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STEEL CREEK PRIMARY PRODUCERS:
PERIPHYTON AND SESTON
L-LAKE/STEEL CREEK BIOLOGICAL MONITORING PROGRAM
JANUARY 1986 - DECEMBER 1991

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February 1992

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**STEEL CREEK PRIMARY PRODUCERS: PERIPHYTON AND
SESTON - L-LAKE/STEEL CREEK BIOLOGICAL
MONITORING PROGRAM - JANUARY 1986 - DECEMBER
1991 (U)**

by

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DOE Contract No. **DE-AC09-89SR18035**

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ACKNOWLEDGEMENTS

The authors wish to express their appreciation to Mac Westbury for his assistance in data management. In addition, they wish to thank the members of the water resources and fisheries groups for their assistance in field work, and William Cody for algal identification. Appreciation is also expressed to Michele Harmon, Rosemarie Thomas, and Marie Davis for their editorial assistance in the preparation of this report. The authors owe a great debt of gratitude to Michael Chimney for his scientific advice and overall direction of this project.

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PREFACE

The Savannah River Site (SRS) encompasses 300 sq mi of the Atlantic Coastal Plain in west-central South Carolina. The Savannah River forms the western boundary of the site (Figure 1). Five major tributaries of the Savannah River -- Upper Three Runs Creek, Four Mile Creek, Pen Branch, Steel Creek, and Lower Three Runs Creek -- drain the site. All but Upper Three Runs Creek receive, or in the past received, thermal effluents from nuclear production reactors. In 1985, L Lake, a 400-hectare cooling reservoir, was built on the upper reaches of Steel Creek to receive effluent from the restart of L-Reactor, and protect the lower reaches from thermal impacts. The lake has an average width of approximately 600 m and extends along the Steel Creek valley approximately 7000 m from the dam to the headwaters. Water level is maintained at a normal pool elevation of 58 m above mean sea level by overflow into a vertical intake tower that has multilevel discharge gates. The intake tower is connected to a horizontal conduit that passes through the dam and releases water into Steel Creek.

The Steel Creek Biological Monitoring Program was designed to meet environmental regulatory requirements associated with the restart of L-Reactor and complements the Biological Monitoring Program for L Lake. This extensive program was implemented to address portions of Section 316(a) of the Clean Water Act. The Department of Energy (DOE) must demonstrate that the operation of L-Reactor will not significantly alter the established aquatic ecosystems.

Figure 1. Location of major aquatic systems on Savannah River Site.

Steel Creek Description

Steel Creek and its main tributary, Meyer's Branch (Figure 1), drain approximately 35 sq mi of the Aiken Plateau before descending to the Coastal Terrace. The headwaters of Steel Creek are located approximately 19 km from the Savannah River. L Lake was created near L-Reactor by construction of a dam across Steel Creek about 5 km upstream of the Steel Creek delta.

Steel Creek received thermal effluents directly from both P- and L-Reactors between 1954 and 1963 (maximum of 835 cfs; Smith et al. 1981; DOE 1984), and then from L-Reactor alone until 1968. The increased flow scoured the upper reaches of Steel Creek and deposited the sediments in a delta where the creek enters the river swamp. The increased sedimentation and the elevated water temperature destroyed all the in-stream vegetation along the upper reaches of the creek and the mature swamp forest at the site of the expanding delta. When thermal discharges ceased in the late 1960s, vegetation became reestablished and ecological succession began. The stream characteristics before the construction of L Lake included shallow braided channels and scrub-shrub or emergent wetland (marsh) communities. Diverse floral and faunal communities existed (Smith et al. 1981 and references therein). Potential influences of L-Reactor on Steel Creek physical parameters include changes in depth, flow, velocity, channel morphology, and water quality.

Biological Monitoring Program

The Steel Creek Biological Monitoring Program is designed to assess various components of the system and identify any changes due to the operation of

L-Reactor or discharge from L Lake, the once-through cooling reservoir for the reactor. An intensive ecological assessment program prior to the construction of the lake (Paller et al. 1986; Firth et al. 1988; and others) provided baseline data with which to compare data accumulated after the lake was filled and began discharging into the creek.

This report summarizes the results of six years' data from Steel Creek under the L-Lake/Steel Creek Monitoring Program. L Lake is discussed separately from Steel Creek in Volumes NAI-SR-138 through NAI-SR-143.

Each major component of the Steel Creek portion of the biological monitoring program is presented in a separate volume as follows:

NAI-SR-144	Steel Creek Water Quality
NAI-SR-145	Steel Creek Fish
NAI-SR-146	Steel Creek Macroinvertebrates
NAI-SR-147	Steel Creek Primary Producers: Periphyton and Seston
NAI-SR-148	Steel Creek Habitat Formers and Channel Mapping
NAI-SR-136	Fish

EXECUTIVE SUMMARY

1. The objectives of the periphyton portion of the L-Lake/Steel Creek Biological Monitoring Program are to evaluate the impact of L-Reactor operations on the biomass, density, and community structure of periphyton assemblages in the Steel Creek system.
2. Periphyton biomass (chlorophyll *a*) on glass slides, was generally higher in the corridor than at other Steel Creek sites during all years. At Station 275, periphyton standing crop (AFDM) was greater in 1988 than in 1986 and 1987, but decreased in 1989 to a level comparable with that documented in 1986.
3. Periphyton biomass and the algal taxa found on glass slides changed very little from year to year for all stations in the Steel Creek corridor. However, the relative abundance of blue-green algae (algae tolerant of organic or thermal pollution) increased on glass slide substrates between 1988 and 1989 at Station 280. Taxa richness decreased between 1988 and 1989 at the two upper corridor sites (Stations 275 and 280). These trends may be indicative of a decrease in water quality at Station 280 despite a more stable hydrologic regime in the corridor during 1989. Periphyton communities seemed to be similar in 1988 through 1991 at corridor Station 290.
4. There were no major differences in periphyton biomass or standing crop between 1986 and 1989 at the Steel Creek marsh and swamp stations,

although both parameters were lower at Station 300 than previously documented. Taxonomically, more green algae and fewer diatoms were found on slides at the marsh stations in 1988 and 1989, except Station 300 where diatoms predominated in 1989. The same trend continued in 1990 and 1991 at Station 330. At Station 300 in 1989, two species of Euglenophyceae were abundant for the first time in the marsh. This may be indicative of the stagnant, pond-like conditions at this site resulting from reduced flow. The relative abundance of blue-green algae increased greatly between 1988 and 1989 at marsh Station 330 and swamp Station 340; this may be indicative of a more stressed environment in 1989 than was found previously (Hooker 1990a). However, this trend was reversed in 1990 and 1991.

5. Bacillariophyta was the most abundant division at downstream channel stations except Station 370 in 1986 and 1990. The amount of green algae at Station 360 was somewhat greater in 1989, possibly due to increased light reaching the channel as canopy cover decreased (Hooker 1990b). The relative abundance of blue-green algae was higher in 1989 on slides than recorded in 1986-1988. This may be a result of Savannah River influence during high water periods and/or a decline in water quality at this site. However, the abundance of blue-green algae declined at Station 290 in 1990 and increased again in 1991 but to levels lower than that in 1989.
6. Mean chlorophyll *a* concentrations found on slides during this study were comparable to those found in an earlier study in streams on the Savannah River Site. Mean AFDM values were also comparable except for Station 275

in 1986 and 1988, when values were greater than the ranges reported in the earlier study.

7. Although there was some evidence that L-Lake discharges may have affected periphyton communities in Steel Creek (particularly in the upper corridor), variability in measured periphyton parameters as a function of landscape geomorphology, site-specific characteristics, and seasonality may have masked impacts. In addition, other possible causal factors (e.g., solar radiation, impact of Savannah River water on downstream channels and effect of grazers), were not documented in this study and, consequently, could not be eliminated from consideration.
8. The objective of the seston portion of the L-Lake/Steel Creek Biological Monitoring Program is to evaluate the impact of L-Reactor operations on the quantity and quality of seston in the Steel Creek System.
9. Overall, seston quantity and quality at the Steel Creek corridor sites were generally lower and more temporally stable during 1988-1991, compared with 1986 and 1987. These patterns may be a result of lower and less variable L-Lake outflow, causing lower rates of scouring of periphytic films, erosion of channel bed and banks, and entrainment of particles from the floodplain. In 1988 and 1989, seston concentration increased and quality decreased downstream of Station 275 in the corridor, which is consistent with seston patterns reported for other sites downstream of lake outlets.

10. Seston concentrations at the marsh stations were fairly consistent among sampling years, although seston was comprised of less organic material at these sites in 1988 and 1989 compared with 1986 and 1987 and was comprised of more organic matter at Station 330 in 1990 and less again in 1991. During each year, seston concentrations were generally highest in summer and lowest in winter and spring, perhaps as a result of greater dilution of particles during winter and spring months (i.e., when baseflows are naturally higher). Temporal fluctuations in seston concentrations and size fractions during 1988 and 1989 were also apparently a result of seasonal patterns of macrophyte growth and senescence, which affected current velocity and seston retention in some of the marsh channels. Seston dynamics at the marsh sites appeared to be influenced more by seasonal factors than by L-Reactor operations.
11. In 1986-1991, seston concentrations at the swamp stations were generally lower and less spatially and temporally variable than at all other sampling sites. This stabilization pattern in the swamp channel was apparently a result of lower current velocities and less periphytic development in combination with high seston retention by the relatively abundant macrophyte beds and the moderately high leaf litter inputs. Moreover, since most of the flow in the swamp channels originates from Four Mile Creek and Pen Branch, the swamp stations were probably less affected by fluctuations in L-Lake discharge than were sites in the Steel Creek corridor, marsh, and channel. Increases in seston quantity and particle size were coincident with autumnal input of drupes and leaf litter to the swamp channels. In 1986-1989, the percent organic material

in seston was higher at the swamp sites than at all other sampling sites (except for Station 275), possibly as a result of the moderately high leaf litter inputs and lower rates of erosion of mineral substrates. In 1990, three of the four stations sampled had approximately the same annual mean seston organic matter concentration and had a higher concentration than channel Station 370. In 1991 three stations again had higher concentrations than Station 370.

12. Seston concentrations at Station 370 exhibited substantial temporal variability during 1986-1988, undoubtedly as a result of the variable flow regime associated with both backflow from the Savannah River during periods of high river discharge and pulses in L-Lake discharge. In 1989, temporal variability was less than 1988 and was about the same amount in 1990. As in previous years, seston quantity was relatively high at this site in 1989, probably due to channel bed and bank erosion (from high current velocities) and high leaf litter inputs to the channel. In 1990, seston quantity was lower probably due to less bed and bank erosion (from lower current velocities). In 1988 and 1989, seston quantity was lower at Station 370 than at the corridor sites sampled, apparently due to less periphytic development and the upstream retention or processing of chlorophyllous seston particles. In 1990, seston quality was higher at Station 370 than the one corridor site sampled, and the one marsh and one swamp site sampled. This probably was due to the effect of allochthonous chlorophyllous material brought in by backflow from the Savannah River. In 1991 there was little observable backflow, and seston quality was lower at Station 370 than at the marsh and swamp sites.

13. At the Meyer's Branch reference site, seston quantity was comparable to that at several of the Steel Creek sampling sites during 1986-1989. In 1988 and 1989, however, seston concentrations at Station 400 were lower than in 1986 and 1987. This trend may indicate natural (i.e., due to changes in annual precipitation) lowering and stabilization of seston loads in the Steel Creek-Meyer's Branch system; however, seston retention may have been higher at Meyer's Branch in 1988 due to the increase in the amount of woody debris in this channel during 1988 which remained in place during 1989.
14. Although some evidence indicates that L-Reactor operations may have affected Steel Creek seston dynamics, other confounding factors make it difficult to discern any cause-and-effect relationships. Because of temporal and spatial heterogeneity, many of the trends indicated by the seston data may have been within the range of natural variability. Seston quantity and quality at the Steel Creek sites were relatively comparable to similar parameters reported for other lotic systems.

1.0 INTRODUCTION

1.1 PERIPHYTON LITERATURE REVIEW

Periphyton is the attached microfloral community that grows on submerged surfaces such as sediments, wood, rocks, artificial substrates, or living organisms (Wetzel 1983). The periphyton community consists of several components: fungi, algae, and other nonattached autotrophic microbes that are swimming or lodged between the attached forms. This community is a useful indicator of water quality because the physical and chemical conditions of the water favor the development of certain components of the periphyton community. Periphyton is itself a component of a larger attached community (Aufwuchs) which also includes protozoa, rotifers, and other hetrotrophic organisms.

The community makeup of periphyton is sensitive to altered thermal regimes as well as to organic and inorganic pollutants (Cairns et al. 1972). The diversity, composition, and biomass of the assemblage change in response to even slight shifts in environmental parameters. Elevation of temperature in an aquatic environment generally results in increased rates of primary production which is likely due to the greater nutrient availability in warmer systems (Tilly 1975; Forester et al. 1974).

The algal component of periphyton can be responsible for a major portion of the autochthonous (in-stream) primary production and is important as a food base in many streams (Minshall 1978). The balance between autochthonous and allochthonous (streamside) inputs plays a key role in the structure of the invertebrate community and the metabolic dynamics of the stream ecosystem

(Cummins 1974). In turn, grazing of periphyton by herbivores can influence algal biomass, productivity, and community structure (Hunter 1980; Gregory 1983). Hunter (1980) found that grazing by snails resulted in a significant decrease in the primary productivity of periphyton grown on glass slides. In streams that are open to sunlight, high autochthonous production can reduce the importance of the allochthonous inputs (Minshall 1978; Cushing and Wolf 1982).

In some situations, periphyton can have an impact on the stream ecosystem apart from its trophic significance. For example, where substrates are limiting for periphytic development, as in sandy-bottomed streams like Steel Creek, aquatic macrophytes may be the only submerged surface available for periphyton development. Shading of Lobelia sp. leaves by epiphytes (periphyton specifically growing on plants) was found to restrict seasonal growth and the water depth at which the macrophytes could grow (Sand-Jensen and Borum 1984).

The development of periphyton in lotic (flowing water) environments is controlled by a variety of physical and chemical variables including pH (Keithan et al. 1988), nutrient availability (Fairchild and Lowe 1984; Pringle 1987), water temperature (Tilman and Kiesling 1984; Vinson and Rushforth 1989), current velocity (Horner and Welch 1981; Stevenson 1984), light intensity (Brylinsky and Mann 1973; Stevenson and Stoermer 1981; Steinman and McIntire 1987), and substrate type (Power and Stewart 1987). Tilman and Kiesling (1984) found that temperature in conjunction with nutrient availability was the most important factor influencing the development of certain taxonomic groups of algae. For example, at temperatures greater than 20 °C, the cyanobacteria were dominant, particularly when the N:P ratio was low. Diatoms dominated when temperatures

were < 12 °C and Si:P ratios were high. Green algae were dominant at both intermediate temperatures (14-17 °C) and intermediate N:P ratios. Several recent nutrient-enrichment studies have documented the importance of nutrients, particularly nitrogen and phosphorous, in limiting algal growth (Fairchild and Lowe 1984; Tate 1985; Pringle 1987; Carrick and Lowe 1988). Nonpoint sources of nutrient enrichment include seeps, storm flow, and runoff. The geologic formation underlying the stream can have an important influence on algal biomass via nutrient inputs from weathering and erosional processes (Lay and Ward 1987).

Current velocity can affect the make-up of periphyton. Periphyton can be scoured from the stream channel during a spate due to redistribution of the sediments (Fisher et al. 1982). High discharge rates can also scour attached algae, depending upon the surface to which they are attached. Higher flow rates, therefore, can select for species which can readily colonize newly cleaned surfaces (Peterson 1986) as well as species which have well developed mechanisms of attachment to the substrate (Poff et al. 1990). Diatom assemblages on artificial substrates exposed to direct currents were found to have lower abundances and fewer taxa than diatom assemblages colonizing substrates in sheltered areas (Horner and Welch 1981). However, differences within a single algal mat exposed to different current velocities may actually be quite minimal (Reiter and Carlson 1986). Characteristics of algal species, such as morphology of attachment structures and production of mucilage involved with adhesion, are important in determining resistance to water forces (Otten and Willemse 1988; Poff et al. 1990).

Because algae are photosynthetic, it can be assumed that their growth is dependent on light availability. Personal observations of several lotic systems indicated greater amounts of algal growth in channels open to sunlight than in shaded reaches. However, attempts to quantify the effects of light on periphyton community development yield conflicting results dependent upon the system under investigation. In one study, growth rates of benthic algae were not limited until light intensity was reduced to 90% of ambient conditions (Triska et al. 1983). In contrast, Hooker (1987) found that nitrate uptake by benthic algae was significantly reduced when communities were shaded only 30%. The community make-up of periphytic algae is also influenced by light regime. The relative abundance of green filamentous algae was found to increase after canopy removal due to logging (Lowe et al. 1986). More recently, Steinman and McIntire (1987) found that the relative abundances of green algae were greater in laboratory streams exposed to higher treatment irradiance. It has been suggested that under low light conditions, the chlorophyll a in streamside vegetation absorbs most of the red and blue wavelengths, leaving little for in-stream processes. Since green algae lack the pigment diversity of other periphytic algae, they may be both quantitatively and qualitatively light-limited when shaded (Lowe et al. 1986; Steinman and McIntire 1987).

Stream channel substrate can be important in governing the development of epipellic (growing on sediments) algae. Finely textured sediments are readily scoured from stream channels during periods of high flow (Fisher et al. 1982). However, survival of an algal species during floods is dependent on both its method of attachment and the characteristics of the substrate to which it is attached (Power and Stewart 1987).

Although environmental variables influence the development of periphyton, biological mechanisms within and outside the community are also important. Accrual rates of periphytic algae are a function of rates of immigration to the surface, reproduction rates, death rates, emigration from the community, and grazer activities (Stevenson 1984).

The detrimental effect of invertebrate grazers, especially snails, on algal biomass and/or diversity has been well documented (Patrick 1970; Hunter 1980; Steinman et al. 1987; Hill and Knight 1987 and 1988). A recent study demonstrated that invertebrate grazing can result in decreased diversity and increased dominance by green algae on enriched substrates (Marks and Lowe 1989). However, a study by DeNicola et al. (1990) indicated that grazing patterns of herbivores are often patchy, thereby maintaining a mosaic of algal patches in different successional stages which may increase overall algal diversity. In most lotic systems, periphyton forms a nearly invisible film on submersed substrates; however, two characteristics make it capable of supporting a large grazer population. First, algae have a more rapid turnover rate than do grazers, even under the conditions of low light intensity often found in streams (McIntire 1973; Minshall 1978). This means that even as some organisms are grazed, others are reproducing at a rate fast enough to replace those lost by depredation. Secondly, numerous field and laboratory studies indicate that periphyton (algae in particular) is a high quality food source for invertebrate consumers (Fuller and MacKay 1981; Hawkins et al. 1982; Steinman et al. 1988). Thus, invertebrates feeding on living periphyton can maintain high assimilation efficiencies and growth rates while ingesting quantitatively less than detritus feeders. Even

after senescence, periphytic material retains much of its original food value and can be used by downstream communities as seston.

A recent study has found that certain non-grazing invertebrates can have a beneficial effect on periphyton communities. Pringle (1985) reported that chironomid cases on artificial substrates actually increased the surface area available for diatom colonization and provided a refugium from mayfly grazers for certain taxa.

1.2 SESTON LITERATURE REVIEW

Seston is defined as suspended particulate organic matter (POM) and its associated assemblage of microorganisms (Wetzel 1983). Suspended solids in streams also include inorganic matter, which is collected and usually included in analyses and discussions of seston; thus, the definition of seston will be broadened in this report, *sensu* Wallace et al. (1982), to include inorganic as well as organic suspended particulate matter. Seston is important in lotic ecosystems as a transport mechanism for reduced organic carbon compounds, as well as a direct food source and "buffer" energy source available throughout the year for many macroconsumers, notably benthic invertebrates (e.g., Cummins 1974; Wallace et al. 1982). Seston may directly or indirectly support much of the aquatic food web in streams (Anderson and Sedell 1979; Cummins and Klug 1979).

The transport of seston in streams is influenced by various factors that govern the patterns of import, storage, decomposition, and export of organic matter. Sheridan and Hubbard (1987) reported that the rate of input of seston in runoff depends upon geology, soils, vegetative cover, topography, climate, and

land use practices. In a pristine stream draining a tall-grass prairie/riparian forest watershed, concentrations of all size categories of seston increased during stormflows (Gurtz et al. 1982). In this same study, the import of particulate organic matter to the stream from plant litter was significantly influenced by extrinsic events such as fire and windstorms. Seston can be retained in a stream by physical structures, such as debris and macrophyte beds, or by morphological features of the channel. Seston also can be converted to biomass by consumers or stored in materials such as fecal pellets, thereby decreasing the rate of downstream seston transport. Gurtz et al. (1982) reported that stream retentiveness or storage may also be an important determinant of organic matter decomposition rates. Additionally, seston transport is dependent on current velocity; slower currents result in increased retentiveness within the channel (Minshall et al. 1983).

Seston is collected from the water column by a group of invertebrates referred to as filter-feeders. These organisms have a variety of morphobehavioral adaptations that allow them to utilize this suspended source of food (Wallace and Merritt 1980). Some of the highest rates of secondary production ever reported occurred where filter-feeding insects colonized snags along the edge of the Satilla River, a typical blackwater river located in southeastern Georgia (Benke et al. 1984). Consumers of seston and benthic detritus are prey for various species of both invertebrate and fish predators, which in turn support top-level carnivores, completing the detritus-based trophic pyramid.

Seston and benthic organic matter originate from detritus produced both outside of (allochthonous) and within (autochthonous) aquatic systems. The

detritus is colonized by an assemblage of microorganisms that directly facilitates its decay and enhances its nutritive value to consumers (Howarth and Fisher 1976). Consumers benefit from both the build-up of microbial biomass which decreases detrital C:N and the increased digestibility of the detritus due to breakdown by microbial hydrolytic exoenzymes (Lenz 1977). Through such nutritional enhancement, the relatively small proportion of detrital weight contributed by bacterial biomass may exert a disproportionately large influence on production by stream and swamp animals (Murray and Hodson 1985). Edwards (1987) demonstrated that the bacterial carbon present in the size fraction of seston collected is very important, because filter-feeding insects partition seston according to size.

In addition to bacterial biomass, seston quality is also determined by the proportion of mass of animal matter and algae (more nutritional) in relation to vascular plant tissue and amorphous detritus (less nutritional). Hence, many detritivores select protein-rich foods such as algae or microbially colonized seston (Calow 1975; Kostalos and Seymour 1976). Seston is almost never quantitatively limiting to consumers; however, it may be unavailable to certain groups of organisms because of the size distribution of the particles present (Mann 1972). While some size fractions are too small to be retained by an organism's filtration apparatus, other fractions are too large to be processed by these devices. Macroinvertebrate (consumer) growth rates, standing crops, and production are all regulated to some extent by seston nutritive content (Taylor and Roff 1982). Thus, alterations in seston quality may have important implications with respect to the structure and function of consumer communities, and ultimately the energy flow of the ecosystem.

Different criteria have been utilized to evaluate the quality of seston as a food source. Kondratieff and Simmons (1984a, b) used chlorophyll *a*, microbial activity, and protein content, whereas Hauer (1985) used the percentage of organic matter within each size fraction. Looking solely at organic matter content may be misleading, as this represents all organic matter and does not distinguish between biologically available and refractory materials. Determining the amount of chlorophyll *a* associated with the organic matter appears more useful because chlorophyll *a* content is indicative of seston algal content, which is a highly nutritive, digestible, and thus preferred, food source (Mann 1972).

There is evidence that in the Steel Creek stream/swamp system, as in other aquatic systems, the detritus-based food web is the critical link in the flow of energy from primary producers to higher trophic levels (Firth 1987). In the Steel Creek and Meyer's Branch systems, the interacting influences of storm flows, stream retentiveness, and stream substrate on seston transport may have important implications with respect to the diversity and density of invertebrates (Leff and McArthur 1988). Hauer (1985) emphasized the importance of recognizing (1) the temporal dynamics of these lotic ecosystems and (2) that changes in seston occur seasonally and are directly related to changes in stream discharge.

1.3 PURPOSE OF STUDY

The purpose of this part of the L-Lake/Steel Creek Biological Monitoring Program is to monitor the current status of attached primary producers and suspended material in the Steel Creek corridor, marsh, swamp, and channel leading into the Savannah River. Because the lower Steel Creek system receives water from the L-Lake reservoir, the program will specifically focus on potential

impacts of the variable L-Lake releases on the creek periphyton/seston. Depending on L-Reactor operation cycles, the volume of L-Lake water released into Steel Creek will alter flow rates, water temperature and biota, including plankton and fish, and add buffering capacity, suspended solids, nitrogen, and phosphorus nutrients. To adequately assess the possible impacts of reactor operation, the following were determined: (1) the biomass (chlorophyll a and AFDM concentration), abundance, and diversity of periphytic algae on glass slide substrates; and (2) the concentration and quality (chlorophyll a and AFDM concentration) of seston in the water column.

The program will synthesize elements of the database to facilitate compliance decisions regarding "balanced biological community" (BBC; Section 316 [a] of the Clean Water Act) criteria. The system should: (1) not be dominated by pollution (thermal) tolerant organisms; (2) have diversity and productivity characteristic of lakes and streams of the region; (3) contain representatives of all trophic (feeding) groups that would be expected in a lake or stream of this region; and (4) contain biotic communities that are self-maintaining (successfully reproducing) and not maintained by continual recruitment of organisms from outside the system.

The first two of the BBC criteria are directly applicable to the periphyton study and will be evaluated in this report for the Steel Creek system. While these criteria cannot be directly documented by studying seston, the quantity and quality of seston can be indirectly related to the productivity of the Steel Creek system. Much of the organic matter transported in streams is seston (Webster et al. 1987). Because it represents a major source of carbon movement,

seston is an integral component of energy flow and nutrient pathways in lotic systems. By serving as an important source of food for filter-feeders and detritivores (Haines 1977), seston forms a vital link between primary production and higher trophic levels in streams (Wallace and Merritt 1980).

2.0 METHODS AND MATERIALS

2.1 SAMPLING PROGRAM

In 1990 and 1991, the scope of work for the L-Lake/Steel Creek Biological Monitoring Program was reduced by Westinghouse Savannah River Company - Savannah River Laboratory. Under the old sampling regime, 14 stations were sampled monthly for periphyton and seston and one station was sampled quarterly. Starting in 1990, periphytic algae and water were sampled quarterly (winter, spring, summer, and fall) at the following four stations: the Steel Creek upstream corridor (Station 290), the marsh (Station 330), the swamp (Station 350), and the channel which drains into the Savannah River (Station 370). Table 2-1 lists the 1991 collection dates. Figure 2-1 shows the locations of all periphyton sampling stations utilized during this study. For a description of previous years (1986-1989) sampling program, see Hooker (1990a) and van Duyn and Stiner (1990).

The upstream corridor (Station 290; Figure 2-1) was characterized by variable flow regimes, dependent upon L-Lake releases (Chimney and Westbury 1990) and consisted of braided, narrow channels with a shifting sand substrate. There was an abundance of logs, debris piles, and stumps in the stream bed. Small beds of aquatic macrophytes frequently clung to stumps, logs, and debris piles. The channel was variably shaded by floodplain vegetation which was dominated by willow (Salix sp.), alder (Alnus serrulata), and button bush (Cephalanthus occidentalis; Toole and Westbury 1992).

Table 2-1. Periphytometer and seston sampling dates in 1991.

Date Collected (1991)	Sampling Program ^a
February 19	P S
May 20	P S
August 16	P
August 20	S
November 19	P S

^aP - periphytometers
S - seston.

Figure 2-1. Location of Steel Creek periphytometer and seston sampling stations. November 1985-December 1991. Only Stations enclosed in boxes were sampled in 1990 and 1991.

The marsh site (Station 330; Figure 2-1) was mostly an open-canopied area with unconsolidated sediments and was dominated by emergent herbaceous vegetation including Polygonum spp., Murdannia keiskei, grasses, and sedges. The marsh channel was relatively unshaded by trees and shrubs; however, submerged aquatic plants shaded much of the water column in the channel (Toole and Westbury 1992). The marsh station was deforested as a result of thermal discharges from L-Reactor over a 14-year period (1954-1968; Smith et al. 1981). In previous NAI reports, marsh stations are collectively referred to as the "delta" because they are within the deltaic fan of Steel Creek.

The swamp site (Station 350; Figure 2-1) was southwest of the marsh station and was located in a deep channel flowing through a tupelo-cypress (Nyssa aquatica - Taxodium distichum) forest with a reduced canopy (Toole and Westbury 1992). The water flowing through this channel primarily originated from Pen branch and Four Mile Creek (Hooker 1990b). At Station 350, the channel was moderately to heavily shaded by trees, and multiple layers of aquatic macrophytes covered most of the substrate (Toole and Westbury 1992) which consisted of sand and clay overlain by silt containing particulate organic matter (pers. obs.).

The Steel Creek downstream channel drains nearly all of the waters from the marsh and swamp system into the Savannah River. The floodplain vegetation at this site (Station 370; Figure 2-1) consisted of bottomland hardwoods (including water ash [Fraxinus caroliniana], bald cypress, tupelo gum, sweet gum [Liquidambar styraciflua], and elm [Ulmus americana] trees; Toole and Westbury 1992). Riparian canopy cover was moderate at this site (Toole and Westbury 1992), but because the channel was quite wide, canopy cover over the channel was

variable. The substrate generally consisted of sand and clay sediments with abundant woody debris in shallower areas. Station 370 is strongly influenced by water levels in the Savannah River.

For a more complete description of the study sites, refer to Toole and Westbury (1992) for the results of the Steel Creek floodplain and channel habitat survey conducted as part of this monitoring program. Data comparing stream habitat along Steel Creek to that of other streams on the Savannah River Site are presented in Mealing et al. (1990).

2.2 PROCEDURES: PERIPHYTON

Four periphytometers, each containing eight glass slides, were incubated for four weeks on a quarterly basis at each of the four stations (Stations 290, 330, 350, and 370; Figure 2-1).

Prior to each sampling date, clean periphytometers were loaded with new glass slides, attached to ropes in the main channel at each station, and allowed to incubate for a four-week period. After incubation, all slides were removed from the periphytometers, put into opaque plastic slide boxes, placed on ice, and delivered to the laboratory. The periphyton accumulation on the glass slides was assayed for chlorophyll *a*, dry mass (DM), ash-free dry mass (AFDM) and taxonomic determinations/enumerations. Algal biomass was quantified by the chlorophyll *a* measurements, which were shown to correlate closely with cell volume (Liaw and MacCrimmon 1978) and photosynthesis under optimum conditions (Jones 1984).

In the laboratory, six slides from each station were used for chlorophyll *a* analysis. Each slide was placed into a tube containing 40.0 mL of 90% aqueous acetone and extracted at 0 °C overnight. The following day, the samples were sonified in an ice bath for 3 minutes at 75 watts (Branson Model 185 sonifier), then the slides were removed and discarded. The sample extracts were then centrifuged for 5 minutes at 2500 rpm (IEC Model S2K centrifuge) and assayed for chlorophyll *a* on a calibrated fluorometer (Turner Model 112) as described for the "corrected" chlorophyll *a* procedure in standard methods APHA (1985) with corrections for pheophytin *a* made according to the method of Lorenzen (1967).

For the gravimetric analyses of ash-free dry mass and dry mass (AFDM and DM respectively), nine slides from each station were scraped. Scrapings from each slide were placed on a separate prewashed/preashed/preweighed glass fiber filter (Gelman AE). Samples were dried to constant weight at 60 °C and weighed to the nearest 0.01 mg with a Mettler analytical balance (Model AE 163) to determine DM. Samples were then combusted at 500 °C for 1 hour, rewetted with a small amount of deionized water (to replace water of hydration), redried to constant weight at 60 °C, and reweighed to the nearest 0.01 mg to determine ash mass.

The AFDM of each sample was calculated using the following equation:

$$\text{AFDM} = \text{DM} - \text{ash mass}$$

where: AFDM = mass of organic matter
DM = mass of inorganic and organic matter
ash mass = mass of inorganic matter.

Five percent of all samples were reweighed at both the dry mass step and the ash mass step for quality control monitoring.

For taxonomic determinations/enumerations, scrapings from two slides were composited into one centrifuge tube for each station. Several mL of 1% Lugol's solution followed by several drops of 100% Lugol's solution were added as a preservative. Subsamples of known volume were taken from each composited sample and examined using the stratified-inverted microscope technique of Munawar and Munawar (1976). Depending upon the algal density, the volume settled in counting chambers was adjusted to obtain counts of at least 500 "units" (i.e., algal cells or filaments). It was shown that density estimates derived from subsample counts of 400 units can be expected to deviate by no more than 10% relative to the entire sample (Lundt et al. 1958; Munawar et al. 1974; Munawar and Munawar 1976).

All large algal cells and colonies in the entire counting chamber were enumerated at 100X. Intermediate-sized algae were counted at 400X along a minimum of one transect (26.0 mm in length) across the chamber. The smallest-sized algae (ultra- and nanoalgae < 15 μ m, such as phytoflagellates and micr unicellular algae) were counted at 1000X along at least one transect 10 mm in length. Algae were counted as individuals when their cells were readily recognizable. However, algae with indistinct cell walls (e.g., Schizothrix) were counted as 25- μ m "units." Enumerations for slides were quantified per mm² of slide surface.

Algae were identified to the lowest possible taxon, usually species. Sketches were made of each taxon to aid in identification and to help maintain taxonomic consistency. Taxa were also categorized by their division: Bacillariophyta (diatoms), Chlorophyta (green algae), Chrysophyta (golden-brown algae), Cyanophyta (blue-green algae), Euglenophyta (euglenoids), etc. Principal

taxonomic references for algal identification included Cooke (1967), Huber-Pestalozzi (1968), Hustedt (1930), Patrick and Reimer (1966), Prescott (1968), Smith (1950), and Whitford and Schumacher (1984).

Group community composition was evaluated by examining numerical abundance (number of organisms/mm²) and relative abundance (%), which was calculated as the percentage of a taxon occurring within each group relative to total abundance. Dominant taxa were considered to be those taxa comprising $\geq 5\%$ of the total population. Species diversity (Shannon-Weiner) was calculated following Pielou (1984).

To aid in the identification of diatoms, burn-mount Hyrax preparations (Patrick and Reimer 1966) were examined at 1000X with a Leitz research photographic microscope. The Hyrax preparations were made by drying a portion of a composite sample on a coverglass, heating the coverglass to 400-450 °C for a minimum of 2 hours to incinerate the diatom cell contents, and mounting the coverglass in Hyrax mounting medium on a microscope slide.

2.3 PROCEDURES: SESTON

Replicate samples of whole water were collected quarterly at each of the four sites (Stations 290, 330, 350, and 370; Figure 2-1) for determinations of total suspended solids (TSS), ash-free dry mass (AFDM), percent organic matter, and chlorophyll *a*. Samples were collected by hand from a depth of 25 cm, placed in securely capped polyethylene bottles, stored on ice in the dark, and transported to the laboratory for processing.

Current velocity was measured at each station at the time of seston collection, using a calibrated General Oceanics flowmeter model 2035 MK III with a 203 model readout or a Marsh-McBirney (Model 201D) current meter. The sensor probe was submerged facing the current at a depth of 25 cm, the depth at which the water samples were collected.

All water samples were thoroughly mixed in the laboratory prior to processing. For the AFDM and TSS analyses, up to 2 L of each water sample (depending upon the amount of solids present) was filtered through a prewashed/preashed/preweighed glass-fiber filter (Gelman AE). Samples were dried to constant weight at ca. 60 °C, as described in Wallace et al. (1982), and weighed with a Mettler analytical balance (Model AE 163) to determine dry mass. Samples were then combusted at 500 °C for 1 hour according to standard methods (APHA 1985), rewetted with a small amount of deionized water, redried to constant weight at ca. 60 °C, and reweighed to the nearest 0.01 mg to determine ash mass.

The AFDM of each filtered sample was calculated by the following equation:

$$\text{AFDM} = \text{DM} - \text{ash mass}$$

where: AFDM = mass of organic matter
DM = TSS or mass of inorganic and organic matter
ash mass = mass of inorganic matter

In reporting TSS and AFDM concentrations of the water samples, the results were corrected for volume of sample processed and are presented as mg/L. Organic matter was also calculated as a percentage of the dry mass ($\text{AFDM} + \text{DM} \times 100$).

Five percent of each set of samples was reweighed at both the dry mass step and the ash mass step to determine weighing precision levels. These data were maintained separately as part of the quality control program. An additional whole-water sample (>5% of samples collected) was randomly selected each month to be used for quality control splits. In the laboratory, each sample was thoroughly mixed and then split. Each replicate was processed as the normal seston sample.

Samples for chlorophyll *a* analysis were processed in subdued light and cool temperatures. Each sample was thoroughly mixed, and a measured volume (up to 250 mL) was filtered through a membrane filter (Metrice/GN-b, 0.45- μ m pore size; comparable to the Millipore HA, 0.45 μ m pore size). The filters were removed from the support screens, placed in a tube containing 10 mL of 90% aqueous acetone, and extracted in a freezer at 0 °C overnight. The samples were brought to room temperature in the dark, sonified at 75 watts for 90 seconds (Branson Model 185 sonifier), centrifuged for 5 minutes at 2500 rpm (IEC model S2K centrifuge), and assayed for chlorophyll *a* on a calibrated fluorometer (Turner Model 112). Chlorophyll *a* concentrations were calculated according to standard methods (APHA 1985), with corrections for pheophytin *a* made according to the method of Lorenzen (1967).

Splits for chlorophyll *a* analysis were also performed on one seston sample per month (> 5% of samples collected). The splitting procedure was the same as that used in the seston AFDM/TSS analysis.

2.4 STATISTICAL ANALYSES

Annual and quarterly means, standard errors, and range of values (annual basis only) were calculated using SAS (1988), with reference made to Sokal and Rohlf (1981) and Green (1979).

Because annual means for previous years (1986-1989) were based on monthly data (n=12), the means, standard errors, and range of values for these years were recalculated using data from only the four quarterly sampling dates (n=4) for this report. This recalculation (chlorophyll a and AFDM annual means only for periphyton) was conducted so that the cumulative data would be comparable among years, per agreement with SRL.

3.0 RESULTS AND DISCUSSION

3.1 RESULTS: PERIPHYTON

3.1.1 Organization of Results

Periphyton biomass is represented in this report by chlorophyll *a* concentration in mg/m² of substrate surface. Standing crop is represented by ash-free dry mass (AFDM) concentration in g/m² of substrate surface. Algal taxonomy data is presented as taxonomic community structure, common taxa, and taxa diversity. In this report, attention will be focused on presenting the results of sampling done in all years for stations being sampled under the 1990 L Lake/Steel Creek Biological Monitoring Program. However, results from data collected at stations included in the previous L-Lake/Steel Creek Biological Monitoring Program, but not included in the 1990 Scope-of-work, will be referred to when appropriate.

The 1990 and 1991 data are reported in text tables and figures as annual and (in some cases) quarterly means and standard error values. Raw data, and minimum (MIN) maximum (MAX) values are included in appendix tables. Each quarter is synonymous with the season in which samples were collected: January-March (winter), April-June (spring), July-September (summer), and October-December (fall).

3.1.2 Biomass and Standing Crop

Annual means and standard errors for chlorophyll *a* accumulated on glass slides are presented in Table 3-1. Range of values for the chlorophyll *a* data are reported in Appendix Table 1.

Table 3-1. Annual means for periphyton chlorophyll *a* content (mg/m²) accumulated on glass slides incubated in Steel Creek and Meyer's Branch. Minimum and maximum values are presented in Appendix Table 1. January 1986-December 1991.

Location	Station	1986 ^a		1987 ^a		1988 ^a	
		Mean	SE ^b	Mean	SE ^b	Mean	SE ^b
Reference Site	255	-	-	-	-	10.26	(1.27)
Corridor	275	7.76	(.74)	13.59	(2.60)	12.62	(1.08)
	280	7.60	(1.07)	3.75	(0.60)	4.61	(0.87)
	285	10.73	(1.02)	15.92	(1.46)	17.40	(2.38)
	290	8.41	(0.70)	12.37	(1.76)	15.62	(1.82)
Marsh	300	5.99	(0.65)	5.95	(1.01)	7.95	(1.32)
	310	6.43	(0.97)	10.15	(1.65)	7.16	(1.70)
	320	6.23	(1.02)	6.38	(1.23)	10.29	(2.01)
	330	7.53	(0.85)	10.47	(1.78)	5.67	(0.81)
Swamp	340	2.44	(0.65)	2.73	(0.68)	1.12	(0.12)
	350	2.57	(0.90)	2.86	(0.93)	0.85	(0.31)
Channel	360	2.44	(0.68)	3.06	(0.54)	3.56	(0.63)
	370	8.00	(0.93)	5.38	(1.51)	8.49	(1.02)
Meyer's Branch	400	2.50	(0.54)	1.01	(0.35)	1.06	(0.35)

^aSummary statistics for 1986-1989 were recalculated for comparison with 1990 and 1991 results by using data only from the four months that corresponded to the 1990 and 1991 quarterly sampling months.

^bStandard error.

Table 3-1 (continued). Annual means for periphyton chlorophyll *a* content (mg/m²) accumulated on glass slides incubated in Steel Creek and Meyer's Branch. Minimum and maximum values are presented in Appendix Table 1. January 1986-December 1991.

Location	Station	1989 ^a		1990		1991	
		Mean	SE ^b	Mean	SE ^b	Mean	SE ^b
Reference Site	255	10.99	(1.25)	-	-	-	-
Corridor	275	10.91	(1.12)	-	-	-	-
	280	10.60	(1.34)	-	-	-	-
	285	14.04	(0.99)	-	-	-	-
	290	9.72	(0.83)	17.61	(0.68)	11.92	(2.11)
Marsh	300	4.41	(0.67)	-	-	-	-
	310	6.19	(0.61)	-	-	-	-
	320	5.41	(0.78)	-	-	-	-
	330	3.65	(0.74)	8.04	(1.52)	4.70	(1.09)
Swamp	340	3.18	(0.56)	-	-	-	-
	350	1.26	(0.38)	4.08	(1.18)	0.95	(0.30)
Channel	360	2.43	(0.65)	-	-	-	-
	370	4.18	(0.88)	5.30	(1.61)	0.96	(0.32)
Meyer's Branch	400	1.14	(0.34)	-	-	-	-

^aSummary statistics for 1986-1989 were recalculated for comparison with 1990 and 1991 results by using data only from the four months that corresponded to the 1990 and 1991 quarterly sampling months.

^bStandard error.

There does not appear to be great differences in annual mean chlorophyll *a* concentrations between years at any station from 1986 through 1991. Generally, mean chlorophyll *a* concentrations were highest at corridor stations and lowest at swamp or channel stations (Table 3-1). Among the corridor stations, chlorophyll *a* concentrations ranged from 3.75 mg/m² at Station 280 (1987) to 17.61 mg/m² at Station 290 (1990). The chlorophyll *a* content at Station 290 was 8.41 mg/m² in 1986. It increased to 15.62 mg/m² by 1988 then decreased to 9.72 mg/m² in 1989, increased to 17.61 mg/m² in 1990, and decreased to 11.92 mg/m² in 1991. Among marsh stations, chlorophyll *a* content ranged from 3.65 mg/m² at Station 330 (1989) to 10.47 mg/m² at Station 330 (1987). At Station 330, chlorophyll *a* concentration increased from 7.53 mg/m² in 1986 to 10.47 mg/m² in 1987, then decreased to 3.65 mg/m² by 1989, increased to 8.04 mg/m² in 1990, and decreased to 4.70 mg/m² in 1991. Among swamp stations, chlorophyll *a* concentrations ranged from 0.85 mg/m² at Station 350 (1988) to 4.08 mg/m² at Station 350 (1990). At Station 350, chlorophyll *a* concentration was 2.57 mg/m² in 1986 and 2.86 mg/m² in 1987, then decreased to 0.85 mg/m² in 1988, increased to 4.08 mg/m² by 1990, and decreased to 0.95 mg/m² in 1991. Among the downstream channel stations, chlorophyll *a* concentrations ranged from 0.96 mg/m² at Station 370 (1991) to 8.00 mg/m² at Station 370 (1986). At Station 370, chlorophyll *a* concentration decreased from 8.00 mg/m² in 1986 to 5.38 mg/m² in 1987, increased to 8.49 mg/m² in 1988, decreased to 4.18 mg/m² in 1989, then increased slightly to 5.30 mg/m² in 1990, and decreased to 0.96 in 1991.

Due to the change in the sampling program reported in Section 2.1, the monthly sampling for chlorophyll *a* concentrations became quarterly sampling in 1990. This change in sampling regime has reduced the sensitivity of the sampling program to detect temporal changes in chlorophyll *a* concentrations. Monthly

chlorophyll *a* concentrations at Stations 290, 330, 350, and 370 from 1986 through 1989 are presented in Figures 3-1 through 3-4 along with the quarterly mean chlorophyll *a* concentrations in 1990 and 1991.

In 1990, chlorophyll *a* concentrations were highest in winter quarter at all four stations; while in 1991, chlorophyll *a* concentrations were highest in winter at only two stations (290 and 330) (Figures 3-1 through 3-4). However, in previous years periphyton biomass was often lowest in winter quarter. The amount of change which took place within and between years varied greatly between stations. The least amount of temporal variation between years in chlorophyll *a* concentration was at Station 350.

The annual mean ash-free dry mass (AFDM) of periphyton accumulated on glass slides (standing crop) after a four-week incubation period for 1986 through 1990 is reported in Table 3-2. Summary statistics are reported in Appendix Table 2.

The lowest mean AFDM recorded in the L-Lake/Steel Creek Biological Monitoring Program, before or after the change in the sampling regime, was 0.26 g/m² at Station 350 in 1988 while the highest AFDM was 35.52 g/m² at Station 275 in 1988 (Table 3-2). Generally, AFDM was higher at the corridor stations than at stations in the marsh, swamp, or channel. From 1986 through 1989, Station 275 consistently had the highest AFDM; however, periphyton was not sampled at this station in 1990 and 1991. Station 275 is closer to the stilling basin of the L-Lake dam than any other station. Due to the random nature of AFDM and the large standard errors, we are unable to discern any trends in the data other than those presented above.

STATION 290

Figure 3-1. Mean chlorophyll a concentrations (mg/m²) accumulated on glass slides incubated at Steel Creek corridor Station 290. Top panel: monthly means; January 1986-December 1989. Bottom panel: quarterly means; vertical bars represent one standard error; 1990 and 1991.

STATION 330

Figure 3-2. Mean chlorophyll *a* concentrations (mg/m²) accumulated on glass slides incubated at Steel Creek marsh Station 330. Top panel: monthly means; January 1986-December 1989. Bottom panel: quarterly means; vertical bars represent one standard error; 1990 and 1991.

STATION 350

Figure 3-3. Mean chlorophyll *a* concentrations (mg/m²) accumulated on glass slides incubated at Steel Creek swamp Station 350. Top panel: monthly means; January 1986-December 1989. Bottom panel: quarterly means; vertical bars represent one standard error; 1990 and 1991.

STATION 370

Figure 3-4. Mean chlorophyll *a* concentrations (mg/m²) accumulated on glass slides incubated at Steel Creek channel Station 370. Top panel: monthly means; January 1986-December 1989. Bottom panel: quarterly means; vertical bars represent one standard error; 1990 and 1991.

Table 3-2. Annual means for periphyton ash-free dry mass (g/m^2) accumulated on glass slides incubated in Steel Creek and Meyer's Branch. Minimum and maximum values are presented in Appendix Table 2. January 1986-December 1991.

Location	Station	1986 ^a		1987 ^a		1988 ^a	
		Mean	SE ^b	Mean	SE ^b	Mean	SE ^b
Reference Site	255	-	-	-	-	1.50	(0.14)
Corridor	275	6.79	(1.51)	5.84	(0.94)	35.52	(7.33)
	280	3.13	(0.38)	1.70	(0.32)	1.49	(0.14)
	285	4.09	(0.52)	3.42	(0.50)	2.18	(0.22)
	290	1.95	(0.28)	1.73	(0.17)	2.07	(0.16)
Marsh	300	1.62	(0.27)	0.96	(0.18)	1.27	(0.12)
	310	1.06	(0.22)	1.20	(0.12)	0.85	(0.13)
	320	0.73	(0.12)	1.00	(0.12)	1.13	(0.18)
	330	1.44	(0.23)	0.79	(0.09)	0.94	(0.09)
Swamp	340	0.63	(0.05)	0.53	(0.07)	0.27	(0.02)
	350	0.58	(0.09)	0.49	(0.08)	0.26	(0.03)
Channel	360	0.50	(0.05)	0.30	(0.04)	0.44	(0.05)
	370	0.96	(0.33)	0.38	(0.07)	0.72	(0.09)
Meyer's Branch	400	1.16	(0.18)	1.03	(0.18)	0.70	(0.09)

^aSummary statistics for 1986-1989 were recalculated for comparison with 1990 and 1991 results by using data only from the four months that corresponded to the 1990 and 1991 quarterly sampling months.

^bStandard error.

Table 3-2 (continued). Annual means for periphyton ash-free dry mass (g/m²) accumulated on glass slides incubated in Steel Creek and Meyer's Branch. Minimum and maximum values are presented in Appendix Table 2. January 1986-December 1991.

Location	Station	1989 ^a		1990		1991	
		Mean	SE ^b	Mean	SE ^b	Mean	SE ^b
Reference Site	255	1.14	(0.13)	-	-	-	-
Corridor	275	6.57	(1.04)	-	-	-	-
	280	1.38	(0.17)	-	-	-	-
	285	2.22	(0.22)	-	-	-	-
	290	2.03	(0.12)	2.29	(0.23)	2.53	(0.19)
Marsh	300	1.05	(0.13)	-	-	-	-
	310	1.02	(0.08)	-	-	-	-
	320	0.87	(0.13)	-	-	-	-
	330	0.68	(0.10)	1.47	(0.14)	1.63	(0.28)
Swamp	340	0.51	(0.06)	-	-	-	-
	350	0.34	(0.05)	0.60	(0.06)	1.11	(0.45)
Channel	360	0.28	(0.04)	-	-	-	-
	370	0.66	(0.10)	0.90	(0.12)	0.58	(0.24)
Meyer's Branch	400	0.62	(0.06)	-	-	-	-

^aSummary statistics for 1986-1989 were recalculated for comparison with 1990 and 1991 results by using data only from the four months that corresponded to the 1990 and 1991 quarterly sampling months.

^bStandard error.

Seasonal mean ash-free dry mass (AFDM) accumulations in 1990 and 1991 are presented in Figures 3-5 through 3-8. At corridor Station 290 and downstream channel Station 370, AFDM accumulation was high in winter, decreased in spring, increased in summer, and decreased in fall. At Station 290 in 1991, AFDM increased between winter and spring quarters and decreased summer and fall quarters. However, at Station 370 AFDM decreased spring, summer and fall quarters. There was little difference in AFDM between quarters at Stations 330 and 350 in 1990 and 1991, except for spring 1991 when there was an unusually high AFDM reading at Station 350. Due to infrequency of sampling at the Steel Creek stations under the present sampling schedule, the data reported in Figures 3-5 through 3-8 may not fully represent the temporal variation of periphyton AFDM standing crop at the four Steel Creek stations.

3.1.3 Algal Taxonomy

3.1.3.1 Taxonomic Community Structure

The 1991 taxonomic community structure is reported as annual mean numerical abundance (Table 3-3 and Appendix Table 3). Organisms from six divisions (Bacillariophyta [diatoms], Chlorophyta [green algae], Chrysophyta [golden-brown algae], Cryptophyta [cryptomonads], Cyanophyta [blue-green algae], and Euglenophyta [euglenoids]) were found on glass slides at Station 350. Organisms representing five divisions were identified on glass slides at Stations 330 and 370; Bacillariophyta, Chlorophyta, Chrysophyta, and Cyanophyta were growing at Stations 330 and 370, while Cryptophyta grew only at Station 370 and Euglenophyta was found only at Station 330. At Station 290, only three divisions (Bacillariophyta, Chlorophyta, and Cyanophyta) were found.

STATION 290 Ash-Free Dry Mass

Figure 3-5. Quarterly mean AFDM concentrations (g/m²) accumulated on glass slides incubated at Steel Creek corridor Station 290. Bars represent one standard error. 1990 and 1991.

STATION 330
Ash - Free Dry Mass

Figure 3-6. Quarterly mean AFDM concentrations (g/m²) accumulated on glass slides incubated at Steel Creek marsh Station 330. Bars represent one standard error. 1990 and 1991.

STATION 350
Ash - Free Dry Mass

Figure 3-7. Quarterly mean AFDM concentrations (g/m^2) accumulated on glass slides incubated at Steel Creek swamp Station 350. Bars represent one standard error. 1990 and 1991.

STATION 370
Ash free dry mass

Figure 3-8. Quarterly mean AFDM concentrations (g/m^2) accumulated on glass slides incubated at Steel Creek channel Station 370. Bars represent one standard error. 1990 and 1991.

Table 3-3. Annual mean and standard error of abundance (organisms/mm²) of algal organisms accumulated on glass periphytometer slides by division at four Steel Creek stations in 1991. Summary statistics are presented in Appendix Table 3.

Division ^a	Mean	SE
<u>Station 290</u>		
Bacillariophyta	2019.7	1006.7
Chlorophyta	760.5	395.1
Cyanophyta	72.6	31.2
<u>Station 330</u>		
Bacillariophyta	977.9	190.3
Chlorophyta	621.4	172.6
Chrysophyta	11.3	11.3
Cyanophyta	40.6	16.9
Euglenophyta	0.7	0.7
<u>Station 350</u>		
Bacillariophyta	579.2	509.9
Chlorophyta	251.7	219.8
Chrysophyta	2.6	2.5
Cryptophyta	0.1	0.1
Cyanophyta	51.3	43.7
Euglenophyta	0.1	0.1
<u>Station 370</u>		
Bacillariophyta	190.4	92.6
Chlorophyta	35.2	14.9
Chrysophyta	1.1	0.9
Cryptophyta	0.3	0.2
Cyanophyta	3.7	1.9

^aBacillariophyta - diatoms
 Chlorophyta - green algae
 Chrysophyta - golden-brown algae
 Cryptophyta - cryptomonads
 Cyanophyta - blue-green algae
 Euglenophyta - euglenoids.

Bacillariophyta (diatoms) had the highest annual mean numerical abundance values of all divisions at all four Steel Creek stations in 1991. The second most abundant division at all stations was Chlorophyta (green algae). Densities of diatoms and green algae were highest at Station 290 and lowest at Station 370 (Table 3-3). The numerical abundance of diatoms was 2019.7 organisms/mm² at Station 290, 977.9 organisms/mm² at Station 330, 579.2 organisms/mm² at Station 350, and 190.4 organisms/mm² at Station 370. Green algae had a numerical abundance of 760.5 organisms/mm² at Station 290, 621.4 organisms/mm² at Station 330, 251.7 organisms/mm² at Station 350, and 35.2 organisms/mm² at Station 370.

Cyanophyta (blue-green algae) was the third most abundant division at all four Steel Creek stations in 1991 (Table 3-3). Like diatoms and green algae, blue-green algal density was highest at Station 290 and lowest at Station 370. The annual mean numerical abundance of blue-green algae was 72.6 organisms/mm² at Station 290, 40.6 organisms/mm² at Station 330, 51.3 organisms/mm² at Station 350, and 3.7 organisms/mm² at Station 370.

Chrysophyta (golden-brown algae) was the fourth most abundant division at Stations 330, 350, and 370 but was absent from Station 290 in 1991 (Table 3-3). This division had an annual mean abundance of 11.3 organisms/mm² at Station 330, 2.6 organisms/mm² at Station 350, and 1.1 organisms/mm² at Station 370. Euglenophyta (euglenoids) was only found at Stations 330 (0.7 organisms/mm²) and 350 (0.1 organisms/mm²), while Cryptophyta (cryptomonads) was only found at Station 350 (0.1 organisms/mm²) and 370 (0.3 organisms/mm²).

Community composition data from 1986 through 1989 is presented as relative abundance by division based on total annual counts in Table 3-4. The 1990 and

Table 3-4. Periphyton community composition on glass slides incubated in Steel Creek and Meyer's Branch. Relative abundance by division based on total annual counts. January 1986-December 1991.

Station	Division ^a	Relative Abundance (%)					
		1986	1987	1988	1989	1990	1991
255 ^b	Bacillariophyta	-	-	80.7	63.2	-	-
	Chlorophyta	-	-	15.9	18.8	-	-
	Chrysophyta	-	-	0.0	0.2	-	-
	Cryptophyta	-	-	0.0	0.0	-	-
	Cyanophyta	-	-	3.3	17.8	-	-
	Euglenophyta	-	-	<0.1	0.1	-	-
275	Bacillariophyta	69.3	16.1	42.6	48.1	-	-
	Chlorophyta	17.9	3.7	40.4	40.4	-	-
	Chrysophyta	0.0	0.0	0.1	<0.1	-	-
	Cryptophyta	0.0	0.0	0.0	0.0	-	-
	Cyanophyta	12.8	80.1	16.8	11.5	-	-
	Euglenophyta	0.0	<0.1	0.1	<0.1	-	-
280	Bacillariophyta	71.8	54.2	79.9	37.4	-	-
	Chlorophyta	18.4	6.7	9.9	28.6	-	-
	Chrysophyta	0.0	0.0	0.0	0.0	-	-
	Cryptophyta	0.0	0.0	<0.1	0.0	-	-
	Cyanophyta	9.8	39.1	10.2	33.7	-	-
	Euglenophyta	<0.1	0.0	0.0	0.3	-	-
	Pyrrophyta	0.0	0.0	<0.1	0.0	-	-
285	Bacillariophyta	81.8	85.4	94.8	80.8	-	-
	Chlorophyta	5.8	1.8	1.2	1.8	-	-
	Chrysophyta	<0.1	0.0	0.1	0.0	-	-
	Cryptophyta	0.0	0.0	0.0	0.0	-	-
	Cyanophyta	12.4	12.8	3.9	17.3	-	-
	Euglenophyta	0.0	0.0	0.0	0.0	-	-
290	Bacillariophyta	28.6	82.2	87.1	84.7	80.1	70.8
	Chlorophyta	62.9	13.9	11.8	12.0	18.7	26.7
	Chrysophyta	0.1	0.0	0.0	0.0	0.0	0.0
	Cryptophyta	0.0	0.1	0.0	0.0	0.0	0.0
	Cyanophyta	8.4	3.8	1.1	3.3	1.2	2.5
	Euglenophyta	0.0	0.0	0.0	0.0	0.0	0.0

^aBacillariophyta - diatoms

Chlorophyta - green algae

Chrysophyta - golden-brown algae

Cryptophyta - cryptomonads

Cyanophyta - blue-green algae

Euglenophyta - euglenoids

Pyrrophyta - dinoflagellates.

^bFull-scale sampling commenced in 1988.

Table 3-4 (continued). Periphyton community composition on glass slides incubated in Steel Creek and Meyer's Branch. Relative abundance by division based on total annual counts. January 1986-December 1991.

Station	Division ^a	<u>Relative Abundance (%)</u>					
		1986	1987	1988	1989	1990	1991
300	Bacillariophyta	43.4	60.8	32.2	52.4	-	-
	Chlorophyta	49.9	29.0	65.4	42.1	-	-
	Chrysophyta	0.2	0.0	0.0	0.1	-	-
	Cryptophyta	<0.1	0.1	0.0	<0.1	-	-
	Cyanophyta	6.4	10.1	2.3	5.3	-	-
	Euglenophyta	<0.1	<0.1	0.1	<0.1	-	-
310	Bacillariophyta	23.0	61.6	36.5	30.3	-	-
	Chlorophyta	72.0	30.8	59.9	54.4	-	-
	Chrysophyta	0.0	0.3	0.1	0.0	-	-
	Cryptophyta	0.0	0.0	0.0	0.0	-	-
	Cyanophyta	5.0	7.3	3.5	15.2	-	-
	Euglenophyta	<0.1	0.0	0.0	0.1	-	- ¹
320	Bacillariophyta	33.4	50.7	55.4	24.1	-	-
	Chlorophyta	56.1	33.4	36.8	69.6	-	-
	Chrysophyta	<0.1	<0.1	0.0	0.0	-	-
	Cryptophyta	0.0	0.1	0.0	0.0	-	-
	Cyanophyta	10.4	15.7	7.8	6.3	-	-
	Euglenophyta	0.0	0.0	0.0	<0.1	-	-
330	Bacillariophyta	58.4	80.7	36.3	24.3	34.9	59.2
	Chlorophyta	27.8	16.0	57.1	41.4	53.6	37.6
	Chrysophyta	<0.1	0.0	0.0	0.0	1.1	0.7
	Cryptophyta	<0.1	<0.1	0.0	<0.1	0.0	0.0
	Cyanophyta	13.7	3.2	6.5	34.2	10.4	2.5
	Euglenophyta	0.0	0.0	<0.1	0.1	0.0	<0.1
340	Bacillariophyta	23.9	28.3	63.3	47.1	-	-
	Chlorophyta	69.3	42.1	30.9	43.5	-	-
	Chrysophyta	0.2	0.1	0.1	0.1	-	-
	Cryptophyta	0.1	0.2	2.7	0.0	-	-
	Cyanophyta	6.5	29.3	3.0	9.2	-	-
	Euglenophyta	0.0	0.1	0.1	0.1	-	-

^aBacillariophyta - diatoms

Chlorophyta - green algae

Chrysophyta - golden-brown algae

Cryptophyta - cryptomonads

Cyanophyta - blue-green algae

Euglenophyta - euglenoids.

Table 3-4 (continued). Periphyton community composition on glass slides incubated in Steel Creek and Meyer's Branch. Relative abundance by division based on total annual counts. January 1986-December 1991.

Station	Division ^a	<u>Relative Abundance (%)</u>					
		1986	1987	1988	1989	1990	1991
350	Bacillariophyta	76.9	52.4	61.1	34.5	60.2	65.5
	Chlorophyta	14.2	30.6	24.7	16.3	37.8	28.4
	Chrysophyta	<0.1	0.1	0.7	0.0	0.0	0.3
	Cryptophyta	0.0	0.0	0.1	0.0	0.0	<0.1
	Cyanophyta	8.7	16.7	12.8	49.2	2.0	5.8
	Euglenophyta	0.1	0.1	0.6	<0.1	0.0	<0.1
360	Bacillariophyta	81.1	87.1	71.3	76.0	-	-
	Chlorophyta	14.9	8.9	4.0	10.6	-	-
	Chrysophyta	0.0	0.1	0.2	<0.1	-	-
	Cryptophyta	0.0	0.0	0.1	0.0	-	-
	Cyanophyta	4.0	3.9	24.3	13.3	-	-
	Euglenophyta	0.0	<0.1	0.2	0.1	-	-
370	Bacillariophyta	40.8	72.1	74.1	64.9	42.6	82.5
	Chlorophyta	58.0	15.2	18.5	14.2	53.4	15.3
	Chrysophyta	<0.1	0.3	0.0	0.0	0.1	0.5
	Cryptophyta	0.0	0.0	<0.1	0.0	<0.1	0.1
	Cyanophyta	1.1	12.4	7.4	20.8	3.9	1.6
	Euglenophyta	0.0	0.0	0.0	0.1	0.0	0.0
400	Bacillariophyta	78.3	89.3	89.5	91.1	-	-
	Chlorophyta	3.2	7.2	1.6	2.3	-	-
	Chrysophyta	0.0	0.2	<0.1	0.1	-	-
	Cryptophyta	0.0	0.0	0.0	<0.1	-	-
	Cyanophyta	18.5	3.2	8.9	6.4	-	-
	Euglenophyta	0.0	<0.1	0.0	<0.1	-	-

^aBacillariophyta = diatoms

Chlorophyta = green algae

Chrysophyta = golden-brown algae

Cryptophyta = cryptomonads

Cyanophyta = blue-green algae

Euglenophyta = euglenoids.

1991 community composition data (Table 3-4) is presented as mean relative annual abundance based on quarterly counts. The above change does not affect the numerical values of the final output; therefore, 1990 and 1991 relative abundance values are comparable with previous years' data.

At corridor Stations 275 and 280, the relative abundance of Cyanophyta (blue-green algae) increased from 1986 to 1987 and decreased from 1987 to 1989 (Table 3-4). The most marked change among years occurred at Station 275, where blue-green algae constituted a relatively minor percentage of the periphyton population in 1986 (12.8%), increased to become predominant in 1987 (80.1% of the total), and then decreased substantially in 1988 (16.8%). In 1989, algal community composition (11.5%) was comparable to that in 1988. The relative abundances of diatoms (Bacillariophyta) and blue-green algae (Cyanophyta) at Station 275 were also more comparable between 1988 and 1989 than in previous years. At Stations 285 and 290, the community composition was comparable between 1987 and 1989. The relative abundance of diatoms decreased and blue-green algae increased between 1988 and 1989 at Stations 280, 285, and 290. In 1989, diatoms were the most abundant division at all corridor stations (from 37.4% at Station 280 to 84.7% at Station 290) and remained so at Station 290 in 1990 and 1991. However, the relative abundance of diatoms at Station 290 has declined slightly from 87.1% (the highest level ever at this station) in 1988 to 70.8% in 1991, while the relative abundance of green algae has risen from 11.8% in 1988 to 26.7% in 1991. Throughout this study blue-green algae has fluctuated between 1.1 and 8.4% at Station 290.

Diatoms became the major algal division at all marsh stations in 1987 but decreased in relative abundance at all stations (except for Station 320) by 1988

(Table 3-4). Between 1988 and 1989, diatoms decreased in abundance at all marsh sites except Station 300, whereas blue-green algae increased and green algae decreased in abundance at all marsh sites except Station 320 over this time period. At all sites, except Station 330, green algae were predominant in 1986. In 1988 and 1989, green algae were also abundant, although diatoms predominated at Station 320 in 1988 and Station 300 in 1989. At Station 330, green algae remained dominant in 1990 with an annual mean relative abundance of 53.6%; however, by 1991, diatoms (59.2%) had a greater relative abundance than green algae (37.6%). Decreases in the relative abundance of blue-green algae from 1987 to 1988 were seen at all marsh sites except Station 330 (3.2% in 1987 to 6.5% in 1988). The relative abundance of blue-green algae at Station 330 in 1989 was 34.2%, the highest for any marsh station during this study. However, it decreased to 10.4% in 1990 and 2.5% in 1991.

During 1986 and 1987, the swamp stations were quite different from one another with regard to the periphyton community composition (Table 3-4). In 1986 and 1987, green algae were most abundant at Station 340 (69.3% and 42.1%), while diatoms were most abundant at Station 350 (76.9% and 52.4%). In 1988, diatoms were most abundant at both stations (63.3% and 61.1% at Stations 340 and 350, respectively). They were dominant again at Station 350 in 1990 with a relative abundance of 60.2% and in 1991 with a relative abundance of 65.5%. Both green and blue-green algae decreased in relative abundance at both stations between 1987 and 1988. Between 1988 and 1989, diatom relative abundance decreased and blue-green algae relative abundance increased at both stations, although more substantially at Station 350. In 1989, blue-green algae were the dominant division at Station 350 and had the highest relative abundance (49.2%) of any

station during this study, except Station 275 in 1987. However, blue-green algae relative abundance decreased to 2.0% in 1990 and rose slightly to 5.8% in 1991.

Diatoms were the major algal division from 1987 through 1989 at both channel stations (Table 3-4). The relative abundance of most algal divisions at these stations was fairly comparable during this period. However, the relative abundance of blue-green algae increased between 1987 (3.9%) and 1988 (24.3%) at Station 360, and between 1988 (7.4%) and 1989 (20.8%) at Station 370, then it decreased at Station 370 to 3.9% in 1990. At Station 370, green algae was dominant in 1986 and 1990, but diatoms predominated from 1987 through 1989 and in 1991.

At Meyer's Branch (sampled from 1986 through 1989), diatoms were predominant in all four years, increasing slightly in abundance each year of sampling (from 78.3% in 1986 to 91.1% in 1989; Table 3-4). Community composition of periphyton was comparable between 1988 and 1989 at Station 400. At Steel Creek Station 255, diatoms predominated in 1988 and 1989, followed by green algae. However, between 1988 and 1989, blue-green algae increased in abundance, from 3.3% to 17.8%.

The quarterly numerical abundance of algal divisions by station for 1991 are reported in Table 3-5, while the quarterly relative abundances of algae divisions are reported in Table 3-6.

The 1991 quarterly numerical abundance of Bacillariophyta (diatoms) at Corridor Station 290 was 776.6 organisms/mm² in winter, 4825.1 organisms/mm² in spring, 365.2 organisms/mm² in summer, and 2112.0 organisms/mm² in fall (Table

Table 3-5. Quarterly numerical abundance (organisms/mm²) of algal organisms by division at Steel Creek stations in 1991.

Division ^a	Winter	Spring	Summer	Fall
<u>Station 290</u>				
Bacillariophyta	776.6	4825.1	365.2	2112.0
Chlorophyta	226.6	1887.1	731.5	196.8
Cyanophyta	4.4	79.1	154.0	52.8
<u>Station 330</u>				
Bacillariophyta	901.8	1197.3	475.8	1336.5
Chlorophyta	218.7	456.3	964.6	846.0
Chrysophyta	0.0	0.0	0.0	45.0
Cyanophyta	0.0	58.5	27.3	76.5
Euglenophyta	2.7	0.0	0.0	0.0
<u>Station 350</u>				
Bacillariophyta	3.5	2106.0	154.4	53.1
Chlorophyta	2.0	910.0	63.2	31.5
Chrysophyta	0.0	0.0	0.0	10.2
Cryptophyta	0.0	0.0	0.0	0.3
Cyanophyta	0.0	182.0	17.6	5.7
Euglenophyta	0.0	0.0	0.0	0.3
<u>Station 370</u>				
Bacillariophyta	6.2	299.7	392.4	63.4
Chlorophyta	0.6	54.9	64.8	20.6
Chrysophyta	0.0	3.6	0.0	0.6
Cryptophyta	0.0	0.9	0.0	0.2
Cyanophyta	0.0	2.7	9.0	3.2

^aBacillariophyta - diatoms
 Chlorophyta - green algae
 Chrysophyta - golden-brown algae
 Cryptophyta - cryptomonads
 Cyanophyta - blue-green algae
 Euglenophyta - euglenoids.

Table 3-6. Quarterly relative abundance (%) of algal organisms by division at Steel Creek stations in 1991.

Division ^a	Winter	Spring	Summer	Fall
<u>Station 290</u>				
Bacillariophyta	77.07	71.05	29.20	89.43
Chlorophyta	22.49	27.79	58.49	8.33
Cyanophyta	0.44	1.16	12.31	2.24
<u>Station 330</u>				
Bacillariophyta	80.29	69.93	32.42	58.01
Chlorophyta	19.47	26.65	65.72	36.72
Chrysophyta	0.0	0.0	0.0	1.95
Cyanophyta	0.0	3.42	1.86	3.32
Euglenophyta	0.24	0.0	0.0	0.0
<u>Station 350</u>				
Bacillariophyta	63.72	65.85	65.65	52.52
Chlorophyta	36.10	28.46	26.87	31.16
Chrysophyta	0.18	0.0	0.0	10.09
Cryptophyta	0.0	0.0	0.0	0.30
Cyanophyta	0.0	5.69	7.48	5.64
Euglenophyta	0.0	0.0	0.0	0.30
<u>Station 370</u>				
Bacillariophyta	90.88	82.84	84.17	72.05
Chlorophyta	8.82	15.17	13.90	23.41
Chrysophyta	0.29	1.00	0.0	0.68
Cryptophyta	0.0	0.25	0.0	0.23
Cyanophyta	0.0	0.75	1.93	3.64

^aBacillariophyta - diatoms
 Chlorophyta - green algae
 Chrysophyta - golden-brown algae
 Cryptophyta - cryptomonads
 Cyanophyta - blue-green algae
 Euglenophyta - euglenoids.

3-5). For Chlorophyta (green algae), the quarterly numerical abundance was 226.6 organisms/mm² in winter, 1887.1 organisms/mm² in spring, 731.5 organisms/mm² in summer, and 196.8 organisms/mm² in fall. Cyanophyta (blue-green algae) had a quarterly numerical abundance of 4.4 organisms/mm² in winter, 79.1 organisms/mm² in spring, 154.0 organisms/mm² in summer, and 52.8 organisms/mm² in fall.

At the marsh station (Station 330), the 1991 quarterly numerical abundance of diatoms was 901.8 organisms/mm² in winter, 1197.3 organisms/mm² in spring, 475.8 organisms/mm² in summer, and 1336.5 organisms/mm² in fall (Table 3-5). Green algae had a quarterly numerical abundance of 218.7 organisms/mm² in winter, 456.3 organisms/mm² in spring, 964.6 organisms/mm² in summer, and 846.0 organisms/mm² in fall. Chrysophyta (golden-brown algae) was only found on slides from Station 330 during fall quarter when it had a numerical abundance of 45.0 organisms/mm². Blue-green algae was not found at Station 330 during winter but had a quarterly numerical abundance of 58.5 organisms/mm² in spring, 27.3 organisms/mm² in summer, and 76.5 organisms/mm² in fall. The quarterly numerical abundance of Euglenophyta (euglenoids) was 2.7 organisms/mm² in winter. euglenoids were not found at Station 330 in spring, summer, or fall quarters.

At the swamp station (Station 350) the 1991 quarterly numerical abundance of diatoms was 3.5 organisms/mm² in winter, 2106.0 organisms/mm² in spring, 154.4 organisms/mm² in summer, and 53.1 organisms/mm² in fall (Table 3-5). At this station, green algae had a numerical abundance of 2.0 organisms/mm² in winter, 910.0 organisms/mm² in spring, 63.2 organisms/mm² in summer, and 31.5 organisms/mm² in fall. Blue-green algae was not found on slides from Steel Creek Station 350 during the winter; however, the numerical abundance of blue-green algae at this station was 182.0 organisms/mm² in spring, 17.6 organisms/mm² in

summer, and 5.7 organisms/mm² in fall. Golden-brown algae, and euglenoids were not found on slides from Station 350 during winter, spring, or summer quarters. However, each of these groups were present during fall with numerical abundances of 10.2 organisms/mm² (golden-brown algae), 0.3 organisms/mm² (cryptomonads), and 0.3 organisms/mm² (euglenoids) respectively.

At the channel station (Station 370) the 1991 quarterly numerical abundance of diatoms was 6.2 organisms/mm² in winter, 299.7 organisms/mm² in spring, 392.4 organisms/mm² in summer, and 63.4 organisms/mm² in fall (Table 3-5). Green algae had a quarterly numerical abundance of 0.6 organisms/mm² in winter, 54.9 organisms/mm² in spring, 64.8 organisms/mm² in summer, and 20.6 organisms/mm² in fall. Golden-brown algae had a numerical abundance of 3.6 organisms/mm² in spring, and 0.6 organisms/mm² in fall. The quarterly numerical abundance of cryptomonads at Station 370 was 0.9 organisms/mm² in spring and 0.2 organisms/mm² in fall; specimens of these two divisions were not found at Station 370 during either winter or summer quarters. There were no blue-green algae found on slides from Station 370 in winter, but blue-green algae had a numerical abundance of 2.7 organisms/mm² in spring, 9.0 organisms/mm² in summer, and 3.2 organisms/mm² in fall.

Quarterly relative abundance of algal divisions in 1991 is recorded in Table 3-6. At Station 290 the relative abundance of Bacillariophyta (diatoms) ranged from 29.20% (spring) to 89.43% (fall). Diatoms had the highest relative abundance during all quarters, except summer when Chlorophyta (green algae) was more abundant. The relative abundance of green algae ranged from 8.33% (fall) to 58.49% (summer). Each quarter, Cyanophyta (blue-green algae) had the smallest

relative abundance of all divisions found at this station. Its relative abundance ranged from 0.44 to 12.31%.

At Station 330 the 1991 relative abundance of diatoms ranged from 32.42% (summer) to 80.29% (winter; Table 3-6). As with Station 290, diatoms had the highest relative abundance at Station 330 during all quarters except summer. The relative abundance of green algae ranged from 19.47 to 65.72%. Blue-green algae relative abundance ranged from 0 to 3.42%. Chrysophyta (golden-brown algae) was only found at Station 330 in fall quarter when its relative abundance was 1.95%, while Euglenophyta (euglenoids) were found only in winter with a relative abundance of 0.24%.

At Station 350, diatoms were the most abundant division during each quarter in 1991. Their relative abundance ranged from 52.52 to 65.85% (Table 3-6). Green algae was the second most abundant group of algae present at this station with a relative abundance ranging from 26.87 to 36.10%. The relative abundance of golden-brown algae was 0.18% in winter and 10.09% in fall; no golden-brown algae was found during spring and summer quarters. Blue-green algae were found during spring, summer, and fall quarters. The relative abundance of organisms from this group of algae ranged 0.0 to 7.48%. Cryptomonads and euglenoids were found only in fall quarter when the relative abundance of each group was 0.30%.

Diatoms were the most abundant algal group at Station 370 during all quarters in 1991 with relative abundance values ranging from 72.05 to 90.88% (Table 3-6). The second most abundant algal group at this site was green algae which had relative abundances ranging from 8.82 to 23.41%. Less common algal groups present were golden-brown algae with relative abundances ranging from 0.0

to 1.0%, blue-green algae with relative abundances ranging from 0.0 to 3.64%, and cryptomonads with relative abundance values ranging from 0.0 to 0.25%.

3.1.3.2 Common Taxa

Individual taxa with relative mean annual abundance values greater than 5.0% in 1991 were considered to be common taxa and are presented with their annual mean numerical abundances and standard errors in Table 3-7. Summary statistics are presented in Appendix Table 4. The above taxa are presented with their quarterly numerical abundance and standard error values in Table 3-8.

At Station 290 in 1991, there were 12 common algal taxa (Table 3-7). These taxa included eight Bacillariophyta (diatoms): Gomphonema parvulum (939.7 organisms/mm²), Cocconeis placentula (355.8 organisms/mm²), Eunotia pectinalis (252.0 organisms/mm²), Achnanthes lanceolata (107.0 organisms/mm²), Cocconeis fluviatilis (51.0 organisms/mm²), Fragilaria vaucheriae (41.3 organisms/mm²), Navicula minima (39.7 organisms/mm²), Melosira varians (26.1 organisms/mm²); three Chlorophyta (green algae): coccoid Chlorophyta spp. < 5 μ (397.2 organisms/mm²), Pseudulvella americana (277.3 organisms/mm²), Leptosira mediciniana (37.7 organisms/mm²); and one Cyanophyta (blue-green algae): coccoid Cyanophyta spp. < 5 μ (70.3 organisms/mm²).

At Station 330 in 1991, there were 13 common algal taxa (Table 3-7). These taxa included nine Bacillariophyta: Gomphonema parvulum (303.4 organisms/mm²), Achnanthes lanceolata (157.3 organisms/mm²), Eunotia pectinalis (104.5 organisms/mm²), Nitzschia paleacea (94.8 organisms/mm²), Fragilaria vaucheriae (55.1 organisms/mm²), Navicula minima (49.5 organisms/mm²), Navicula cryptocephala (46.7 organisms/mm²), Melosira varians (28.0 organisms/mm²), Cocconeis

Table 3-7. Annual mean and standard error for numerical abundance (organisms/mm²) of common algal taxa (taxa with a relative abundance $\geq$ 5%) at Steel Creek stations in 1991. Summary statistics are presented in Appendix Table 4.

Taxa Name	Mean	SE
<u>Station 290</u>		
<u>Gomphonema parvulum</u>	939.7	718.9
coccoid Chlorophyta spp. < 5 μ	397.2	235.0
<u>Cocconeis placentula</u>	355.8	235.5
<u>Pseudulvella americana</u>	277.3	167.8
<u>Eunotia pectinalis</u>	252.0	119.8
<u>Achnanthes lanceolata</u>	107.0	44.7
coccoid Cyanophyta spp. < 5 μ	70.3	32.3
<u>Cocconeis fluviatilis</u>	51.0	21.4
<u>Fragilaria vaucheriae</u>	41.3	41.3
<u>Navicula minima</u>	39.7	30.5
<u>Leptosira mediciniana</u>	37.7	21.9
<u>Melosira varians</u>	26.1	17.6
<u>Station 330</u>		
<u>Gomphonema parvulum</u>	303.4	142.0
coccoid Chlorophyta spp. < 5 μ	250.4	61.3
<u>Pseudulvella americana</u>	163.2	163.2
<u>Achnanthes lanceolata</u>	157.3	90.9
<u>Eunotia pectinalis</u>	104.5	22.2
<u>Nitzschia paleacea</u>	94.8	44.0
<u>Leptosira mediciniana</u>	72.7	42.5
<u>Fragilaria vaucheriae</u>	55.1	53.6
<u>Navicula minima</u>	49.5	18.1
<u>Navicula cryptocephala</u>	46.7	16.9
<u>Chlamydomonas</u> spp. 5 - 9.9 μ	33.8	33.8
<u>Melosira varians</u>	28.0	26.7
<u>Cocconeis fluviatilis</u>	26.3	26.3
<u>Station 350</u>		
<u>Navicula minima</u>	202.7	188.3
coccoid Chlorophyta spp. < 5 μ	154.1	137.4
<u>Gomphonema parvulum</u>	107.4	96.4
<u>Eunotia pectinalis</u>	88.7	71.0
<u>Achnanthes lanceolata</u>	70.6	61.2
coccoid Cyanophyta spp. < 5 μ	28.1	23.4
<u>Oedogonium</u> spp. sm	7.0	4.3
<u>Nitzschia paleacea</u>	5.6	3.0
<u>Nitzschia gracilis</u>	3.0	1.7

Table 3-7 (continued). Annual mean and standard error for numerical abundance (organisms/mm²) of common algal taxa (taxa with a relative abundance $\geq$ 5%) at Steel Creek stations in 1991. Summary statistics are presented in Appendix Table 4.

Taxa Name	Mean	SE
<u>Station 350 (continued)</u>		
<u>Uronema elongatum</u>	2.0	2.0
coccoid Chrysophyta spp. < 5 μ	1.4	1.4
<u>Pseudovella americana</u>	0.3	0.3
<u>Fragilaria vaucheriae</u>	0.2	0.2
<u>Station 370</u>		
<u>Achnanthes lanceolata</u>	105.9	60.3
<u>Eunotia pestinalis</u>	29.1	15.9
<u>Gomphonema parvulum</u>	22.8	9.6
<u>Leptosira mediciniana</u>	16.2	11.9
coccoid Chlorophyta spp. < 5 μ	11.7	5.3
<u>Navicula minima</u>	7.5	3.2
<u>Nitzschia paleacea</u>	4.9	2.5
<u>Navicula cryptocephala</u>	3.7	2.2
<u>Cymbella minuta</u>	1.4	0.7
<u>Stigeoclonium</u> spp.	1.3	1.3
<u>Fragilaria vaucheriae</u>	0.3	0.3

Table 3-8. Quarterly numerical abundance (organisms/mm²) of common algal taxa (taxa with a relative abundance value $\geq$ 5%) at Steel Creek stations in 1991.

Taxa Name	Winter	Spring	Summer	Fall
<u>Station 290</u>				
<u>Achnanthes lanceolata</u>	0.0	0.0	0.0	196.8
coccoid Chlorophyta spp. < 5 μ	202.4	1096.1	213.4	0.0
coccoid Cyanophyta spp. < 5 μ	0.0	0.0	154.0	0.0
<u>Cocconeis fluviatilis</u>	0.0	0.0	63.8	0.0
<u>Cocconeis placentula</u>	0.0	418.1	0.0	998.4
<u>Eunotia pectinalis</u>	0.0	553.7	96.8	331.2
<u>Fragilaria vaucheriae</u>	165.0	0.0	0.0	0.0
<u>Gomphonema parvulum</u>	321.2	3084.9	0.0	336.0
<u>Leptosira mediciniana</u>	0.0	0.0	69.3	0.0
<u>Melosira varians</u>	77.0	0.0	0.0	0.0
<u>Navicula minima</u>	0.0	0.0	130.9	0.0
<u>Pseudulvella americana</u>	0.0	678.0	431.2	0.0
<u>Station 330</u>				
<u>Achnanthes lanceolata</u>	0.0	417.3	0.0	148.5
<u>Chlamydomonas</u> spp. 5 - 9.9 μ	0.0	0.0	0.0	135.0
coccoid Chlorophyta spp. < 5 μ	156.6	393.9	140.9	310.5
<u>Cocconeis fluviatilis</u>	0.0	0.0	105.3	0.0
<u>Eunotia pectinalis</u>	83.7	0.0	170.3	0.0
<u>Fragilaria vaucheriae</u>	216.0	0.0	0.0	0.0
<u>Gomphonema parvulum</u>	178.2	276.9	0.0	706.5
<u>Leptosira mediciniana</u>	0.0	0.0	128.7	162.0
<u>Melosira varians</u>	108.0	0.0	0.0	0.0
<u>Navicula cryptocephala</u>	75.6	0.0	0.0	0.0
<u>Navicula minima</u>	0.0	93.6	0.0	0.0
<u>Nitzschia paleacea</u>	0.0	117.0	0.0	207.0
<u>Pseudulvella americana</u>	0.0	0.0	652.6	0.0
<u>Station 350</u>				
<u>Achnanthes lanceolata</u>	0.0	253.5	24.0	0.0
coccoid Chlorophyta spp. < 5 μ	0.5	565.5	40.0	10.5
coccoid Chrysophyta spp. < 5 μ	0.0	0.0	0.0	5.7
coccoid Cyanophyta spp. < 5 μ	0.0	0.0	14.4	0.0
<u>Eunotia pectinalis</u>	0.4	299.0	50.4	0.0
<u>Fragilaria vaucheriae</u>	0.7	0.0	0.0	0.0
<u>Gomphonema parvulum</u>	1.4	396.5	13.6	18.0
<u>Navicula minima</u>	0.0	767.0	40.0	0.0
<u>Nitzschia gracilis</u>	0.0	0.0	0.0	5.4
<u>Nitzschia paleacea</u>	0.0	0.0	0.0	7.8

Table 3-8 (continued). Quarterly numerical abundance (organisms/mm²) of common algal taxa (taxa with a relative abundance value $\geq$ 5%) at Steel Creek stations in 1991.

Taxa Name	Winter	Spring	Summer	Fall
<u>Station 350 (continued).</u>				
<u>Oedogonium</u> spp. sm	0.0	0.0	0.0	5.1
<u>Pseudovella americana</u>	1.3	0.0	0.0	0.0
<u>Uronema elongatum</u>	0.0	0.0	0.0	8.1
<u>Station 370</u>				
<u>Achnanthes lanceolata</u>	0.6	202.5	217.8	0.0
coccoid Chlorophyta spp. < 5 μ	0.0	26.1	0.0	9.6
<u>Cymbella minuta</u>	0.5	0.0	0.0	0.0
<u>Eunotia pectinalis</u>	1.2	50.4	62.1	0.0
<u>Fragilaria vaucheriae</u>	1.2	0.0	0.0	0.0
<u>Gomphonema parvulum</u>	1.8	20.7	48.6	20.0
<u>Leptosira mediciniana</u>	0.0	0.0	50.4	0.0
<u>Navicula cryptocephala</u>	0.0	0.0	0.0	5.8
<u>Navicula minima</u>	0.0	0.0	0.0	5.6
<u>Nitzschia paleacea</u>	0.0	0.0	0.0	11.2
<u>Stigeoclonium</u> spp.	0.0	0.0	0.0	5.0

fluviatilis (26.3 organisms/mm²); and four Chlorophyta: coccoid Chlorophyta spp. <5 μ (250.4 organisms/mm²), Pseudulvella americana (163.2 organisms/mm²), Leptosira mediciniana (72.7 organisms/mm²), Chlamydomonas spp. 5-9.9 μ (33.8 organisms/mm²).

At Station 350 in 1991, there were 13 common algal taxa (Table 3-7). These taxa included seven Bacillariophyta: Navicula minima (202.7 organisms/mm²), Gomphonema parvulum (107.4 organisms/mm²), Eunotia pectinalis (88.7 organisms/mm²), Achnanthes lanceolata (70.6 organisms/mm²), Nitzschia paleacea (5.6 organisms/mm²), Nitzschia gracilis (3.0 organisms/mm²), Fragilaria vaucheriae (0.2 organisms/mm²); four Chlorophyta: coccoid Chlorophyta spp. <5 μ (154.1 organisms/mm²), Oodogonium spp. sm (7.0 organisms/mm²), Uronema elongatum (2.0 organisms/mm²), Pseudulvella americana (0.3 organisms/mm²); one Chrysophyta: coccoid Chrysophyta spp. <5 μ (1.4 organisms/mm²); and one Cyanophyta: coccoid Cyanophyta spp. <5 μ (28.1 organisms/mm²).

At Station 370 in 1991, there were 11 algal taxa (Table 3-7). These taxa included eight Bacillariophyta: Achnanthes lanceolata (105.9 organisms/mm²), Eunotia pectinalis (29.1 organisms/mm²), Gomphonema parvulum (22.8 organisms/mm²), Navicula minima (7.5 organisms/mm²), Nitzschia paleacea (4.9 organisms/mm²), Navicula cryptocephala (3.7 organisms/mm²), Cymbella minuta (1.4 organisms/mm²), Fragilaria vaucheriae (0.3 organisms/mm²); and three Chlorophyta: Leptosira mediciniana (16.2 organisms/mm²), coccoid Chlorophyta spp. <5 μ (11.7 organisms/mm²), and Stigeoclonium spp. (1.3 organisms/mm²).

The numerical abundance of common taxa (taxa with a $\geq$ 5% relative annual mean abundance) each quarter in 1991 is listed in Table 3-8. During winter

quarter there were three Bacillariophyta taxa (Fragilaria vaucheriae [165.0 organisms/mm²], Gomphonema parvulum [321.2 organisms/mm²], Melosira varians [77.0 organisms/mm²]) and one Chlorophyta taxon (coccolid Chlorophyta spp. <5 μ [202.4 organisms/mm²]) common on slides incubated at Station 290. Three Bacillariophyta taxa (Cocconeis placentula [418.1 organisms/mm²], Eunotia pectinalis [553.7 organisms/mm²], Gomphonema parvulum [3084.9 organisms/mm²]) and two Chlorophyta taxa (coccolid Chlorophyta spp. <5 μ [1096.1 organisms/mm²], Pseudulvella americana [678.0 organisms/mm²]) were common during spring quarter. In summer quarter there were three common Bacillariophyta taxa (Cocconeis fluviatilis [63.8 organisms/mm²], Eunotia pectinalis [96.8 organisms/mm²], Navicula minima [130.9 organisms/mm²]), three common Chlorophyta taxa (coccolid Chlorophyta spp. <5 μ [213.4 organisms/mm²], Leptosira mediciniana [69.3 organisms/mm²]), Pseudulvella americana 431.2 [organisms/mm²]), and one common Cyanophyta taxa (coccolid Cyanophyta spp. <5 μ [154.0 organisms/mm²]) common at Station 290. There were four common Bacillariophyta taxa during fall quarter: Achnanthes lanceolata (196.8 organisms/mm²), Cocconeis placentula (998.4 organisms/mm²), Eunotia pectinalis (331.2 organisms/mm²), and Gomphonema parvulum (336.0 organisms/mm²).

In winter quarter, there were five common Bacillariophyta taxa (Eunotia pectinalis [83.7 organisms/mm²], Fragilaria vaucheriae [216.0 organisms/mm²], Gomphonema parvulum [178.2 organisms/mm²], Melosira varians [108.0 organisms/mm²], Navicula cryptocephala [75.6 organisms/mm²]) and one common Chlorophyta taxon (coccolid Chlorophyta spp. <5 μ [156.6 organisms/mm²]) found on slides incubated at Station 330 (Table 3-8). There were four common Bacillariophyta taxa (Achnanthes lanceolata [417.3 organisms/mm²], Gomphonema parvulum [276.9 organisms/mm²], Navicula minima [93.6 organisms/mm²], Nitzschia paleacea [117.0 organisms/mm²]) and one common Chlorophyta taxon (coccolid

Chlorophyta spp. $<5 \mu$ [393.9 organisms/mm²]) found on slides incubated at Station 330 during spring quarter. In summer quarter there were two Bacillariophyta taxa (Cocconeis fluviatilis [105.3 organisms/mm²], Eunotia pectinalis [170.3 organisms/mm²]) and three Chlorophyta taxa (coccoid Chlorophyta spp. $<5 \mu$ [140.4 organisms/mm²], Leptosira mediciniana [128.7 organisms/mm²], Pseudulvella americana [652.6 organisms/mm²]) common on slides incubated at Station 330. There were three Bacillariophyta taxa (Achnanthes lanceolata [148.5 organisms/mm²], Gomphonema parvulum [706.5 organisms/mm²], Nitzschia paleacea [207.0 organisms/mm²]) and three Chlorophyta taxa (Chlamydomonas spp. 5 - 9.9 μ [135.0 organisms/mm²], coccoid Chlorophyta spp. $<5 \mu$ [310.5 organisms/mm²], Leptosira mediciniana [162.0 organisms/mm²]) common during fall quarter.

In winter quarter, there were three Bacillariophyta taxa (Eunotia pectinalis [0.4 organisms/mm²], Fragilaria vaucheriae [0.7 organisms/mm²], Gomphonema parvulum [1.4 organisms/mm²]) and two Chlorophyta taxa (coccoid Chlorophyta spp. $<5 \mu$ [0.5 organisms/mm²], Pseudulvella americana [1.3 organisms/mm²]) common at Steel Creek Station 350 (Table 3-8). There were four common Bacillariophyta taxa (Achnanthes lanceolata [253.5 organisms/mm²], Eunotia pectinalis [299.0 organisms/mm²], Gomphonema parvulum [396.5 organisms/mm²], Navicula minima [767.0 organisms/mm²]) and one common Chlorophyta taxon (coccoid Chlorophyta spp. $<5 \mu$ [565.5 organisms/mm²]) in spring quarter. In summer quarter there were four common Bacillariophyta taxa (Achnanthes lanceolata [24.0 organisms/mm²], Eunotia pectinalis [50.4 organisms/mm²], Gomphonema parvulum [13.6 organisms/mm²], Navicula minima [40.0 organisms/mm²]), one Chlorophyta taxon (coccoid Chlorophyta spp. $<5 \mu$ [40.0 organisms/mm²]), and one Cyanophyta taxon (coccoid Cyanophyta spp. $<5 \mu$ [14.4 organisms/mm²]). There were three Bacillariophyta taxa (Gomphonema parvulum [18.0 organisms/mm²], Nitzschia

gracilis [5.4 organisms/mm²], Nitzschia paleacea [7.8 organisms/mm²]), three Chlorophyta taxa (coccolid Chlorophyta spp. <5 μ [10.5 organisms/mm²], Oedogonium spp. sm [5.1 organisms/mm²], Uronema elongatum [8.1 organisms/mm²]), and one Chrysophyta taxon (coccolid Chrysophyta spp. < 5 μ [5.7 organisms/mm²]) common during fall quarter.

In winter quarter there were five common Bacillariophyta taxa found at Steel Creek Station 370 during 1991 (Table 3-8): Achnanthes lanceolata [0.6 organisms/mm²], Cymbella minuta [0.5 organisms/mm²], Eunotia pectinalis [1.2 organisms/mm²], Fragilaria vaucheriae [1.2 organisms/mm²], and Gomphonema parvulum [1.8 organisms/mm²]. There were three Bacillariophyta taxa (Achnanthes lanceolata [202.5 organisms/mm²], Eunotia pectinalis [50.4 organisms/mm²], Gomphonema parvulum [20.7 organisms/mm²]) and one Chlorophyta taxon (coccolid Chlorophyta spp. <5 μ [26.1 organisms/mm²]) common during spring quarter. In summer quarter there were three common Bacillariophyta taxa (Achnanthes lanceolata [217.8 organisms/mm²], Eunotia pectinalis [62.1 organisms/mm²], Gomphonema parvulum [48.6 organisms/mm²]) and one common Chlorophyta taxon (Leptosira mediciniana [50.4 organisms/mm²]). There were one Bacillariophyta taxon (Gomphonema parvulum [20.0 organisms/mm²]) and five Chlorophyta taxa (coccolid Chlorophyta spp. <5 μ [9.6 organisms/mm²], Navicula cryptocephala [5.8 organisms/mm²], Navicula minima [5.6 organisms/mm²], Nitzschia paleacea [11.2 organisms/mm²], Stigeoclonium spp. [5.0 organisms/mm²]) common during fall quarter.

3.1.3.3 Taxa Diversity

Taxa diversity was calculated by using the Shannon-Weiner Diversity Index. The 1991 quarterly values for the four Steel Creek stations sampled in 1991 are

reported on Table 3-9. At Station 290, the quarterly diversity values were 2.17 (winter), 1.83 (spring), 1.98 (summer), and 1.99 (fall). The index at Station 330 was 2.56 (winter), 2.35 (spring), 1.98 (summer), and 2.43 (fall). The index at Station 350 was 2.16 (winter), 2.49 (spring), 2.44 (summer), and 2.98 (fall). At Station 370, taxa diversity values were 2.19 (winter), 1.65 (spring), 1.92 (summer), and 2.79 (fall).

3.2 DISCUSSION: PERIPHYTON

3.2.1 Organization of Discussion

The discussion will first evaluate the physical and chemical variables affecting periphyton in Steel Creek and Meyer's Branch. The results for each location will then be discussed with emphasis on comparing differences seen through time and assessing these differences in terms of natural variability. Pre- and post-impoundment comparisons will be made where data are available. The final portion of the discussion will contrast the periphyton communities in the Steel Creek system to those found in other southeastern United States streams. For data on periphyton taxa richness and a complete taxa list, refer to Appendix Tables 5 and 6, respectively.

3.2.2 Independent Variables Affecting Periphyton

Two basic groups of factors affect the development of periphyton communities in lotic environments: (1) chemical parameters and (2) physical features of the habitat to which the periphytic organisms are exposed. These factors, in addition to the biological factors such as predation and competition, also influence the community composition and biomass of periphyton.

Table 3-9. Shannon-Weiner Diversity Index for each Steel Creek station by quarter in 1991.

Station	Winter	Spring	Summer	Fall
290	2.16543	1.83051	1.98076	1.98791
330	2.56159	2.35140	1.98187	2.43073
350	2.16065	2.48645	2.44238	2.97931
370	2.18675	1.65043	1.91815	2.78813

Chemical parameters include pH, alkalinity, hardness, dissolved nutrients, and dissolved organic material. The importance of nutrients in limiting algal growth, and ultimately biomass, has been well documented (Fairchild and Lowe 1984; Pringle 1987, Welch et al. 1989). Water quality measurements in the Steel Creek - Meyer's Branch system are documented in Kretchmer (1992). Nutrient concentrations were found to be similar to levels found in other streams of the southeastern United States. When peak concentrations of nutrients known to enhance algal growth (nitrate and phosphate) were compared with peak periphyton biomass in 1986 through 1989, there appeared to be no correlations. Nutrient concentrations did not appear to be limiting at any of the Steel Creek sites (Chimney 1991); however, additional testing would required to verify this hypothesis.

Physical characteristics of the habitat include water temperature, current velocity (both in the water column and within the periphyton community), substrate type, and light regime. In this study, substrate type strongly influenced the biomass and composition of the algal communities (Hooker 1990a). Glass slide substrates generally select for diatoms and may not provide equal surfaces for periphytic development (Weitzel et al. 1979). In addition, slides are not representative of any natural substrate occurring in the Steel Creek - Meyer's Branch system. This bias for diatoms limits the effectiveness of sampling techniques used in this monitoring program in determining the community structure and composition of the Steel Creek drainage system. Stevenson (1984) found that storms had an effect on the algal community.

Irradiance levels have been shown to influence algal primary productivity as well as community structure (Steinman and McIntire 1987; Steinman et al.

1988). Attenuation of light was not measured as a part of this study. It is, therefore, difficult to evaluate to what extent differences in shading regimes between sites and years may have affected periphyton biomass and community composition.

Temperature is a major determinant of species composition of diatoms on glass slides with maximum diversity and species richness obtained at temperatures between 25 and 30 °C (Vinson and Rushforth 1989). The dominance of blue-green algae and the decrease in diatoms with temperatures exceeding 35 °C in freshwater has been documented (e.g., Gibbons and Sharitz 1974; Patrick 1974).

Other factors affecting the community structure biomass and standing crop in a periphyton community are the presence of herbivores such as macroinvertebrates, and meteorological events. For example, Hill and Harvey (1990) found that the presence of grazers, such as the snail Elima clavigeris, reduced the biomass and productivity of the loose upper layer of the periphyton community while increasing the biomass and productivity of the lower, tightly-attached layer. DeNicola et al. (1990) found that the patchy grazing patterns of Juga silicula (a snail) and Baetis spp. (a mayfly) may contribute to the maintenance of a mosaic of algal patches in different seral stages, thereby increasing algal diversity in the periphyton community.

Although there was a possibility that L-Reactor operations affected periphyton communities at the Steel Creek sites, variability in measured periphyton parameters as a result of differences in substrate type, site characteristics, and season may have masked any potential impacts. Furthermore,

other possible causal factors (e.g., light availability) were not documented in this study and, consequently, cannot be eliminated from consideration.

3.2.3 Meyer's Branch

The Meyer's Branch site (Station 400) was used as a reference station in this study to demonstrate natural variability of the periphyton community on a variety of substrates from 1986 through 1989. Because of temporal and spatial heterogeneity in lotic systems, a trend would have to vary dramatically from what was seen in reference (unstressed) systems to be considered something more than natural variability.

The Meyer's Branch station was discriminated from other study sites by the same variables in all years. The mean monthly chlorophyll *a* concentrations in 1989 were comparable to those documented in 1986 through 1988. This result cannot be compared to other stations in masse, however, because of spatial heterogeneity, which is a part of all natural systems. For example, the seasonal trends seen at Station 400 are more typical of a closed-canopy stream site and cannot be extrapolated to open- or reduced-canopy areas. However, the extent of the variability of the periphyton community in Meyer's Branch between 1986 and 1989 can be used to evaluate the other sites.

3.2.4 Corridor Stations

On periphytometer slides, biomass was generally higher in the corridor than at other sites during this study. Monthly chlorophyll *a* concentrations on slides were comparable between years at most corridor sites, although when averaged over the entire year, 1989 values were somewhat less than 1988. Chlorophyll *a* content increased from 9.72 (1989) to 17.61 mg/m² (1990) at Station 290 and then fell to

11.92 mg/m². At Station 280, annual mean chlorophyll *a* in 1987 and 1988 was greatly reduced from levels in 1986 as a result of very low biomass accumulations during late spring and summer; an increase in biomass occurred in 1989 due to summer peaks. A downstream decrease in AFDM in Steel Creek was apparent in all years. A large increase in AFDM on slides was found at Station 275 in 1988 without a corresponding increase in chlorophyll *a*. In 1989, AFDM was lower at Station 275 than in previous years. It was the great numbers of blackfly larvae (*Simulium* sp.) rather than algae, covering all substrates at this station in 1988 (Lauritsen 1989) which undoubtedly accounted for the measured increase in standing crop. These organisms were not as abundant on slides in 1989 as in 1988 (Hooker 1990a). Since these organisms are filter feeders rather than grazers, it is doubtful whether they had a deleterious effect on the periphyton at this site. Therefore, the chlorophyll *a* concentrations are representative of the periphyton community.

Blue-green algae was the dominant algal division on slides at Station 275 in 1987 but was greatly reduced in abundance in 1988 and 1989. The percentage of blue-green algae also decreased in 1988 at Station 280 and was no higher in 1989. Blue-green algae are usually dominant when temperatures exceed 35 °C or when nitrogen is limiting and are frequently encountered in streams with organic wastes (Cairns et al. 1972; Palmer 1977). Stations with high (> 20%) relative abundances of blue-green algae in 1989 were Stations 280, 330, 350, and 370. However, at Stations 330, 350, and 370 the reduction in relative abundance of blue-green algae between 1990 and 1991 ranged from 69.6 to 95.9%.

Diatoms of the genus *Gomphonema* have been emphasized as indicators of industrial wastes (Palmer 1977), *Gomphonema parvulum* was a common taxon at most

sites; however, it was also common during at least one season at both the unimpacted reference site (Meyer's Branch) and Station 255. Therefore, it was not useful as an indicator species for this study. Other algae which are tolerant of organic pollution, such as Navicula cryptocephala and coccoid Cyanophyta, were common at Station 400. No high-temperature tolerant taxa were common at any station during this study.

Based on an earlier study on algal and protozoan communities in the Savannah River (Patrick et al. 1967), Cairns et al. (1972) stated that in a comparison of any two stations on a single reach of river, one would have a high probability of finding less than half of the species at one site also identified at the other station. Similarity indices for the corridor stations showed over 50% similarity between the taxa found between years, with the exception of Station 275 in 1988, indicating more similarity in taxa between years than is commonly expected within a given site (Hooker 1990a).

Species composition varies through time on a seasonal basis. Changes in temperature and light regime influence the seasonal succession of algal taxa (Round 1981). In areas where temperatures remain fairly constant and stream reaches are shaded, certain taxa may be common throughout the year (Kroji and Lowe 1987). At most stations during this study, similarities in the common taxa for a given season were seen between years; however, it was difficult to discern any clear-cut trends in dominant taxa. Species of the genera Achnanthes, Gomphonema, and Navicula, were common diatom taxa at many stations during all years (Hooker 1990a). As these taxa are mostly eurythermal, inhabiting a wide variety of mid-range temperatures, it is not surprising that they occur in the Steel Creek system. It is a natural phenomenon for taxa composition to change

from season to season and area to area, while the number of taxa remains relatively constant (Cairns 1974).

3.2.5 Marsh Stations

There were no major differences in the annual mean chlorophyll *a* concentrations or AFDM between 1986 and 1989 at any of the marsh stations, nor were there any major changes in these parameters at Station 330 in 1990 and 1991.

The taxonomic community structure on glass slides in 1989 had proportionately more green algae and fewer diatoms than in 1987 at all of the marsh stations, although diatoms were the most abundant group at Station 300 in 1989. At Station 330 green algae remained the most abundant group until 1991 when diatoms became most abundant with a relative abundance of 59.2%. A large increase in blue-green algae occurred at Station 330 between 1988 and 1989, perhaps indicating a decrease in water quality at this site. In 1990, and 1991 the relative abundance of blue-green algae at Station 330 decreased to levels comparable to those found in 1986 through 1988.

3.2.6 Swamp Stations

There were no temporal or spacial differences in chlorophyll *a* concentrations and AFDM on slides at the swamp sites that seemed outside of the range of natural variation. Station 340 was dominated by green algae in 1986 and 1987, whereas Station 350 was dominated by diatoms. In 1988, community composition was comparable between both sites (diatom dominated). However, in 1989, Station 350 was dominated by blue-green algae, while it was diatom dominated in 1990 and 1991.

3.2.7 Channel Stations

In 1989, as in previous years, the channel stations had dissimilar patterns of mean chlorophyll *a* concentrations on glass slides. Both sites had decreases in the annual mean chlorophyll *a* and AFDM between 1988 and 1989; however, the multi-variate analysis using all periphyton parameters showed that these two sites were less similar in 1989 than they had been the previous year (Hooker 1990a). The chlorophyll *a* content and ash free dry mass concentrations were comparable between 1990 and previous years at Station 290. However, there was an apparent drop in chlorophyll *a* content in 1991 while AFDM remained similar to previous years.

With respect to community composition, diatoms predominated at both sites on slides; *G. parvulum* was the most common taxon in 1989 (Hooker 1990a). However in 1990, green algae became dominant with the most abundant taxa being coccoid Chlorophyta spp. < 5 μ . By 1991 diatoms regained dominance with *A. lanceolata* being the most abundant taxon. The relative abundance of blue-green algae was highest at Station 370 in 1989, but was reduced substantially by 1990. By 1991 the relative abundance of this division was 1.6%. The effect of river inflow on water quality at Station 370 during floods has not been ascertained and is not a part of this study. Changes in the periphyton community at Station 370 may have been greatly influenced by changes in conditions along the Savannah River.

3.3 RESULTS: SESTON

3.3.1 Organization of Results

Seston results are reported in two sections: (1) current velocity data and (2) whole water data. The parameters presented in the latter section are: concentrations of total suspended solids (TSS; mg/L), ash-free dry mass (AFDM;

mg/L), organic material (OM; % of TSS by weight), and chlorophyll *a* concentrations ($\mu\text{g/L}$). All 1990 and 1991 data are also presented by station and sampling period in Appendix Table 7. Seston size fraction data were not obtained during 1990 or 1991.

In most cases the data are reported as annual means, monthly means (1986-1989), and quarterly means (1990 and 1991). Minima and maxima are presented in appendix tables. For most parameters, results are compared among the six years of the monitoring program (1986-1991). Quarterly sampling of Station 255 commenced in October 1987 (upon agreement with SRL); therefore, annual means (1988 and 1989 only) will be reported for this reference site.

3.3.2 Current Velocity

Figure 3-9 presents 1990 and 1991 annual means and standard errors for current velocity at the four Steel Creek stations monitored and variability among the quarterly measurements at each of these stations.

As might be expected, the higher mean annual current velocities were found at the corridor and channel stations where the flow of water is more channelized and less subject to sheet flow. Mean annual current velocities for 1990 and 1991, respectively, were 0.26 and 0.31 m/sec at corridor Station 290, 0.18 and 0.36 m/sec at channel Station 370, 0.16 and 0.18 m/sec at Station 330, and 0.15 and 0.19 m/sec at Station 350 (Figure 3-9).

The variability of annual mean current velocities among these four stations was about the same in 1991 as in 1989 and 1990. However, Stations 290 and 370 were less alike in 1990 while Stations 330 and 350 were almost identical (Figure

Figure 3-9. Instantaneous current velocity (m/sec) measured during seston collection at Steel Creek Stations 290, 330, 350, and 370. Top panel: annual means; vertical bars are standard errors, 1990 and 1991. Bottom panel: quarterly means; 1991.

3-9; van Duyn and Stiner 1990). During 1991 current velocity peaked in spring (0.39 m/sec) at Station 290, in winter (0.42 m/sec) at Station 330, in winter (0.40 m/sec) at Station 350, and in winter (0.42 m/sec) at Station 370 (Figure 3-9).

Biannual diel water sampling and current velocity measurements were performed in Steel Creek during February and August. Degrees of freedom, F values, and Probability of a greater F (Prob > F) associated with a Friedman's two-way analysis by ranks tests are presented in Table 3-10. Differences in station ranks for current velocity were not statistically significant at the $\alpha = 0.05$ level (F = 0.22 and Prob > F = 0.8750).

3.3.3 Whole Water

3.3.3.1 Total Suspended Solids

Annual means and standard errors for total suspended solids (TSS) in seston whole water samples collected from Steel Creek stations are presented in Table 3-11. Minimum and maximum values are given in Appendix Table 8.

At corridor Station 290, a trend of lower TSS values began with an annual mean TSS concentration of 2.54 mg/L in 1988 (the year L-Reactor was shut down in July) and continued in 1989 (3.53 mg/L), 1990 (3.18 mg/L), and 1991 (2.22 mg/L; Table 3-11). The 1991 annual mean seston TSS concentration was the lowest recorded at this station during this study. Higher annual means were measured in 1986 (5.49 mg/L) and 1987 (5.28 mg/L). The maximum value recorded for 1991 (3.84 mg/L) was the lowest maximum value recorded at this site during the study (Appendix Table 8).

Table 3-10. Degrees of freedom, F values, and probabilities of a greater F associated with Friedman's two-way analysis by ranks for seston parameters monitored during 1991 biannual diel sampling at Steel Creek Stations 290, 330, and 350.

Parameter	F value	Prob > F
Currant Velocity	0.22	0.8750
Total Suspended Solids	0.00	1.0000
Ash Free Dry Mass	0.22	0.8750
Percent Organic Matter	0.22	0.8750
Chlorophyll <i>a</i>	0.22	0.8750
Model df = 3		
Error df = 2

2 of 2

Table 3-11. Annual means for seston TSS concentration (mg/L) in whole water collected from Steel Creek. Minimum and maximum values are given in Appendix Table 8. January 1986-December 1991.

Location	Station	1986 ^a		1987 ^a		1988 ^a	
		Mean	SE ^b	Mean	SE ^b	Mean	SE ^b
Reference Site	255	-	-	-	-	5.96	(1.79)
Corridor	275	4.91	(0.70)	6.08	(0.97)	3.41	(0.16)
	280	7.05	(0.95)	9.85	(1.25)	4.87	(0.20)
	285	6.33	(1.07)	8.67	(1.97)	3.24	(0.50)
	290	5.49	(1.33)	5.28	(1.25)	2.54	(0.46)
Marsh	300	3.85	(1.20)	4.14	(1.22)	2.15	(0.44)
	310	6.03	(1.83)	2.40	(0.36)	7.98	(3.15)
	320	5.64	(2.39)	4.83	(0.57)	5.45	(1.40)
	330	3.10	(0.59)	2.75	(0.26)	3.45	(0.88)
Swamp	340	2.07	(0.31)	1.91	(0.17)	1.63	(0.23)
	350	2.89	(0.70)	1.66	(0.17)	3.27	(0.60)
Channel	360	4.36	(1.23)	2.43	(0.26)	4.66	(0.82)
	370	6.93	(1.34)	5.68	(0.80)	4.76	(0.31)
Meyer's Branch	400	4.60	(0.71)	5.85	(1.25)	3.37	(0.56)

^aSummary statistics for 1986-1989 were recalculated for comparison with 1990 and 1991 results by using data only from the four months that corresponded to the 1990 and 1991 quarterly sampling months.

^bStandard error.

Table 3-11 (continued). Annual means for seston TSS concentration (mg/L) in whole water collected from Steel Creek. Minimum and maximum values are given in Appendix Table 8. January 1986-December 1991.

Location	Station	1989 ^a		1990		1991	
		Mean	SE ^b	Mean	SE ^b	Mean	SE ^b
Reference Site	255	3.11	(0.49)	-	-	-	-
Corridor	275	3.84	(0.39)	-	-	-	-
	280	4.61	(0.31)	-	-	-	-
	285	4.63	(0.49)	-	-	-	-
	290	3.53	(0.38)	3.18	(0.20)	2.22	(0.28)
Marsh	300	3.91	(0.54)	-	-	-	-
	310	4.86	(0.75)	-	-	-	-
	320	4.09	(0.90)	-	-	-	-
	330	4.79	(1.31)	4.04	(1.02)	2.05	(0.21)
Swamp	340	3.03	(0.66)	-	-	-	-
	350	2.07	(0.15)	2.76	(0.39)	1.55	(0.19)
Channel	360	9.34	(3.63)	-	-	-	-
	370	5.60	(0.75)	3.04	(0.25)	2.32	(0.25)
Meyer's Branch	400	3.88	(0.71)	-	-	-	-

^aSummary statistics for 1986-1989 were recalculated for comparison with 1990 and 1991 results by using data only from the four months that corresponded to the 1990 and 1991 quarterly sampling months.

^bStandard error.

To more easily evaluate year to year variation in seston quantity at each of the four stations sampled in 1990 and 1991, 1986-1989 monthly mean TSS concentrations in whole water are presented in Figures 3-10 to 3-13. Quarterly mean TSS concentrations for 1990 and 1991 are also plotted in these figures. Because of the within- and between-year variability at most stations, only general trends over time will be discussed.

Monthly mean TSS concentrations at Station 290, during 1986-1989, are presented in Figure 3-10 along with the quarterly mean values measured in 1990 and 1991. TSS concentrations were lower and more stable over time from 1988 through 1991 than 1986 and 1987. All 1989, 1990, and 1991 mean values were less than 7 mg/L.

In 1986, TSS measurements were lowest in February and increased between April and July at Station 290 (Figure 3-10). In 1987, TSS decreased through spring and early summer, then increased after July. In 1988, there were increases in March and July. In 1989, there was an increase in winter, a decrease in spring and summer, and a slight increase in fall (October). During 1990, the higher level in winter and decreased levels in spring and summer were reversed. During 1991 the winter low (1.71 mg/L) was lower than that of 1990 (2.48 mg/L) and was almost equalled by the quarterly mean TSS measured in summer (1.86 mg/L) and fall (1.88 mg/L). The TSS measurements were highest in 1991 in spring (3.45 mg/L).

Compared to corridor Station 290, marsh Station 330 exhibited an increase in annual mean TSS concentrations from 1988 through 1990. Annual mean seston TSS concentration at Station 330 was 3.45, 4.79, and 4.04 mg/L in 1988, 1989, and

Station 290

+ TSS in 1986
 * TSS in 1987
 X TSS in 1988
 o TSS in 1989

Figure 3-10. Mean TSS concentrations (mg/L) in whole water collected at Steel Creek Station 290. Top panel: monthly means; January 1986-December 1989. Bottom panel: quarterly means; vertical bars are standard errors. 1990 and 1991.

Station 330

Figure 3-11. Mean TSS concentrations (mg/L) in whole water collected at Steel Creek Station 330. Top panel: monthly means; January 1986-December 1989. Bottom panel: quarterly means; vertical bars are standard errors. 1990 and 1991.

Station 350

+ TSS in 1986
* TSS in 1987

X TSS in 1988
O TSS in 1989

Figure 3-12. Mean TSS concentrations (mg/L) in whole water collected at Steel Creek Station 350. Top panel: monthly means; January 1986-December 1989. Bottom panel: quarterly means; vertical bars are standard errors. 1990 and 1991.

Station 370

+ TSS in 1986 X TSS in 1988
 * TSS in 1987 O TSS in 1989

Figure 3-13. Mean TSS concentrations (mg/L) in whole water collected at Steel Creek Station 370. Top panel: monthly means; January 1986-December 1989. Bottom panel: quarterly means; vertical bars are standard errors. 1990 and 1991.

1990, respectively as opposed to 3.10 mg/L in 1986 and 2.75 mg/L in 1987 (Table 3-11). In 1991 the mean annual TSS concentration at Station 330 was 2.05 mg/L. This was not only opposite to the trend of increasing concentrations since 1988, but was the lowest mean annual TSS concentration recorded at this station since this project began in 1986.

The 1990 maximum TSS value of 9.65 mg/L was the second highest maximum value at Station 330 (Appendix Table 8). The 1991 maximum value of 2.86 mg/L is the lowest maximum value recorded at Station 330 during this study.

Monthly mean TSS concentrations measured at Station 330 during 1986-1989 are presented in Figure 3-11 along with the 1990 and 1991 quarterly mean TSS concentrations. Overall, the temporal pattern of TSS at Station 330 was more consistent among years than at Station 290 (Figure 3-10). However, Station 330 was more variable over time within 1988, 1989, and 1990. Note especially the contrast in variabilities between stations during 1990. During that year, quarterly mean TSS concentrations at Station 330 ranged between 8.48 mg/L in summer and 2.01 mg/L in fall, while at Station 290 it ranged between 2.48 mg/L in winter and 3.49 mg/L in summer. During 1991, Stations 290 and 330 had about the same variability. Quarterly mean TSS concentrations at Station 330 ranged between 1.27 mg/L in fall and 2.74 mg/L in spring, while concentrations at Station 290 ranged between 1.71 mg/L in winter and 3.45 mg/L in spring.

Mean annual TSS concentrations at Station 350 in 1989 (2.07 mg/L) and 1990 (2.76 mg/L) were less than the 1988 level (3.27 mg/L) and about equal to, or somewhat above, the 1986 (2.89 mg/L) and 1987 (1.66 mg/L) levels (Table 3-11). Mean annual TSS in 1991 (1.55 mg/L) was the lowest value recorded during this

study. Also, the fact that in 1990 and 1991 TSS levels at Station 350 were lower than those of the three other stations was consistent with the trend observed at Station 350 since 1986 except in 1988 when mean TSS at Station 290 was lower.

During 1991, the TSS concentrations at Station 350 ranged from 0.86 to 2.30 mg/L (Appendix Table 8). In contrast, the minimum concentration in 1990 (1.58 mg/L) was the highest minimum value recorded; the 1991 minimum (0.86 mg/L) was the third lowest measured from 1986-1991.

Monthly mean TSS concentrations at Station 350 during 1986-1989 are plotted in Figure 3-12 accompanied by the quarterly mean TSS concentrations measured in 1990 and 1991. Relative to the other three stations sampled in 1990 and 1991, Station 350 showed, overall, the lowest and least variable concentrations of TSS among years. Exceptions occurred in 1990 and 1991 where Station 290 displayed more stability (Figure 3-10). TSS at Station 350 varied between < 1 and ca. 4 mg/L, with the exception of small concentration peaks in August and September 1986 and November 1988 (Figure 3-12). In 1991, quarterly mean TSS at Station 350 was lowest in the fall as was the case in 1990. However, in 1991 it was highest in spring as opposed to being high in summer and winter during 1990.

In 1991, the 2.32 mg/L TSS concentration was the lowest mean annual value recorded at Station 370 from 1986 through 1991 (Table 3-11). As was the case at Station 290, the mean annual TSS levels at Station 370 for 1988 (4.76 mg/L) and 1989 (5.60 mg/L) was below the 1986 (6.93 mg/L) and 1987 (5.68 mg/L) levels.

Like Station 290, the maximum concentration of seston TSS measured at Station 370 in 1990 (4.10 mg/L) was the lowest maximum concentration during this

study (Appendix Table 8). However, the minimum concentration in 1990 (1.98 mg/L) was also the lowest concentration from 1986 through 1990 at that station.

Monthly mean TSS concentrations at channel Station 370 during 1986-1989 are plotted in Figure 3-13 along with the quarterly mean TSS concentrations measured in 1990 and 1991. The 1990 pattern of quarterly mean TSS concentrations somewhat resembles that of swamp Station 350, although their summer trends were reversed (i.e., a decrease at Station 370; [Figure 3-13]; and an increase at Station 350; [Figure 3-12]). The 1991 pattern at Station 370 was similar to that of Station 350 from spring to summer when they both had decreases in mean TSS concentrations.

Quarterly mean TSS levels at Station 370 during 1991 were somewhat lower than in 1990, although they exhibited about the same amount of temporal variability (Figure 3-13). They ranged from 1.40 mg/L in summer to 3.19 mg/L in winter. The overall trends were the same in 1990 and 1991. During both years quarterly mean TSS concentrations decreased from winter through summer and increased in the fall.

3.3.3.2 Ash-Free Dry Mass

Annual 1986 through 1989 means and standard errors for ash-free dry mass (AFDM) in seston whole water samples at Steel Creek and Meyer's Branch stations are presented in Table 3-12, as are these measurements for four stations in 1990 and 1991. The minimum and maximum values are given in Appendix Table 9.

The annual mean AFDM concentration in 1991 (0.81 mg/L) at Station 290 was less than the annual mean AFDM concentration in 1990 (1.47 mg/L) and 1989 (1.46

Table 3-12. Annual means for seston AFDM concentration (mg/L) in whole water collected from Steel Creek. Minimum and maximum values are given in Appendix Table 9. January 1986-December 1991.

Location	Station	1986 ^a		1987 ^a		1988 ^a	
		Mean	SE ^b	Mean	SE ^b	Mean	SE ^b
Reference Site	255	-	-	-	-	1.32	(0.26)
Corridor	275	3.11	(0.50)	2.63	(0.16)	1.98	(0.19)
	280	3.34	(0.51)	3.22	(0.11)	1.71	(0.04)
	285	2.63	(0.42)	2.89	(0.49)	1.01	(0.13)
	290	2.24	(0.48)	2.20	(0.36)	0.87	(0.09)
Marsh	300	1.97	(0.59)	1.76	(0.42)	0.95	(0.13)
	310	1.78	(0.54)	1.19	(0.14)	2.18	(0.67)
	320	2.30	(0.96)	1.88	(0.15)	1.61	(0.36)
	330	1.27	(0.24)	1.21	(0.08)	1.23	(0.23)
Swamp	340	1.07	(0.18)	1.07	(0.12)	0.80	(0.09)
	350	1.24	(0.31)	0.84	(0.08)	1.33	(0.26)
Channel	360	1.30	(0.32)	0.92	(0.08)	1.46	(0.22)
	370	1.64	(0.20)	1.44	(0.16)	1.29	(0.13)
Meyer's Branch	400	2.48	(0.97)	2.32	(0.50)	1.42	(0.19)

^aSummary statistics for 1986-1989 were recalculated for comparison with 1990 and 1991 results by using data only from the four months that corresponded to the 1990 and 1991 quarterly sampling months.

^bStandard error.

Table 3-12 (continued). Annual means for seston AFDM concentration (mg/L) in whole water collected from Steel Creek. Minimum and maximum values are given in Appendix Table 9. January 1986-December 1991.

Location	Station	1989 ^a		1990		1991	
		Mean	SE ^b	Mean	SE ^b	Mean	SE ^b
Reference Site	255	0.88	(0.12)	-	-	-	-
Corridor	275	2.66	(0.47)	-	-	-	-
	280	2.12	(0.29)	-	-	-	-
	285	1.66	(0.30)	-	-	-	-
	290	1.46	(0.20)	1.47	(0.21)	0.81	(0.11)
Marsh	300	1.73	(0.19)	-	-	-	-
	310	1.71	(0.19)	-	-	-	-
	320	1.37	(0.20)	-	-	-	-
	330	1.85	(0.45)	1.43	(0.19)	0.85	(0.11)
Swamp	340	1.47	(0.37)	-	-	-	-
	350	1.16	(0.06)	1.22	(0.23)	0.68	(0.07)
Channel	360	5.25	(3.36)	-	-	-	-
	370	1.55	(0.18)	1.25	(0.24)	0.75	(0.04)
Meyer's Branch	400	1.64	(0.27)	-	-	-	-

^aSummary statistics for 1986-1989 were recalculated for comparison with 1990 and 1991 results by using data only from the four months that corresponded to the 1990 and 1991 quarterly sampling months.

^bStandard error.

mg/L; Table 3-12). Like TSS (Table 3-11), the 1989-1991 AFDM levels continued the trend begun in 1988 (0.87 mg/L) of levels lower than those in 1987 (2.20 mg/L) and 1986 (2.24 mg/L).

The minimum and maximum AFDM concentrations at Station 290 in 1991 (0.51 and 1.21 mg/L) were greater than the comparable statistic at each of the other three stations with the following two exceptions: the minimum at Station 370 (0.64 mg/L) and the maximum at Station 330 (1.22 mg/L; Appendix Table 9).

To more clearly evaluate year-to-year (1986-1989) variability in AFDM concentrations of whole water samples at each of the four Steel Creek stations sampled in 1990 and 1991, monthly mean AFDM data are plotted by sampling year in Figures 3-14 to 3-17 along with quarterly mean AFDM data for 1990 and 1991. All the monthly mean values from 1986-1989 were less than 4 mg/L and the majority of values were less than 3 mg/L. During 1990, all four stations exhibited mean quarterly AFDM values $\leq$ 2.20 mg/L. During 1991, they exhibited mean quarterly AFDM values $\leq$ 1.17 mg/L (Figures 3-14 to 3-17). Except for minor variations in the degree of change in concentration, temporal patterns of AFDM concentration in 1986-1989 were the same as the patterns previously discussed for TSS (Figures 3-10 to 3-13; Section 3.3.3.1).

At the four stations sampled in 1990 and 1991, the quarterly mean AFDM (Figures 3-14 to 3-17) tended to mirror the variability previously discussed for TSS (Figures 3-10 to 3-13; Section 3.3.3.1). However, occasionally the summer low in TSS would not correlate with the fall low in AFDM, as was the case at Station 370 in 1991. Since the summer and fall lows were 1.40 and 0.66 mg/L for TSS and AFDM respectively, such exceptions are not significant.

Station 290

X AFDM in 1986
O AFDM in 1987

* AFDM in 1988
+ AFDM in 1989

Figure 3-14. Mean AFDM concentrations (mg/L) in whole water collected at Steel Creek Station 290. Top panel: monthly means; January 1986-December 1989. Bottom panel: quarterly means; vertical bars are standard errors. 1990 and 1991.

Station 330

Figure 3-15. Mean AFDM concentrations (mg/L) in whole water collected at Steel Creek Station 330. Top panel: monthly means; January 1986-December 1989. Bottom panel: quarterly means; vertical bars are standard errors. 1990 and 1991.

Station 350

Figure 3-16. Mean AFDM concentrations (mg/L) in whole water collected at Steel Creek Station 350. Top panel: monthly means; January 1986-December 1989. Bottom panel: quarterly means; vertical bars are standard errors. 1990 and 1991.

Station 370

Figure 3-17. Mean AFDM concentrations (mg/L) in whole water collected at Steel Creek Station 370. Top panel: monthly means; January 1986-December 1989. Bottom panel: quarterly means; vertical bars are standard errors. 1990 and 1991.

At Station 330, the 1991 annual mean AFDM concentration (0.85 mg/L) was less than that of 1990 (1.43 mg/L), 1989 (1.85 mg/L), 1988 (1.23 mg/L), 1987 (1.21 mg/L), and 1986 (1.27 mg/L) levels (Table 3-12). At Station 350, the concentration in 1990 (1.22 mg/L) was about equal to that in 1989 (1.16 mg/L), slightly less than in 1988 (1.33 mg/L), while the mean level in 1986 (1.24 mg/L) was somewhat higher than in 1987 (0.84 mg/L). The 1991 annual mean AFDM concentration (0.68 mg/L) was less than that measured in 1986-1990.

Annual 1990 mean seston AFDM concentration at Station 370 (1.25 mg/L) was less than the value for 1989 (1.55 mg/L) and slightly lower than in 1988 (1.29 mg/L; Table 3-12). The minimum concentration measured in 1990 (0.03 mg/L) was the smallest concentration measured at any of the stations in this study from 1986 to 1991 (Appendix Table 9). The 1991 annual mean AFDM concentration at Station 370 (0.75 mg/L) was less than that measured in 1986-1990. The maximum value in 1990 (2.03 mg/L) and in 1991 (0.94 mg/L) were the lowest maximum values measured at the four stations in each of those years.

3.3.3.3 Percent Organic Matter

The 1986-1991 annual means for seston organic matter concentration as percent of TSS (% TSS) by weight are given in Table 3-13. The minimum and maximum values are presented in Appendix Table 10.

At Station 290, the trend toward lower annual mean seston organic matter concentration exhibited in 1988 (37.78% of TSS) and 1989 (41.72% of TSS) was reversed in 1990 (46.48% of TSS; Table 3-13). The 1991 concentration (37.17% of TSS) was the lowest concentration from 1986-1991 at Station 290. In 1990, the minimum and maximum values measured were 25.74% of TSS and 69.89% of TSS, respec-

Table 3-13. Annual means for relative seston organic matter concentration (% of TSS by weight) in whole water collected from Steel Creek. Minimum and maximum values are given in Appendix Table 10. January 1986-December 1991.

Location	Station	1986 ^a		1987 ^a		1988 ^a	
		Mean	SE ^b	Mean	SE ^b	Mean	SE ^b
Reference Site	255	-	-	-	-	26.32	(2.15)
Corridor	275	62.54	(6.48)	52.51	(8.82)	58.06	(4.45)
	280	46.00	(4.03)	37.02	(5.27)	35.32	(1.01)
	285	42.44	(3.56)	37.24	(3.35)	31.88	(1.30)
	290	42.71	(3.77)	48.18	(5.35)	37.78	(3.25)
Marsh	300	58.48	(13.82)	47.10	(3.34)	48.28	(3.66)
	310	36.10	(4.70)	52.28	(4.72)	35.78	(4.90)
	320	46.68	(4.88)	40.88	(2.98)	31.48	(1.38)
	330	41.91	(2.59)	45.38	(2.51)	39.34	(2.47)
Swamp	340	52.15	(3.73)	55.90	(3.76)	52.84	(4.13)
	350	46.49	(4.06)	51.33	(1.82)	39.88	(2.68)
Channel	360	32.58	(2.48)	38.66	(1.48)	33.15	(2.46)
	370	25.35	(2.13)	26.68	(2.01)	26.90	(1.28)
Meyer's Branch	400	47.91	(13.86)	39.24	(1.09)	44.70	(2.43)

^aSummary statistics for 1986-1989 were recalculated for comparison with 1990 and 1991 results by using data only from the four months that corresponded to the 1990 and 1991 quarterly sampling months.

^bStandard error.

Table 3-13 (continued). Annual means for relative seston organic matter concentration (% of TSS by weight) in whole water collected from Steel Creek. Minimum and maximum values are given in Appendix Table 10. January 1986-December 1991.

Location	Station	1989 ^a		1990		1991	
		Mean	SE ^b	Mean	SE ^b	Mean	SE ^b
Reference Site	255	29.21	(1.51)	-	-	-	-
Corridor	275	67.35	(6.33)	-	-	-	-
	280	44.66	(3.27)	-	-	-	-
	285	35.19	(4.34)	-	-	-	-
	290	41.72	(3.44)	46.48	(5.69)	37.17	(4.35)
Marsh	300	45.56	(2.81)	-	-	-	-
	310	37.23	(2.69)	-	-	-	-
	320	39.19	(6.13)	-	-	-	-
	330	40.78	(2.94)	46.99	(9.59)	40.97	(2.09)
Swamp	340	47.70	(2.62)	-	-	-	-
	350	57.55	(3.64)	46.30	(9.24)	44.87	(2.58)
Channel	360	42.49	(7.35)	-	-	-	-
	370	28.51	(1.31)	39.33	(7.45)	35.09	(4.15)
Meyer's Branch	400	43.49	(1.15)	-	-	-	-

^aSummary statistics for 1986-1989 were recalculated for comparison with 1990 and 1991 results by using data only from the four months that corresponded to the 1990 and 1991 quarterly sampling months.

^bStandard error.

tively (Appendix Table 10). These were the lowest minimum and highest maximum measured at Station 290 during this study. This same trend was exhibited at each of the three other stations sampled in 1990. In 1991 the minimum and maximum values (26.67 and 58.78% of TSS respectively) reflected a moderation of the extreme values exhibited in 1990. This was also the case at the other three stations sampled.

Station 330 rather closely mirrored Station 290, not only in relative seston organic matter concentration in 1986 (41.91% of TSS) and 1987 (45.38% of TSS), but also the reduced levels in 1988 (39.34% of TSS) and 1989 (40.78% of TSS) and the increased level in 1990 (46.99% of TSS; Table 3-13). Like Station 290, Station 330 in 1991 exhibited a reduced annual mean seston organic matter concentration (40.97% of TSS).

The maximum value (93.14% of TSS) measured in 1990 at Station 330, was the highest level of seston organic matter concentration measured at any Steel Creek station (Appendix Table 10). In 1991 the maximum value (51.38% of TSS) was a little above the maximum in 1986 (50.62% of TSS).

Station 350 was comparable to Station 330 in relative seston organic matter concentration in 1988 (39.88% of TSS) and 1990 (46.30% of TSS) and somewhat comparable to 1986 (46.49% of TSS) and 1987 (51.33% of TSS; Table 3-13). However, in 1989 while Stations 290 and 330 continued in a downward trend, Station 350 levels rose by almost one-half to 57.55% of TSS from 39.88% of TSS. In 1991, annual mean seston organic matter concentration (44.87% of TSS) was again somewhat comparable to that of Station 330.

With the exceptions of 1990 and 1991, channel Station 370 exhibited the most stable mean annual relative seston organic matter concentrations, among years, of all the Steel Creek stations. These measured 25.35, 26.68, 26.90, and 28.51% of TSS in 1986, 1987, 1988, and 1989 respectively. In 1990, the levels increased to 39.33% of TSS. In 1991, the annual mean seston organic matter concentration leveled off somewhat at 35.09 mg/L (Table 3-13). The minimum level measured in 1990, however, was 1.40% of TSS, the lowest value measured at all stations in all years from 1986-1990 (Appendix Table 9). In 1991, the minimum level measured (25.21 mg/L) was very similar to the 1989 value (25.91 mg/L). The maximum level (60.00 mg/L) was the highest level measured at the four stations in 1991 (Appendix Table 9).

The 1990 and 1991 quarterly means for % TSS are plotted in Figures 3-18 to 3-21. No monthly or quarterly means for % TSS were generated from 1986 to 1989. With some exceptions, temporal patterns of percent organic matter of TSS were overall the same as those previously described for AFDM (Figures 3-14 to 3-17; Section 3.3.3.2). There were some exceptions. In 1990 at Station 330 the AFDM was less (0.94 mg/L) in fall than in summer (1.67 mg/L), while the % TSS was higher (46.36%) in fall than in summer (19.06%). In 1991, at Station 290, the AFDM was less (1.05 mg/L) in summer than in spring (1.14 mg/L), while the % TSS was higher (56.68%) in summer than in spring (33.1%).

3.3.3.4 Chlorophyll *a*

Annual means for seston chlorophyll *a* concentrations at Steel Creek stations from 1986 through 1991 are presented in Table 3-14. The minimum and maximum values measured each year are given in Appendix Table 11.

SESTON QUARTERLY MEAN PERCENT ORGANIC MATTER AT STATION 290

Figure 3-18. Quarterly means and standard errors for the percentage of organic matter found in TSS at Steel Creek Station 290. Vertical bars are standard errors. 1990 and 1991.

SESTON QUARTERLY MEAN PERCENT ORGANIC MATTER AT STATION 330

Figure 3-19. Quarterly means and standard errors for the percentage of organic matter found in TSS at Steel Creek Station 330. Vertical bars are standard errors. 1990 and 1991.

SESTON QUARTERLY MEAN PERCENT ORGANIC MATTER AT STATION 350

Figure 3-20. Quarterly means and standard errors for the percentage of organic matter found in TSS at Steel Creek Station 350. Vertical bars are standard errors. 1990 and 1991.

SESTON QUARTERLY MEAN PERCENT ORGANIC MATTER AT STATION 370

Figure 3-21. Quarterly means and standard errors for the percentage of organic matter found in TSS at Steel Creek Station 370. Vertical bars are standard errors. 1990 and 1991.

Table 3-14. Annual means for seston chlorophyll *a* concentration ($\mu\text{g/L}$) in whole water collected from Steel Creek. Minimum and maximum values are given in Appendix Table 11. January 1986-December 1991.

Location	Station	1986 ^a		1987 ^a		1988 ^a	
		Mean	SE ^b	Mean	SE ^b	Mean	SE ^b
Reference Site	255	-	-	-	-	0.75	(0.13)
Corridor	275	12.20	(2.69)	15.10	(3.53)	5.76	(1.25)
	280	11.11	(2.09)	14.46	(4.83)	-	-
	285	7.22	(1.32)	12.63	(3.84)	-	-
	290	4.49	(1.11)	8.24	(2.57)	0.85	(0.23)
Marsh	300	1.73	(0.23)	4.54	(0.80)	-	-
	310	1.36	(0.21)	5.02	(1.84)	-	-
	320	1.80	(0.52)	8.04	(2.97)	-	-
	330	1.26	(0.22)	2.38	(0.77)	-	-
Swamp	340	0.75	(0.23)	0.9	(0.37)	-	-
	350	0.88	(0.27)	1.19	(0.44)	-	-
Channel	360	0.81	(0.15)	1.30	(0.28)	-	-
	370	0.70	(0.13)	1.05	(0.22)	0.57	(0.09)
Meyer's Branch	400	0.27	(0.09)	0.40	(0.08)	-	-

^aSummary statistics for 1986-1989 were recalculated for comparison with 1990 and 1991 results by using data only from the four months that corresponded to the 1990 and 1991 quarterly sampling months.

^bStandard error.

Table 3-14 (continued). Annual means for seston chlorophyll *a* concentration ($\mu\text{g/L}$) in whole water collected from Steel Creek. Minimum and maximum values are given in Appendix Table 11. January 1986-December 1991.

Location	Station	1989 ^a		1990		1991	
		Mean	SE ^b	Mean	SE ^b	Mean	SE ^b
Reference Site	255	0.44	(0.08)	-	-	-	-
Corridor	275	5.37	(0.89)	-	-	-	-
	280	-	-	-	-	-	-
	285	-	-	-	-	-	-
	290	2.10	(0.89)	0.74	(0.13)	1.14	(0.24)
Marsh	300	-	-	-	-	-	-
	310	-	-	-	-	-	-
	320	-	-	-	-	-	-
	330	-	-	1.14	(0.11)	1.49	(0.27)
Swamp	340	-	-	-	-	-	-
	350	-	-	1.20	(0.23)	1.05	(0.22)
Channel	360	-	-	-	-	-	-
	370	0.85	(0.10)	2.52	(1.06)	0.83	(0.12)
Meyer's Branch	400	-	-	-	-	-	-

^aSummary statistics for 1986-1989 were recalculated for comparison with 1990 and 1991 results by using data only from the four months that corresponded to the 1990 and 1991 quarterly sampling months.

^bStandard error.

The annual mean seston chlorophyll a concentration at Station 290 was twice as large in 1987 (8.24 $\mu\text{g/L}$) as in 1986 (4.49 $\mu\text{g/L}$; Table 3-14). The 1988 mean concentration (0.85 $\mu\text{g/L}$) and 1989 mean concentration (2.10 $\mu\text{g/L}$) were approximately one-fifth and one-half the 1986 concentration, respectively. The 0.74 $\mu\text{g/L}$ mean of 1990 and the 1.14 $\mu\text{g/L}$ mean of 1991 continued the reduced chlorophyll a concentrations that began in 1988. The 1991 mean, though higher than that of 1990, was still well below the 1989 mean.

To more easily evaluate year-to-year variations, monthly mean chlorophyll a concentrations during 1986-1989 at Stations 290 and 370 are plotted in Figures 3-22 and 3-25, respectively. Monthly mean chlorophyll a concentrations during 1986 and 1987 at Stations 330 and 350 are plotted in Figures 3-23 and 3-24, respectively; no samples were collected at these two stations during 1988 and 1989. Quarterly mean chlorophyll a concentrations measured at the four stations in 1990 and 1991 are also plotted in Figures 3-22 to 3-25.

At corridor Station 290, the considerable temporal variability in mean monthly chlorophyll a concentrations displayed in 1986 and 1987, especially during the first half of the year, decreased substantially 1988 and 1989, and was reduced even further in 1990, although variability increased somewhat in 1991 (Figure 3-22). Chlorophyll a concentrations at Station 290 during 1990 ranged from 0.31 to 1.34 $\mu\text{g/L}$ and from 0.45 to 2.34 $\mu\text{g/L}$ in 1991 (Figure 3-22; Appendix Table 11).

The annual mean seston chlorophyll a concentration at Station 330 in 1987 (2.38 $\mu\text{g/L}$) was double the concentration in 1986 (1.26 $\mu\text{g/L}$; Table 3-14). During

Station 290

Figure 3-22. Mean chlorophyll a concentrations ($\mu\text{g/L}$) in whole water samples collected at Steel Creek Station 290. Note difference in scale for corridor stations from those used for channel stations. Top panel: monthly means; January 1986-December 1989. Bottom panel: quarterly means; vertical bars are standard errors. 1990 and 1991.

STATION 330

Figure 3-23. Mean chlorophyll a concentrations ($\mu\text{g/L}$) in whole water samples collected at Steel Creek Station 330. Top panel: monthly means; vertical bars are standard errors; January 1986-December 1987. Bottom panel: quarterly means; vertical bars are standard errors. 1990 and 1991.

STATION 350

Figure 3-24. Mean chlorophyll a concentrations (µg/L) in whole water samples collected at Steel Creek Station 350. Top panel: monthly means; vertical bars are standard errors; January 1986-December 1987. Bottom panel: quarterly means; vertical bars are standard errors. 1990 and 1991.

Station 370

Figure 3-25. Mean chlorophyll a concentrations ($\mu\text{g/L}$) in whole water samples collected at Steel Creek Station 370. Top panel: monthly means; vertical bars are standard errors; January 1986-December 1989. Bottom panel: quarterly means; vertical bars are standard errors. 1990 and 1991.

1990, the mean annual seston chlorophyll *a* concentration was 1.14 $\mu\text{g/L}$ and 1.49 $\mu\text{g/L}$ in 1991.

Considerable variability was displayed in the mean monthly seston chlorophyll *a* concentrations at Station 330 (especially during the first half of each year) during 1986 and to a lesser degree during 1987 (Figure 3-23). Variability in the mean seston quarterly chlorophyll *a* concentrations measured during 1990 was practically nonexistent. In 1991 variability increased. There was a high in spring (2.72 $\mu\text{g/L}$) and low in summer (0.97 $\mu\text{g/L}$). During 1990, the minimum and maximum seston chlorophyll *a* measured at Station 330 were 0.62 and 1.56 $\mu\text{g/L}$ respectively. These were the highest minimum and lowest maximum recorded at this station during this study. In 1991 the minimum and maximum seston chlorophyll *a* concentrations measured were 0.67 and 2.62 $\mu\text{g/L}$, respectively (Appendix Table 11).

At Station 350, the annual mean chlorophyll *a* concentration in 1987 (1.19 $\mu\text{g/L}$) was 35% higher than that measured in 1986 (0.88 $\mu\text{g/L}$; Table 3-14). During 1990, the mean annual seston chlorophyll *a* concentration was 1.20 $\mu\text{g/L}$.

Similar to Station 330 (Figure 3-23), there was considerable variability displayed in mean monthly seston chlorophyll *a* concentrations at Station 350 in 1986 and less in 1987 (Figure 3-24). Temporal variability at Station 350 in 1987 closely mirrored that at Station 330 from March through December.

In 1990, Station 350 exhibited about the same amount of variability in mean quarterly chlorophyll *a* concentrations as did Station 290 (Figures 3-24 and 3-22, respectively). Measurements at both stations increased in spring over winter

amounts. However, at Station 350, quarterly mean chlorophyll *a* decreased from 2.15 $\mu\text{g/L}$ in spring to 0.75 $\mu\text{g/L}$ in summer and 0.60 $\mu\text{g/L}$ in fall, while Station 290 dropped from 1.29 $\mu\text{g/L}$ in spring to 0.48 $\mu\text{g/L}$ in summer before rising to 0.73 $\mu\text{g/L}$ in fall. Both stations displayed similar variabilities in 1990 but at somewhat higher quarterly mean chlorophyll *a* levels, with one exception: Station 290 levels dropped in fall instead of rising.

At Station 370, the annual mean chlorophyll *a* concentrations in 1988 (0.57 $\mu\text{g/L}$) and in 1989 (0.85 $\mu\text{g/L}$) were approximately one-half and eight-tenths, respectively, that of the 1987 level (1.05 $\mu\text{g/L}$; Table 3-14). The exception to the post-1987 decrease in concentrations was the 2.52 $\mu\text{g/L}$ mean annual concentration in 1990. This was about one-and-a-half times the 1987 level. Levels in 1991 (0.83 $\mu\text{g/L}$) once again decreased.

As at Station 290 (Figure 3-22), chlorophyll *a* levels and temporal variability at Station 370 decreased from 1986 through 1988 (Figure 3-25). During 1989, however, mean chlorophyll *a* levels were generally higher than in 1988. Concentrations peaked in April 1986 and 1987, in March 1988, and in July 1989.

During 1990, mean quarterly seston chlorophyll *a* concentrations at Station 370 peaked earlier, in winter (7.25 $\mu\text{g/L}$) and was midway between the high levels of 1986 and 1987 (Figure 3-25). Beginning in spring (May), the variability was similar to the 1986-1989 variability. In 1991 mean quarterly seston chlorophyll *a* concentrations peaked in spring at much lower levels (1.51 $\mu\text{g/L}$).

During the biannual diel water sampling performed in Steel Creek in February and August of 1991, none of the differences in the station ranks for the seston parameters (TSS, AFDM, %OM, chlorophyll *a*) were consistent enough to be statistically significant at the $\alpha = 0.05$ level (F values ranged from 0.00 to 0.22 and Prob > F ranged from <0.8750 to 1.0000; Table 3-10).

3.4 DISCUSSION

3.4.1 Organization of Discussion

The discussion will first evaluate the trends in seston quantity and quality at each sampled location in Steel Creek and Meyer's Branch and the independent variables that are most likely affecting these patterns. This evaluation will then be followed by a summary discussion focusing on the 316 (a) demonstration as it relates to seston.

3.4.2 General Observations

The amount of seston present in a channel is primarily a function of three factors: (1) availability and sources of particulate material and (2) number and type of retentive features in the channel, both of which vary as a result of (3) flow regime and seasonal patterns. For a review of these independent variables as they would affect seston quantity in the Steel Creek-Meyer's Branch system, the reader is referred to Hooker and Stiner (1988).

During 1986-1988, release of water from L Lake frequently exceeded 10 m³/sec. At times there was a ten-fold increase from Steel Creek corridor baseflows, which were less than 1 m³/sec in 1985 (Firth et al. 1986). The pattern of releases was erratic during 1986 and 1987, but was less variable during 1988 and 1989 (van Duyn and Stiner 1990). In both 1986 and 1987, the

reactor was not operated during hot summer months; starting in July 1988, L-Reactor was placed on standby status. Water pumping operations continued during this period in 1988 and during all of 1989 although to a much lesser degree; therefore, some fluctuation in L-Lake discharge flows continued from July 1988-December 1989 (van Duyn and Stiner 1990).

3.4.3 Steel Creek Corridor

The concentration of seston water at the Steel Creek corridor sites was generally lower and more temporally stable in 1988 and 1989, compared with 1986 and 1987. This trend was probably a direct result of the decrease in variability in outflow at the L-Lake dam in 1988 and 1989 compared with 1986 and 1987 (van Duyn and Stiner 1990). Throughout most of 1986 and 1987, periodic episodes of high flow were probably responsible for significant seston transport in the corridor, due to channel bed and bank erosion and entrainment of particles from the floodplain (Firth 1987, Hooker and Stiner 1988). In 1988, however, L-Lake outflow was (1) less variable during the reactor-up period (January-June) and (2) lower for a greater portion of the year due to the extended reactor-down period (July-December). In 1989, L-Lake outflow was also relatively lower and more stable throughout the year due to the extended reactor-down period. Other sources of variation may have had an influence on seston concentration at the corridor location, since lower and less variable concentrations also occurred in 1988 and 1989 at the reference site on Meyer's Branch and in 1989 at the reference site on Steel Creek, Station 255 (van Duyn and Stiner 1990). During 1990, Station 290, the only corridor station sampled, continued the trend of lower TSS and showed more stability than in any previous years.

APPENDICES

Appendix Table 1.

Minimum and maximum values for annual periphyton chlorophyll *a* content (mg/m²) accumulated on glass slides incubated in Steel Creek and Meyer's Branch. Means and standard errors are presented in Table 3-1. January 1986-December 1991.

Location	Station	1986 ^a		1987 ^a		1988 ^a	
		MIN	MAX	MIN	MAX	MIN	MAX
Reference Site	255	-	-	-	-	0.15	18.82
Corridor	275	1.76	15.28	1.01	41.85	3.02	20.36
	280	1.58	15.56	0.58	8.73	0.09	15.11
	285	0.62	16.80	2.52	31.22	2.58	38.13
	290	4.96	14.87	1.01	34.02	7.08	44.97
Marsh	300	1.36	13.36	1.07	18.12	0.37	18.52
	310	0.47	14.04	0.35	31.80	0.33	19.02
	320	0.43	15.56	0.05	18.92	0.18	23.08
	330	0.14	15.15	0.06	26.28	0.40	13.27
Swamp	340	0.05	16.80	0.01	9.36	0.24	2.71
	350	0.01	16.11	0.01	16.41	0.02	7.18
Channel	360	0.03	9.82	0.01	8.27	0.10	9.21
	370	0.07	20.52	0.13	32.87	1.34	17.43
Meyer's Branch	400	0.04	7.96	0.02	5.51	0.02	5.25

^aSummary statistics for 1986-1989 were recalculated for comparison with 1990 and 1991 results by using data only from the four months that corresponded to the 1990 and 1991 quarterly sampling months.

Appendix Table 1 (continued).

Minimum and maximum values for annual periphyton chlorophyll *a* content (mg/m²) accumulated on glass slides incubated in Steel Creek and Meyer's Branch. Means and standard errors are presented in Table 3-1. January 1986-December 1991.

Location	Station	1989 ^a		1990		1991	
		MIN	MAX	MIN	MAX	MIN	MAX
Reference Site	255	2.33	20.91	-	-	-	-
Corridor	275	2.19	20.73	-	-	-	-
	280	0.92	20.14	-	-	-	-
	285	4.90	20.59	-	-	-	-
	290	1.39	16.33	9.57	22.35	0.00	38.35
Marsh	300	0.13	10.00	-	-	-	-
	310	0.09	11.08	-	-	-	-
	320	1.39	11.74	-	-	-	-
	330	0.05	10.67	0.67	24.03	0.00	27.13
Swamp	340	0.45	8.20	-	-	-	-
	350	0.01	6.93	0.14	17.64	0.00	5.60
Channel	360	0.05	10.56	-	-	-	-
	370	0.01	11.23	0.04	23.99	0.00	7.37
Meyer's Branch	400	0.02	5.04	-	-	-	-

^aSummary statistics for 1986-1989 were recalculated for comparison with 1990 and 1991 results by using data only from the four months that corresponded to the 1990 and 1991 quarterly sampling months.

Appendix Table 2.

Minimum and maximum values for annual periphyton ash-free dry mass (g/m²) accumulated on glass slides incubated in Steel Creek and Meyer's Branch.

Means and standard errors are presented in Table 3-2.

January 1986-December 1991.

Location	Station	1986 ^a		1987 ^a		1988 ^a	
		MIN	MAX	MIN	MAX	MIN	MAX
Reference Site	255	-	-	-	-	0.06	3.22
Corridor	275	0.05	29.16	<0.01	17.85	5.72	190.97
	280	0.41	7.30	0.02	9.43	0.38	3.54
	285	0.63	13.42	0.19	11.71	0.36	5.78
	290	0.21	8.12	0.80	5.52	0.46	3.49
Marsh	300	0.15	5.09	0.16	5.43	0.25	2.58
	310	0.00	3.58	0.27	2.84	0.11	2.50
	320	0.00	2.42	0.09	2.67	0.01	2.99
	330	0.02	5.89	0.12	2.07	0.11	2.65
Swamp	340	0.27	1.16	0.07	2.03	0.09	0.83
	350	0.12	1.59	0.03	1.52	0.05	0.64
Channel	360	0.09	1.22	0.02	0.99	0.05	1.36
	370	0.10	10.18	0.02	1.48	0.01	2.34
Meyer's Branch	400	0.25	3.28	0.14	4.56	<0.01	1.74

^aSummary statistics for 1986-1989 were recalculated for comparison with 1990 and 1991 results by using data only from the four months that corresponded to the 1990 and 1991 quarterly sampling months.

Appendix Table 2 (continued).

Minimum and maximum values for annual periphyton ash-free dry mass (g/m^2) accumulated on glass slides incubated in Steel Creek and Meyer's Branch.

Means and standard errors are presented in Table 3-2.

January 1986-December 1991.

Location	Station	1989 ^a		1990		1991	
		MIN	MAX	MIN	MAX	MIN	MAX
Reference Site	255	0.24	3.37	-	-	-	-
Corridor	275	0.52	22.91	-	-	-	-
	280	0.15	4.08	-	-	-	-
	285	0.42	5.59	-	-	-	-
	290	0.93	4.06	0.34	6.25	0.90	6.17
Marsh	300	0.17	2.71	-	-	-	-
	310	0.23	2.09	-	-	-	-
	320	0.09	2.67	-	-	-	-
	330	0.05	2.15	0.07	4.05	0.14	7.65
Swamp	340	0.18	1.98	-	-	-	-
	350	0.09	1.33	0.06	1.50	0.01	15.73
Channel	360	0.01	1.12	-	-	-	-
	370	0.02	1.92	0.09	2.64	0.03	8.84
Meyer's Branch	400	0.16	1.50	-	-	-	-

^aSummary statistics for 1986-1989 were recalculated for comparison with 1990 and 1991 results by using data only from the four months that corresponded to the 1990 and 1991 quarterly sampling months.

Appendix Table 3.

Annual mean, standard error, and range of numerical abundance values
(organisms/mm²) by division at Steel Creek stations in 1991.

Division ^a	Mean	SE	Min	Max
<u>Station 290</u>				
Bacillariophyta	2019.7	1006.7	365.2	4825.1
Chlorophyta	760.5	395.1	196.8	1887.1
Cyanophyta	72.6	31.2	4.4	154.0
<u>Station 330</u>				
Bacillariophyta	977.9	190.3	475.8	1336.5
Chlorophyta	621.4	172.6	218.7	964.6
Chrysophyta	11.3	11.3	0.0	45.0
Cyanophyta	40.6	16.9	0.0	76.5
Euglenophyta	0.7	0.7	0.0	2.7
<u>Station 350</u>				
Bacillariophyta	579.2	509.9	3.5	2106.0
Chlorophyta	251.7	219.8	2.0	910.0
Chrysophyta	2.6	2.5	0.0	10.2
Cryptophyta	0.1	0.1	0.0	0.3
Cyanophyta	51.3	43.7	0.0	182.0
Euglenophyta	0.1	0.1	0.0	0.3
<u>Station 370</u>				
Bacillariophyta	190.4	92.6	6.2	392.4
Chlorophyta	35.2	14.9	0.6	64.8
Chrysophyta	1.1	0.9	0.0	3.6
Cryptophyta	0.3	0.2	0.0	0.9
Cyanophyta	3.7	1.9	0.0	9.0

^aBacillariophyta - diatoms
 Chlorophyta - green algae
 Chrysophyta - golden-brown algae
 Cryptophyta - cryptomonads
 Cyanophyta - blue-green algae
 Euglenophyta - euglenoids.

Appendix Table 4.

Summary statistics for common algal taxa accumulated on glass periphytometer slides at four Steel Creek stations in 1991.

Taxa Name	Mean	SE	Min	Max
<u>Gomphonema parvulum</u>	939.7	718.9	16.5	3084.9
coccoid Chlorophyta spp. < 5 μ	397.2	235.0	76.8	1096.1
<u>Cocconeis placentula</u>	355.8	235.5	0.0	998.4
<u>Pseudulvella americana</u>	277.3	167.8	0.0	678.0
<u>Eunotia pectinalis</u>	252.0	119.8	26.4	553.7
<u>Achnanthes lanceolata</u>	107.0	44.7	17.6	196.8
coccoid Cyanophyta spp. < 5 μ	70.3	32.3	0.0	154.0
<u>Cocconeis fluviatilis</u>	51.0	21.4	0.0	101.7
<u>Fragilaria vaucheriae</u>	41.3	41.3	0.0	165.0
<u>Navicula minima</u>	39.7	30.5	2.2	130.9
<u>Leptosira mediciniana</u>	37.7	21.9	0.0	81.6
<u>Melosira varians</u>	26.1	17.6	0.0	77.0

Station 330

<u>Gomphonema parvulum</u>	303.4	142.0	52.0	706.5
coccoid Chlorophyta spp. < 5 μ	250.4	61.3	140.4	393.9
<u>Pseudulvella americana</u>	163.2	163.2	0.0	652.6
<u>Achnanthes lanceolata</u>	157.3	90.9	29.7	417.3
<u>Eunotia pectinalis</u>	104.5	22.2	74.1	170.3
<u>Nitzschia paleacea</u>	94.8	44.0	3.9	207.0
<u>Leptosira mediciniana</u>	72.7	42.5	0.0	162.0
<u>Fragilaria vaucheriae</u>	55.1	53.6	0.0	216.0
<u>Navicula minima</u>	49.5	18.1	13.5	93.6
<u>Navicula cryptocephala</u>	46.7	16.9	3.9	75.6
<u>Chlamydomonas</u> spp. 5 - 9.9 μ	33.8	33.8	0.0	135.0
<u>Melosira varians</u>	28.0	26.7	0.0	108.0
<u>Cocconeis fluviatilis</u>	26.3	26.3	0.0	105.3

Station 350

<u>Navicula minima</u>	202.7	188.3	0.0	767.0
coccoid Chlorophyta spp. < 5 μ	154.1	137.4	0.5	565.5
<u>Gomphonema parvulum</u>	107.4	96.4	1.4	396.5
<u>Eunotia pectinalis</u>	88.7	71.0	0.4	299.0
<u>Achnanthes lanceolata</u>	70.6	61.2	0.2	253.5
coccoid Cyanophyta spp. < 5 μ	28.1	23.4	0.0	97.5
<u>Oedogonium</u> spp. sm	7.0	4.3	0.0	19.5
<u>Nitzschia paleacea</u>	5.6	3.0	0.1	13.0
<u>Nitzschia gracilis</u>	3.0	1.7	0.0	6.5

Appendix Table 4 (continued).

Summary statistics for common algal taxa accumulated on glass periphytometer slides at four Steel Creek stations in 1991.

Taxa Name	Mean	SE	Min	Max
<u>Station 350 (continued).</u>				
<u>Uronema elongatum</u>	2.0	2.0	0.0	8.1
coccoid Chrysophyta spp. < 5 μ	1.4	1.4	0.0	5.7
<u>Pseudulvella americana</u>	0.3	0.3	0.0	1.4
<u>Fragilaria vaucheriae</u>	0.2	0.2	0.0	0.7
<u>Station 370</u>				
<u>Achnanthes lanceolata</u>	105.9	60.3	0.7	217.8
<u>Eunotia pectinalis</u>	29.1	15.9	1.2	62.1
<u>Gomphonema parvulum</u>	22.8	9.6	1.9	48.6
<u>Leptosira mediciniana</u>	16.2	11.9	0.0	50.4
coccoid Chlorophyta spp. < 5 μ	11.7	5.3	0.3	26.1
<u>Navicula minima</u>	7.5	3.2	0.1	15.3
<u>Nitzschia paleacea</u>	4.9	2.5	0.1	11.2
<u>Navicula cryptocephala</u>	3.7	2.2	0.0	9.0
<u>Cymbella minuta</u>	1.4	0.7	0.0	2.7
<u>Stigeoclonium</u> spp.	1.3	1.3	0.0	5.0
<u>Fragilaria vaucheriae</u>	0.3	0.3	0.0	1.2

Appendix Table 5.

Periphyton taxa richness by quarter at four Steel Creek stations.
January-December 1991.

Station	Winter	Spring	Summer	Fall
290	26.0	18.0	15.0	23.0
330	28.0	32.0	25.0	30.0
350	25.0	28.0	30.0	37.0
370	24.0	20.0	27.0	38.0

Appendix Table 6.

Periphyton taxa list by quarter for four Steel Creek stations.
January-December 1991.

Division	Taxa Name	Winter	Spring	Summer	Fall
<u>Station 290</u>					
BACILLARIOPHYTA	<u>Achnanthes lanceolata</u>	X	X	X	X
	<u>Achnanthes minutissima</u>	X	X		X
	<u>Cocconeis fluviatilis</u>		X	X	X
	<u>Cocconeis placentula</u>	X	X		X
	<u>Cyclotella meneghiniana</u>	X			
	<u>Cymbella minuta</u>	X	X	X	X
	<u>Eunotia curvata</u>	X			
	<u>Eunotia pectinalis</u>	X	X	X	X
	<u>Fragilaria vaucheriae</u>	X			
	<u>Gomphonema parvulum</u>	X	X	X	X
	<u>Melosira varians</u>	X	X		X
	<u>Meridion circulare</u>	X			
	<u>Navicula arvensis</u>	X	X		
	<u>Navicula cryptocephala</u>	X	X	X	X
	<u>Navicula decussis</u>				X
	<u>Navicula lateropunctata</u>				X
	<u>Navicula minima</u>	X	X	X	X
	<u>Navicula pseudoarvensis</u>				X
	<u>Navicula spp.</u>				X
	<u>Nitzschia filiformis</u>	X			
	<u>Nitzschia fonticola</u>	X	X		
	<u>Nitzschia gracilis</u>		X		
	<u>Nitzschia pales</u>	X			X
	<u>Nitzschia paleacea</u>	X		X	X
	<u>Synedra tenera</u>	X			
	<u>Synedra ulna</u>	X			X
CHLOROPHYTA	<u>Ankistrodesmus spiralis</u>	X			
	<u>Characium spp.</u>			X	
	<u>Closterium kutzingii</u>	X			
	coccoid Chlorophyta spp. 5 - 9.9 μ	X			X
	coccoid Chlorophyta spp. < 5 μ	X	X	X	X
	<u>Hyalotheca dissiliens</u>	X			
	<u>Leptosira mediciniana</u>			X	X
	<u>Oedogonium spp. lg</u>			X	
	<u>Pseudolvella americana</u>		X	X	
	<u>Scenedesmus denticulatus</u>		X		X
	<u>Scenedesmus dimorphus</u>			X	
	<u>Stigeoclonium spp.</u>		X		

Appendix Table 6 (continued).

Periphyton taxa list by quarter for four Steel Creek stations.
January-December 1991.

Division	Taxa Name	Winter	Spring	Summer	Fall
<u>Station 290 (continued).</u>					
CYANOPHYTA	coccoid Cyanophyta spp. < 5 μ		X	X	X
	<u>Lyngbya subtilis</u>	X			
	<u>Oscillatoria geminata</u>				X
<u>Station 330</u>					
BACILLARIOPHYTA	<u>Achnanthes hungarica</u>		X	X	
	<u>Achnanthes lanceolata</u>	X	X	X	X
	<u>Achnanthes minutissima</u>	X	X	X	
	<u>Caloneis bacillum</u>	X			
	<u>Cocconeis fluviatilis</u>			X	
	<u>Cocconeis placentula</u>	X	X		X
	<u>Cyclotella meneghiniana</u>	X	X		X
	<u>Cymbella minuta</u>	X	X	X	X
	<u>Eunotia curvata</u>	X	X		
	<u>Eunotia pectinalis</u>	X	X	X	X
	<u>Fragilaria vaucheriae</u>	X			X
	<u>Frustulia vulgaris</u>				X
	<u>Gomphonema parvulum</u>	X	X	X	X
	<u>Gomphonema turris</u>		X	X	
	<u>Melosira varians</u>	X	X		
	<u>Meridion circulare</u>	X			
	<u>Navicula arvensis</u>	X	X		
	<u>Navicula cryptocephala</u>	X	X	X	X
	<u>Navicula decussis</u>	X			
	<u>Navicula minima</u>	X	X	X	X
	<u>Navicula minuscula</u>		X		
	<u>Navicula pseudoarvensis</u>			X	X
	<u>Navicula rhynchocephala</u> var. <u>germainii</u>				X
	<u>Navicula</u> spp.		X	X	
	<u>Navicula symmetrica</u>				X
	<u>Nitzschia acicularis</u>				X
	<u>Nitzschia amphibia</u>		X	X	
	<u>Nitzschia fonticola</u>	X	X		
	<u>Nitzschia gracilis</u>		X		
	<u>Nitzschia ignorata</u>				X
	<u>Nitzschia microcephala</u>			X	
	<u>Nitzschia palea</u>	X	X		X
	<u>Nitzschia paleacea</u>	X	X	X	X
	<u>Surirella angustata</u>	X	X		
	<u>Synedra rumpens</u>	X	X		

Appendix Table 6 (continued).

Periphyton taxa list by quarter for four Steel Creek stations.
January-December 1991.

Division	Taxa Name	Winter	Spring	Summer	Fall
<u>Station 330 (continued).</u>					
BACILLARIOPHYTA	<u>Synedra tenara</u>	X			
	<u>Synedra ulna</u>				X
CHLOROPHYTA	<u>Ankistrodesmus falcatus</u>		X	X	
	<u>Characium</u> spp.		X	X	X
	<u>Chlamydomonas</u> spp. 5 - 9.9 μ				X
	coccoid Chlorophyta spp. 5 - 9.9 μ		X	X	X
	coccoid Chlorophyta spp. < 5 μ	X	X	X	X
	<u>Leptosira mediciniana</u>			X	X
	<u>Oedogonium</u> spp. lg			X	
	<u>Oedogonium</u> spp. sm			X	
	<u>Pseudulvella americana</u>			X	
	<u>Scenedesmus biuga</u>	X			
	<u>Scenedesmus dimorphus</u>		X		
	<u>Scenedesmus scornis</u>		X		
	<u>Staurostrum alternans</u>	X			
	<u>Ulothrix zonata</u>	X			
	<u>Uronema elongatum</u>	X			X
CHRYSOPHYTA	coccoid Chrysophyta spp. 5 - 9.9 μ				X
	coccoid Chrysophyta spp. < 5 μ				X
CYANOPHYTA	<u>Chamaesiphon minutus</u>			X	
	coccoid Cyanophyta spp. < 5 μ		X	X	X
	<u>Oscillatoria geminata</u>		X		X
	<u>Phormidium molle</u>		X		X
	<u>Phormidium</u> spp.				X
EUGLENOPHYTA	<u>Euglena</u> spp.	X			
<u>Station 350</u>					
BACILLARIOPHYTA	<u>Achnanthes hungarica</u>			X	
	<u>Achnanthes lanceolata</u>	X	X	X	X
	<u>Achnanthes minutissima</u>	X	X		X
	<u>Cocconeis fluviatilis</u>		X	X	
	<u>Cocconeis pediculus</u>	X			
	<u>Cocconeis placentula</u>	X	X	X	
	<u>Cyclotella meneghiniana</u>			X	X
	<u>Cymbella minuta</u>	X	X	X	X

Appendix Table 6 (continued).

Periphyton taxa list by quarter for four Steel Creek stations.
January-December 1991.

Division	Taxa Name	Winter	Spring	Summer	Fall
<u>Station 350 (continued).</u>					
BACILLARIOPHYTA	<u>Eunotia curvata</u>		X	X	
	<u>Eunotia flexuosa</u>	X			
	<u>Eunotia pectinalis</u>	X	X	X	X
	<u>Eunotia tenella</u>	X			
	<u>Fragilaria vaucheriae</u>	X			
	<u>Frustulia vulgaris</u>				X
	<u>Gomphonema parvulum</u>	X	X	X	X
	<u>Gomphonema subclavatum</u>			X	
	<u>Gomphonema turris</u>			X	
	<u>Melosira varians</u>	X			
	<u>Meridion circulare</u>	X			
	<u>Navicula confervacea</u>			X	
	<u>Navicula cryptocephala</u>	X	X	X	X
	<u>Navicula minima</u>	X	X	X	X
	<u>Navicula minuscula</u>		X		
	<u>Navicula pseudoarvensis</u>			X	X
	<u>Navicula spp.</u>	X		X	X
	<u>Nitzschia acicularis</u>				X
	<u>Nitzschia amphibia</u>		X	X	
	<u>Nitzschia fonticola</u>	X	X		
	<u>Nitzschia gracilis</u>		X		X
	<u>Nitzschia palea</u>			X	
	<u>Nitzschia paleacea</u>	X	X	X	X
	<u>Pinnularia braunii</u>			X	
	<u>Surirella angustata</u>	X			
	<u>Synedra delicatissima</u>				X
	<u>Synedra rumpens</u>		X		
	<u>Synedra ulna</u>	X			
CHLOROPHYTA	<u>Ankistrodesmus falcatus</u>		X	X	
	<u>Ankistrodesmus spiralis</u>		X		
	<u>Characium spp.</u>		X	X	X
	<u>Chlamydomonas spp. 5 - 9.9 μ</u>				X
	<u>coccoid Chlorophyta spp. 5 - 9.9 μ</u>		X	X	X
	<u>coccoid Chlorophyta spp. < 5 μ</u>	X	X	X	X
	<u>Cosmarium angulosum</u>				X
	<u>Cosmarium contractum</u>				X
	<u>Cosmarium regnellii</u>		X		
	<u>Leptosira mediciniana</u>		X	X	X
	<u>Mougeotia spp.</u>				X

Appendix Table 6 (continued).

Periphyton taxa list by quarter for four Steel Creek stations.
January-December 1991.

Division	Taxa Name	Winter	Spring	Summer	Fall
<u>Station 350 (continued).</u>					
CHLOROPHYTA	<u>Oedogonium</u> spp. lg				X
	<u>Oedogonium</u> spp. sm	X	X	X	X
	<u>Oocystis pusilla</u>				X
	<u>Pediastrum tetras</u>		X		
	<u>Pseudulvella americana</u>	X			
	<u>Staurostrum gracile</u>				X
	<u>Staurostrum punctulatum</u>	X			
	<u>Ulothrix zonata</u>	X			
	<u>Uronema elongatum</u>				X
CHRYSOPHYTA	<u>Chrysoflagellate</u> spp. < 5 μ				X
	coccoid Chrysophyta spp. 5 - 9.9 μ	X			
	coccoid Chrysophyta spp. < 5 μ				X
	<u>Dinobryon divergens</u>				X
	<u>Cryptomonas erosa</u>				X
CYANOPHYTA	<u>Anabaena</u> spp.			X	
	coccoid Cyanophyta spp. < 5 μ		X	X	X
	<u>Lyngbya limnetica</u>				X
	<u>Lyngbya</u> spp.		X		
	<u>Oscillatoria geminata</u>		X		X
	<u>Phormidium molle</u>			X	
	<u>Phormidium</u> spp.			X	
	<u>Schizothrix</u> spp.				X
EUGLENOPHYTA	<u>Euglena</u> spp.				X
<u>Station 370</u>					
BACILLARIOPHYTA	<u>Achnanthes hungarica</u>		X	X	
	<u>Achnanthes lanceolata</u>	X	X	X	X
	<u>Achnanthes minutissima</u>	X	X		X
	<u>Cocconeis fluvialilis</u>			X	
	<u>Cocconeis placentula</u>	X	X	X	
	<u>Cyclotella meneghiniana</u>	X			X
	<u>Cymbella minuta</u>	X		X	X
	<u>Eunotia curvata</u>	X	X	X	X
	<u>Eunotia flexuosa</u>	X			
	<u>Eunotia pectinalis</u>	X	X	X	X
	<u>Fragilaria</u> sp. 1	X			
	<u>Fragilaria vaucheriae</u>	X			

Appendix Table 6 (continued).

Periphyton taxa list by quarter for four Steel Creek stations.
January-December 1991.

Division	Taxa Name	Winter	Spring	Summer	Fall
<u>Station 370 (continued).</u>					
BACILLARIOPHYTA	<u>Frustulia vulgaris</u>				X
	<u>Gomphonema clevei</u>			X	
	<u>Gomphonema parvulum</u>	X	X	X	X
	<u>Gomphonema turris</u>			X	X
	<u>Meridion circulare</u>	X			X
	<u>Navicula cryptocephala</u>	X		X	X
	<u>Navicula minima</u>	X	X	X	X
	<u>Navicula paucivittata</u>			X	
	<u>Navicula pseudoarvensis</u>			X	X
	<u>Navicula seminulum</u>			X	
	<u>Navicula spp.</u>		X	X	X
	<u>Navicula tenelloides</u>			X	X
	<u>Nitzschia acicularis</u>				X
	<u>Nitzschia amphibia</u>			X	
	<u>Nitzschia clausii</u>				X
	<u>Nitzschia filiformis</u>				X
	<u>Nitzschia fonticola</u>	X			
	<u>Nitzschia gracilis</u>			X	X
	<u>Nitzschia palea</u>			X	X
	<u>Nitzschia paleacea</u>	X	X	X	X
	<u>Pinnularia subcapitata</u>				X
	<u>Synedra delicatissima</u>				X
	<u>Synedra rumpens</u>		X		
	<u>Synedra ulna</u>				X
CHLOROPHYTA	<u>Ankistrodesmus falcatus</u>	X			
	<u>Characium spp.</u>		X	X	X
	<u>Chlamydomonas spp. 5 - 9.9 μ</u>				X
	coccoid Chlorophyta spp. 10 - 15 μ	X			
	coccoid Chlorophyta spp. 5 - 9.9 μ	X	X		
	coccoid Chlorophyta spp. < 5 μ	X	X	X	X
	<u>Leptosira mediciniana</u>		X	X	
	<u>Oedogonium spp. sm</u>	X			
	<u>Pseudulvella americana</u>		X		
	<u>Scenedesmus quadricauda</u>				X
	<u>Staurastrum punctulatum</u>	X			
	<u>Stigeoclonium spp.</u>				X
	<u>Uronema elongatum</u>	X			X

Appendix Table 6 (continued).

Periphyton taxa list by quarter for four Steel Creek stations.
January-December 1991.

Division	Taxa Name	Winter	Spring	Summer	Fall
<u>Station 370 (continued).</u>					
CHRYSTOPHYTA	<u>Chrysoflagellate</u> spp. < 5 μ	X			X
	coccoid Chrysophyta spp. 5 - 9.9 μ	X			
	coccoid Chrysophyta spp. < 5 μ				X
CRYPTOPHYTA	<u>Cryptomonas</u> <u>erosa</u>	X			X
CYANOPHYTA	coccoid Cyanophyta spp. < 5 μ	X			X
	<u>Lyngbya</u> <u>subtilis</u>			X	
	<u>Oscillatoria</u> <u>geminata</u>	X			X
	<u>Oscillatoria</u> <u>tenuis</u>				X
	<u>Phormidium</u> spp.			X	X
	<u>Schizothrix</u> spp.			X	X

Appendix Table 7.

All Steel Creek Seston sample data for CVEL (m/sec), TSS (mg/L), AFDM (mg/L),
 % OM, and Chl a ($\mu\text{g/L}$), by sampling period.
 January-December 1991.

STATION	TYPE	PERIOD	TIME	SUBREP	CVEL*	TSS	AFDM	PCTORG	CHLA
<u>FEBRUARY 1991</u>									
290	DIEL	1	819	1	0.25	1.72	0.52	30.50	1.26
290	DIEL	2	1048	1	0.25	2.33	0.69	29.72	2.88
290	DIEL	3	1300	1	0.24	2.50	0.82	32.93	3.16
290	DIEL	4	1534	1	0.29	2.43	0.77	31.69	3.01
290	DIEL	5	1800	1	0.30	2.03	0.64	31.60	2.91
290	DIEL	6	2035	1	0.26	1.87	0.48	25.74	2.35
290	DIEL	7	15	1	0.26	2.08	0.61	29.33	3.21
290	DIEL	8	220	1	0.27	1.94	0.51	26.36	1.72
290	DIEL	9	419	1	0.32	8.42	3.10	36.77	1.97
290	DIEL	10	635	1	0.34	2.60	0.61	23.46	1.75
290	QUARTER	1	819	1	0.25	1.72	0.52	30.50	1.26
290	QUARTER	1	819	2	0.25	1.69	0.52	30.50	1.44
330	DIEL	1	1002	1	0.42	1.88	0.65	34.31	2.35
330	DIEL	2	1159	1	0.39	2.45	0.79	32.11	2.35
330	DIEL	3	1407	1	0.44	1.77	0.60	34.28	2.55
330	DIEL	4	1640	1	0.44	1.91	0.65	33.94	1.97
330	DIEL	5	1857	1	0.42	2.37	0.72	30.32	2.50
330	DIEL	6	2200	1	0.30	1.88	0.59	31.37	0.71
330	DIEL	7	129	1	0.33	1.95	0.60	30.95	0.85
330	DIEL	8	318	1	0.38	1.65	0.48	29.43	0.60
330	DIEL	9	512	1	0.32	1.76	0.49	27.84	0.80
330	DIEL	10	721	1	0.36	1.80	0.67	37.22	2.16
330	QUARTER	1	1002	1	0.42	1.88	0.65	34.31	2.35
330	QUARTER	1	1002	2	0.42	1.92	0.65	33.51	1.04
350	DIEL	1	948	1	0.40	1.30	0.51	38.91	0.81
350	DIEL	2	1149	1	0.34	1.29	0.50	38.76	0.46
350	DIEL	3	1354	1	0.35	1.31	0.47	35.94	0.00
350	DIEL	4	1629	1	0.36	1.27	0.47	37.35	0.31
350	DIEL	5	1842	1	0.34	1.57	0.50	31.75	0.00
350	DIEL	7	117	1	0.32	1.40	0.47	33.33	0.17
350	DIEL	8	329	1	0.29	1.44	0.54	37.36	0.07
350	DIEL	9	526	1	0.32	9.98	2.34	23.46	0.27
350	DIEL	10	731	1	0.24	2.02	0.56	27.90	0.85
350	QUARTER	1	948	1	0.40	1.30	0.51	38.91	0.81
350	QUARTER	1	948	2	0.40	1.19	0.48	40.59	0.70
370	QUARTER	1	909	1	0.42	3.24	0.94	29.09	0.73
370	QUARTER	1	909	2	0.42	3.13	0.86	27.48	0.83

Appendix Table 7 (continued).

All Steel Creek Seston sample data for CVEL (m/sec), TSS (mg/L), AFDM (mg/L),
% OM, and Chl a ($\mu\text{g/L}$), by sampling period.
January-December 1991.

STATION	TYPE	PERIOD	TIME	SUBREP	CVEL*	TSS	AFDM	PCTORG	CHLA
<u>MAY 1991</u>									
290	QUARTER	1	950	1	0.39	3.05	1.06	34.86	2.07
290	QUARTER	1	950	2	0.39	3.84	1.21	31.34	2.55
330	QUARTER	1	1120	1	0.03	2.61	1.11	42.66	2.58
330	QUARTER	1	1120	2	0.03	2.86	1.22	42.66	2.86
350	QUARTER	1	1200	1	0.04	2.15	0.75	34.93	2.15
350	QUARTER	1	1200	2	0.04	2.30	1.00	43.46	2.30
370	QUARTER	1	1045	1	0.30	2.07	0.73	35.31	1.36
370	QUARTER	1	1045	2	0.30	2.18	0.74	34.17	1.65

Appendix Table 7 (continued).

All Steel Creek Seston sample data for CVEL (m/sec), TSS (mg/L), AFDM (mg/L),
 % OM, and Chl a ($\mu\text{g/L}$), by sampling period.
 January-December 1991.

STATION	TYPE	PERIOD	TIME	SUBREP	CVEL*	TSS	AFDM	PCTORG	CHLA
<u>AUGUST 1991</u>									
290	DIEL	1	952	1	0.24	1.77	0.97	54.58	0.86
290	DIEL	2	1133	1	0.24	1.52	0.98	64.47	0.73
290	DIEL	3	1359	1	0.26	1.94	0.90	46.51	0.69
290	DIEL	4	1629	1	0.25	1.70	0.88	52.07	0.63
290	DIEL	5	1910	1	0.24	1.51	0.71	47.02	0.52
290	DIEL	6	2240	1	0.34	1.82	0.82	45.25	0.32
290	DIEL	7	55	1	0.40	1.76	0.92	52.41	0.31
290	DIEL	8	310	1	0.40	2.56	0.96	37.77	0.24
290	DIEL	9	540	1	0.38	1.61	0.71	44.16	0.36
290	DIEL	10	800	1	0.38	2.19	1.20	54.76	0.46
290	QUARTER	1	952	1	0.24	1.77	0.97	54.58	0.86
290	QUARTER	1	952	2	0.24	1.94	1.14	58.78	0.76
330	DIEL	1	850	1	0.11	2.42	1.09	45.19	1.21
330	DIEL	2	1040	1	0.10	2.45	1.19	48.79	1.05
330	DIEL	3	1310	1	0.11	2.52	1.23	48.70	0.93
330	DIEL	4	1543	1	0.11	3.30	1.60	48.37	0.62
330	DIEL	5	1808	1	0.09	2.64	1.23	46.63	0.65
330	DIEL	6	2100	1	0.20	1.71	0.85	50.00	0.43
330	DIEL	7	2340	1	0.25	5.27	1.11	21.07	0.37
330	DIEL	8	200	1	0.20	2.32	1.04	44.66	0.31
330	DIEL	9	425	1	0.20	2.51	1.17	46.67	0.24
330	DIEL	10	650	1	0.20	2.10	0.89	42.22	0.40
330	QUARTER	1	850	1	0.11	2.42	1.09	45.19	1.21
330	QUARTER	1	850	2	0.11	2.14	1.10	51.38	0.73
350	DIEL	1	905	1	0.04	1.55	0.77	49.20	0.88
350	DIEL	2	1050	1	0.04	1.47	0.16	11.19	0.83
350	DIEL	3	1317	1	0.00	1.82	0.91	49.73	0.93
350	DIEL	4	1550	1	0.02	1.76	1.01	57.10	0.69
350	DIEL	5	1817	1	0.05	1.62	0.81	49.85	0.53
350	DIEL	6	2145	1	0.05	1.75	0.78	44.57	0.41
350	DIEL	7	0	1	0.05	1.57	0.76	47.94	0.36
350	DIEL	8	215	1	0.04	1.84	0.89	48.37	0.25
350	DIEL	9	440	1	0.04	1.85	0.91	49.45	0.28
350	DIEL	10	710	1	0.03	3.82	1.79	46.83	0.60
350	QUARTER	1	905	1	0.04	1.55	0.77	49.20	0.88
350	QUARTER	1	905	2	0.04	1.95	0.85	43.48	0.94
370	QUARTER	1	820	1	0.38	1.60	0.70	43.44	0.65
370	QUARTER	1	820	2	0.38	1.20	0.72	60.00	0.64

Appendix Table 7 (continued).

All Steel Creek Seston sample data for CVEL (m/sec), TSS (mg/L), AFDM (mg/L),
% OM, and Chl a ($\mu\text{g/L}$), by sampling period.
January-December 1991.

STATION	TYPE	PERIOD	TIME	SUBREP	CVEL*	TSS	AFDM	PCTORG	CHLA
<u>NOVEMBER 1991</u>									
290	QUARTER	1	1155	1	0.35	1.85	0.56	30.11	0.54
290	QUARTER	1	1155	2	0.35	1.90	0.51	26.67	0.50
330	QUARTER	1	957	1	0.16	1.26	0.47	37.45	0.97
330	QUARTER	1	957	2	0.16	1.28	0.52	40.63	1.26
350	QUARTER	1	1040	1	0.29	0.86	0.44	50.92	0.57
350	QUARTER	1	1040	2	0.29	1.05	0.61	57.50	0.83
370	QUARTER	1	926	1	0.34	2.60	0.68	26.05	0.73
370	QUARTER	1	926	2	0.34	2.52	0.64	25.21	0.69

*CVEL - currnt velocity

TSS - total suspended solids

AFDM - Ash-free dry mass

PCTORG - percent organic matter

CHLA - chlorophyll a.

Appendix Table 8.

Minimum and maximum values for annual seston TSS concentration (mg/L) in whole water collected from Steel Creek. Means and standard errors are presented in Table 3-11. January 1986-December 1991.

Location	Station	1986 ^a		1987 ^a		1988 ^a	
		MIN	MAX	MIN	MAX	MIN	MAX
Reference Site	255	-	-	-	-	1.58	14.07
Corridor	275	2.00	7.54	3.02	10.76	2.73	4.11
	280	3.33	11.17	5.50	14.70	4.13	5.64
	285	2.82	9.89	2.26	17.39	2.26	5.52
	290	2.02	10.67	1.62	10.93	1.37	4.42
Marsh	300	1.46	9.33	1.68	10.57	0.96	4.25
	310	1.38	14.82	1.04	3.67	1.27	22.61
	320	1.13	16.73	2.55	6.90	1.87	11.44
	330	1.59	6.40	1.90	3.54	1.19	7.36
Swamp	340	0.95	3.46	0.94	2.56	0.54	2.17
	350	0.83	5.62	0.87	2.13	0.70	5.60
Channel	360	1.89	9.91	1.38	3.41	1.66	7.20
	370	4.55	16.06	2.87	9.25	3.59	6.01
Meyer's Branch	400	2.24	8.24	2.62	11.72	1.10	5.13

^aSummary statistics for 1986-1989 were recalculated for comparison with 1990 and 1991 results by using data only from the four months that corresponded to the 1990 and 1991 quarterly sampling months.

Appendix Table 8 (continued).

Minimum and maximum values for annual seston TSS concentration (mg/L) in whole water collected from Steel Creek. Means and standard errors are presented in Table 3-11. January 1986-December 1991.

Location	Station	1989 ^a		1990		1991	
		MIN	MAX	MIN	MAX	MIN	MAX
Reference Site	255	1.65	5.63	-	-	-	-
Corridor	275	2.75	6.14	-	-	-	-
	280	3.71	6.08	-	-	-	-
	285	2.99	6.48	-	-	-	-
	290	2.25	5.09	2.29	3.96	1.69	3.84
Marsh	300	2.06	7.11	-	-	-	-
	310	1.97	7.16	-	-	-	-
	320	1.64	8.68	-	-	-	-
	330	1.40	10.42	1.75	9.65	1.26	2.86
Swamp	340	1.28	7.43	-	-	-	-
	350	1.38	2.65	1.58	5.03	0.86	2.30
Channel	360	2.37	32.48	-	-	-	-
	370	3.07	8.36	1.98	4.10	1.20	3.24
Meyer's Branch	400	1.61	6.02	-	-	-	-

^aSummary statistics for 1986-1989 were recalculated for comparison with 1990 and 1991 results by using data only from the four months that corresponded to the 1990 and 1991 quarterly sampling months.

Appendix Table 9.

Minimum and maximum values for annual seston AFDM concentration (mg/L) in whole water collected from Steel Creek. Means and standard errors are presented in Table 3-12. January 1986-December 1991.

Location	Station	1986 ^a		1987 ^a		1988 ^a	
		MIN	MAX	MIN	MAX	MIN	MAX
Reference Site	255	-	-	-	-	0.50	2.56
Corridor	275	0.89	4.33	2.05	3.19	1.31	2.87
	280	1.05	4.60	2.75	3.84	1.58	1.88
	285	0.99	4.51	0.91	4.47	0.63	1.63
	290	0.63	4.04	0.92	3.64	0.59	1.26
Marsh	300	0.71	4.55	0.83	3.75	0.56	1.52
	310	0.62	4.52	0.57	1.55	0.56	5.20
	320	0.60	6.95	1.44	2.42	0.67	3.09
	330	0.78	2.63	0.98	1.55	0.48	2.26
Swamp	340	0.57	1.88	0.49	1.66	0.41	1.05
	350	0.46	2.89	0.51	1.11	0.24	2.34
Channel	360	0.67	3.06	0.58	1.24	0.67	2.32
	370	1.10	2.44	0.91	2.15	0.91	1.88
Meyer's Branch	400	0.30	8.98	0.94	4.69	0.56	2.09

^aSummary statistics for 1986-1989 were recalculated for comparison with 1990 and 1991 results by using data only from the four months that corresponded to the 1990 and 1991 quarterly sampling months.

Appendix Table 9 (continued).

Minimum and maximum values for annual seston AFDM concentration (mg/L) in whole water collected from Steel Creek. Means and standard errors are presented in Table 3-12. January 1986-December 1991.

Location	Station	1989 ^a		1990		1991	
		MIN	MAX	MIN	MAX	MIN	MAX
Reference Site	255	0.45	1.33	-	-	-	-
Corridor	275	1.57	5.55	-	-	-	-
	280	1.28	3.46	-	-	-	-
	285	0.82	3.29	-	-	-	-
	290	0.87	2.37	0.87	2.77	0.51	1.21
Marsh	300	0.88	2.48	-	-	-	-
	310	0.95	2.65	-	-	-	-
	320	0.65	2.33	-	-	-	-
	330	0.52	3.53	0.82	2.31	0.47	1.22
Swamp	340	0.61	3.93	-	-	-	-
	350	0.96	1.49	0.29	2.20	0.44	1.00
Channel	360	0.93	28.66	-	-	-	-
	370	0.96	2.24	0.03	2.03	0.64	0.94
Meyer's Branch	400	0.77	2.55	-	-	-	-

^aSummary statistics for 1986-1989 were recalculated for comparison with 1990 and 1991 results by using data only from the four months that corresponded to the 1990 and 1991 quarterly sampling months.

Appendix Table 10 (continued).

Minimum and maximum values for relative annual seston organic matter concentration (% of TSS by weight) in whole water collected from Steel Creek. Means and standard errors are presented in Table 3-13. January 1986-December 1991.

Location	Station	1989 ^a		1990		1991	
		MIN	MAX	MIN	MAX	MIN	MAX
Reference Site	255	23.57	35.71	-	-	-	-
Corridor	275	44.17	90.31	-	-	-	-
	280	34.49	56.87	-	-	-	-
	285	26.31	59.28	-	-	-	-
	290	30.30	54.91	25.74	69.89	26.67	58.78
Marsh	300	32.97	60.13	-	-	-	-
	310	29.21	48.72	-	-	-	-
	320	16.38	65.92	-	-	-	-
	330	30.88	56.40	14.17	93.14	33.51	51.38
Swamp	340	33.64	55.52	-	-	-	-
	350	46.29	75.12	18.30	89.07	34.93	57.50
Channel	360	27.32	88.25	-	-	-	-
	370	25.91	36.61	1.40	68.94	25.21	60.00
Meyer's Branch	400	0.1	48.45	-	-	-	-

^aSummary statistics for 1986-1989 were recalculated for comparison with 1990 and 1991 results by using data only from the four months that corresponded to the 1990 and 1991 quarterly sampling months.

Appendix Table 10.

Minimum and maximum values for relative annual seston organic matter concentration (% of TSS by weight) in whole water collected from Steel Creek. Means and standard errors are presented in Table 3-13. January 1986-December 1991.

Location	Station	1986 ^a		1987 ^a		1988 ^a	
		MIN	MAX	MIN	MAX	MIN	MAX
Reference Site	255	-	-	-	-	16.82	32.44
Corridor	275	44.36	81.46	27.11	79.39	38.61	73.29
	280	31.48	59.94	21.40	60.54	30.97	39.82
	285	34.77	59.03	25.69	51.91	25.67	37.17
	290	30.94	58.64	31.50	67.75	28.05	50.32
Marsh	300	28.80	81.26	35.48	60.00	34.79	62.13
	310	18.32	51.39	42.27	81.13	22.21	57.99
	320	30.95	70.93	34.77	56.97	24.55	35.56
	330	31.15	50.62	38.04	55.41	29.39	47.83
Swamp	340	36.33	68.25	46.96	80.89	42.93	76.64
	350	29.86	60.80	45.55	57.93	33.81	57.30
Channel	360	23.46	42.13	32.90	45.28	26.64	46.36
	370	15.19	33.24	20.16	36.19	21.69	32.29
Meyer's Branch	400	10.81	98.83	35.28	45.45	37.94	58.14

^aSummary statistics for 1986-1989 were recalculated for comparison with 1990 and 1991 results by using data only from the four months that corresponded to the 1990 and 1991 quarterly sampling months.

Appendix Table 11.

Minimum and maximum values for annual seston chlorophyll *a* concentration ($\mu\text{g/L}$) in whole water. Means and standard errors were presented in Table 3-14. January 1986-December 1991.

Location	Station	1986 ^a		1987 ^a		1988 ^a	
		MIN	MAX	MIN	MAX	MIN	MAX
Reference Site	255	-	-	-	-	0.31	1.36
Corridor	275	0.91	21.10	4.72	33.56	0.66	11.08
	280	4.44	20.78	2.89	36.88	-	-
	285	2.87	12.01	3.06	31.72	-	-
	290	2.10	11.40	0.26	19.79	0.19	2.25
Marsh	300	1.03	2.83	2.80	8.70	-	-
	310	0.40	2.25	1.68	14.46	-	-
	320	0.50	4.91	2.33	21.94	-	-
	330	0.57	2.17	0.09	5.68	-	-
Swamp	340	0.00	1.39	0.02	2.75	-	-
	350	0.00	2.28	0.22	4.04	-	-
Channel	360	0.00	1.34	0.59	2.93	-	-
	370	0.00	1.14	0.58	2.32	0.11	0.83
Meyer's Branch	400	0.00	0.72	0.22	0.77	-	-

^aSummary statistics for 1986-1989 were recalculated for comparison with 1990 and 1991 results by using data only from the four months that corresponded to the 1990 and 1991 quarterly sampling months.

Appendix Table 11 (continued).

Minimum and maximum values for annual seston chlorophyll *a* concentration ($\mu\text{g/L}$) in whole water. Means and standard errors were presented in Table 3-14. January 1986-December 1991.

Location	Station	1989 ^a		1990		1991	
		MIN	MAX	MIN	MAX	MIN	MAX
Reference Site	255	0.12	0.71	-	-	-	-
Corridor	275	2.03	8.99	-	-	-	-
	280	-	-	-	-	-	-
	285	-	-	-	-	-	-
	290	0.36	5.20	0.31	1.34	0.45	2.34
Marsh	300	-	-	-	-	-	-
	310	-	-	-	-	-	-
	320	-	-	-	-	-	-
	330	-	-	0.62	1.56	0.67	2.62
Swamp	340	-	-	-	-	-	-
	350	-	-	0.56	2.30	0.53	2.11
Channel	360	-	-	-	-	-	-
	370	0.45	1.15	0.38	8.26	0.59	1.52
Meyer's Branch	400	-	-	-	-	-	-

^aSummary statistics for 1986-1989 were recalculated for comparison with 1990 and 1991 results by using data only from the four months that corresponded to the 1990 and 1991 quarterly sampling months.

Chlorophyll *a* concentrations at the sampled corridor sites (Stations 275 and 290) were much lower and more stable in 1988 and 1989 than in 1986 and 1987. As was the case for TSS, this 1988-1989 pattern of chlorophyll *a* concentration may have occurred as a result of the lower and more stable outflows from L Lake during these years. The more erratic, high outflows from L Lake during 1986 and 1987 (van Duyn and Stiner 1990) probably recruited greater chlorophyllous particles via repeated floodplain inundation and scouring of periphyton films on corridor substrates (Stiner 1989). These high outflows also resulted in more lake particles entering the corridor. Duncan and Blinn (1989) found significant negative correlations between current velocity and total epilithic diatoms during periods of increasing or changing discharge in Oak Creek in Northern Arizona. The 1990 mean annual chlorophyll *a* concentration at Station 290 was the lowest measured at that station during the six years of this study. The 1991 mean was the third lowest. Overall mean annual chlorophyll *a* has also been lower at this station than any other corridor station measured each year.

The percentage of organic material in seston remained relatively the same over 1986-1991, indicating that the sources of seston were probably similar among years at the corridor sites. While percent cover from vegetation was low at the corridor sites relative to the other Steel Creek sites (Toole and Westbury 1992), terrestrial leaf litter probably comprised a portion of the seston loading at these stations, as in previous years (Peter and Westbury 1990). An important part of the seston loading was also particulate matter derived directly from L Lake.

Prior to the construction of L Lake (1984-1985), the percentage of organic material in seston at the sampled corridor sites (Stations 280 and 290) was much

lower than during pumping operations (1986-1988). This could have been due in part to sloughing of dense periphyton films on corridor substrates, which may have grown in response to increased nutrients in L-Lake outflow during 1986-1988 (Firth 1987). Moreover, levels of lake phytoplankton input to corridor sites immediately downstream of L Lake were probably greater in 1986-1988 as a result of increased lake nutrients and increased L-Lake outflow. Station 275, the corridor site nearest the L-Lake outflow, had the highest levels of chlorophyll *a* and organic material in seston of all sampling sites during 1986-1989, possibly as a result of this enhanced algal growth. However, in 1988 and 1989, the substantial reductions in chlorophyll *a* concentration at Station 275 may have resulted from reduced lake nutrients due to reactor shut down and lower outflow from L Lake.

From 1986 to 1989, TSS was higher at Stations 280 and 285 than at Station 275. Stations 280 and 285 have very large floodplains which, during times of high flow, could offer a higher reserve of material for entrainment (Hooker and Stiner 1988). These floodplains were inundated during much of the year, particularly prior to reactor shutdown (Breiner 1989). On the other hand, channelized, fast-flowing areas such as those at Station 275 are not as conducive to particle entrainment. However, the corridor sites downstream of Station 275 consist primarily of braided channels, which are likely to be more depositional than a single channel because of lower flow rates. Hence, the net effect of the corridor channels on seston loads is difficult to interpret. This is partly due to the fact that only one of many channels across the floodplain is sampled for this study. In 1990 and 1991, the trend toward lower TSS levels exhibited at all four corridor stations since 1988 continued at Station 290.

The higher chlorophyll *a* and organic matter concentrations at Station 275 compared with downstream stations, suggests a decrease in seston quality with distance downstream of L Lake. Other studies have reported an increase in seston quantity and a decrease in seston quality with distance downstream of lake outlets (Kondratieff and Simmons 1984b; Morin and Peters 1988).

3.4.4 Steel Creek Marsh

In 1989, concentrations of seston at the marsh stations were comparable to those in the corridor. Mean annual seston levels at these stations were similar among years (1984-1989), suggesting fairly consistent seston transport at the marsh stations, regardless of reactor operating status. Temporal trends in seston and organic matter concentrations showed seasonal patterns that were comparable among years and among all marsh stations. This suggests that seasonal influences may be more important in affecting seston concentrations than the reactor discharge at the marsh stations. In general, seston concentrations were highest in summer and lowest in late winter and spring, perhaps indicating that the higher baseflows associated with winter and spring months resulted in greater dilution of particles, whereas lower flows of summer resulted in higher seston concentrations. During the summers of 1988 and 1989, this situation may have been exacerbated by reactor shut-down. During 1990 and 1991, mean annual TSS at marsh Station 330 was comparable to that of corridor Station 290.

Slight year-to-year variations in seasonal seston peaks in the marsh appeared to be a result of station-specific factors. For example, the highest peaks in seston concentration at Station 300 in 1988 and 1989 were reduced from the peaks exhibited in 1986 and 1987. This apparently occurred as a result of channel obstruction by macrophyte growth in the summers of 1988 and 1989 (S.

Stiner, pers. obs.), which increased seston retention and promoted sedimentation via decreased current velocity. There was no detectable current velocity at this station during July and August of 1988 (Chimney 1989), and very low current velocities during July through September of 1989 (Chimney and Westbury 1990). Seston concentrations were highest at Station 310 during the summer of 1988 due to the loss of dense macrophyte beds that had obstructed the channel during the winter and spring of 1988 (S. Stiner, pers. obs.). Current velocity at Station 310 increased in August of 1988 (Chimney 1989) because of this macrophyte loss, and flow was rechannelized. Seston levels peaked, probably as a result of increases in both channel erosion and entrainment of periphytic and macrophytic particles previously retained by the living macrophytes (Stiner 1989). In 1989, seston concentrations were highest in late summer and, as in 1988, this was at a time of increased current velocity (Chimney and Westbury 1990) following macrophyte senescence.

At all marsh stations, except Station 300, seston was comprised of greater percentages of organic material in 1989 than in 1988 but less than in 1986 and 1987. In 1990 the seston organic matter concentration at Station 330 was the highest of all the years of this study (1986-1991).

3.4.5 Steel Creek Swamp

In 1991, as in the five previous sampling years, seston concentrations at the swamp stations were generally lower than at all other sampled sites. This pattern is probably a result of several factors: the relatively low current velocities found at these sites, less periphytic development (Hooker 1990a), and seston retention by both the macrophyte beds (Hooker 1990b) and the relatively high leaf litter inputs (268-297 g/m²/day in 1984-1985; Firth et al. 1986). In

addition, the swamp channels receive most of their discharge flow from Four Mile Creek and Pen Branch; therefore, the swamp stations are probably less influenced by fluctuations in L-Lake discharge than the other Steel Creek monthly sampling stations.

Seston concentrations were less variable over time at the swamp stations than all other sampling sites. Temporal patterns were similar between the two swamp stations and among the four sampling years. Although both stations exhibited some small peaks in seston concentration over the years (1986-1989), levels were relatively uniform throughout the seasons within each sampling year. Hence, seston levels appear to be more temporally and spatially consistent and less influenced by seasonal and variable-discharge effects at the swamp locations than the other Steel Creek-Meyer's Branch stations (van Duyn and Stiner 1990). Relative to the other three Steel Creek stations sampled in 1990, Station 350 showed overall the lowest and most stable seston concentrations among years, with the exception that Station 290 showed more stability over the four quarters sampled in 1990.

In 1986-1989, the percent organic material in seston was higher at the swamp sites than at all other sites, with the exception of corridor Station 275. Because periphytic development appeared to be relatively low at the swamp (Hooker 1990a), probably due to shaded conditions, the organic particles most likely originated from the moderately high leaf litter inputs. Because of slower current velocities and the macrophyte beds for seston retention, litter inputs would probably have longer residence times for processing at the swamp location than the corridor, channel, and some marsh sites. In addition, the flow regime at the swamp sites is probably less conducive to inorganic inputs from channel

bed and bank erosion than the corridor and channel sites. During 1990 the three (corridor, marsh, and swamp) stations were about the same in seston organic matter concentration. Only levels in the channel Station 370 were lower. In 1991, Station 370 was again the lowest.

3.4.6 Steel Creek Channel

Station 370 exhibited much variability in seston concentration among years and among seasons within each year. This temporal heterogeneity was undoubtedly a result of both the variable flow regimes associated with backflow from the Savannah River during periods of high river discharge and the pulses in L-Lake discharge. Concentration peaks were highest in the summer of 1988 and 1989, possibly as a result of decreased dilution of suspended solids due to low discharge flow rates associated with this season and the reactor-down period. Conversely, the concentration peak of October 1989 probably resulted from seston contributed by backflow from the Savannah River, which was very high at the time (pers. obs.).

During 1986-1991, percent organic matter was lower at Station 370 than at all other sites (except Station 255 in 1988), possibly as a result of higher inputs of inorganic material via stream bank and bed erosion. Stream bank erosion increases with increased current velocity and channel width (Odgaard 1987), two characteristics of the Steel Creek channel sites relative to the other sampling sites (this report; Hooker 1989). Due to erratic flow regimes associated with pulses in L-Lake discharge and backflow from the Savannah River, erosion was undoubtedly a major source of seston at downstream channel sites. Although aquatic macrophytes were relatively uncommon at the channel sites (Hooker 1990b), it is likely that some particles from senescing macrophytes in

the marsh and swamp were transported downstream to these sites. Additionally, high leaf litter inputs to the channel sites (343-504 g/m²/day in 1984-1985; Firth et al. 1986) probably contributed a major portion of the seston loading at the channel sites.

In 1986-1987, chlorophyll a levels at the channel sites were lower than the corridor and marsh stations sampled, suggesting that most of the chlorophyllous particles were retained and/or processed at upstream sites with little entrainment of new particles into the channel. In 1988, the mean annual chlorophyll a concentration at Station 370 was two-thirds that of the Steel Creek reference station (Station 255), which is a relatively shaded site unimpacted by L-Lake discharge. In 1989, Station 370 had double the mean annual chlorophyll a concentration of Station 255; periphyton chlorophyll a content on glass slide substrates was less at Station 370 than Stations 275 and 290 (Hooker 1990a). Hence, less periphytic development available for scouring at Station 370 may explain the lower suspended chlorophyll a concentrations at this site in 1989 than at Stations 275 and 290.

In 1990, the opposite relationship pertained. Station 370 had over three times the mean annual seston chlorophyll a concentration of Station 290 and more than double that of the other two stations sampled. Periphyton chlorophyll a content on glass slide substrates, however, was less at Station 370 than Stations 290 and 330 and slightly more than Station 350. Therefore, the greater amount of seston chlorophyll a at Station 370 must have been due to another effect, such as temporary backflow from the Savannah River. This was the case during the winter (February) sampling in 1990 (pers. obs.). The highest levels of chlorophyll a were also measured at that time.

In 1986, 1987 and 1988 chlorophyll *a* levels peaked in Spring (as did discharge from L Lake) and were lowest during the summer and fall at the channel sites. In 1989, chlorophyll *a* concentration may have resulted from the unique L-Lake outflow regime during this year compared with 1986-summer of 1988, when the reactor was on line. In 1990, as mentioned previously, chlorophyll *a* levels peaked in winter, possibly due to the backflow (actually sheet flow across the floodplain) from the Savannah River at the time of sampling. In 1991, chlorophyll *a* concentration again peaked in spring and at a much lower level than in 1990. There was no significant period of high backflow from the Savannah River in 1991.

3.4.7 Reference Sites

Seston concentrations at Meyer's Branch (Station 400) were lower in 1988 and 1989 than in previous years and were much decreased from levels exhibited during the pre-reactor sampling period (1984-1985). This trend may indicate natural (e.g., due to changes in annual precipitation) lowering and stabilization of seston loads in the Steel Creek-Meyer's Branch system, which might partially explain the 1988-1989 pattern exhibited by many of the Steel Creek sites, particularly in the corridor. Additionally, the great increase in the density of woody debris at Station 400 in 1988 (Hooker 1989) which remained in 1989 (Hooker 1990b) may have contributed to increased seston retention at this site (Leff and McArthur 1988).

The most notable similarity between seston levels at Station 255 and the Steel Creek corridor sites is the trend towards lower levels since 1988. However, because seston and seston chlorophyll *a* were sampled at Station 255 only once during each quarter (fall 1987-fall 1989), it is difficult to speculate about seasonal or year-to-year trends in seston levels at this site.

3.4.8 Comparisons to Other Lotic Systems

Depending on the system under investigation, various ranges in chlorophyll *a*, TSS, and AFDM concentrations have been reported. Concentrations of suspended chlorophyll *a* ranged from 0.45 $\mu\text{g/L}$ (Station 290) to 2.62 $\mu\text{g/L}$ (Station 330) at Steel Creek stations in 1991 (Appendix Table 11). Ranges of 1 to 65 $\mu\text{g/L}$ have been documented for a forested stream during spring and summer (Lush and Hynes 1978). However, a study on a natural geothermal tributary found chlorophyll *a* levels of 0 to 2 $\mu\text{g/L}$ over a two-year period (Lamberti and Rech 1987). This is comparable to the concentrations found at the Steel Creek sites in 1991.

Concentrations of TSS ranged from 0.86 mg/L (Station 350) to 3.84 mg/L (Station 290) at the Steel Creek sites in 1991 (Appendix Table 8). Lamberti and Rech (1987) found that TSS ranged from < 1 to 5.0 mg/L in their system, which is comparable to the range in concentration found at all of the Steel Creek sites sampled in 1991.

Concentrations of AFDM ranged from 0.44 mg/L (Station 350) to 1.22 mg/L (Station 330) at Steel Creek sites in 1991 (Appendix Table 9). In a pre-impoundment study on the Steel Creek-Meyer's Branch system, Hauer (1985) found seston AFDM concentrations ranging from 0.97 to 5.69 mg/L in the Steel Creek corridor. Somewhat lower levels were found in the present study, where AFDM ranged from 0.51 to 1.21 mg/L in the corridor (Station 290) during 1991 (Appendix Table 9). In a separate study, TSS concentrations were between 1.76 and 16.88 mg/L at five Steel Creek stations sampled from August 1981 to January 1982 (Smith et al. 1981). This range is considerably higher than that reported in the present study; however, the maximum concentration in the present study was somewhat lower.

Concentrations of seston TSS, AFDM, and chlorophyll *a* in riffle streams of various lake outlets of southern Quebec during spring in 1985 averaged 6.0, 2.2, and 1.1 $\mu\text{g/L}$, respectively (Morin and Peters 1988). For each parameter, these values are within the concentration ranges for the Steel Creek sites in 1990 (Toole and van Duyn 1991) but above the ranges for the Steel Creek sites in 1991 except for chlorophyll *a*. Weber and Moore (1967) obtained a range of 1.0 to 31.0 mg/L ash-free dry weight for the seston in the Little Miami River (Clark County, OH) during a year-long study.

Concentrations of TSS in streamflow from Coastal Plain watersheds in Georgia during 1979-1981 averaged 15 mg/L (Sheridan and Hubbard 1987), which is higher than the mean annual 1990 concentration at each of the stations. The authors attributed the low TSS levels in southern Coastal Plain streams to deposition of transported material within the floodplains of these low-gradient drainage systems. Low average TSS concentrations in streamflow from other watersheds in the Coastal Plain (e.g., 13 mg/L; Perlman 1985) are typical of this region and could explain the relatively low TSS levels at the sites in the present study. However, it has recently been stressed that the discrete (grab sampling) method of sampling suspended solids in streams does not adequately sample storm and bedload transport (Cuffney and Wallace 1988). Consequently, this method of sampling, which was utilized in the present study, may underestimate seston transport compared with estimates obtained by continuous measurement. A recent study of initial and final concentrations of seston during storm flows to Meyer's Branch and the Steel Creek corridor during 1985-1986 indicated that seston concentrations at both sites were substantially higher than levels reported in the present study because of the influence of storm flows (Leff and McArthur 1988).

4.0 SUMMARY AND CONCLUSIONS

4.1 PERIPHYTON

In a study by Bott et al. (1986) on periphyton communities in streams of the Savannah River Site, 1985 annual mean chlorophyll *a* concentrations were presented for a number of thermal and nonthermal stream sites. Mean chlorophyll *a* concentrations on glass slides at the nonthermal sites ranged from 0.64 mg/m² at Steel Creek Station 360 to 25.71 mg/m² at an Upper Three Runs Creek station. The range in the present study during 1991 was from 0.95 mg/m² at Station 350 to 11.92 mg/m² at Station 290 (Table 3-1). The range of annual mean AFDM in the 1985 study (Bott et al. 1986) was from 0.17 g/m² at Steel Creek Station 360 to 4.11 g/m² at the Upper Three Runs Creek station. During 1991, mean AFDM concentrations ranged from 0.58 g/m² at Station 370 to 2.53 g/m² at Station 290 (Table 3-2).

Mean annual AFDM and chlorophyll *a* concentrations during the present study were comparable to those found by Bott et al. (1986). However, AFDM concentrations at Station 275 in both 1986 and 1988 were outside of the ranges found in their 1985 study (Hooker 1989).

Enrichment or eutrophication of lotic systems can increase periphyton biomass; levels of 600 mg/m² of chlorophyll *a* are common (Welch et al. 1989). A review of 19 enrichment studies indicates that the threshold level for nuisance biomass levels of periphyton in streams is 100-150 mg/m² (Welch et al. 1989). The biomass of periphyton in the Steel Creek system is considerably below the nuisance level.

These comparisons indicate that, although values were somewhat high for corridor sites in 1989, all Steel Creek stations were comparable to other southeastern United States stream sites with respect to periphyton biomass and standing crop. Therefore, these parameters were probably not detrimentally affected by L-Lake discharges.

Station 275 was not within the range documented for AFDM at other sites in 1988 and thus appeared to be negatively impacted by L-Lake releases. However, the high AFDM documented during this study is probably reflective of the large populations of blackfly larvae found at Station 275, rather than the periphyton community. The AFDM concentration at Station 275 in 1989 was within the ranges reported for other studies.

The periphyton community structure has not exhibited large changes over the course of the study. Most stations were dominated by Bacillariophyta (diatoms) and Chlorophyta (green algae) most years. The one noteworthy exception to the above trend was Station 275 in 1987 when (Cyanophyta) blue-green algae dominated at the site. Since high levels of blue-green algae are often associated with high water temperatures and low nitrogen content, the warm water effluent of L-Reactor may have contributed to high levels of blue-green algae at Station 275 in 1987. While the number of periphyton taxa found on slides incubated at all Steel Creek stations has remained relatively constant, the actual taxa present has fluctuated capriciously over time. However, this is probably a natural phenomenon (Cairns 1974).

4.2 SESTON

Seston quantity and quality at the Steel Creek corridor sites were generally lower and more temporally stable from 1988 to 1991 compared with 1986 and 1987. These patterns may be a result of lower and less variable L-Lake outflow, causing lower rates of scouring of periphytic films, erosion of channel bed and banks, and entrainment of particles from the floodplain. In 1988 and 1989, seston was higher in concentration but lower in quality downstream of Station 275 in the corridor, which is consistent with seston patterns reported for other sites downstream of lake outlets.

Seston concentrations at the marsh stations were fairly consistent among sampling years, although seston was comprised of less organic material at these sites in 1988 and 1989 compared with 1986 and 1987 and was comprised of more organic matter at Station 330 in 1990 and less again in 1991. During each year, seston concentrations were generally highest in summer and lowest in winter and spring, perhaps as a result of greater dilution of particles during winter and spring months (i.e., when baseflows are naturally higher). Temporal fluctuations in seston concentrations and size fractions during 1988 and 1989 were also apparently a result of seasonal patterns of macrophyte growth and senescence, which affected current velocity and seston retention in some of the marsh channels. Seston dynamics at the marsh sites appeared to be influenced more by seasonal factors than by L-Reactor operations.

In 1986-1991, seston concentrations at the swamp stations were generally lower and less spatially and temporally variable than at all other sampling

sites. This stabilization pattern in the swamp channel was apparently a result of lower current velocities and less periphytic development in combination with high seston retention by the relatively abundant macrophyte beds and the moderately high leaf litter inputs. Moreover, since most of the flow in the swamp channels originates from Four Mile Creek and Pen Branch, the swamp stations were probably less affected by fluctuations in L-Lake discharge than were sites in the Steel Creek corridor, marsh, and channel. Increases in seston quantity and particle size were coincident with autumnal input of drupes and leaf litter to the swamp channels. In 1986-1989, the percent organic material in seston was higher at the swamp sites than at all other sampling sites (except for Station 275), possibly as a result of the moderately high leaf litter inputs and lower rates of erosion of mineral substrates. In 1990, three of the four stations sampled had approximately the same annual mean seston organic matter concentration and had a higher concentration than channel Station 370. In 1991, three stations again had higher concentrations than Station 370. Seston concentrations at Station 370 exhibited much temporal variability during 1986-1988, undoubtedly as a result of the variable flow regime associated with both backflow from the Savannah River during periods of high river discharge and pulses in L-Lake discharge. In 1989, temporal variability was less than 1988 and was about the same amount in 1990 and 1991. As in previous years, seston quantity was relatively high at this site in 1989, probably due to channel bed and bank erosion (from high current velocities) and high leaf litter inputs to the channel. In 1990, seston quantity was lower probably due to less bed and bank erosion (from lower current velocities). In 1988 and 1989, seston quantity was lower at Station 370 than at the corridor sites sampled, apparently due to less periphytic development and the upstream retention or processing of chlorophyllous

seston particles. In 1990, seston quality was higher at Station 370 than at the corridor, marsh, and swamp sites sampled. This probably was due to the effect of allochthonous chlorophyllous material brought in by backflow from the Savannah River. In 1991, there was little observable backflow, and seston quality was lower at Station 370 than at the marsh and swamp sites.

At the Meyer's Branch reference site, seston quantity was comparable to that at several of the Steel Creek sampling sites during 1986-1989. In 1988 and 1989, however, seston concentrations at Station 400 were lower than in 1986 and 1987. This trend may indicate natural (i.e., due to changes in annual precipitation) lowering and stabilization of seston loads in the Steel Creek-Meyer's Branch system; however, seston retention may have been higher at Meyer's Branch in 1988 due to the increase in amount of woody debris in this channel during 1988 which remained in place during 1989.

Although some evidence indicates that L-Reactor operations may have affected Steel Creek seston dynamics, other confounding factors make it difficult to discern any cause-and-effect relationships. Because of temporal and spatial heterogeneity, many of the trends indicated by the seston data may have been within the range of natural variability. Seston quantity and quality at the Steel Creek sites were relatively comparable to similar parameters reported for other lotic systems.

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