0.00
Pelecypoda	0.00	0.00	0.00	0.51	0.00	0.18	0.00	0.00
Amphipoda	0.00	0.19	0.00	0.00	0.00	0.00	0.40	0.00
Hydracarina	0.00	0.00	0.00	0.26	2.22	0.00	0.11	0.52
Nemertea	0.00	0.00	0.00	0.00	0.00	0.00	2.79	0.81
Nematoda	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12
Turbellaria	0.00	0.00	0.00	0.00	0.00	0.00	8.95	0.23
Total	100.01	100.02	100.00	100.01	100.00	100.01	100.00	99.99

Source: Specht 1994b; Specht and Paller 1995.
[a]Note that station designations between the years are not comparable.

the macroinvertebrate community at Road C. At Road A-13.2, Ephemeroptera (45%), Tanytarsini (20%), and Trichoptera (13%) were the most common organisms (Table 5-83). Collector-gatherer was the most common functional feeding group at both locations (Table 5-84). The macroinvertebrate community at Road C underwent substantial recovery between 1993 and 1994 (Specht and Paller 1995).

Table 5-84. Relative Abundance (Percent Composition) of Macroinvertebrate Functional Groups in Fourmile Branch, July - August 1993 and September 1994

	Stations[a]							
	1993						1994	
Functional Group	**Rd E-1**	**Rd 4**	**Rd C**	**Rd C- 4**	**Rd A-7**	**Rd A-13.2**	**Rd C**	**Rd A-13.2**
Collector-Gatherers	61.42	77.23	15.00	74.87	41.14	42.05	66.19	55.97
Collector-Filterers	0.67	4.74	0.00	3.08	35.69	10.01	4.85	14.25
Predators	37.03	12.71	10.00	16.41	8.25	10.18	27.82	8.69
Scrapers	0.22	4.93	75.00	1.79	8.78	35.82	0.57	15.76
Shredders	0.67	0.38	0.00	3.85	0.23	0.79	0.40	0.98
Piercer-Herbivores	0.00	0.00	0.00	0.00	5.91	1.14	0.17	4.35
Total	100.01	99.99	100.00	100.00	100.00	99.99	100.00	100.00

Source: Specht 1994b; Specht and Paller 1995.
[a]Station designations between the years are not comparable.

Fish

Introduction

Classifying Studies

Fish studies in Fourmile Branch can be classified temporally into three phases. The earliest phase (prior to 1980) was descriptive and nonquantitative. Results of this work are summarized in a list of species and their relative abundances in Fourmile Branch and other riverine ecosystems (Bennett and McFarlane 1983), which is not discussed further.

Assessment of Thermal Impacts

The second and most extensive phase (1983-1985) concentrated on the assessment of impacts caused by the thermal discharges from C Reactor. Fourmile Branch was sampled at various locations, including the ambient temperature section of the stream above C Reactor, the section below C Reactor, and the section that flowed through the Savannah River floodplain swamp (Figure 5-31). These studies focused on distribution and relative abundance, reproduction, and habitat use.

Assessment of Potential Impacts from Contaminants

The third phase of work (performed in 1990) was undertaken to assess potential impacts to fish communities associated with contaminants outcropping from the waste disposal sites in F and H Areas. The latter work also documented the changes that have occurred in the Fourmile Branch fish community since C Reactor operations were terminated in 1985. The following discussion summarizes the second and third phases of fisheries work.

Station	
01	headwaters
02	Road 4
03	Road C
04	Road A-7
05	Road 3
06	Road A
07	Road A-13.2
08	delta
09	swamp
10	swamp
11	swamp
12	creekmouth

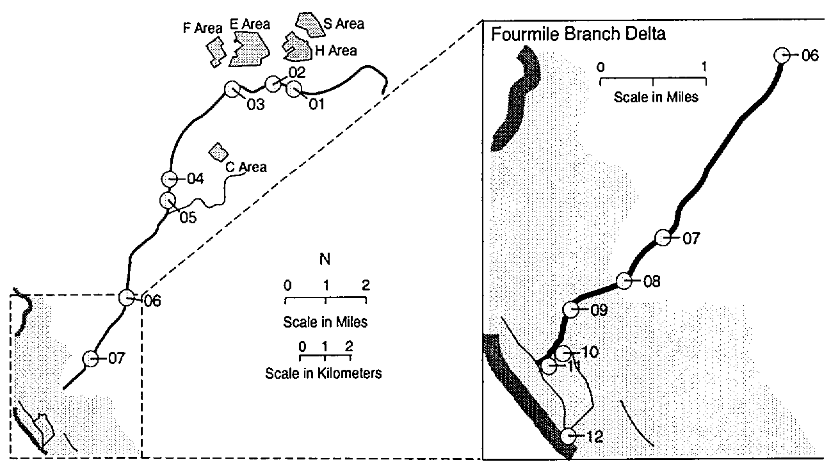

Figure 5-31. Fish Sampling Stations on Fourmile Branch

C-Reactor Operations

Fish Movements in Relation to Reactor Operation

Introduction

Fish were observed to enter the lower reaches of Fourmile Branch (i.e., the portion of Fourmile Branch that runs through the SRS Savannah River floodplain swamp) during reactor outages. These movements were studied by Aho et al. (1986) in Fourmile Branch and a similar section of Pen Branch. This work was conducted from September 1983 to December 1985 and involved collections made with fyke nets near the mouths and in the lower swamp reaches of both creeks. The sampling periods encompassed 3 and 16 outages of C and K Reactors, respectively.

Methods

Nets were placed in the stream channels one to two days before the outage. Thereafter, the nets were checked daily for the presence of fish until reactor restart. During periods when heated effluents were being released into either Fourmile Branch or Pen Branch, fish use was minimal. Fish never were captured in the fyke nets, and the resident fish assemblage was depauperate, dominated by the mosquitofish (>90% numerical abundance). Following a cessation in reactor production activities and a return to seasonally ambient water temperatures, fish were observed moving upstream from the Savannah River swamp system into both streams.

Seasonal Variation

The use of these upstream swamp habitats by fish varied seasonally. Timing of fish movement was comparable among years with the least upstream movement during the winter. Greatest movement occurred during spring and early summer, and intermediate levels of stream use occurred during summer and fall. Fish moved into the creeks predominantly along the streambank, but high catches occurred in mid-channel nets on several occasions during the summer and fall. Declining water levels and a return to ambient temperatures across the width of the stream associated with a reactor outage reduced the importance of the streambank route to upstream migrants.

Reactor Shutdown

Reinvasion of fish into the stream channels was rapid, with individuals captured within 12 hours of the cessation of reactor operations (Figure 5-32). There was no single pulse of upstream movement after the streams returned to ambient water temperatures and reduced discharge rates. Recolonization was variable for the duration of the shutdown (Figure 5-32).

Movement

Fish released following capture and later recaptured showed that several species made movements of 3-5 km (1.8-3.1 mi) within a week of their release. Fish that moved away from the original point of capture moved downstream, made local movements, or shifted laterally within the stream. Local movement was defined as recapture of the same fish at the same net within the same reactor cycle.

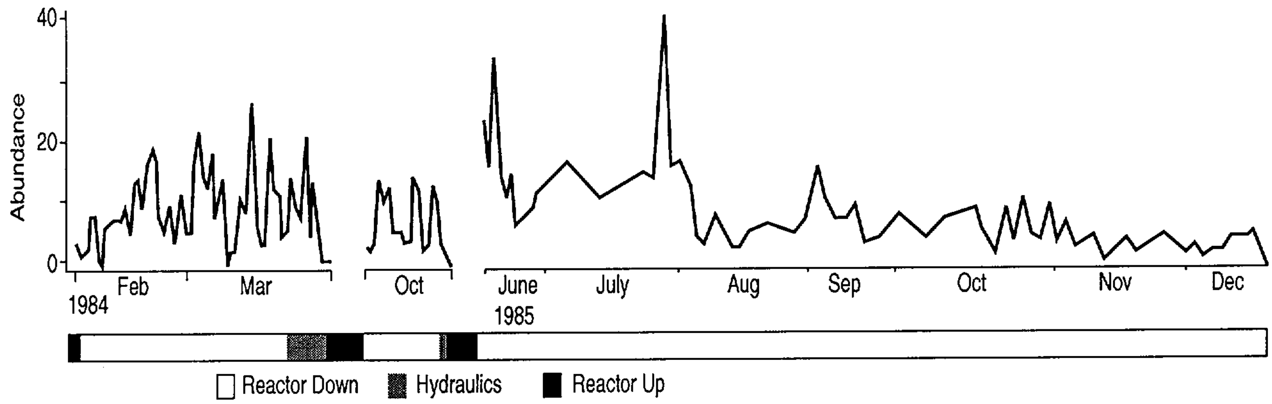

Figure 5-32. Variability in the Daily Mean Number of Individuals Entering Fourmile Branch at Different Reactor Cycles, 1983-1985

Upstream Migration

A dam approximately 1 km (0.6 mi) above the nets limited upstream migration within Fourmile Branch. Additionally, a nearby backwater served as a limited refuge area when water temperatures were high (McFarlane 1976). Observations during reactor outages revealed that the dam provides a barrier to the upstream migration of fish independent of reactor operation.

Species Collected

Totals of 39 and 29 species of fish were collected from the Fourmile Branch and Pen Branch channels (Aho et al. 1986), respectively. Centrarchids (sunfishes and basses) were the most abundant taxa, more than 30% of the species (Figure 5-33). Four species (spotted sunfish [*Lepomis punctatus*], lake chubsucker [*Erimyzon sucetta*], golden shiner [*Notemigonus crysoleucas*], and redbreast sunfish [*Lepomis auritus*]) accounted for more than 50% of the fish

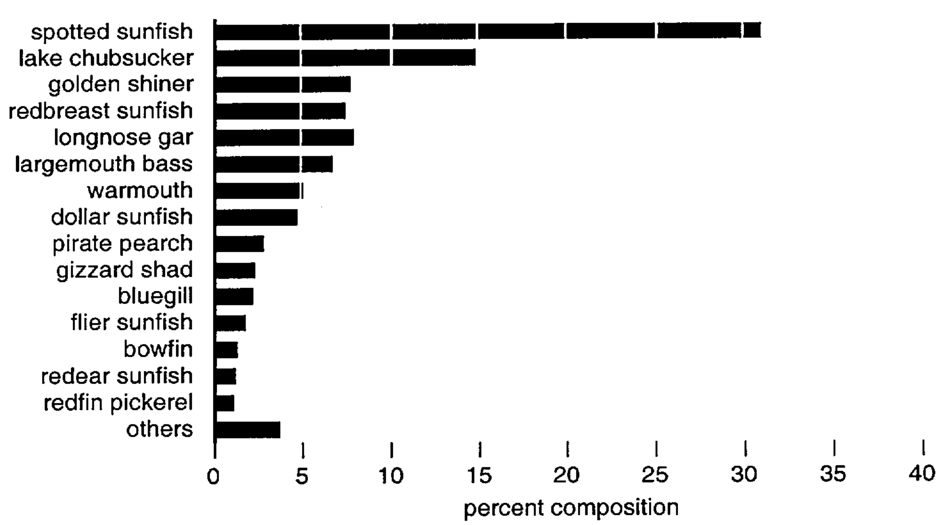

Figure 5-33. Overall Percent Composition of the Fish Assemblage Caught in Fyke Nets in Fourmile Branch (Source: Aho et al. 1986)

entering the stream channels. Individuals caught moving into the stream included both juveniles and adults. Cyprinids, principally the coastal shiner *(Notropis petersoni)*, and mosquitofish *(Gambusia affinis)*, frequently were observed in the streams during periods of ambient conditions. Their absence from the collection (Figure 5-33) reflects a sampling bias of the nets against small fishes.

Effects of Reactor Restart

The number of fish killed when thermal conditions were reestablished was low compared to the cumulative number that moved upstream during ambient water temperature conditions. Visual observations suggested that fish responded to the increased flow rates and release of heated effluents associated with a reactor restart by moving downstream into the Savannah River floodplain swamp. Some potential refuge areas existed along the stream margin (e.g., marshes and isolated groundwater seepage zones), but were either ephemeral or too small to provide sufficient shelter for the number of fish that migrated upstream during reactor outages.

Fish Assemblages at Thermal Swamp Sites

Introduction

Aho et al. (1986) also studied the fish assemblage structure within the Savannah River swamp system. Four sites (FMl, FM2, FM3, and FM4) were in or near the flow path of Fourmile Branch (original text has descriptions of locations). A total of 11,996 individuals representing 51 species were collected by electrofishing during the study. (Table 5-85 lists the species collected in Fourmile Branch.) The vast majority of species were categorized as year-round residents. However, two species (hickory shad [*Alosa mediocris*] and striped mullet [*Mugil cephalus*]) were migratory. Centrarchids and cyprinids represented more than 40% of the taxa and individuals.

Faunal Groups

Although the more common species occurred throughout the Savannah River swamp system, a cluster analysis based on relative abundance provided evidence of spatial variation (Figure 5-34). Eight major faunal group clusters were formed. The four sites within Fourmile Branch grouped together, along with the three sites associated with Stave Island (downstream of Fourmile Branch in the Savannah River Swamp) and one site in Steel Creek. Temporal variability in assemblage composition was minor compared to spatial differentiation of the groupings. In the majority of cases (>70%), the seasonal censuses from the same site (spring, summer, and fall) fell within the same cluster.

Dominant Species in Faunal Groups

While no cluster had a unique fish fauna, cross classifying the clusters with the dominant fish species (those contributing at least 5% of the numerical size of a faunal group) highlighted basic compositional differences between the different groups (Table 5-86). Large-bodied species, such as the bowfin (*Amia calva*), gizzard shad (*Dorosoma cepedianum*), longnose gar (*Lepisosteus osseus*), and largemouth bass (*Micropterus salmoides*) were the dominant species of the depauperate Group A assemblage, which included the Fourmile Branch sites. Largemouth bass, brook silversides (*Labidesthes sicculus*), longnose gar, and cyprinids also were identified as common species (Figure 5-33). For the remaining faunal

Table 5-85. Fish Species Present at Four Fourmile Branch Study Sites within the Savannah River Swamp System

	Location			
	Fourmile 1	**Fourmile 2**	**Fourmile 3**	**Fourmile 4**
Coastal shiner		x	x	x
Golden shiner	x			
Spotted sucker	x	x		x
Mosquitofish	x			
Brook silversides			x	x
Largemouth bass	x	x	x	x
Spotted sunfish	x			x
Redbreast sunfish		x		
Bluegill		x		
Redear sunfish		x	x	
American eel	x	x		
Longnose gar	x		x	x
Florida gar	x		x	
Bowfin	x		x	x
Chain pickerel	x	x		
Gizzard shad	x	x	x	x
Hickory shad[a]	x	x		

Source: Aho et al. (1986).
[a]Fewer than five individuals were collected.

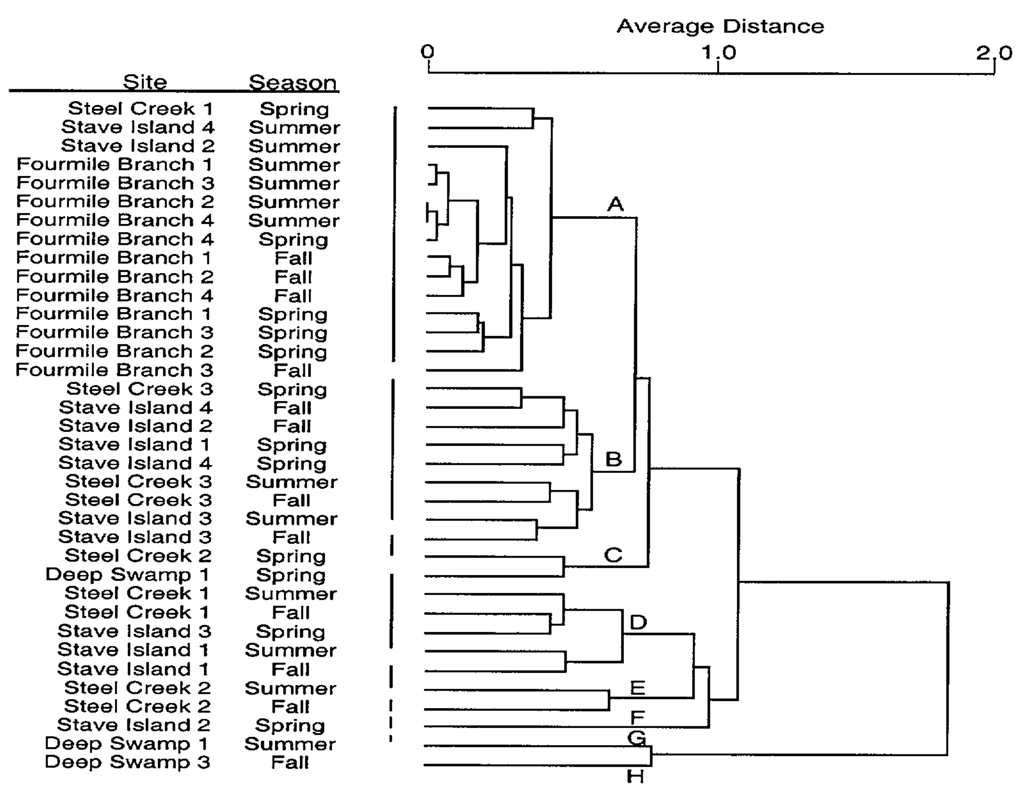

Figure 5-34. Average Linkage Cluster Analysis of the Fish Assemblage Structure from Collections from Twelve Sites During Three Seasons in the Savannah River Swamp System

Table 5-86. Two-Way Table Comparing Faunal Clusters and Fish Species Associations Contributing at Least 5 Percent to the Abundance of a Specific Cluster within the Savannah River Swamp System.

	Faunal Cluster[a]							
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**
mean richness[b]	2.1	11.6	13.8	10.7	18.3	13	15	12.5
mean abundance[b]	2.1	14.5	9.6	23.5	31.7	32.5	40.8	48.4
bowfin	>10%							
longnose gar	>10%							
gizzard shad	>10%	>5%						
brook silversides		>10%	>5%	>10%	>10%	>10%	>10%	>10%
largemouth bass	>5%	>10%		>10%	>5%	>5%		
golden shiner			>5%					>5%
chain pickerel			>10%					
ironcolor shiner		>5%	>10%		>10%		>10%	>10%
coastal shiner		>5%			>10%	>5%	>5%	>5%
lake chubsucker			>5%	>5%	>10%	>5%		
spotted sunfish			>5%		>10%			>5%
pirate perch						>10%		
redbreast sunfish						>5%		
mosquitofish							>10%	

Source: Aho et. al. 1986.
[a]Faunal clusters are as shown in Figure 5-34.
[b]Mean species richness is derived from the total number of species from each site-season collection; mean abundance is the mean number of fish per 50-m transect.

clusters, the species assemblage had greater representation by minnows and centrarchids. Groups C through E represented a shift in general body shape from large-bodied to an assemblage dominated by small-bodied fishes.

Spatial Differentiation

The spatial differentiation in assemblage structure corresponded to two major habitat gradients within the Savannah River swamp system (Table 5-87). Faunal cluster A was most closely linked with sites that had high water temperatures. Areas experiencing high levels of thermal loading had depauperate assemblages dominated by mosquitofish when water temperatures were elevated, but were rapidly reinvaded when ambient temperature conditions returned. The second gradient involved different degrees of canopy closure. Faunal Cluster B was associated with sites characterized as having a predominantly closed overstory of cypress and tupelo, limited emergent macrophyte growth, and low habitat complexity; open water and standing tree buttresses were the dominant habitat features. The number of species was moderate compared to other groups, but abundance was low and dominated by taxa commonly associated with less structured habitats. Open canopy, braided water courses with periodically high flow rates, and high habitat diversity with extensive macrophyte growth and downed timber characterized faunal clusters C through H and included sites where the canopy had been lost as a result of prior disturbances. Species associated with structurally complex habitats dominated these groups. Subtle elevations in water temperature at sites near Stave Island (SI2, SI3, and SI4) did not appear to additionally influence assemblage structure for either open or closed canopy groups.

Table 5-87. Summary of the Site Characteristics for the Twelve Locations Studied for Fish Species Composition within the Savannah River Swamp System

	Site Name											
Habitat Characteristics	**Steel Creek 1**	**Steel Creek 2**	**Steel Creek 3**	**Deep Swamp**	**Stave Island 1**	**Stave Island 2**	**Stave Island 3**	**Stave Island 4**	**Fourmile Branch 1**	**Fourmile Branch 2**	**Fourmile Branch 3**	**Fourmile Branch 4**
Percent shaded	5	0	75	10	50	60	80	30	70	0	0	0
Percent vegetation	2	80	5	70	20	10	5	30	0	0	0	0
Dominant riparian vegetation	Macrophyte	Macrophyte	Cypress /tupelo	Macrophyte	Cypress /tupelo	Cypress/ tupelo	Cypress/ tupelo	Cypress/ tupelo	Tupelo	Disturbed[a]	Disturbed	Disturbed
Temperature (max. °C)	24.1	26.3	24.2	24.0	23.8	26.9	28.5	31.5	42.3	44.9	43.6	45.4
Temperature condition	Ambient	Ambient	Ambient	Ambient	Ambient	Slightly heated	Slightly heated	Slightly heated	Heated	Heated	Heated	Heated
Maximum depth (m)	1.5	1.2	1.9	1.6	1.0	1.5	1.1	1.5	2.1	1.4	1.6	0.5
Mean current velocity (cm/s)	35	24	22	11	5	18	16	18	55	36	23	47

Source: Aho et al. 1986.
[a] No instream macrophytes or overhanging vegetation.

Effects of Canopy Cover

Several factors may have contributed to the difference in species richness and abundance between open- and closed-canopy areas. The occurrence of macrophyte growth can affect fish-assemblage dynamics by providing a refuge from predators (Werner and Hall 1979; Werner et al. 1983; Keast 1978). Macrophytes also may influence the availability of food resources by increasing the amount of substrate for secondary productivity of aquatic invertebrates, the dominant prey category for most of the fishes in the Savannah River swamp system.

Fish Assemblages at Thermal Stream Sites

Upstream of C Reactor

Paller et al. (1986) electrofished Fourmile Branch above C Reactor (at SRS Road A-7) on six dates and identified 20 taxa. Minnows were the most numerically abundant taxon followed by redbreast sunfish, spotted sunfish (*Lepomis punctatus*), and pirate perch (*Aphredoderus sayanus*) (Table 5-88). These taxa were also among the most numerous species in the undisturbed upper coastal plain streams of South Carolina as determined by Meffe and Sheldon (1988).

Table 5-88. Number of Fish Collected During Electrofishing at Fourmile Branch Near Road A-7

Taxa	12/21/84	12/31/84	2/28/85	5/17/85	8/8/85	8/9/85	All Dates Combined
minnow spp.	0	2	5	143	57	41	248
redbreast sunfish	30	4	21	18	8	24	105
spotted sunfish	5	5	15	22	4	6	57
pirate perch	16	7	11	5	1	1	41
creek chubsucker	6	11	5	1	1	4	28
dollar sunfish	4	0	1	11	1	1	18
tessellated darter	0	0	8	6	2	0	16
yellow bullhead	5	0	4	3	1	2	15
largemouth bass	1	0	3	2	1	3	10
grass pickerel	5	0	1	0	0	1	7
American eel	1	0	0	2	0	1	4
mosquitofish	3	0	0	0	0	0	3
warmouth	0	0	1	0	1	1	3
madtom	0	2	0	0	0	0	2
redear sunfish	0	0	0	2	0	0	2
bluegill sunfish	0	0	0	0	0	1	1
blackbanded darter	0	0	0	0	1	0	1
yellow perch	0	0	0	1	0	0	1
flat bullhead	0	0	0	0	1	0	1
bluehead chub	0	0	0	0	0	1	1

Source: Paller et al. 1986.

Downstream of C Reactor

No attempts were made to collect adult or juvenile fish in the portion of Fourmile Branch immediately below C Reactor. It is assumed that this area was devoid of fish when C Reactor was operating (except for some possible short-term migration of fish into this area during reactor outages) because average monthly temperatures during C-Reactor operation exceeded 50°C (122°F) throughout the year.

Paller and Saul (1986) studied fish communities in SRS streams between November 1984 and August 1985. Sampling stations for this study included sites near Road A and Road A-13.2, where electrofishing was scheduled quarterly. Collection data from those sites are summarized in Table 5-89. The observations from the study by Paller and Saul (1986) indicate that only mosquitofish inhabited the portion of Fourmile Branch below the C Reactor outfall during reactor operation. However, when C Reactor shut down, sunfish migrated into the area according to the findings of Aho et al. (1986) discussed earlier.

Effects of Cool Water

Paller and Saul (1986) collected additional samples in the lower reaches of Fourmile Branch (February 21, 1985). They sampled fish on one occasion (February 21, 1985) in the Fourmile Branch delta using a backpack electroshocker. Collections were taken from relatively cool backwater areas during a period of reactor operation. Only one specimen, a brook silverside, was captured. Mosquitofish were observed in the cooler portions of the Fourmile Branch delta on numerous occasions when C Reactor was operating. Thus, mosquitofish were undoubtedly year-round residents of portions of the delta.

Table 5-89. Fish Collected from Fourmile Branch near Road A and Road A-13.2

Date	C Reactor Status	Taxa	Number Collected
12/3/84	up	mosquitofish	55
3/1/85	up	mosquitofish	5
5/9/85	up	mosquitofish	15
8/19/85	down	mosquitofish	42

Source: Paller and Saul 1986.

Effects of Reactor Operation

Paller and Saul (1986) electrofished the mouth of Fourmile Branch on 15 occasions (Table 5-90). Eleven taxa were represented. They found that few or no fish were present when C Reactor was operating and water temperatures were elevated, but that fish rapidly reinvaded the area during reactor outages.

Ichthyoplankton Distribution

Introduction

Paller and Saul (1986) also collected ichthyoplankton from seven sampling stations on Fourmile Branch during 1984 and 1985. One station was situated near Road A-7 in the undisturbed headwaters upstream from the confluence with the reactor cooling water effluent. One station was at Road A, approximately 8 km (5 mi) downstream from C Reactor, one at the inflow into the delta, three in the thermal swamp downstream from the delta, and one in the creek mouth (Figure 5-31). The three thermal swamp stations were grouped together in the following analysis because they had similar habitats and temperatures.

Table 5-90. Fish Collected from the Fourmile Branch Delta

	1984			1985											
Species	11/7	12/5	12/14	1/4	1/10	1/17	2/6	2/14	2/21	2/28	3/7	3/14	3/21	4/10	8/19
largemouth bass	5	1	0	1	0	1	0	0	0	0	2	0	1	0	0
bluegill sunfish	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1
channel catfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
redbreast sunfish	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1
brook silverside	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
bowfin	4	0	0	1	0	0	0	0	0	0	0	0	0	0	0
minnow spp.	1	0	0	0	0	0	1	0	0	0	0	0	0	0	2
spotted sucker	0	0	0	1	0	0	0	0	1	0	0	2	0	0	1
longnose gar	0	0	0	0	1	0	1	2	0	0	0	2	1	0	0
gizzard shad	0	0	0	0	0	0	1	0	0	1	0	1	0	0	1
lake chubsucker	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0

Source: Paller and Saul 1986.

Effects of Reactor Operation

A total of 206 ichthyoplankton was collected from Fourmile Branch between March 14 and July 31, 1984. Centrarchids were the most abundant taxa, although brook silverside and blueback herring (*Alosa aestivalis*) were also well-represented (Table 5-91).

C Reactor was operating at full power throughout April and May 1984, and operation was intermittent during March. As a result, temperatures at Road A ranged from 33.9 to 40.1°C (93-104°F), and temperatures at the inflow into the delta ranged from 30.1 to 44.8°C (86.1-112.6°F) during the spring spawning season of 1984 (Figure 5-35). Ichthyoplankton were absent from these sites with the exception of some brook silverside eggs and unidentifiable eggs collected from the Road A sample site in May 1984. These eggs probably drifted into the channel of Fourmile Branch from cooler side-channel waters (Paller 1985).

Thermal Variation in Swamp

Temperatures in the Fourmile Branch thermal swamp and creek mouth ranged from 18 to 42°C (64.4 to 107.6°F), and were lower and much more variable than at the inflow into the Fourmile Branch delta and at the Road A sample stations. The temperature variability in the thermal swamp was due to the intermittent intrusion of relatively cool river water during periods of high water in the Savannah River. During these periods, the river water displaced the thermal plume and created suitable habitats for fishes in normally hot areas. Most of the larvae collected from the Fourmile Branch thermal swamp during April and May 1984 were spawned during periods of high river water levels when the swamp was inundated with cool river water. These larvae were principally centrarchids, but also included blueback herring and threadfin or gizzard shad (*Dorosoma* spp.). Some larvae also were collected when temperatures were relatively high (37°C [98.6°F]) in mid-April 1984. These larvae may have drifted into the main swamp channels from the cooler backwater areas (Paller 1985).

Table 5-91. Number and Percent Composition of Ichthyoplankton Collected from Fourmile Branch, March 14-July 31, 1984

Taxa	Number	Percent
gizzard and/or threadfin shad	16	7.8
blueback herring	21	10.2
unid. herring or shad	4	1.9
sunfish and/or bass	66	32.0
crappie	5	2.4
yellow perch	1	0.5
darters	2	1.0
minnows	14	6.8
carp	3	1.5
brook silverside	28	13.6
unid. ichthyoplankton[a]	46	22.3
total	206	100.0

Source: Paller 1985.
[a]Primarily eggs.

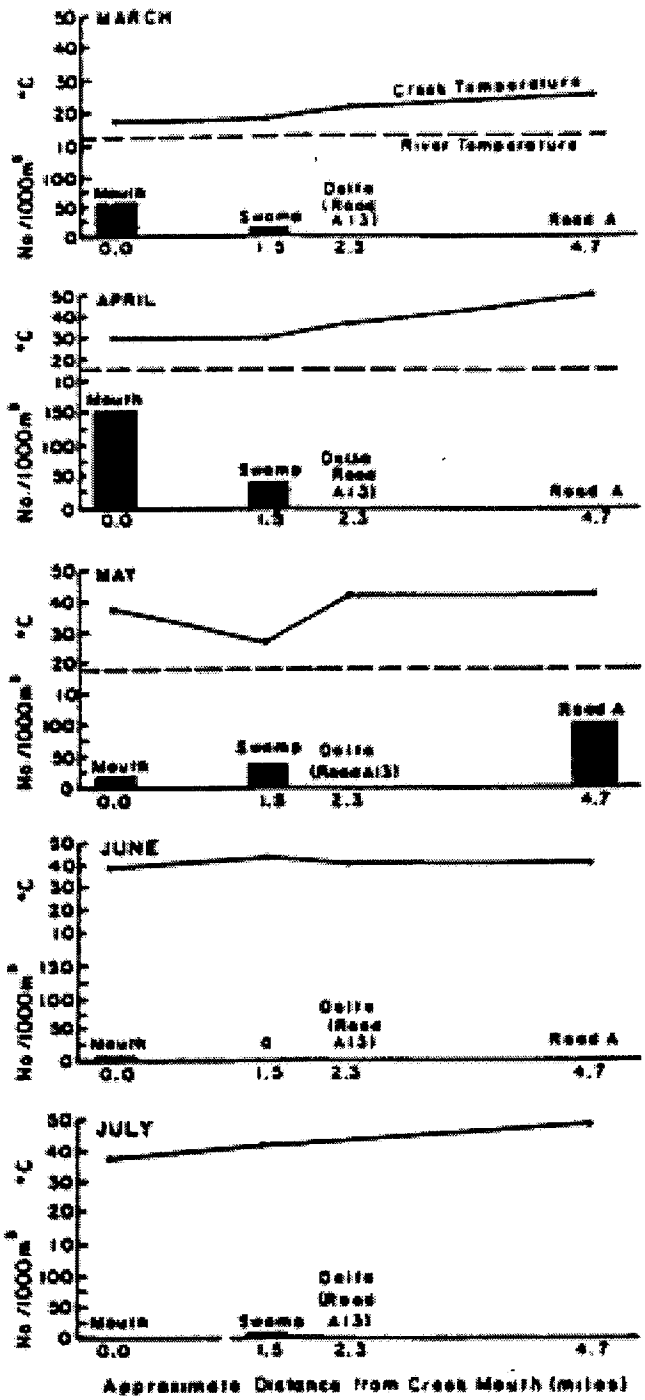

Figure 5-35. Average Ichthyoplankton Densities and Water Temperatures at Four Sampling Stations in Fourmile Branch March-July 1984

A total of 174 ichthyoplankton was collected from Fourmile Branch between February and July 1985 (Table 5-92). Unidentified ichthyoplankton (primarily eggs) were most common. Mean densities of ichthyoplankton upstream from C Reactor were generally low (<15/ 1000 m^3) (Figure 5-36), and most of the organisms collected were minnows or centrarchids. Throughout the sampling, ichthyoplankton were largely absent from the sample station near Road A, where water temperatures sometimes exceeded 40°C (104°F) when C Reactor was operating. Farther downstream in the delta, some cooling had occurred, but temperatures still remained near 40°C (104°F) during much of the sampling.

Mouth of Fourmile Branch

No larvae or eggs were collected from the mouth of Fourmile Branch except in February, March, and May 1984. The ichthyoplankton densities in the mouth of Fourmile Branch were greatest in May. All of the ichthyoplankton collected during May were unidentifiable eggs. They were taken on a single sample date when C Reactor was briefly shutdown and the water temperature was 27°C (80.6°F). These data suggest that fish began spawning in the creek mouth as soon as temperatures became tolerable (Paller 1985).

Comparison of 1984 and 1985 Data

Except for the densities at the creek mouth, ichthyoplankton were less abundant in Fourmile Branch during 1985 than during 1984 (Figure 5-37). The differences in the swamp and creek mouth ichthyoplankton densities probably were due to differences in the level of the Savannah River during those years. During the spring of 1984, the swamp was intermittently flooded by cool river water (Paller 1985). Most of the larvae taken from the swamp during 1984 were collected when the swamp was flooded. Conversely, the Savannah River generally remained below flood stage during 1985, and relatively few ichthyoplankton were collected from Fourmile Branch.

Effects of Temperature on Ichthyoplankton

Introduction

Aho et al. (1986) studied larval fish assemblages at nine sampling locations in the Savannah River swamp system during 1985. Five stations spanned a wide range of temperatures (temperatures elevated 2-19°C [7.2-34°F] above ambient) along the plumes from Fourmile Branch and Pen Branch. These were numbered 1 through 5, from hottest to coolest. The other four stations near the mouth of Steel Creek were at ambient temperatures (Aho [1986] has a description of station locations). Each sampling station was an area roughly 50 m (164 ft) in diameter and included both channels and adjacent shallows (except two stations that had no distinct channels).

Effect of Reactor Operation

At stations within the thermal plumes, water temperatures changed suddenly when reactors stopped and started. During these reactor cycles, recording thermometers showed temperatures fell to ambient levels (and subsequently rose) at about 1°C (1.8°F)/hr at the Fourmile Branch stations. Stations 4 and 5 had more gradual temperature changes due to their distances from the main flow from Pen Branch. The most extreme fluctuations among the nonthermal sites occurred at the station in a shallow disturbed area that lacked canopy vegetation, where temperatures changed 20°C (36°F) over two weeks in February.

Table 5-92. Number and Percent Composition of Ichthyoplankton Collected from Fourmile Branch, February-July 1985

	Number	Percent
blueback herring	3	1.7
minnows	14	8.0
carp	7	4.0
mosquitofish	2	1.2
brook silverside	2	1.2
sunfish and/or bass	14	8.0
crappie	3	1.7
darters	6	3.4
unid. ichthyoplankton[a]	123	70.7
total	174	99.9

Source: Paller et al. 1986.
[a] Primarily eggs.

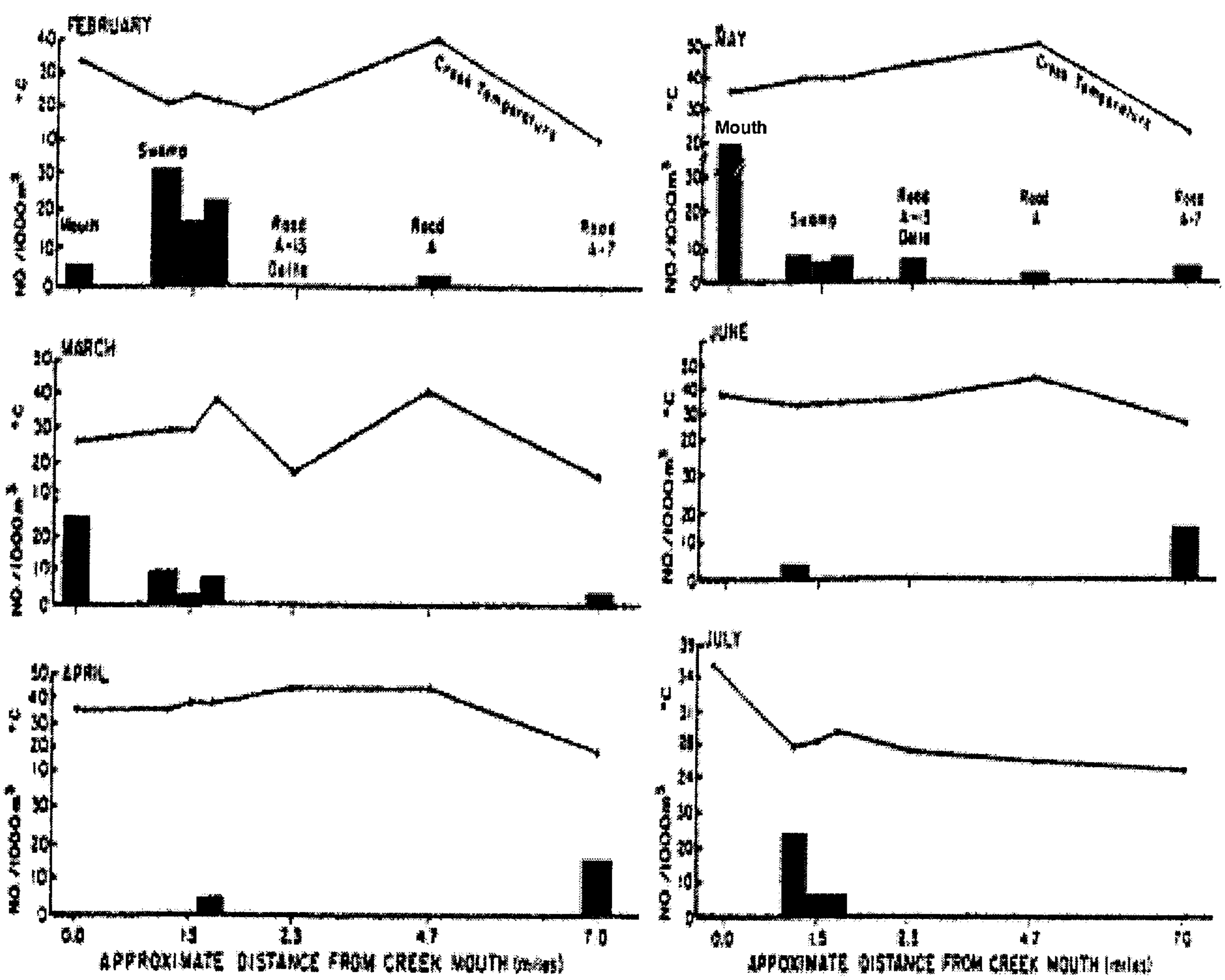

Figure 5-36. Monthly Mean Water Temperature and Ichthyoplankton Density at Each Sampling Site in Fourmile Branch, February-July 1985

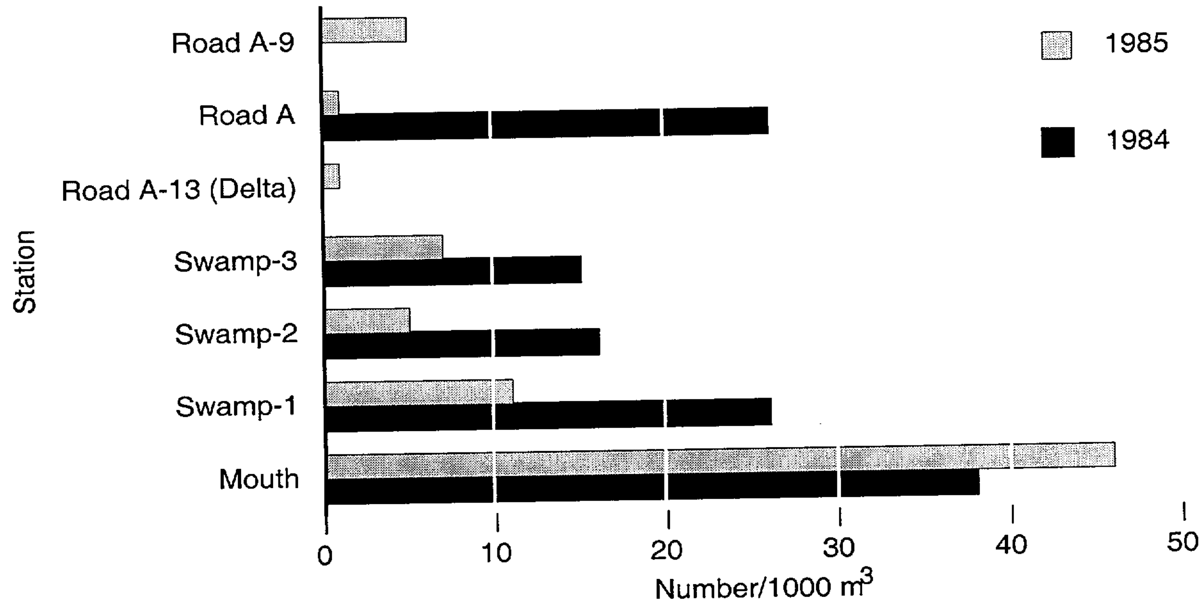

Figure 5-37. Total Ichthyoplankton Densities at Fourmile Branch Locations during the 1984 and 1985 Sampling Program (Source: Paller et al. 1986)

No larvae were collected in the first week of January at any location, although water temperatures exceeded 15°C (59°F) in the hottest thermal areas. Densities began to rise at thermal Stations 1 through 3 by the end of January. In the ambient temperature areas, density peaks occurred later in the year.

Densities

The timing of peak ichthyoplankton densities differed by as much as eight weeks between the hottest thermal area and the ambient temperature stations (Figure 5-38). Seasonal patterns were advanced, even at Station 5, where temperatures were only about two degrees warmer than in the natural or previously disturbed habitats (Figure 5-38).

Maximum densities occurred two to four weeks earlier in the previously disturbed areas, where canopy trees had been killed, than in the natural areas; although water temperatures were similar (Figure 5-38).

Reproductive Phenology

In the thermal areas, reproductive phenology was disrupted in several respects. Most pronounced was a disruption in the sequence of appearance of larvae of different taxa. Larval cyprinids, golden shiners, brook silversides, sunfish, and darters all were taken at Stations 1 and 2 by the first week of February, suggesting that many of the normally spring- or summer-spawning species began to reproduce in the thermal areas in early January. Some of these species may have been capable of spawning during the fall and early winter in thermal areas. Water quality values other than temperature appeared similar at all stations. Thus, shifts in reproduction or changes in species composition probably result directly or indirectly from differences in temperature, light intensity, or trophic base of the community.

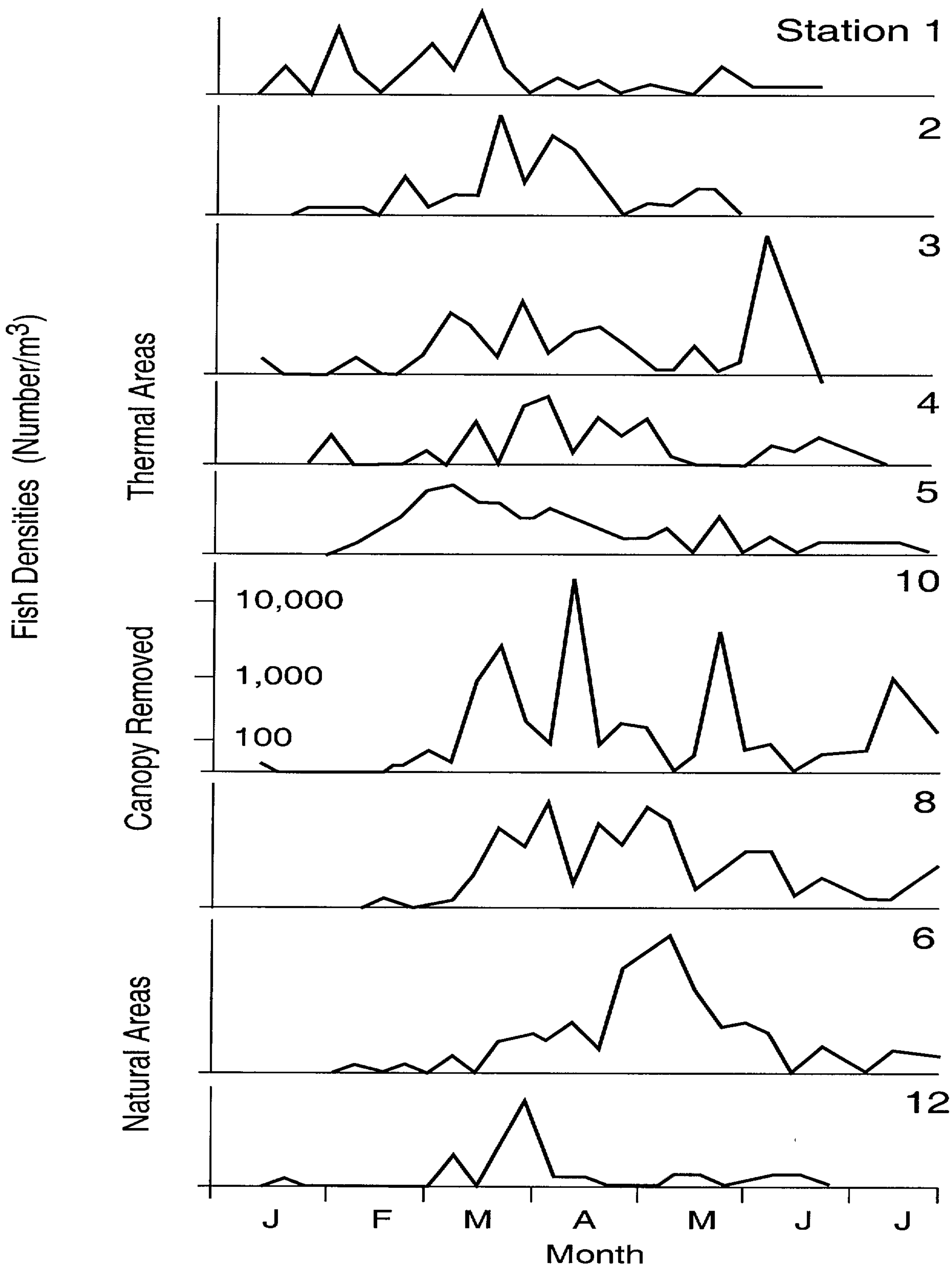

Figure 5-38. Seasonal Changes of Total Ichthyoplankton Density at each Station (These station numbers do not correspond to those on the map in Figure 5-33)

F- and H-Area Impacts

Introduction

Paller and Storey (1990) electrofished Fourmile Branch during June 26–July 2, 1990, to assess the impacts of outcropping groundwater from the F- and H-Area seepage basins on fish abundance and distribution. Effluents formerly discharged to the basins contained sodium hydroxide, nitric acid, low levels of radionuclides (mostly tritiated water), and dissolved metals (Looney et al. 1988, Haselow et al. 1990). These effluents seeped into the ground, migrated through the subsurface strata, and outcropped into Fourmile Branch and adjacent wetlands. Seepage basin discharge appeared to cause elevated conductivity, total dissolved solids, nitrate, phosphate, sodium, potassium, and, possibly, cadmium levels in Fourmile Branch downstream from the seepage basins (Looney et al. 1988). In addition, gross beta and tritium levels were above either the proposed or established drinking water standards at one or more points in Fourmile Branch (Haselow et al. 1990).

Effects of Seepage Basin Constituents on Fish

The occurrence of elevated levels of several seepage basin constituents in Fourmile Branch water raised concerns about possible impacts to aquatic organisms. Gladden et al. (1985) reviewed the historical data from the upper reaches of Fourmile Branch to determine if outcropping effluent from the seepage basins was adversely affecting the instream communities. He concluded that there was no clear evidence of adverse impacts due to the seepage basin effluent, but said the data were insufficient to evaluate possible local effects. To provide more information, a sampling program was designed to assess the abundance, distribution, and tissue contaminant levels of Fourmile Branch fish upstream and downstream from the seepage basins. This program included seven sample stations: six in Fourmile Branch, including locations upstream from (Stations 1 and 2) and downstream from (Stations 3 - 6) the seepage basins, and one in Pen Branch (Figure 5-31). The sample station in Pen Branch was included primarily to serve as a source of uncontaminated fish to establish background levels of potential tissue contaminants. Three 100-m (328 ft) stream segments were electrofished at each sample station.

Sampling Program

Fish assemblage structure differed among sample stations. Pirate perch, redbreast sunfish, and creek chubsuckers (*Erimyzon oblongus*) dominated Station 1. Several types of shiners (*Notropis* spp.) (dusky, yellowfin, or taillight) and sunfishes (*Lepomis* spp.) (dollar, spotted, or redbreast) dominated Stations 2-4. Mosquitofish, redbreast sunfish, spotted sunfish, and yellow bullhead dominated Stations 5 and 6. The number of fish collected per 100 m (catch per unit effort or CPUE) also differed among stations (Table 5-93). The lowest CPUE in Fourmile Branch occurred at Station 2 (44.7 fish/100 m) and the highest occurred at station 4 (149.7 fish/100 m). However, a comparison of collections at Stations 1 and 2 (above the outcropping zone) with Stations 3 and 4 (below the outcropping zone) indicated that species number and total (i.e., all species summed) CPUE were higher below the outcropping zone than above (Figure 5-39; Table 5-94). On an individual species basis, four species decreased below the outcropping zone, while nine increased. These differences were not indicative of adverse impacts due to seepage basin outcropping and were more likely from habitat differences among stations.

Table 5-93. Relative Abundance (Percent Composition) of Fish Collected at Six Sample Stations in Fourmile Branch and One Sample Station in the Headwaters of Pen Branch, June 1990

	Fourmile Branch						
Species	**1**	**2**	**3**	**4**	**5**	**6**	**Pen Branch at Road B**
American eel	0.0	0.0	0.0	0.2	1.1	0.0	0.0
eastern mudminnow	0.0	0.0	0.0	0.0	0.0	0.0	0.3
redfin pickerel	2.8	3.0	1.6	0.9	1.7	0.0	1.5
bluehead chub	0.0	0.0	1.2	6.0	1.1	0.2	4.3
golden shiner	1.9	0.0	0.0	0.0	0.0	0.0	0.0
ironcolor shiner	0.0	0.0	0.0	0.0	0.0	0.0	0.2
dusky shiner	0.0	22.4	30.5	2.2	8.0	3.9	1.5
yellowfin shiner	0.0	0.0	17.6	41.9	1.1	0.0	72.4
taillight shiner	5.2	0.0	11.3	4.5	0.0	0.0	0.0
coastal shiner	0.0	0.0	0.0	0.7	1.7	0.2	0.0
creek chub	0.0	0.0	0.0	0.0	0.0	0.0	1. 5
creek chubsucker	13.7	21.6	3.1	2.2	0.0	0.0	2.3
yellow bullhead	5.2	15.7	1.2	4.9	12.5	12.9	0.0
tadpole madtom	0.0	3.0	3.1	0.0	2.3	0.5	0.0
margined madtom	0.0	0.0	3.1	0.0	0.0	0.0	0.3
speckled madtom	0.0	0.0	0.0	0.0	0.0	0.0	0.2
pirate perch	36.5	7.5	5.9	2.7	2.3	6.3	4.0
lined topminnow	0.0	0.0	0.0	0.0	0.0	0.0	0.1
mosquitofish	0.5	0.7	2.7	0.4	18.2	39.4	0.3
redbreast sunfish	20.4	3.7	7.0	16.7	28.4	24.6	2.8
dollar sunfish	8.5	9.7	0.0	0.4	0.0	0.0	0.8
spotted sunfish	5.2	12.7	3.1	11.1	16.5	11.9	0.8
largemouth bass	0.0	0.0	0.0	0.2	0.0	0.0	0.0
savannah darter	0.0	0.0	8.6	1.1	0.0	0.0	0.0
tessellated darter	0.0	0.0	0.0	2.4	0.0	0.0	6.2
blackbanded darter	0.0	0.0	0.0	1.3	5.1	0.0	0.4
Total	99.9	100.0	100.0	99.8	100.0	99.9	99.9
Total number fish	211	134	256	449	176	411	952
Total number species	10	10	14	18	13	9	18

Key to sample station locations:
1 Fourmile Branch 1.1 km (0.7 mi) upstream from Road 4.
2 Fourmile Branch at Road 4.
3 Fourmile Branch at Road C.
4 Fourmile Branch at Road A-7.
5 Fourmile Branch downstream at Road A (not on map in Figure 5-33).
6 Fourmile Branch at Cassels Pond (just upstream of delta/swamp).

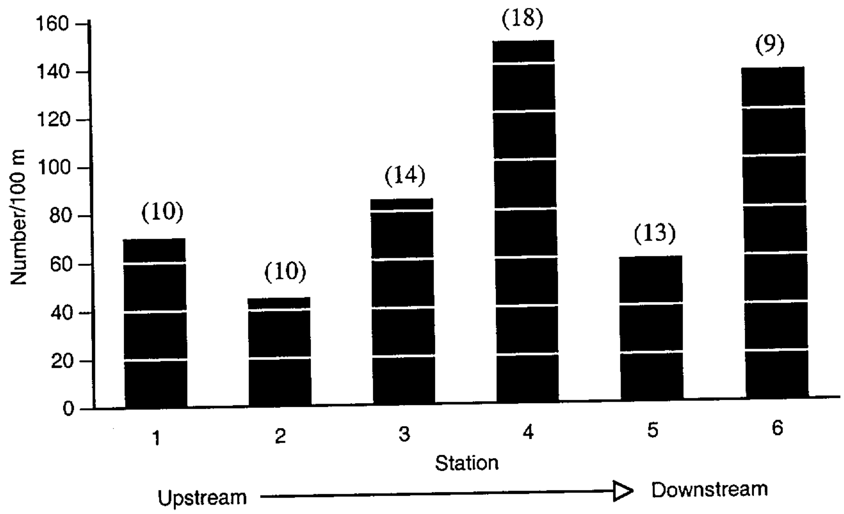

Figure 5-39. Mean Electrofishing Catch per Unit Effort at Sample Stations in Fourmile Branch (Number of species collected is in parentheses)

Table 5-94. Mean (Standard Error) Electrofishing Catch Per Unit Effort (CPUE Expressed as Number Fish Per 100 m) at Six Sample Stations in Fourmile Branch and One Sample Station in the Headwaters of Pen Branch, June 1990

	Fourmile Branch						
Species	**1**	**2**	**3**	**4**	**5**	**6**	**Pen Branch at Road B**
American eel	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.3 (0.3)	0.7 (0.3)	0.0 (0.0)	0.0 (0.0)
eastern mudminnow	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	1.0 (0.6)
redfin pickerel	2.0 (1.0)	1.3 (1.3)	1.3 (0.8)	1.3 (0.7)	1.0 (0.6)	0.0 (0.0)	4.7 (1.2)
bluehead chub	0.0 (0.0)	0.0 (0.0)	1.0 (0.6)	9.0 (3.5)	0.7 (0.7)	0.3 (0.3)	13.7 (3.2)
golden shiner	1.3 (0.7)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0 0)	0.0 (0.0)
ironcolor shiner	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.7 (0.3)
dusky shiner	0.0 (0 0)	10.0 (1.0)	26.0 (15.0)	3.3 (3.3)	4.7 (4.7)	5.3 (3.0)	4.7 (4.2)
yellowfin shiner	0.0 (0.0)	0.0 (0.0)	15.0 (4.5)	62.7 (2.7)	0.7 (0.3)	0.0 (0.0)	229.7 (40.9)
taillight shiner	3.7 (1.9)	0.0 (0.0)	9.7 (0.9)	6.7 (1.9)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
coastal shiner	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	1.0 (1.0)	1.0 (1.0)	0.3 (0.3)	0.0 (0.0)
creek chub	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	4.7 (2.2)
creek chubsucker	9.7 (3.3)	9.7 (3.8)	2.7 (1.5)	3.3 (2.4)	0.0 (0.0)	0.0 (0.0)	7.3 (3.5)
yellow bullhead	3.7 (1.2)	7.0 (3.0)	1.0 (0.6)	7.3 (2.3)	7.3 (2.8)	17.7 (5.7)	0.0 (0.0)
tadpole madtom	0.0 (0.0)	1.3 (0.9)	2.7 (1.7)	0.0 (0.0)	1.3 (0.7)	0.7 (0.7)	0.0 (0 0)
margined madtom	0.0 (0.0)	0.0 (0.0)	2.7 (0.3)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	1.0 (0.6)
speckled madtom	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.7 (0.3)
pirate perch	25.7 (13.2)	3.3 (0.7)	5.0 (2.1)	4.0 (0.6)	1.3 (0.7)	8.7 (3.3)	12.7 (4.4)
lined topminnow	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.3 (0.3)
mosquitofish	0.3 (0.3)	0.3 (0.3)	2.3 (1.2)	0.7 (0.7)	10.7 (5.4)	54.0 (9.0)	1.0 (0.6)
redbreast sunfish	14.3 (2.8)	1.7 (0.3)	6.0 (1.0)	25.0 (6.7)	16.7 (6.8)	33.7 (18.4)	9.0 (6.5)
dollar sunfish	6.0 (1.5)	4.3 (1.2)	0.0 (0.0)	0.7 (0.7)	0.0 (0.0)	0.0 (0.0)	2.7 (0.9)
spotted sunfish	3.7 (0.9)	5.7 (1.7)	2.7 (1.5)	16.7 (6.4)	9.7 (2.7)	16.3 (5.5)	2.7 (0.7)
largemouth bass	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.3 (0.3)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
savannah darter	0.0 (0.0)	0.0 (0.0)	7.3 (0.9)	1.7 (0.9)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
tessellated darter	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	3.7 (1.9)	0.0 (0.0)	0.0 (0.0)	19.7 (6.1)
blackbanded darter	0.0 (0 0)	0.0 (0.0)	0.0 (0.0)	2.0 (1.2)	3.0 (1.2)	0.0 (0.0)	1.3 (0.3)
Total CPUE	70.3 (22.4)	44.7 (1.9)	85.3 (24.3)	149.7 (17.3)	58.7 (13.0)	137.0 (27.2)	317.6 (62.9)
Total species	10	10	14	18	13	9	18

Key to sample station locations:
1 Fourmile Branch 1.1 km (0.7 mi) upstream from Road 4.
2 Fourmile Branch at Road 4.
3 Fourmile Branch at Road C.
4.Fourmile Branch at Road A-7.
5 Fourmile Branch downstream of Road A (not on map in Figure 5-33).
6 Fourmile Branch at Cassels Pond (just upstream of delta/swamp).

Table 5-94. Mean (Standard Error) Electrofishing Catch Per Unit Effort (CPUE Expressed as Number Fish Per 100 m) at Six Sample Stations in Fourmile Branch and One Sample Station in the Headwaters of Pen Branch, June 1990

	Fourmile Branch						
Species	**1**	**2**	**3**	**4**	**5**	**6**	**Pen Branch at Road B**
American eel	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.3 (0.3)	0.7 (0.3)	0.0 (0.0)	0.0 (0.0)
eastern mudminnow	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	1.0 (0.6)
redfin pickerel	2.0 (1.0)	1.3 (1.3)	1.3 (0.8)	1.3 (0.7)	1.0 (0.6)	0.0 (0.0)	4.7 (1.2)
bluehead chub	0.0 (0.0)	0.0 (0.0)	1.0 (0.6)	9.0 (3.5)	0.7 (0.7)	0.3 (0.3)	13.7 (3.2)
golden shiner	1.3 (0.7)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0 0)	0.0 (0.0)
ironcolor shiner	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.7 (0.3)
dusky shiner	0.0 (0 0)	10.0 (1.0)	26.0 (15.0)	3.3 (3.3)	4.7 (4.7)	5.3 (3.0)	4.7 (4.2)
yellowfin shiner	0.0 (0.0)	0.0 (0.0)	15.0 (4.5)	62.7 (2.7)	0.7 (0.3)	0.0 (0.0)	229.7 (40.9)
taillight shiner	3.7 (1.9)	0.0 (0.0)	9.7 (0.9)	6.7 (1.9)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
coastal shiner	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	1.0 (1.0)	1.0 (1.0)	0.3 (0.3)	0.0 (0.0)
creek chub	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	4.7 (2.2)
creek chubsucker	9.7 (3.3)	9.7 (3.8)	2.7 (1.5)	3.3 (2.4)	0.0 (0.0)	0.0 (0.0)	7.3 (3.5)
yellow bullhead	3.7 (1.2)	7.0 (3.0)	1.0 (0.6)	7.3 (2.3)	7.3 (2.8)	17.7 (5.7)	0.0 (0.0)
tadpole madtom	0.0 (0.0)	1.3 (0.9)	2.7 (1.7)	0.0 (0.0)	1.3 (0.7)	0.7 (0.7)	0.0 (0 0)
margined madtom	0.0 (0.0)	0.0 (0.0)	2.7 (0.3)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	1.0 (0.6)
speckled madtom	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.7 (0.3)
pirate perch	25.7 (13.2)	3.3 (0.7)	5.0 (2.1)	4.0 (0.6)	1.3 (0.7)	8.7 (3.3)	12.7 (4.4)
lined topminnow	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.3 (0.3)
mosquitofish	0.3 (0.3)	0.3 (0.3)	2.3 (1.2)	0.7 (0.7)	10.7 (5.4)	54.0 (9.0)	1.0 (0.6)
redbreast sunfish	14.3 (2.8)	1.7 (0.3)	6.0 (1.0)	25.0 (6.7)	16.7 (6.8)	33.7 (18.4)	9.0 (6.5)
dollar sunfish	6.0 (1.5)	4.3 (1.2)	0.0 (0.0)	0.7 (0.7)	0.0 (0.0)	0.0 (0.0)	2.7 (0.9)
spotted sunfish	3.7 (0.9)	5.7 (1.7)	2.7 (1.5)	16.7 (6.4)	9.7 (2.7)	16.3 (5.5)	2.7 (0.7)
largemouth bass	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.3 (0.3)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
savannah darter	0.0 (0.0)	0.0 (0.0)	7.3 (0.9)	1.7 (0.9)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
tessellated darter	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	3.7 (1.9)	0.0 (0.0)	0.0 (0.0)	19.7 (6.1)
blackbanded darter	0.0 (0 0)	0.0 (0.0)	0.0 (0.0)	2.0 (1.2)	3.0 (1.2)	0.0 (0.0)	1.3 (0.3)
Total CPUE	70.3 (22.4)	44.7 (1.9)	85.3 (24.3)	149.7 (17.3)	58.7 (13.0)	137.0 (27.2)	317.6 (62.9)
Total species	10	10	14	18	13	9	18

Key to sample station locations:
1 Fourmile Branch 1.1 km (0.7 mi) upstream from Road 4.
2 Fourmile Branch at Road 4.
3 Fourmile Branch at Road C.
4.Fourmile Branch at Road A-7.
5 Fourmile Branch downstream of Road A (not on map in Figure 5-33).
6 Fourmile Branch at Cassels Pond (just upstream of delta/swamp).

Changes in Fish Assemblage with Habitat Alterations

While not a consequence of seepage basin operation, species number and total CPUE decreased downstream from Station 4 (Table 5-94). Mosquitofish, a species commonly associated with thermal and post-thermal sites on the SRS (Aho et al. 1986), increased in abundance below Station 4. These changes are likely from habitat alterations associated with past thermal discharge from C Reactor. Decreases in species number and CPUE at these stations indicate that recovery from C-Reactor operation was not yet complete at the time of this study.

Fish Communities Comparison with Unimpacted Streams

The fish community below the outcropping zone, but above the former point of C Reactor cooling water entry, also was evaluated by comparing it to the fish communities in nearby unimpacted streams of similar size and generally similar habitat. Three unimpacted stream reaches (upper Meyers Branch, upper Steel Creek, and upper Pen Branch [Station 7]) were used in this comparison. Species number at Stations 3 and 4 in Fourmile Branch was comparable to species number in the other streams. Relative abundance at Stations 3 and 4 was generally similar to that in the other streams, except that sunfishes constituted a slightly higher percentage of the community and minnows a slightly lower percentage.

Fish Analysis for RCRA Trace Metals

Fish collected from Fourmile Branch and Pen Branch were analyzed for Resource Conservation and Recovery Act (RCRA) trace metals using standard U.S. Environmental Protection Agency methods. Loehle and Paller (1990) report the results of the analyses. Silver, arsenic, beryllium, cadmium, copper, nickel, lead, antimony, and thallium were all either undetectable or had only a few detectable values. Mercury values were all well below 1 μg/l. For the total group of fish analyzed, there were no differences among sampling sites for aluminum, chromium, or zinc. Selenium concentrations differed among sites; fish collected near the H-Area and two control sites had the highest concentrations. When the analysis was restricted to sunfishes only, the seepage basin site was shown to be slightly elevated. Among species, yellowfin shiners had higher aluminum and zinc concentrations than sunfishes and bottom fish.

Summary of Studies

These studies provided no indication that outcropping groundwater from the F- and H-Area seepage basins adversely affected the fish community in Fourmile Branch. Because there was an absence of adverse changes in community structure below the outcropping zone, community structure in this region generally was comparable to community structure in other relatively unimpacted SRS streams, and there was no indication of significant accumulation of heavy metals in the fish. However, they do indicate that habitat alterations from past C-Reactor operations still were influencing fish community structure in Fourmile Branch at the time of the study.

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5.4 Pen Branch

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Drainage Description and Surface Hydrology

General Description

Pen Branch drains an area of about 55 km^2 (21 mi^2) and is approximately 24 km (15 mi) long. The creek flows southwesterly, from its headwaters about 3.2 km (2 mi) east of K Area to the Savannah River swamp (Figure 5-40). After entering the swamp, the creek flows parallel to the Savannah River for about 8 km (5 mi) before it enters and mixes with the waters of Steel Creek about 0.4 km (0.2 mi) from the mouth of Steel Creek on the Savannah River. In its headwaters, Pen Branch is a largely unperturbed blackwater stream, similar to the headwater reaches of Fourmile Branch. Indian Grave Branch is the principal tributary of Pen Branch.

Pen Branch discharges into the Savannah River floodplain swamp rather than flowing directly into the Savannah River. The discharge of Pen Branch into the swamp formed a delta where water temperatures typically ranged from 25 to 40°C (45 to 72°F) above ambient during reactor operations. The flow from Pen Branch spreads over the delta and continues through the swamp as shallow sheet flow until entering the lower reaches of Steel Creek; from there it travels to the Savannah River. When the Savannah River inundates the floodplain swamp, Pen Branch flows along the northern border of the swamp and crosses the Steel Creek delta. When the Savannah River is not flooding, the Pen Branch flow enters the Steel Creek channel downstream from the swamp. By the time Pen Branch discharged into Steel Creek during reactor operation, its temperature was near ambient, due to dilution and cooling in the swamp.

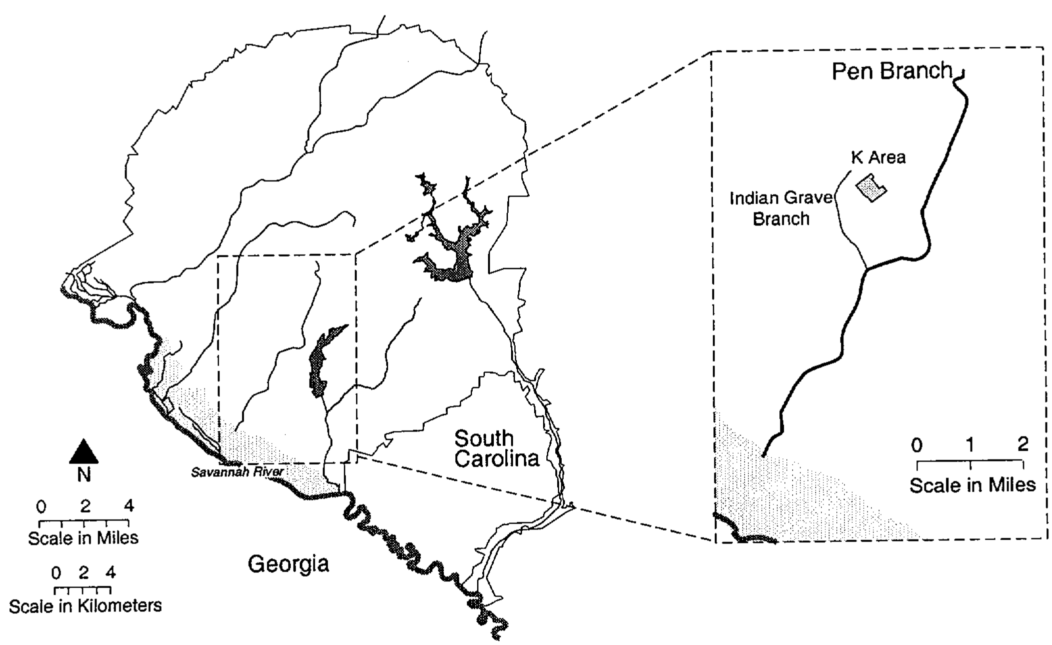

Figure 5-40. Location of Pen Branch on SRS

Effluents Contribution

Until K Reactor shut down in 1988, Indian Grave Branch received thermal effluent from K Reactor. With K-Reactor discharge, the natural flow of about 0.3 m^3/s (10 ft^3/s) was increased to about 11.3 m^3/s (400 ft^3/s). K-Reactor cooling water discharges, which originated from the Savannah River, changed the water quality and temperature and flow regimes in Pen Branch (Firth et al. 1986). Currently, the Pen Branch system receives nonthermal effluents (i.e., nonprocess cooling water, ash basin effluent waters, powerhouse waste water, and sanitary waste water) from K Area and sanitary effluent from the Central Shops Area. K Reactor has been placed on permanent shutdown; therefore, flow and temperature will no longer affect the stream.

Pen Branch, via Indian Grave Branch, receives the following National Pollutant Discharge Elimination System (NPDES) permitted discharges: cooling water, blowdown, powerhouse wastewater, stormwater, 186 basin overflow, and sanitary wastewater.

Flow Measurements

The U.S. Geological Survey measures flow at several locations on Pen Branch. Table 5-95 summarizes flow statistics for Pen Branch at SRS Road B and at SRS Road A-13.2 (Figure 5-41). Records at SRS Road A-13.2 date back to November 1976 (no records from February 1983 through April 1983). In water-year 1995, the mean flow of Pen Branch at Road A-13.2 was 1.6 m^3/s (55.8 ft^3/s). Over the period of record (water-years 1977-1995) at Road A-13.2, the mean flow was 5.9 m^3/s (210 ft^3/s), the 7-day low flow was 0.25 m^3/s (8.8 ft^3/s), and the 7Q10 was 0.15 m^3/s (5.46 ft^3/s). The maximum, minimum, and mean daily flows from December 1983 to September 1995 at SRS Road B are shown in Figure 5-42. The maximum, minimum and mean daily flows from October 1982 to September 1995 at Road A-13.2 are shown in Figure 5-43.

	Station Name
01	at SRS Road B
02	at SRS Road A-13.2

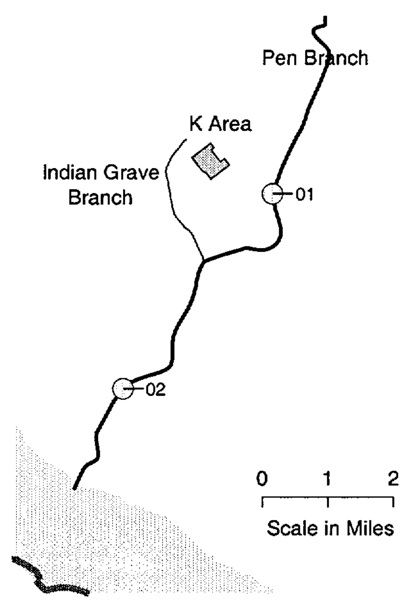

Figure 5-41. Flow Measurement Sampling Stations for Pen Branch

Table 5-95. Flow Summary for Pen Branch

			Range						7Q10		7-Day Low Flow	
			Mean		Low		High					
Station Name	Station Number	Period of Record	cms	cfs	cms	cfs	cms	cfs	cms	cfs	cms	cfs
at Road B at SRS	021973471	1983-1995	0.21	7.5	0.01	0.21	10.5	372	0.01	0.27	0.01	0.22
at Road A-13.2 at SRS	02197348	1976-1995	5.9	210	0.24	8.6	21.5	760	0.15	5.46	0.25	8.8

cms = cubic meters per second.
cfs = cubic feet per second.

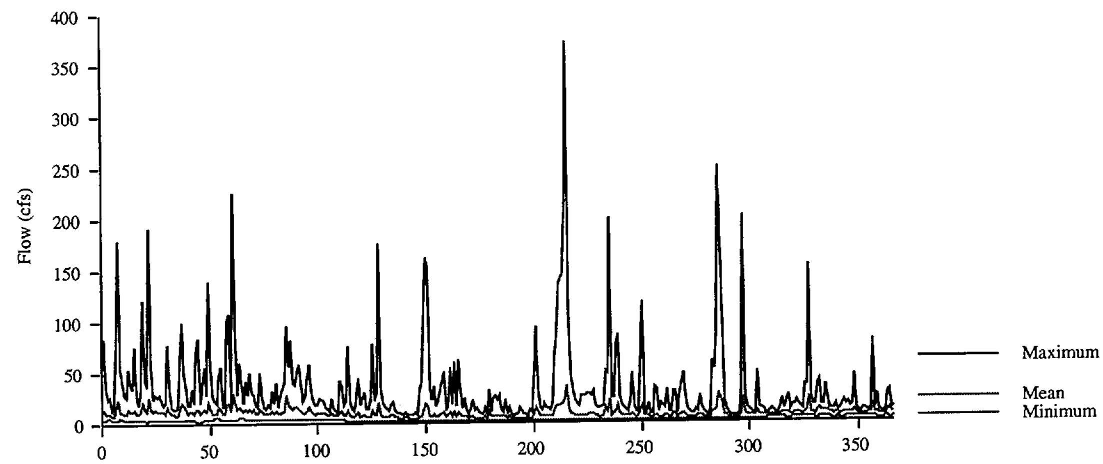

Figure 5-42. Maximum, Mean, and Minimum Flow for Pen Branch at SRS Road B, December 1988-September 1995

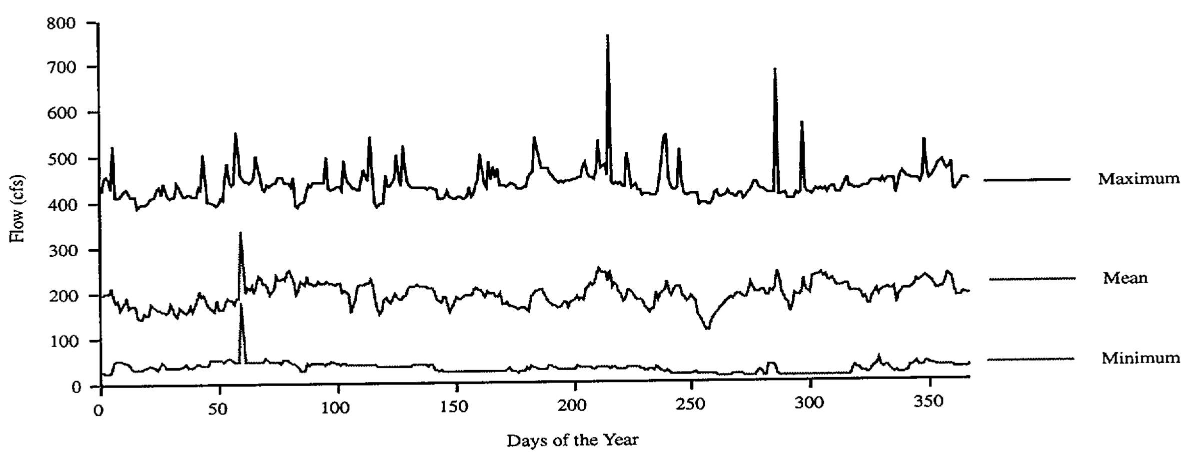

Figure 5-43. Maximum, Mean, and Minimum Flow for Pen Branch at SRS Road A-13.2, October 1982-September 1995

Water Chemistry and Quality

Studies and Monitoring

Water-Quality Monitoring

The WSRC Environmental Monitoring Section (EMS) has conducted routine water quality monitoring of the Pen Branch system since 1973. EMS monitors one location on Pen Branch near Road A-17 (Figure 5-44; location 04) monthly for physical and biological water quality indicators and quarterly for metals. EMS also collects an additional sample annually and analyzes it for pesticides, herbicides, and PCBs. All routine water quality monitoring data reported in the following sections can be found in the annual SRS Environmental Reports.

Comprehensive Cooling Water Study

Five locations on the Pen Branch system were studied from 1983 to 1985 as part of the Comprehensive Cooling Water Study (CCWS). This study was designed to assess present and proposed SRS activities on water quality. The Pen Branch sampling locations (Figure 5-44) include the following:

- Pen Branch at Road B (01) - measured the effects of the effluent from the Central Shops Area
- Indian Grave Branch downstream of K-Reactor Effluent (02) - measured the effects of the thermal effluent
- Pen Branch at Road A-13 (03) - downstream of confluence of Indian Grave Branch and Pen Branch

Station Number	
01	Road B
02	Downstream of K-Reactor effluent
03	Road A-13
04	Road A-17
05	Pen Branch upsream of confluence with Steel Creek
06	Road C
07	Road A

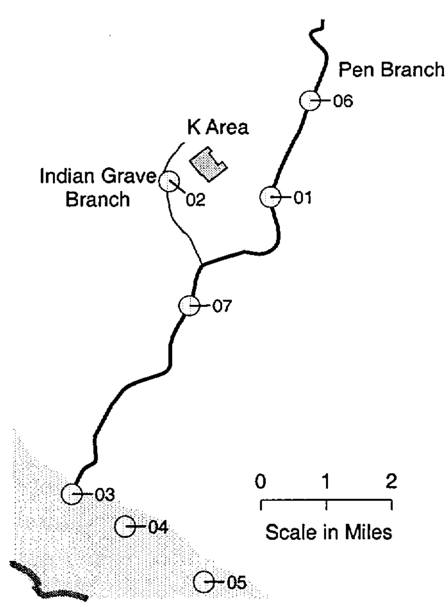

Figure 5-44. Water Chemistry and Quality Sampling Stations for Pen Branch

- Pen Branch at Road A-17 (04) - measured concentrations after release to the Savannah River Swamp
- Pen Branch upstream of Steel Creek confluence (05) - measured thermal effluents and upriver waters during periods of high river water, which overflows into the Savannah River Swamp

The data collected downstream of K-Reactor effluent during the CCWS reflect impacts associated with reactor operation and are not relevant to the current conditions of the stream. However, because limited monitoring data are available for the Pen Branch system, all data will be presented.

Comprehensive results and discussion of CCWS data can be found in Newman et al. (1986) and Lower (1987).

Priority Pollutants Survey

In 1984, a special instream survey of priority pollutants was conducted to determine the levels of volatile, acid, and base/neutral organic compounds in the Pen Branch system. Three stations - near Road C, Road B, and Road A - were established in Pen Branch. Newman et al. (1986) and Lower (1987) documented these results. Lower (1987) also reported the results of analyses for pesticides and PCBs in the Pen Branch system.

Field Data

Water Temperature

During reactor operation, mean temperatures in thermal portions of the Pen Branch watershed (33.5 - 48.1°C [95.9 - 118.5°F]) ranged from 18 to 33°C (32 to 59°F) above those of the upstream nonthermal waters (17.4°C [63.3°F]) (Table 5-96). The temperatures at the thermal sites fluctuated more widely than those of the nonthermal site due to the reactor cycle. The shutdown of K Reactor in 1987 decreased temperatures to an average of 22°C (71.6°F) in the Pen Branch system.

pH Measurements

The pH values for the thermal sites (mean 7.46) were higher than those of the nonthermal site (mean 6.89), reflecting Savannah River source-water pH levels. Over the past 9 years, the pH near Road A-17 has ranged from 5.7-8.6 (Table 5-96).

Physical Characteristics and General Chemistry

Dissolved Oxygen

The dissolved oxygen concentration is inversely related to water temperature, reflected in the data the CCWS generated. The mean dissolved oxygen concentrations in the thermal waters were much lower (5.3-7.5 mg/l or 87-90% saturation) than those at the nonthermal site. Mean dissolved oxygen concentration was 8.12 mg/l at the Pen Branch nonthermal site. Because there has been no thermal input to the Pen Branch system since 1987, the mean dissolved oxygen concentrations (8.5 mg/l between 1987 and 1991 and 9.1 mg/l between 1992

Table 5-96. Pen Branch Field Data

	Water Temperature (°C)	pH	Stream Depth (cm)	Stream Velocity (cm/sec)
Pen Branch at Road B (CCWS)[a]				
Mean	15.2	6.93	75	48
Range	1.4- 24.0	5.10 - 9.00	40 - 164	9 - 140
Samples	46	46	28	40
Indian Grave Branch downstream of K-Reactor effluent (CCWS)[a]				
Mean	48.1	7.42	100	183
Range	7.6 - 68.0	5.90 - 8.70	31 - 143	45 - 260
Samples	46	46	34	
Pen Branch at Road A-13 (CCWS)[a]				
Mean	42.6	7.42	119	124
Range	7.1 - 60-.0	5.60 - 8.59	91 - 127	7 - 180
Samples	45	44	28	39
Pen Branch at Road A-17 (CCWS)[a]				
Mean	33.5	8.11	29	15
Range	7.90 - 46.3	5.70 - 9.25	23 - 41	-15 - 140
Samples	46	45	21	39
Pen Branch at Road A-17 (1987 - 1991)[b]				
Mean	22			
Range	7.8 - 56	5.7 - 7.9	NA	NA
Samples	60	60		
Pen Branch Swamp upstream of Steel Creek confluence (CCWS)[a]				
Mean	17.4	6.89	120	20
Range	1.0 - 29.0	6.40 - 8.10	21 - 259	5 - 41
Samples	42	45	21	37
Pen Branch at Road A - 13.2 (1992 - 1995)[c]				
Mean	17.8	6.6		
Range	4.9 - 30.6	6 - 8.6	NA	NA
Samples	48	48		

NA = Not analyzed.
Blank spaces = Mean not calculated due to insufficient data in report.
[a]CCWS = Comprehensive Cooling Water Study (Newman et al. 1986).
[b]1987-1991 = Data taken from Arnett et al. 1992; Cummins et al. 1990, 1991; Davis et al. 1989; Mikol et al. 1988.
[c]1992-1995 = Data taken from Arnett 1993, 1994, 1995, and 1996.

and 1995) at Road A-17 have been similar to the concentrations measured at the nonthermal site during the CCWS (Table 5-97).

Suspended Solids and Turbidity

The CCWS measured a wide range of total suspended solids concentrations (mean 3.14-13.9 mg/l). At locations with slower water velocities, the total suspended solids concentrations were lower than at locations with higher water velocities. Data collected from 1987 to 1991 at Road A-17 indicate slightly higher total suspended solids concentrations (mean 7.7 mg/l). Between 1992 and 1995, total suspended solids concentrations were even higher (8.25 mg/l). Turbidity between 1992 and 1995 was about half of what it was during the CCWS (7.08 NTU).

Conductivity

Mean specific conductivity increased from 45.6 μS/cm at the nonthermal sites to 73.4 μS/cm at the thermal sites (Table 5-97). This change was linked to the specific conductance of Savannah River source water (Lower 1987). Routine water quality monitoring since the CCWS has measured a wide range of specific conductance (13-171 μS/cm), with a mean of 77 μS/cm.

Major Anions and Cations

Alkalinity, Chloride, and Sulfate

During the CCWS, mean concentrations of total alkalinity, chloride, and sulfate ranged from 13.8 to 17.9 mg/l, 2.48 to 6.02 mg/l, and 2.53 to 5.26 mg/l, respectively. The maximum total alkalinity, chloride, and sulfate concentrations were measured at the thermal sites and likely reflected the chemistry of the Savannah River water used to cool the reactor. Mean concentrations of total alkalinity (18.2 mg/l), chloride (7.1 mg/l), and sulfate (7.4 mg/l) from 1987 to 1991 have been slightly higher than the ranges measured during the CCWS (Table 5-98). Between 1992 and 1995, mean values of chloride, alkalinity, and sulfate were lower still (Table 5-98).

Calcium, Magnesium, Sodium, and Potassium

Concentrations of total calcium, magnesium, and sodium measured from 1987 to 1991 near Road A-17 are similar to those concentrations measured during the CCWS (Table 5-99). The CCWS determined that nearly all of the calcium, magnesium, sodium, and potassium in Pen Branch waters were in the dissolved fraction (Newman et al. 1986). The mean concentration of calcium was slightly higher at the nonthermal site than at the thermal sites. Magnesium, sodium and potassium, however, were higher at the thermal sites than at the nonthermal sites. SRS does not measure potassium during routine water quality monitoring. Calcium, magnesium, and sodium values between 1992 and 1995 were similar to those measured during the CCWS (Table 5-99).

Aluminum, Iron, and Manganese

Concentrations of total and dissolved aluminum measured during the CCWS were higher in the waters of the thermal sites than in those of the nonthermal site (Table 5-99). Approximately 92% of the aluminum was associated with the solid phase at the nonthermal site and

Table 5-97. Pen Branch Physical Characteristics and General Chemistry

	Dissolved Oxygen (mg/l)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Total Suspended Solids (mg/l)
Pen Branch at Road B (CCWS)[a]				
Mean	8.12	45.6	10.6	9.63
Range	5.80 - 12.3	28.2 - 75.0	3.10 - 52.2	0.25 - 72.4
Samples	46	38	43	45
Indian Grave Branch downstream of K-Reactor effluent (CCWS)[a]				
Mean	5.32	74.6	21.4	10.0
Range	2.70 - 11.5	50.7 - 90.1	7.30 - 61.5	0.25 - 43.2
Samples	45	36	43	45
Pen Branch at Road A-13 (CCWS)[a]				
Mean	5.63	73.4	21.3	13.9
Range	3.30 - 11.1	48.9 - 91.4	3.00 - 55.0	1.60 - 145.5
Samples	45	37	42	43
Pen Branch at Road A-17 (CCWS)[a]				
Mean	7.53	71.9	14.6	4.63
Range	5.50 - 12.3	47.7 - 98.3	3.80 - 57.4	0.25 - 36.7
Samples	45	38	43	45
Pen Branch Swamp upstream of Steel Creek confluence (CCWS)[a]				
Mean	6.65	73.1	5.40	3.14
Range	3.5 - 14.0	46.8 - 95.1	1.30 - 25.5	0.25 - 17.2
Samples	43	35	40	42
Pen Branch at Road A-17 (1987-1991)[b]				
Mean	8.5	69	6.6	7.7
Range	4.2 - 11	13 - 171	1.1 - 54.1	2.0 - 42
Samples	60	60	60	60
Pen Branch at Road A-13.2 (1992-1995)[c]				
Mean	9.1	77	7.08	8.25
Range	6.3 - 14.8	2.0 - 170	3.49 - 27.9	2.8 - 28
Samples	48	48	48	48

NA = Not analyzed.
NTU = Nephelometric Turbidity Units.
Blank Spaces = Mean not calculated due to insufficient data in report.
[a]CCWS = Comprehensive Cooling Water Study (Newman et al. 1986).
[b]1987-1991 = Data taken from Arnett et al. 1992; Cummins et al. 1990, 1991; Davis et al. 1989; Mikol et al. 1988.
[c]1992-1995 = Data taken from Arnett 1993, 1994, 1995, and 1996.

Table 5-98. Pen Branch Major Anions

	Alkalinity (mg $CaCO_3$/l)	Chloride (mg/l)	Sulfate (mg/l)
Pen Branch at Road B (CCWS)[a]			
Mean	13.8	2.48	2.53
Range	2.85 - 30.6	1.90 - 3.20	0.25 - 7.67
Samples	45	45	28
Indian Grave Branch downstream of K-Reactor effluent (CCWS)[a]			
Mean	17.8	5.86	5.21
Range	11.7 - 22.3	2.70 - 8.40	0.75 - 10.3
Samples	44	46	28
Pen Branch at Road A-13 (CCWS)[a]			
Mean	16.8	5.64	5.03
Range	7.40 - 22.0	2.90 - 8.10	0.25 - 9.94
Samples	44	45	26
Pen Branch at Road A-17 (CCWS)[a]			
Mean	16.0	6.02	4.97
Range	7.71 - 22.0	2.90 - 8.20	1.96 - 8.02
Samples	44	46	28
Pen Branch Swamp upstream of Steel Creek confluence (CCWS)[a]			
Mean	17.9	5.81	5.26
Range	8.00 - 26.4	2.50 - 9.10	2.07 - 7.94
Samples	42	43	25
Pen Branch at Road A-17 (1987-1991)[b]			
Mean	18.2	7.1	7.4
Range	4 - 25	3.2 - 27	3.0 - 20
Samples	60	60	60
Pen Branch at Road A-13.2 (1992-1995)[c]			
Mean	16.5	6.06	6.9
Range	10 - 21	3 - 12.91	4 - 19
Samples	48	48	48

NA = Not analyzed.
Blank Spaces = Mean not calculated due to insufficient data in report.
[a]CCWS = Comprehensive Cooling Water Study (Newman et al. 1986).
[b]1987-1991 = Data taken from Arnett et al. 1992; Cummins et al. 1990, 1991; Davis et al. 1989; Mikol et al. 1988.
[c]1992-1995 = Data taken from Arnett 1993, 1994, 1995, and 1996.

Table 5-99. Pen Branch Major Cations (Total)

	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Potassium (mg/l)	Aluminum (mg/l)	Iron (mg/l)	Manganese (mg/l)
Pen Branch at Road B (CCWS)[a]							
Mean	5.27	0.524	1.85	<0.368	0.709	1.23	0.097
Range	0.011 - 10.1	0.001 - 1.29	1.01 - 5.80	<0.368 - 1.22	<0.038 - 3.68	<0.003 - 2.36	<0.0004 - 0.231
Samples	39	39	39	39	39	39	15
Indian Grave Branch downstream of K-Reactor effluent (CCWS)[a]							
Mean	3.30	1.32	7.30	1.12	1.09	1.11	0.100
Range	2.67 - 4.37	1.16 - 1.45	3.99 - 10.5	<0.368 - 2.02	0.105 - 2.87	0.035 - 3.22	<0.0004 - 0.291
Samples	39	39	39	39	39	39	16
Pen Branch at Road A-13 (CCWS)[a]							
Mean	3.89	1.20	6.46	1.01	1.020	0.999	0.104
Range	2.80 - 13.1	0.485 - 1.45	1.47 - 10.5	<0.368 - 2.08	0.049 - 3.03	0.006 - 2.32	<0.0004 - 0.322
Samples	38	38	38	38	38	38	15
Pen Branch at Road A-17 (CCWS)[a]							
Mean	3.14	1.13	7.08	0.960	0.823	0.871	0.089
Range	2.57 - 4.28	0.978 - 1.61	3.15 - 10.9	<0.368 - 1.93	0.182 - 2.30	0.424 - 2.35	<0.0004 - 0.309
Samples	39	39	39	39	39	39	16
Pen Branch Swamp upstream of Steel Creek confluence (CCWS)[a]							
Mean	3.33	1.24	6.88	0.960	0.350	0.972	0.071
Range	2.65 - 3.96	0.932 - 1.46	2.99 - 12.6	<0.368 - 1.72	0.080 - 1.27	0.019 - 1.79	<0.0004 - 0.140
Samples	36	36	36	36	36	36	15
Pen Branch at Road A-17 (1987-1991)[b]							
Mean	3.95	1.09	9.45		0.92	0.66	<0.95
Range	2.1 - 5.8	0.78 - 1.40	4.9 - 14.0	NA	0.04 - 1.8	0.03 - 1.3	<0.01 - 0.18
Samples	18	18	19		19	20	18
Pen Branch at Road A-13.2 (1992-1995)[c]							
Mean	4.49	0.98	6.86	NA	0.29	0.74	0.08
Range	0.976 - 6.36	0.689 - 1.258	3.29 - 9.99		0.055 - 0.56	0.351 - 1.34	0.02 - 0.185
Samples	16	16	16		15	16	16

NA = Not analyzed.
Blank Spaces = Mean not calculated due to insufficient data in report.
[a]CCWS = Comprehensive Cooling Water Study (Newman et al. 1986).
[b]1987-1991 = Data taken from Arnett et al. 1992; Cummins et al. 1990, 1991; Davis et al. 1989; Mikol et al. 1988.
[c]1992-1995 = Data taken from Arnett 1993, 1994, 1995, and 1996.

92-93% was associated with the solid phase at the thermal sites. Total and dissolved iron concentrations were higher at the nonthermal site than those at the thermal sites. Approximately 83-86% of the iron was in the solid phase. Mean total manganese concentrations ranged from 0.071 to 0.104 mg/l. Roughly 20-28% of the manganese was in the solid phase (Newman et al. 1986). From 1987 to 1995, concentrations of total aluminum, iron, and manganese were slightly lower than those measured during the CCWS (Table 5-99). The higher concentrations during the CCWS reflected Savannah River source water concentrations.

Nutrients

Phosphorus

All measured forms of phosphorus were higher in the thermal portions of this system than at the nonthermal site during the CCWS. Whereas 13% of the phosphorus was present as dissolved orthophosphate at the nonthermal site, 49-59% at the thermal site was dissolved orthophosphate. At the nonthermal site, 62% of the phosphorus was not orthophosphate, and 27-38% of the phosphorus at the thermal sites was not orthophosphate. The speciation and concentrations of phosphorus in the thermal sites reflected, at least partially, the phosphorus speciation and concentrations in the Savannah River (Newman et al. 1986). Only total phosphorus is measured during the routine monitoring, but concentrations of total phosphorus near Road A-17 were similar to those measured at Road A-17 during the CCWS (Table 5-100).

Nitrogen

Concentrations of nitrogen species are in Table 5-100. Although the mean concentrations of organic nitrogen did not differ greatly between the thermal and nonthermal sites, the percentage of nitrogen in the organic form was 73% in the nonthermal waters and only 23-26% in the thermal waters (Newman et al. 1986). Routine monitoring does not measure for organic nitrogen in Pen Branch. During the CCWS, mean ammonia, nitrite, and nitrate concentrations were higher at the thermal sites than at the nonthermal site, reflecting the nitrogen species and concentrations in the Savannah River. Since 1987, concentrations of ammonia and nitrate have remained similar to those concentrations measured during the CCWS. Nitrite has not been measured since the CCWS.

Trace Elements

Newman et al. (1986) measured low levels of trace elements during the CCWS. Routine monitoring detection limits are higher than the concentrations measured during the CCWS; therefore, only CCWS data are discussed in this section (Table 5-101). Mean total arsenic concentrations were similar in the nonthermal waters (1.6 µg/l) and the thermal waters (1.3 to 2.8 µg/l) of Pen Branch. Mean total cadmium concentrations ranged from 0.29 µg/l upstream of the Steel Creek confluence to 0.99 µg/l at Road A-13. Although mean total chromium concentrations were as high as 10.4 µg/l, mean dissolved chromium concentrations were below the detection limit at all sites (Newman et al. 1986). Mean total copper concentrations were approximately 2.1-3.2 µg/l. The highest mean concentration of total nickel (4.3 µg/l) was found near Road A-13 (4.3 µg/l). Mean total zinc concentrations ranged from 4.7-6.2 µg/l. Mercury and uranium and concentrations were below the detection limit in Pen Branch waters (Newman et al. 1986).

Table 5-100. Pen Branch Nutrients

	Total Phosphorus (mg/l)	Total Ortho-phosphate (mg/l)	Organic Nitrogen (mg/l)	Total Kjeldahl Nitrogen (mg/l)	Ammonia (mg/l)	Nitrite (mg/l)	Nitrate (mg/l)
Pen Branch at Road B (CCWS)[a]							
Mean	0.042	0.017	0.216	0.236	0.039	0.002	0.050
Range	<0.010 - 0.147	0.003 - 0.059	0.012 - 0.860	0.045 - 0.900	0.005 - 0.700	<0.001 - 0.005	0.011 - 0.184
Samples	46	41	45	46	46	44	43
Indian Grave Branch downstream of K-Reactor effluent (CCWS)[a]							
Mean	0.114	0.080	0.225	0.298	0.109	0.019	0.288
Range	0.028 - 0.275	0.037 - 0.146	0.015 - 0.680	0.075 - 0.770	0.013 - 0.210	0.005 - 0.041	0.038 - 0.685
Samples	45	41	39	46	46	43	43
Pen Branch at Road A-13 (CCWS)[a]							
Mean	0.093	0.071	0.171	0.239	0.075	0.021	0.310
Range	<0.010 - 0.286	0.013 - 0.133	0.010 - 0.829	0.080 - 0.855	0.016 - 0.230	<0.001 - 0.048	0.094 - 0.510
Samples	45	39	44	45	45	42	42
Pen Branch at Road A-17 (CCWS)[a]							
Mean	0.103	0.076	0.190	0.221	0.048	0.008	0.228
Range	<0.010 - 0.239	0.005 - 0.144	0.015 - 0.593	0.035 - 0.610	0.005 - 0.250	0.001 - 0.031	0.019 - 0.454
Samples	46	42	43	46	46	44	43
Pen Branch Swamp upstream of Steel Creek confluence (CCWS)[a]							
Mean	0.065	0.045	0.206	0.224	0.027	0.003	0.091
Range	<0.010 - 0.188	0.004 - 0.113	0.019 - 0.624	0.032 - 0.640	0.005 - 0.220	<0.001 - 0.010	<0.001 - 0.378
Samples	43	37	42	43	43	40	39
Pen Branch at Road A-17 (1987-1991)[b]							
Mean	0.075				0.055		0.27
Range	0.0 - 0.24	NA	NA	NA	<0.01 - 0.23	NA	0.10 - 0.85
Samples	60				60		60
Pen Branch at Road A-13.2 (1992-1995)[c]							
Mean[d]	0.08		0.22[e]		0.08		0.38[f]
Range	ND - 0.18	NA	0.06 - 0.43	NA	ND - 0.15	NA	0.18 - 0.45
Samples	12		24		28		24

NA = Not analyzed.
ND = None detected.
Blank Spaces = Mean not calculated due to insufficient data in report.
[a]CCWS = Comprehensive Cooling Water Study (Newman et al. 1986).
[b]1987-1991 = Data taken from Arnett et al. 1992; Cummins et al. 1990, 1991; Davis et al. 1989; Mikol et al. 1988.
[c]1992-1995 = Data taken from Arnett 1993, 1994, 1995, and 1996.
[d]Nondetectable quantities were excluded from the calculation of the mean.
[e]Nitrite + nitrate; 1992-1993.
[f]1994-1995.

Table 5-101. Pen Branch Trace Elements (Total)

	Arsenic (μg/l)	Cadmium (μg/l)	Chromium (μg/l)	Copper (μg/l)	Lead (μg/l)	Nickel (μg/l)	Zinc (mg/l)
Pen Branch at Road B (CCWS)[a]							
Mean	1.6	0.36	6.6	3.0	1.8	2.8	6.1
Range	<0.4 - 6.2	<0.04 - 2.00	<0.4 - 49.0	<0.4 - 14.1	<0.4 - 6.0	<0.4 - 8.7	<0.4 - 23.1
Samples	15	15	15	15	15	15	15
Indian Grave Branch downstream of K-Reactor effluent (CCWS)[a]							
Mean	2.6	0.56	10.4	3.0	2.3	3.8	5.8
Range	<0.4 - 10.8	<0.04 - 1.80	<0.4 - 71.0	<0.4 - 9.1	<0.4 - 9.3	<0.4 - 11.0	<0.4 - 25.9
Samples	16	16	16	16	16	16	16
Pen Branch at Road A-13 (CCWS)[a]							
Mean	2.8	0.99	10.1	3.0	1.3	4.3	5.7
Range	<0.4 - 10.7	<0.04 - 11.3	<0.4 - 90.0	<0.4 - 6.5	<0.4 - 5.0	<0.4 - 18.0	<0.4 - 27.7
Samples	15	15	15	15	15	15	15
Pen Branch at Road A-17 (CCWS)[a]							
Mean	2.3	0.37	7.1	3.2	2.4	3.2	6.2
Range	<0.4 - 8.2	<0.04 - 1.6	<0.4 - 57.0	<0.4 - 7.1	<0.4 - 18.7	<0.4 - 13.0	<0.4 - 21.6
Samples	16	16	16	16	16	16	16
Pen Branch Swamp upstream of Steel Creek confluence (CCWS)[a]							
Mean	1.3	0.29	7.5	2.1	2.0	2.0	4.7
Range	<0.4 - 5.0	<0.04 - 1.42	<0.4 - 65.0	<0.4 - 15.0	<0.4 - 5.4	<0.4 - 7.5	<0.4 - 22.0
Samples	15	15		15		15	15
Pen Branch at Road A-17 (1987-1991)[b]							
Mean							
Range	NA	<10 - <20	<10 - <50	<10 - 320	<3 - <50	<10 - 80	<10 - 170
Samples		20	20	20	20	20	20
Pen Branch at Road A-13.2 (1992-1995)[c]							
Mean[d]	NA	<10	<15	60	<5	<30	18
Range		ND - <10	ND - <10	ND - 158	ND - 11	ND - <50	ND - 105
Samples		4	4	15	5	4	11

NA = Not analyzed.
ND = Not detected.
Blank Spaces = Mean not calculated due to insufficient data in report.
[a]CCWS = Comprehensive Cooling Water Study (Newman et al. 1986).
[b]1987-1991 = Data taken from Arnett et al. 1992; Cummins et al. 1990, 1991; Davis et al. 1989; Mikol et al. 1988.
[c]1992-1995 = Data taken from Arnett 1993, 1994, 1995, and 1996.
[d]All nondetected quantities were excluded from the calculation of the mean.

Organic Carbon

Total organic carbon concentrations were similar for thermal and nonthermal sites in Pen Branch (Table 5-102). However, the nonthermal site had slightly more organic carbon in the dissolved phase (77%) relative to those of the thermal sites (68-69%) (Newman et al. 1986).

Priority Pollutants

The Pen Branch system had below detectable concentrations of all 88 tested volatile, acid, and base/neutral organics. The 1984 study also confirmed the lack of variability between thermal and nonthermal waters (Lower 1987).

Pesticides, Herbicides, and PCBs

Water samples collected annually during routine monitoring are analyzed for pesticides, herbicides, and PCBs. None of the analytes has been detected in the Pen Branch system.

Lower (1987) reports the results of analyses for pesticides, herbicides, and PCBs from 1982 to 1985; results from 1967 to 1981 can be found in Gladden et al. (1985). During these periods, concentrations also were near or below detection limits at all locations.

Chemical, Including Radionuclide, and Toxicity Assessment Studies

In 1994, a study was done to determine if the macroinvertebrate *Ceriodaphnia* is adversely affected by Pen Branch water that does not receive National Pollutant Discharge Elimination System (NPDES) discharges; if *Ceriodaphnia* can be cultured for extended times in Pen Branch water; and if *Ceriodaphnia* cultured in Pen Branch water are sensitive to a reference toxicant. SRS surface waters are extremely soft, with hardness ranging from approximately 2 to 30 mg/l. Waters this soft may not have adequate calcium or trace minerals to support long-term survival of *Ceriodaphnia*. Detailed results of this study are in Specht (1994a) and in Chapter 7 of this document.

Pen Branch water was never acutely toxic (measured as percent survival) to *Ceriodaphnia dubia* in 11 monthly tests. However, it was chronically toxic (measured as reproductive success) in 5 of 11 monthly tests. Results of the acute reference toxicant (sodium chloride) tests on Pen Branch water indicated that the test organisms in that water were slightly more sensitive to the reference toxicant than other organisms cultured in standard dilute mineral water. Reproduction in Pen Branch waters in the presence of the reference toxicant was more successful than reproduction in the control population in the presence of the reference toxicant. These results suggest that water from Pen Branch may be superior to dilute mineral water as dilution and control water for chronic toxicity testing of SRS waters (Specht 1994a).

No studies on chemical or radionuclide contaminants have been done in Pen Branch.

Table 5-102. Pen Branch Carbon Concentrations

	Total Organic Carbon (mg/l)	Dissolved Organic Carbon (mg/l)	Particulate Organic Carbon (mg/l)
Pen Branch at Road B (CCWS)[a]			
Mean	5.99	5.12	3.40
Range	0.36-11.84	2.61 - 9.30	0.24 - 10.7
Samples	25	9	10
Indian Grave Branch downstream from K-Reactor effluent (CCWS)[a]			
Mean	6.49	5.04	2.66
Range	2.85 - 12.9	1.16 - 7.25	0.58 - 6.10
Samples	25	9	10
Pen Branch at Road A-13 (CCWS)[a]			
Mean	6.82	5.73	3.44
Range	4.40 - 13.2	3.59 - 7.90	0.56 - 11.7
Samples	23	10	9
Pen Branch at Road A-17 (CCWS)[a]			
Mean			
Range	NA	NA	NA
Samples			
Pen Branch upstream of Steel Creek confluence (CCWS)[a]			
Mean	6.81	5.48	1.02
Range	2.86 - 13.7	3.62 - 10.1	0.20 - 2.50
Samples	22	11	11
Pen Branch at Road A-17 (1987-1991)[b]			
Mean	6.42	5.75	2.43
Range	1.84 - 10.5	3.73 - 8.80	0.45 - 6.12
Samples	25	10	10

NA = Not analyzed.
Blank Spaces = Mean not calculated due to insufficient data in report.
[a]CCWS = Comprehensive Cooling Water Study (Newman et al. 1986).
[b]1987-1991 = Data taken from Arnett et al. 1992; Cummins et al. 1990, 1991; Davis et al. 1989; Mikol et al. 1988.

Algae

Phytoplankton

Phytoplankton has not been studied in the Pen Branch drainage system. The potential for activities to impact the phytoplankton is low. Phytoplankton contribute insignificantly to the food chain base in this and other shallow streams.

Periphyton

Studies of the ecology of the thermal and nonthermal streams of SRS that were conducted between 1983 and 1985 (Firth et al. 1986; Specht 1987) included the periphyton community of Pen Branch. The analyses of the periphyton communities in these studies included taxonomic identifications, chlorophyll analyses, and measurement of ash-free dry weight.

Reactor operations undoubtedly affected periphyton species composition and abundance. Periphyton differed in type between thermal and nonthermal sites. Green algae and diatoms characterized the nonthermal sites, while thick mats of blue-green algae were unevenly distributed at the thermal sites (Specht 1987). Also, variations in periphyton biomass values were higher at the thermal stream sites than at the nonthermal sites. The densely canopied Pen Branch swamp station had a significantly lower periphyton biomass than the Pen Branch delta station. Biomass at the Pen Branch swamp station did not appear to be affected by the status of K Reactor (Firth et al. 1986).