WSRC-RP-90-778

COMPLIANCE OF THE SAVANNAH RIVER SITE D-AREA COOLING SYSTEM WITH ENVIRONMENTAL REGULATIONS (U)

DEMONSTRATION IN ACCORDANCE WITH SECTION 316(a) OF THE CLEAN WATER ACT
SEPTEMBER 1988 - FEBRUARY 1990

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Westinghouse Savannah River Company
Savannah River Site
Aiken, SC 29808

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BEAVER DAM CREEK 316(A) DEMONSTRATION

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ABSTRACT

This document presents information relating to a demonstration under Section 316(a) of the Clean Water Act for the 400-D Area cooling system at the Savannah River Site (SRS) near Aiken, South Carolina. The demonstration was mandated because the National Pollution Discharge Elimination System (NPDES) permit for SRS (SC0000175), granted on January 1, 1984, specified in-stream temperature limits in SRS streams of 32.2°C and a ΔT limit of 2.8°C above ambient. To achieve compliance with in-stream temperature limits, the Department of Energy (DOE) and the South Carolina Department of Health and Environmental Control (SCDHEC) entered into a Consent Order (84-4-W) which temporarily superseded the temperature requirements and identified a process for attaining compliance. The preferred option for achieving thermal compliance in Beaver Dam Creek consisted of increased flow, with mixing of the raw water basin overflow with the cooling water discharge during the summer months. Although this action can achieve in-stream temperatures of less than 32.2°C, ΔT's still exceed 2.8°C. Therefore, a 316 (a) Demonstration was initiated to determine whether a balanced indigenous biological community can be supported in the receiving stream with ΔT's in excess of 2.8°C.

A Biological Monitoring Program for Beaver Dam Creek was approved by SCDHEC in June 1988 and implemented in September 1988. The program monitored the water quality, habitat formers, zooplankton, macroinvertebrates, fish, other vertebrate wildlife and threatened and endangered species in Beaver Dam Creek for an 18-month period (September 1988-February 1990). This document summarizes information collected during the monitoring program and evaluates the data to determine whether Beaver Dam Creek presently supports a balanced indigenous biological community.

In the fall of 1988, extended reactor outages resulted in a decrease of the site's electrical and steam demands. Power generation in D Area was reduced, with resultant decreases in outfall temperatures and ΔT's in the receiving stream. Thermal mitigation, via increased flow, was not required during the summer of 1989. Therefore, the data collected during the biological monitoring program are reflective of the thermal and flow regimes that exist when D Area is operating at a reduced power level but do not reflect normal operating conditions for 400-D Area. The results of the monitoring program are being submitted to SCDHEC, as specified in the approved study plan. However, upon returning to a normal level of power generation, additional biological monitoring will be performed to document the effects of thermal mitigation on Beaver Dam Creek during normal operating conditions.

The dominant factors influencing biotic communities in Beaver Dam Creek during thermal mitigation are decreases in maximum stream temperatures and ΔT's during the summer months and an increase in stream discharge during periods of mitigation. The data collected during the biological monitoring program indicate that under the conditions of reduced power generation that existed during the 316(a) Demonstration, the structure and function of biotic communities were not adversely

affected by the thermal component of D-Area effluents. Additional studies will be necessary to determine the effect of routine levels of electrical and steam generation on the biotic communities of the receiving stream.

SUMMARY AND CONCLUSIONS

Background

This document presents information relating to a 316(a) Demonstration for the Savannah River Site's 400-D Area cooling system. The demonstration was mandated because the National Pollution Discharge Elimination System (NPDES) permit for the Savannah River Site (SC0000175), granted on January 1, 1984, specified in-stream temperature limits of 32.2°C and a ΔT limit of 2.8°C. Prior to issuance of the permit the Savannah River Site (SRS) had no in-stream limits for temperature, except in the Savannah River. To achieve compliance with in-stream temperature limits, the U.S. Department of Energy (DOE) and the South Carolina Department of Health and Environmental Control (SCDHEC) entered into a Consent Order (84-4-W) on January 3, 1984, that temporarily superseded the temperature requirements in the NPDES permit and identified a process for attaining compliance. The preferred thermal mitigation alternative would achieve maximum in-stream temperatures of less than 32.2°C, but would not meet the ΔT limit of 2.8°C. Therefore, a 316(a) Demonstration was initiated to confirm that ΔT's in excess of 2.8°C would not adversely affect the biotic community of the receiving stream. In March 1988, a study plan for the 316(a) Demonstration was submitted to SCDHEC for approval. The study plan was approved by SCDHEC in June 1988. In September 1988 an 18-month biological monitoring program was initiated in Beaver Dam Creek to provide the data necessary to prepare the 316(a) Demonstration. The results of the study are summarized in this report.

The 400-D Area has operated a coal-fired power plant at the Savannah River Site since 1952. The plant consists of four low pressure turbogenerators, one of which is cooled by a small mechanical draft cooling tower. The remaining turbogenerators are cooled by a once-through cooling system, which uses water pumped from the Savannah River and discharges to Beaver Dam Creek, via the D-001 outfall.

Prior to thermal mitigation, temperatures during the summer months often exceeded 32.2°C. Thermal mitigation is accomplished, on an as-needed basis during the summer months, by activating one or two additional pumps at the 681-5G pumphouse. The pumphouse pumps additional water from the Savannah River to a raw-water receiving basin in 400-D Area. Overflow from the basin mixes with the powerhouse effluent stream before discharging to Beaver Dam Creek, thus reducing the temperature of the effluent stream. Because sufficient pumping capacity was available at the pumphouse, no new construction was required to implement the mitigation program. However, increased operation of the existing pumps required circulation of more water from the Savannah River, with a concomitant increase in electrical consumption and pump maintenance costs. The thermal mitigation alternative was selected because it:

- Could meet in-stream maximum temperature requirements
- Could be implemented more expeditiously than the other mitigation alternatives
- Had the lowest cost of any regulatory and environmentally acceptable mitigation alternative

In the fall of 1988, extended reactor outages resulted in a decrease in site electrical and steam demands. Power generation in 400-D Area was reduced, with resultant decreases in outfall temperatures and ΔT's in the receiving stream. Thermal mitigation, via increased flow, was not required during the summer of 1989. Therefore, the data collected during the biological monitoring program are reflective of the thermal and flow regimes that exist when 400-D is operating at a reduced power level, but do not reflect normal operating conditions. The results of the monitoring program are being submitted to SCDHEC, as specified in the approved study plan. However, upon returning to a normal level of electrical and steam generation, additional biological monitoring will be performed to document the effects of thermal mitigation on Beaver Dam Creek during normal operating conditions.

Objectives

The objectives of the Beaver Dam Creek Biological Monitoring Program were to confirm that ΔT's in the receiving stream in excess of 2.8°C would not preclude the presence of a balanced biological community (BBC) in Beaver Dam Creek. For the purposes of this 316(a) Demonstration, a BBC is defined as one that:

- is not dominated by pollution (thermally) tolerant organisms
- has diversity and productivity characteristic of that found in other unperturbed streams of the southeastern region
- has populations that are successfully reproducing
- has all of the trophic levels that would be expected in an unperturbed southeastern stream.

The Biological Monitoring Program for Beaver Dam Creek was approved by SCDHEC in June 1988 and implemented in September 1988 to provide the information necessary to determine if Beaver Dam Creek supports a BBC. The Biological Monitoring Program includes evaluations of the water quality, habitat formers, zooplankton, macroinvertebrates, fish, other vertebrate wildlife (herpetofauna and waterfowl), and threatened and endangered species.

The effectiveness of the mitigation program was to be evaluated by comparing data collected prior to mitigation (1984-1985) with the data collected during this program (1988-1990). However, reduced power production in D Area negated the need for thermal mitigation during the study. Therefore, a comparison of the 1984-1985 data with the data from this study is not a true comparison of premitigation conditions with post-mitigation conditions, but rather is a comparison of premitigation conditions with that of reduced operating conditions.

For the purposes of the monitoring program, seven sampling stations were established in Beaver Dam Creek to sample the various habitats of the creek. Because D-Area provides almost all of the discharge for Beaver Dam Creek, it was not possible to establish an upstream reference station in Beaver Dam Creek. Although one of the sampling stations was located in the original intermittent stream channel of the creek (Station 1A), upstream from the confluence of the 400-D Area discharge canal, this station was usually dry, except after periods of heavy precipitation. Therefore, it was seldom possible to compare the portion of Beaver Dam Creek that receives thermal discharges with an ambient section of the stream.

Summary of Results

Beaver Dam Creek, a small intermittent stream prior to SRS operations, drains a watershed area of approximately 2.2 km^2. The creek travels through distinctly different types of narrow channel, delta, slough, and river swamp areas. For almost 30 years, Beaver Dam Creek received effluent from both the 400-D Area powerhouse and from the heavy water production facility, which produced a combined discharge of as high as 3.7 m^3/s (130 cfs). The heavy water production facility was shut down in 1982, reducing the discharge to Beaver Dam Creek to about 2.5 m^3/s (88 cfs). During the current period of reduced electrical and steam generation, flows have generally been less than 2.5 m^3/s. Soils in the Beaver Dam Creek watershed are dominated by sandy types. Vegetation in the watershed consists mainly of pines and upland hardwoods in the drier areas, bottomland hardwoods, scrub-shrub and herbaceous assemblages in wetter areas, and cypress-tupelo in the river swamp. Land use in the Beaver Dam Creek watershed is dominated by the 400-D Area complex.

Forty water quality parameters were assessed monthly at seven stations in Beaver Dam Creek. The data show that the water quality of Beaver Dam Creek is greatly influenced by operations in 400-D Area. Water pumped from the Savannah River for D-Area operations makes up almost all of the stream discharge. In addition to thermal discharges from a coal-fired power plant, the creek receives coal ash basin effluent, sanitary treatment plant effluent, and intermittent discharges from storm water runoff, and a filter backwash surge basin. The original intermittent stream channel of Beaver Dam Creek receives most of its discharge from rainfall and runoff, whereas downstream from 400-D Area, most of the discharge is water that has been pumped from the Savannah River. Water collected from the original intermittent stream channel had lower temperature, pH, dissolved oxygen, conductivity and nutrient levels than water from stations located downstream from the D-001 outfall and higher levels of total hardness, total suspended solids, turbidity, aluminum, iron, lead, zinc, and barium. During the 18-month study, water temperatures in Beaver Dam Creek never exceeded the maximum NPDES limit of 32.2°C. However, ΔT values were often more than 2.8°C higher than both the Savannah River and the station located in the intermittent stream channel.

Discharges from 400-D Area began to impact the wetlands adjacent to Beaver Dam Creek soon after operations began in 1952. By 1974, 167 hectares of wetlands had been impacted. When discharge temperatures were reduced in the early 1970's (due to a reduction in heavy water production), stabilization and initial revegetation of impacted wetlands began largely through the invasion of scrub-shrub vegetation, such as willow, other bottomland hardwoods and buttonbush. The most rapid revegetation has occurred since 1985, as young bottomland hardwood species and scrub-shrub species began to develop a new closed canopy over previously impacted areas. From 1985 to 1989, 56 hectares of revegetation canopy areas have developed adjacent to Beaver Dam Creek, with 103 hectares of impacted area remaining in the Beaver Dam Creek area. It is anticipated that revegetation will continue, as long as temperatures and flows remain lower than they were during the early years of D-Area operation, when both the power plant and the heavy water facility operated.

Zooplankton species diversity, taxa richness and density varied considerably from month to month at all stations. Species diversity and taxa richness tended to be highest in the summer and lowest in the winter, while no seasonal pattern was evident for density. Mean total zooplankton densities generally showed a downstream increase from Station 1 to Station 5, but no consistent longitudinal trends were observed for species diversity or taxa richness. Microzooplankton (protozoans and rotifers) accounted for most of the taxa richness and protozoans contributed more to the total zooplankton densities than any other major taxonomic group. In comparison to an earlier study (December 1984 – August 1985) of the zooplankton community of Beaver Dam Creek, mean densities and total taxa richness were higher in the present study, while species diversity values were somewhat lower.

Beaver Dam Creek supports a diverse macroinvertebrate community, with at least 163 species collected during this study. Like most coastal plain streams in the southeast, the macroinvertebrate community is numerically dominated by chironomids. Other abundant groups of macroinvertebrates include mayflies, caddisflies, beetles, oligochaetes, and nonchironomid dipterans. Macroinvertebrate densities were generally higher in the upstream reaches of the stream (Stations 1 - 3) than in downstream areas. Densities varied seasonally, with higher densities observed in late winter and in summer at most stations. The sampling station located closest to the D-001 outfall (Station 1) had fewer macroinvertebrate taxa and slightly lower biomass than the other sampling stations, but was similar to the other stations with respect to density and mean number of taxa. There were some indications of longitudinal changes in the relative abundances of macroinvertebrate taxonomic groups in Beaver Dam Creek. The relative abundance of mayflies and beetles increased in a downstream direction, while the relative abundance of caddisflies decreased in a downstream direction.

Macroinvertebrate data from this study were compared to similar data collected in Beaver Dam Creek in 1984-1985. The data indicate that macroinvertebrate densities have not changed appreciably, but that there has been a slight increase in the mean number of taxa. In addition, the taxonomic composition of the stream has improved substantially, with most stations exhibiting increases in the relative abundance of mayflies, snails, beetles, caddisflies, and Tanytarsini chironomids and an overall decline in the relative abundance of Chironomini chironomids.

Macroinvertebrate data from Beaver Dam Creek were compared with data from eight other southeastern streams. The comparisons indicate that Beaver Dam Creek is similar to the other streams with respect to overall taxonomic composition, density of organisms, and biomass, but that species richness in Beaver Dam Creek is somewhat lower than most of the other streams, particularly at the most upstream station.

Forty-five species of fish were collected in Beaver Dam Creek by electrofishing and hoopnetting. The most abundant species collected by electrofishing were spotted sucker, coastal shiner, redbreast sunfish, largemouth bass, and spotted sunfish. The most abundant species collected by hoopnetting were channel catfish, redbreast sunfish, bluegill, and flat bullhead. Species richness did not differ significantly among stations, but electrofishing catch per unit effort was significantly lower at the most upstream station (Station 1). Station 1 is closest to the D-Area outfall and is more strongly influenced by high flows from the 400-D Area power plant than the other sampling stations.

Ichthyoplankton samples collected from Beaver Dam Creek indicated that at least nine taxa spawned in the stream. Sunfishes composed most of the ichthyoplankton, followed by darters and suckers. The highest ichthyoplankton densities occurred in the downstream areas of Beaver Dam Creek. Spawning peaked in April and May.

Comparisons with earlier data showed that electrofishing catch per unit effort in Beaver Dam Creek was higher during the present study than in previous years. Hoopnetting catch per unit effort was fairly similar among years. The same dominant taxa were present in all years, although their relative ranking changed. Ichthyoplankton catches were lower in 1988 than in previous years and relative abundance showed substantial shifts. However, high inter-annual variability in ichthyoplankton density and species composition is typical of unimpacted streams on the SRS. Variability in adult fish and ichthyoplankton catches among years may be due to water level (river flooding), population interactions, and various other factors that influence recruitment.

Comparisons of fisheries data from Beaver Dam Creek with similar data from nine other southeastern streams indicated that Beaver Dam Creek supported a greater than average number of species and a particularly rich sunfish, minnow, catfish, and sucker fauna. The relatively high species richness in Beaver Dam Creek is probably a result of habitat diversity (stream, swamp, and slough habitats) and the connection of Beaver Dam Creek with the Savannah River, which permits incursions by riverine and anadromous species. While there is some evidence that the extreme upper reaches of Beaver Dam Creek provide poorer quality habitat than the lower reaches, the stream as a whole supports a diverse fish community with representatives from all trophic levels.

Except for waterfowl, there is little specific information on wildlife use within the Beaver Dam Creek area. Data were collected for mallard and wood duck use during seven years of aerial observations during the winters between 1981 and 1990. The available data indicate that waterfowl use in the vicinity of Beaver Dam Creek may have declined with the reduction of flows and water levels in the area.

Three of the 37 species of plants and animals listed by the Federal Government, State of South Carolina, or the South Carolina Heritage Trust as Endangered, Threatened, or of Special Concern known to currently or previously occur on the SRS are potentially affected by the Beaver Dam Creek mitigation plan. The shortnose sturgeon occurs in low numbers in the Savannah River, but is not likely to be affected by the mitigation activities for Beaver Dam Creek. The American alligator, which is classified as "threatened by similarity of appearance" occurs in high densities in Beaver Dam Creek. Mitigation activities are not expected to have any detrimental effects on the alligator population. The American wood stork has substantially reduced its use of the Beaver Dam Creek area since 1986, when the Kathwood Lake mitigation project first became available for foraging use. The Beaver Dam Creek mitigation program may limit access to the area for foraging storks due to the higher water levels produced by the extra flow. The availability of the preferred foraging area provided by the Kathwood project would offset any potential impact from thermal mitigation activities in Beaver Dam Creek.

BEAVER DAM CREEK 316(a) DEMONSTRATION

1.0 INTRODUCTION

1.1 Site Mission

Under the Atomic Energy Act of 1954, the United States Department of Energy (DOE) and its predecessor agencies are responsible for developing and maintaining the capability to produce all defense nuclear materials required for the U.S. defense program. To accomplish this mission DOE operates the Savannah River Site (SRS) near Aiken, South Carolina.

The primary mission of SRS is to produce tritium, plutonium, and special nuclear materials for the nation's defense program. Weapons materials produced at SRS are sent to other DOE facilities for fabrication into weapon components (DOE, 1980).

1.2 Site Description and History

SRS is located in South Carolina along the Savannah River, about 40 km southeast of Augusta, Georgia, and 32 km south of Aiken, South Carolina (Figure 1-1; Dukes, 1984). The site borders the Savannah River for 27 km and occupies about 778 km^2 of land that includes swamplands, pine forests, fields, ponds, and streams (Wilde, 1985). Surface waters on SRS include six tributaries of the Savannah River, the Savannah River swamp, approximately 190 Carolina bays, and more than 50 man-made impoundments. A more detailed description of the SRS site is reported by Dukes (1984).

SRS was established in the early 1950's to produce plutonium and tritium for the United States weapons program. SRS was operated for the federal government (currently by DOE) from inception until 1989 by E.I. du Pont de Nemours and Company. In April 1989, Westinghouse Savannah River Company (WSRC) became the prime contractor responsible for operation of the site.

The SRS complex (Figure 1-2) includes a fuel and target fabrication plant, five production reactors, two chemical separations facilities, a heavy water rework facility, three coal-fired power plants, waste storage facilities, and the Defense Waste Processing Facility (DWPF; currently under construction) (DOE, 1984).

The five reactors began operating between 1953 and 1955. R Reactor and C Reactor were placed on standby in 1964 and 1985, respectively. L Reactor was placed on standby in 1968 due to a decreasing demand for special nuclear materials (DOE, 1984) and was restarted in the fall of 1985 (Halverson et al., 1987). K, L, and P reactors were placed on standby in 1988 and are currently undergoing safety-related upgrades.

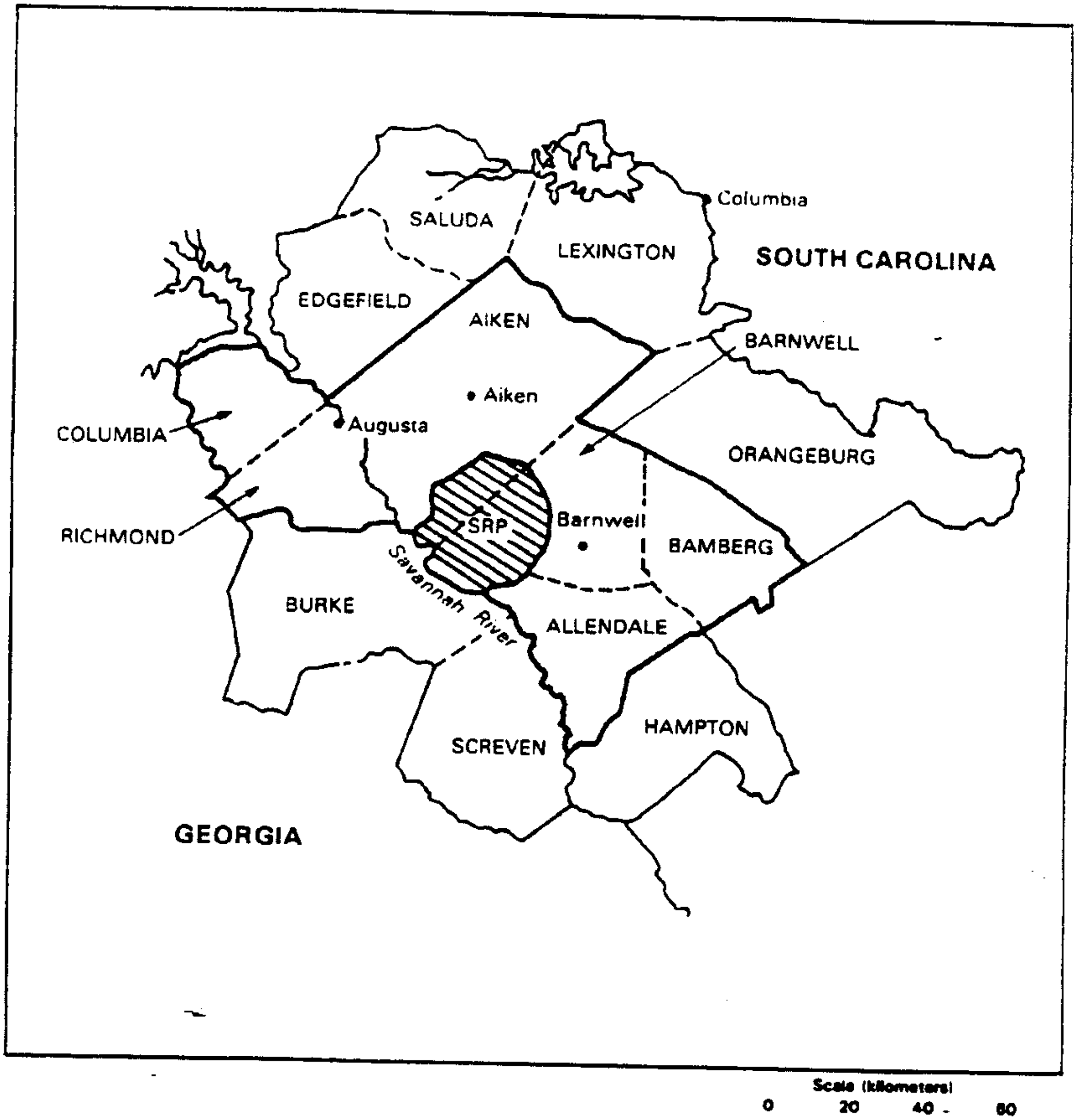

Figure 1-1. Location of the Savannah River Plant

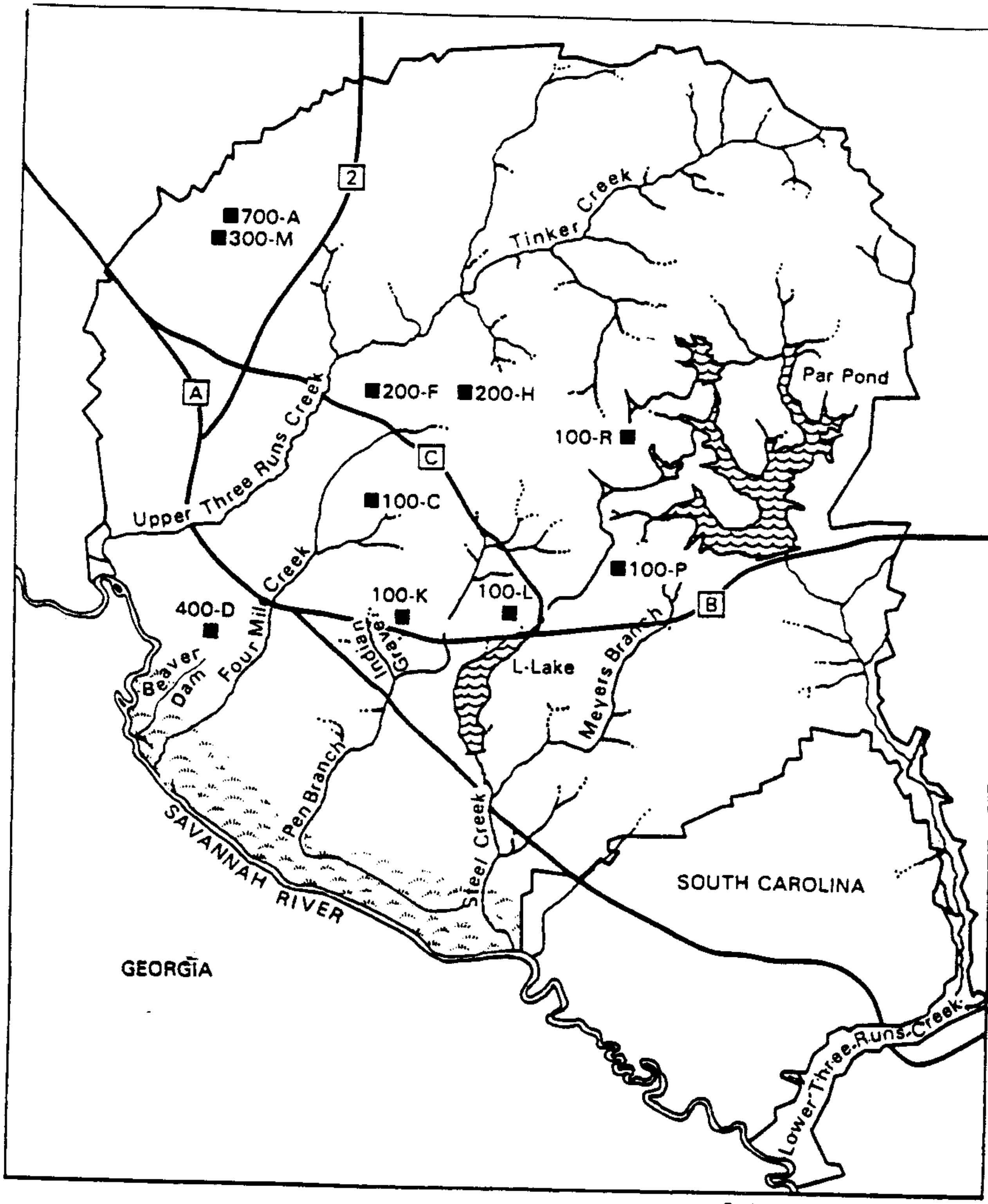

Figure 1-2. The Savannah River Plant Site

Scale (kilometers)
0 4 8

1.3 400-D Area Operational and Environmental History

1.3.1 Operational History

Historically, D Area consisted of two facilities: a coal-fired power plant and a heavy water production plant. During the construction of D Area, a canal was dug to convey the effluents from both the heavy water facility and the power plant to the Savannah River swamp, via Beaver Dam Creek.

From 1952 to 1976 the heavy water facility was operated to produce heavy water in sufficient quantities for the initial charging and operation of the production reactors. Heavy water was extracted from Savannah River water via hydrogen sulfide extraction, distillation, and electrolysis. This process was used between 1952 and 1957. In 1957, eight of the original 24 extraction towers were placed on standby, and in 1958 eight more extraction towers were placed on standby and the electrolysis unit was removed from the process (Miller, 1984).

A heavy water rework unit was set up in 1956 to repurify heavy water returned from the reactors, using three of the original distillation towers; in 1960 a fourth tower was added. In 1976, the production of heavy water was decreased significantly as a result of recirculation of rework water, and by 1982 the last of the eight extraction towers were shut down, terminating production of new heavy water (Miller, 1984). However, the heavy water rework facility continues to repurify heavy water from the reactors, on an as-needed basis.

Built in 1952, the coal-fired power plant provides steam to the reactor and separations areas of the SRS, as well as electricity to the site electrical grid. The power plant is equipped with four low pressure turbogenerators and their associated condensers. The condensers are cooled by two cooling water systems: a recirculating system which utilizes a small mechanical draft cooling tower and a once-through system. Both systems use water from the Savannah River for cooling. The recirculating system can cool only one condenser at a time, either No. 3 or No. 4. Normally condensers 1, 2, and 3 are cooled by the once-through system and condenser 4 is cooled by the recirculating system. However, when condenser 4 is not operating, condenser 3 is cooled by the recirculating system. Blowdown effluent and evaporation from the cooling tower are negligible; thus essentially all of the water pumped from the river is discharged to Beaver Dam Creek. The once-through system discharges heated water to the D-001 outfall which flows to Beaver Dam Creek via a discharge canal (Figure 1-3).

Prior to thermal mitigation, three river water pumps were operated to provide cooling water for the powerhouse condensers during routine operating conditions. Resulting temperatures at the D-001 outfall ranged from a minimum of about 10°C during the winter months to a maximum of about 34°C during the summer. Corresponding average Δ T's were about 7 to 10°C during the winter and about 4 to 8°C during the summer and maximum delta t's were 8 to 13°C during the winter and 7 to 10°C in summer (Du Pont, 1987).

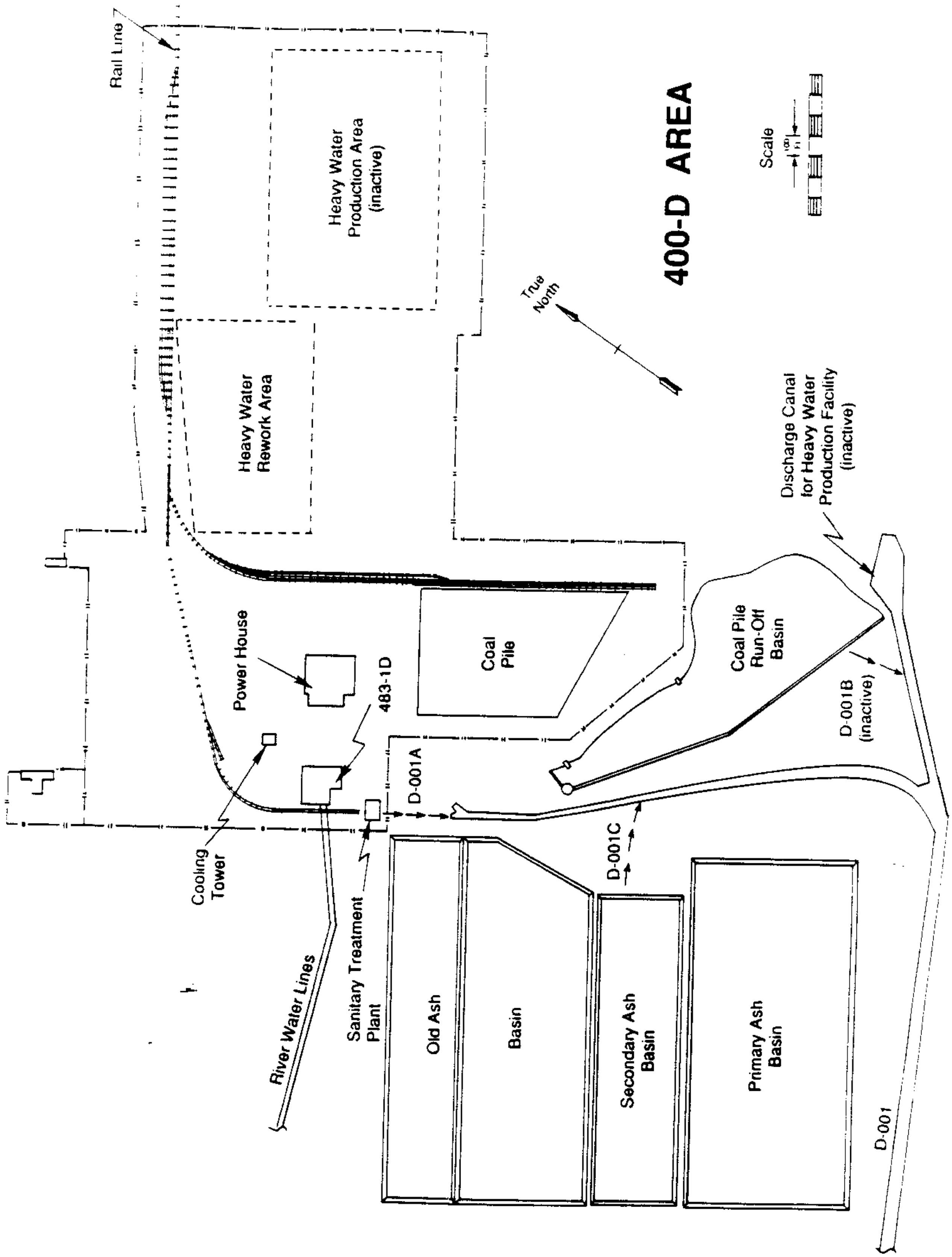

Figure 1-3. D-Area Facilities and NPDES Outfall Locations

Discharges from the heavy water facility included thermal effluent and high concentrations of hydrogen sulfide. No water quality data for Beaver Dam Creek is available for the early years of D-Area operation. However, temperature data collected beginning in 1971 indicate that from 1971 to 1978 water temperatures at the D-001 monitoring station were at times as high as 43°C (Miller, 1984; also, see Table 4.5.1-3 in Section 4.5.1). In general, stream temperatures declined between 1973 and 1983, due to a decrease in the production of heavy water (Figure 1-4; Miller, 1984). The volume of effluent discharged to Beaver Dam Creek also declined in response to the reduction in heavy water production, from approximately 3.7 m^3/sec (130 cfs) in the mid-1950's to about 2.5 m^3/sec (88 cfs) during routine operation of D Area during the late 1980's.

In addition to the thermal discharge from D Area, Beaver Dam Creek also receives overflow from a coal ash disposal basin [0.13 m^3/s (3MGD)] treated sanitary effluent [0.00044 m^3/s (0.01 MGD)], and intermittent discharges from the heavy water rework facility, the Building 772-D laboratories, storm water runoff, and a filter backwash surge basin. The creek also has received infrequent discharges from a coal pile runoff basin via the D-001B outfall.

The coal ash effluent contains coal ash particulates (<3 mg/L as a daily average), trace elements normally found in coal ash, as well as chlorine (0.5 mg/L), sodium carbonate (1 to 3 mg/L), sodium phosphate (0.1 mg/L), and sodium sulfite (Du Pont, 1988). In addition, sodium sulfate from the neutralization facility is periodically discharged into the ash basin.

Both the sanitary effluent and the thermal discharge contain chlorine. Routine chlorination of the D-Area cooling water takes place at the 681-5G pumphouse. Gaseous chlorine is added at the pumphouse to produce a free residual chlorine (FRC) concentration of 1.0 mg/L. Under present operating conditions, chlorine is added to the cooling water for approximately one hour, once per week. Effluent from the sanitary plant is chlorinated continuously using sodium hypochlorite to attain a total residual chlorine (TRC) concentration of 2 to 3 mg/L at the D-001A outfall.

Discharges from the 772-D laboratories are intermittent, and contain laboratory chemicals in the quantities listed in Table 1-1 (Du Pont, 1987). Discharges from the heavy water rework facility include intermittent releases of drum wash water and rework effluent. The drum wash water contains deuterium, tritium, and trace elements (Table 1-2; Du Pont, 1987). The drum wash water is discharged once a month for seven hours at the rate of about 35 gpm. The rework effluent contains 0.4 mol % of deuterium and 10 µCi/ml of tritium and is periodically discharged at the rate of 250 gallons/minute (gpm) during four or five months per year.

In the mid-1970's, pH values in Beaver Dam Creek ranged from 3.6 and 11.4 (Miller, 1984), which suggests that the creek was subject to a number of chemical spills during this time.

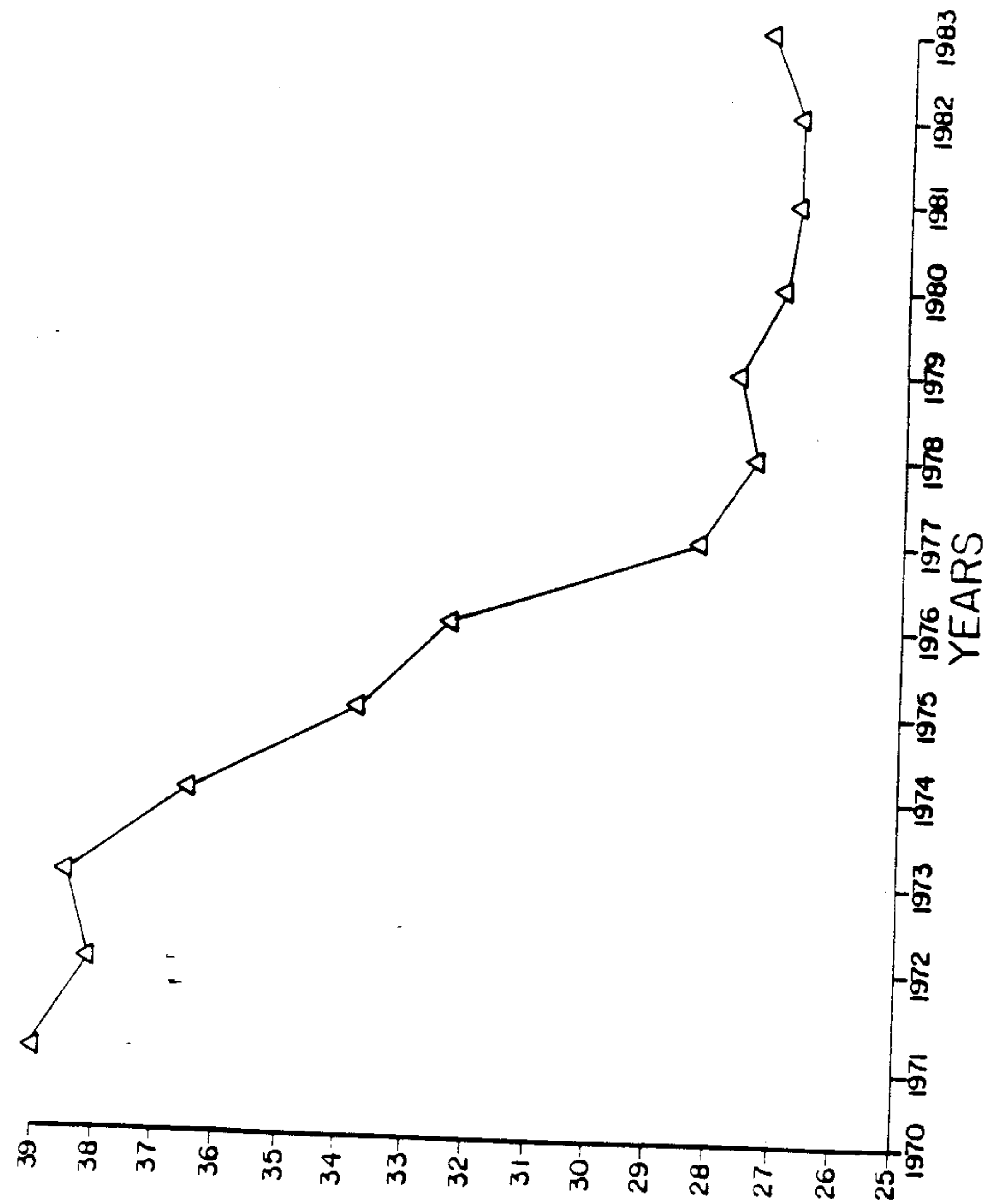

Figure 1-4. Average Annual Temperature Profile from 1971-1983 for Beaver Dam Creek (swamp area)

Table 1-1. Building 772-D Laboratory Discharges to Beaver Dam Creek

Chemical	Amount
Buffer solutions	250 L/yr
Hydroxylamine sulfate	25 kg/yr
Isopropyl alcohol	10-20 L/yr
KCl	50 g/yr
Dilute acids	Trace
Dilute bases	Trace
Ammonia	Trace
Nitrates	Trace
Oxylates	Trace
Permanganates	Trace
Peroxides	Trace
Sulfates	Trace
	Trace

Source: Specht et al. (1987)

Table 1-2. D-Area Drum Wash Waste Water Analyses

Parameter	Measurement
D_2O	0.10 mol %
Tritium	2.77 μCi/ml
pH	6.12
Mercury	0.005 mg/L
Beta	1 c/mL
Alpha	1 c/mL
Arsenic	<0.1 mg/L
Barium	3.0 μg/L
Chromium	65 μg/L
Lead	40 μg/L
Selenium	<0.2 mg/L
Silver	<0.05 mg/L
Gold	<0.05 mg/L
Boron	<1.0 mg/L
Cadmium	<1.0 mg/L
Copper	<0.05 mg/L
Dysprosium	<1.0 mg/L
Europium	<1.0 mg/L
Gadolinium	<0.5 mg/L
Samarium	<1.0 mg/L
Lithium	<0.1 mg/L
Sodium	>>2.0 mg/L

Source: Specht et al. (1987)

1.3.2 Environmental History

In 1952, D Area began releasing thermal effluents to Beaver Dam Creek. By 1955, a thermal delta had developed and approximately 19 hectares (47 acres) of swamp had been defoliated (Miller, 1984). This loss of canopy (treekill zone) is not only attributed to the temperature and flow of the effluents, but also to coal ash deposition. In the early years of D-Area operation, the ash basin outflow was not directed toward the effluent canal, but directly to the swamp. From 1956 to 1974 canopy damage continued, resulting in a total of about 167 defoliated hectares (413 acres; Miller, 1984). This loss of canopy is believed to be due more to the high temperatures of the effluent than the flow rate, since flow was decreasing with production (Miller, 1984). The period from 1974 to 1985 showed a decline in damaged canopy and a regrowth of about 7 hectares (17.5 acres; Mackey, 1987). Possible explanations for this regrowth may be the drop in effluent temperature during this period or the corresponding decrease in flow as heavy water production was curtailed.

Other perturbations to the Beaver Dam Creek watershed include the logging in 1966 of approximately 480 acres of swamp between the Savannah River and Beaver Dam Creek.

1.4 Regulatory Background

On January 1, 1984, South Carolina Department of Health and Environmental Control (SCDHEC) issued a National Pollutant Discharge Elimination System (NPDES) permit (Number SC0000175) for the Savannah River Site. In this permit, cooling water discharge limitations included a temperature limitation in on-site streams of 32.2°C and a Δ T limit of 2.8°C. Prior to issuance of the permit, there were no in-stream limits for temperature, except in the Savannah River. To achieve compliance with in-stream temperature limitations, DOE and SCDHEC entered into a Consent Order (84-4-W) on January 3, 1984, that temporarily superseded the temperature requirements in the NPDES permit and identified a process for attaining compliance. Major elements of this process included a DOE agreement to complete a comprehensive study of the thermal effects of major SRS thermal discharges, the submittal of a thermal mitigation study, and the selection and implementation of cooling water systems (DOE, 1986).

On October 3, 1984, DOE submitted its Thermal Mitigation Study to SCDHEC describing the cooling water systems that could be implemented by C- and K Reactors and the D-Area coal-fired powerhouse to achieve compliance with Federal and State water quality standards (DOE, 1986).

A draft Environmental Impact Statement (EIS) entitled "Alternative Cooling Water Systems, Savannah River Plant, Aiken, South Carolina" was prepared in 1985, and subsequent to public review and comment, a final EIS was completed in March 1986. The preferred thermal mitigation alternative in the EIS for the D-Area powerhouse was increased flow, with mixing of the raw-water basin overflow with the cooling water discharge (DOE, 1986). Although this alternative would achieve maximum in-stream temperatures of less than 32.2°C, Δ T's would still exceed 2.8°C. Section 316(a) of the Clean Water Act states that Δ T's may exceed 2.8°C if it can be demonstrated that the receiving stream can maintain a balanced indigenous community with the higher Δ T.

In March 1988, a study plan for a 316(a) Demonstration was prepared by DOE and submitted to SCDHEC for approval. The study plan was approved on June 28 1988, and in September 1988, an 18-month biological monitoring program was initiated in Beaver Dam Creek to provide the data necessary to prepare a 316(a) Demonstration. The monitoring program was concluded in February 1990, and the results of the study are summarized in this report.

2.0 THERMAL MITIGATION PROGRAM FOR BEAVER DAM CREEK

2.1 Description of Thermal Mitigation Program

The D-Area powerhouse uses water pumped from the Savannah River for cooling. Most of this water is discharged from the condensers via the D-001 outfall into an excavated canal that discharges into the original channel of Beaver Dam Creek about 1 km downstream from the D-001 outfall. A closed-loop recirculation system utilizing a small mechanical draft cooling tower provides cooling for one of the four condensers.

During normal operating conditions, water is pumped by three of six pumps located in the Building 681-5G pumphouse, which is situated on a small inlet cove of the Savannah River, about 1.6 km upstream from the mouth of Beaver Dam Creek. The rated capacity of each pump is about 0.8 cubic meters per second, with a maximum sustained flow for all six pumps of about 4.5 cubic meters per second. The water flows through a underground pipeline to a raw-water receiving basin in Building 483-1D (Figure 1-3). Excess water not utilized in the powerhouse and 400-D Area water-treatment plant overflows a weir to mix with the powerhouse effluent stream before discharging into the D-Area outfall canal (Figure 1-3). The corresponding flow rate in Beaver Dam Creek at the Environmental Protection Department monitoring station (Figure 1-3) using various numbers of pumps is as follows: two pumps, 1.7 cubic meters per second; three pumps, 2.6 cubic meters per second; four pumps, 3.5 cubic meters per second; five pumps, 4.1 cubic meters per second; and six pumps, 4.5 cubic meters per second.

Thermal mitigation for D-Area is accomplished by increased pumping of cooling water from the Savannah River, on an as-needed basis. Discharge temperatures are monitored at the compliance point and displayed in the powerhouse control room. When the discharge temperature exceeds 30.5°C, an additional pump is activated at the 5G pumphouse. During extreme summer conditions, it may be necessary to activate two additional pumps (for a total of five pumps) to maintain an outfall temperature of less than 32.2°C. The existing one-unit recirculation system with a mechanical draft cooling tower continues normal operation.

Because sufficient pumping capacity was already available in the Building 681-5G pumphouse, no new construction was required to implement increased flow with mixing. However, increased operation of the existing pumps requires circulation of more water from the Savannah River, consumption of more electricity, and a slight increase in pump maintenance costs.

2.2 Thermal Mitigation Schedule, September 1988 - February 1990

During routine operation of the 400-D powerhouse, three pumps are operated at the 681-5G pumphouse to provide sufficient cooling water for the turbo-generators. Due to reduced electrical and steam demands, less cooling water was needed and the number of pumps operating was reduced to two on September 29, 1988. The powerhouse continued to operate with just two pumps through most of the biological monitoring program. A third pump was activated during five periods during the summer of 1989 (Table 2.2-1) in order to maintain temperatures at the D-001 outfall of less than 32.2°C. However, it was never necessary to activate a fourth or fifth pump, which would be the case if thermal mitigation were required during routine operating conditions. A third pump was also run between September 11 and 22, 1989 but was not required for thermal mitigation. A comparison of mean daily water temperatures from October 9, 1988 through February 28, 1990 for the Savannah River near Jackson SC, 400-D, Beaver Dam Creek at the mouth (USGS , 1989, 1990), and sample Stations 1 and 5 (Nagle et al, 1990) and number of operating pumps is shown in Figure 2.2-1. This figure shows the relationship between the time periods during which extra pumps were run and water temperatures in the river, 400-D discharge, and areas of Beaver Dam Creek. The mitigation activities were effective in maintaining water temperatures below the maximum allowable 32.2°C level.

TABLE 2.2-1. Mitigation Periods, September 1988 - February 1990.

May 7 and 8, 1989
July 28, 1989
July 31 through August 14,1989
August 23 through 25, 1989
August 27, 1989

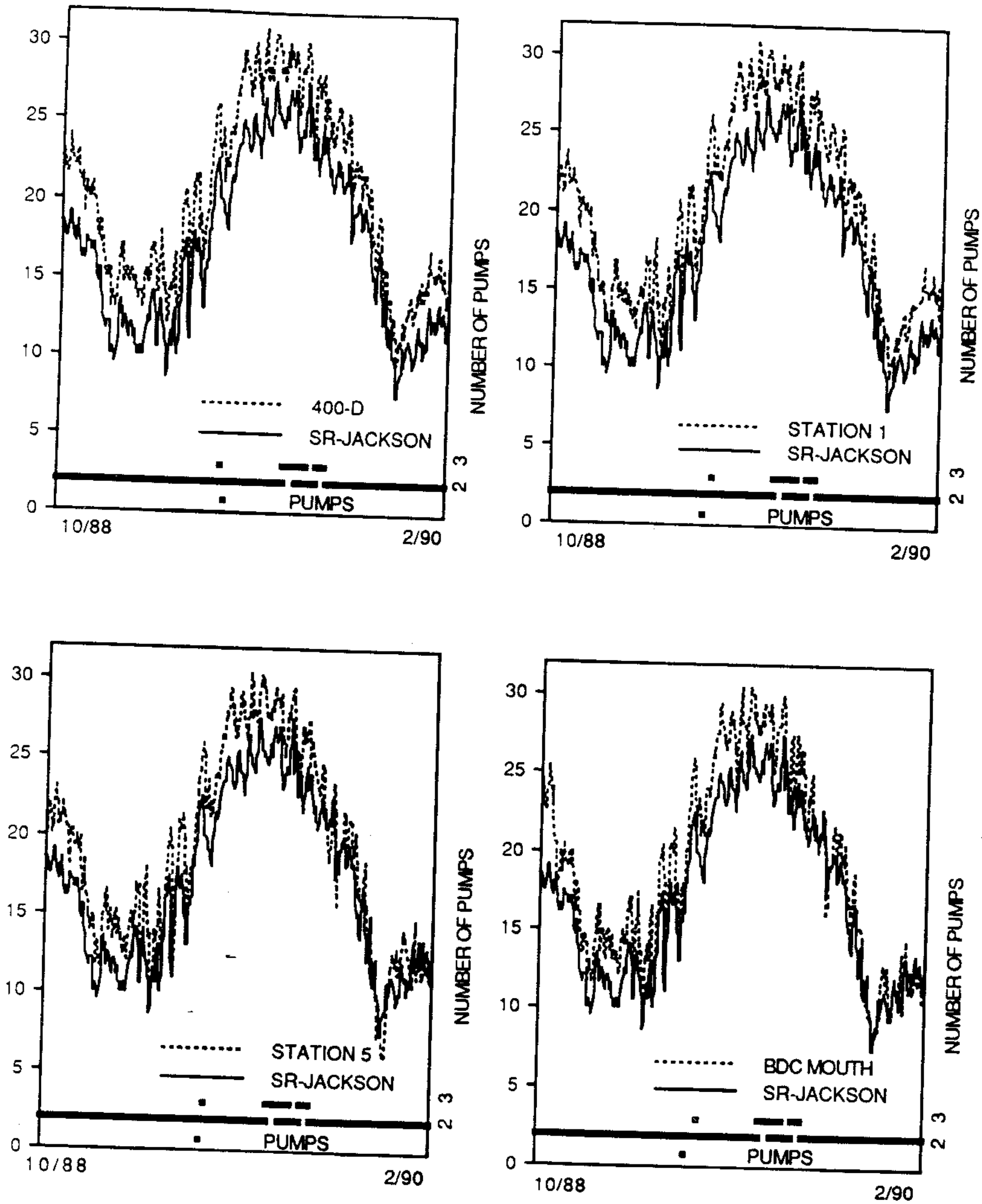

Figure 2.2-1. Water Temperature and 400-D Area Pump Operation During October 1988 through February 1990

3.0 EVALUATION CRITERIA FOR BIOLOGICAL SYSTEMS

The term "balanced biological community" as used in this report is considered to be synonymous with the term "balanced indigenous population" as found in Section 316(a) of the Clean Water Act. The stated objective of this legislation is "... to assure the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife in and on the body of water into which the discharge is to be made ...". The term "balanced indigenous population", however, is not clearly defined. In 1977, the U.S. Environmental Protection Agency (EPA) published guidelines for the preparation of thermal effects studies that provide better guidance concerning the requirements for compliance with the objectives of the original legislation (EPA, 1977). Although the criteria vary somewhat among different taxonomic groups, four general criteria for acceptable performance of biological systems have been identified from that document and are used, as appropriate, in the evaluation of the biota of the Beaver Dam Creek ecosystem. These criteria are that Beaver Dam Creek:

- Should not be dominated by pollution (thermally) tolerant species.
- Should have biotic diversity and productivity characteristic of that found in other streams of the region.
- Should have populations that are reproducing and are not maintained by repeated restocking or reseeding.
- Should have all trophic groups that would be expected in an ecosystem of that type.

The first of these criteria concerns the factors that control the structure of aquatic communities. In order to meet this criterion, the release of thermal effluents must not elevate temperatures in the receiving stream to such an extent that the biotic community is dominated by organisms that are especially heat tolerant, and that those species that are thermally intolerant are absent from the community. Thus, the Beaver Dam Creek biological community has been evaluated to determine whether the ecosystem is dominated by thermally tolerant organisms.

The second criterion concerns the overall structure and functioning of the ecosystem. In order to satisfy this criterion, the release of thermal effluents into Beaver Dam Creek should not substantially alter the number of species or the productivity (e.g. growth or standing crop) of species populations beyond the range of values observed in other aquatic ecosystems in the same region.

The third criterion addresses the perpetuation and persistence of species populations in the aquatic ecosystem. In order to satisfy this criterion, the release of thermal effluents into Beaver Dam Creek should not result in conditions whereby the thermal tolerance of the most sensitive life stages of aquatic species are chronically exceeded, thereby precluding adequate reproduction, and eventually eliminating the species from the ecosystem. Because Beaver Dam Creek has never been stocked or had species intentionally introduced into the ecosystem, the presence of a species in Beaver Dam Creek documents its ability to perpetuate and persist in the ecosystem.

The fourth criterion relates to the functional integrity of the ecosystem. In order to satisfy this criterion, the release of thermal effluents into Beaver Dam Creek should not stress the species populations or alter the movement of energy and nutrients though the ecosystem in such a manner that major ecosystem functions are disrupted or absent from the aquatic community. Examples of such major functional groups include primary producers (mostly periphyton and aquatic macrophytes), decomposers (mostly bacteria and fungi), primary consumers(many zooplankton, macroinvertebrates and some fish) and secondary consumers (mostly macroinvertebrates and fish) and tertiary consumers (mostly large predacious fish). Many species shift from one trophic level to another at different life stages or feed at multiple trophic levels, thereby providing a degree of functional redundancy in the ecosystem. Therefore, in many instances, it was difficult to assign a species to a trophic level, or to document that the trophic structure of the ecosystem was not perturbed. However, because higher trophic levels are dependent upon lower trophic levels for sustenance, the presence of higher trophic levels was taken as an indication that lower trophic levels were functioning adequately.

4.0 BEAVER DAM CREEK

4.1 Overview and Description of Sampling Stations

Beaver Dam Creek originates approximately 1.5 km southeast of 400-D (Figure 4-1) and flows generally southwest for a distance of about 6 km before entering the Savannah River at River Mile 152.1. Beaver Dam Creek was not identified in the 1951-1953 study of SRS streams conducted by the University of South Carolina and is believed to have carried low or intermittent flow before SRS operation (Brown et al., 1972). The stream was named by SRS personnel in 1956 (Dukes, 1984). In the early 1950's a discharge canal, approximately 1.6 km in length, was excavated from the heavy water production area in D Area to what is believed to be the original intermittent stream channel of Beaver Dam Creek. Portions of the discharge canal are heavily rip-rapped with large rocks and the gradient of the canal is sufficiently steep to cause the effluent to cascade over the rip-rap.

Just downstream of the discharge canal the stream is relatively deep, narrow and fast-flowing, but becomes wider and slower flowing as it enters the delta that was formed when the combined discharges from the heavy water production area and the power plant inundated part of the Savannah River swamp and destroyed the original cypress-tupelo forest. The delta is a relatively open area, where scattered large dead trees still stand in some areas, and lush growths of bottomland shrubs and sawgrass grow along the banks of the stream. During high flow conditions, water spreads out across the delta and forms a shallow, slow-flowing pool. Because water is not confined to the channel during periods of high flow, water levels in the delta are more stable than in the remainder of the creek. However, when the Savannah River experiences severe flooding, river water inundates the entire lower portion of Beaver Dam Creek and the delta, causing water levels in the delta to rise by 50 cm or more.

Downstream from the delta, Beaver Dam Creek flows through an area that is heavily canopied for a distance of about 0.5 km, before entering into a broad, slow-flowing slough-like area that contains heavy growths of macrophytes along both banks. After flowing through the slough for about 1 km, the creek channel becomes narrow and deep, with steep banks and almost complete canopy cover and flows for about 1.5 km before entering the Savannah River at River Mile 152.1.

Seven sampling stations were selected in Beaver Dam Creek to represent the different habitats of the stream. Station 1A, located in the original Beaver Dam Creek stream channel (Figure 4-1) is upstream from the effluent canal. This channel is completely dry except during periods of significant rainfall.

Station 1 is located just downstream from the end of the D-Area discharge canal, approximately 1 km downstream from the D-001 outfall (Figure 4-1). The channel is among the deepest (about 1.4 m) and narrowest (about 4.3 m) of all of the sampling stations. The creek has steep banks approximately 1 m in

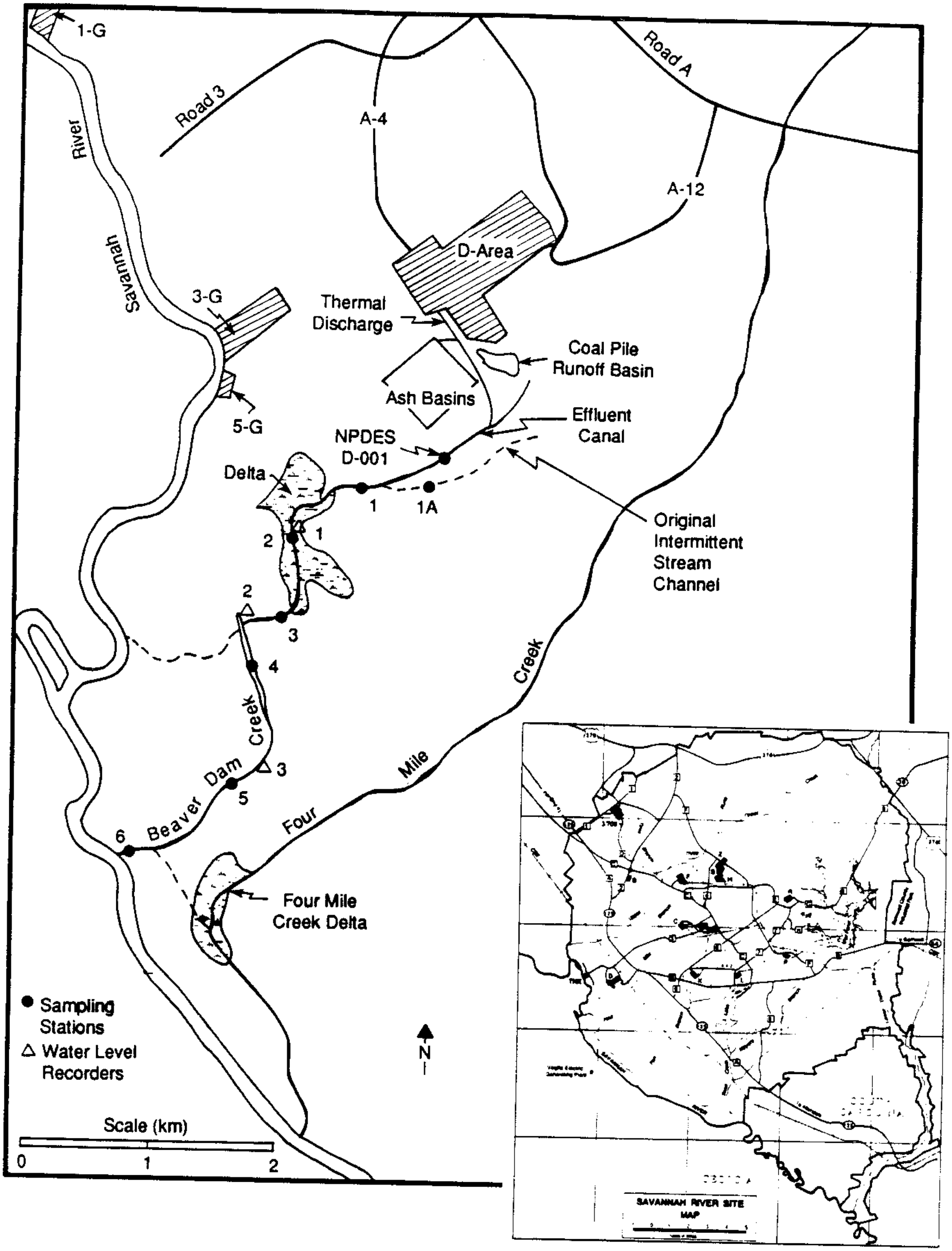

Figure 4-1. Location of Sampling Stations in Beaver Dam Creek

height, which the creek rarely overflows. Velocities at mid-channel are relatively swift (about 0.5 m/sec), and the stream channel is almost devoid of macrophyte growth. Habitat structure is provided by numerous partially submerged stumps and submerged logs. Canopy cover is more than 75%, with alder and other wetland shrub species bordering the creek (Nagle et al., 1990).

Station 2, located 0.7 km downstream from Station 1, is in the delta of Beaver Dam Creek (Figure 4-1). During low flow conditions, water flows in a distinct channel through the delta. During low flow conditions, the channel is about 4 to 6 m wide, and 0.8 m deep, with velocities of about 0.45 m/sec at mid-channel. The banks are lined with heavy growths of alder and other shrubby vegetation. Macrophyte growth is present in about 10 to 20% of the creek channel, but is confined mostly to the sides of the channel (Nagle et al., 1990).

Station 3 is located about 0.6 km downstream from Station 2 and is characterized by a well-formed serpentine channel that is generally 1 m deep and about 4.2 m wide, with velocities of about 0.45 m/sec at mid-channel. Aquatic macrophytes are present along the banks, and occupy about 20% of the stream channel. A few submerged logs are present at the downstream end of the station. Canopy cover at Station 3 varies from less than 50% at the upstream end of the station to virtually full canopy cover at the downstream portion of the station (Nagle et al., 1990).

Station 4 is about 0.5 km downstream from Station 3, in the slough-like portion of the stream. The creek channel is approximately 20 m wide, but approximately 75% of the channel is overgrown with aquatic macrophytes (primarily Myriophyllum). The stream channel in the slough is relatively straight and shallow (less than 1 meter), with relatively low velocities (0.3 meters/second), although velocities can increase to as much as 0.5 meters/second under low-flow conditions when water flow is restricted to the center portion of the channel. Aquatic macrophytes provide most of the stream structure at Station 4, along with a few submerged logs. Although mature trees line the banks, the closest trees are about 10 meters from the central channel, and provide minimal canopy cover (Nagle et al., 1990).

Downstream of Station 4, the stream channel meanders and has steep banks. At Station 5, which is about 0.7 km downstream from the slough, the channel is narrow (5 meters), deep (greater than 1 meter), and swift, with velocities in excess of 0.7 meters/second. Vines and shrubs choke the stream banks and overhang the channel. Much of the upstream portion of the station has a relatively open canopy (less than 25%), while the downstream end of the station is heavily canopied greater than 75%), as mature trees replace the shrubs along the banks. Habitat structure at Station 5 is relatively complex, with numerous submerged logs and overhanging vegetation (Nagle et al., 1990).

Station 6, is located about 0.8 km downstream from Station 5 near the mouth of Beaver Dam Creek. Stream width averages about 7 meters, mid-channel depths are generally about 2 meters, and stream velocity is about 0.3 meters/second during low flow conditions. The stream has steep banks and numerous tree roots are exposed. Canopy cover is near 100%, which precludes the presence of aquatic macrophytes. Excellent fish habitat is provided by large numbers of submerged logs. Station 6 is greatly influenced by the Savannah River and often undergoes flow fluctuations of two meters or more during river flooding. During river flooding the stream reverses its course and river water inundates the stream as far upstream as Station 2 in the delta (Nagle et al., 1990).

4.2 Watershed Characteristics

Beaver Dam Creek has been described by most authors (Nagle et. al., 1990; Bauer et. al., 1989; Specht, 1987; Firth et. al., Tinney et. al., 1986; Brown et al., 1972) as being an intermittent stream prior to SRS operations. This evaluation is strongly supported by data for the reach of the stream above the 400-D Area discharge canal (Nagle et al., 1990). The upper reach of the stream contained water only after significant rainfall events. As an intermittent stream, the watershed area of the original Beaver Dam Creek would be expected to be relatively small. Estimates of watershed area are approximately 2.2 km^2. In it's original condition, Beaver Dam Creek flowed 2.9 kilometers through the Savannah River swamp (Nagle et al., 1990). Beaver Dam Creek is now attributed a length of approximately 6 kilometers (Specht, 1987). This increase of stream length is probably a result of the increased flows from years of operation producing a relatively distinct channel through the swamp beyond where the original intermittent stream flow dispersed into the swamp.

The characteristics of the actual Beaver Dam Creek watershed are difficult to describe for two reasons. First, since Beaver Dam Creek was initially an intermittent stream, the majority of the water currently flowing through the system is provided by 400-D Area operations, not by a true watershed. Second, the downstream half of Beaver Dam Creek as it now exists within the Savannah River swamp does not, in a strict sense, drain that area of the swamp, but in fact only provides a channel through the swamp for the flows introduced by 400-D Area operations.

Soils in the Beaver Dam Creek watershed are distributed between three different types. The majority of the area is characterized by Troup loamy sand, terrace phase, which is a relatively productive soil occurring on old stream terraces not subject to flooding. Beaver Dam Creek also passes through an area of Orangeburg and Red Bay soils on a somewhat elevated ridge before entering the Savannah River swamp (Aydelott, 1977). The Savannah River swamp, through which Beaver Dam Creek passes for much of its length, is not characterized for soil type.

Vegetation cover of the Beaver Dam Creek watershed is comprised mainly of pines and hardwoods in the drier areas, bottomland hardwoods, scrub-shrub and herbaceous assemblages in wetter areas, and cypress-tupelo, mature hardwoods, emergent and submergent macrophytes in the swamp (Nagle et al., 1990).

Past operations in the 400-D Area had substantial impact on the vegetation of Beaver Dam Creek. By 1966, over 103 hectares of the swamp had experienced total or partial canopy loss. Partial canopy loss appeared to stabilize around 1966, but total loss continued. From 1974 to 1978, total canopy loss continued but was balanced by reductions in partial loss. There are indications that regrowth occurred between 1978 and 1985. (Tinney et. al., 1986). For a detailed discussion of the current status of the impacted area see Section 4.5.1.

Land use in the Beaver Dam Creek watershed is dominated by the 400-D Area complex. There are also support roads and right-of-ways. There is some limited pine production in the area, and logging of hardwoods was done during the early 1960's in the swamp between Beaver Dam Creek and the Savannah River (Tinney et al., 1986).

4.3 Hydrology

Beaver Dam Creek drains a relatively small watershed area (2.2 km^2) and prior to the 1952 onset of discharges from 400-D Area was probably an intermittent stream (Specht 1987). Beaver Dam Creek was not identified in an on-site stream survey during 1951 -1953 and was not named until 1956 (Dukes, 1984). The hydrology of Beaver Dam Creek is almost entirely determined by 400-D Area discharges. Currently Beaver Dam Creek receives condenser cooling water from the powerhouse, neutralization wastewater, sanitary wastewater, ash basin effluent waters, and various laboratory wastes (Bauer et al., 1989). Until early 1982, Beaver Dam Creek also received heavy water plant process cooling water producing discharge flows up to about 3.7 m^3/sec (130 cfs). Since the heavy water process was shut down in 1982 the effluent has been reduced to about 2.5 m^3/sec (88 cfs)(Dukes, 1984).

Hydrologically Beaver Dam Creek can be divided into three relatively distinct areas. The upper reach of the creek upstream from 400-D Area discharges is intermittent and its hydrology is mainly dependent on rainfall events (Nagle et al., 1990). The middle reaches of Beaver Dam Creek from just downstream of the discharge canal to the delta vary in gradient and channel morphometry, but the flows are determined largely by discharge of water from 400-D Area operations and rainfall. The lower reach of Beaver Dam Creek has hydrologic properties determined by flows from 400-D Area operations, rainfall, Savannah River levels (Nagle et al., 1990), and input from Four Mile Creek (Dukes, 1984).

During the recent 18 month (September 1988 to February 1990) study of Beaver Dam Creek, the upper reach above the 400-D Area discharge contained adequate water for sample collection during only five of the 18 sampling events. Rainfall was recorded at 400-D Area just prior to all but one of the successful sampling events. There were three sampling attempts preceded by significant rainfall when insufficient water was available for sampling (Nagle et al., 1990). Values for flow volume and velocity in the intermittent upper reach of Beaver Dam Creek are not available.

The middle reach of Beaver Dam Creek is comprised of distinct areas. The upper-most area is deep and narrow with well defined banks as high as a meter or more above stream level. Velocities are relatively high (0.53 meters per second, m/sec) in this area, but the creek meanders quite a bit and seldom overflows its banks. Further downstream Beaver Dam Creek enters a delta area where water levels fluctuate little except during extreme river flooding. During low flows the creek travels at approximately 0.45 m/sec in a well defined, low-banked channel. During high flows the water spreads out across the delta forming a slow-flowing (approximately 0.2 m/sec) shallow pool. Below the delta Beaver Dam Creek flows in a well defined channel and into a straight, wide slough-like area with well defined banks. Flow velocity in the slough ranges from 0.3 to 0.5 m/sec. Below the slough the creek narrows and increases velocity (up to 0.7 m/sec.) before flowing into the lower most portion of the creek. (Nagle et al., 1990)

The lower-most portion of Beaver Dam Creek is the deepest (nearly 2 meters) section of the creek and has banks that are more than two meters above normal creek level. The lower area of Beaver Dam Creek is greatly affected by large fluctuations in Savannah River levels. At normal river levels this portion of the creek is slow-flowing (less than 0.3 m/sec), but when the river level is elevated river water inundates the stream channel and water flows upstream from the river to the swamp as far upstream as the delta (Nagle et al., 1990).

4.4 Water Quality

This section of the report summarizes the results of water quality studies conducted in Beaver Dam Creek from September 1988 through February 1990. Unless otherwise noted, data contained in this section are summarized from Nagle et al. (1990). Monthly field measurements of depth, water velocity, temperature, dissolved oxygen, pH, and conductivity were made concurrently with water collection for laboratory analysis of other water chemistry parameters. Sampling methods and data analysis techniques are detailed in Nagle et al. (1990).

4.4.1 Chemical Parameters

The means for chemical parameters sampled at each station during the study period are presented in Table 4.4-1. Data for Station 1A (in the original ephemeral stream channel) reflects five successful sampling events out of 18 attempts. Generally, Station 1A was dry and water samples could not be taken. Water quality parameters at Station 1A were consistently different from all other stations on Beaver Dam Creek (Table 4.4-1). Station 1A had the lowest mean values for pH, conductivity, dissolved oxygen, temperature, ortho-phosphorus, sulfate, nitrate, total phosphorus, and dissolved and total strontium (Table 4.4-1). 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.

Table 4.4-1. Mean Values for Water Chemistry Parameters at Stations Sampled in Beaver Dam Creek, September 1988 - February 1990

Parameter	Station 1	1A[a]	2	3	4	5	6	Detection Limit
pH	6.76	4.42	6.68	6.60	6.58	6.50	6.61	0.1
Conductivity (µS/cm)	129	57	131	128	127	128	124	1
Dissolved Oxygen (mg/L)	8.43	6.21	8.34	8.00	7.76	7.70	7.92	0.1
Temperature (°C)	19.9	13.2	19.8	19.4	19.1	18.8	18.7	0.1
Ortho-Phosphorus (mg P/L)	0.076	0.007	0.077	0.075	0.072	0.069	0.069	0.004
Total Hardness (mg $CaCO_3$/L)	22.1	25.6	22.4	23.1	22.7	23.4	22.4	0.5
Total Suspended Solids (mg/L)	17	105	14	19	14	16	22	1
Turbidity (NTU)	16.7	98.1	13.6	13.8	12.8	13.4	17.0	0.1
Sulfate (mg/SO_4/L)	19.8	9.7	19.1	18.7	18.4	17.8	17.0	1
Nitrate (mg N/L)	0.41	0.04	0.42	0.43	0.42	0.42	0.40	0.01
Total Phosphorus (mg P/L)	0.137	0.060	0.134	0.136	0.130	0.127	0.135	0.004
Dissolved Sodium (mg/L)	16.8[b]	-	-	-	-	-	-	0.05
Dissolved Aluminum (mg/L)	0.140	0.854	0.180	0.127	0.144	0.133	0.126	0.05
Dissolved Arsenic (mg/L)	0.0031	0.0006	0.0033	0.0027	0.0027	0.0027	0.0024	0.003
Dissolved Barium (mg/L)	0.0218	0.0494	0.0220	0.0216	0.0216	0.0213	0.0207	0.005
Dissolved Cadmium (mg/L)	0.001	0.001	<0.001	0.001	<0.001	0.001	<0.001	0.01
Dissolved Chromium (mg/L)	0.002	0.001	0.002	0.002	0.002	0.003	0.003	0.02
Dissolved Copper (mg/L)	0.002	0.002	0.002	0.001	0.002	0.002	0.002	0.01
Dissolved Iron (mg/L)	0.266	0.963	0.299	0.290	0.294	0.315	0.302	0.02
Dissolved Lead (mg/L)	0.0003	0.0010	0.0003	0.0002	0.0003	0.0003	0.0002	0.003
Dissolved Manganese (mg/L)	0.053	0.3985	0.0520	0.0561	0.0605	0.0659	0.0699	0.005
Dissolved Mercury (mg/L)	0.00004	0.00004	0.00004	0.00003	0.00005	0.00003	0.00002	0.0001
Dissolved Selenium (mg/L)	0.0011	0.0007	0.0009	0.0007	0.0009	0.0007	0.0011	0.006
Dissolved Silver (mg/L)	0.00002	0.00003	0.00004	0.00001	0.00001	0.00003	0.00001	0.0005
Dissolved Strontium (mg/L)	0.0471	0.0190	0.0472	0.0462	0.0457	0.0454	0.0442	0.005
Dissolved Zinc (mg/L)	0.005	0.012	0.006	0.004	0.005	0.003	0.004	0.01
Total Aluminum (mg/L)	0.611	1.776	0.596	0.630	0.641	0.710	0.802	0.05
Total Arsenic (mg/L)	0.0034	0.0008	0.0039	0.0033	0.0031	0.0029	0.0027	0.03
Total Barium (mg/L)	0.0269	0.0569	0.0278	0.0283	0.0284	0.0277	0.0283	0.005
Total Cadmium (mg/L)	0.001	0.001	0.0001	0.001	0.001	0.001	0.000	0.01
Total Chromium (mg/L)	0.003	0.004	0.005	0.003	0.004	0.003	0.003	0.02
Total Copper (mg/L)	0.001	0.003	0.003	0.003	0.003	0.003	0.004	0.01
Total Iron (mg/L)	0.906	2.362	0.982	1.129	1.039	1.094	1.286	0.02
Total Lead (mg/L)	0.0038	0.0061	0.0030	0.0017	0.0019	0.0028	0.0021	0.003
Total Manganese (mg/L)	0.096	0.421	0.097	0.108	0.104	0.108	0.131	0.005
Total Mercury (mg/L)	0.00004	0.00005	0.00005	0.00005	0.00005	0.00020	0.00003	0.0001
Total Selenium (mg/L)	0.0012	0.0008	0.0010	0.0010	0.0011	0.0009	0.0008	0.006
Total Silver (mg/L)	0.00006	0.00005	0.00012	0.00010	0.00082	0.00006	0.00005	0.0005
Total Strontium (mg/L)	0.0459	0.0199	0.0469	0.0461	0.0467	0.0452	0.0437	0.005
Total Zinc (mg/L)	0.0010	0.021	0.010	0.010	0.011	0.008	0.009	0.01

[a] Five sampling dates.

[b] Sodium was sampled only at Station 1.

The mean value for total mercury at Station 5 (0.00020 mg/L) is above the detection limit of 0.0001 mg/L, while the mean at all other stations is well below the detection limit (Table 4.4-1). This was caused by a single high value of 0.00293 at Station 5 in January 1990 (Nagle et al., 1990; Appendix Table 2). The median value for total mercury is below the detection limit at Station 5.

The mean value for total silver at Station 4 (0.00082 mg/L) is above the detection limit of 0.0005 mg/L, while the mean at all other stations is well below the detection limit (Table 4.4-1). This was caused by a single high value of 0.01360 mg/L in January 1989 (Nagle et al., 1990; Appendix 2). The median value for total silver is below the detection limit at Station 4 (Nagle et al., 1990; Appendix Table 1).

The low pH values and high levels of total hardness, total suspended solids, turbidity, dissolved and total aluminum, dissolved and total iron, and dissolved and total manganese at Station 1A can be attributed to the influence of runoff from the rainfalls (McDiffett et al. 1989). Aluminum, iron, and manganese are common metals in soil, and along with low pH, are expected components of runoff water (Stumm and Morgan, 1981). Increased concentrations of these elements in water can also contribute to elevated levels of total hardness, total suspended solids, and turbidity. Relatively high means at Station 1A for dissolved and total barium and dissolved lead as compared with Stations 1-6 (Table 4.4-1) are not readily explained.

Excluding Station 1A, means for the study period were generally similar among stations (Table 4.4-1). Mean pH and dissolved oxygen exhibited slight downstream decreases from Stations 1 - 5. Mean temperature and sulfate exhibited similar decreases from Station 1 to Station 6 (Table 4.4-1).

Mean values for dissolved and total arsenic, dissolved and total cadmium, dissolved and total chromium, dissolved and total copper, dissolved lead, dissolved and total mercury (except at Station 5), dissolved and total selenium, dissolved and total silver (except at Station 4), and dissolved and total zinc were near or below the detection limit at all regularly sampled stations (Table 4.4-1).

Nagle et al. (1990) compared the water quality data for Beaver Dam Creek with U.S. Environmental Protection Agency (EPA) Primary and Secondary Drinking Water Standards and U.S. EPA Water Quality Criteria for Fresh Water, as well as data available in the literature from 20 representative southeastern lotic systems. The pH range at upstream station 1A was below EPA drinking water and fresh water criteria and generally below the range listed for the 20 other lotic systems. Compared to EPA criteria and values reported for the other lotic systems, Beaver Dam Creek Station 1A had relatively high values for turbidity, TSS, iron, manganese, and aluminum. Other chemical parameters at Station 1A were within EPA limits and comparable to those of other lotic systems in the region.

Since station 1A was dry during most of the 18 month study and was only sampled on five occasions, in most cases after heavy rains, the rainwater runoff from Station 1A would not be expected to meet EPA standards for drinking water or fresh water criteria for water quality. It would also be expected to differ from continuously flowing stream water chemistry, especially for pH, TSS, aluminum, and manganese. Low pH and high relative levels of TSS, aluminum, and manganese can usually be found in runoff water (Stumm and Morgan, 1981).

At Beaver Dam Creek Stations 1-6, minimum pH values were lower than the range listed for the EPA drinking water and freshwater standards, but were comparable to values from other streams of the region. Maximum values for turbidity, manganese, mercury, iron, copper, silver, lead, zinc, and aluminum at Stations 1-6 were in excess of EPA criteria on one or more occasions.

4.4.2 Physical Parameters

4.4.2.1 Temperature

Data were obtained from 6 October 1988 to 28 February 1990 by digital recording thermometers at Stations 1 - 6 in Beaver Dam Creek. The highest temperature recorded in Beaver Dam Creek for the sampling period was 31.9°C at both Stations 1 and 2 on 28 June 1989 and the lowest recorded temperature was 3.5°C at Station 3 on 24 December 1989. Daily fluctuations generally ranged between 1 and 3°C. Where 18 month temperature profiles were complete (Station 1, 3, and 5), a typical seasonal pattern was observed, with lows of approximately 12°C from December 1988 through February 1989 and highs of around 31°C in July and August. Temperatures between stations were generally similar; only a slight downstream decrease (approximately 1°C) was observed from Station 1 to Station 6.

Temperature changes observed at the 5G pumphouse (Figure 4.4-1) generally followed the seasonal pattern seen at the creek stations but were typically 2 - 4°C cooler. Temperature differences between Station 1 of Beaver Dam Creek and the 5G pumphouse intake are presented in Figure 4.4-2. For most of October 1988, temperature differences between Station 1 and 5G generally ranged from about 1°C to 4°C, with considerable fluctuation. From November 1988 to the middle of August 1989, differences between Station 1 and 5G were usually 2.5 to 5°C. Temperature differences fluctuated the most during August and September 1989, with Δ T's as great as 8°C and as little as 0°C. The temperature data from this study indicate that temperatures in Beaver Dam Creek never exceeded 32.2°C, but the Δ T between Station 1 and the 5G pumphouse often exceeded 2.8°C.

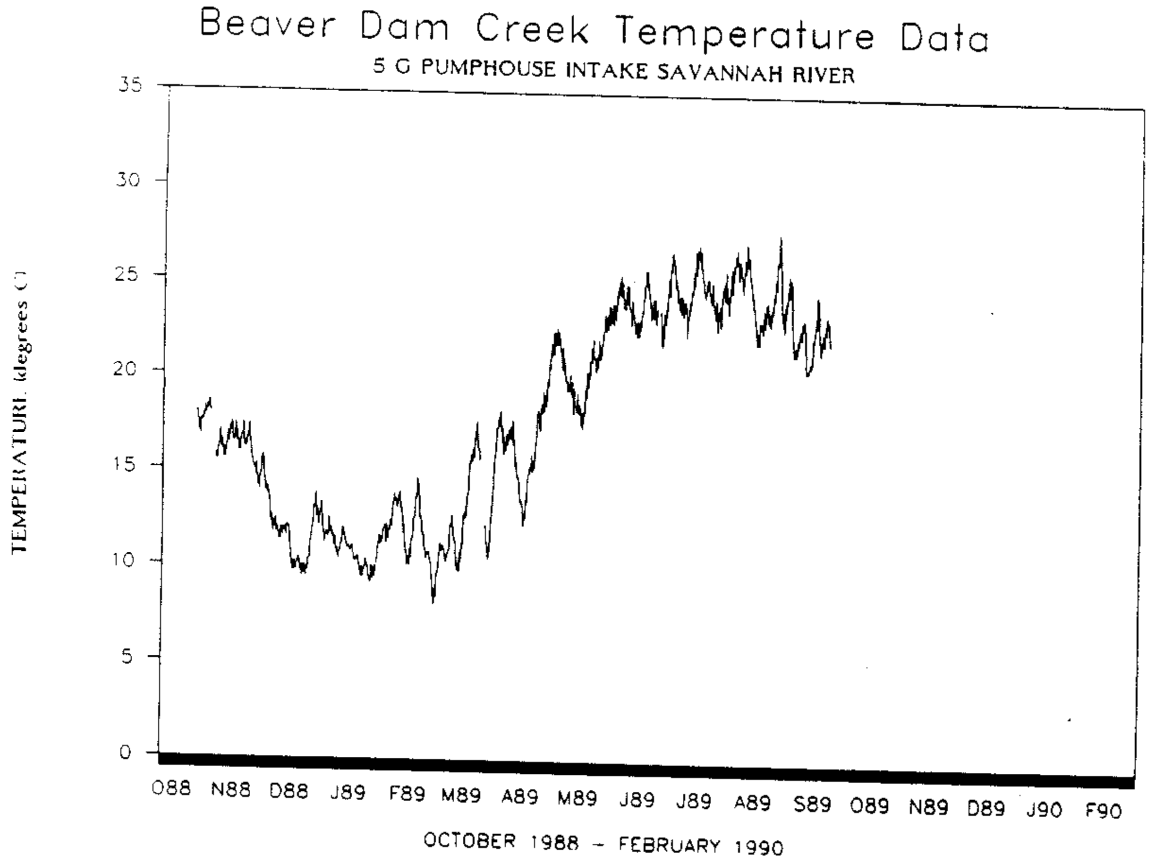

Figure 4.4-1. Instantaneous Digital Temperature Recorder Data Near the 5G Pumphouse Intake on the Savannah River.

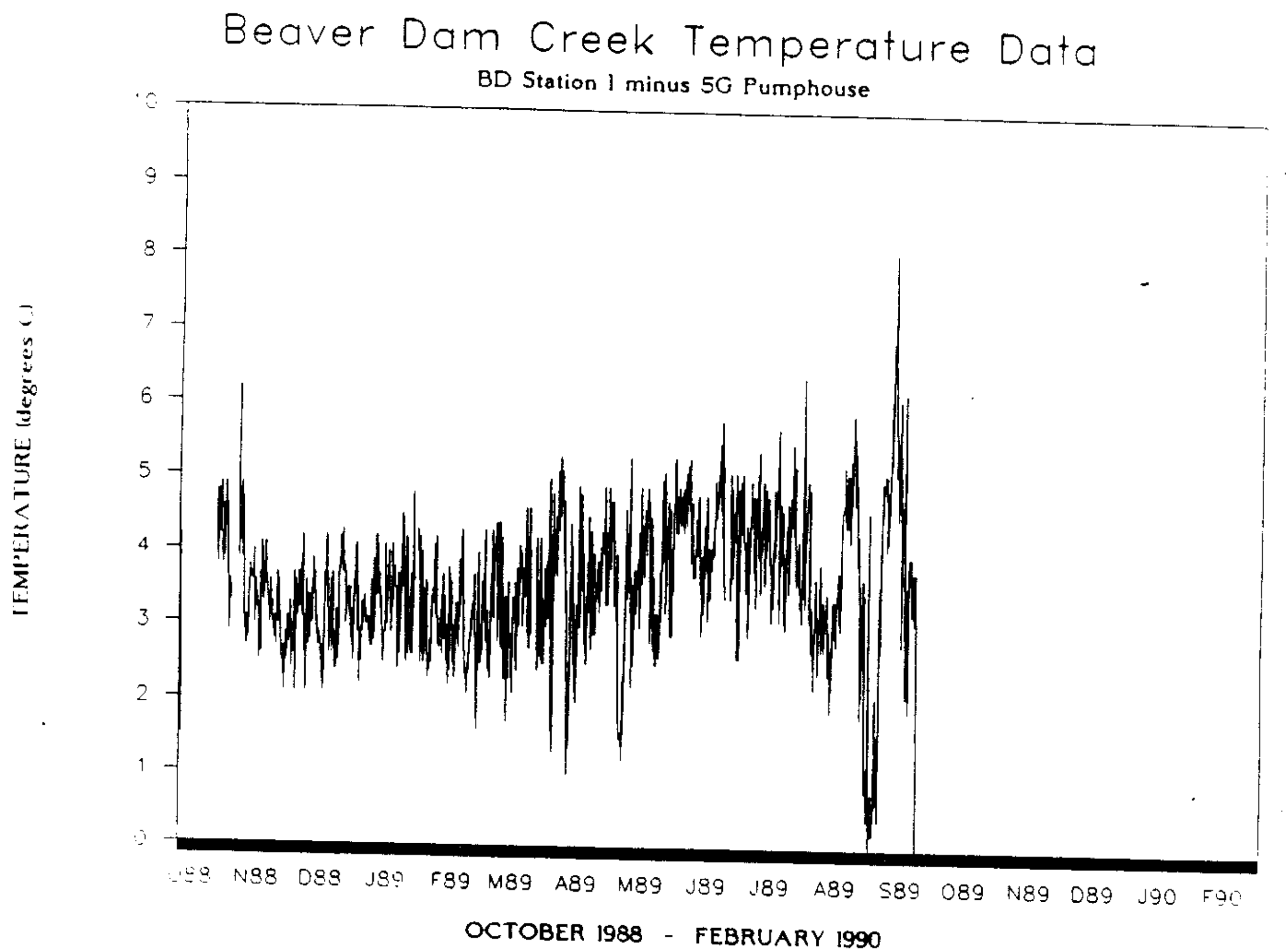

Figure 4.4-2. Instantaneous Temperature Differences Between Station 1 and the 5G Pumphouse.

4.4.2.2 Creek Discharge

Mean estimated discharge data for regular monthly and storm event sampling are summarized from Nagle et al. (1990) in Table 4.4-2. Only routine sampling is discussed in this section; storm event sampling is discussed in Section 4.4.2.3. Monthly discharges at all stations are plotted from the 18 month period in Figure 4.4-3.

Mean estimated discharge for 18 months at each station ranged from 1.34 to 1.83 m^3/sec (Table 4.4-2). Smaller 18 month mean discharge estimations at Stations 2 and 3 (1.34 and 1.43 m^3/sec, respectively) than at Station 1 (1.66 m^3/sec) could be due to measurement techniques. The width of the channel was defined by the creek banks or the edges of macrophyte beds. Depth and velocity were not measured in macrophyte beds, consequently, discharge calculations at stations with large macrophyte beds along the stream edges may have been underestimated. At Stations 2 and 3, the discharged transects include macrophyte beds on both sides of the creek; flow through these beds was not estimated. There are no macrophyte beds at Station 1; thus, the measurement of velocity was not obstructed and a more representative discharge could be calculated.

Monthly discharges were generally similar at all stations, with most measurements between 1 and 2 m^3/sec (Figure 4.4-4). Notable exceptions occurred at Station 6 in April 1989 (discharge of 5.63 m^3/sec) and at Station 4 in February 1990, with a discharge of 5.70 m^3/sec, the greatest of the entire study (Figure 4.4-3). The April 1989 discharge measurement at Station 6 closely followed a period of measurable rainfall at D Area. Thus, the increased discharge measurement that month could reflect a runoff surge passing by the creek mouth station at the time of velocity and depth measurements. Water from Four Mile Creek joins Beaver Dam Creek downstream of Station 5. Any flow from that source caused by runoff could also have contributed to the high discharge measurement in April 1989 at Station 6.

The high relative discharge in February 1990 at Station 4 (Figure 4.4-3) was probably due to both Beaver Dam Creek discharge and elevated Savannah River levels. No discharge could be measured at Station 3, upstream of Station 4, in February 1990, which indicates Savannah River flooding. There was flow at Station 3, but it was moving perpendicular to normal Beaver Dam Creek flow and, therefore was deemed to be influenced by the Savannah River. It can be assumed from this that Station 4 flow, although traveling in the normal direction, was also influenced by the Savannah River. Nagle et al. (1990) also reported that no discharge could be measured at Stations 5 or 6 in February 1990.

All stations showed slightly elevated discharge in September of 1988 and 1989 (Figure 4.4-3). These sampling dates coincided with an increase from two to three pumps at D Area (Figure 4.4-4). The operation of three pumps at D Area did not reflect a mitigation situation, since three-pump operation is considered normal operating procedure. However, increased pumping in late July and

Table 4.4-2. **Comparison of Data for Discharge, Total Suspended Solids (TSS), and Turbidity for Regular Monthly Sampling and Storm Event Samplings for Beaver Dam Creek. September 1988 - February 1990[a].**

Station	N	DISCHARGE (m^3/sec) Mean	Min	Max	TSS[b] (mg/L) Mean	Min	Max	TURBIDITY[b] (NTU) Mean	Min	Max
1Regular	(18)	1.66	1.31	2.16	17	7	91	16.7	4.2	73.0
1 Storm	(5)	1.92	1.44	2.97	11	8	17	9.4	6.3	13.1
2 Regular	(18)	1.34	0.95	2.09	14	6	35	13.6	4.5	59.0
2 Storm	(5)	1.33	1.05	1.74	10	5	15	8.7	5.6	10.8
2 Regular[c]	(16)	1.43	0.95	1.86	19	3	40	13.8	4.4	59.0
3 Storm	(5)	1.66	1.09	2.21	11	9	13	8.3	5.7	9.7
4 Regular[c]	(17)	1.64	0.90	5.70	14	2	24	12.8	4.4	52.0
4 Storm	(5)	1.51	1.38	1.74	9	7	11	9.3	5.7	12.5
5 Regular[c]	(14)	1.59	0.92	2.19	16	3	29	13.4	5.3	30.0
5 Storm[d]	(4)	2.01	1.75	2.54	11	4	15	7.9	6.8	9.1
6 Regular[c]	(14)	1.83	1.16	5.63	22	7	63	17.0	5.0	79.0
6 Storm[d]	(4)	1.79	1.43	2.52	15	11	26	9.9	7.3	14.6

[a] Source: Nagle et al. (1990)

[b] Means for TSS and turbidity at all six stations were based on the full complement of sampling events.

[c] Note that the N size for discharge is fewer than the 18 regular sampling events because at times no velocities were observed due to Savannah River flooding.

[d] During one storm_event, Savannah River flooding resulted in no observed velocities.

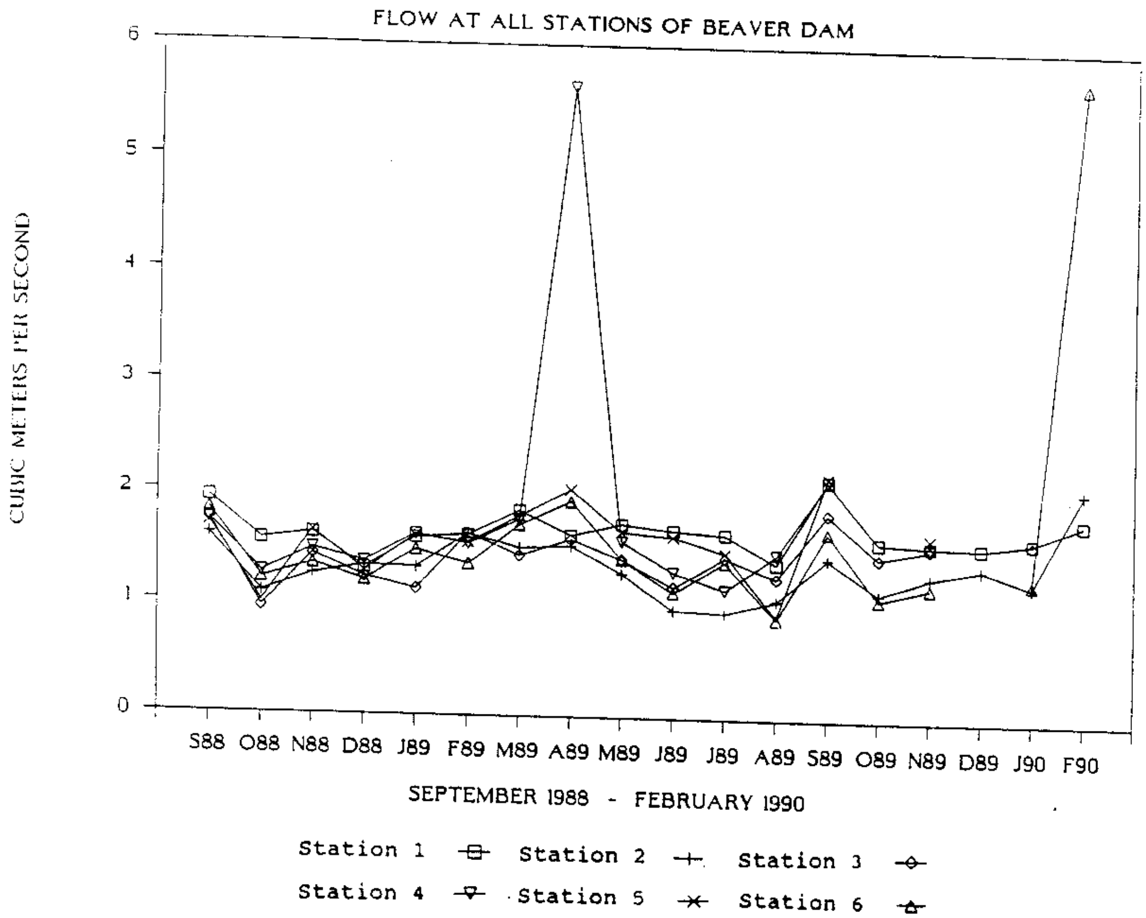

Figure 4.4-3. Discharge (m^3/s) at Beaver Dam Creek Sampling Stations. Discharge Values in October 1989 at Station 5 and 6, December 1989 at Stations 3-6, January 1990 at Stations 5 and 6, and February 1990 at Stations 3,5,6 Are Not Represented Because No Detectable Velocity Was Present. September 1988 - February 1990.

Source: Nagle et al. (1990)

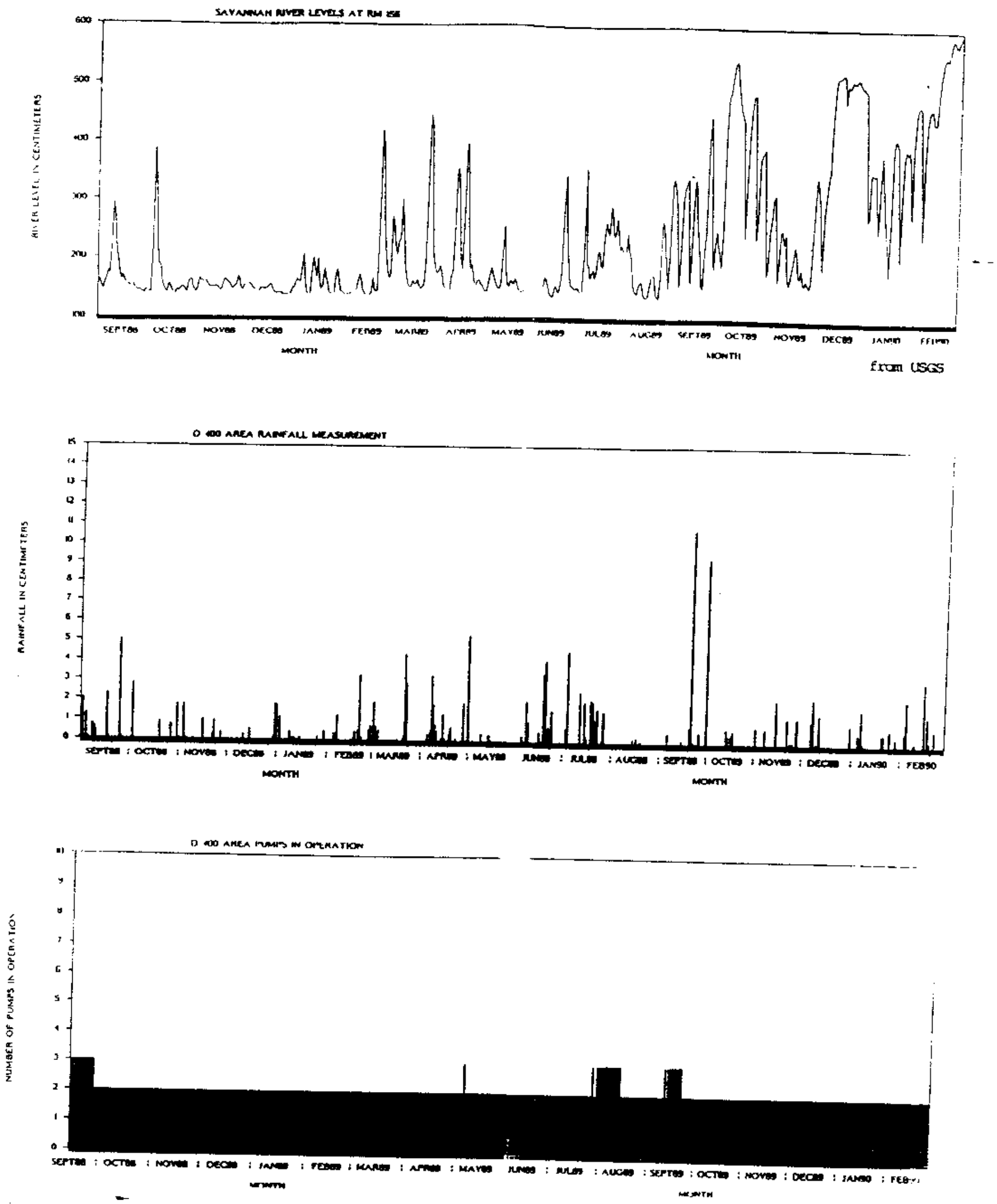

Figure 4.4-4. Bottom: Number of Pumps Operating at D Area; Middle: Rainfall Recorded at D-Area (cm); and Top: Savannah River Levels (cm) Near Jackson Landing, River Mile 156.8. Savannah River Levels Are Not Corrected to Sea Level. September 1988 - February 1990

early August 1989 (Figure 4.4-1) was not reflected in discharge measurements (Figure 4.4-4). This probably explained by the fact that monthly discharge measurements took place on 18 July 1989, before three pumps were used, and on 22 August 1989, after D Area had returned to two pumps again. No other consistent trends in flow are evident.

Examination of Savannah River levels (Figure 4.4-4) indicates that high water levels in October and December 1989, and January and February 1990 coincided with missing discharge values. This observation as well as field notes made by field personnel indicate that Savannah River flooding into Beaver Dam Creek during these months was responsible for unmeasurable discharge values.

4.4.2.3 Storm Event Sampling

Stream discharge, depth, velocity, total suspended solids (TSS) and tubidity were measured at each station immediately following periods of heavy precipitation (2.54 cm or more in a 24 hour period) in order to determine the normal range of these parameters in Beaver Dam Creek. Mean discharge, TSS, and turbidity for storm event data are found in Table 4.4-2. Creek depth, velocity, and discharge data for storm event sampling are presented in Nagle et al. (1990) Appendix Table 5.

Five storm events (rainfall greater than 2.54 cm in 24 hr) were sampled during the study. Storm event sampling took place on 4 October 1988 after 2.79 cm of rain was recorded at D Area on 3 October 1988, 21 June 1989 after 4.06 cm of rain was recorded at D Area on 20 June 1989, 5 July 1989 after 4.57 cm of rain was recorded at D Area on 4 July 1989, 22 September 1989 after 10.80 cm of rain was recorded at D Area on 21 September 1989, and 2 October 1989 after 9.35 cm of rain was recorded at D Area on 1 October 1989. Rainfall data were obtained the morning of the sampling event (C. E. Jumper, pers. comm.)

There were no consistent differences between discharge estimates during regular monthly sampling and storm event sampling (Table 4.4-2). Mean total suspended solid and turbidity values for storm events were consistently lower at all stations than the 18 month means. However, the ranges of storm event data for both parameters at all stations fell within the 18 month ranges (Table 4.4-2).

These data indicate that stream discharge, TSS, and turbidity at Stations 1 - 6 of Beaver Dam Creek were not perceptibly altered when sampled within 24 hr of the five designated storm events. With the exception of D Area, the watershed of Beaver Dam Creek is largely vegetated. As a result, runoff and soil erosion effects appeared to be minimal at Stations 1 - 6 within 24 hr of the designated storm events. Changes in stream water quality may peak during early stages of increasing stream discharge from a storm events (McDiffett, et al. 1989). Sampling design for storm events in Beaver Dam Creek precluded sampling of early stages of a storm event.

Therefore, the full effect of storm events on Beaver Dam Creek water quality may not be shown from these data.

4.4.2.4 Water Levels

Data from 25 August 1988 to 28 February 1990 from Beaver Dam Creek water level Recorders 1, 2, and 3 are presented in Figure 4.4-5. Levels from Recorder 1, located near Station 2 in the Beaver Dam Creek delta fluctuated least. Creek levels at this station generally ranged from approximately 90 to 105 cm. Exceptions to this occurred during early October 1989, when there was a brief increase to about 140 cm; during most of December 1989 within an increase to approximately 120 cm; and the last week of February 1990 with a level for 145 cm, the highest recorded at this site during the study.

Water levels at Recorder 2, located at the upstream end of the Beaver Dam slough upstream of Station 4 were more variable than at Recorder 1 (Figure 4.4-5). Creek levels at this location remained between approximately 65 and 105 cm for a majority of the study. The creek level dropped briefly to about 55 cm in the last week of August 1989. Creek levels at Recorder 2 were greater than 106 cm 11 times during the study. Water level increased for a few days in the third week of February 1989 (to about 121 cm), the end of March 1989 (to about 142 cm), the middle of April 1989 (to about 125 cm), and the third week of September 1989 (to about 140 cm; Figure 4.4-5).

Creek level increases lasting one week or longer were observed at Recorder 2 in early October 1989 (to about 215 cm; the highest level at this recorder); in the third week of October 1989 (to about 173 cm); in December 1989, when the longest sustained creek level increase (to about 186 cm) lasted nearly a month; in mid-January 1990 (to about 119 cm); in late January/early February 1990 (to about 152 cm); and at the end of February 1990 (to about 215 cm); again the highest level at this recorder; Figure 4.4-5.

Water levels at Recorder 3, upstream of Station 5, were too low to be recorded (less than 70 cm) for most of the time between 25 September 1988 and 25 September 1989 due to sediment in the stand-pipe. Sharp creek level increases during this time generally lasted a few days and coincided with those seen at Water Level Recorder 2, only greater in magnitude. Maximum levels reached at Recorder 3 were ca. 140 cm in early October 1988; ca. 161 cm in February 1980; ca. 180 cm in late March 1989; ca. 110 and 165 cm in April 1989; ca. 103 cm in late June and early July 1989; and ca. 169 cm in the third week of September 1989. After sediment was removed from the stand-pipe, the lowest creek level was recorded at this unit (ca. 44 cm) at the end of September 1989 (Figure 4.4-5).

The greatest fluctuations of any recorder occurred at Recorder 3 from October 1989 to the end of the study in February 1990. Recorder malfunction resulted in the loss data for some of this time (23 October to 21 November 1989). Again, these water level changes coincided with those recorded at Water Level Recorder 2, but were greater in magnitude. The water level increased by about 135 cm (from

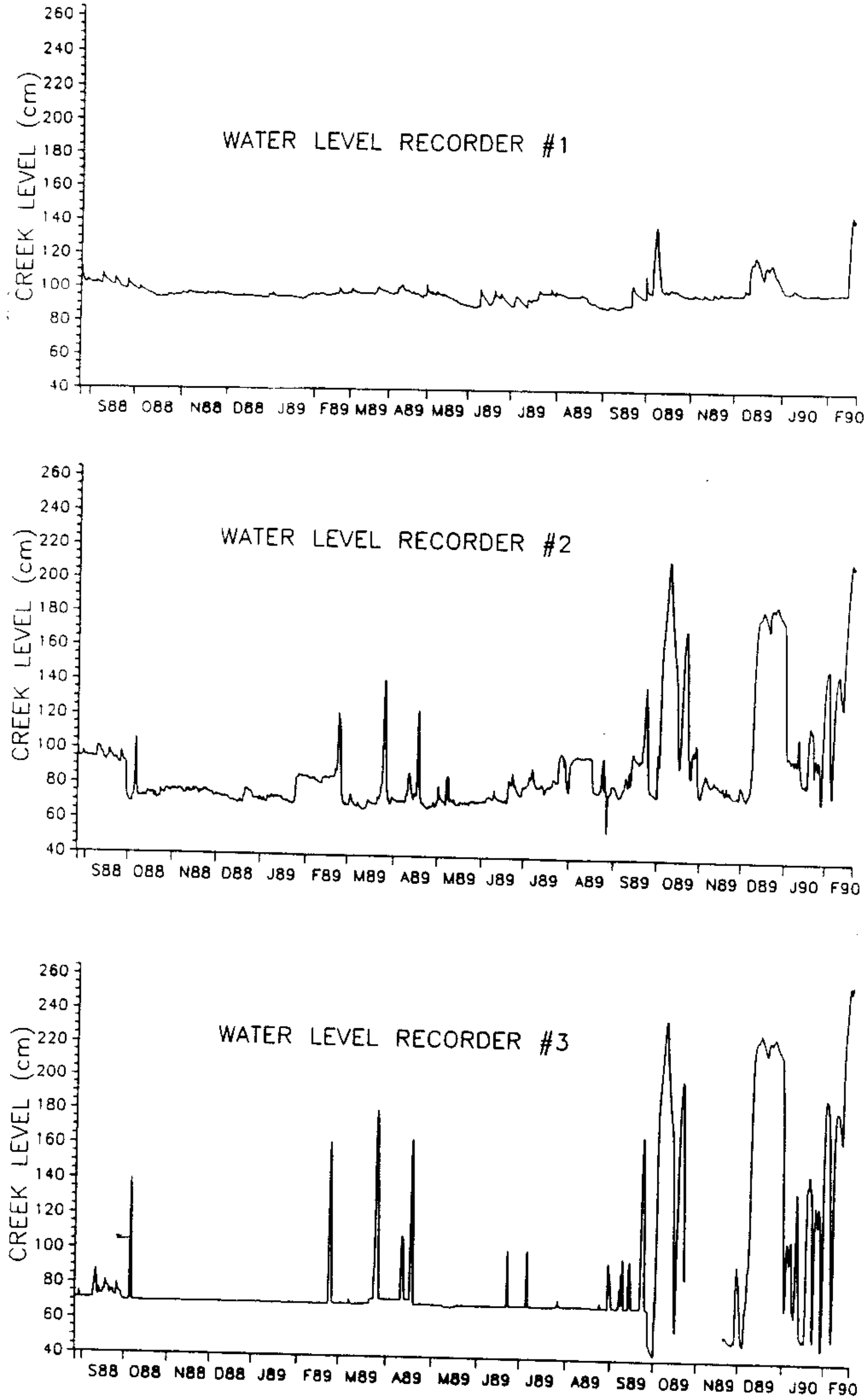

Figure 4.4-5. Water levels (cm) at Water Level Recorders 1, 2, and 3 in Beaver Dam Creek. 25 August 1988 - 28 February 1990.

about 80 cm to 215 cm) at Recorder 2 in early October 1989. During that same period the level at Recorder 3 changed by 190 cm (from about 45 cm to 235 cm). Similar differences in magnitude occurred in December 1989 (a change of about 115 cm at Recorder 2 and 180 cm at Recorder 3) and January/February 1990 (a change of about 135 cm at Recorder 2 and 210 cm at Recorder 3; Figure 4.4-5).

A likely explanation for the differences between Recorder 1 in the delta (little change in water level) and Recorders 2 and 3 (greater water level changes) is that water in the delta simply cannot rise to levels found in high-banked channel areas, because it spreads out over the delta.

Three of the factors that can influence water levels in Beaver Dam Creek are D-Area pump operation, rainfall at D Area, and Savannah River level. These factors were examined for the 18 months of the study to assess their effect on Beaver Dam Creek water levels (Figure 4.4-1). It is difficult to determine the degree of influence of each variable on creek levels separately, as their combined effect may be compounded. However, when these data are compared to the water level data it is apparent that these variables exerted some effect on creek level from September 1988 to February 1990.

For most of the study, two pumps operated at D Area, pumping water into Beaver Dam Creek via an effluent canal from the D-001 outfall. Three pumps were used in September 1988, briefly at the beginning of May 1989, briefly in late July/early August 1989, in August 1989, and in September 1989 (Figure 4.4-4). Water Level Recorder 1, closest to D Area, indicated slight elevation in creek level during these times (Figures 4.4-4 and 4.4-5).

Water Level Recorder 2 also indicated higher relative creek levels during these times; whereas slight creek increases at Water Level Recorder 3 corresponded to increased pumping only in September 1988.

Because rainfall greater than 1 cm at D Area generally coincided with increased river levels, it is difficult to separate the effects of rainfall from river level on the creek level. In general, when rainfall levels and Savannah River levels showed an increase, that increase was reflected in Beaver Dam Creek levels (Figures 4.4-4; 4.4-5). Although this effect was not apparent in the delta (Recorder 1) for most of the first year, levels at Recorder 2 and, to a greater extent, Recorder 3, did rise when rainfall and river levels increased. Beginning in October 1989, large increases in Savannah River levels were not accompanied by significant rainfall accumulations at D Area (Figure 4.4-4). Changes in river level from October 1989 to the end of the study affected the water level at all three Beaver Dam Creek stations. Only the large river level increases in October and December 1989 and February 1990 are obvious at Recorder 1. The pattern of creek level changes at Recorders 2 and 3 more closely mimics the changes in Savannah River level (Figure 4.4-5).

These comparisons suggest that area rainfall accumulations and changing Savannah River levels influenced Beaver Dam Creek water levels more than

D-Area pumphouse operations. They also suggest that from October 1989 to February 1990, increased Savannah River levels exerted the greatest influence on Beaver Dam Creek levels.

4.5 Ecology

4.5.1 Wetland Vegetation

Beaver Dam Creek is one of six streams that drain SRS and flow into the Savannah River. The other five include Upper Three Runs Creek, Four Mile Creek, Pen Branch, Steel Creek, and Lower Three Runs Creek. Upper Three Runs Creek is the largest and the only stream on the SRS which has not received thermal effluents. Beaver Dam Creek has received effluents from the D-Area heavy water facility and coal-fired power plant. These discharges have influenced the wetland vegetation patterns found along Beaver Dam Creek.

4.5.1.1 SRS Savannah River Swamp

The four streams that have received the greatest input of thermal effluents (Beaver Dam Creek, Four Mile Creek, Pen Branch, and Steel Creek) flow into a contiguous 3,020-hectare portion of the Savannah River swamp. The swamp is separated from the main flow of the Savannah River by a 3-meter-high, natural levee along the Savannah River (Smith et al., 1981). The levee and several small islands within the swamp support mesic, hardwood forest, communities (Whipple et al., 1981). The geomorphology of the SRS Savannah River swamp is described in detail by Stevenson (1982). In addition to thermal effluents, sediments have been deposited in the swamp as a result of upstream erosion and transport by these effluents. The swamp reduces water velocities, allowing most of the suspended sediments in the streams to settle (Sharitz et al., 1974; Ruby et al., 1981).

During most of the year, the cooling water from Beaver Dam Creek enters the Savannah River through a breach in the levee at the mouth of Beaver Dam Creek. During non-flooded conditions, the cooling water disperses from the delta area of Beaver Dam Creek and flows through side channels into former oxbow lakes and channels of the Savannah River within the SRS Savannah River swamp (Stevenson, 1982; Shines and Tinney, 1983, 1984; Negri et al., 1985; Negri and Shines, 1986, 1988; Christensen et al., 1987; Negri, 1987). The flow of water through the swamp is substantially altered during river flooding (Shines and Tinney, 1983). Flow from the Savannah River enters the swamp when river water level exceeds about 26 meters above mean sea level. Most river flooding of the swamp occurs between January and April (Figure 4.5.1-1, Aho et al., 1986). Flooding can increase the water depth 3 to 4 meters in the swamp (Repaske, 1981). Increases in water level changes of 1 to 2 meters were observed at the Beaver Dam Creek water level stations during river floods in 1989 and 1990 (Nagle et al., 1990).

When the river floods the swamp, the thermal flows are more constrained towards the upland terrace forming the northeast border of the swamp. Many

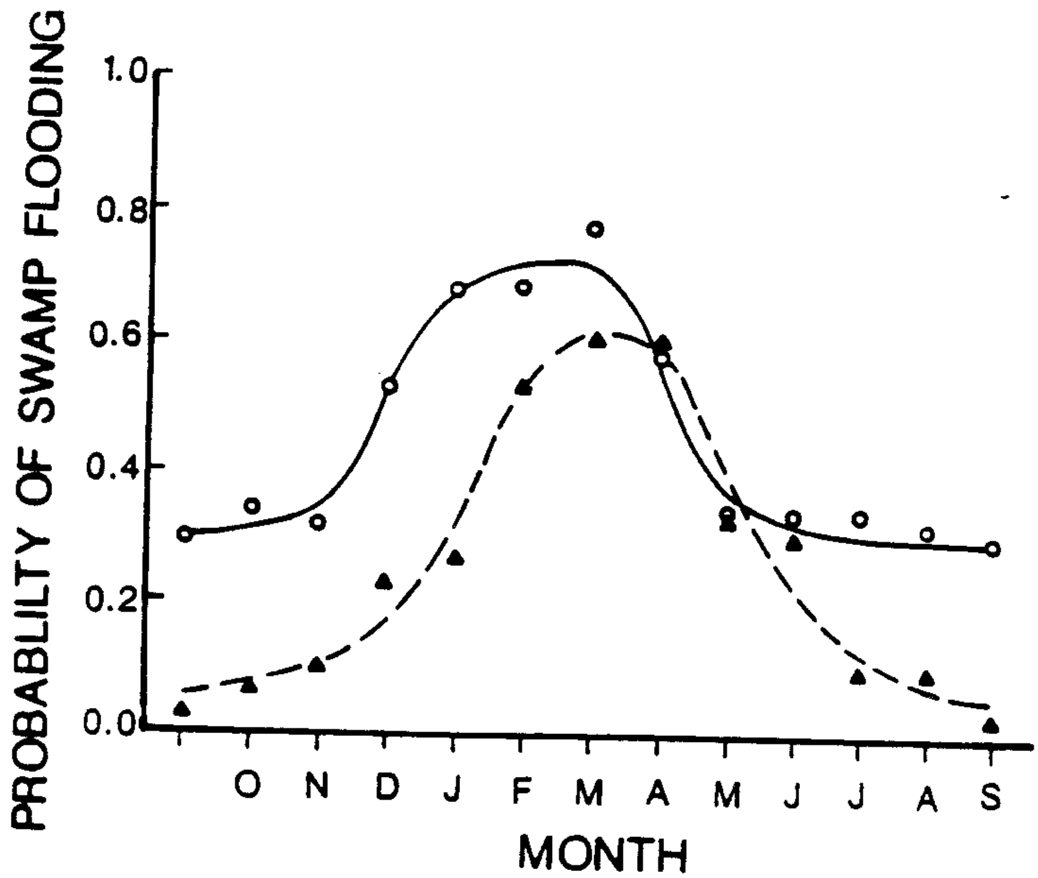

Figure 4.5.1-1. Monthly Probabilities of the Savannah River Flooding.

Flood frequencies prior to the completion of the Clarks Hill Dam in 1954 are shown in open circles and as a solid line. Flood frequencies after 1954 are shown as triangles and a dashed line. (Aho et al., 1986) of the recent wetlands changes in the swamp appear to have occurred in this region (Tinney et al., 1986; Jensen et al., 1987).

Large portions of the Savannah River swamp forest were lumbered in the late 1800s, and second-growth forest has regenerated (Sharitz et al., 1974). Prior to the establishment of the SRS, the swamp forest was characterized by a closed canopy. Shortly after power house and reactor operations were initiated, forested wetland canopy losses resulted from the combined effects of thermal effluents, increased flows, and sedimentation (Sharitz et al., 1974; Repaske, 1981). These effects were most pronounced in the stream floodplains, the resulting swamp deltas, and immediately surrounding channels in the swamp (Tinney et al., 1986).

In the delta regions, emergent marsh and scrub-shrub species are now prevalent. Dominant emergent marsh species include cattail (Typha latifolia), knotweed (Scirpus cyperinus), and smartweed (Polygonum spp.). The scrub-shrub communities are most often dominated by willow (Salix spp.) and buttonbush (Cephalanthus occidentalis).

The remaining swamp area is comprised of species present prior to reactor operations. Bald cypress (Taxodium distichum) and tupelo gum (Nyssa aquatica) occur along the stream channels and in low areas subjected to prolonged inundation. Red maple (Acer rubrum), water ash (Fraxinus caroliniana), water elm (Planera aquatica), and other bottomland hardwoods dominate the better drained sites. Occasional upland ridges, the remnants of previous levees left as the river channel shifted, support a mesic hardwood forest which includes water oak (Quercus nigra), willow oak (Q. phellos), and sweet gum (Liquidambar styraciflua) (Sharitz et al., 1974; Jensen et al., 1984, 1986; Christensen et al., 1988).

4.5.1.2 Historical Trends in Vegetational Patterns in the SRS Savannah River Swamp

There is evidence indicting that the Savannah River swamp continues to change in response to over 35 years of SRS operations. The reduction in tree canopy along the Savannah River swamp thermal gradient has previously been studied photogrammetrically by Sharitz et al., 1974; Repaske, 1981; Christensen et al., 1984a and 1984b; and Tinney et al., 1986. In the study by Sharitz et al., (1974), two dates of photography were examined and four categories of reactor effluent impact were defined on the basis of the percentage of tree kill. Results vary from these early surveys with Sharitz et al., 1974, reporting 194 ha of total tree kill in the swamp from thermal effects with another 115 ha having moderate effects. Repaske (1981) reported 240 ha of tree kill in the Four Mile Creek, Pen Branch, and Steel Creek deltas. Tinney et al., 1986, reported from 1985 aerial photography that 366 ha had total tree kill or canopy loss in the SRS swamp with another 418 ha showing some canopy effects. Both photographic (Tinney, 1986) and multispectral aircraft scanner surveys (Christensen et al., 1984a, 1984b) have shown trends toward revegetation of portions of the Steel Creek and Beaver Dam Creek deltas and adjacent SRS Savannah River swamp with the lowering of thermal effects, both flow and temperature (Jensen et al., 1986; Mackey, 1987; Christensen et al., 1988). For example, with the shutdown of C Reactor, rapid revegetation of the Four Mile Creek swamp delta has been observed since June 1985.

4.5.1.3 Historical Vegetation Trends in the Beaver Dam Creek Area

In 1952, the D-Area facilities began releasing thermal effluents into Beaver Dam Creek. These facilities included the heavy water facility and the coal-fired power plant. Initial flows were as high as 3.5 cubic meters per second (Table 4.5.1-1). Since 1982, the thermal releases have been from the power plant, since the heavy water facility has been shut down. Monthly USGS flow data at the 400-D, SRS Environmental Protection Monitoring Station are given in Table 4.5.1-2 for 1982 through early 1990.

The thermal effluents to Beaver Dam Creek generally have been lower in both discharge volume and temperature than effluents from the SRS reactors (Mackey, 1986). As a result, there probably has been less stream erosion and deposition of sediments in the swamp when compared to the streams that have received reactor effluents. Tables 4.5.1-3 and 4.5.1-4 summarize monthly temperature data for Beaver Dam Creek at the SRS Health Protection Monitoring Station (400-D) and at the USGS station at the mouth of Beaver Dam Creek. Temperature data from the mouth of Beaver Dam Creek (prior to June 1985) would also include a contribution from C-Reactor operations because of flow from Four Mile Creek to Beaver Dam Creek. Figures 4.5.1-2 and 4.5.1-3 also summarize the annual temperatures and flow of Beaver Dam Creek monitoring stations. In general, there has been a decline in temperature of Beaver Dam Creek since 1972. In addition to thermal discharge, the Beaver Dam Creek swamp area has received some effluents from the power plant's ash basin. Fly ash deposition appears to have affected at least 8 to 10 hectares of the swamp adjacent to the stream delta (Evans and Giesy, Jr., 1978; Mackey, 1987).

Aerial photographs of the Beaver Dam Creak area have been periodically acquired since 1951. These images provide a history of overall effects of thermal releases from the D-Area facilities on the SRS portion of the Savannah River swamp. These photographs have been evaluated through 1985 by Tinney et al. (1986) using the following criteria:

- No visible damage
- Partial Canopy Loss (5 to 95 percent canopy loss)
- Total Canopy Loss (95 to 100 percent canopy loss)

The results of a previous historical study of the aerial photography of the Beaver Dam Creek Delta are presented in Tinney et al., (1986) and Mackey (1987). These data are summarized in Table 4.5.1-5 and Figure 4.5.1-4 and updated using the above criteria and standard photographic interpretation techniques (Tinney et al., 1986) for 1989 using natural color aerial photography for 2 May 1989.

Table 4.5.1-1. Average Annual Beaver Dam Creek Flow and Temperature Data

Year	Discharge (m^3/s)[a]	SRS D-001 Monitoring Station Temperature (°C)[b]	Mouth Temperature (°C)[c]
1952	—	—	—
1953	—	—	—
1954	—	—	—
1955	—	—	—
1956	3.4	—	—
1957	3.5	—	—
1958	3.1	—	19.6
1959	3.0	—	27.6
1960	2.6	—	26.5
1961	2.5	—	—
1962	2.5	—	29.1
1963	2.1	—	29.1
1964	2.5	—	29.1
1965	—	—	29.4
1966	—	—	29.1
1967	—	—	29.1
1968	—	—	—
1969	—	—	—
1970	—	—	—
1971	—	39.0	—
1972	—	38.1	—
1973	—	38.5	24.7
1974	—	36.5	24.0
1975	2.6	33.8	21.4
1976	2.2	32.4	21.2
1977	2.2	28.3	21.9
1978	2.1	27.4	22.3
1979	2.2	27.7	19.8
1980	2.3	27.0	20.9
1981	3.2	26.8	24.1
1982	2.5	26.8	24.0
1983	2.5	27.3	21.4
1984	2.6	26.1	21.8
1985	2.5	26.2	24.2
1986	2.5	—	23.6
1987	2.5	—	21.1
1988	2.0	24.1	23.7
1989	1.8	21.6	21.0

[a] For the years 1956 through 1964, the data are for the pumphouse which supplies river water to D Area. For the years 1975 through 1989, the data are flow measurements made at the Health Protection Monitoring Station on Beaver Dam Creek before the flow discharges into the Savannah River swamp on the SRS. Data for other years were not available.

[b] For the years 1971 through 1989, the temperature data are annual average data acquired at the Environmental Protection Monitoring Station on Beaver Dam Creek before the flow enters the Savannah River swamp on the SRS. Data for other years were not available.

[c] USGS Monitoring Data for mouth of Beaver Dam Creek

Table 4.5.1-2. Monthly Average Flow Data for Beaver Dam Creek (m^3/s) at the 400-D SRS D-001 Monitoring Station

Year	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1982	2.0	2.6	2.8	2.8	2.6	2.6	2.6	2.6	2.6	2.4	2.3	2.8
1983	2.7	2.8	2.8	2.8	2.6	2.4	1.9	2.2	2.4	2.3	2.5	2.5
1984	2.6	2.4	2.3	2.3	2.3	2.6	2.8	2.8	2.7	2.3	2.2	2.3
1985	2.4	2.6	2.4	2.4	2.3	2.6	2.4	2.4	2.6	2.5	2.8	2.5
1986	2.5	2.5	2.4	2.3	2.3	2.5	2.8	2.6	2.6	2.8	2.3	2.3
1987	2.5	2.5	2.4	2.3	2.3	2.6	2.8	2.5	2.6	2.5	2.3	2.1
1988	2.1	2.0	2.0	1.9	1.8	1.6	2.3	2.4	2.2	1.7	1.8	1.8
1989	1.8	1.8	1.8	1.9	1.8	1.8	1.9	2.2	2.0	1.5	1.7	2.0
1990	1.7	1.7	1.8	1.7	1.6							

Table 4.5.1-3. Monthly Temperature Data (°C) for Beaver Dam Creek at the SRS D-001 Monitoring Station*

Year	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1971	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	41.2	36.8
1972	38.6	NA	NA	NA	NA	40.8	34.5	38.5	NA	NA	NA	NA
1973	NA	NA	NA	NA	NA	NA	38.5	41.0	38.5	36.0	40.0	37.0
1974	NA	39.0	35.0	37.0	39.0	38.0	40.0	37.0	36.0	35.0	33.0	33.0
1975	29.0	32.0	29.0	33.0	33.0	36.0	36.0	NA	37.0	37.0	35.0	35.5
1976	29.0	NA	29.0	35.0	31.0	32.0	34.5	35.5	38.0	36.0	27.0	29.0
1977	10.0	30.0	24.0	29.0	30.0	33.0	33.0	31.0	34.0	32.0	28.0	26.0
1978	3.5	25.0	25.6	25.5	25.2	25.0	NA	43.0	34.0	20.0	32.0	19.0
1979	24.5	27.0	25.0	26.0	25.0	29.0	30.0	30.0	30.0	31.0	NA	27.0
1980	NA	26.0	25.0	24.0	28.0	27.0	30.0	36.0	NA	28.0	24.0	22.0
1981	23.0	16.0	NA	NA	27.0	33.0	NA	NA	33.0	29.0	NA	NA
1982	14.0	18.0	22.0	27.0	34.0	33.0	33.0	32.0	32.0	28.0	25.0	23.0
1983	21.0	21.0	22.0	NA	27.0	28.0	33.0	33.0	34.0	31.0	27.0	23.0
1984												
1985												
1986												
1987										22.0	23.5	21.5
1988	19.5	19.0	21.5	26.0	29.0	31.0	30.0	29.0	26.5	23.0	19.5	15.0
1989	14.5	15.0	17.0	21.0	24.5	28.5	29.0	27.5	26.5	23.5	19.4	13.0
1990	13.3	15.1	16.4	20.3	24.7							

*Data obtained from the SRS Health Protection Station on Beaver Dam Creek
Note: NA—Not Available

Table 4.5.1-4. **Monthly Average Temperature Data (°C) for the Mouth of Beaver Dam Creek ***

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1958	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	19.6	NA
1959	20.0	22.8	24.7	27.5	30.6	32.8	33.4	31.7	30.6	30.3	24.7	22.2
1960	20.0	22.8	27.2	27.5	30.6	32.8	33.6	32.8	30.8	29.4	25.0	23.1
1961	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1962	20.6	22.8	27.2	30.0	33.3	33.3	33.6	32.8	32.8	29.4	29.4	23.6
1963	20.6	22.8	27.2	30.0	33.3	33.6	33.6	32.8	32.8	29.4	29.4	23.6
1964	20.6	22.8	27.2	30.0	33.3	33.6	33.6	32.8	32.8	29.4	29.4	23.6
1965	20.6	25.6	27.2	30.0	33.3	33.6	33.6	32.8	32.8	30.0	29.4	23.6
1966	20.6	22.8	27.2	30.0	33.3	33.6	33.6	32.8	32.8	29.4	29.4	23.6
1967	20.6	22.8	27.2	30.0	33.3	33.6	33.6	32.8	32.8	29.4	29.4	23.6
1968	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1969	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1970	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1971	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1972	NA	NA	NA	NA	NA	NA	31.7	37.0	33.0	NA	NA	NA
1973	NA	NA	NA	NA	NA	NA	NA	NA	NA	28.5	25.8	19.9
1974	14.0	12.8	18.1	21.5	29.2	29.6	32.5	30.6	33.5	26.7	19.7	19.6
1975	15.1	11.5	11.8	15.6	23.5	29.1	29.2	30.4	28.9	25.4	19.6	16.1
1976	14.1	17.6	16.4	21.7	24.2	24.3	25.8	30.7	29.2	23.0	17.2	10.0
1977	9.1	17.5	16.6	15.5	27.7	29.4	29.7	28.9	28.8	23.2	19.6	16.3
1978	10.7	8.0	17.7	21.8	26.1	27.1	30.5	30.0	28.9	NA	NA	NA
1979	NA	NA	NA	NA	NA	NA	NA	NA	NA	24.2	19.5	15.7
1980	13.4	14.1	15.3	14.9	20.3	22.9	31.2	29.9	29.3	22.5	18.8	17.8
1981	16.6	17.0	20.1	24.7	25.9	29.5	30.4	27.8	34.6	24.0	20.5	17.7
1982	14.1	14.5	20.2	23.2	25.5	29.7	30.4	30.4	27.9	23.9	20.5	17.6
1983	12.6	10.4	12.3	14.3	25.6	25.5	30.6	32.1	28.9	25.6	21.0	18.0
1984	12.5	12.0	13.0	19.0	21.0	30.5	31.0	26.0	29.0	25.5	20.5	21.0
1985	18.0	14.5	22.0	25.0	27.5	29.0	29.5	29.5	25.5	27.5	24.0	19.0
1986	15.0	15.5	20.0	25.5	28.5	30.5	29.0	28.5	28.5	23.5	22.0	17.0
1987	12.0	12.5	15.5	18.0	23.0	27.5	27.5	27.0	25.0	22.5	22.0	21.0
1988	20.0	18.0	22.0	26.0	27.5	30.0	29.0	28.5	26.0	23.0	19.5	15.0
1989	14.5	15.0	17.0	21.0	24.5	28.5	29.0	27.5	26.0	20.5	18.6	10.1
1990	11.3	11.6	13.8	19.4	22.0							

*USGS Monitoring Data

NA - Not Available

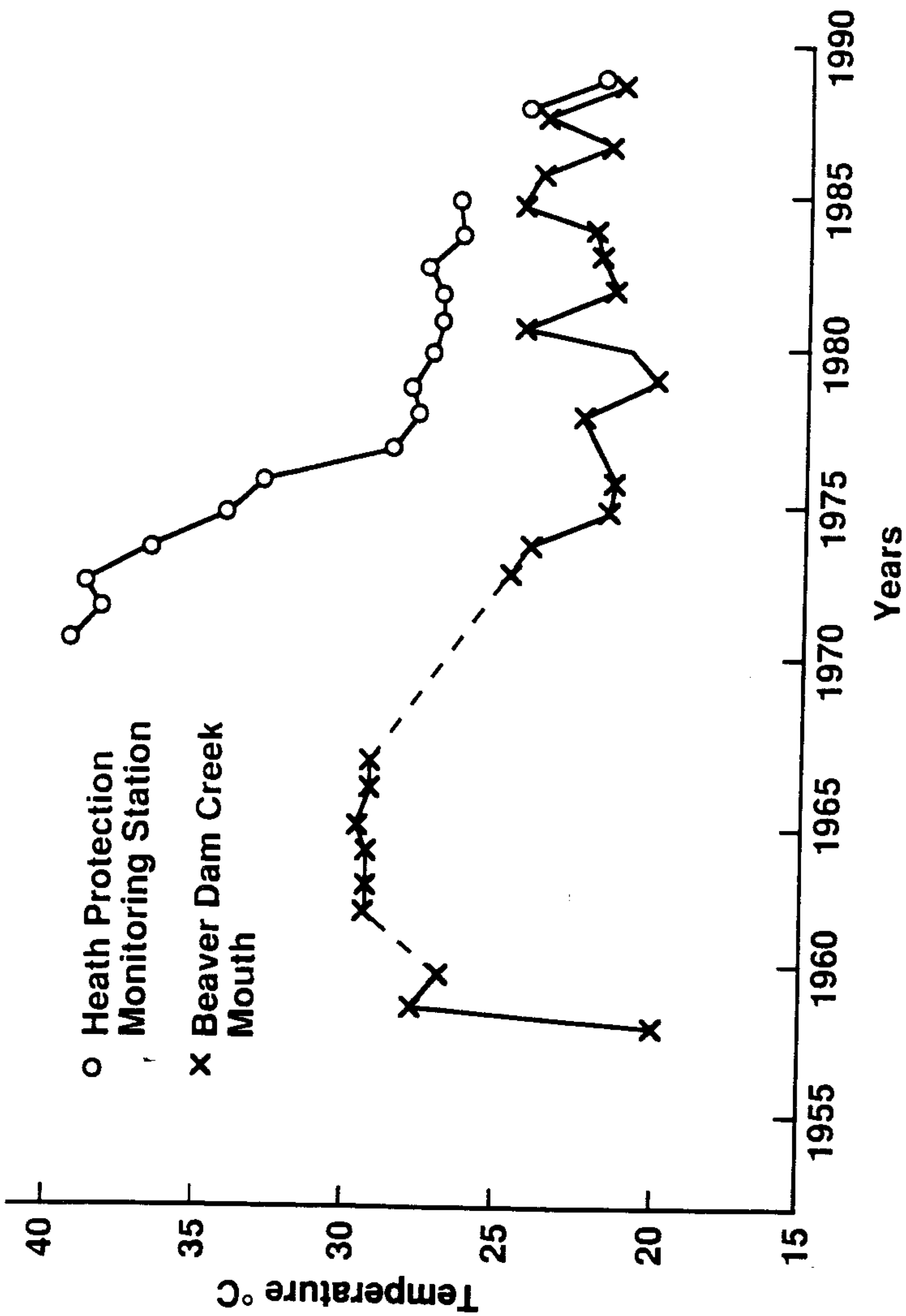

Figure 4.5.1-2. Average Annual Temperature for Beaver Dam Creek, 1958-1989

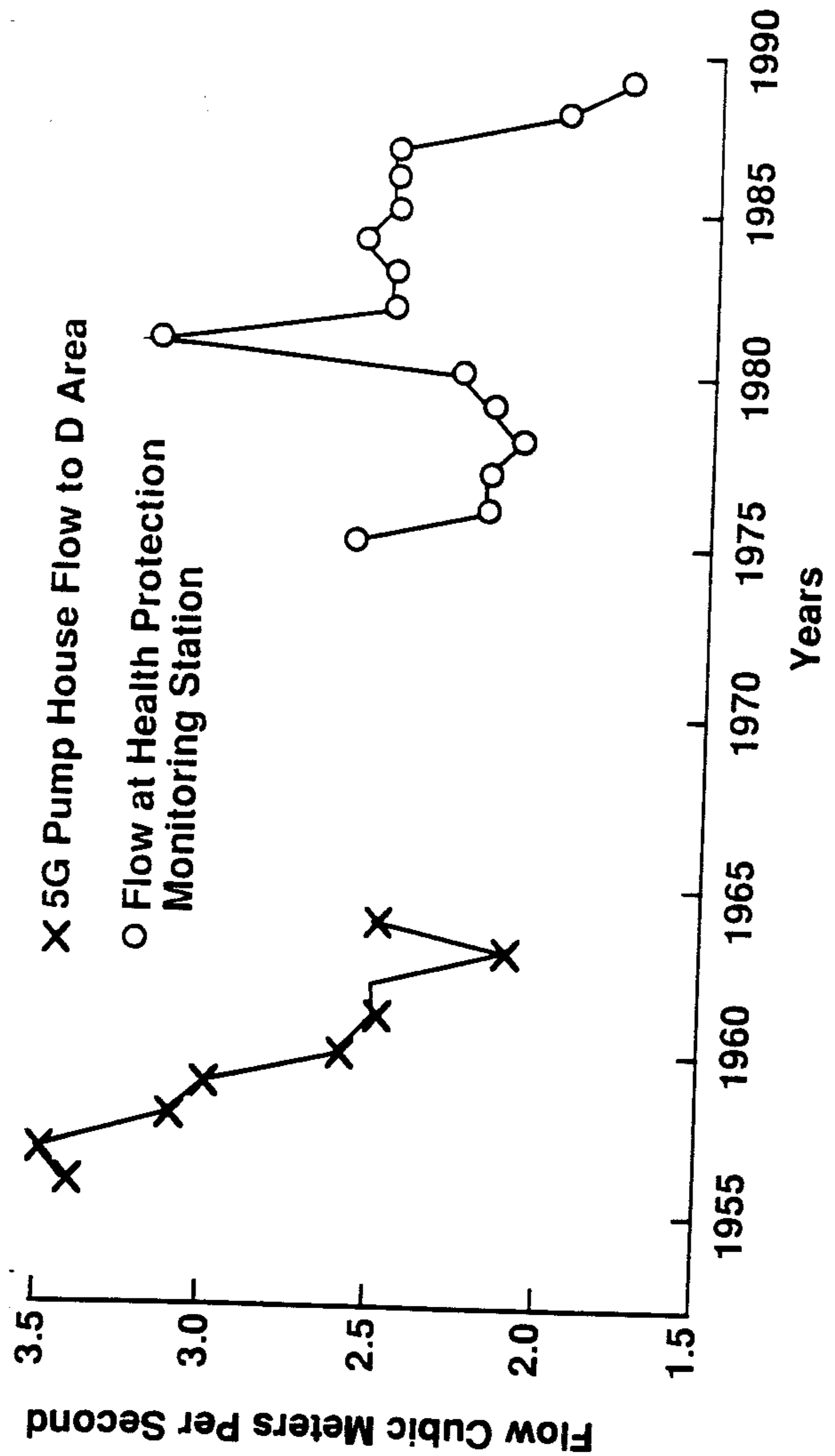

Figure 4.5.1-3. Average Annual Flow for Beaver Dam Creek, 1956-1989

Table 4.5.1-5. Area in Each Impact Category for Beaver Dam Creek[a]

Year	Partial Canopy Loss Zone[b]	Total Canopy Loss Zone[c]	Total Affected Area	Average Delta Expansion Rate (Hectares/Year)
1956	19.1	—	19.1	—
1961	40.4	13.6	54.0	7.0
1966	76.9	26.8	103.7	9.9
1974	77.1	89.9	167.0	7.9
1978	67.3	97.5	164.8	-0.6
1982	76.1	80.9	157.0	-2.0
1984	84.0	80.1	164.1	3.6
1985[d]	85.4	74.5	159.9	-4.2
1989	74.3	28.7	103.0	-14.2

[a] Units are in hectares.
[b] 5 to 95 percent canopy loss.
[c] 95 to 100 percent canopy loss.
[d] Data for 1956 through 1985 are from Tinney et al., 1986.

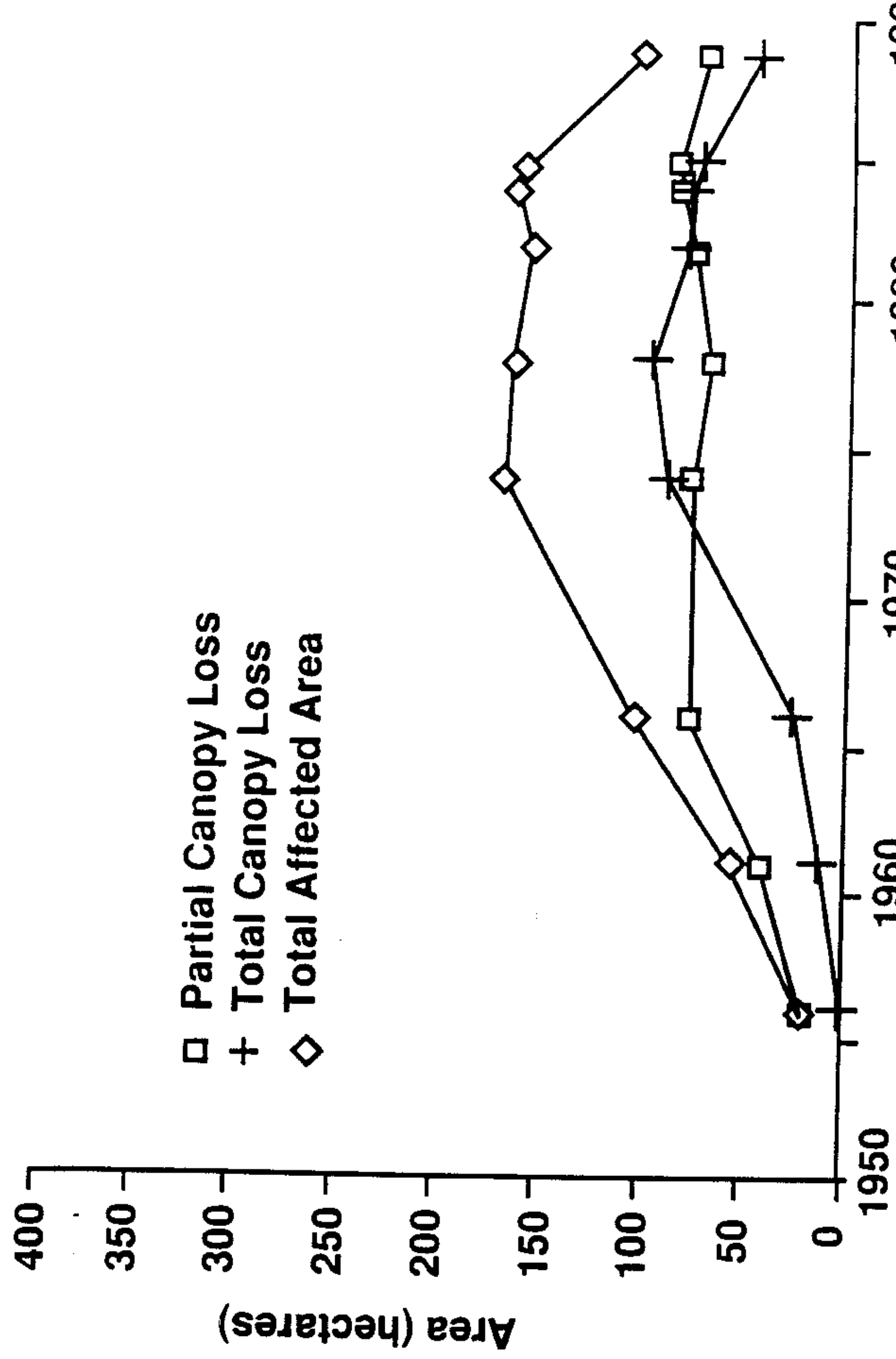

Figure 4.5.1-4. Beaver Dam Creek Delta Wetlands Impact Areas

In 1956, the impacted area in the swamp covered 19.1 hectares. During the next 10 years, the total area affected expanded to 103.6 hectares, an average increase of 7.0 hectares per year between 1956 and 1961, and 9.9 hectares per year between 1961 and 1966. A large area of bottomland hardwoods located in the swamp between the Savannah River and the Beaver Dam Creek delta was timbered during late 1966. Between 1974 and 1982 the total area affected appeared to stabilize. It was noted that there was a concurrent decrease in effluent temperature, which began to decrease in 1973 and continued to decline until 1978 (Figure 4.5.1-2). Effluent discharge temperatures remained relatively stable after 1978, although discharge flow rates increased slightly during the period 1981 to 1982 (Figure 4.5.1-3). In 1984 the total area affected was 164.1 hectares. This was an increase of 7.1 hectares over 1982 conditions. Almost all the apparent expansion was in the partial canopy loss category. In 1985, revegetation was once again noted in the delta region. The total area affected was 159.9 hectares, with revegetation of 4.2 hectares from 1984 conditions. The revegetation changes were from both total to partial canopy loss (5.6 hectares) and from partial canopy loss to swamp forest (4.2 hectares). In 1989, the total area affected was estimated at 103 hectares (Table 4.5.1-5). Between 1985 to 1989 extensive revegetation of the Beaver Dam Creek delta area has occurred. This revegetation has occurred primarily in areas of former ash basin effects north of where Beaver Dam Creek enters the SRS Savannah River swamp and south toward the Four Mile Creek delta area. Revegetation is occurring as scrub-shrub and persistent marsh communities are converted primarily through natural succession to young bottomland hardwood forests (Christensen et al., 1988).

4.5.1.4 Comparison of Beaver Dam Creek to Other SRS Swamp Streams

Summary graphs of the total areas affected on the delta areas in the SRS Savannah River swamp are presented in Figure 4.5.1-5. Beaver Dam Creek has had lower flow compared to the streams receiving reactor effluents. As a result of the lower flow, there probably was less stream erosion and delta deposition. Historically, the discharge temperatures have been less than those of the reactor effluents. An annual average discharge temperature of 39°C was recorded in 1972, which is similar to the 40°C to 45°C levels common in the other deltas. However, since the early 1970's temperatures in Beaver Dam Creek have declined substantially (Figure 4.5.1-2) The geomorphology of the Beaver Dam Creek delta area has permitted flooding of former oxbow and side channels from Beaver Dam Creek, resulting in a relatively large impact area compared to the temperature and flow (Tinney et al., 1986). This situation is somewhat similar to the influence of Four Mile Creek on the swamp area between the Four Mile Creek and Pen Branch deltas (Tinney et al., 1986; Mackey, 1987). Revegetation of the Beaver Dam Creek delta areas with hardwood bottomland forests and scrub-shrub vegetation appears to be following trends observed in the Steel Creek and Four Mile Creek deltas once flows and temperatures decline (Smith et al., 1981; Tinney et al., 1986; Mackey, 1987). In deeper water areas near the Beaver Dam Creek, tupelo and cypress may be able to re-establish themselves if flows remain reduced.

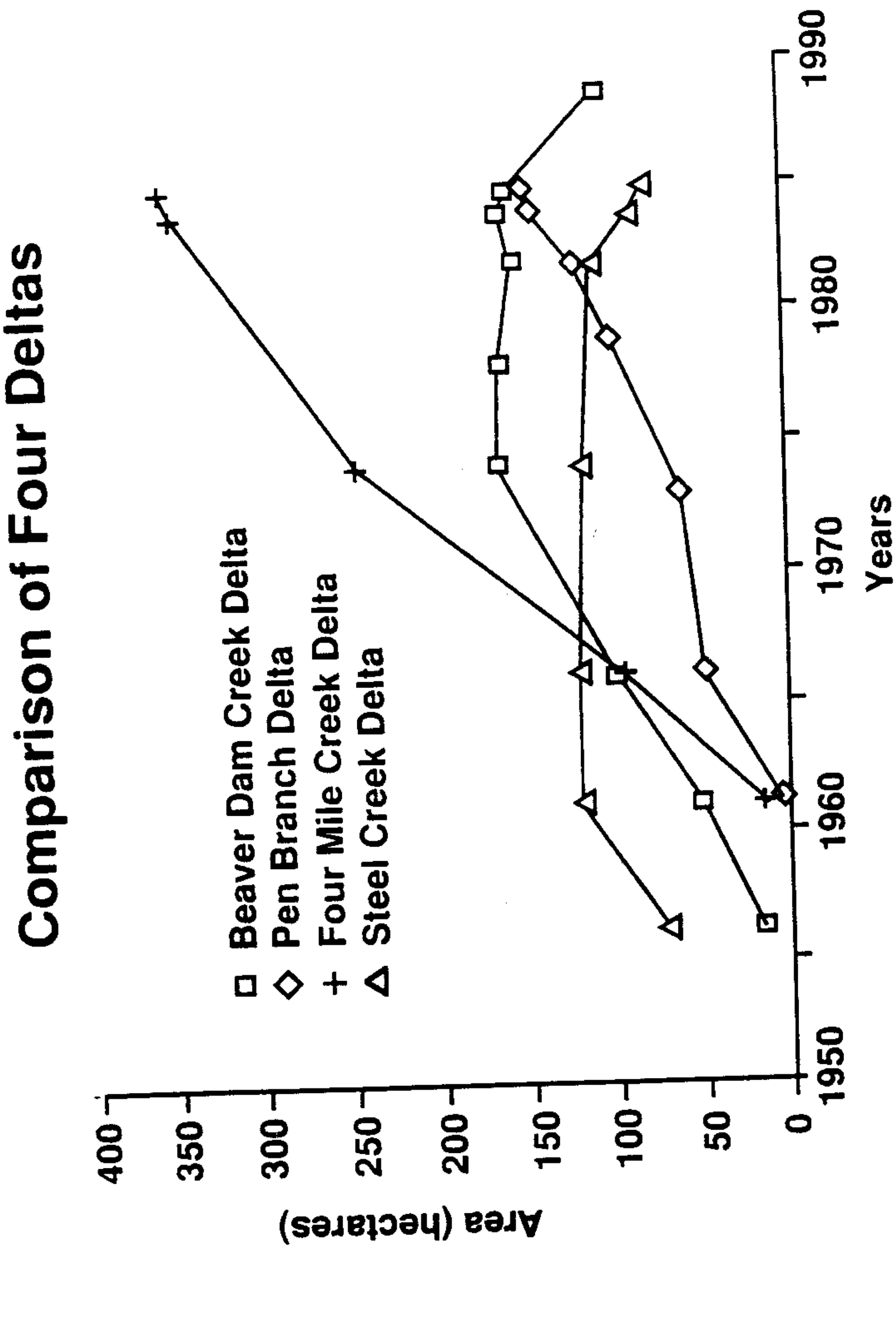

Figure 4.5.1-5. Summary of SRS Delta Wetlands Impact Areas

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4.5.2 Zooplankton

This section summarizes the results of zooplankton studies conducted on Beaver Dam Creek from September 1988 through February 1990 and compares these data with similar data collected in Beaver Dam Creek during 1984-1985. Sampling protocols and data analysis techniques, along with a more detailed discussion of the study can be found in Nagle et al. (1990).

4.5.2.1 Species Diversity

Mean zooplankton species diversity indices (expressed as taxa diversity) for all Beaver Dam Creek stations are presented in Figure 4.5.2-1. Mean monthly species diversity ranged from 0.0 to 2.00. Species diversity at Station 1A ranged from 0.6 to 0.7. This station was only sampled from December 1989 to February 1990 due to an absence of water for most sampling dates. Diversity varied widely from month to month at the other Beaver Dam Creek stations and tended to be lowest at all stations from November through January and highest in May through August. The diversity values showed no consistent upstream-downstream trends.

4.5.2.2 Taxa Richness

A total of 102 zooplankton taxa were identified (Table 4.5.2-1). Microzooplankton (Protozoa and Rotifera) accounted for 78.4% (80 taxa) of the total number of taxa observed. Protozoa was represented by 34 taxa, Rotifera by 46 taxa, Cladocera by 11 taxa, Copepoda (Cyclopoida/Calanoida and Harpacticoida) by 10 taxa, and Ostracoda by one taxon (Table 4.5.2-1). The overall taxa richness for each station ranged from a low of 12 at Station 1A (sampled only during the last three months of the study) to a high of 54 at Station 3 (Table 4.5.2-2). Protozoans accounted for 33.0 to 51.3% of all taxa observed at each station. Rotifers accounted for 25.0 to 38.2%, and macrozooplankton (Copepoda, Cladocera, and Ostracoda comprised 15.4 to 41.7% of the taxa (Table 4.5.2.-2). Monthly taxa richness values ranged from 0 to 18 (Figure 4.5.2-2). Taxa richness tended to be highest in summer and lowest in winter at all stations. No spatial trends in taxa richness were observed among stations (Figure 4.5.2-2).

4.5.2.3 Density

Monthly mean zooplankton density ranged from 0 to 117 organisms/L between September 1988 and February 1990 (Figure 4.5.2-3). The mean zooplankton density at all Beaver Dam Creek stations fluctuated considerably during the study. Mean total zooplankton density for the entire study generally showed a down-stream increase from Station 1 to Station 5 (Table 4.5.2-3). However, mean densities at Stations 4 and 6 dropped lower than those at Station 5. Mean total zooplankton density was lowest at Station 1A, the intermittently flowing stream.

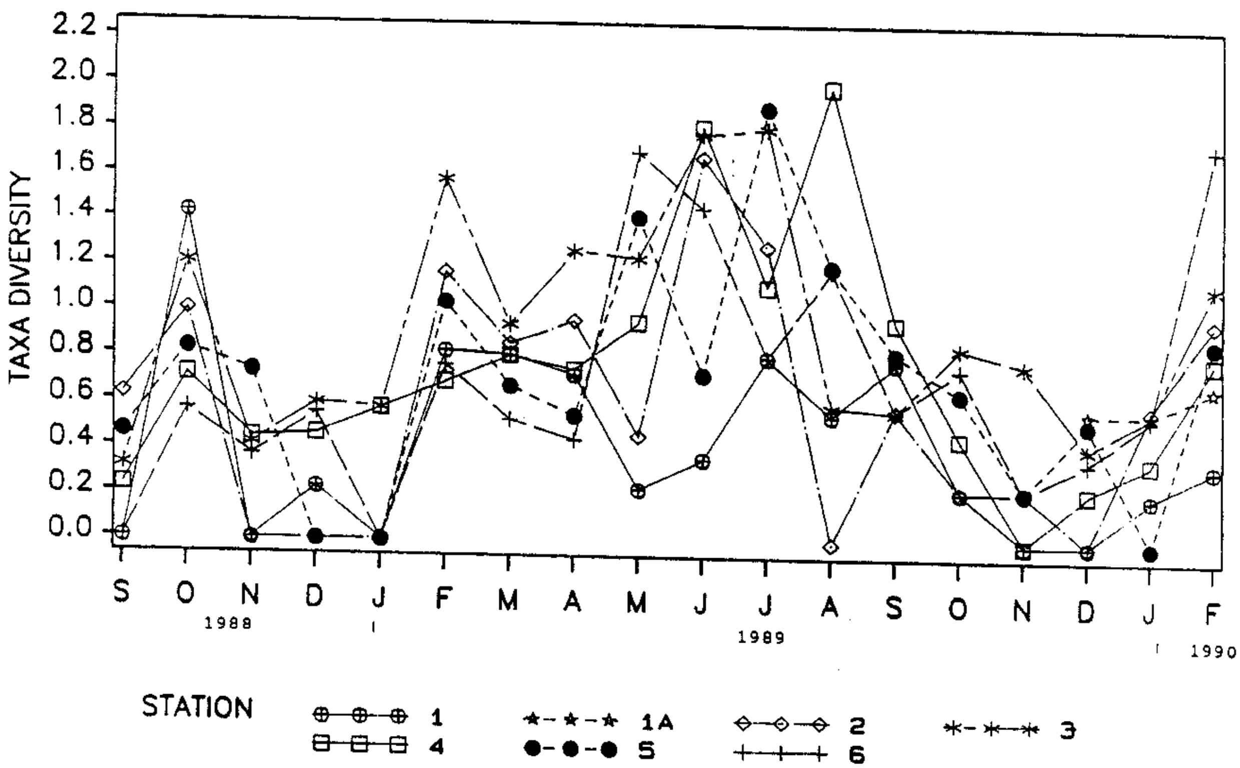

Figure 4.5.2-1 Mean Zooplankton Taxa Diversity at Each Station in Beaver Dam Creek. September 1988 - February 1990

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Table 4.5.2-1. **Zooplankton Taxa Identified at Each Station in Beaver Dam Creek. September 1988 - February 1990**

Taxon	Station 1A[a]	1	2	3	4	5	6
Protozoa							
Acanthocystis spp.		X	X	X	X	X	X
Amoeba spp.				X		X	X
Arcella dentata				X			
Arcella discoides	X	X	X		X	X	X
Arcella vulgaris						X	
Campanella sp.			X				
Campanella umbellaria			X				
Carchesium sp.		X	X	X	X	X	X
Centropyxis aculeata		X	X	X	X	X	X
Centropyxis ecornis		X	X	X	X	X	X
Centropyxis spp	X		X	X	X	X	X
Chilodonella sp.				X			
Chilophrya sp.					X		
Ciliate - unidentified spp. 100 - 200 µ	X				X	X	X
Ciliate - unidentified spp. 50 - 99 µ		X	X	X	X	X	X
Ciliate - unidentified spp. < 50 µ		X	X	X	X	X	X
Cothurnia sp.			X	X	X	X	X
Cyphoderia sp.			X	X			
Didinium sp.				X			
Difflugia sp. 1	X	X	X	X	X	X	X
Dileptus spp.			X				
Epistylis spp.		X	X	X	X	X	X
Euglypha spp.		X	X	X	X	X	X
Orthodonella sp.				X			
Platycola sp.							X
Podophrya sp.		X	X	X	X	X	X
Protozoan - unident. spp. 100 - 200 µ			X	X		X	
Pyxicola affinis		X	X	X	X	X	X
Rhabdostyla spp.		X	X				
Spathidium sp.						X	
Suctorian ciliate - unidentified spp.				X	X		X
Thuricolopsis sp.			X				
Vaginicola sp.				X			
Vorticella sp. 1		X	X	X	X	X	X
Rotifera							
Bdelloidea - unidentified supp.		X	X	X	X	X	X
Cephalodella gibba			X		X		
Cephalodella spp.			X	X	X		
Collotheca spp.				X			
Colurella spp.		X	X				
Conochiloides dossuarius				X			X
Conochilus unicornis		X					

Table 4.5.2-1. (Contd) Zooplankton Taxa Identified at Each Station in Beaver Dam Creek. September 1988 - February 1990

Taxon	Station 1A[a]	1	2	3	4	5	6
Rotifera (continued)							
Dicranophorus forcipatus			X			X	
Dipleuchlanis propatula		X	X	X	X	X	
Euchlanis sp.				X	X		
Habrotrocha sp.		X	X	X	X		X
Keratella cochlearis				X			X
Keratella cochlearis var. hispida	X				X		
Keratella crassa		X			X		X
Keratella serrulata f. curvicornis	X						
Lecane inermis							X
Lecane ludwigi				X			
Lecane luna		X	X		X		
Lepadella acuminata							X
Lepadella patella					X		
Lepadella spp.				X		X	X
Lindia sp.		X	X		X		
Manfredium eudactylotum						X	
Monostyla bulla						X	
Monostyla lunaris		X					X
Monostyla spp.	X						
Monostyla stenroosi		X				X	
Notholca acuminata					X		
Notommata sp.				X			
Platyias patulus				X			
Platyias quadricornis				X			
Ploesoma truncatum		X				X	
Polyarthra dolicoptera							X
Polyarthra euryptera			X				X
Polyarthra vulgaris		X	X	X	X		X
Rotifer - unidentified spp.			X			X	X
Rotifer - unidentified spp. 100 - 200 µ		X	X	X	X	X	
Rotifer - unidentified spp. 50 - 99 µ				X	X		
Synchaeta oblonga						X	X
Synchaeta pectinata							X
Synchaeta stylata			X	X	X	X	X
Testudinella patina f. triloba				X			X
Testudinella sp.						X	
Testrasiphon hydrocora				X			
Trichocerca porcellus			X				
Trichotria tetractis				X	X		

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Table 4.5.2-1. (Contd) **Zooplankton Taxa Identified at Each Station in Beaver Dam Creek. September 1988 - February 1990**

Taxon	Station 1A[a]	1	2	3	4	5	6
Cladocera							
Alona gutuata			X				
Alona rectangula			X	X			
Alona setulosa							X
Alona sp.					X	X	
Bosmina longirostris	X	X	X	X		X	X
Chydorus brevilabris	X	X	X		X	X	X
Daphnia ambiqua			X		X		X
Diaphanosoma brachyurum		X	X				
Eurycercus (bullatifrons) sp.							X
Ilyocryptus sordidus				X	X		
Ilyocryptus spinifer					X	X	X
Cyclopoida/Calanoida							
Calanoid copepodid		X					
Cyclopoid copepodid	X	X	X	X	X	X	X
Cyclops sp.							X
Diaptomus mississippiensis		X	X	X	X		
Diaptomus sp.				X			X
Mesocyclops edax	X			X			X
Microcyclops varicans rubellus					X		
Nauplius larvae - unidentified spp.	X	X	X	X	X	X	X
Tropocyclops prasinus				X	X		
Harpacticoida				X	X		
Ostracoda			X	X	X		X

[a]Sampled in December 1989 and January and February 1990 only
Total number of zooplankton taxa identified = 102.

Table 4.5.2-2. **Zooplankton Taxa Richness in Beaver Dam Creek by Station from September 1988 - February 1990**

Taxon	Station						
	1A[a]	1	2	3	4	5	6
Protozoa	4	14	22	23	18	20	19
Rotifera	3	13	15	20	17	13	17
Cladocera	2	3	6	3	5	4	6
Cyclopoida/Calanoida	3	4	3	6	5	2	5
Harpacticoida	0	0	0	1	1	0	0
Ostracoda	0	0	1	1	1	0	1
Total	12	34	47	54	47	39	48

[a]Sampled in December 1989 and January and February 1990 only.

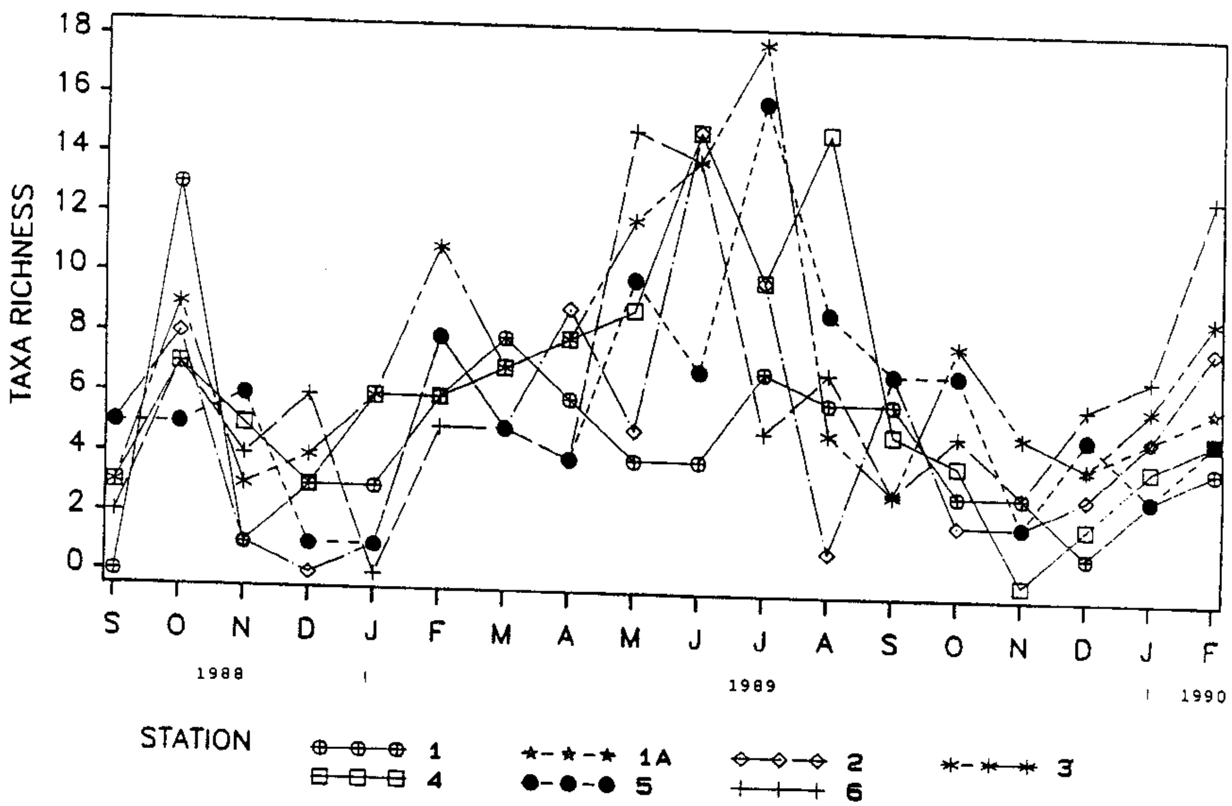

Figure 4.5.2-2 **Zooplankton Taxa Richness at Each Beaver Dam Creek Station. September 1988 - February 1990**

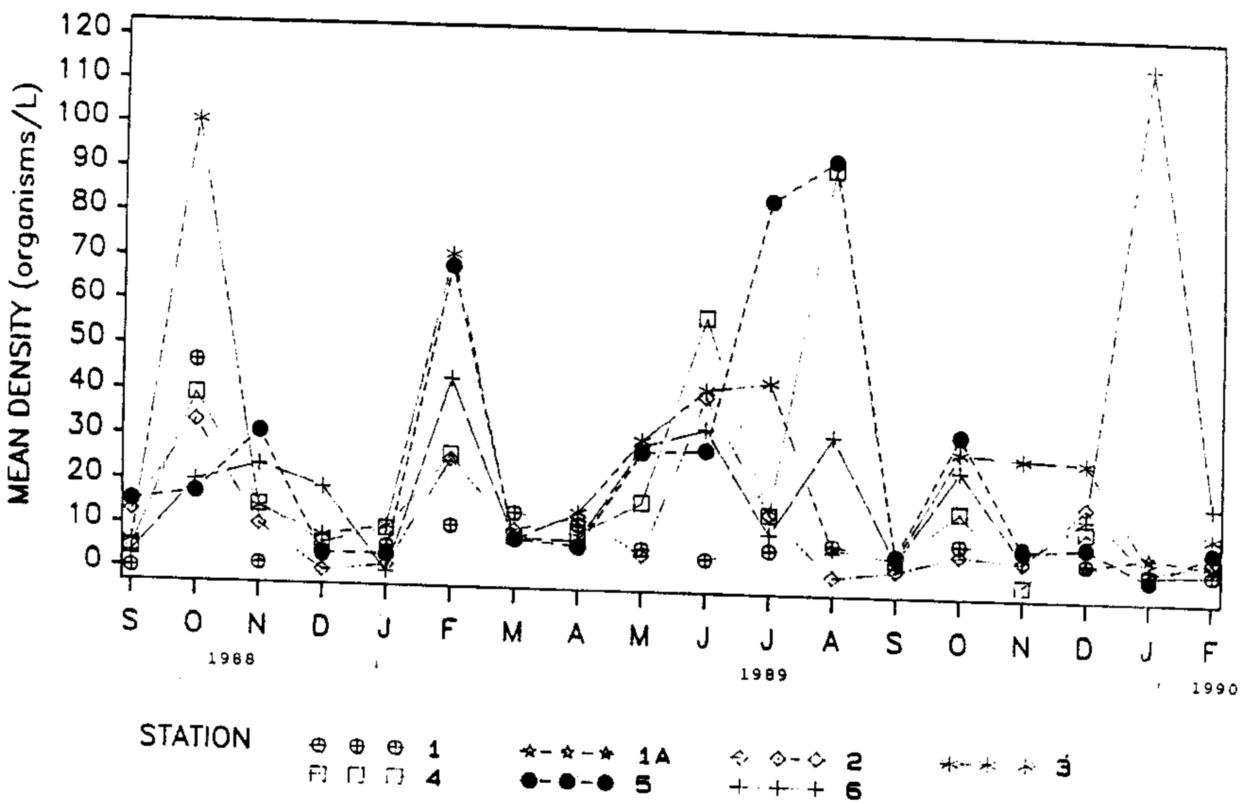

Figure 4.5.2-3 **Mean Zooplankton Density (Organisms/L; All Taxa Combined) at Each Station in Beaver Dam Creek. September 1988 - February 1990**

Table 4.5.2-3. **Mean Density (organisms/L) of Major Taxonomic Groups of Zooplankton. September 1988 - February 1990**

Station	Protozoa	Rotifera	Cladocera	Copepoda	Ostracoda	All Taxa
1	5.9	1.4	0.2	1.2	0.0	8.7
1A[a]	2.7	1.0	0.5	1.7	0.0	5.9
2	9.4	1.1	0.3	0.9	0.2	11.9
3	20.1	2.4	0.2	3.2	0.3	26.2
4	14.1	2.5	0.6	1.8	0.3	19.3
5	19.1	2.4	0.4	3.7	0.0	25.6
6	17.9	2.2	0.5	2.4	0.5	23.5

[a]Sampled in December 1989 and January and February 1990 only.

Total zooplankton density results were statistically analyzed using a 2-way ANOVA and Tukey's Studentized Range (HSD) Test. Station 1A was excluded because it was only sampled three times. The results indicated were significantly different ($F = 14.31$, $p = 0.001$). The analyses also indicated significant temporal differences ($F = 16.86$, $p = 0.001$) during the period that these samples were collected. However, no distinct seasonal pattern was apparent. The results of Tukey's test indicated that zooplankton density at Station 1 differed significantly from Station 5 and that zooplankton density at Station 2 differed from Station 3 and Station 5. It was not clear why zooplankton density at these stations was significantly different.

Protozoa was the dominant taxonomic group at all stations, comprising 45.8 to 79.0% of the total zooplankton density (Table 4.5.2-4). Rotifera accounted for 9.2 to 17.0% and Copepoda (Cyclopoida/Calanoida and Harpacticoida) for 7.6 to 28.8% of the total density. Cladocera accounted for more than 5% of the total zooplankton density at only one station (Station 1A; 8.5%). Ostracoda never accounted for as much as 3% of the total zooplankton density. No upstream-downstream trends were observed for any major taxonomic group.

4.5.2.4 Comparison To Previous Study

Zooplankton in Beaver Dam Creek were previously studied by Chimney and Cody (1986a), when two stations were sampled from December 1984 to August 1985. Two similar stations from the present Beaver Dam Creek study were selected for comparison. The location of Stations 6 and 7 from the earlier study are similar to the locations represented by Stations 3 and 4, respectively, of the the present Beaver Dam Creek study. Field and laboratory procedures in the Chimney and Cody (1986a) study were also similar to those in the present Beaver Dam Creek study.

Some differences in taxonomic data were apparent between the two studies. Total taxa richness was higher for the 1988 - 1990 study (Table 4.5.2-5), with more Protozoa, Rotifera, and Copepoda taxa present. However, the earlier study recorded twice as many Cladocera taxa as the 1988 - 1990 study. Ostracoda numbers were the same for both studies.

There were also differences in mean densities between the two studies (Table 4.5.2-6). Comparisons of Station 3 (present study) with Station 6 (Chimney and Cody 1986a) and Station 4 (present study) with Station 7 (Chimney and Cody 1986a) show differences for each major taxonomic group. With the exception of Cladocera, higher mean densities were observed in the present study than in the earlier study (Table 4.5.2-6). Mean species diversity comparisons between the two studies are presented in Table 4.5.2-7. In contrast to density, mean species diversity valves in the present study were lower than those reported in the earlier study.

Table 4.5.2-4 Relative Abundance of Major Zooplankton Taxonomic Groups at Each Station in Beaver Dam Creek. September 1988 - February 1990.

Station	Protozoa	Rotifera	Cladocera	Copepoda	Ostracoda	Total[b]
1	67.82	16.09	2.30	13.79	0.00	100.00
1A[a]	45.76	16.95	8.47	28.81	0.00	99.99
2	78.99	9.24	2.52	7.56	1.68	99.99
3	76.72	9.16	0.76	12.21	1.15	100.00
4	73.06	12.95	3.11	9.33	1.55	100.00
5	74.61	9.38	1.56	14.45	0.00	100.00
6	76.17	9.36	2.13	10.21	2.13	100.00

[a] Sampled in December 1989 and January and February 1990 only.
[b] Some totals may not equal 100.00 due to rounding.

Table 4.5.2-5. Zooplankton Taxa Richness of Savannah River Aquatic Ecology Program 1984 -1985 (Stations 6 and 7) and Beaver Dam Creek Study 1988 - 1990 (Stations 3 and 4)

Taxa	1984 -1985 Study[a]	Present Study[b]
Protozoa	7	26
Rotifera	15	27
Cladocera	14	7
Copepoda	4	8
Ostracoda	1	1
TOTAL	41	69

[a]Savannah River Aquatic Ecology Program, 1984 - 1985; Stations 6 and 7 (Chimney and Cody 1986a).
[b]1988 - 1990; Stations 3 and 4.

Table 4.5.2-6. Mean Density (organisms/L) of Major Zooplankton Taxonomic Groups for the Beaver Dam Creek Study (1988 - 1990) and the Savannah River Aquatic Ecology Program (1984 - 1985)

Station	Taxa[a]					
	PRO	ROT	CLA	COP	OST	All Taxa
3[b]	20.1	2.4	0.2	3.2	0.3	26.2
4[b]	14.1	2.5	0.6	1.8	0.3	19.3
6[c]	2.5	1.4	1.6	2.7	0.1	8.3
7[c]	0.9	1.3	1.0	1.6	0.2	5.0

[a]PRO-Protozoa; ROT-Rotifera; CLA-Cladocera; COP-Copepoda; OST-Ostracoda.

[b]Beaver Dam Creek Study (1988 - 1990).

[c]Savannah River Aquatic Ecology Program (1984 - 1985); Chimney and Cody (1986a).

Table 4.5.2-7. Mean Zooplankton Species Diversity for the Beaver Dam Creek Study (1988 - 1990) and the Savannah River Aquatic Ecology Program (1984 - 1985)

Station	Mean
3[a]	0.93
4[a]	0.74
6[b]	1.20
7[b]	1.19

[a]Beaver Dam Creek Study (1988 - 1990).
[b]Savannah River Aquatic Ecology Program (1984 - 1985); Chimmey and Cody (1986a).

4.5.3 Macroinvertebrates

This section summarizes the results of macroinvertebrate studies conducted in Beaver Dam Creek from September 1988 through February 1990 and compares these data with data collected during the Comprehensive Cooling Water Study in 1984 and 1985 and also with data from other regional streams. Data contained in the section are summarized from Nagle et al. (1990). Macroinvertebrates were sampled at seven stations in Beaver Dam Creek (Figure 4-1). However, macroinvertebrate samples were never collected at Station 1A, because this station was either completely dry, or did not contain enough water to submerse the sampling substrates. Therefore, data are reported for only six stations.

The primary sampling program for macroinvertebrates was conducted monthly by collecting five Hester-Dendy multiplate samplers at each sampling station. Although multiplate samplers are somewhat selective in terms of the taxa that colonize them (Rosenburg and Resh, 1982), they were used in this study to provide a uniform substrate for colonization and to facilitate comparison of data collected in this study with data collected prior to mitigation. In order to supplement the taxa lists from the multiplate sampling program, macroinvertebrates were also collected quarterly at each station with drift nets and dip nets. Detailed sampling methods can be found in Nagle et al. (1990).

The primary objectives of the Beaver Dam Creek macroinvertebrate program were (1) to characterize the structure (species composition, species richness, relative abundance of taxa, density of organisms, biomass, and relative abundance of functional feeding groups) of the macroinvertebrate community; (2) to determine the success of thermal mitigation in Beaver Dam Creek by comparing data collected during this study with data collected in 1984 and 1985 prior to mitigation; and (3) to compare the macroinvertebrate community of Beaver Dam Creek with those of other southeastern streams, in order to determine if the community structure of Beaver Dam Creek is similar to streams that do not receive thermal discharges.

4.5.3.1 Community Structure

This section describes the macroinvertebrate community of Beaver Dam Creek in terms of species composition, species richness, density of organisms, biomass, and trophic structure. In addition, the effectiveness of the mitigation program was to be evaluated by comparing macroinvertebrate data collected prior to mitigation (1984 - 1985) with the data collected during this program (1988 - 1990). However, reduced power production in 400-D Area negated the need for thermal mitigation during this study. Therefore, a comparison of the 1984 - 1985 data with the data from this study is not a true comparison of pre-mitigation conditions with post-mitigation conditions, but rather is a comparison of pre-mitigation conditions with that of reduced operating conditions.

4.5.3.1.1 Species Composition and Abundance

4.5.3.1.1.1 Hester Dendy Multiplate Samplers

This section summarizes the results of the monthly multiplate sampling program for macroinvertebrates. Results of the supplemental sampling program are presented in Section 4.5.3.1.1.2.

For all sampling methods combined, 163 macroinvertebrate taxa were collected from Beaver Dam Creek during the 18-month sampling program (Table 4.5.3-1). Of these taxa, 124 were collected on the multiplate samplers and 39 were collected exclusively by the supplemental sampling methods. By station, the total number of taxa collected ranged from 88 taxa at Station 1 to 116 taxa at Station 4 (Table 4.5.3-1), and the mean number of taxa collected per station ranged from 14.3 at Station 5 to 22.2 at Station 2 (Table 4.5.3-2).

As a group, Chironomidae were by far the most common macroinvertebrates in Beaver Dam Creek, comprising from 51.12% (Station 5) to 75.86% (Station 1) of the organisms collected from the multiplate samplers (Table 4.5.3-3). At Stations 1 through 4, the chironomid subfamily Orthocladiinae was the most abundant macroinvertebrate taxon, accounting for 22.43 to 29.64% of the organisms collected, while at Stations 5 and 6, chironomids of the tribe Chironomini were most abundant (20.64 and 25.00 %, respectively). Tanytarsini chironomids were also abundant at all stations comprising 8.43 to 19.93% 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; 0.75 to 26.52%), caddisflies (Trichoptera; 2.09 to 11.80%), beetles (Coleoptera; 1.04 to 11.87%), oligochaete worms (1.35 to 6.55%), and non-chironomid dipterans (0.82 to 5.55%; Table 4.5.3-3).

During the 18-month sampling program, mean densities of macroinvertebrates on the multiplate samplers ranged from 773.8 organisms/m^2 at Station 5 to 2348.0 organisms/m^2 at Station 2 (Table 4.5.3-2). Densities at upstream Stations 1, 2, and 3 were generally higher than at downstream Stations 4, 5, and 6 throughout the sampling program. Macroinvertebrate densities varied seasonally, with higher densities observed in late winter and in summer at most stations (Figure 4.5.3-1). Mean densities were generally lower during the fall and winter of 1989 - 1990 than during the same time period in 1988 - 1989 (Figure 4.5.3-1). The decline in densities may be due in part to extended flooding of much of Beaver Dam Creek by the Savannah River during much of this period (see Figure 4.4-4 for flood events).

4.5.3.1.1.2 Supplemental Sampling Program

As discussed in Section 4.5.3.1.1, the supplemental sampling methods collected 39 taxa that were not collected by the multiplate samplers. 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

Table 4.5.3-1. 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.

Class/Order	Taxon	Station 1	2	3	4	5	6
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

Table 4.5.3-1. (Contd) **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.**

Class/Order	Taxon	Station 1	2	3	4	5	6
Odonata	Order Odonata (unid.)	X		X	X		
Odonata	Suborder Anisoptera (unid.)	*	X	X	X	X	X
Odonata	Boveria spp.	X		X		*	
Odonata	Boveria 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

Table 4.5.3-1. (Contd) **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.**

Class/Order	Taxon	Station 1	2	3	4	5	6
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
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

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Table 4.5.3-1. (Contd) **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.**

Class/Order	Taxon	Station 1	2	3	4	5	6
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		
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.)		*				

Table 4.5.3-1. (Contd) **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.**

Class/Order	Taxon	Station 1	2	3	4	5	6
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
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 spp.	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.	*	*	*	*		

Table 4.5.3-1. (Contd) **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.**

Class/Order	Taxon	Station 1	2	3	4	5	6
Diptera	Family Empididae (unid.)	X	X	X	X	X	X
Diptera	<u>Chelifera</u> sp.	X	X	X	X	X	X
Diptera	<u>Dolichocephala</u> sp.	X	X				
Diptera	<u>Hemerodromia</u> 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					

[a]Higher level taxa not included in count if a lower level taxon was present.

Table 4.5.3-2. **Descriptive Statistics for Total Macroinvertebrate Densities (Organisms/m²) and Mean Number of Taxa from Quantitative (Multiplate) Sampling in Beaver Dam Creek. September 1988 - February 1990.**

Station	Mean	Med[a]	N	SD[a]	CV[a]	Min[a]	Max[a]	Mean No. of Taxa
1	1636.0	1273.7	90	1179.4	72.1	5.6	6463.7	16.2
2	2348.0	2069.8	90	1272.3	54.2	597.8	6257.0	22.2
3	1867.3	1379.9	89[b]	1392.2	74.6	162.0	6011.2	19.6
4	1451.8	1125.7	90	1241.8	85.5	44.7	6430.2	21.2
5	773.8	698.3	90	534.4	69.1	50.3	2910.6	14.3
6	1295.8	1167.6	85[c]	707.9	54.6	273.7	3804.5	18.4

[a] Abbreviations: Med - Median; N - Total number of samples analyzed; SD - Standard Deviation; CV - Coefficient of Variation; Min - Minimum; Max - Maximum.

[b] Only four samples were collected at Station 3 in January 1989.

[c] Samples were not retrieved from Station 6 in February 1990 due to high water levels.

Table 4.5.3-3. Mean Relative Abundance (Percent Composition) of Higher Order Taxonomic Groups of Macroinvertebrates from Quantitative Sampling in Beaver Dam Creek. September 1988 - February 1990.

Taxon	Sta 1	Sta 2	Sta 3	Sta 4	Sta 5	Sta 6
Coelenterata	<0.01	0.00	<0.01	0.00	0.01	0.00
Turbellaria	0.08	0.09	0.20	0.34	0.33	0.06
Nematoda	0.40	0.52	0.24	0.20	0.08	0.17
Polychaeta	0.00	<0.01	<0.01	<0.01	0.00	0.00
Oligochaeta	5.30	6.55	4.68	4.59	1.35	3.26
Hirudinea	0.01	0.01	0.01	0.05	0.00	0.02
Gastropoda	3.93	3.20	1.78	1.85	3.33	1.49
Pelecypoda	0.00	0.00	0.00	0.01	0.00	0.00
Hydracarina	0.25	0.62	0.47	0.45	0.43	0.44
Isopoda	0.00	0.00	0.06	0.18	0.02	0.00
Amphipoda	0.03	0.01	0.06	0.53	0.08	0.16
Decapoda	0.00	0.00	0.00	0.28	0.00	0.00
Collembola	0.00	0.04	0.00	0.01	0.03	0.00
Ephemeroptera	0.75	9.06	12.42	12.14	26.52	18.72
Odonata	0.08	0.17	0.24	1.28	0.18	0.30
Plecoptera	0.00	0.00	0.01	0.00	0.01	0.10
Hemiptera	0.00	<0.01	0.00	0.00	0.00	0.00
Coleoptera	1.72	1.04	2.09	1.29	11.87	5.09
Megaloptera	0.17	0.20	0.16	0.25	0.24	0.12
Neuroptera	0.00	0.00	0.00	0.00	0.00	0.01
Trichoptera	5.86	11.80	6.02	4.83	2.09	4.03
Lepidoptera	<0.01	0.03	0.05	0.18	0.07	0.01
Non-chir. Diptera	5.55	3.94	2.35	0.82	2.25	1.92
Chironomidae (unid.)	8.51	4.05	4.24	6.62	3.02	6.53
Orthocladiinae	27.54	28.99	29.64	22.43	18.12	15.87
Tanypodinae	1.35	1.30	1.73	2.81	0.90	1.65
Tanytarsini	14.43	15.01	19.93	19.72	8.43	15.02
Chirononini	24.01	13.24	13.53	18.87	20.64	25.00
Diamesiinae	0.02	0.16	0.08	0.25	0.01	0.05
Totals	100.00	100.00	100.00	100.00	100.00	100.00

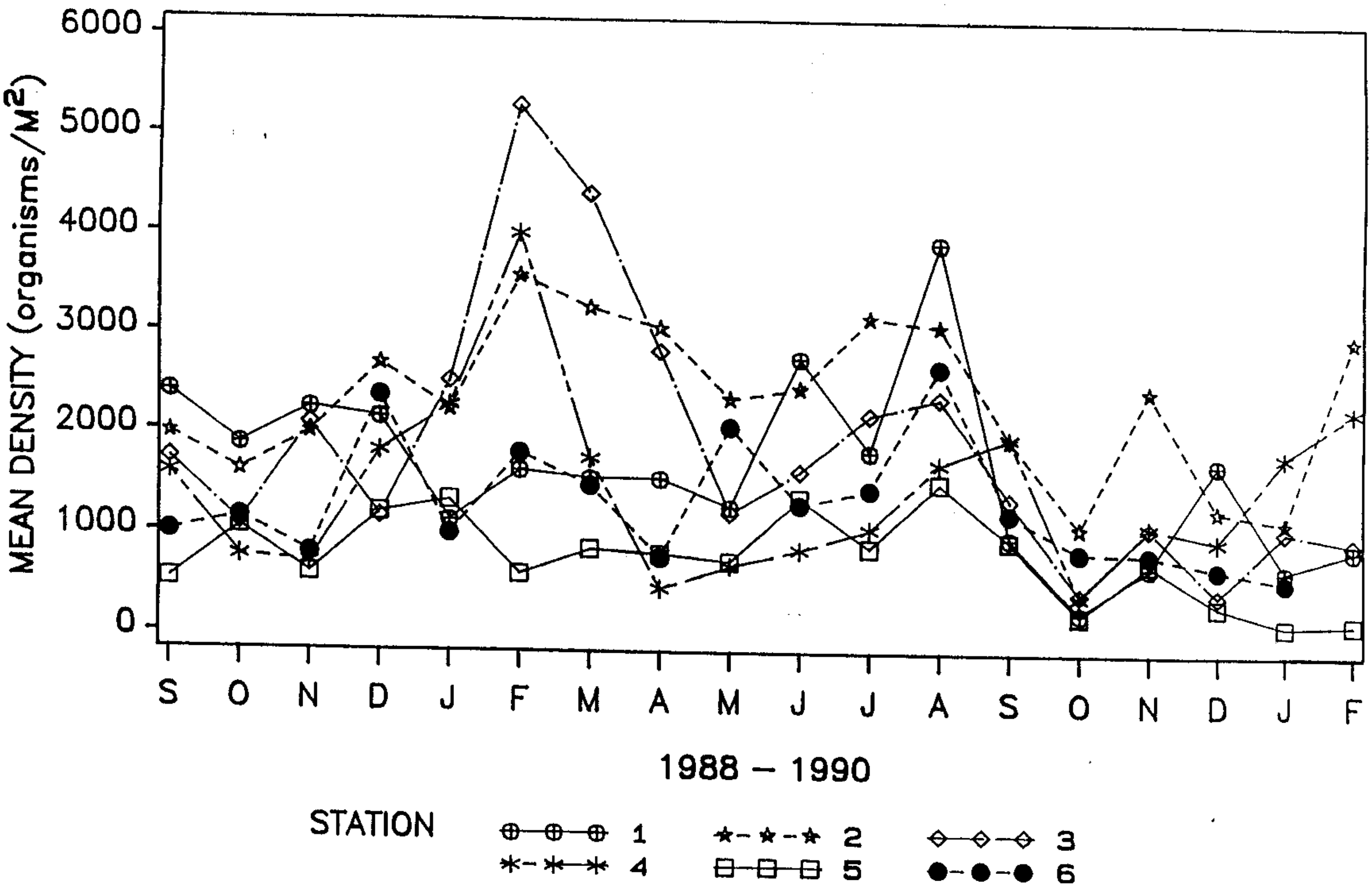

Figure 4.5.3-1. Mean Monthly Densities of Macrointertebrates Collected on Hested-Dendy Multiplate Samplers in Beaver Dam Creek. September 1988 - February 1990

beetles (Coleoptera; Table 4.5.3-1). 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.

4.5.3.1.2 Biomass

Mean macroinvertebrate biomass on the multiplate samplers, for all sampling dates combined, ranged from 0.1848 g ash-free dry mass (AFDM)/m^2 at Station 1 to 0.3943 g AFDM/m^2 at Station 4 (Table 4.5.3-4). The higher biomass at Station 4 is largely due to the occasional collection of a crayfish or prawn on a multiplate sampler (Nagle et al., 1990), which resulted in biomass as high as 4.000 g/m^2 (Table 4.5.3-4) and skewed the biomass data at this station. Excluding Station 4, biomass at the remaining 5 stations ranged from 0.1848 g AFDM/m^2 at Station 1 to 0.2728 g AFDM/m^2 at Station 2 (Table 4.5.3-4).

4.5.3.1.3 Functional Feeding Groups

In order to compare the trophic structure of the macroinvertebrate communities at the 6 sampling stations, macroinvertebrates from the multiplate collections were assigned to one of seven functional feeding groups (collector-gatherer, collector-filterer, scraper, predator, shredder, piercer-herbivore or piercer-carnivore) based on the classification system described by Merritt and Cummins (1984). Insect pupae, which do not feed, were not assigned to a functional feeding group, but were included in density estimates. The functional group assignment for each macroinvertebrate taxon collected in Beaver Dam Creek can be found in Nagle et al. (1990).

Collector-gatherers were the most abundant functional group at all stations, accounting for 42.21% (Station 1) to 64.97% (Station 5) of the organisms collected (Table 4.5.3-5). Collector-filterers were the second-most abundant functional group at most stations, comprising 10.30 to 25.92% of the collections. Shredders were also abundant at most stations, ranging in abundance from 9.52% at Station 3 to 20.52% at Station 1 (Table 4.5.3-5). Predators accounted for 3.71 to 6.70% of the collections, while the remaining functional groups combined generally comprised less than 10% of the organisms collected (Table 4.5.3-5).

With respect to biomass, predators dominated the biomass at Stations 1 through 3 (45.35 to 62.08%), while shredders dominated at Station 4 (44.06%) and collector-gatherers dominated at Stations 5 (53.19%) and 6 (52.59%) (Table 4.5.3-5). The disparity between numerical dominance and dominance by biomass for functional groups is largely due to substantial differences in the size of macroinvertebrates. Predators are typically large organisms, as are some shredders, such as crayfish and tipulid dipterans. In contrast, most collector-gatherers and collector-filterers are relatively small.

Table 4.5.3-4. Descriptive Statistics for Total Macroinvertebrate Biomass ($g\ AFDM/m^2$) from Quantitative Sampling in Beaver Dam Creek. September 1988 - February 1990.

Station	Mean Biomass	Med	N	SD	CV	Min	Max
1	0.1848	0.0778	90	0.2695	145.8	0.0005	1.2000
2	0.2728	0.1661	90	0.3022	110.8	0.0307	1.6000
3	0.2251	0.1351	89[a]	0.3069	136.3	0.0094	2.0000
4	0.3943	0.1858	90	0.6000	150.9	0.0073	4.0000
5	0.2148	0.1153	90	0.3751	174.6	0.0039	2.6000
6	0.2216	0.1714	85[b]	0.1978	89.2	0.0158	1.6000

[a]Only four samples were collected at Station 3 in January 1989.

[b]Samples were not retrieved from Station 6 in February 1990 due to high water levels.

Table 4.5.3-5. Relative Abundance (Percent) of Macroinvertebrate Functional Groups and Functional Group Biomass from Multiplate Samplers in Beaver Dam Creek. September 1988 - February 1990

Functional Group Composition (Percent)

Functional Group	Station 1	2	3	4	5	6
Collector–gatherer	42.21	49.40	53.70	50.03	64.97	54.34
Collector-filterer	20.45	25.92	25.31	22.31	10.30	18.39
Shredder	20.52	10.59	9.52	15.08	12.23	14.59
Scraper	4.26	3.33	1.92	2.09	5.09	3.27
Predator	6.70	5.60	4.64	5.96	3.71	4.58
Piercer-carnivore	0.25	0.62	0.47	0.46	0.43	0.46
Piercer-herbivore	0.05	0.20	0.06	0.15	0.03	0.16
Nonfeeding (pupae)	5.56	4.34	4.38	3.92	3.25	4.22
Total[a]	100.00	100.00	100.00	100.00	100.01	100.01

Functional Group Biomass (Percent)

Functional Group	Station 1	2	3	4	5	6
Collector–gatherer	5.08	14.12	31.15	18.16	53.19	52.59
Collector-filterer	24.09	25.57	18.41	2.39	3.47	10.63
Shredder	5.61	3.52	3.41	44.06	1.89	3.45
Scraper	2.09	4.21	1.52	0.81	3.84	5.65
Predator	62.08	52.34	45.35	34.24	37.55	27.28
Piercer-carnivore	1.03	0.14	0.14	0.06	0.06	0.37
Piercer-herbivore	0.01	0.10	0.02	0.27	0.00	0.03
Total[a]	99.99	100.00	100.00	99.99	100.00	100.00

[a]Some totals may not equal 100%, due to rounding.

4.5.3.2 Spatial Trends

The six sampling stations were located from 1.0 to 4.9 km downstream from the D-001 outfall. As discussed in Section 4.4, stream temperatures near the creek mouth (Station 6) averaged about 1.2°C cooler than at Station 1 (Table 4.4-1). If the macroinvertebrate community of Beaver Dam Creek was adversely affected by the thermal effluent, stations closest to the thermal outfall would be expected to be perturbed to a greater extent than those stations located farther downstream. Therefore, the macroinvertebrate data were examined for longitudinal trends that might be indicative of thermal perturbation.

Station 1 had fewer macroinvertebrate taxa and slightly lower biomass than the other sampling stations (Tables 4.5.3-1 and 4.5.3-4), but was similar to the other sampling stations with respect to densities of organisms and mean number of taxa (Table 4.5.3-2). There were some indications of longitudinal changes in the relative abundances of macroinvertebrate taxonomic groups in Beaver Dam Creek. Station 1 had the lowest relative abundance of mayflies (0.75%) and the highest relative abundance of chironomids (75.86%; Table 4.5.3-3) 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 5 and 6 (11.87 and 5.09%, respectively) than at the four upstream stations (1.04 to 2.09%; Table 4.5.3-3). Conversely, trichopterans were more abundant at the three upstream stations (5.86 to 11.80%) than at the three downstream stations (2.09 to 4.83%; Table 4.5.3-3).

It is difficult to separate the effects of habitat differences among the six sampling stations from the possible effects of thermal perturbation. The presence of fewer taxa, and relatively low abundance of mayflies and high abundance of chironomids are all possible indicators of stress. If the stress were thermal or chemical, a more distinct downstream trend would have been expected, with the macroinvertebrate community at Station 2 exhibiting characteristics that were intermediate between those of Station 1 and Station 3. However, Station 2, was very similar to the four sampling stations located farther downstream (Stations 3 through 6) with respect to most parameters, even though it was located just 700 meters downstream from Station 1, and had mean monthly temperatures that averaged just 0.1°C lower than those at Station 1 (Table 4.4-1). Therefore, it appears that differences at Station 1 were more probably due to differences in habitat. As discussed in Section 4.1, Beaver Dam Creek at Station 1 is relatively narrow and deep, with relatively swift currents and no aquatic macrophytes.

With respect to functional group composition, shredders comprised a greater percentage of the organisms collected at Station 1 (20.52%) than at the other stations (9.52 to 15.08%) and predator biomass comprised a greater percentage of total biomass at Station 1 (62.08%) than at the other stations (27.28 to 52.34%) (Table 4.5.3-5). In general, the relative abundance of collector-gatherers increased in a downstream direction, ranging from 42.21% at Station 1 to 64.97% at Station 5, and then declining to 54.34% at Station 6 (Table 4.5.3-5). Predator biomass decreased in a downstream direction, from 62.08% at Station

1 to 27.28% at Station 6 (Table 4.5.3-5). The differences in functional group composition are probably more a function of habitat differences than of thermal perturbation. Station 1 has a narrow channel, with a nearly complete canopy, which would result in substantial inputs of leaf litter, thus providing food for shredders. In general, the relative abundance of collectors increases in a downstream direction in most streams (Vannote et al., 1980), as the organic matter present in the stream becomes finer, due to physical abrasion and processing by other macroinvertebrates. There is no ready explanation for the greater predator biomass at the upstream stations. However, predator biomass can be highly variable, since the presence of a one large predator can greatly increase overall predator biomass at a station.

4.5.3.3 Comparison to Pre-Mitigation (1984-1985) Data

Data from this study were compared to data collected at five stations in Beaver Dam Creek from October 1984 to September 1985 (Firth et al., 1986) as part of the Comprehensive Cooling Water Study (CCWS) (Specht, 1987). Four of the five stations sampled in 1984 - 1985 were identical to stations sampled during this study; but one CCWS station (Station 5) was located approximately 1 km farther upstream than the most upstream station in this study. This station was not sampled in the present study, because it was located in the man-made canal, rather than in the stream channel.

The major differences between stream conditions during this study and the study conducted in 1984 - 1985 are lower maximum stream temperatures during the summer months (maximum stream temperature did not exceed 31.9°C (Nagle et al., 1990), as compared to 34°C in 1984 - 1985 (Firth et al., 1986)[1] and lower Δ T's during the winter, due to reduced power generation. However, since the use of more than three pumps was never required to maintain the outfall temperature below 32.2°C, the effects of increased flow resulting from thermal mitigation cannot be evaluated at this time.

In 1984 - 1985, the number of macroinvertebrate taxa collected at 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 4.5.3-6). In both sampling programs, the most upstream station had the fewest number of taxa, while the slough-like area (Station 7 in 1984 - 1985, Station 4 in 1988 - 1990) had the most taxa. The mean density of macroinvertebrates collected on multiplate samplers ranged from 921.2 to 1776.5 organisms/m^2 in 1984 - 1985 and from 773.8 to 2348.0 organisms/m^2 in 1988 - 1990 (Table 4.5.3-7). Densities were comparable between studies for any given station. The mean biomass of macroinvertebrates ranged from 0.076 to 0.220 g AFDM/m^2 in 1984 - 1985, while biomass in 1988 - 1990 was substantially higher at most stations, ranging from 0.185 to 0.394 g AFDM/m^2 (Table 4.5.3-7).

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[1] Firth et al., (1986) reported a maximum stream temperature of 36.7°C for one station (Station 3 in the present study) in June 1985. However, this temperature is suspect, since maximum temperatures at the stations located upstream and downstream of this station were 33.0 and 33.5°C, respectively.

Table 4.5.3-6. Total Number of Macroinvertebrate Taxa Collected on Multiplate Samplers in Beaver Dam Creek. October 1984-September 1985, September 1988-February 1990.

Beaver Dam Creek Station		All Taxa		Taxa Richness Less Chironomidae
1984-1985[a]	1988-1990[b]	1984-1985[a]	1988-1990[b]	1988-1990[b]
5[c]	-	36	-	-
-	1	-	67	41
-	2	-	69	47
6	3	42	71	44
7	4	61	92	64
8	5	50	68	46
9[d]	6	47[c]	82	57

Source: [a] Specht (1987)
[b] This study
[c] Station 5 was located approximately 0.8 km upstream from Station 1 (1988-1990), in the D-Area discharge canal.
[d] Chimney and Cody (1986b)

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Table 4.5.3-7. **Mean Density and Biomass of Macroinvertebrates Collected on Multiplate Samples in Beaver Dam Creek. October 1984-September 1985, September 1988-February 1990.**

Beaver Dam Creek Station		Mean Density (No./m²)		Mean Biomass (g AFDM/m²)	
1984-1985[a]	1988-1990[b]	1984-1985[a]	1988-1990[b]	1984-1985[a]	1988-1990[b]
5[c]	-	1626.9	-	0.118	-
-	1	-	1636.0	-	0.185
-	2	-	2348.0	-	0.273
6	3	1776.5	1867.2	0.076	0.225
7	4	1131.9	1451.8	0.173	0.394
8	5	921.2	773.8	0.170	0.215
9	6	1253.6	1295.8	0.220	0.222

Source: [a]Specht (1987). Station numbers used in the 1984-1985 study differ from those used in the 1989-1990 study.

[b]This study

[c]Station 5 was located approximately 0.8 km upstream from Station 1 (1988-1990), in the D-Area discharge canal.

The taxonomic composition of Beaver Dam Creek has changed substantially since 1984-1985, 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 (Tables 4.5.3-3 and 4.5.3-8). Many species of Chironomini are generally considered to be pollution-tolerant (Beck, 1977), while most species of mayflies and caddisflies are intolerant of poor water quality (Hynes, 1970). Therefore it appears that, with respect to taxonomic composition, the macroinvertebrate community of Beaver Dam Creek has undergone substantial improvement since 1984 - 1985.

4.5.3.4 Comparison to Regional Streams

To satisfy the requirements of a balanced indigenous biological community, the macroinvertebrate community of Beaver Dam Creek must be similar to those found in other unimpacted streams of the region. Therefore, macroinvertebrate data from Beaver Dam Creek were compared to those of other southeastern coastal plain streams to determine if the macroinvertebrate community of Beaver Dam Creek differed substantially from those of streams that do not receive thermal effluents. It is often difficult to make direct comparisons of macroinvertebrate data from different sources, due to differences in sampling methods, sampling effort, habitat types, and level of taxonomic resolution. Therefore, any conclusions drawn from these comparisons should be made cautiously.

Eight southeastern streams were selected for comparison with Beaver Dam Creek, including six other streams on SRS (Upper Three Runs Creek, a non-thermal section of Four Mile Creek, a non-thermal section of Pen Branch, Steel Creek, Meyer's Branch, and Lower Three Runs Creek). The data from these streams were collected using sampling methods that were identical to those used in Beaver Dam Creek. However, chironomids were identified to genus in this study and in Steel Creek, while the level of chironomid taxonomic resolution for the other SRS streams was generally to subfamily or tribe. In order to make the data sets comparable, taxonomic richness for Beaver Dam Creek and Steel Creek is reported using the same level of taxonomic resolution as that used for the other SRS streams. Off-site streams included in the comparisons are the Satilla River in south Georgia and Cedar Creek, which is a coastal plain stream in South Carolina. These data differ from the data from Beaver Dam Creek in that the samples were collected from natural substrates and finer mesh sieves were used, which retain smaller organisms and result in higher estimates of macroinvertebrate density.

The number of taxa (excluding chironomid genera) collected from multiplate samplers at stations in Beaver Dam Creek during 1988 to 1990 ranged from 41 to 64 (Table 4.5.3-9). The number of taxa collected from other SRS streams during the Comprehensive Cooling Water Study in 1984 - 1985 ranged from 54 to 75 (Table 4.5.3-10), while the number of taxa reported for stations in Cedar Creek ranged from 47 to 53 (Table 4.5.3-10). Table 4.5.3-11 lists all of the taxa collected at the non-thermal CCWS stations as well as the taxa collected in

Table 4.5.3-8. Mean Relative Abundance (Percent Composition) of Higher Order Taxonomic Groups of Macroinvertebrates Collected on Hester Dendy Multiplate Samplers. October 1984-September 1985.

Taxon	Station 5	6	7	8	9
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

a Taxa were grouped in "Chironomidae"
b Some totals may not equal 100.00 due to rounding
Source: Stations 5,6,7,8 calculated from Firth et al. (1986)
Station 9 calculated from Chimney and Cody (1986b)

Table 4.5.3-9. **Mean Density and Biomass (Ranges Given if There Was More Than One Sampling Station) of Macroinvertebrates Collected on Multiplate Samplers in Beaver Dam Creek (September 1988 - February 1990) and SRS Streams.**

Location	Mean Density (no./m^2)	Mean Biomass (g/m^2) AFDM	No. of Taxa Collected
Upper Three Runs[a]	582.7	0.494	62
Four Mile	2109.3	0.351	67
Pen Branch	695.2	0.187	70
Pen Branch Swamp	1620.0	0.320	55
Steel Creek	496.0-1326.3	0.212-0.599	55-66
Steel Creek Delta	484.7-1411.2	0.159-0.715	54-75
Steel Creek Swamp	605.1-1446.6	0.196-0.248	61-67
Meyer's Branch	565.0-876.9	0.073-0.129	59-60
Lower Three Runs	743.5-5549.8	0.411-0.604	56-67
Beaver Dam[b]	773.8-2348.0	0.185-0.394	67-92
Beaver Dam[c]			41-64

[a]Source: Specht (1987).

[b]Total number of taxa identified.

[c]Total number of taxa minus Chironomidae genera not identified in the CCWS study (Specht 1987).

Table 4.5.3-10. Density, Biomass, and Taxa Richness of Macroinvertebrates From Different Locations on the Savannah River Site and Other Locations in the Southeastern U.S.

Location		Density (no./m²)	Biomass (g AFDM/m²)	Number of Taxa	Study
Savannah River Site - Reference Stream Sites					
Upper Three Runs Creek	(Station 1)	583	0.494	62	Firth et al. (1986)
Four Mile Creek	(nonthermal) (Station 12)	2109	0.351	67	Firth et al. (1986)
Pen Branch	(nonthermal) (Station 20)	695	0.187	70	Firth et al. (1986)
Meyer's Branch	(Station 39)	565	0.073	60	Firth et al. (1986)
	(Station 40)	833	0.117	59	Firth et al. (1986)[a]
Lower Three Runs Creek	(Station 42)	5550	0.604	56	Firth et al. (1986)
	(Station 43)	744	0.411	67	Firth et al. (1986)
Savannah River Site - Reference Swamp Sites					
Pen Branch	(nonthermal) (Station 24)	1620	0.320	55	Firth et al. (1986)
Satilla River					
Third-order site		43,767[b] (33,315)	0.359 (3.056)[c]	-[d]	Benke et al. (1984)
Fourth-order site		17,566[b] (26,207)	0.376 (5.243)[c]	-[d]	Benke et al. (1984)

[a]Recomputed from Firth et al. (1986). Stations designators of Firth et al. (1986) were multiplied by 10 to represent stations numbers in this study.

[b]Computed from data given in Benke et al. (1984). 100 m mesh sieve used for processing most samples. Values in parentheses for snag substrates.

[c]Dry mass converted to ash-free dry mass assuming AFDM was approximate by 90% of dry mass. Values in parentheses for snag substrates.

[d]Data not provided by authors. However, an appendix lists 63 taxa from snag, 31 from sand, and 41 from mud substrates. Combining those, there were 104 taxa present at the two sites.

Table 4.5.3-10. Density, Biomass, and Taxa Richness of Macroinvertebrates From Different Locations on the Savannah River Site and Other Locations in the Southeastern U.S. (Continued)

Location	Density (no./m^2)	Biomass (g AFDM/m^2)	Number of Taxa	Study
Cedar Creek				
Upstream site	7836[e]	0.491[c]	53+[f]	Smock et al. (1985)
Swamp site	8339[e]	0.293[c]	47+[f]	Smock et al. (1985)
Downstream site	8616[e]	0.188[c]	47+[f]	Smock et al. (1985)
Savanah River Site - Steel Creek				
Pre-impoundment - Stream Stations				
1985 (Stations 28, 29, 37)	713-1680	0.175-0.552	51-63	Firth et al. (1986)[a]
Post-impoundment - Stream Stations				
1986 (Stations 280, 290, 370)	2996-6689	0.335-1.428	41-54	O'Hop et al. (1988)
1987 (Stations 280, 290, 370)	995-5854	0.289-1.033	48-59	O'Hop et al. (1988)
1988 (Stations 280, 290, 370)	1815-5206	0.388-1.750	52-60	Lauritsen (1989)
Pre-impoundment - Delta and Swamp Stations				
1985 (Stations 30,31,32,33,34,35)	444-1497	0.146-0.644	52-66	Firth et al. (1986)[a]
Post-impoundment - Delta and Swamp Stations				
1986 (Stations 300,310,320,330,340,350)	865-1751	0.126-0.551	52-58	O'Hop et al. (1988)
1987 (Stations 300,310,320,330,340,350)	733-1549	0.107-0.220	47-60	O'Hop et al. (1988)
1988 (Stations 300,310,320,330,340,350)	748-893	0.106-0.367	48-64	Lauritsen (1989)

[c]Dry mass converted to ash-free dry mass assuming AFDM was approximately 90% of dry mass. Values in parentheses for snag substrates.
[e]150 µm mesh sieve used for processing samples. Biomass by length-dry mass regressions.
[f]Some taxa were represented only in a miscellaneous category in an appendix to the study and could not be counted. Therefore, the number of taxa given here is an underestimate of those collected by the study.

Table 4.5.3-10. Density, Biomass, and Taxa Richness of Macroinvertebrates from Different Locations on the Savannah River Site and Other Locations in the Southeastern U.S. (Continued)

Location	Density (no./m^2)	Biomass (g AFDM/m^2)	Number of Taxa	Study
Beaver Dam Creek				
Station 1	1636.0	0.1848	88	This study
Station 2	2348.0	0.2728	102	This study
Station 3	1867.3	0.2251	106	This study
Station 4	1451.8	0.3943	116	This study
Station 5	773.8	0.2148	92	This study
Station 6	1295.8	0.2216	102	This study

Table 4.5.3-11. **List of Macroinvertebrate Taxa Collected from Multiplate Samplers in Beaver Dam Creek (September 1988 - February 1990) and SRS Streams (Source: Specht 1987)**

Taxon	Functional Group[a]	Streams[b]									Beaver Dam Creek	
		UTR	FM	PB	PBS	SC	SCD	SCS	MB	LTR	1984-1985	1988-1990
Hydra	FG4											X
Turbellaria	FG4	X	X	X	X	X	X	X	X	X	X	X
Nematoda	FG1	X	X	X	X	X	X	X	X	X	X	X
Polychaeta												
Manayunkia	FG2											X
Oligochaeta	FG1	X	X	X	X	X	X	X	X	X	X	X
Hirudinea	FG4			X	X	X	X	X	X	X	X	X
Gastropoda	FG3		X	X	X	X	X	X	X	X	X	X
Family Ancylidae	FG3			X	X	X	X			X	X	X
Ferrissia rivularis	FG3		X	X	X	X	X	X	X	X	X	
Laevapex fuscus	FG3				X		X				X	
Family Hydrobiidae												
Amnicola	FG3		X		X	X	X	X		X	X	X
Somatogyrus	FG3				X		X					
Family Lymnaeidae												
Pseudosuccinea columella	FG3		X		X		X					X
Family Physidae												
Physella heterostropha	FG3		X	X	X	X	X	X	X	X	X	X
Family Planorbidae	FG3				X		X	X	X			X
Gyraulus parvus	FG3		X		X	X	X	X	X	X		
Helisoma trivolvis	FG3		X	X	X	X	X	X	X	X	X	X
Menetus dilatatus	FG3						X		X	X		X
Family Pleuroceridae												
Elimia (Goniobasis sp)	FG3								X	X		
Family Viviparidae												
Campeloma decisum	FG3				X	X	X	X		X	X	
Pelecypoda												
Family Corbiculidae												
Corbicula fluminea	FG2			X	X	X			X	X	X	X
Family Sphaeriidae	FG2	X		X		X			X	X	X	X
Family Unionidae												
Elliptio complanata	FG2								X			
Crustacea												
Isopoda												
Asellus	FG1				X	X	X	X		X	X	X
Amphipoda	FG1					X		X				X
Family Gammaridae												
Gammarus fasciatus	FG1					X	X	X	X	X	X	X
Family Talitridae												
Hyalella azteca	FG1		X	X	X	X	X	X	X	X	X	X
Family Palaenonidae												
Palaemonetes paludosus	FG6											X
Family Cambaridae	FG6											X
Family Procambaridae												
Procambarus	FG6			X		X	X	X				X
Order Collembola	FG1		X			X						X
Family Isotomidae	FG1							X		X		

[a] FG-1 - Collector - gatherer
FG-2 - Collector - filterer
FG-3 - Scraper
FG-4 - Engulfer - predator
FG-5 - Piercer - herbivore
FG-6 - Shredder
FG-7 - Piercer - carnivore

[b] UTR - Upper Three Runs
FM - Four Mile
PB - Pen Branch
PBS - Pen Branch Swamp
SC - Steel Creek
SCD - Steel Creek Delta
SCS - Steel Creek Swamp
MB - Meyer's Branch
LTR - Lower Three Runs

Table 4.5.3-11. List of Macroinvertebrate Taxa Collected from Multiplate Samplers in Beaver Dam Creek (September 1988 - February 1990) and SRS Streams (Source: Specht 1987) (Continued)

Taxon	Functional Group[a]	Streams[b] UTR	FM	PB	PBS	SC	SCD	SCS	MB	LTR	Beaver Dam Creek 1984-1985	Beaver Dam Creek 1988-1990
Family Poduridae												
<u>Podura aquatica</u>	FG1		X						X	X		
Family Sminthuridae												
<u>Sminthurides</u>	FG1					X						
Arachnida												
Hydracarina	FG7	X	X	X	X	X	X	X	X	X	X	X
Insecta												
Ephemeroptera	FG1											X
Family Baetidae	FG1										X	X
<u>Baetis</u>	FG1	X	X	X	X	X	X	X	X	X	X	X
Family Baetiscidae												
<u>Baetisca</u>	FG1									X		
<u>Centroptilum</u>	FG1						X					
<u>Pseudocloeon</u> sp.	FG3					X						
Family Caenidae												
<u>Caenis</u>	FG1	X	X	X	X	X	X	X	X	X	X	X
Family Ephemerellidae	FG1		X			X				X		X
<u>Danella simplex</u>	FG1			X		X			X			
<u>Ephemerella</u>	FG1											X
<u>Ephemerella invaria</u>	FG1	X	X	X	X	X	X		X	X	X	
<u>Eurylophella</u> sp.	FG1											X
<u>Eurylophella temporalis</u>	FG1	X	X	X	X	X	X	X	X	X	X	X
<u>Serratella deficiens</u>	FG1	X				X			X	X		
Family Heptageniidae	FG1	X			X	X		X			X	X
<u>Heptagenia</u>	FG3	X				X				X	X	X
<u>Pseudiron</u>	FG4										X	X
<u>Stenacron</u> sp.	FG1								X			X
<u>Stenacron interpunctatum</u>	FG1		X	X	X	X	X	X			X	
<u>Stenonema</u> sp.	FG1											X
<u>Stenonema modestum</u>	FG1	X	X	X	X	X	X	X	X	X	X	
Family Leptophlebiidae												
<u>Paraleptophlebia</u>	FG1								X	X		
Family Neoephemeridae	FG1	X										
<u>Neoephemera youngi</u>	FG1	X	X	X		X	X		X	X		
Family Oligoneuriidae												
<u>Isonychia</u>	FG2		X	X			X		X	X		
Family Tricorythidae												
<u>Tricorythodes</u>	FG1		X	X	X	X	X		X	X	X	X
Odonata												
Anisoptera	FG4		X	X				X	X	X	X	X
Family Aeshnidae	FG4											X
<u>Boveria</u> spp.	FG4											X
<u>Boveria vinosa</u>	FG4		X	X		X	X	X		X	X	X
<u>Nasiaeshna pentacantha</u>	FG4		X	X								
Family Corduliidae												
<u>Neurocordulia molesta</u>	FG4					X	X	X				X
<u>Tetragoneuria</u> sp.	FG4											X

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Table 4.5.3-11. List of Macroinvertebrate Taxa Collected from Multiplate Samplers in Beaver Dam Creek (September 1988 - February 1990) and SRS Streams (Source: Specht 1987) (Continued)

Taxon	Functional Group[a]	Streams[b] UTR	FM	PB	PBS	SC	SCD	SCS	MB	LTR	Beaver Dam Creek 1984-1986	Beaver Dam Creek 1988-1990
Family Gomphidae	FG4					X					X	X
Hagenius brevistylus	FG4							X				
Family Libellulidae	FG4											X
Erythemis simplicicollis	FG4						X					X
Pachydiplax longipennis	FG4				X							
Family Macromiidae	FG4											X
Didymops tranversa	FG4											X
Macromia spp.	FG4											X
Zygoptera	FG4		X	X	X	X	X	X		X	X	X
Family Calopterygidae	FG4											X
Calopteryx	FG4						X	X			X	
Hetaerina spp.	FG4		X	X		X					X	X
Hetaerina titia	FG4											X
Family Coenagrionidae	FG4						X		X		X	X
Argia	FG4	X	X	X	X	X	X	X	X	X	X	X
Enallagma	FG4		X	X	X	X	X	X		X	X	X
Ischnura spp.	FG4			X			X				X	X
Plecoptera	FG4	X		X		X			X			X
Family Capniidae												
Allocapnia virginiana	FG6								X	X		
Family Chloroperlidae												
Alloperla furcula	FG4	X										
Family Leuctridae												
Leuctra	FG6	X										
Family Nemouridae	FG6											X
Amphinemura nigritta	FG6								X			
Family Perlidae	FG4	X	X	X		X			X	X		X
Acroneuria abnormis	FG4	X		X	X	X			X	X		X
Agnetina	FG4					X				X		
Paragnetina fumosa	FG4	X		X		X	X		X	X		
Perlesta spp.	FG4											X
Perlesta placida	FG4	X	X	X	X	X	X	X	X	X	X	
Neoperla	FG4	X										
Family Perlodidae												
Clioperla clio	FG4					X						
Helopicus bogaloosa	FG4	X	X	X		X			X			
Isoperla	FG4	X	X	X		X	X		X			
Family Pteronarcyidae												
Pteronarcys dorsata	FG6	X	X	X		X			X	X		
Family Taeniopterygidae	FG3											
Taeniopteryx longicera	FG6	X	X	X		X			X	X		
Taeniopteryx robinae	FG6		X	X					X	X		
Hempiptera												
Family Corixidae -	FG5											X
Family Naucoridae												
Pelocoris	FG7						X					
Coleoptera	FG4											X

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Table 4.5.3-11. List of Macroinvertebrate Taxa Collected from Multiplate Samplers in Beaver Dam Creek (September 1988 - February 1990) and SRS Streams (Source: Specht 1987) (Continued)

Taxon	Functional Group[a]	Streams[b]									Beaver Dam Creek	
		UTR	FM	PB	PBS	SC	SCD	SCS	MB	LTR	1984-1985	1988-1990
Coleoptera (Continued)												
Family Curculionidae	FG6						X				X	X
Family Dryopidae												
<u>Helichus</u>	FG3			X					X			
Family Dytiscidae				X								X
<u>Hydroporus</u>							X					
<u>Lioporius</u> <u>pilatei</u>						X						
Family Elmidae	FG1	X	X	X		X	X		X	X	X	X
<u>Ancyronyx</u> <u>variegatus</u>	FG1	X	X	X	X	X	X		X	X	X	X
<u>Dubiraphia</u>	FG1	X	X			X			X		X	
<u>Macronychus</u> <u>glabratus</u>	FG1	X	X	X	X	X	X	X	X	X	X	X
<u>Microcylloepus</u> <u>pusillus</u>	FG1		X	X		X	X	X	X		X	X
<u>Gonielmis</u> sp.	FG1	X										
<u>Promoresia</u> <u>elegans</u>	FG1	X										
<u>Stenelmis</u>	FG3	X	X	X	X	X	X	X	X	X	X	X
Family Eubriidae												
<u>Ectopria</u> <u>nervosa</u>	FG3			X	X	X			X	X		
Family Gyrinidae												X
<u>Dineutes</u>	FG4	X		X	X	X	X	X	X	X	X	X
<u>Gyrinus</u>	FG4		X		X		X	X	X		X	X
Family Haliplidae												
<u>Peltodytes</u> spp.	FG5											X
Family Hydrophilidae												
<u>Hydrochus</u> sp.	FG6											X
Family Hydrophilidae												
<u>Berosus</u>	FG5/FG6				X		X	X		X	X	X
<u>Hydrobius</u>	FG4/FG1		X									
Family Noteridae	FG4											X
<u>Hydrocanthus</u>	FG4											X
Megaloptera												
Family Corydalidae	FG4	X									X	X
<u>Chauliodes</u>	FG4							X				X
<u>Corydalus</u> <u>cornutus</u>	FG4	X	X	X	X	X	X	X	X	X	X	X
<u>Nigronia</u>	FG4			X		X						
Neuroptera												
Family Sialidae												
<u>Sialis</u>	FG4			X		X			X			
Family Sisyridae	FG7											
<u>Climacia</u> <u>areolaris</u>	FG7											X
Trichoptera	FG1											X
Family Brachycentridae												
<u>Brachycentrus</u>	FG2	X		X	X	X	X	X	X	X	X	
Family Calamoceratidae												
<u>Anisocentropus</u>	FG6									X		
Family Hydropsychidae	FG2	X	X	X		X			X		X	X
<u>Cheumatopsyche</u> spp.	FG2	X	X	X	X	X	X	X	X	X	X	X
<u>Hydropsyche</u>	FG2	X	X	X	X	X	X	X	X	X	X	X
<u>Macrostemum</u> <u>carolina</u>	FG2		X	X		X	X	X	X	X	X	X

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FG-2 - Collector - filterer
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Table 4.5.3-11. List of Macroinvertebrate Taxa Collected from Multiplate Samplers in Beaver Dam Creek (September 1988 - February 1990) and SRS Streams (Source: Specht 1987) (Continued)

Taxon	Functional Group[a]	Streams[b] UTR	FM	PB	PBS	SC	SCD	SCS	MB	LTR	Beaver Dam Creek 1984-1986	Beaver Dam Creek 1988-1990
Family Hydroptilidae	FG5									X		X
Hydroptila	FG5	X	X			X	X	X	X		X	X
Mayatrichia	FG3	X										X
Ochrotrichia	FG1							X				
Orthotrichia	FG5	X				X		X		X		
Oxyethira	FG5	X	X	X	X	X	X	X	X	X	X	X
Family Lepidostomatidae												
Lepidostoma	FG6	X										
Family Leptoceridae	FG1											
Ceraclea	FG1	X		X		X		X	X	X	X	X
Nectopsyche	FG6		X	X		X	X		X			X
Nectopsyche candida	FG6	X				X	X			X	X	X
Oecetis	FG4	X	X	X	X	X	X	X	X	X	X	X
Triaenodes spp.	FG6	X	X						X		X	X
Family Limnephilidae								X				
Pycnopsyche	FG6	X			X	X	X	X	X			
Family Philopotamidae	FG2											X
Chimarra	FG2	X	X	X		X	X	X	X	X	X	X
Family Polycentropodidae	FG2					X			X		X	X
Cernotina	FG4		X		X		X	X			X	X
Cyrnellus	FG2									X	X	X
Neureclipsis	FG2		X			X	X		X		X	X
Nyctiophylax	FG4								X			
Polycentropus	FG4	X	X	X	X	X	X	X		X	X	X
Phylocentropus	FG2				X	X			X	X		
Family Psychomyiidae												
Lype diversa	FG1	X	X	X	X	X		X	X	X	X	
Lepidoptera	FG6											X
Family Pyralidae	FG6											X
Munroessa	FG6										X	X
Neargyractis	FG3		X				X				X	X
Parapoynx	FG6	X	X				X	X		X	X	X
Synclita	FG6						X				X	
Diptera												
Family Ceratopogonidae	FG4	X	X	X	X	X	X	X	X	X	X	X
Bezzia	FG4							X		X		
Subfamily Ceratopogoniinae	FG4											X
Subfamily Forcipomyiinae	FG1	X	X	X	X	X				X	X	X
Atrichopogan	FG1	X										
Family Chaoboridae												
Chaoborus punctipennis	FG4				X	X		X	X		X	X

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Table 4.5.3-11. **List of Macroinvertebrate Taxa Collected from Multiplate Samplers in Beaver Dam Creek (September 1988 - February 1990) and SRS Streams (Source: Specht 1987) (Continued)**

Taxon	Functional Group[a]	Streams[b]									Beaver Dam Creek	
		UTR	FM	PB	PBS	SC	SCD	SCS	MB	LTR	1984-1985	1988-1990
[c]Family Chironomidae	FG1											
Subfamily Chironominae	FG5											X
Tribe Chironomini (unid.)	FG1	X	X	X	X	X	X	X	X	X	X	
Chironomus sp.	FG1											X
Cladopelma sp.	FG1											X
Cryptochironomus sp.	FG4											X
Dicrotendipes sp.	FG1											X
Glyptotendipes sp.	FB6											X
Microtendipes sp.	FG2											X
Nilothauma sp.	FG1											X
Parachironomus sp.	FG4											X
Phaenopsectra sp.	FG3											X
Polypedilum sp.	FG1											X
Saetheria sp.	FG1											X
Stelechomyia spp.	FG1											X
Stelechomyia perpulchra	FG1											X
Stenochironomus sp.	FG6											X
Stictochironomus	FG1											X
Tribelos sp.	FG1											X
Pseudochironomus sp.	FG1											X
Robackia claviger	FG1											X
Tribe Tanytarsini	FG2					X		X				
Tribe Tanytarsini (unid.)	FG2	X	X	X	X	X	X	X	X	X	X	X
Nimbocera sp.	FG2											X
Rheotanytarsus sp.	FG2											X
Tanytarsus (T.) spp.	FG2											X
Subfamily Diamesinae	FG1											X
Potthastia	FG1	X		X	X	X	X	X	X	X	X	X
Subfamily Orthocladiinae	FG1	X	X	X	X	X	X	X	X	X	X	X
Subfamily Orthocladiinae (unid.)	FG1											X
Brillia sp.	FG1											X
Cardiocladius sp.	FG4											X
Cricotopus sp.	FG1											X
Cricotopus bicinctus gr.	FG1											X
Nanocladius sp.	FG1											X
Parakiefferiella sp.	FG1											X
Parametriocnemus sp.	FG1											X
Rheocricotopus sp.	FG1											X
Symposiocladius sp.	FG6											X
Tvetenia sp.	FG1											X
Corynoneura sp.	FG1											X
Thienemanniella sp.	FG1											X

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[c] Chironomidae were identified to genus level in the Beaver Dam Creek 1988 - 1990 study only.

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Table 4.5.3-11. List of Macroinvertebrate Taxa Collected from Multiplate Samplers in Beaver Dam Creek (September 1988 - February 1990) and SRS Streams (Source: Specht 1987) (Continued)

Taxon	Functional Group[a]	Streams[b]									Beaver Dam Creek	
		UTR	FM	PB	PBS	SC	SCD	SCS	MB	LTR	1984-1986	1988-1990
Subfamily Tanypodinae	FG4	X	X	X	X	X	X	X	X	X	X	X
Subfamily Tanypodinae (unid.)	FG4											
Clinotanypus sp.	FG4											X
Coelotanypus sp.	FG4											X
Nilotanypus sp.	FG4											X
Procladius sp.	FG4											X
Tribe Pentaneuriini (unid.)	FG4											
Ablabesmyia sp.	FG4											X
Conchapelopia gr.	FG4											X
Labrundinia sp.	FG4											X
Larsia sp.	FG4											X
Monopelopia sp.	FG4											X
Family Tabanidae (unid.)	FG7									X		
Chrysops sp.	FG1									X		X
Tabanus sp.	FG7											X
Family Stratiomyidae												
Odontomyia sp.	FG1											X
Family Athericidae												
Atherix	FG4	X										
Family Empididae	FG4	X	X	X		X	X	X	X	X	X	X
Chelifera	FG4											X
Dolichocephala	FG4											X
Hemerodromia	FG4	X							X			X
Family Ephydridae	FG1											X
Family Muscidae	FG4									X		
Family Psychodidae	FG1											
Telmatoscopus	FG1											X
Family Simuliidae	FG2	X	X	X		X			X	X		
Simulium	FG2	X	X	X	X	X	X	X	X	X	X	X
Family Tipulidae	FG6			X		X						X
Antocha	FG1						X					
Helius	FG6											
Limonia	FG6											X
Tipula	FG6	X	X	X		X			X	X		X

[a] FG-1 - Collector - gatherer
FG-2 - Collector - filterer
FG-3 - Scraper
FG-4 - Engulfer - predator
FG-5 - Piercer - herbivore
FG-6 - Shredder
FG-7 - Piercer - carnivore

[b] UTR - Upper Three Runs
FM - Four Mile
PB - Pen Branch
PBS - Pen Branch Swamp
SC - Steel Creek
SCD - Steel Creek Delta
SCS - Steel Creek Swamp
MB - Meyer's Branch
LTR - Lower Three Runs

[c] Chironomidae were identified to genus level in the Beaver Dam Creek 1988 - 1990 study only.

Beaver Dam Creek. The overall taxonomic composition of the streams is fairly similar. Most of the common taxa in SRS non-thermal streams were also collected in Beaver Dam Creek. However, differences in physical characteristics, such as water velocity, substrate composition and canopy cover create different habitats, which result in differences in species dominance among the streams or stations within a stream.

The mean density of organisms in Beaver Dam Creek ranged from 773.8 to 2348.0 organisms/m^2, which is somewhat higher than the densities reported for Upper Three Runs Creek (582.7 organisms/m^2), Meyer's Branch (565.0 to 876.9 organisms/m^2), and Steel Creek (484.7 to 1446.6 organisms/m^2), but similar to the densities reported for the unperturbed section of Four Mile Creek (2109.3 organisms/m^2), Pen Branch swamp (1620.0 organisms/m^2) and Lower Three Runs Creek (743.5 to 1932.3 organisms/m^2), excluding the station on Lower Three Runs Creek that was just below the Par Pond Dam, where densities are influenced by seston inputs from Par Pond and averaged 5549.8 organisms/m^2 (Table 4.5.3-9). Densities from the Satilla River (Benke et al., 1984) and Cedar Creek (Smock et al., 1985) are not directly comparable to the densities reported for Beaver Dam Creek, since the samples were processed through finer mesh sieves (100 µm and 150 µm), which retained many of the early instars that pass through the standard 600 µm (U.S. Standard #30) sieve (Weber, 1973) that was used to process samples from Beaver Dam Creek and streams sampled during the CCWS.

Macroinvertebrate biomass in Beaver Dam Creek ranged from 0.185 to 0.394 g/m^2, while biomass in other SRS streams ranged from 0.073 g/m^2 (Meyer's Branch) to 0.715 g/m^2 (Steel Creek delta; Table 4.5.3-9). Biomass in the Satilla River ranged from 0.359 to 0.376 g/m^2, and in Cedar Creek biomass ranged from 0.188 to 0.491 g/m^2 (Table 4.5.3-10).

These data indicate that species richness in Beaver Dam Creek, particularly at Station 1, may be somewhat lower than in other southeastern streams, but that with respect to overall taxonomic composition, density of organisms and biomass, Beaver Dam Creek is similar to unimpacted streams in the southeast.

In summary, Beaver Dam Creek supports a reasonably diverse and productive macroinvertebrate community, which is not unlike those found in many southeastern coastal plain streams. However, operating conditions that existed during the collection of these data differ somewhat from those that will exist during full operating conditions, and further study will be necessary to determine the effect of normal operating conditions, with thermal mitigation via increased pumping, on the macroinvertebrate community.

4.5.4 Fish

This section summarizes the results of fish sampling conducted in Beaver Dam Creek from September 1988 through February 1990 and compares these data with data collected during the Comprehensive Cooling Water Overwintering Study (1983-1985) and the Comprehensive Cooling Water Study (1984 - 1985) and also with data from other regional streams. Data contained in this section are summarized from Nagle et al. (1990).

4.5.4.1 Adult Fish

Six stations in Beaver Dam Creek were sampled monthly from September 1988 through February 1990 by boat electrofishing. There were three contiguous 100 m transects at each sample station. Initially, all six stations were also sampled by hoopnetting (two nets per sample station). However, hoopnet sampling was permanently suspended at Stations 2, 3, and 4 after January 1989 to prevent accidental trapping of alligators. For similar reasons, hoopnet sampling was temporarily suspended at all stations during March and April, the months of maximum alligator movement on SRS streams.

Species Composition and Abundance of Adult Fish. A total of 2,627 adult and juvenile fish, representing 45 species, was collected by electrofishing and hoopnetting over the 18 month study. Most of the fish (2,294 individuals and 43 species) were collected by electrofishing.

The number of fish collected by electrofishing ranged from 561 at Station 2 and 532 at Station 5 to 167 at Station 1 (Table 4.5.4-1). The number of species collected from each station was less variable ranging from 25 - 32. Electrofishing catches varied on a monthly basis, and long term patterns were not evident (Figure 4.5.4-1),

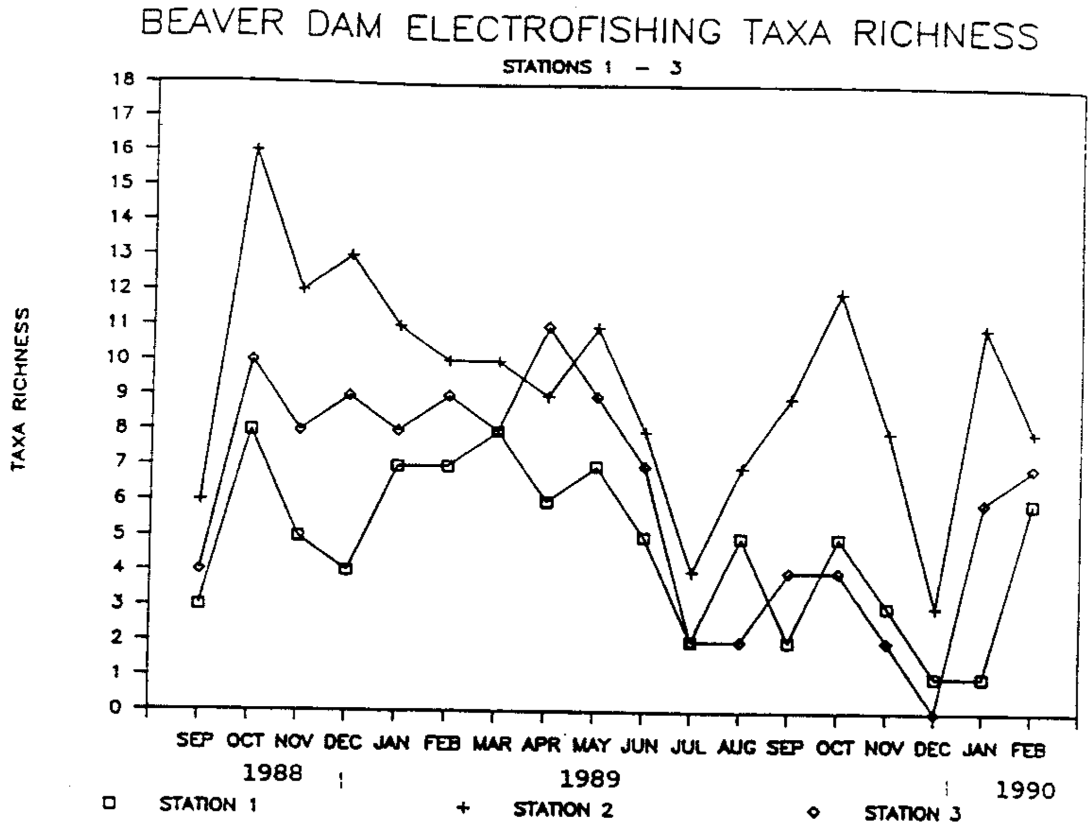
The results of 2-way ANOVA (split-plot design) and Tukey's Studentized Range (HSD) Tests indicated that electrofishing taxa number differed significantly among stations ($p \leq 0.05$) and that fewer taxa were collected at Station 1 than at the other stations. Station 1 is located closest to the D-Area outfall and is more strongly influenced by high flow rates than the other sample stations. A major portion of the sample area at Station 1 is strongly channelized with little vegetation or instream structure to serve as foraging or refuge areas for fish. Stations 2, 4, and 5, in contrast, are generally open canopy with abundant aquatic and shoreline vegetation.

For further analysis, the electrofishing data were converted to catch per unit effort (CPUE expressed as number caught per 100 m) 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 2 to approximately 3.1 fish/100 m at Station 1 (Table 4.5.4-2). The overall mean for all stations was 7.1 fish/100 m. CPUE fluctuated widely on a monthly basis, reaching as high as 23.7 fish/100 m and as low as 0.0 fish/100 m (Figure 4.5.4-2). CPUEs of 0.0 occurred only in December 1989, when Stations 3, 4, 5, and 6 were inundated by Savannah River flood waters. Flooding greatly increased water depth at these stations and allowed fish to disperse into the surrounding floodplain.

Table 4.5.4-1. Total Number of Fish and Species Collected by Electrofishing in Beaver Dam Creek. September 1988 - February 1990.

Species	Stations 1	2	3	4	5	6	All Stations 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
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		1
speckled madtom						1	1
lined topminnow		2		3			5
mosquitofish	1			1			2
brook silverside	1		2	4	2		9
stiped 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.



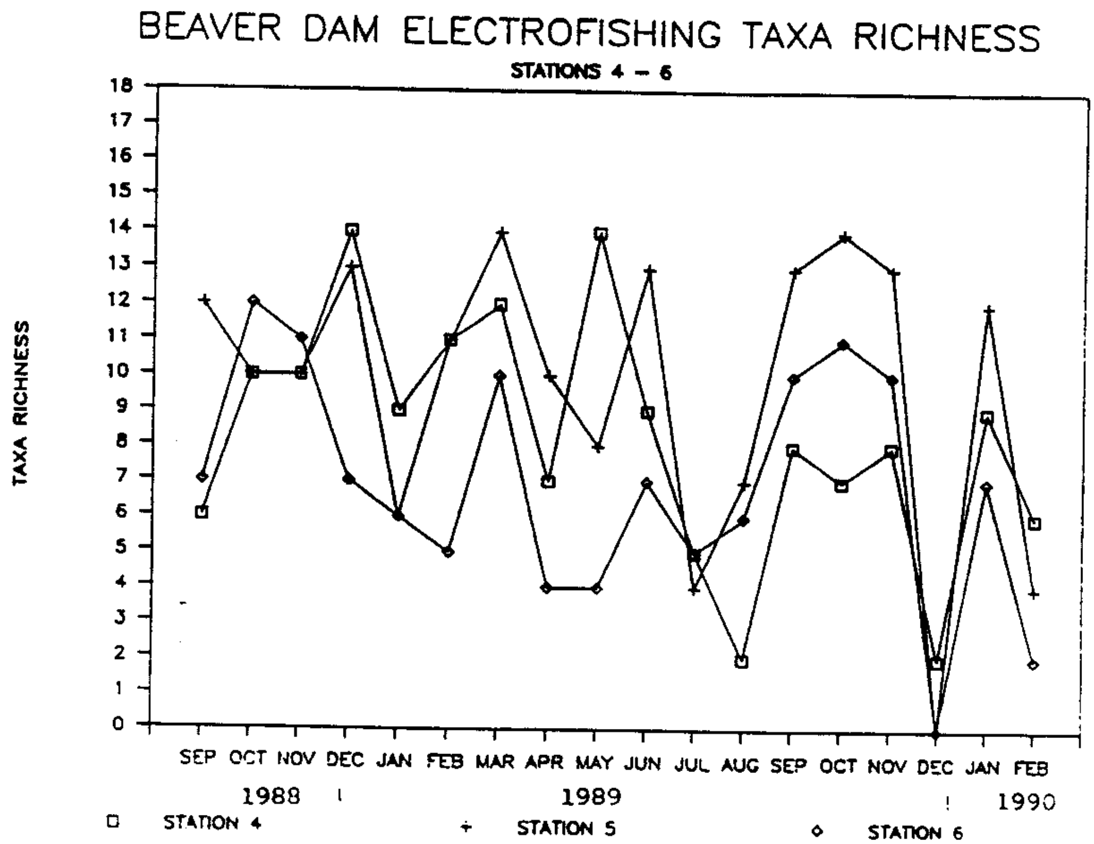


Figure 4.5.4-1. Monthly Electrofishing Taxa Richness at Each Station in Beaver Dam Creek. September 1988 – February 1990.

Table 4.5.4-2. Electrofishing CPUE (no./100 m) at Stations 1 - 6 in Beaver Dam Creek. September 1988 - February 1990.

Species	Stations 1	2	3	4	5	6	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
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	0.15	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	0.44	0.15	0.19
Total # fish/100 m	3.09	10.39	6.05	7.00	9.85	6.09	7.08

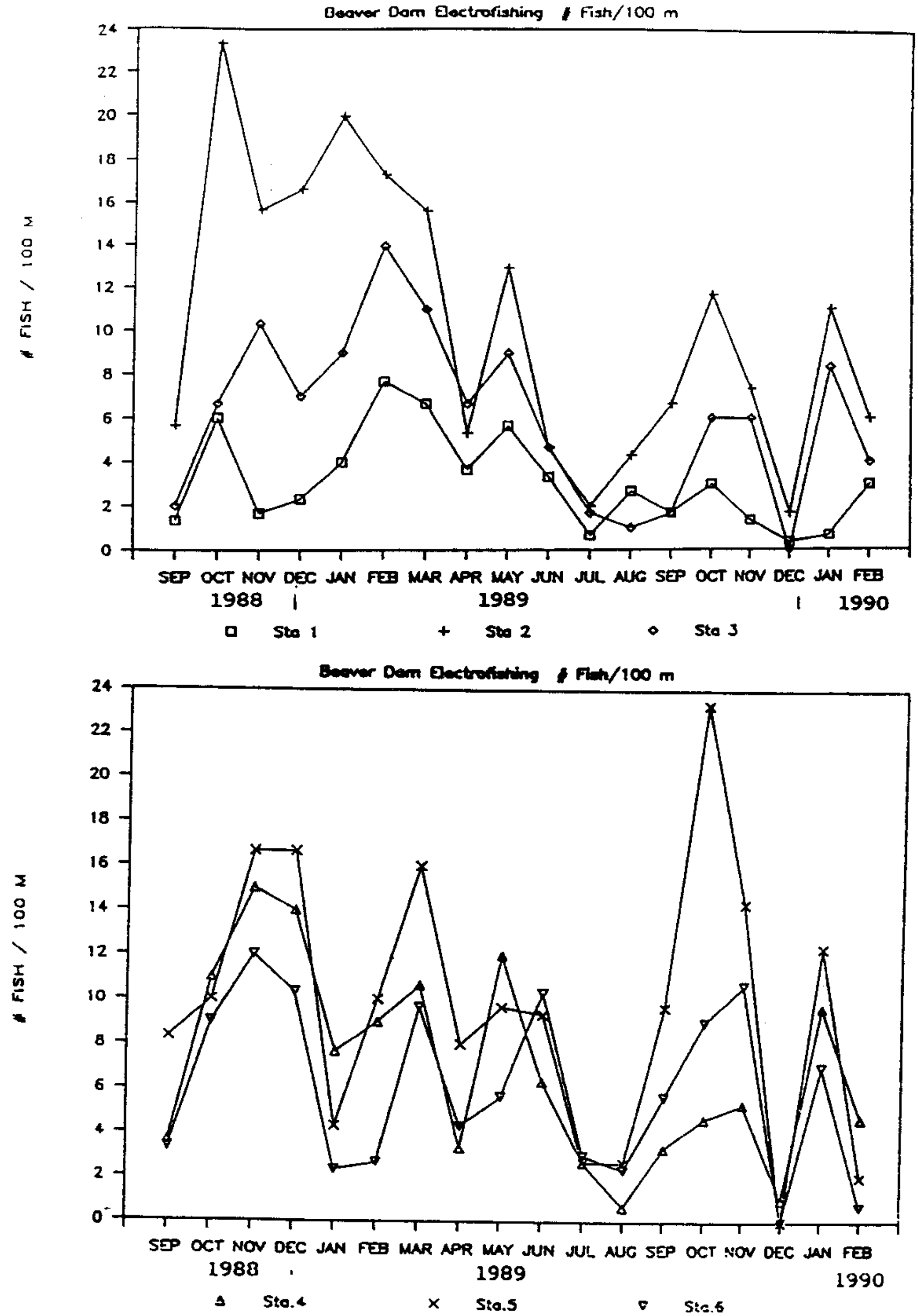


Figure 4.5.4-2. Monthly Electrofishing CPUE (No./100 m) at Each Station in Beaver Dam Creek. September 1988 - February 1990

ANOVA (split-plot design) and Tukey's Studentized Range (HSD) Tests indicated that CPUE differed significantly ($p \leq 0.05$) among stations and was significantly lower at Station 1 than at the other stations. Species number at Station 2 was significantly higher than at Stations 3, 6, and 1. The low CPUE at Station 1 was probably a result of high current velocities and relatively poor habitat. Other differences were probably the result of local variations in instream structure, vegetation, substrate, current velocity and other factors that influenced habitat quality and sampling efficiency.

The most abundant (by number) species 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). Sunfish (Centrarchidae) were the most abundant family, composing nearly 40% of the fish collected from Beaver Dam Creek. Minnows and shiners (26%) and suckers (17.3%) were also abundant (Figure 4.5.4-3, Table 4.5.4-3). Several taxa, including the bannerfin shiner, blackbanded darter and channel catfish, 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.

Fewer fish (333 specimens representing 17 species) were collected by hoopnetting than by electrofishing (Table 4.5.4-4). The greatest number of fish (96) and greatest number of species (13) were collected from Station 6, located in the mouth of Beaver Dam Creek. While Stations 2, 3, and 4 were sampled for only four months due to the high potential for alligator mortality, they yielded a total of 13 species and 99 individuals indicating that fish were abundant at these stations. Hoopnet catches were low during the winter of both 1989 and 1990, probably because of seasonal reductions in fish activity and movement.

ANOVA (split-plot design) and Tukey's Studentized Range (HSD) Tests of the hoopnetting taxa richness data indicated that taxa richness did not differ significantly among stations. Only Stations 1, 5, and 6 were included in this analysis to maintain equal sample sizes at each station.

For further analysis, the hoopnetting data were converted to catch per unit effort (CPUE expressed as number caught per net per day, Table 4.5.4-5). Mean CPUE for Stations 1, 5, and 6 ranged from 0.71 - 1.00 fish/net day. Mean CPUE for the stations sampled only during the first four months of the study ranged from 1.0 fish/net day at Station 4 to 2.5 fish/net day at Station 2. The highest average monthly CPUE was 2.8 fish/net day recorded in May 1989 (Figure 4.5.4-4). Catch rates were generally higher during the warmer months. Zero catch rates occurred most often during the fall and winter of 1988 - 1989, especially at Station 1. ANOVA of the hoopnet CPUE data from Stations 1, 5, and 6 indicated that these stations were not significantly different at $p \leq 0.05$.

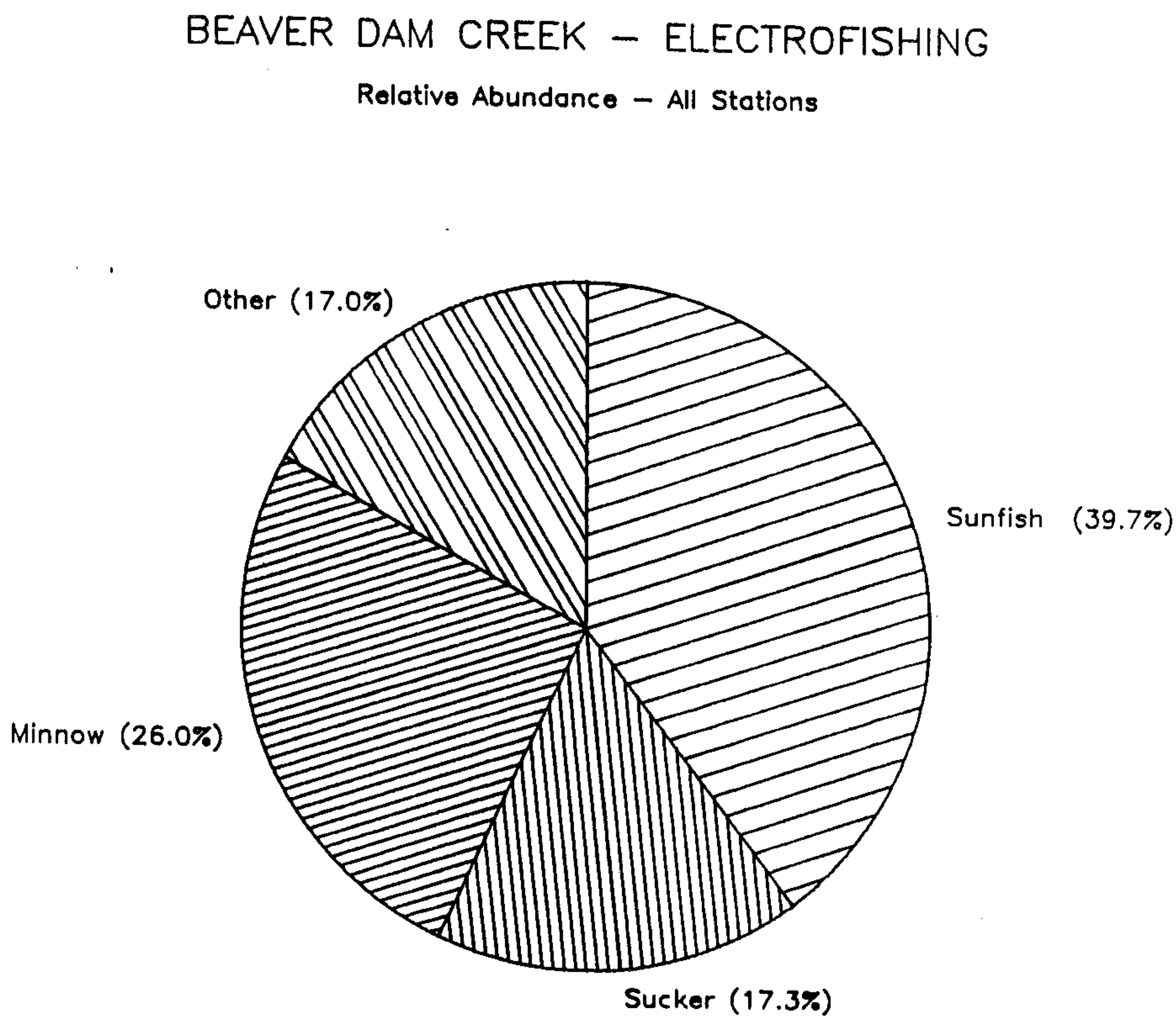


Figure 4.5.4-3. Relative Abundance of Fish Taxa Collected by Electrofishing at Each Station in Beaver Dam Creek. September 1988 – February 1990

Table 4.5.4-3. Relative Abundance (Percent Composition) of Species Collected by Electrofishing at Stations 1 - 6 in Beaver Dam Creek. September 1988 - February 1990.

Species	Stations 1	2	3	4	5	6	All Stations 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
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 4.5.4-4. Total Number of Fish and Species Collected by Hoopnetting in Beaver Dam Creek. No Hoopnets Were Set During March and April, 1989. September 1988 - February 1990.

Species	Stations						All Stations Combined
	1	2[a]	3[a]	4[a]	5	6	
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 # species	10	7	3	11	9	13	17

[a] Sampling at these stations was discontinued after December due to the danger hoopnets present to the large alligator population at these stations.

[b] Not included in taxa count.

Table 4.5.4-5. Hoopnetting CPUE (no./net day) at Stations 1 - 6 in Beaver Dam Creek. September 1988 - February 1990[a].

Species	Stations 1	2[a]	3[a]	4[a]	5	6
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	2.46	0.67	1.00	0.73	1.00

[a] Stations 2, 3, and 4 discontinued after four months. No nets were set in March or April, 1989.

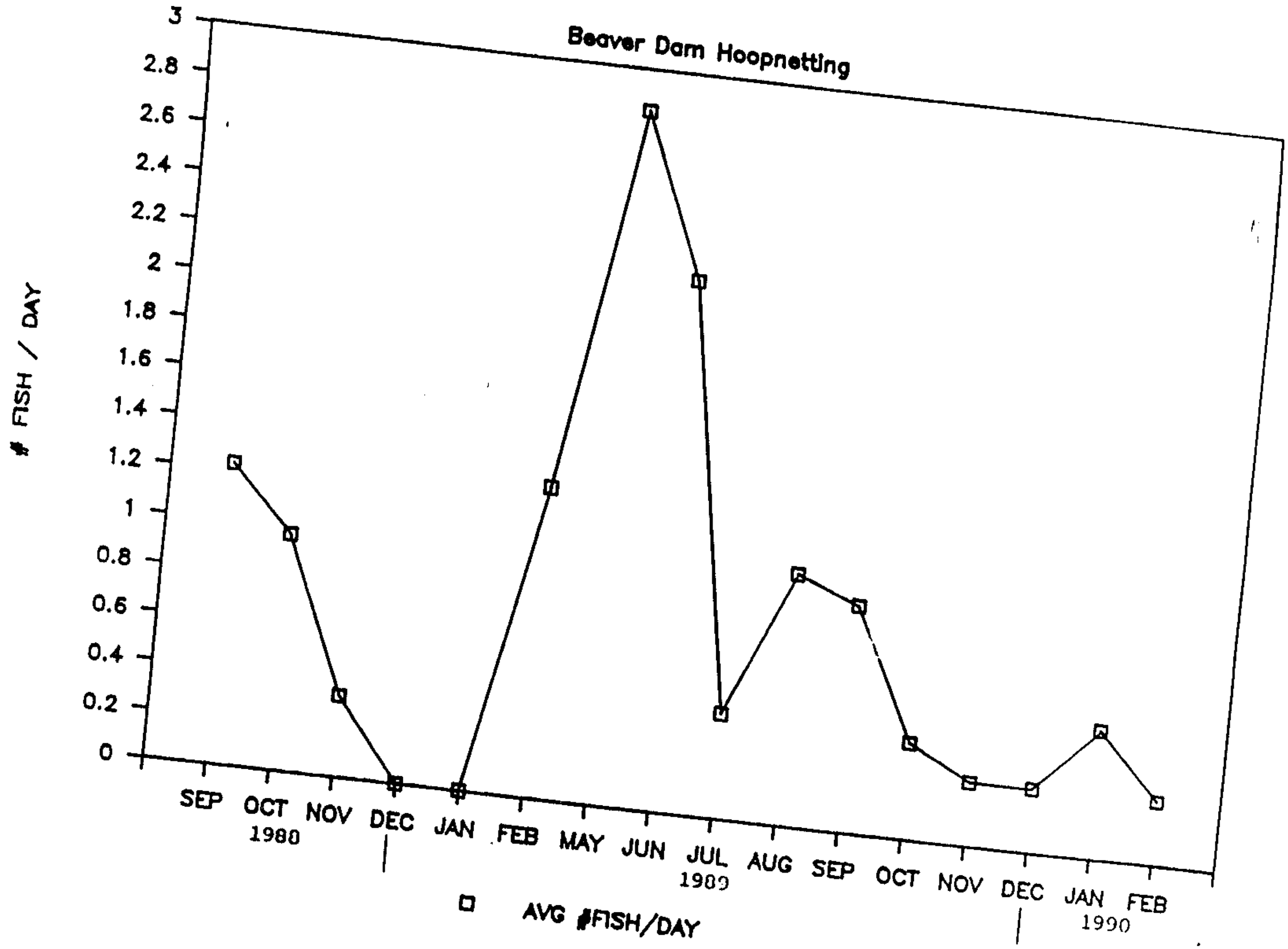


Figure 4.5.4-4. Monthly Mean Hoopnetting CPUE (No./Net Day) in Beaver Dam Creek. September 1988 - February 1990

Channel catfish (Ictalurus punctatus) 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 4.5.4-6). No other species constituted more than 4.0% of the total catch. The predominance of these species reflects the selectivity of hoopnets for relatively large fish that utilize bottom habitats. Species composition at Stations 1, 5, and 6 (which were sampled more consistently than Stations 2, 3, and 4) was fairly similar, although white catfish (Ictalurus catus) and flat bullhead were better represented at Stations 5 and 6. These species may have entered the lower reaches of Beaver Dam Creek (where Stations 5 and 6 are located) from the Savannah River.

4.5.4.2 Ichthyoplankton

Paired 0.5 m (0.505 mm mesh) plankton nets mounted side by side in an aluminum frame were used to collect ichthyoplankton (drifting fish larvae and eggs) from Beaver Dam Creek. The nets were suspended in the current at a depth of 0.5 m until approximately 50 m^3 of water was filtered by each net. An attempt was made to sample all stations weekly, although some samples were missed because of low water levels (Station 1) or flooding (Station 6). The Beaver Dam Creek sampling program encompassed only one complete spawning season, from February through July 1989. While small numbers of larvae and eggs were also collected in February 1990, they are not included in the following analyses.

A total of 82 larval fish and 15 fish eggs, representing at least nine taxa, were collected from Beaver Dam Creek during February through July 1989 (Table 4.5.4-7). Station 6 had the most ichthyoplankton (42 specimens) and the most taxa (7 excluding unknowns), followed by Station 5 (21 specimens and four taxa) and Station 2 (14 specimens and four taxa). Stations 1 and 3 had only five specimens each. The greatest ichthyoplankton catches were in April (55 specimens) and May (17 specimens) (Table 4.5.4-8). Few ichthyoplankton were collected in the remaining four months of the ichthyoplankton sampling period. Centrarchids were the most abundant group, composing approximately 53% of the total number of larvae and eggs (Figure 4.5.4-5). The most abundant identifiable centrarchids included Lepomis spp., bluegill, and pygmy sunfish (Elassoma spp.) (Table 4.5.4-7). Percids (darters) composed another 20% of the ichthyoplankton collected from Beaver Dam Creek and catostomids (spotted sucker and Erimyzon (chubsucker)) larvae composed approximately 12%.

Mean ichthyoplankton densities ranged from 1.7/1000 m^3 at Station 3 to 15.8/1000 m^3 at Station 6 (Table 4.5.4-9). The mean overall density for all stations was 5.7/1000 m^3. The highest average monthly density for the creek as a whole was in April (21.4/1000 m^3). Monthly density for the other months

Table 4.5.4-6. **Relative Abundance (Percent Composition) of Species Collected by Hoopnetting at Stations 1 - 6 in Beaver Dam Creek. September 1988 - February 1990[a].**

Species	Stations						All Stations Combined
	1	2[a]	3[a]	4[a]	5	6	
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 2, 3, and 4 discontinued after four months. No nets were set in March or April, 1989.

Table 4.5.4-7. **Total Number of Ichthyoplankton Collected from Stations 1 - 6 in Beaver Dam Creek. February - July 1989.**

Taxon	Stage	Stations 1	2	3	4	5	6	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 4.5.4-8. Monthly Ichthyoplankton Collections from Beaver Dam Creek. February - July 1989.

Taxa	FEB	MAR	APR	MAY	JUN	JUL
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

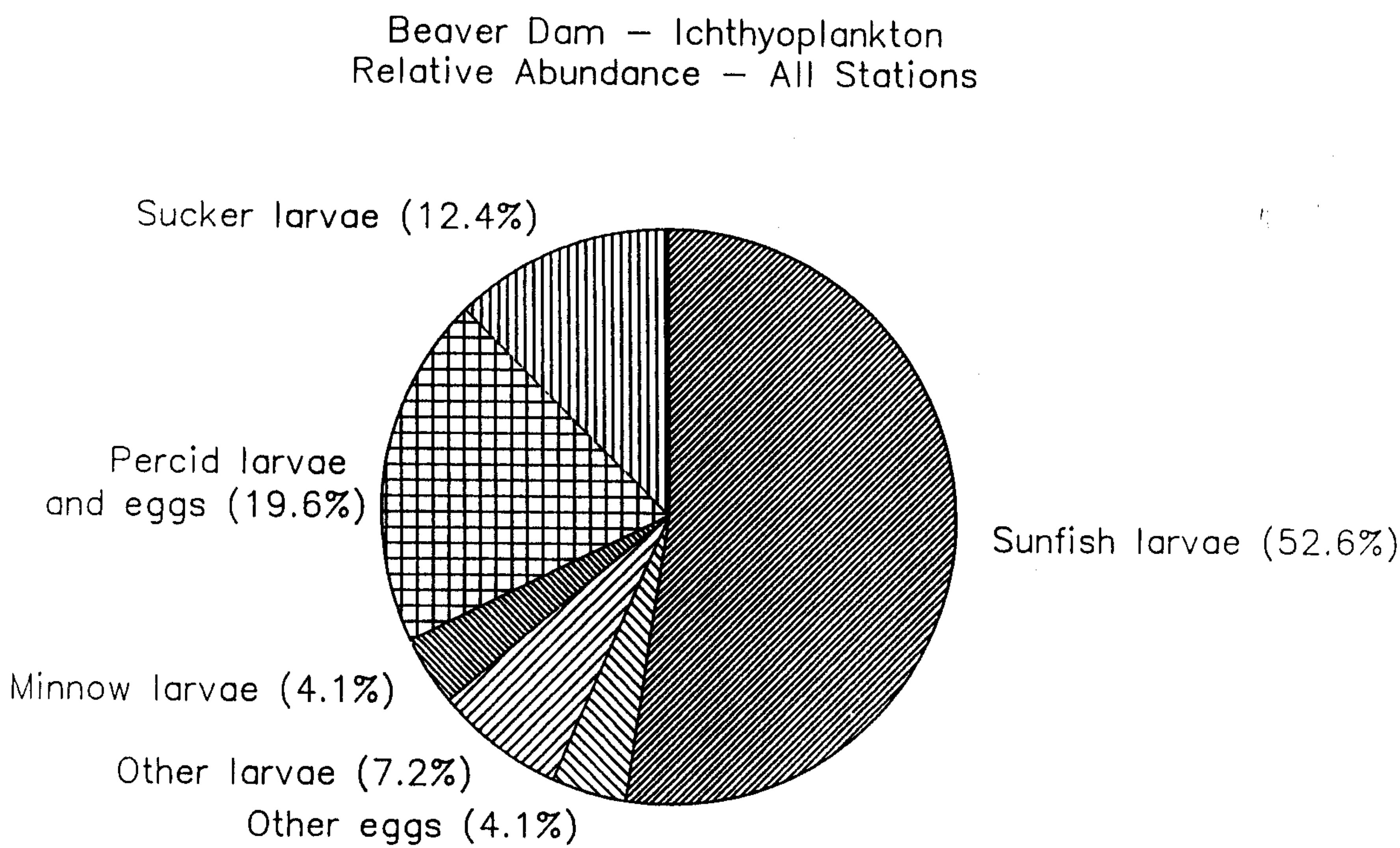


Figure 4.5.4-5. Relative Abundance of Families in Beaver Dam Creek Ichthyoplankton Collections. February - July 1989

Table 4.5.4-9. **Average Densities (Organisms/1000 m^3) of Ichthyoplankton Collected from Stations 1-6 in Beaver Dam Creek. February - July 1989.**

Species	Stage	Station 1	2	3	4	5	6	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.

ranged from 1.6/1000 m^3 in July to 6.4/1000 m^3 in May. Station 6 had the highest mean total density for all months combined (15.8/1000 m^3) followed by Station 5 (6.9/1000 m^3), Station 2 (4.8/1000 m^3), and Station 4 (3.5/1000 m^3).

4.5.4.3 Comparison to Pre-Mitigation (1984 - 1985) Data

Adult Fish. Fisheries data collected from Beaver Dam Creek during the 1984 - 1985 Comprehensive Cooling Water Study (CCWS) can be compared to fisheries data collected during the present (September 1988 - February 1990) monitoring study although such comparisons are weakened by differences in methodology, sample location, and level of effort. The original intent of these comparisons was to determine if the fish community changed as a result of mitigation activities implemented since the 1983 - 1985 studies. However, the lack of mitigation activity in the creek during the the present monitoring study precluded this possibility.

The Comprehensive Cooling Water Study involved two fish sampling programs on Beaver Dam Creek: one quarterly, and one reporting on winter fish distribution (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 3-6; three 100-m transects were sampled at each site. The overwintering study, which was conducted to assess fish distribution during the winter, included one sample station in the mouth of Beaver Dam Creek during 1984 and three sample stations in the mouth (Station 6), lower reaches of the floodplain swamp (roughly analagous to Station 5), and upper reaches of the floodplain (roughly analagous to Station 2) during 1985. Three 100-m electrofishing transects were located in the mouth during 1984; one 100-m electrofishing transect was located at each site during 1985. In addition, hoopnets were set in the mouth of the creek during 1985. Electrofishing methods in the Comprehensive Cooling Water Study were similar to those in the present study except that minnows were not always collected during the CCWS. Species composition data from the Beaver Dam Creek quarterly study will not be included in the following comparisons since this information was not presented in the Comprehensive Cooling Water Study final report.

Table 4.5.4-10 illustrates overall mean electrofishing CPUE values from the mouth of Beaver Dam Creek during the 1984 quarterly study, 1984 overwintering study, and the present study. CPUE was considerably higher in the present study (7.1/100 m) than in the quarterly (1.6/100 m) or overwintering (1.4/100 m) studies. Even if minnows are excluded from the present study, CPUE remains substantially higher than in the previous studies.

Table 4.5.4-10. Comparison of 1983 - 84[a] CCWS Electrofishing Catch Per Unit Effort (No./100m) Near the Mouth of Beaver Dam Creek (Station 6) to Present Study.

Sampling Program	No./100 m[b]
Quarterly	1.6
Overwintering (Nov. - March)	1.4
Present (Sept. 88 - Feb. 90)	6.1

[a]Source: Paller and Osteen (1985).
[b]Mean CPUE in the creek mouth.

Table 4.5.4-11 illustrates CPUE values from Stations 3, 4, 5, and 6 during the quarterly study and the present study. To make the comparison more accurate, CPUE means for the present study were calculated only for the same four months that were sampled in the quarterly study. Again, electrofishing CPUE in the earlier study was substantially lower than in the present study. The same pattern is observed in Table 4.5.4-12 which illustrates mean values for Stations 2, 5, and 6 during the 1985 overwintering study and the present study. Variability in recruitment may be contributing to the interannual differences in CPUE observed among studies. High variability in recruitment is typical of fish populations and can result in large annual fluctuations in abundance (Carpenter and Kitchell, 1987).

Minnows were excluded from the following comparisons of species composition between the present study and the overwintering study, only months sampled during both studies were included in the comparisons. Electrofishing data from the overwintering study indicated that the dominant species, in rank order, at Stations 2, 5, and 6 were spotted sunfish, redbreast sunfish, largemouth bass, bowfin, and gizzard shad (Table 4.5.4-13). Dominant species at the same stations during the present study were spotted sucker, redbreast sunfish, largemouth bass, spotted sunfish, striped mullet and bluegill. The two studies differed in the relative abundance of spotted suckers (dominant during the present study but relatively uncommon during the overwintering study) and bowfin (common during the overwintering study but relatively uncommon during the present study). Definite reasons for these differences are unknown but interannual variations in recruitment and subtle changes in habitat between studies (e.g., aquatic growth) are possible causes. Spotted sunfish, largemouth bass, and redbreast sunfish were dominant taxa during both studies. These taxa are common in southeastern streams.

Table 4.5.4-14 illustrates the mean overall hoopnetting catch rates from the mouth of Beaver Dam Creek (Station 6) during the quarterly study, overwintering study, and the present study. The mean CPUE for the present study (1.0 fish/net day) was higher than for the quarterly study (0.4 fish/net day) but similar to the overwintering study (1.2 fish/net day). Channel catfish were strongly dominant during the present study, constituting 58.3% of the total catch (Table 4.5.4-15). Other taxa showing substantial relative abundance were the snail bullhead (Ictalurus brunneus), white catfish, flat bullhead, redbreast sunfish and bluegill. Channel catfish (23.3%) were also dominant during the over-wintering program but flat bullhead (17.8%), black crappie (Pomoxis nigromaculatus) (13.7%), redear sunfish (8.2%), and blueback herring (Alosa aestivalis) (8.2%) constituted substantial proportions of the catch.

Table 4.5.4-12. Comparison of Electrofishing CPUE (No./100 m) 1984 - 1985 CCWS Overwintering Program and the Present Study.

Sample Site[a]	Overwintering[b] no./100 m	Present no./100m
Station 2	2.6	10.4
Station 5	4.8	9.9
Station 6	1.7	6.1

[a]Overwintering sample sites correspond to stations listed.
[b]Paller and Saul (1986).

Table 4.5.4-13. Dominant Species[a] Collected from Beaver Dam Creek by Electrofishing at Stations 2, 5, and 6 During the CCWS (1983), Overwintering Study (1984 - 1985), and at Each Station During This Study.

Species	
NOVEMBER 1984 - APRIL 1985[b]	SEPTEMBER 1988 - FEBRUARY 1990
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[c] (2.7%)	bluegill (2.2%)

[a]Excluding minnows and other small fishes.
[b]Paller and Saul (1986).
[c]bluegill ranked eighth.

Table 4.5.4-14. Comparison of CPUE (No./Net Day) Hoopnetting in Beaver Dam Creek Between CCWS (1983 - 1985) Collections and the Present Study[a].

	1983-84[b]	1984-85[c]
Quarterly sampling program	0.8	0.4
Overwintering program	NR[d]	1.2
Present study	1.0	

[a]Average CPUE at sample site in the mouth of the creek.
[b]Source: Paller and Osteen (1985).
[c]Source: Paller and Saul (1986).
[d]Beaver Dam Creek hoopnet data not reported separately that year.

Table 4.5.4-15. **Dominant Species Collected from Hoopnets at Station 6 During the CCWS Overwintering Study (1984 - 1985) and the Current Study.**

Species	Relative Abundance (%) NOV 1984 - APR 1985[a]	SEP 1988 - FEB 1990
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[b]	(2.7)	4.2

[a]Paller and Saul (1986).

[b]Bluegill ranked tenth in abundance for November 1984 - April 1985, and sixth for September 1988 - February 1990.

Based on the limited comparable data, hoopnet catch per unit effort varied less between years than electrofishing catch per unit effort. This may be partly a result of more consistent methodology. Hoopnets do not capture minnows; hence, the inconsistent collection of this taxonomic group did contribute to sampling variability as it did with the electrofishing samples. While there was some indication of variability among years, the preceding comparisons, in total, indicate the continued presence of a diverse fish community in Beaver Dan Creek during the period from 1983 through 1989.

Larval Fish. Ichthyoplankton were collected from five sample stations in Beaver Dam Creek during the 1984 - 1985 CCWS. Four of these sample stations were analogous to the stations sampled in 1989: mouth (Station 6), lower swamp (Station 5), slough (Station 4), and upper swamp (Station 3). The fifth station was located upstream of Station 1 in the current study. Sampling methodology was similar for both studies.

The total number of ichthyoplankton collected from Beaver Dam Creek in 1989 (97 individuals) was 29% of the 1984 total (334 individuals, Table 4.5.4-16) and 38% of the 1985 total (253 individuals, Table 4.5.4-17). 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 abundances differed among years. While sunfishes (Centrarchidae) were dominant during 1984 and 1989 (Tables 4.5.4-7 and 4.5.4-16), they constituted a comparatively small proportion of the total catch in 1985 (11.4%, Table 4.5.4-17). Similarly, the relative abundance of clupeids (herring and shad), suckers, darters, and brook silversides varied substantially among years.

Mean ichthyoplankton densities in 1984, 1985, and 1989 were highest in the creek mouth and the stations (4 and 5) in the lower reaches of Beaver Dam Creek (Table 4.5.4-9). 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 ichthoplankton 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.

Table 4.5.4-11. Comparison of Mean Electrofishing CPUE (No./100 m) Between 1984 - 85 CCWS Quarterly Data and Data from the Present Study.

Sample Site[a]	Quarterly[b]	Present[c]
Station 3	4.4	8.6
Station 4	6.3	9.2
Station 5	2.7	9.8
Station 6	1.4	5.7

[a]Quarterly sites correspond to stations listed.
[b]Paller and Saul (1986).
[c]Means taken from Nov 88, Feb 89, May 89, Aug 89. See text.

Table 4.5.4-16. 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/or 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/or 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	
unid. ichthyoplankton[b]	35	10.5	
Total	334	100.0	

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

Table 4.5.4-17. **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/or 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/or bullhead	1	0.4	
unid. ichthyoplankton[b]	118	46.6	
Total	253	100.0	

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

4.5.4.4 Comparison to Regional Streams

Adult Fish. One method of determining the quality of a fish community is to compare it to unimpacted fish communities in similar habitats. The Beaver Dam Creek fish community was compared to fish communities from several non-thermal sites on the SRS and to published data from other southeastern streams (summarized in Paller et al., 1988). While these studies differed in methodology, effort, and the presentation of data, they provided at least general indications of the status of the fish communities under examination. Variables that could be compared included species richness, relative abundance of dominant species and families, and, in some cases, catch per unit effort.

Taxa richness and relative abundance of adult fish in Beaver Dam Creek and the other southeastern streams are presented in Table 4.5.4-18. The on-site streams are Upper Three Runs Creek, Lower Three Runs Creek, and Steel Creek; the first has never received thermal effluent while the others are post-thermal. Lower Three Runs Creek received thermal effluent from 1953 to 1958, and Steel Creek from 1954 to 1968. McFarlane (1976) reported that the recovery of the Steel Creek fish community was "almost complete" by 1976. The offsite creeks included in the comparison are Shoal Creek (AL), Barbaree Creek (AL), the Tennessee-Tombigbee Waterway (TN), Duke swamp (NC), and Haggard Mill Creek (NC). Most of these streams have been anthropogenically influenced to some degree, but none were severely impacted.

Total number of species ranged from 21 in Upper Three Runs Creek to 59 in Steel Creek. The total in Beaver Dam Creek, 45, is near the maximum. The high species number in Beaver Dam Creek is partly a function of sampling effort; however, it also reflects the habitat diversity of this stream which contains swamp, slough, and stream environments. Families particularly rich in species in Beaver Dam Creek include the centrarchids (sunfish and black bass, 9 species), cyprinids (minnows, 8 species), ictalurids (catfish, 7 species), and the catostomids (suckers, 5 species).

Relative abundance estimates indicate that 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 4.5.4-18). While the relative abundances of minnows and sunfishes were within the range of the other southeasterns streams, the relative abundances of suckers and catfishes were greater. The high relative abundance of catfishes in Beaver Dam Creek is due, in part, to the intensive hoopnet sampling effort in this stream but also relects the abundance of these fish. Catfishes may enter Beaver Dam Creek from the Savannah River where they are common (Paller and Saul, 1987). Similarly, many of the spotted suckers collected from Beaver Dam Creek may have originated in the Savannah River where this species has been collected in relatively large numbers (Paller and Saul, 1987).

Table 4.5.4-18. Species Number and Relative Abundance (% Composition) of Fishes in Nine Southeastern Streams. Relative Abundances Are Based on the Number on Individual Fish in Each Family.

Family	Beaver Dam Creek[a] No.	Beaver Dam Creek[a] %	Shoal Creek, AL[b] No.	Shoal Creek, AL[b] %	Barbaree Creek, AL[c] No.	Barbaree Creek, AL[c] %	Tombigbee Waterway, TN[d] No.	Tombigbee Waterway, TN[d] %	Duke Swamp, NC[e] No.	Duke Swamp, NC[e] %
bowfin	1	2							1	1
gars	2	3					1	<1	1	<1
freshwater eels	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 & 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]present study, 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 4.5.4-18. (Continued). Species Number and Relative Abundance (% Composition) of Fishes in Nine Southeastern Streams. Relative Abundances Are Based on the Number on Individual Fish in Each Family.

Family	Haggard Mill Creek[f] No.	Haggard Mill Creek[f] %	Steel Creek[g] No.	Steel Creek[g] %	Lower Three Runs[h] No.	Lower Three Runs[h] %	Upper Three Runs[h] No.	Upper Three Runs[h] %
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 & black basses	11	22	13	39	9	69	7	46
perches	2	4	6	3	4	6		
drums								
mullets			1	<1				
sculpins								
TOTAL	28		59		35		21	

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

CPUE comparisons were restricted to the onsite streams (sampled during the CCWS) where sampling methods were relatively consistent and similar to those in the present study. Quarterly electrofishing CPUE in Upper Three Runs Creek, Steel Creek, and Lower Three Runs Creek ranged from 0.0 - 26.7/100 m (Table 4.5.4-19). CPUE in Beaver Dam Creek (0.7 - 16.6/100 m) fell within this range. Mean quarterly hoopnetting CPUE ranged from 0.43 fish/net day in Upper Three Runs Creek to 0.75 fish/net day in Lower Three Runs Creek (Table 4.5.4-20). 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 compares 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 southeastern streams.

Ichthyoplankton. The nonthermal tributaries sampled for ichthyoplankton during the CCWS were Steel Creek, Upper Three Runs Creek, and Lower Three Runs Creek. 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 4.5.4-21).

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 as reflected in the differences between 1984 and 1985 observed during the CCWS (Table 4.5.4-21).

Additional comparisons were made between the ichthyoplankton data collected from Beaver Dam Creek in 1989 and ichthyoplankton data collected from Steel Creek and Meyer's Branch during 1986 and 1987 (Paller et al., 1988) (Table 4.5.4-22). The most common groups in Beaver Dam Creek were, in rank order, sunfishes, darters, suckers, minnows, and clupeids. The most common groups in Steel Creek were, in rank order, sunfishes, clupeids, minnows, suckers, and darters. If blueback herring, an anadromous species that uses the SRS tributaries of the Savannah River for spawning only, are removed from the list, the rank ordering of the dominant species in both creeks are fairly similar. Meyer's Branch, a large, relatively unimpacted tributary of Steel Creek contained relatively few taxa (5); they were in rank order, darters, minnows, suckers, and sunfishes.

The preceding comparisons stress the fact that ichthyoplanton taxonomic composition and abundance is highly variable among streams and annually. This variability may be responsible for some of the differences between Beaver Dam Creek and the other streams. However, because Beaver Dam Creek is a comparatively small stream, it may be less attractive to some species than

Table 4.5.4-19. **Comparison of Mean Electrofishing Catch Per Unit Effort (no./100 m) from Beaver Dam Creek[a] and Nonthermal Streams[b] on the SRS.**

Creek (no. sample sites)	no./100 m (min.-mas.)	mean CPUE (no./100 m)
Upper Three Runs (3)	0.3 - 10.0	4.1
Steel Creek (1)	0.0 - 7.3	3.3
Lower Three Runs (3)	0.3 - 26.7	9.7
Beaver Dam Creek (6)	0.7 - 17.3	8.4

[a]From Nov 88, Feb 89, May 89, and Aug 89 sample dates.
[b]Adapted from Paller and Saul (1986).

Table 4.5.4-20. **Comparison of Mean Hoopnetting Catch Rates (no./net day) in the Mouths of Beaver Dam Creek[a] and Nonthermal Creeks[b] on the SRS.**

Creek Mouth	no./net day (standard error)
Upper Three Runs	0.43 (0.15)
Steel Creek	0.93 (0.36)
Lower Three Runs	0.75 (0.24)
Beaver Dam Creek	1.38 (0.64)

[a]Calculated from Nov 88, Feb 89, May 89, and Aug 89 sample dates.
[b]From Paller and Saul (1986).

Table 4.5.4-21. Number and Percent Composition of Ichthyoplankton Collected from Steel Creek, Upper Three Runs Creek, and Lower Three Runs Creek. 1984 - 1985.

	Steel Creek				Upper Three Runs Creek				Lower Three Runs Creek			
	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
unid. 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
unid. 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/or 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												
mud minnow	5	0.3										
Amblyopsidae												
swamp fish	8	0.5	1	0.1								

Source: Specht (1987)

Table 4.5.4-21. (Continued) Number and Percent Composition of Ichthyoplankton Collected from Steel Creek, Upper Three Runs Creek, and Lower Three Runs Creek. 1984 - 1985.

	Steel Creek				Upper Three Runs Creek				Lower Three Runs Creek			
	1984		1985		1984		1985		1984		1985	
Taxa	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
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/or bullhead	4	0.3	1	0.1								
Belonidae												
neddlefish	2	0.1										
Percichthyidae												
striped bass			1	0.1								
unid. 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 1513.

[c]Higher taxon not counted if lower taxa were present.

Table 4.5.4-22. **Mean ichthyoplankton density (no./1000 m^3) in Steel Creek (excluding Station 275) and Meyer's Branch in 1986 and 1987[a] and in Beaver Dam Creek in 1989.**

	Steel Creek		Meyer's Branch		Beaver Dam Creek
	1986	1987	1986	1987	1989
longnose gar		0.03			
Clupeidae	0.12	0.12			0.06
blueback herring	10.84	5.06			
American shad	0.62	0.61			
pickerel	0.33	0.04			
Cyprinidae	2.47	2.58	6.1	6.0	0.08
common carp					0.06
ironcolor shiner	2.57	1.46			0.11
Catostomidae					0.24
Erimyzon	0.80	7.97	1.0		0.06
spotted sucker	0.04	0.02	0.5		0.43
redhorse	0.16				
pirate perch	0.02	0.12			
brook silverside	1.72	0.59			
Centrarchidae		0.87		0.2	1.20
Elassoma	4.23	2.54			0.74
bluespotted sunfish	11.78	4.95			
Lepomis	8.19	5.67			1.03
redbreast sunfish		0.04			
warmouth		0.50			
spotted sunfish		0.12			
largemouth bass	0.7				
Pomoxis		0.08			0.12
Percidae					0.05
Percina		1.85	4.1	6.2	0.40
darter	2.59	3.10	2.1		0.55
unknown	1.75	4.97	0.07	0.04	0.60

[a]Adapted from Paller et al. (1987), (1988).

large streams like Steel Creek, Upper Three Runs, and Lower Three Runs. This may be particularly important for some of the anadromous species whose selection of spawning streams is partly dependent on discharge (Frankensteen, 1976).

4.5.5 Wildlife

The number of diverse habitats on the SRS support a wide variety of wildlife. Within the vertebrates alone there can be found as many as 93 species of reptiles and amphibians, 213 species of birds, and 48 species of mammals (Wike et al., 1989). Except for the waterfowl, there is little information regarding wildlife habits and use in the Beaver Dam Creek area.

Waterfowl utilize most of the suitable habitat available on the SRS and large numbers have been present since the site was closed to public access in the early 1950's (Wike et al., 1989). Thirty-one species (not including the wading birds) of waterfowl have been documented as occurring on the SRS between 1952 and 1985; of the 31, eight have been known to occur in the Beaver Dam Creek area (Mayer et al., 1986). The Savannah River Ecology Laboratory (SREL) has been conducting waterfowl research and surveys during the past 16 years, including waterfowl use of the SRS, wood duck reproductive biology, and waterfowl wintering ecology. The most extensive work in the Beaver Dam Creek area has been with the wood duck and mallard.

Data for seven years of wood duck and mallard use of the Beaver Dam Creek area collected by SREL (McCort, 1990) and flow data from the USGS gauging station at D Area (USGS Station Number 02197326; USGS 1990, 1989, 1988, 1987, 1986, 1985, 1984, 1983, and 1982) are presented in Table 4.5.5-1. Analysis of the data suggests that waterfowl use of the Beaver Dam Creek area may be dependent on flow within the systems. Fewer waterfowl are observed when flows are low. Frequency of observation periods where no waterfowl are seen is higher during low flow periods. Waterfowl use in the Beaver Dam Creek area has been much lower in recent years since the extended reactor outage has reduced demand, and flow requirements, at the 400-D Area powerhouse. Figure 4.5.5-1 shows the total number of wood ducks and mallards observed during the seven winter sampling periods. When the data are compared using the mean number of ducks seen per observation there is a significant ($p = 0.001$, Spearman Correlation value = -0.488) negative correlation with sampling winter, fewer animals were seen per observation in the more recent years (Figure 4.5.5-2). There is also a significant ($p \leq 0.001$, Spearman Correlation value = -0.701) negative correlation between sampling winter and monthly mean flow (Figure 4.5.5-3). Lower flows, leading to lower water levels, may affect waterfowl use in wetland areas by limiting available open water simply by leaving dry areas or encouraging colonization of former marsh areas by scrub-shrub vegetation. The Beaver Dam Creek waterfowl data show a significant ($p = 0.003$, Spearman Correlation value = -0.431) negative correlation between flow and the frequency of observations recording no waterfowl use. Higher flow conditions are more likely to have waterfowl use. There is also a significant ($p = 0.003$, Spearman Correlation value = 0.442)

TABLE 4.5.5-1 Waterfowl Observation and Beaver Dam Creek Flow Data, October 1981 - April 1990.

Winter	Month	Number of Samples	Wood Ducks	Mallards	Total	Mean/ Sample	Flow (CFS)
81-82	October	2	3	0	3	1.50	95
81-82	November	4	7	16	23	5.75	91
81-82	December	4	0	215	215	53.75	87
81-82	January	4	6	300	306	76.50	70
81-82	February	4	5	362	367	90.50	94
81-82	March	5	2	14	16	3.20	101
82-83	September	2	0	0	0	0.00	92
82-83	October	3	0	0	0	0.00	84
82-83	November	2	10	3	13	6.50	81
82-83	December	2	12	0	12	6.00	98
82-83	January	3	7	97	104	34.67	95
82-83	February	3	11	173	184	61.33	98
82-83	March	3	0	5	5	1.67	99
83-84	October	4	13	0	13	3.25	82
83-84	November	4	6	44	50	12.50	90
83-84	December	4	32	171	203	50.75	90
83-84	January	2	5	182	187	93.50	91
83-84	February	4	4	166	170	42.50	87
83-84	March	5	35	104	139	27.80	84
83-84	April	1	3	0	3	3.00	84
84-85	October	1	2	0	2	2.00	83
84-85	November	4	2	0	2	0.50	78
84-85	December	5	44	96	140	28.00	82
84-85	January	4	51	290	341	85.25	86
84-85	February	3	93	348	441	147.00	91
84-85	March	4	20	38	58	14.50	87
85-86	October	1	0	0	0	0.00	88
85-86	November	2	0	1	1	0.50	101
85-86	December	2	17	56	73	36.50	90
85-86	January	2	6	11	17	8.50	90
85-86	February	2	11	37	48	24.00	88
85-86	March	3	4	0	4	1.33	87
88-89	November	1	0	0	0	0.00	64
88-89	December	2	0	0	0	0.00	64
88-89	January	2	0	2	2	1.00	65
88-89	February	1	0	0	0	0.00	63
88-89	March	3	0	4	4	1.33	64
89-90	October	1	0	0	0	0.00	54
89-90	November	2	0	0	0	0.00	61
89-90	December	2	0	27	27	13.50	63
89-90	January	2	0	10	10	5.00	60
89-90	February	1	0	0	0	0.00	60
89-90	March	1	0	0	0	0.00	64
89-90	April	1	0	0	0	0.00	60

Source USGS (1990, 1989, 1988, 1987, 1986, 1985, 1984, 1983, 1982)

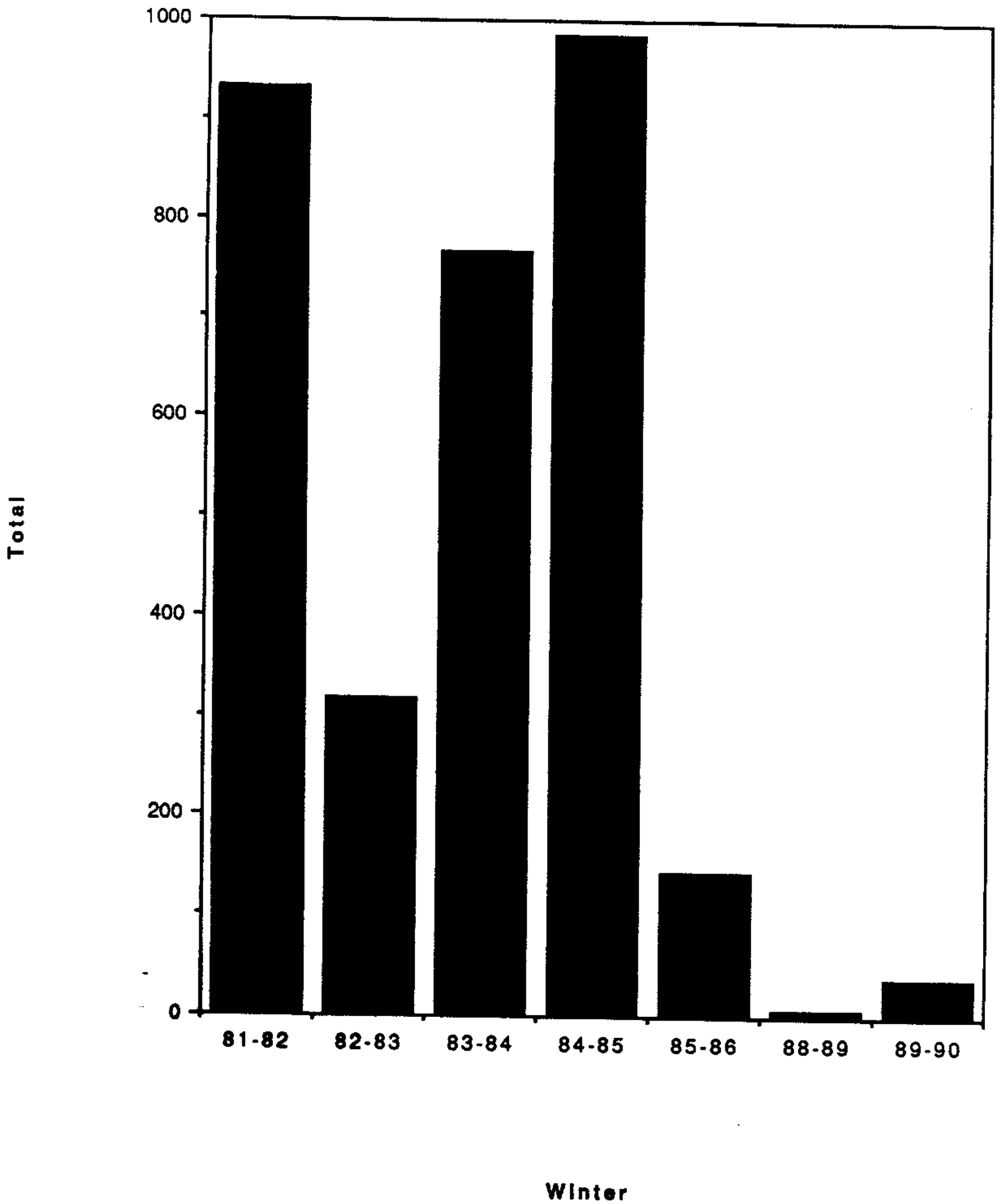


Figure 4.5.5-1. Total Number of Wood Ducks and Mallards Observed in the Beaver Dam Creek Area

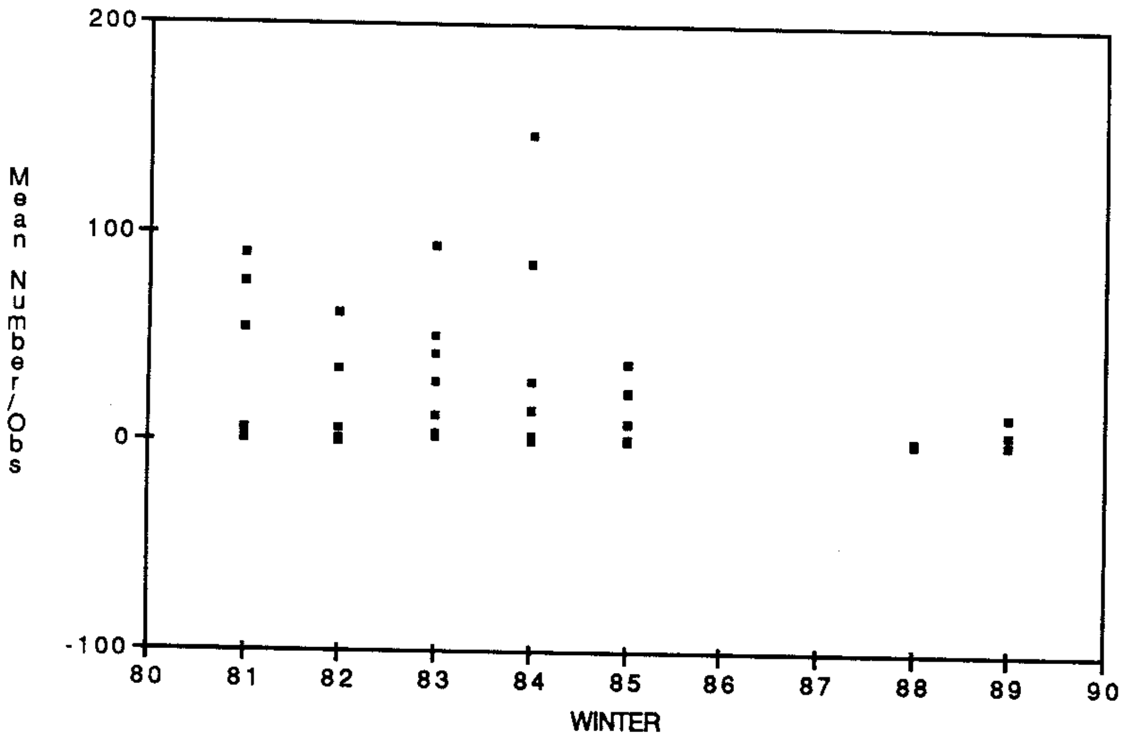


Figure 4.5.5-2. Mean Number of Wood Ducks and Mallards Per Observation in the Beaver Dam Creek Area

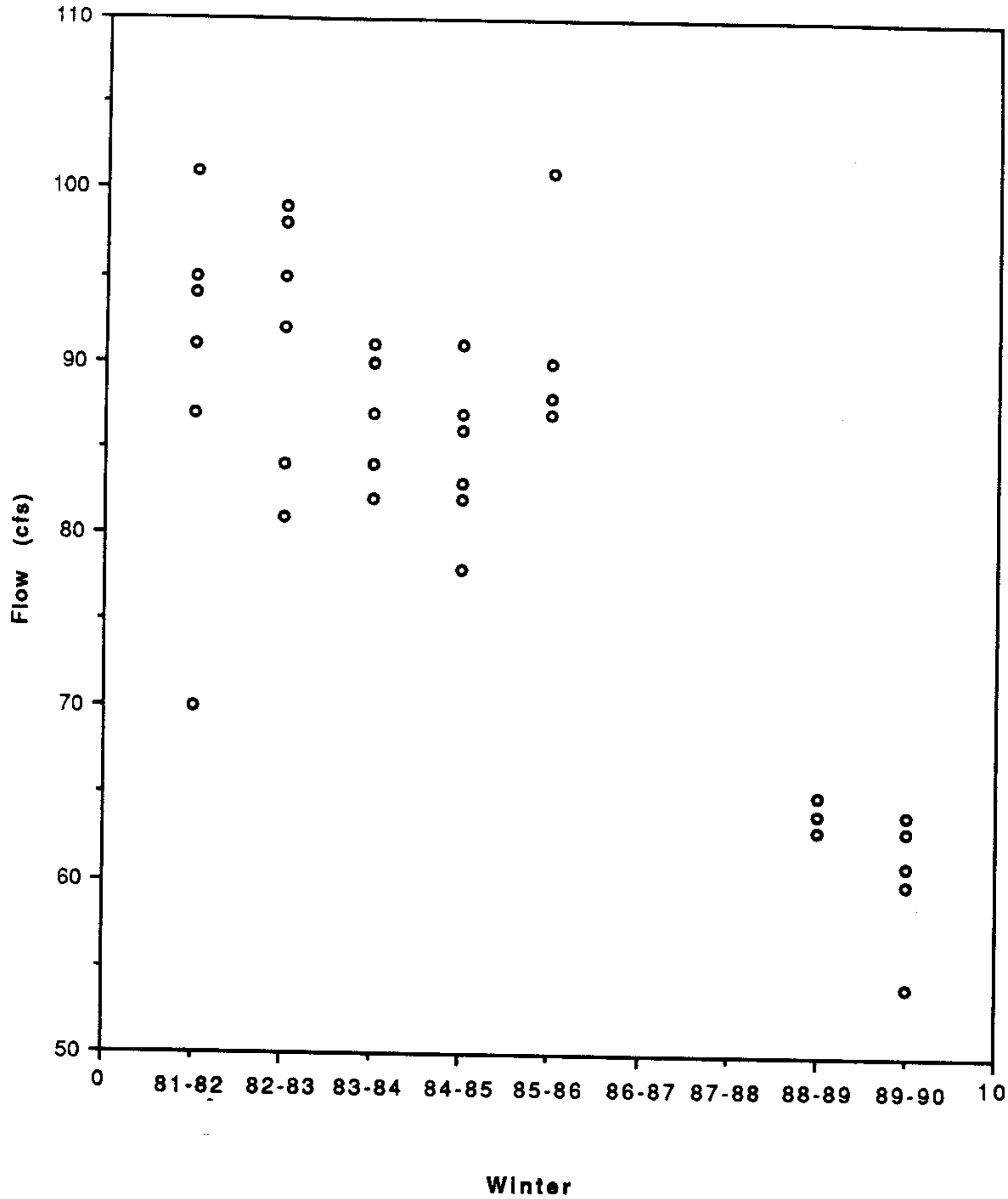


Figure 4.5.5-3. Mean Monthly Flows Versus Winter Survey Periods in Beaver Dam Creek

positive correlation between flow and the mean number of waterfowl sighted per observation (Figure 4.5.5-4). More waterfowl are likely to be observed during higher flow conditions than during low flow conditions. Figure 4.5.5-5 shows the relationship of average number of ducks per observation and mean flow during the sample winter on a by-winter basis. It is apparent that a reduction in flows occurred before the 1988-1989 winter sampling. This was caused by a lower demand on the 400-D Area powerhouse resulting from the cessation of reactor operation.

The thermal mitigation plan for Beaver Dam Creek has the potential to augment waterfowl use of the area due to the increased water levels. Because mitigation would only occur during summer months when waterfowl are not generally found in the Savannah River swamp, increased use would probably not be a direct result of the increased flows. However, the higher flows may contribute to maintaining larger marshy areas in the Beaver Dam Creek area thus increasing available area for waterfowl use during the winter.

4.5.6 Threatened and Endangered Species

There are 37 species of plants and animal listed by the U.S. Fish and Wildlife Service (USFWS), State of South Carolina, or the South Carolina Heritage Trust as Endangered, Threatened, or Of Special Concern that are known to currently or previously occur on the SRS (Wike et al., 1989). Three of the listed species are potentially affected by the Beaver Dam Creek thermal mitigation plan: American alligator (Alligator mississippiensis) listed by the USFWS as threatened by similarity of appearance; wood stork (Mycteria americana), listed as endangered by the State of South Carolina and the USFWS; and the shortnose sturgeon (Acipenser brevirostrum), also listed as endangered by the State of South Carolina and the USFWS.

4.5.6.1 Shortnose Sturgeon

Shortnose sturgeon spawn in the Savannah River and larvae have been collected near the SRS pumphouses. However, shortnose sturgeon are not known to enter the swamp or tributary creeks and threfore will not be affected by discharges from 400-D Area.

4.5.6.2 American Alligator

Although the American alligator was abundant in the United States as late as 1890, the population declined to less than 100,00 by the mid-twentieth century mainly as a result of intense hunting and habitat destruction (King, 1972). Federal protection enacted in the 1960's and 1970's allowed the populations to recover to the point where the United States Fish and Wildlife Service reclassified it from endangered/threatened to threatened by similarity of appearance (DOI, 1987). The alligator is the largest reptile found on the SRS, reaching a length in excess of 3.7 meters and a weight of 150 kilograms. The alligator has

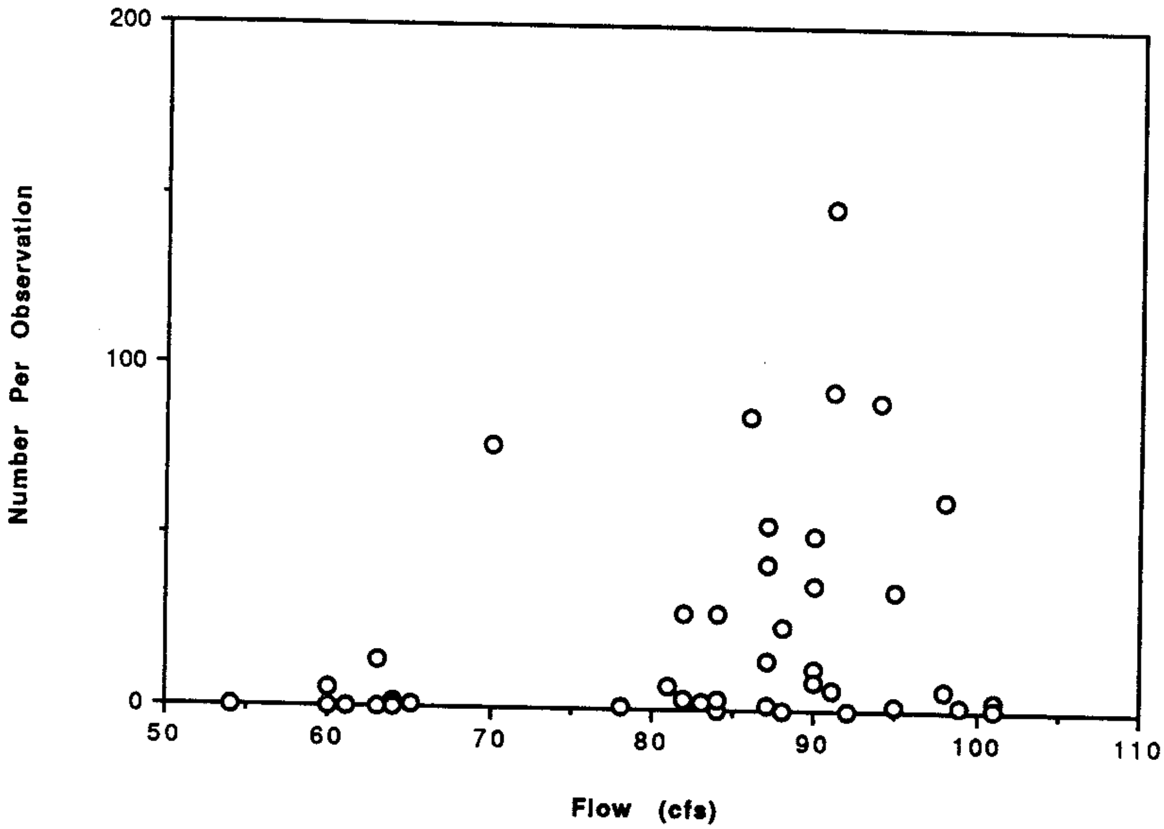


Figure 4.5.5-4. Mean Number of Wood Ducks and Mallards Per Observation Versus Beaver Dam Creek Flows

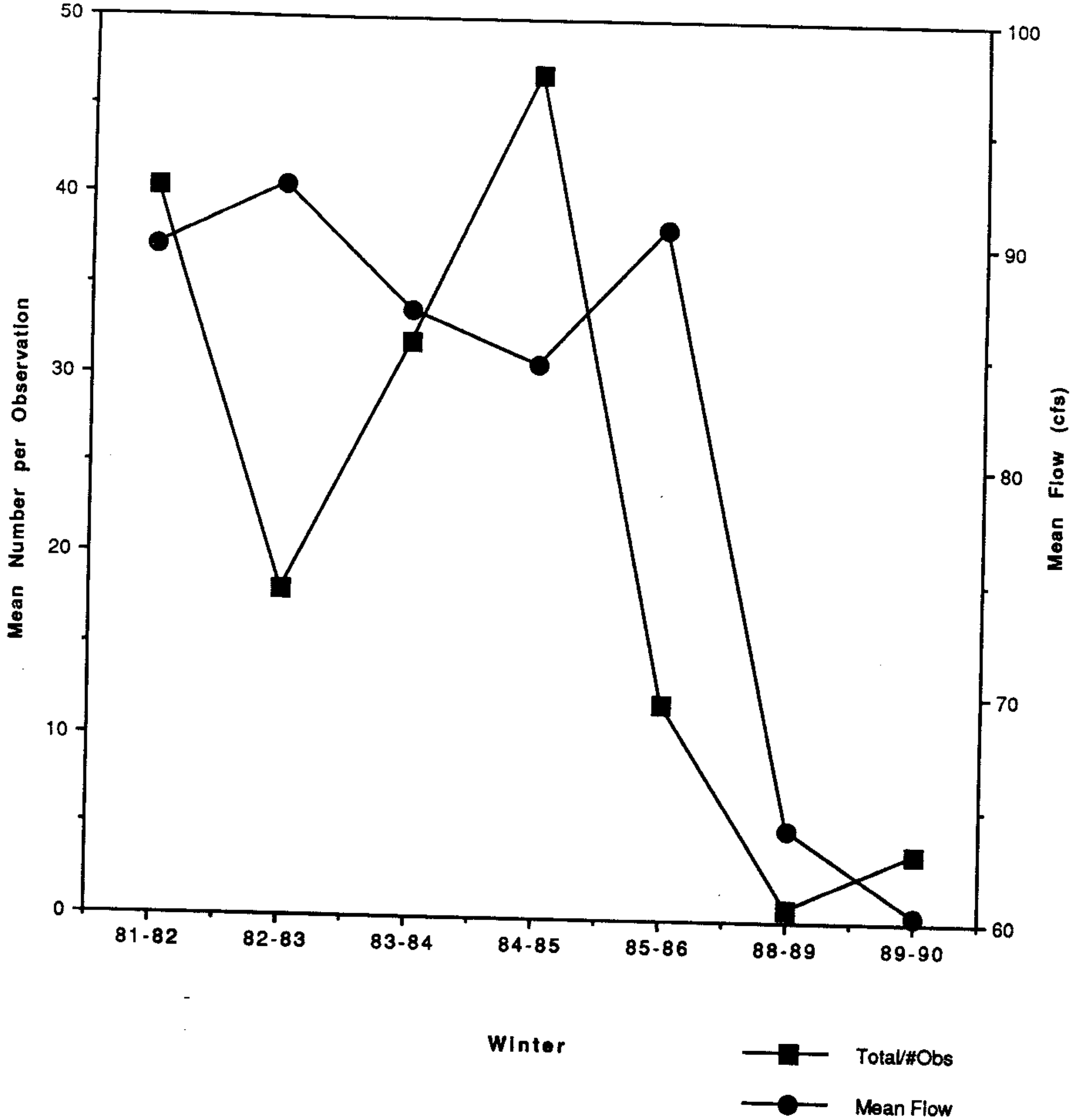


Figure 4.5.5-5. Mean Number of Wood Ducks and Mallards Per Observation and Mean Monthly Flows in Beaver Dam Creek Versus Winter Survey Periods

been studied extensively on the SRS (Murphy, 1977, 1981; Smith et al., 1981, 1982a, 1982b; Seigel et al., 1986; Brandt, 1989; Seigel, 1989).

Data from 27 aerial surveys of Beaver Dam Creek during 1983-1986 resulted in 260 sightings of alligators, the highest frequency of sightings from anywhere on SRS. Ground surveys confirmed the high density of alligators in the Beaver Dam Creek area. Size distribution of the alligator population from the aerial surveys (Figure 4.5.6-1) suggests active recruitment into the population. The data from Beaver Dam Creek surveys suggests that this area has the highest density population of alligators on the SRS. This high density may be the result of several factors. Beaver Dam Creek has a moderate amount of relatively undisturbed high-quality heterogeneous habitat that provides good nesting habitat and shelter and foraging sites for hatchlings and juveniles. The moderate thermal effluents at Beaver Dam Creek may also enhance growth and survival by allowing the alligators to forage throughout the year and by decreasing mortality from freezing temperatures. (Seigel, 1989)

There is no data currently available for the Beaver Dam Creek alligator population during the September 1988 through February 1990 thermal mitigation period. Since the mitigation plan will not substantially alter the winter temperature or flow regime of Beaver Dam Creek, it would not be expected to decrease the beneficial effects of the low level thermal input. There is the potential for nest mortality from fluctuating water levels during the nesting season (late May through September). Although alligators will construct nest cavities between 32 and 42 cm above water level, a rise of as little as 25 cm may cause mortality (Seigel, 1986). Water levels in Beaver Dam Creek are affected by 400-D Area discharge, rainfall, and Savannah River levels. Although extra pumping causes slight elevations in Beaver Dam Creek, precipitation and Savannah River level influence water level in the creek more than 400-D Area pumphouse operations (Nagle et al., 1990). Changes in summer flow patterns from the operation of extra pumps for thermal mitigation should not be great enough to affect alligator use of Beaver Dam Creek habitat.

4.5.6.3 Wood Stork

A detailed account of the on-going SREL wood stork program begun in 1983, the relationship of water levels and stork foraging, and stork use of the SRS Savannah River swamp appears in Wike et al. (1989). A comparison of Beaver Dam Creek, total SRS, and Kathwood Lake sightings appears in Figure 4.5.6-2. Kathwood Lake is a project near SRS developed to mitigate possible loss of wood stork foraging area in the Steel Creek delta due to increased flows accompanying L-Reactor restart (Mackey, 1985). Kathwood Lake was completed in the fall of 1985, and wood storks have used the foraging ponds extensively since the summer of 1986. The project is considered to more than compensate for any potential decline in available foraging areas in the Steel Creek delta (Wike et al., 1989). Figure 4.5.6-2 shows a decrease in use of the Beaver Dam Creek area by storks since the ponds at Kathwood Lake have been

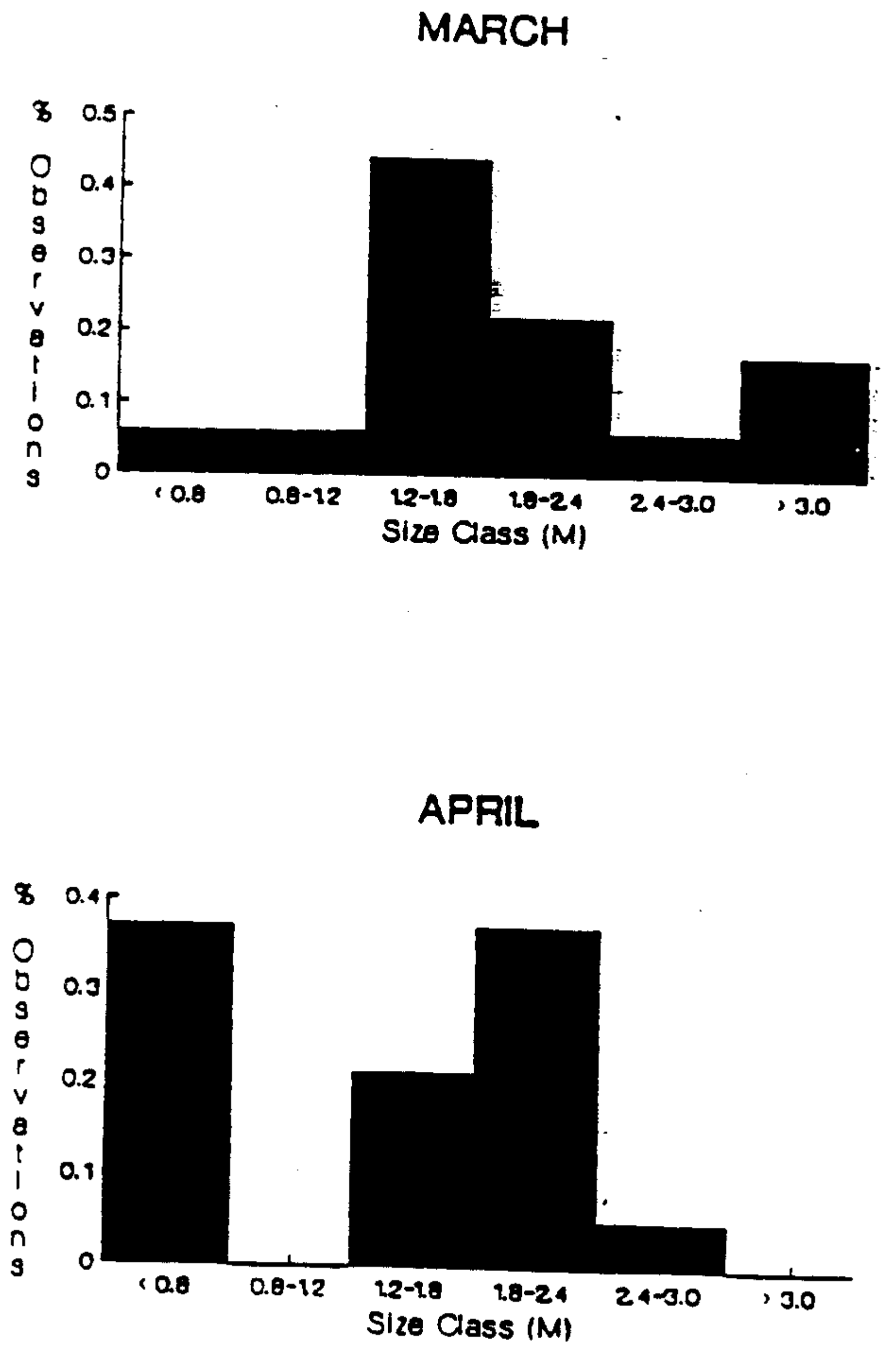


Figure 4.5.6-1. Size Structure of the Beaver Dam Creek Alligator Population as Assessed by Aerial Surveys in 1984 (Source: Seigel, 1989)

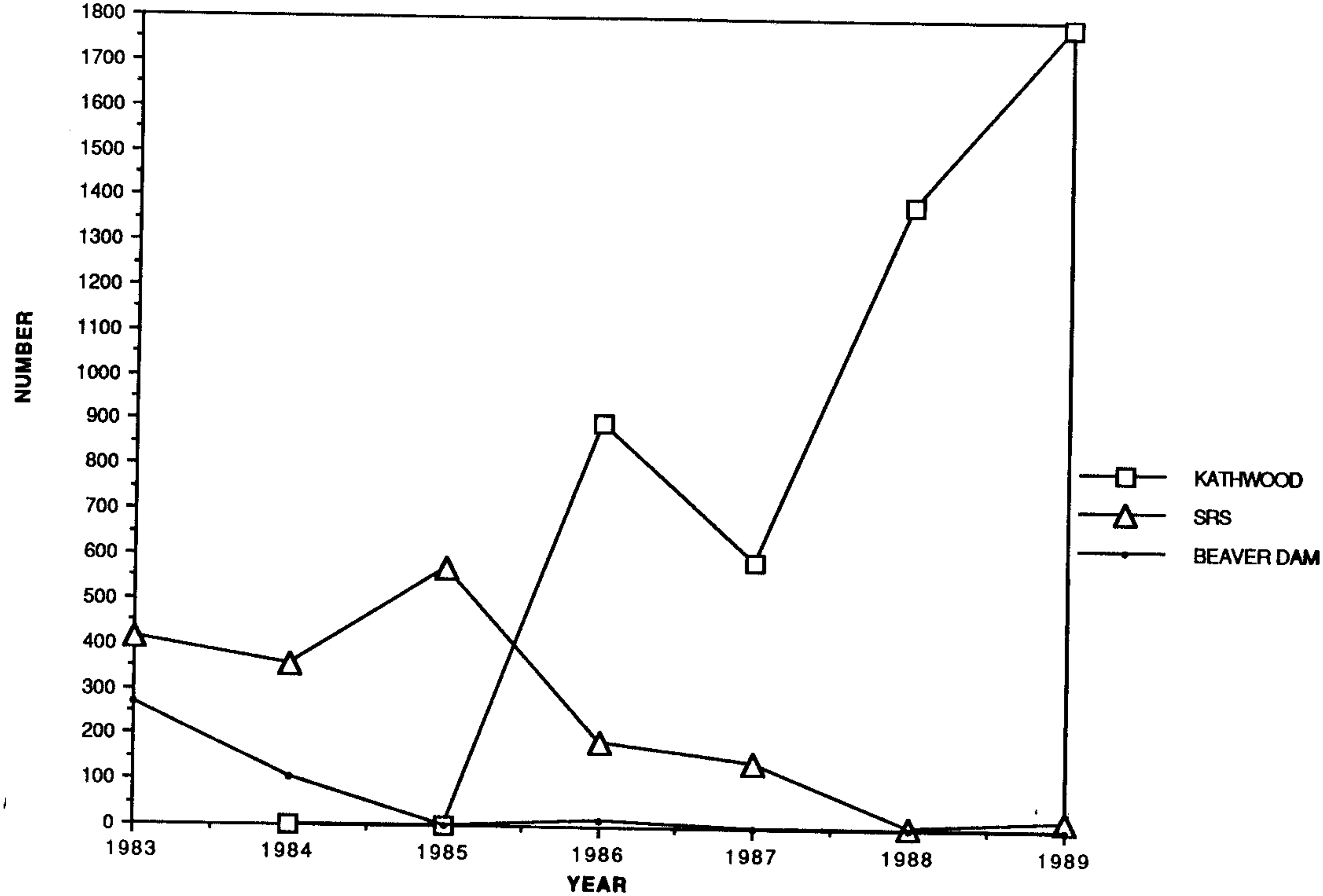


Figure 4.5.6-2. Number of Storks Observed at Beaver Dam Creek, SRS, and Kathwood Lake

available. Discharges from 400-D Area have not exceeded the range of normal operations (three pumps) during the study period. Therefore, decreased wood stork activity in Beaver Dam Creek cannot be attributed to mitigation activities.

5.0 STATUS OF BEAVER DAM CREEK

The objective of the Beaver Dam Creek Biological Monitoring Program is to determine whether the mitigation program for Beaver Dam Creek is adequate to permit the development and/or perpetuation of a balanced biological community (BBC) in Beaver Dam Creek. A BBC is defined as one that:

- Is not dominated by pollution (thermally) tolerant species
- Has biotic diversity and productivity characteristic of that found in other streams in the region
- Has population that are reproducing and are not maintained by repeated restocking and reseeding
- Has all trophic groups that would be expected in an ecosystem of this type.

The Biological Monitoring Program was developed and implemented for Beaver Dam Creek to provide information with which to evaluate the maintenance of a BBC in Beaver Dam Creek. Seven sampling stations were established in Beaver Dam Creek, from the original intermittent stream channel upstream of D-Area discharges to the mouth of the creek. Biological monitoring was initiated in September 1988 and data were collected through February 1990. The biological monitoring program for Beaver Dam Creek includes evaluations of the water quality, wetland vegetation, zooplankton, macroinvertebrates, fish, other vertebrate wildlife, and threatened and endangered species of the creek.

In the fall of 1988, extended reactor outages resulted in a decrease in the site electrical and steam demands. Power generation in D Area was reduced, with resultant decreases in outfall temperatures and ΔT's in the receiving stream. Thermal mitigation, via increased flow, was not required during the summer of 1989. Therefore, the data collected during the biological monitoring program are reflective of the thermal and flow regimes that exist when D Area is operating at a reduced power level, but do not reflect normal operating conditions for D Area. Upon returning to a normal level of power generation, additional biological monitoring will be performed to document the effects of thermal mitigation on Beaver Dam Creek during normal operating conditions.

5.1 Hydrology

Beaver Dam Creek drains a relatively small watershed area (2.2 km^2) and prior to the onset of discharges from 400-D Area in 1952 was probably an intermittent stream (Specht, 1987). The hydrology of Beaver Dam Creek is almost entirely determined by 400-D Area discharges. Until early 1982, Beaver Dam Creek received heavy water plant process cooling water, which produced discharge flows up to 3.7 m^3/s (130 cfs). Since the heavy water process was shut down in 1982 the effluent has been reduced to about 2.5 m^3/s (90 cfs) (Dukes, 1984). Flows have decreased further since the cessation of reactor operation in 1988. The increase in flows from the mitigation plan would not be expected to cause variation of significant magnitude in most of the Beaver Dam Creek system to adversely affect the maintenance of a balanced biological community.

5.2 Water Quality

The water chemistry of Beaver Dam Creek is greatly influenced by operations in D Area. In addition to thermal discharges from a coal-fired power plant, Beaver Dam Creek receives coal ash basin effluent, sanitary treatment plant effluent, and intermittent discharges from storm water runoff, a filter back-wash surge basin and a coal pile runoff basin. In the present study, Station 1A, located in the original ephemeral stream upstream from D-Area discharges, was compared to six sampling locations along the creek between D Area and the Savannah River. The six downstream stations were sampled monthly for 18 months. However, the upstream station (1A) only contained enough water to be sampled on 5 of the 18 sampling dates. Relative to the downstream stations, water quality values at Station 1A were lower for temperature, pH, dissolved oxygen, conductivity, and most nutrients (including nitrate and phosphorus), and higher for total hardness, total suspended solids, turbidity, aluminum, iron, lead, zinc and barium.

The original ephemeral stream system, represented by Station 1A, is primarily formed from rainfall and runoff; whereas the downstream locations (Stations 1-6) are mainly comprised of water discharged from D Area. This water from D-Area is primarily derived from the Savannah River to which it is eventually discharged.

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. However, the water temperature at Stations below the thermal discharge from the D-Area power plant) were often more than 2.8°C higher than the water temperatures at the 5G pumphouse at the Savannah River or the upstream station (1A). Thus, the second NPDES temperature limitation (maximum ΔT of 2.8°C) was frequently exceeded.

5.3 Ecology

5.3.1 Wetland Vegetation

Previous studies have investigated four swamp deltas created by SRS cooling water discharges; three from reactor thermal effluents, and one delta resulting from D-Area discharges into Beaver Dam Creek. The D-Area thermal effluents were from a coal-fired power plant and heavy water facility.

Different flow rates and temperature levels, as well as individual geomorphologies, have affected the rates of canopy loss and revegetation in the delta impact areas. The Beaver Dam Creek and Four Mile Creek deltas are irregular in shape and have larger impacts, probably due to the nearby swamp geomorphology. Several former river channels and areas of local relief have tended to channelize their effluents. In contrast, Pen Branch and Steel Creek deltas are fan-shaped, indicating more uniform depositional patterns.

Recent trends suggest that Beaver Dam Creek delta has stabilized and is in an early stage of revegetation, especially since declines in temperature and flows occurred in the early 1970s. Revegetation of the Beaver Dam Creek delta area with bottomland hardwoods and scrub-shrub communities is likely to continue under the present operating conditions.

5.3.2 Zooplankton

Mean zooplankton species diversity varied substantially at all stations during the study, but at most stations, diversity was highest between May and August 1989. No consistent upstream-downstream trends were observed for species diversity. Microzooplankton (Protozoa and Rotifera) accounted for most of the taxa richness. Although taxa richness varied considerably between stations over the course of the study, most stations reached their highest taxa richness from May through August 1989. No striking spatial pattern was observed from taxa richness. Monthly mean zooplankton densities varied sporadically at all stations. Protozoans were the most abundant major taxonomic group. Mean total zooplankton densities for the entire study generally showed a downstream increase from Station 1 to Station 5.

Comparative data from an earlier study (December 1984 - August 1985) with the present study (September 1988 - February 1990) revealed some differences. Total mean densities and total taxa richness values were higher for present study while species diversity values were higher in the former study.

The zooplankton community of Beaver Dam Creek appeared to be balanced. Pollution tolerant species were not dominant and the species diversity, taxa richness, and density values did not reveal a significant effect from thermal stress or any other type of pollution.

5.3.3 Macroinvertebrates

Beaver Dam Creek supports a reasonably diverse macroinvertebrate community, consisting of at least 163 species. Like most coastal plain streams in the southeast, the macroinvertebrate community of Beaver Dam Creek is numerically dominated by chironomids (primarily Orthocladiinae, Chironomini, and Tanytarsini), and to a lesser extent by mayflies, caddisflies, aquatic beetles, oligochaetes, and non-chironomid dipterans. The macroinvertebrate data indicate that the station closest to the D-001 outfall (Station 1) differs somewhat from the other portions of the stream with respect to overall species richness, taxonomic composition, and biomass. Fewer taxa were collected at Station 1 than at the other stations, although the mean number of taxa collected each month was within the range reported for the other stations. Station 1 also had the lowest abundance of mayflies and the highest relative abundance of chironomids of all of the stations. Although macroinvertebrate densities at Station 1 were within the range of those reported for the other stations, Station 1 had the lowest macroinvertebrate biomass of any of the six stations. These differences are not believed to be due to thermal stress, because Station 2, which is located just 700 m downstream from Station 1 and had temperatures that averaged just 0.1°C cooler than Station 1, was similar to the remaining stations with respect to all of the parameters that were measured. Rather, the differences are probably due to lower habitat diversity. Station 1 has no aquatic macrophytes, and the stream channel is relatively deep and narrow, with less structure (submerged logs and other vegetative debris) than is found at the other stations.

The macroinvertebrate community of Beaver Dam Creek has improved since 1984 - 1985, with increases in the relative abundance of mayflies, caddisflies, beetles, snails, and Tanytarsini chironomids and an overall decrease in the relative abundance of Chironomini chironomids. Increases in the mean number of taxa collected and in biomass were also observed at most stations. However, macroinvertebrate densities have remained remarkably consistent, considering the natural temporal variability that is observed in most lotic ecosystems.

The macroinvertebrate community of Beaver Dam Creek meets the four criteria of a balanced indigenous community, in that: (1) the macroinvertebrate community is not dominated by thermally tolerant taxa; (2) the community is diverse, with at least 163 taxa collected to date; (3) the community is self-maintaining, as evidenced by stable macroinvertebrate densities and populations in the absence of stocking or species introductions; and (4) the presence of various trophic levels. In summary, Beaver Dam Creek supports a reasonably diverse and productive macroinvertebrate community, which is not unlike those found in many southeastern coastal plain streams.

5.3.4 Fish

Station 1 differs from the other sampling stations in Beaver Dam Creek. The fish assemblage collected from this reach was characterized by relatively low abundance and taxa number. Station 1 is located closest to the D-Area outfall and is more strongly influenced by high flow rates than the other sample stations. A major portion of the sample area at Station 1 is strongly channelized with little vegetation or instream structure to serve as foraging or refuge areas for fish.

Considered as a whole, however, Beaver Dam Creek supports a diverse fish community that compares favorably with the fish communities in other southeastern streams. Species richness is high and abundance (as reflected in CPUE) is within the range expected for unimpacted streams. The relatively high species richness in Beaver Dam Creek is probably a result of habitat diversity. Beaver Dam Creek contains swamp, slough, and stream habitats. Another factor that increases species richness in Beaver Dam Creek is its connection with the Savannah River which permits incursions by riverine and anadromous species.

In addition to being diverse, the Beaver Dam Creek fish community contains representatives of all the trophic groups expected in southeastern streams. Large piscivores include largemouth bass, bowfin, longnose gar, Florida gar, pickerel, channel catfish, and white catfish. The occurrence of smaller, largely invertebrate-eating fishes, such as sunfishes and bullheads, ensures an intermediary link between the lower food chain and the large piscivores. The "rough" fishes, such as shad and suckers, that occur in Beaver Dam Creek can utilize foods such as detritus and burrowing invertebrates that are largely inaccessible to other groups. Small "forage" species such as minnows, shiners, and brook silverside feed on small invertebrates and constitute forage for piscivorous species.

5.3.5 Wildlife

The number of diverse habitats on the SRS support a wide variety of wildlife. Except for the waterfowl, there is little information regarding wildlife habits and use in the Beaver Dam Creek area. The most extensive work in the Beaver Dam Creek area has been with the wood duck and mallard. Use of the Beaver Dam Creek area by waterfowl has decreased in recent years. This appears to be due to the reduction of flow caused by decreased demand on the 400-D Area powerhouse during the extended reactor outage. The increased flow associated with the mitigation plan may increase the amount of habitat available for waterfowl use.

5.3.6 Endangered and Protected Species

Three species potentially affected by the Beaver Dam Creek thermal mitigation plan are listed as threatened or endangered, the American alligator (Alligator mississippiensis) listed by the USFWS as threatened by similarity of appearance; the wood stork (Mycteria americana), listed as endangered by the State of South Carolina and the USFWS; and the shortnose sturgeon (Acipenser brevirostrum), also listed as endangered by the State of South Carolina and the USFWS. The shortnose sturgeon population in the Savannah River is not expected to be impacted by mitigation activities for Beaver Dam Creek. According to data collected from 1983 through 1986, the highest density of alligators on the SRS is found in the Beaver Dam Creek area. Thermal mitigation at 400-D Area is not expected to have any significant negative impacts on the alligator population. Although high flows reduce the available foraging area for wood storks, the increase in flow from the mitigation plan for Beaver Dam Creek is not expected to be of sufficient magnitude to adversely affect stork usage.

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