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# A BENTHIC INVERTEBRATE MONITORING STUDY ON THE ATHABASCA RIVER, WHITECOURT, ALBERTA, 1994

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# A BENTHIC INVERTEBRATE MONITORING STUDY ON THE ATHABASCA RIVER, WHITECOURT, ALBERTA, 1994

Prepared for

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## EXECUTIVE SUMMARY

Alberta Newsprint Company (ANC) operates an integrated thermomechanical pulp (TMP) and paper mill near Whitecourt, Alberta. A benthic invertebrate monitoring program is included as part of the environmental program for the mill, as required under the Clean Water Act by Alberta Environmental Protection. Baseline benthic invertebrate monitoring programs were conducted during the spring and fall of 1989 and the spring of 1990 to establish pre-operational conditions in the Athabasca River. The pulp and paper mill became operational in August 1990. Water is obtained from the Athabasca River for process use and following treatment, effluent is discharged to the Athabasca River at a rate of about 15,000 $m^3$/day. During the fall of 1990, a benthic monitoring program was conducted to establish start-up conditions and during 1991, 1992 and 1993, to establish operational conditions in the Athabasca River.

The monitoring program was continued during the fall of 1994. The objectives of this program were to determine if there were any differences in benthic invertebrate community structure between sites, to evaluate the general water quality conditions of the Athabasca River as reflected by the benthic invertebrate community structure and to determine if there were any differences between pre-operational and operational conditions in the Athabasca River.

All requirements of the federal Environmental Effects Monitoring (EEM) benthic invertebrate program were incorporated into the annual monitoring program, including Quality Assurance and Quality Control (QA/QC) methods. The EEM benthic invertebrate sampling design was based on the historical monitoring design to allow for the use of established sampling sites and historical data for the study area.

Seven sites, which were established in 1989, were sampled for this survey, as well as two sites which were added as part of the EEM program. Three sites were located upstream of the ANC effluent outfall as background sites and six sites were located downstream of the effluent outfall to a distance of 33 km as potential impact and recovery sites. Four of these downstream sites were located between the effluent outfall and the confluence of the McLeod River with the Athabasca River. The two sites farther downstream were located downstream of the Millar Western Pulp Ltd. (Millar Western) effluent outfall and the farthest site was also located downstream of the Whitecourt sewage treatment plant outfall.

Benthic invertebrate sampling was conducted during the fall (8 to 13 October) of 1994. Five replicate benthic samples were collected at each site using a modified Neill-Hess cylinder sampler enclosing an area of 0.0892 $m^2$. All sampling sites were in run areas and as similar as possible with regard to physical characteristics. The physical characteristics of water velocity, water depth and substrate composition were documented at each sampling location. Water quality sampling consisting of standard field measurements and laboratory analyses, and periphytic chlorophyll *a* sampling was conducted at each site.

Each benthic sample was sorted by a combination of a whole sort and a subsampling method and enumerated in the laboratory. All organisms were identified to the lowest practical taxonomic level (genus where possible).

The basic computations of total number of taxa, number of Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa, total number of organisms, total standing crop (number/$m^2$), standing crop of each major taxonomic group and Shannon-Weaver species diversity were calculated for each benthic sample, along with statistical analyses. Any differences in benthic community structure (using reciprocal averaging ordination (RA)) and feeding group structure (using a trophic guild analysis) between sites were determined for the data. A statistical comparison was made between the pre-operational (1989) and operational (1990 to 1994) fall data, to assess the effects of pulp mill effluent on the benthic invertebrates of the Athabasca River, using a repeated measures design.

A QA/QC program was implemented during this study and Standard Operating Procedures (SOPs) were used for all field and laboratory procedures and reporting of data.

There were some variations in the physical characteristics of water velocity and substrate composition, but very little in water depth between sites. Water velocity differences between sites resulted from hydraulic and minor habitat differences between reaches of the river. The fall 1994 survey was conducted during flows which were similar to the historical mean monthly flow for October in the Athabasca River. Substrates at all sites consisted mainly of cobbles and pebbles, with a few gravels. Generally, these minor differences in physical characteristics do not cause any detectable differences in benthic community structure between sites.

The water quality data indicated that the Athabasca River was a well oxygenated, alkaline stream during the fall survey. Effluent discharge from the ANC mill did not affect pH, dissolved oxygen, biochemical oxygen demand, true color or total Kjeldahl nitrogen at downstream sites. Conductivity and total suspended solids concentrations at sites below ANC appeared to be marginally affected by effluent discharge. Total phosphorus concentrations were higher at downstream sites than at background sites, likely as a result of pulp mill and sewage treatment effluent inputs.

Detailed water quality analyses at upstream Site 2 and downstream Site 3 indicated that most parameters were below detection limits and/or did not exceed provincial (AASWQIG) or federal (CWQG) guidelines. Metal concentrations, which are not generally considered to be a major component of pulp mill effluent, were below detection limits, except for iron, manganese and vanadium which were slightly above background values, but below the AASWQIG and CWQG. Neither resin or fatty acids were detected at Sites 2 or 3, and total resin and fatty acid concentrations in ANC's treated effluent were well below the AASWQIG of 0.1 mg/L.

Chlorophyll a was significantly higher at downstream sites than at background sites and it was also significantly higher at near-field sites than far-field sites. There appeared to be an effect on periphytic chlorophyll a in the river from the ANC effluent. There was less algal growth in the river, both upstream and downstream of the ANC mill, in the fall of 1994 compared to 1993. This was likely a result of the lower than average summer and fall flows in the Athabasca River in 1993, which caused increased algal growth.

A total of 138 taxa of benthic invertebrates has been identified from the 1989 to 1994 samples collected from the Athabasca River. Of these, 75 taxa were identified from the October 1994 samples, of which two were new taxa not previously collected.

The total number of taxa, the number of EPT taxa and the total number of organisms were significantly higher at downstream sites than at background sites. The total number of taxa was also significantly higher at far-field sites than at near-field sites, whereas the total number of organisms was significantly higher at near-field sites than at far-field sites. Species diversity was slightly lower at downstream sites than at background sites, and was slightly lower at near-field sites than at far-field sites.

The highest chlorophyll *a* value was found at Site 3A, which also had the highest standing crop of benthic invertebrates during the fall survey. The relationship between the amount of chlorophyll *a* and the standing crop of organisms (i.e. the higher the chlorophyll *a*, the higher the standing crop) occurred at most sites.

Chironomidae was the dominant taxonomic group at all sites, followed by Ephemeroptera, Oligochaeta and remaining groups. Trichoptera and Plecoptera were present in smaller numbers. Both the number of EPT and the number of Chironomidae were significantly higher at downstream sites than at background sites and were also significantly higher at near-field sites than at far-field sites.

The RA analysis indicated that there were three sample clusters. Cluster I consisted of the main group of sites (Sites 1A, 1, 2, 3A, 3, 4 and 6), Cluster II of Site 7 and Cluster III of Site 5.

A number of taxa have been found to respond to organic enrichment, by increasing in numbers, as a response to an increase in food availability, if oxygen is not limiting. During the fall 1994 survey, as in previous surveys, the dominant benthic community structure of the background sites indicated the presence of mild organic enrichment. The ANC effluent appeared to contribute additional organic enrichment to the river at Sites 3A, 4 and 5 (as indicated by the standing crop), however, there was a shift in the benthic community structure only at Site 5. This shift did not appear to have occurred at other downstream sites, where the benthic community structure was similar to background sites. The lower standing crop of organisms at Sites 6 and 7, and the similarity of their benthic community structure to background sites indicated that the Millar Western and Whitecourt sewage treatment effluents did not appear to contribute any additional organic enrichment to the river at these sites. Some recovery of the river may have been occurring at these two farthest downstream sites.

The trophic analysis showed that all sites during the fall survey were dominated by detritivore/herbivores and detritivores, which is a common natural trait of most streams in North America. These groups were followed by carnivores and omnivores. The trophic analysis indicated that there were some differences in feeding group structure between the groups of sites identified by the RA analysis. Increases or decreases in the numbers of detritivore/herbivores, detritivores, carnivores and omnivores caused shifts in the feeding group structure between sites. This occurred as a result of the change in the nature of the food supply caused by mild organic enrichment in this reach of the Athabasca River from the pulp mill and sewage effluents.

In 1994, the benthic invertebrates of the Athabasca River at downstream sites responded to mild organic enrichment. The increase in mean standing crop of benthic invertebrates at downstream Sites 3A, and to a lesser extent at Sites 3, 4 and 5, in comparison to background sites, was likely the result of organic loading from the ANC effluent. Tolerant taxa, mainly Chironomidae, as well as intolerant taxa (Ephemeroptera and Trichoptera), increased in numbers at these sites, as a response to organic enrichment. This is a typical response to organic enrichment. There was no decrease in the total number of taxa at downstream sites, and in fact, there was a significant increase in the total number of taxa and the number of EPT taxa, indicating that only mild organic enrichment was occurring in the Athabasca River as a result of organic loading from the ANC effluent. Mild organic enrichment, due to nutrient addition (phosphorus) from the ANC effluent, has apparently over the years caused an increase in the abundance of tolerant taxa, such as Chironomidae, but oxygen depletion has not been sufficient to cause a decrease in the more sensitive EPT taxa, which have also increased.

The comparison of pre-operational and operational data for the fall indicated that there was no evidence of major effects on the benthic community of the river from the ANC discharge, when the impact over all downstream sites was compared between the one pre-operational and five operational years and when far-field effects were compared between the pre-operational and operational years. There was, however, evidence of significant increases in the numbers of organisms at near-field sites as a result of the organic enrichment from the ANC discharge, when the impact of far-field effects was compared between 1989 and 1994.

# 1.0 INTRODUCTION

Alberta Newsprint Company (ANC) operates an integrated thermomechanical pulp (TMP) and paper mill near Whitecourt, Alberta. A benthic invertebrate monitoring program is included as part of the environmental program for the mill, as required under the Clean Water Act by Alberta Environmental Protection. Baseline benthic invertebrate monitoring programs were conducted during the spring and fall of 1989 and the spring of 1990 to establish pre-operational conditions in the Athabasca River (Luoma and Shelast 1990, 1991). The pulp and paper mill became operational in August 1990. Water is obtained from the Athabasca River for process use and following treatment, effluent is discharged to the Athabasca River at a rate of about 15,000 $m^3$/day. During the fall of 1990, the benthic monitoring program was conducted to establish start-up conditions (Luoma and Shelast 1991) and from 1991 to 1993, to establish operational conditions (Luoma and Shelast 1992, 1993, 1994). The monitoring of operational conditions was continued during the fall of 1994 and is documented in this report.

Benthic invertebrates are a useful monitoring tool since their community structure can reflect general water quality conditions over time. Benthic invertebrates are good indicators of disturbance primarily because of the long term stability of their populations and because they constitute an easily sampled community which is abundant and diverse enough to be responsive to both gross and subtle environmental changes (Hynes 1960, Gaufin 1973, Kovalak 1981). If the physical characteristics (substrate, water velocity and depth) of the sampling sites are standardized, then the water quality can be used to determine the potential causes for any changes in the benthic community structure.

The objective of the fall 1994 benthic invertebrate monitoring program was to assess the effects of the ANC pulp and paper mill effluent on the benthic invertebrate community and water quality of the Athabasca River, specifically:

- to determine if there were any differences in benthic invertebrate community structure between sampling sites in 1994,
- to evaluate the general water quality conditions of the Athabasca River as reflected by the benthic invertebrate community structure, and
- to determine if there were any differences between pre-operational and operational conditions in the Athabasca River.

All requirements of the federal Environmental Effects Monitoring (EEM) benthic invertebrate program (Environment Canada and Department of Fisheries and Oceans 1992) were incorporated into the annual monitoring program, including Quality Assurance and Quality Control (QA/QC) methods. The EEM benthic invertebrate sampling design was based on the historical monitoring design to allow for the use of established sampling sites and historical data for the study area (Luoma et al. 1994). As part of the EEM program, two additional sites were sampled during the fall 1994 survey. These sites were added to the monitoring program to provide additional information for the areas defined as reference and near-field.

## 2.0 METHODOLOGY

### 2.1 SITE LOCATIONS

Seven sites, which were established in 1989 (Luoma and Shelast 1990) on the Athabasca River, were sampled for benthic invertebrates during the fall 1994 survey (Figure 1). Sites 1 and 2 were located appoximately 2.5 and 1 km, respectively, upstream of the effluent outfall as background sites. Sites 3, 4 and 5 were located between the effluent outfall and the confluence of the McLeod River with the Athabasca River as potential impact sites. Sites 3 and 4 were located on the north bank of the river approximately 1 and 3 km, respectively, downstream of the effluent outfall and Site 5 approximately 8.5 km downstream on the south bank. Sites 6 and 7 were located on the south bank approximately 13 and 33 km, respectively, downstream of the effluent outfall, also as potential impact or recovery sites. These two sites were located downstream of the confluence of the McLeod River and the Millar Western Pulp Ltd. (Millar Western) effluent outfall, and Site 7 was also located downstream of the Whitecourt sewage treatment plant outfall.

Two sites (Sites 1A and 3A), which were added as part of the EEM program, were located approximately 3 km upstream and 0.6 km downstream, respectively, of the effluent outfall (Figure 1). Site 1A was added to the reference area because of the observed high variability at the two existing reference sites. Site 3A was added to provide a second near-field site closer to the effluent outfall.

A plume delineation study was conducted during the low flow period in May 1993 (125 $m^3/s$) (Webb 1993). This study indicated that Sites 3, 3A and 4 were exposed to a range of 0.1 to 0.2% effluent and less than 0.05% effluent by Site 5.

### 2.2 PHYSICAL AND CHEMICAL SAMPLING

Field sampling for physical and chemical parameters and for benthic invertebrates was conducted between 8 and 13 October 1994.

Many factors can regulate the occurrence and distribution of benthic invertebrates. The most important of the physical habitat factors are water velocity and substrate (Hynes 1972).

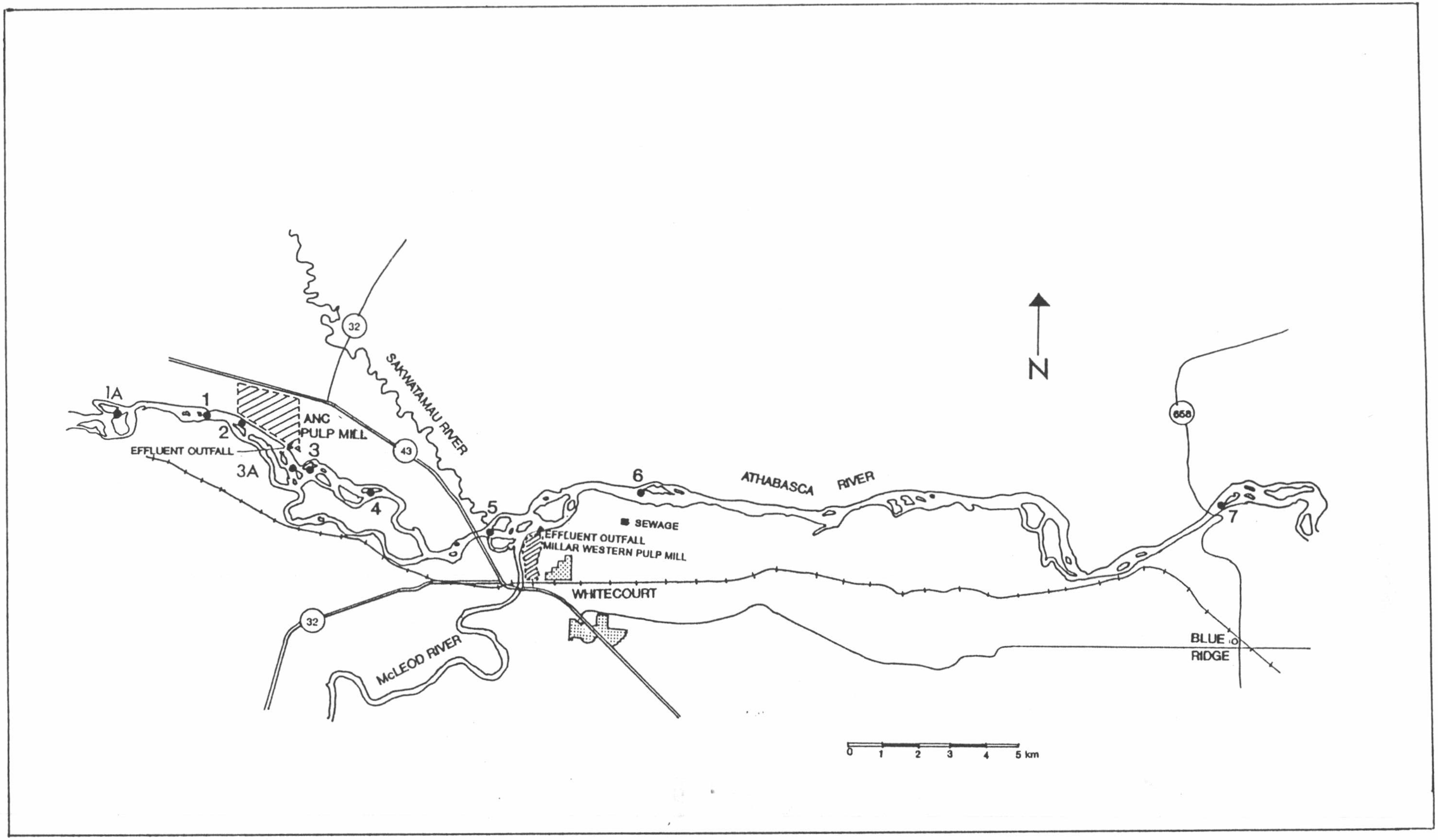



Figure 1. Benthic invertebrate sampling sites on the Athabasca River.

All sampling sites were in run areas and were as similar as possible with regard to water velocity, water depth and substrate composition to reduce inter-site variability. The physical characteristics of each sampling location were documented so that any habitat differences could be taken into account when interpreting differences in benthic invertebrate distribution patterns and community structure between sites.

Substrates at each sample location were classified using a modification of the Wentworth classification system (Cummins 1962). All loose substrates contained within the benthic sampler were removed, put into size categories using standard Tyler geologic screens, and weighed with a portable spring scale. These size category weights were then converted into percentages of the total substrate weight. Water velocity was measured 2 cm from the bottom with a Price AA current meter and water depth with a metre stick at each sample location. Three measurements were taken within the sampler area, from which an average was calculated for each sample. All sites were photographed.

Water quality sampling, consisting of field measurements of pH using a pHep+ Hanna Instruments pH meter ($\pm$ 0.1 unit), conductivity using a Hach Model 16300 portable conductivity meter ($\pm$ 10 $\mu$mhos/cm), dissolved oxygen using a YSI Model 54A dissolved oxygen meter ($\pm$ 0.2 ppm), and water temperature using a pocket thermometer ($\pm$ 0.5°C) was conducted at each benthic site. Water samples were collected at each site, except at the two EEM sites (Sites 1A and 3A), taking grab samples about 20 cm below the water surface. All bottles used for water samples were received from the analytical laboratory. Bottles were rinsed three times with site water prior to filling and standard preservatives were added, where required. All samples were kept cool on ice, until delivered to the laboratory. Water samples were analyzed by Alpha Laboratory Services Ltd. of Edmonton for true color, total phosphorus, total Kjeldahl nitrogen (TKN), total suspended solids (TSS) and biochemical oxygen demand (5 day) ($BOD_5$) using standard methods (APHA-AWWA-WEF 1992) and approved Alberta Environment methods (Alberta Environment 1987). All BOD samples were shipped to the laboratory for analysis within 24 hours of sampling.

A more detailed water chemistry analysis was conducted for Site 2 (just upstream of the effluent outfall) and Site 3 (just downstream of the effluent outfall). Parameters analyzed at these sites included total phenols, total organic carbon, total metals, and resin and fatty acids. These parameters were analyzed using standard methods by Alpha Laboratories

Services Ltd., except for resin and fatty acids which were analyzed by Enviro-Test Laboratories of Edmonton.

The periphytic algae (epilithic algae which are attached to rocks) were sampled for chlorophyll *a* at each benthic site. Three replicate samples of randomly selected submerged rocks from the river were delineated by a template and the area scraped clean using a scalpel. Each replicate consisted of a composite scraping with a 4 $cm^2$ template from two rocks, so that each replicate represented a total of 8 $cm^2$ area scraped. This provided a total of three 8 $cm^2$ area replicate samples for each site. Each replicate was filtered onto a Whatman GF/C filter with a porosity of 0.45 $\mu$m, wrapped in aluminum foil and then frozen on dry ice. These samples were analyzed by Chemex Labs Alberta Inc. of Calgary for chorophyll *a* using the spectrophotometric method outlined in Standard Methods (APHA-AWWA-WEF 1992).

## 2.3 BENTHIC INVERTEBRATE SAMPLING

Benthic samples were collected using a modified Neill-Hess cylinder sampler with a collecting net of 250 $\mu$m mesh and enclosing a surface area of 0.0892 $m^2$. During sampling, the sampler was forced into the substrate to a depth of 5 to 10 cm. Large substrates were removed and scraped into a bucket to ensure that attached organisms were collected. Smaller substrates were agitated in the sampler to dislodge all other organisms which were then carried by the stream current into the collecting bottle. Samples consisting of organisms and detritus from the collecting bottle and bucket were concentrated over a 180 $\mu$m mesh standard sieve, stored in jars and preserved in 10% formaldehyde for laboratory identification and enumeration. Five replicate samples were taken at each site to ensure that all representative benthic communities were assessed and to provide an acceptable level of confidence on the data (Needham and Usinger 1956, Wilhm and Dorris 1968, Alberta Environment 1990).

## 2.4 BENTHIC SAMPLE ANALYSIS

The benthic samples were stained with rose bengal prior to sorting in the laboratory. Each benthic sample was sorted by a combination of a whole sort and a subsampling method. The whole sort/subsampling method was used because the samples contained a large amount of detritus/algae which consisted of a fairly homogeneous mixture and/or extremely large numbers of small benthic organisms which could not be feasibly counted.

The benthic sample was initially sieved into coarse (>1 mm) and fine (0.180 to 1 mm) fractions. Sample material remaining in the coarse fraction was sorted using the whole sort method. The whole sort method consisted of systematically sorting through the sample under a dissecting microscope using a gridded petri dish to pick out all organisms. Sample material remaining in the fine fraction was sorted using the subsampling method of Wrona et al. (1982). The fine material was placed into the subsampling apparatus (an Imhoff cone) and water was added to provide a total volume of 1 L. This mixture was agitated for five minutes to ensure thorough mixing. Subsamples were removed from the agitated mixture and systematically sorted under a dissecting microscope using the gridded petri dish to pick out all organisms. The size and number of subsamples taken depended on the amount of fine material and/or numbers of organisms present in the sample. All sorted organisms in both coarse and fine fractions were identified and enumerated. The numbers of each taxon occurring in the total fine fraction were obtained by multiplying the respective counts by the volumetric proportion which the subsamples represented of the total fine fraction. These counts were then added to the counts obtained from the coarse fraction for each taxon.

A re-sorting of the sample residues was conducted on 10% of the samples by a different sorter to determine the level of sorting efficiency. The number of invertebrates initially recovered from the sample was expressed as a percentage of the total number after the re-sort (total of initial and re-sort count).

All organisms were identified to the lowest practical taxonomic level (genus where possible) using current literature and nomenclature. Samples of chironomid larvae (midges) were mounted on microscope slides using CMCP-9 mounting medium and identified to genus by mouth parts using a compound microscope. The commonest chironomid species were distinguishable on the basis of gross morphology, requiring only a few mounts (5 to 10) as checks, while mounts were made for all rare or less commonly occurring species. All taxa were identified using the keys from the following references:

| | |
|---|---|
| Ephemeroptera: | Edmunds et al. (1976), Provonsha (1990) |
| Trichoptera: | Wiggins (1977) |

| | |
|---|---|
| Plecoptera: | Baumann et al. (1977), Stewart and Stark (1988) |
| Diptera (Chironomidae): | Bode (1983), Epler (1987, 1992), Grodhaus (1987a, 1987b), Jackson (1977), Oliver and Roussel (1983), Oliver et al. (1990), Roback (1985), Walker et al. (1992), Wiederholm (1983, 1986) |
| Diptera (others): | McAlpine et al. (1981) |
| General: | Brooks and Kelton (1967), Clifford (1991), Edmondson (1959), Klemm (1985), Merritt and Cummins (1984), Pennak (1989), Thorp and Covich (1991), Usinger (1956) |

All organisms were stored in vials with 70% isopropyl alcohol for archiving. The reference collection produced from previous surveys was updated with additional species from the fall 1994 samples.

## 2.5 DATA AND STATISTICAL ANALYSES

All new taxa identified from the 1994 samples were added to the species list. The basic computations of total number of taxa, number of Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa, total number of organisms, total standing crop (number/$m^2$) and standing crop of each major taxonomic group (Ephemeroptera, Trichoptera, Plecoptera, Chironomidae, Oligochaeta and remaining groups) were calculated for each sample and means were calculated for each site. Confidence limits for all means were calculated at the 95% level.

Shannon-Weaver species diversity was also calculated for each sample, as were means and confidence limits for each site. Species diversity (Shannon and Weaver 1949), which reflects both the number of taxa and the evenness of distribution of the individuals among the taxa, was calculated as follows:

$$H' = - \sum_{i=1}^{s} p_i \ln p_i$$

where "s" is the number of species, "$p_i$" is the proportion of the total number of individuals consisting of the ith species, and "ln" is the natural logarithm. The use of a diversity index (a derived variable) to describe benthic community data was used for presentation purposes only, as suggested by Kovalak (1981).

Statistical analyses were conducted using analysis of variance (ANOVA) to determine whether total number of taxa, number of EPT taxa, total number of organisms (standing crop), number of EPT and number of Chironomidae were significantly different between sites. Generally in monitoring studies, only a few impact-related comparisons are of interest and planned comparisons can be determined by orthogonal contrasts (Sokal and Rohlf 1981, Hoke et al. 1990). *A priori* testing, using orthogonal contrasts, was conducted to determine differences between groups of sites (spatial contrasts). Sites were grouped into background (Sites 1A, 1 and 2), near-field (Sites 3A, 3, 4 and 5) and far-field (Sites 6 and 7). Spatial contrasts consisted of: (1) the difference between the average of downstream or impact sites (all six) and the average of the background sites, which tested for the average impact over all downstream sites, and (2) the difference between the average of the near-field sites and the average of the far-field sites, which tested for far-field effects (whether impacts extend to the far-field sites).

Benthic invertebrate data are generally not normally distributed and rarely satisfy the basic assumptions of parametric statistics. However, violations of these assumptions, especially normality, do not necessarily invalidate the statistical test, since tests such as ANOVA are extremely robust (Glass et al. 1972, Green 1979). Therefore, ANOVA will generally be valid, even on extremely non-normal populations, especially when there are equal and large sample sizes (Glass et al. 1972, Harris 1975), and if appropriate transformations are used (Green 1979). Transformations are used to normalize data or homogenize variances (Green 1979). The logarithmic transformation tends to be adequate, more comprehensible and more biologically meaningful than other transformations.

Environmental stress can affect entire groups of benthic invertebrates (major taxonomic groups). Somewhat arbitrarily, benthic invertebrates have been divided into two types: "tolerant taxa" such as Chironomidae and Oligochaeta, which can withstand relatively important changes in their habitat, and "intolerant taxa" such as Ephemeroptera, Plecoptera and Trichoptera, which can withstand minor changes only (Anderson 1989). Although these two types of benthic invertebrates commonly cohabit, a marked deterioration or a marked improvement in water quality will usually result in the numerical dominance of one type over the other. In this study, the group of "intolerant taxa" (EPT group) and a "tolerant taxa" (Chironomidae group) were included as variables in the data analyses. Although, the individual taxa from the same major group tend to respond relatively uniformly, exceptions are not uncommon and the intensity of response can vary considerably among taxa

(Anderson 1989). Therefore, an analysis of the community structure was also included to assess changes of dominant taxa between sites.

The benthic data were analyzed by RA, a computer-assisted pattern recognition technique (Hill 1973, Gauch et al. 1977), to determine the benthic invertebrate community structure of sites. RA ordinates (aligns) sites on species by the method of successive approximation across environmental gradients (Hill 1973, Gauch et al. 1977). The result of this analysis is to group samples into biological units (clusters) determined by faunal assemblages of highest similarity. The separation and/or clustering of benthic communities indicated by RA is generally along the most significant environmental gradients (Culp 1978, Crowther 1979, Culp and Davies 1980, Crowther and Luoma 1985).

A trophic guild analysis was used to determine the benthic community feeding group structure of sites. Each taxon was classified into a feeding group of either carnivore, detritivore, herbivore, detritivore/herbivore, herbivore/carnivore, carnivore/detritivore, or omnivore. This trophic classification depends on the dominant food consumed and/or feeding mechanisms of the species (Table 1) (modified from Merritt and Cummins 1984). The feeding group assigned to each taxon was determined from Merritt and Cummins (1984) for the insects and from the available literature (listed in Section 2.4) for all other organisms. The percent of each feeding group of the total number was calculated for each sample and site to determine any differences in benthic community feeding structure between sites. These differences were then compared to the separation of sites indicated by RA. The limited available literature and research to date does not allow the trophic guild analysis to be accurate at the species level or to take into account that organisms may change their feeding habits during their life history. The trophic guild analysis is intended only to provide a general indication of differences in feeding group structure between sites.

A comparison was made between the pre-operational and operational fall data from 1989 to 1994 to assess the effects of the ANC pulp and paper mill effluent on the benthic invertebrates of the Athabasca River. The two EEM sites (Sites 1A and 3A) were not included in these analyses since there are no pre-operational data for these sites. Spatial differences were compared before and after the mill became operational. The data were statistically analyzed using a repeated measures design with the sites divided into areas (background, near-field and far-field) and the sites used as replicates within areas, re-sampled each year (EVS 1992, Green 1993). The variables analyzed were total number of

**Table 1. Trophic classification of benthic invertebrates (modified from Merritt and Cummins 1984).**

| Functional Feeding Group | Dominant Food | Feeding Mechanism |
|---|---|---|
| Carnivore (C) | Living animal tissue | Engulfers - whole animals or parts<br>Piercers - attack prey and pierce tissues and cells and suck fluids |
| Detritivore (D) | Decomposing fine particulate organic matter | Collectors - filterers or suspension feeders-gatherers or deposit (sediment) feeders (includes surface film feeders) |
| | Decomposing coarse particulate organic matter or vascular plant tissue | Shredders - chewers and wood borers |
| Herbivore (H) | Living vascular hydrophyte plant tissue | Shredders - chewers and miners |
| | Periphyton - attached algae and associated material | Scrapers - grazing scrapers of mineral and organic surfaces |
| | Living vascular hydrophyte cell and tissue fluids or filamentous (macroscopic) algal cell fluids | Piercers - pierce tissues or cells and suck fluids |
| Detritivore/Herbivore (DH) | See above | See above |
| Herbivore/Carnivore (HC) | See above | See above |
| Carnivore/Detritivore (CD) | See above | See above |
| Omnivore (O) | All types - whatever is available | Various types |

taxa, number of EPT taxa, total number of organisms (standing crop), number of EPT and number of Chironomidae. Species diversity was not statistically analyzed, but was graphed to determine general trends between years.

The basic computations were conducted using developed Basic programs. Statistical analyses were conducted using either Statistix (Version 4.0) (Analytical Software 1992) or SYSTAT (Wilkinson 1990). The RA (Fortran) program was run on the University of Calgary AIX/Unix system. All input data were archived on disk.

## 2.6 QUALITY ASSURANCE AND QUALITY CONTROL

A QA/QC program was implemented during this study and it followed, where appropriate, the one described for conducting EEM studies (Environment Canada and Department of Fisheries and Oceans 1993). Standard Operating Procedures (SOPs) were used for all field procedures (such as sample collection, sample shipping, sample storage, chain-of-custody forms), laboratory procedures (such as benthic sample sorting, subsample size, re-sorting, reference collection, and chemical QC, duplicate and spike checks) and reporting of data (including data entry checks). Documentation regarding QA/QC is provided in Appendix A.

# 3.0 RESULTS AND DISCUSSION

## 3.1 PHYSICAL CHARACTERISTICS

River flow conditions and the physical characteristics of sites can influence the water and habitat quality of the river and therefore, the benthic invertebrate community. Athabasca River flows recorded at Windfall (Station No. 07AE001) for the fall 1994 survey, as well as previous surveys from 1989 to 1993, are shown in Figure 2 (Environment Canada 1990, 1991a, unpublished data 1991, 1992, 1993, and preliminary unpublished data 1994). The fall 1994 survey was conducted during flows which were similar to the historical mean monthly flow for October. Mean daily discharge during the survey ranged from 147 to 184 $m^3/s$. The mean monthly discharge for October 1994 was 155 $m^3/s$ (Environment Canada preliminary unpublished data 1994). The historical (1960 to 1990) mean monthly discharge for October was 179 $m^3/s$ (Environment Canada 1991b).

The mean daily discharge in the Athabasca River during September, prior to sampling, decreased from 271 to 172 $m^3/s$ (water level decrease of 0.314 m) (Figure 3). Discharge then increased for the next four days to 316 $m^3/s$ (water level increase of 0.435 m) on 3 October due to local rainfall. This was followed by another decrease to 184 $m^3/s$ (water level decrease of 0.389 m) on 8 October, at the start of the field survey (Environment Canada preliminary unpublished data 1994).

The physical characteristics of water velocity, water depth and substrate composition were kept as similar as field conditions allowed between sample locations within a site, as well as between sites (Appendix B). There was some variation in mean water velocity (difference of 24 cm/s) but very little in mean water depth (difference of 2 cm) between sites (Figure 4). Mean water velocity at the substrate surface between sites ranged from 19 to 43 cm/s and mean water depth ranged from 33 to 35 cm. Water velocity differences between sites resulted from hydraulic and minor habitat differences between reaches of the river.

Substrates at all sites consisted mainly of cobbles and pebbles, with a few gravels (Figure 5). Cobbles were the dominant substrate at Sites 2, 3A and 7 and pebbles were dominant at Sites 1A, 1, 3 and 4. Cobbles comprised between 62.8 and 71.4% of the substrate at sites where they were dominant, while pebbles comprised between 27.0 and 37.1%. Pebbles comprised between 55.6 and 63.8% of the substrate at sites where they were dominant,

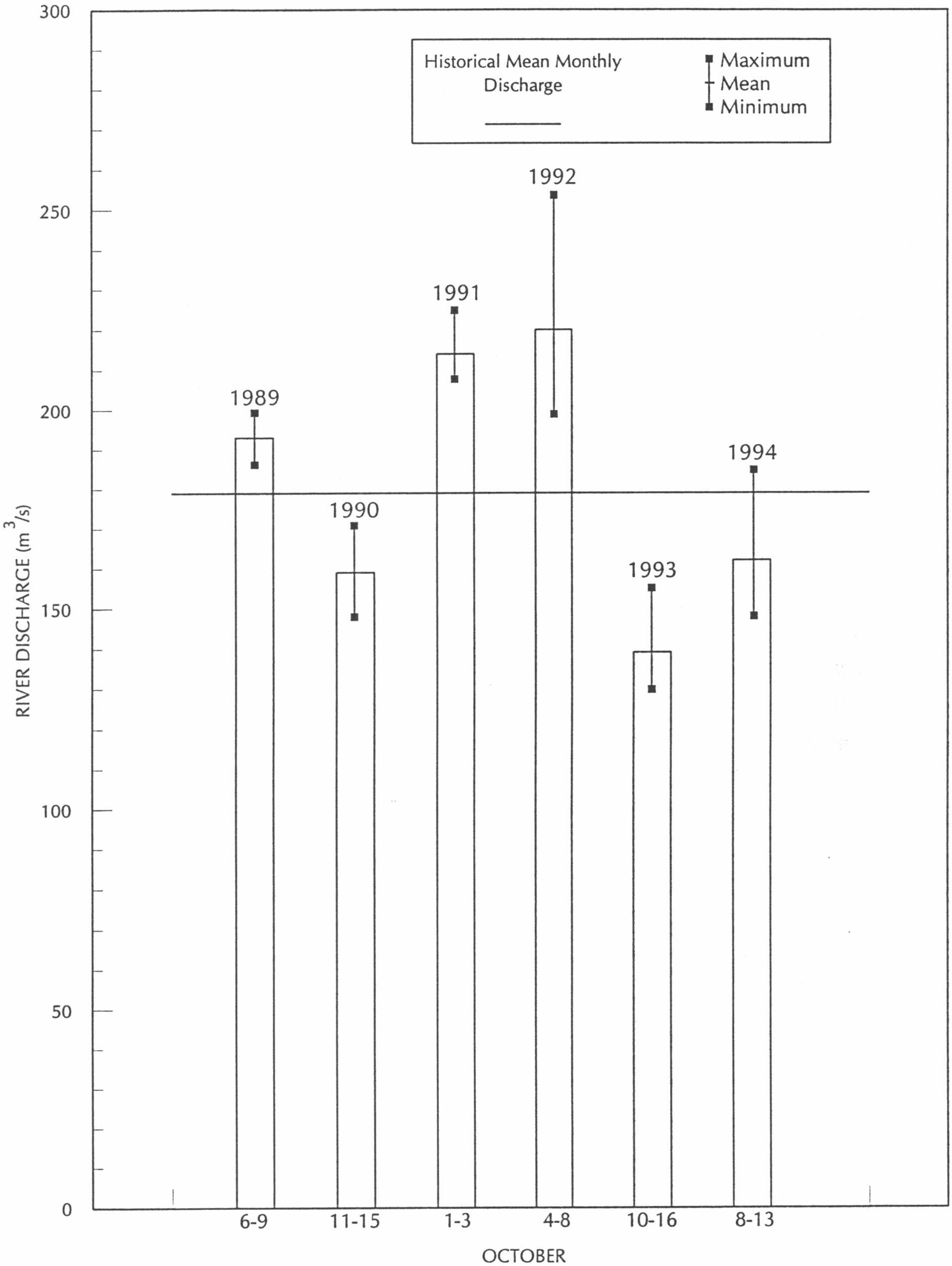



**Figure 2.** **Mean daily discharge during fall surveys and historical mean monthly discharge (October) of the Athabasca River at Windfall (Station No. 07AE001).**

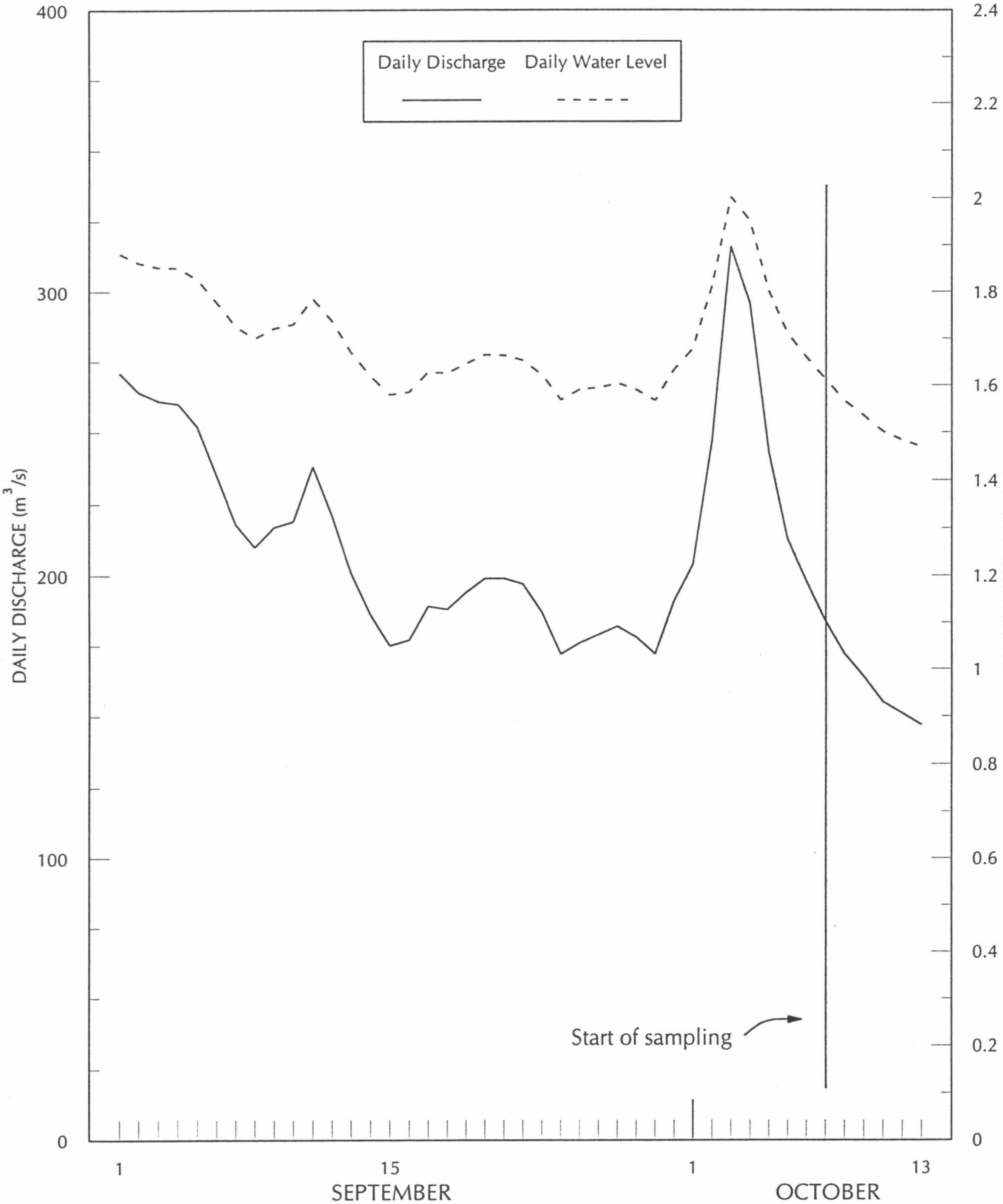



**Figure 3.** **Daily discharge and daily water level prior to and during the fall 1994 benthic survey for the Athabasca River at Windfall (Station No. 07AE001).**

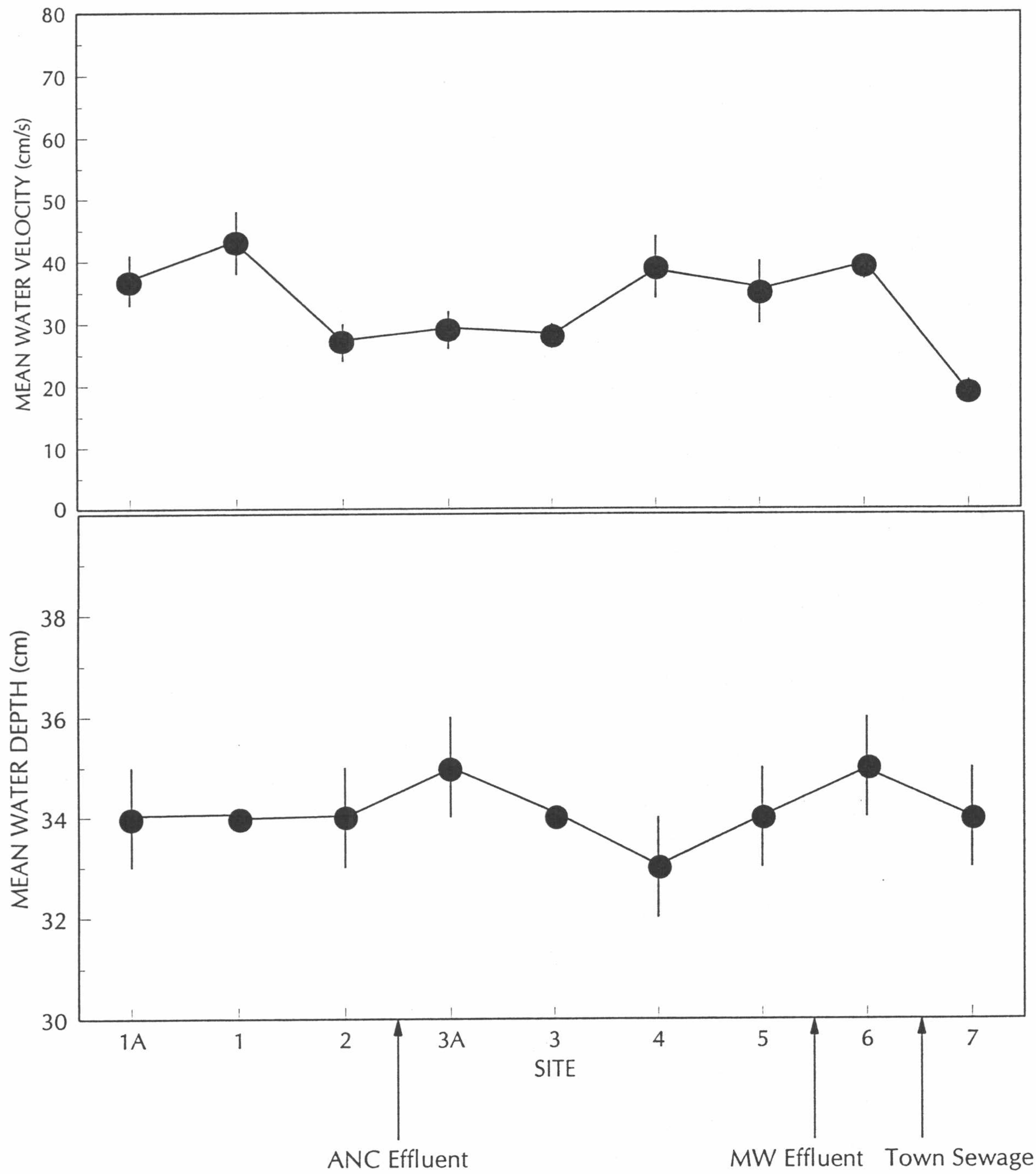



**Figure 4.** **Mean water velocity and water depth with 95% confidence limits for sites on the Athabasca River, October 1994.**

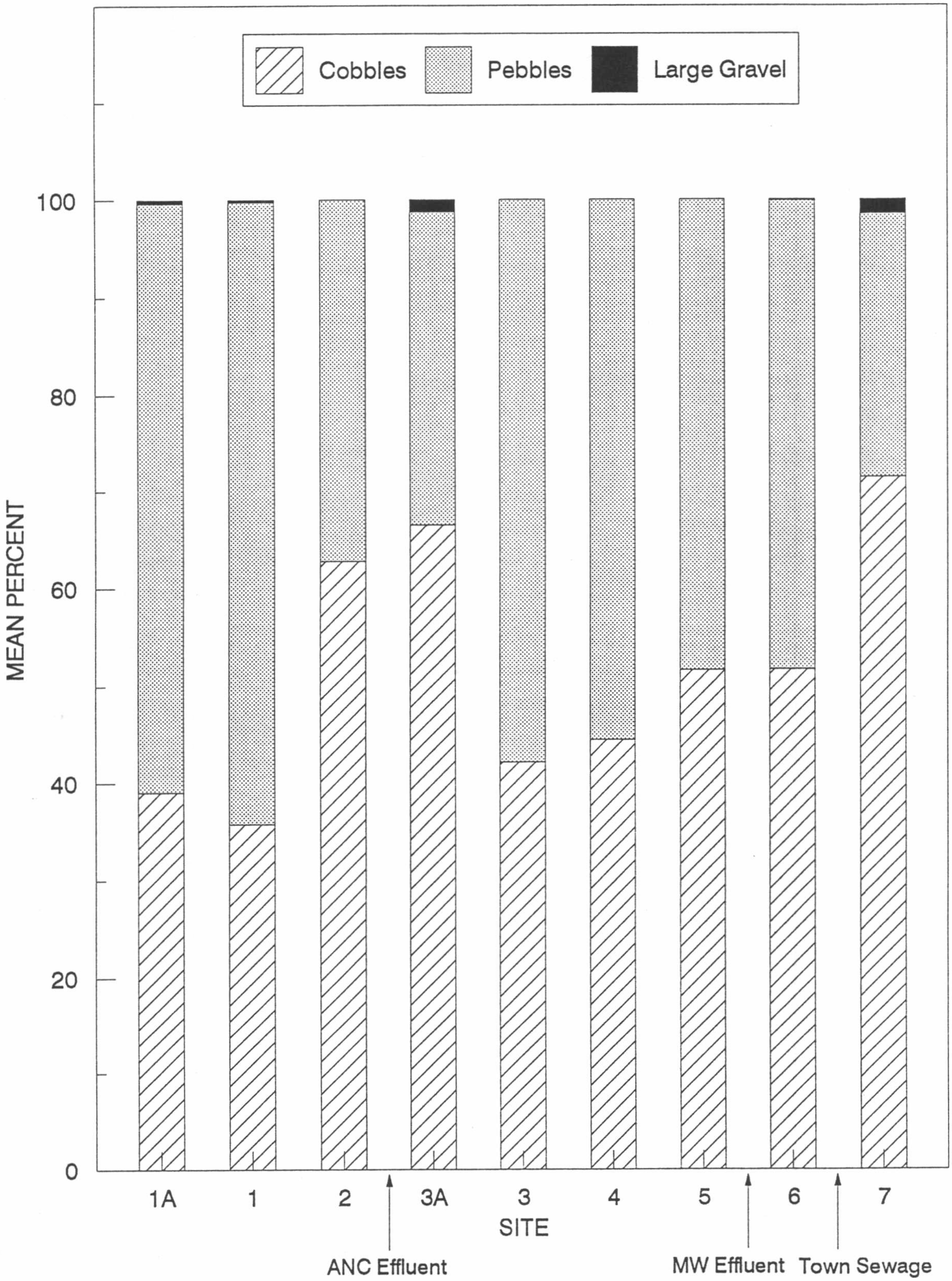



**Figure 5.** **Mean percent of substrate size distribution (by weight) for sites on the Athabasca River, October 1994.**

while cobbles comprised 35.8 and 44.4%. At Sites 5 and 6, the substrate composition of cobbles and pebbles was similar, with cobbles comprising 51.6% and pebbles comprising between 48.2 and 48.4% of the substrate. Gravels comprised less than 2% of the substrate and sand less than 1%.

Generally, these minor differences in physical characteristics of water velocity, water depth and substrate do not cause any detectable differences in benthic community structure between sites. Any habitat differences between sites were, however, considered in the interpretation of the benthic invertebrate results.

## 3.2 WATER QUALITY

The results of the fall 1994 field and laboratory water quality analyses for all sites on the Athabasca River are presented in Tables 2 and 3. These data were based on single grab samples taken at each site and provide a description of water quality only at the time of sampling. ANC final treated effluent quality data for the fall (August, September, October) of 1994 are shown in Table 4. Mean monthly treated effluent discharge to the river ranged from 17,142 to 18,387 $m^3$/d in the fall. A summary of Millar Western effluent quality fall data is presented in Appendix C.

The pH values recorded during the survey ranged from 8.3 to 8.5. The pH values recorded at both background and downstream sites were within both the Alberta Ambient Surface Water Quality Interim Guidelines (AASWQIG) of 6.5 to 8.5 and the Canadian Water Quality Guideline (CWQG) of 6.5 to 9.0 (Alberta Environmental Protection 1993, CCREM 1987). The mean monthly pH value of the ANC treated effluent ranged from 7.6 to 7.9, and the pH of Millar Western's treated effluent ranged from 8.1 to 8.4 during the fall. These effluent discharges did not affect pH values at any downstream sites.

Conductivity values at all sites ranged from 295 to 340 μmhos/cm. The mean monthly conductivity values for the ANC effluent ranged from 961 to 1,124 μmhos/cm, and the Millar Western effluent had conductivity values ranging from 6,328 to 6,667 μmhos/cm. Conductivity values in the Athabasca River were elevated slightly above background levels at sites below ANC, likely the result of discharge of treated effluent from ANC.

**Table 2. Water quality results of samples collected from the Athabasca River, October 1994.**

| | Site / Date | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Parameter | 1A<br>10/10 | 1<br>10/10 | 2<br>11/10 | 3A<br>11/10 | 3<br>12/10 | 4<br>12/10 | 5<br>12/10 | 6<br>8/10 | 7<br>13/10 | AASWQIG | CWQG |
| pH (units)* | 8.3 | 8.4 | 8.3 | 8.4 | 8.4 | 8.4 | 8.5 | 8.5 | 8.4 | 6.5 - 8.5 | 6.5 - 9.0 |
| Conductivity (μmhos/cm)* | 300 | 295 | 315 | 340 | 320 | 310 | 310 | 295 | 330 | - | - |
| Dissolved Oxygen (ppm)* | 11.2 | 11.1 | 11.6 | 11.3 | 12.5 | 11.5 | 11.7 | 11.8 | 11.7 | 5.0 | 5.0 - 9.5 |
| DO (percent saturation)* | 103 | 104 | 104 | 105 | 109 | 103 | 107 | 110 | 107 | - | - |
| Temperature (°C)* | 8.0 | 9.0 | 7.0 | 8.5 | 6.0 | 5.0 | 8.0 | 9.0 | 8.0 | Increase of 3° C | - |
| Biochemical Oxygen Demand (5 day) (mg/L) | NS | <1.0 | <1.0 | NS | <1.0 | <1.0 | <1.0 | 1.3 | <1.0 | - | - |
| True Color (Pt-Co units) | NS | 5 | 5 | NS | 5 | 5 | 5 | 5 | 5 | Increase of 30 units | - |
| Total Suspended Solids (mg/L) | NS | <1 | 2 | NS | 3 | 2 | 6 | 3 | 2 | Increase of 10 mg/L | Increase of 10 mg/L |
| Total Phosphorus (mg/L as P) | NS | 0.014 | 0.012 | NS | 0.026 | 0.025 | 0.030 | 0.013 | 0.024 | 0.05 | - |
| Total Kjeldahl Nitrogen (mg/L as N) | NS | 0.1 | 0.1 | NS | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 1.0 | - |

| | |
|---|---|
| * | Measured in the field. |
| Date | Day and Month |
| NS | Not Sampled |
| AASWQIG | Alberta Ambient Surface Water Quality Interim Guidelines (Alberta Environmental Protection 1993) |
| CWQG | Canadian Water Quality Guidelines for Freshwater Aquatic Life (CCREM 1987) |
| DO | Dissolved Oxygen |
| Pt-Co | Platinum-Cobalt |

Table 3. **Water quality results for selected parameters of samples collected at Sites 2 and 3 on the Athabasca River, October 1994. All values in mg/L unless otherwise stated.**

| Parameter | Site / Date: Site 2 11/10* | Site / Date: Site 3 12/10 | AASWQIG | CWQG |
|---|---|---|---|---|
| Total Phenols | <0.001 | <0.001 | 0.005 | 0.001 |
| Total Organic Carbon | 5 | 6 | - | - |
| Metals | | | | |
| Total Arsenic | <0.001 | <0.001 | 0.01 | 0.05 |
| Total Cadmium | <0.001 | <0.001 | 0.01 | 0.0018* |
| Total Chromium | <0.004 | <0.004 | 0.05 | 0.002 |
| Total Cobalt | <0.005 | <0.005 | - | - |
| Total Copper | <0.002 | <0.002 | 0.02 | 0.006** |
| Total Iron | 0.119 | 0.128 | 0.30 | 0.30 |
| Total Lead | <0.001 | <0.001 | 0.005 | 0.007** |
| Total Manganese | 0.005 | 0.006 | 0.05 | - |
| Total Mercury | <0.0001 | <0.0001 | 0.0001 | 0.0001 |
| Total Molybdenum | <0.004 | <0.004 | - | - |
| Total Nickel | <0.006 | <0.006 | - | 0.15** |
| Total Selenium | <0.001 | <0.001 | 0.01 | 0.001 |
| Total Silver | <0.003 | <0.003 | 0.05 | 0.0001 |
| Total Vanadium | <0.004 | 0.005 | - | - |
| Resin Acids | | | | |
| Abietic Acid | ND | ND | - | - |
| Dehydroabietic Acid | ND | ND | - | - |
| Isopimaric Acid | ND | ND | - | - |
| Levopimaric Acid | ND | ND | | |
| Neoabietic Acid | ND | ND | - | - |
| Palustric Acid | ND | ND | - | - |
| Pimaric Acid | ND | ND | - | - |
| Sandaracopimaric Acid | ND | ND | - | - |
| 12-Chlorodehydroabietic Acid | ND | ND | - | - |
| 14-Chlorodehydroabietic Acid | ND | ND | - | - |
| 12,14-Dichlorodehydroabietic Acid | ND | ND | - | - |
| Fatty Acids | | | | |
| Arachidic Acid | ND | ND | - | - |
| Linoleic Acid*** | ND | ND | - | - |
| Linolenic Acid | ND | ND | - | - |
| Myristic Acid | ND | ND | - | - |
| Oleic Acid*** | ND | ND | - | - |
| Palmitic Acid | ND | ND | - | - |
| Stearic Acid | ND | ND | - | - |
| 9,10-Dichlorostearic Acid | ND | ND | - | - |
| Total Resin and Fatty Acids | 0 | 0 | 0.1 | - |

(continued)

Table 3. (concluded)

| Parameter | Site / Date<br>Site 2<br>11/10* | <br>Site 3<br>12/10 | AASWQIG | CWQG |
|---|---|---|---|---|
| Surrogate Recovery | | | | |
| O-Methylpodocarpic Acid (%) | 95 ± 10 | 95 ± 10 | - | - |
| Tricosanoic Acid (%) | 103 ± 6.2 | 103 ± 6.2 | - | - |

| | |
|---|---|
| * | Resin and fatty acids at Site 2 were sampled on 12/10. |
| ** | At hardness > 180 mg/L ($CaCO_3$) |
| *** | Linoleic and oleic acid results were method blank and glassware proof corrected, but they are also constituents of the detergent used in cleaning laboratory glassware. |
| Date | Day and Month |
| ND | Not Detected. Detection limit was 0.001 mg/L for all target compounds. |
| AASWQG | Alberta Ambient Surface Water Quality Interim Guidelines (Alberta Environmental Protection 1993) |
| CWQG | Canadian Water Quality Guidelines for Freshwater Aquatic Life (CCREM 1987) |

**Table 4. Average monthly concentrations of selected parameters for ANC final treated effluent, fall (August - October ) 1994.**

| Parameter* | August | September | October |
|---|---|---|---|
| Discharge ($m^3/d$) | 17,142 | 18,387 | 17,258 |
| pH (units) | 7.6 | 7.7 | 7.9 |
| Conductivity (µmhos/cm) | 961 | 975 | 1,12~~5~~4 |
| Temperature (°C) | 31.5 | 29.8 | 27.4 |
| Biochemical Oxygen Demand (5 day) (mg/L) | 4 | 5 | 4 |
| True Color (Pt-Co units) | 178 | 179 | 218 |
| Total Suspended Solids (mg/L) | 10 | 14 | 11 |
| Total Phosphorus (as P) (mg/L) | 7.2 | 5.6 | 4.9 |
| Total Kjeldahl Nitrogen (mg/L) | 1.8 | 2.3 | 2.8 |
| Total Phenols (mg/L) | 0.040 | 0.033 | 0.020 |
| Resin Acids (mg/L) | | | |
| Abietic Acid | ND | ND | ND |
| Dehydroabietic Acid | ND | ND | ND |
| Isopimaric Acid | ND | ND | ND |
| Levopimaric Acid | ND | ND | ND |
| Neoabietic Acid | ND | ND | ND |
| Palustric Acid | ND | ND | ND |
| Pimaric Acid | ND | ND | ND |
| Sandaracopimaric Acid | ND | ND | ND |
| Fatty Acids (mg/L) | | | |
| Arachidic Acid | ND | ND | ND |
| Linoleic Acid | ND | ND | 0.014 |
| Linolenic Acid | ND | ND | ND |
| Myristic Acid | ND | ND | ND |
| Oleic Acid | ND | ND | ND |
| Palmitic Acid | ND | 0.011 | ND |
| Stearic Acid | ND | ND | ND |
| Total Resin and Fatty Acids | 0 | 0.011 | 0.014 |

Source: Alberta Newsprint Company (unpublished data)

* All monthly averages were based on daily values, except for total phosphorus and total Kjeldahl nitrogen which were weekly values, and total phenols and total resin and fatty acids which were monthly values.

ND Not Detected. Detection limit was 0.010 mg/L or lower.

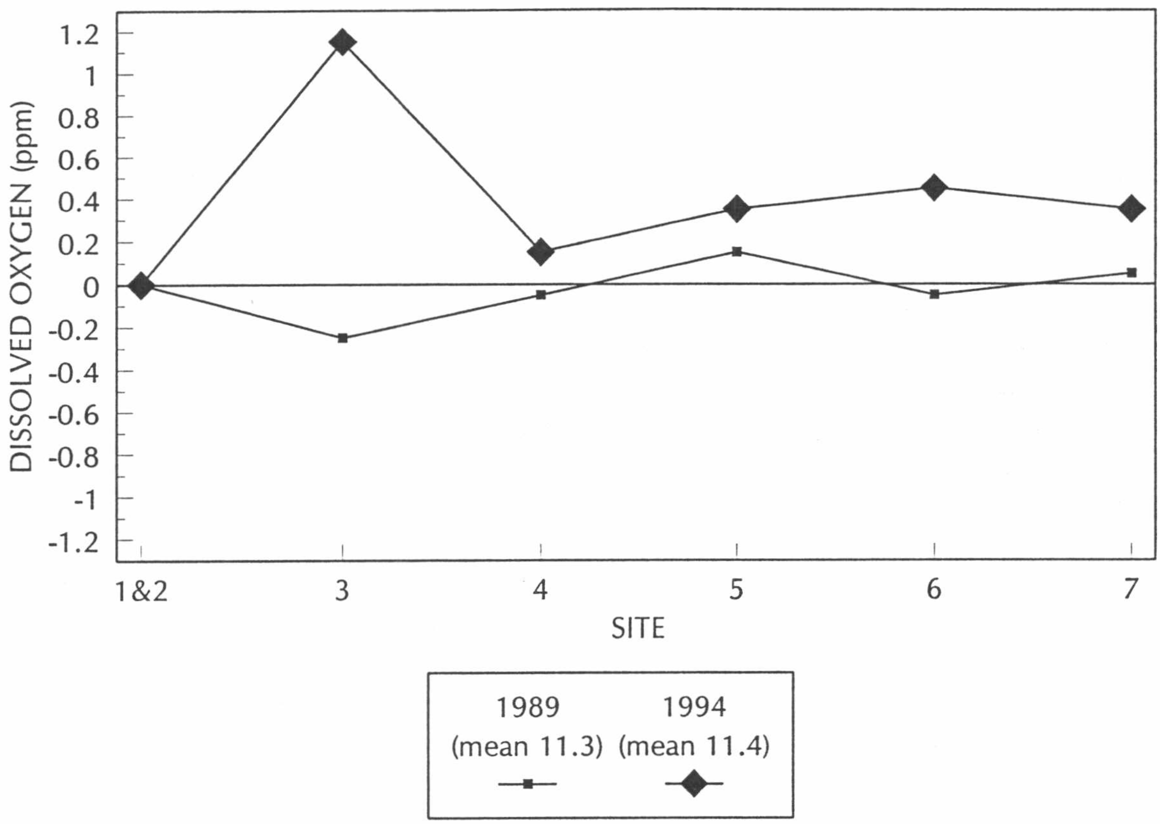
Pt-Co Platinum-Cobalt

Dissolved oxygen (DO) concentrations at all sites ranged from 11.1 to 12.5 ppm, which represented 103 to 110% saturation. Since the solubility of oxygen in water is temperature dependent and there were water temperature differences between sites (5.0 to 9.0 °C) during field measurements for dissolved oxygen, an appropriate comparison would be in saturation levels. When saturation levels were compared, sites below ANC, Millar Western and the Whitecourt sewage treatment plant were at or above background levels (Figure 6). Dissolved oxygen data for ANC effluent were not available since ANC is no longer required by Alberta Environmental Protection to monitor dissolved oxygen in its treated effluent. DO levels in the treated effluent have consistently exceeded the previous original 1990 Licence to Operate minimum requirement of 5.0 mg/L. A comparison of pre-operational (1989) and 1994 dissolved oxygen concentrations and saturation levels indicated that levels for both parameters were higher during the 1994 survey (Figure 6). Levels for both parameters were similar to or higher at downstream sites than at background sites during both the pre-operational and the 1994 survey (Figure 6).

Biochemical oxygen demand (BOD), a measure of the amount of oxygen required to oxidize organic matter in water, exhibited little variation between sites. $BOD_5$ values in river samples were below the detection limit of <1.0 mg/L at all sites, except Site 6 where a concentration of 1.3 mg/L was recorded. In the fall, the mean monthly BOD concentration in the ANC treated effluent ranged from 4 to 5 mg/L, and the Millar Western effluent had BOD concentrations ranging from 52 to 97 mg/L. Effluent discharge from ANC had no effect on BOD or dissolved oxygen concentrations in the river, while the Millar Western effluent was a likely contributor to the slight increase in the BOD concentration at Site 6.

True color values were identical at all sites with a value of 5 Pt-Co units. The mean monthly true color values recorded for the ANC treated effluent in the fall ranged from 178 to 218 Pt-Co units, and for the Millar Western effluent from 734 to 900 Pt-Co units. A comparison of pre-operational (1989) and 1994 true color values indicated that color in the Athabasca River was similar between the two years (Figure 7). True color values in 1994 were the same at background and downstream sites, while in 1989 (pre-operational year) true color values were 1 Pt-Co unit lower at downtream sites than at background sites (Figure 7).

Total suspended solids (TSS) concentrations ranged from <1 to 6 mg/L, with sites below effluent discharges having slighly elevated TSS values compared to the background sites.



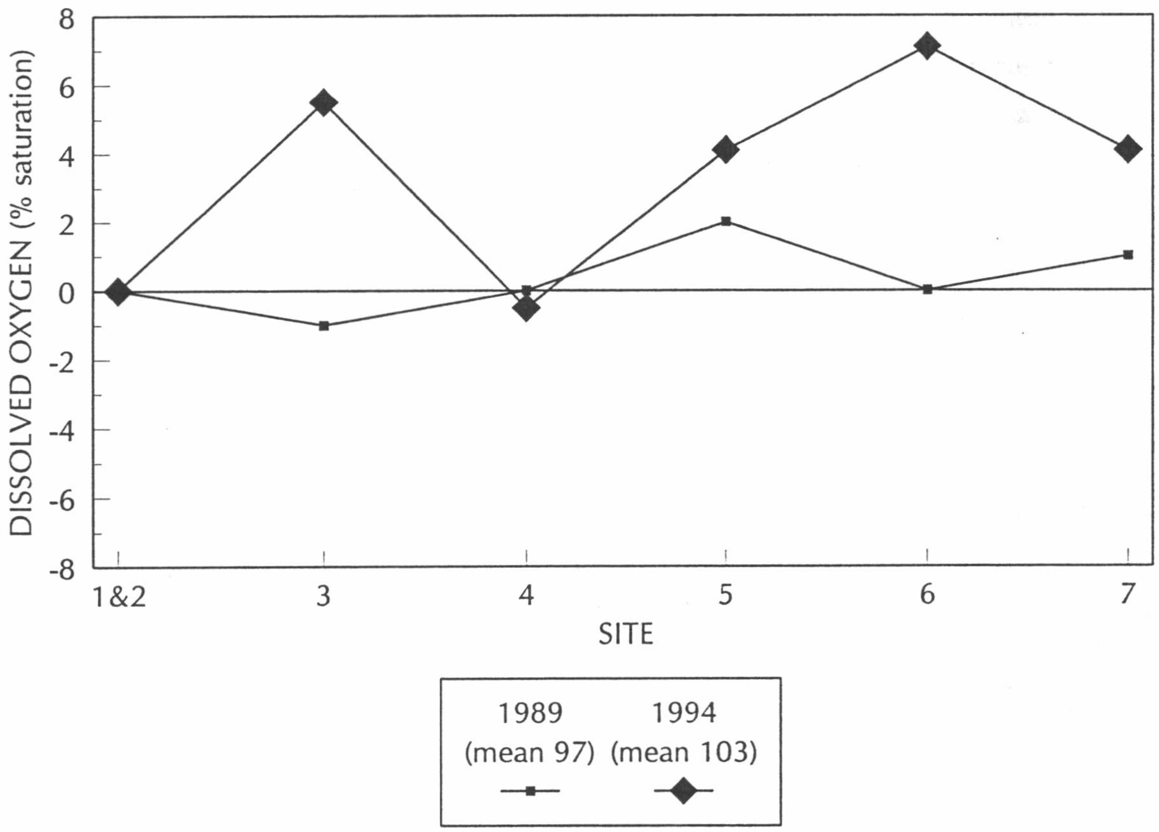
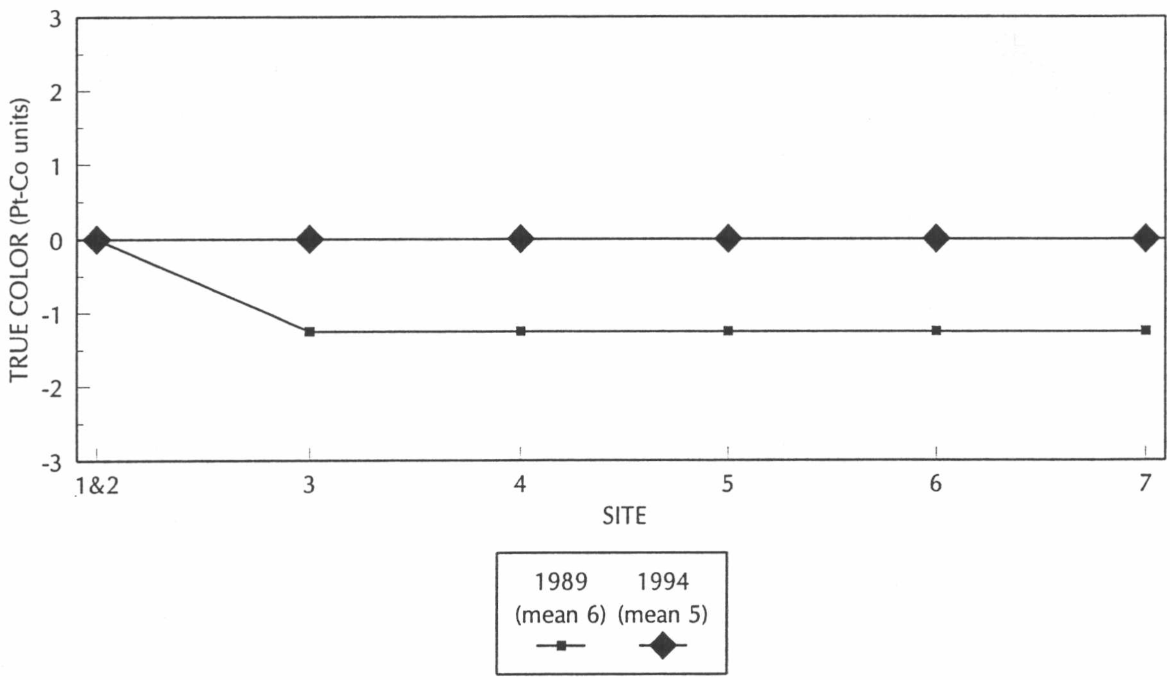




**Figure 6.** **Dissolved oxygen (ppm and % saturation) for downstream sites on the Athabasca River relative to mean of background Sites 1 and 2, fall 1994 compared to the pre-operational year (1989).**



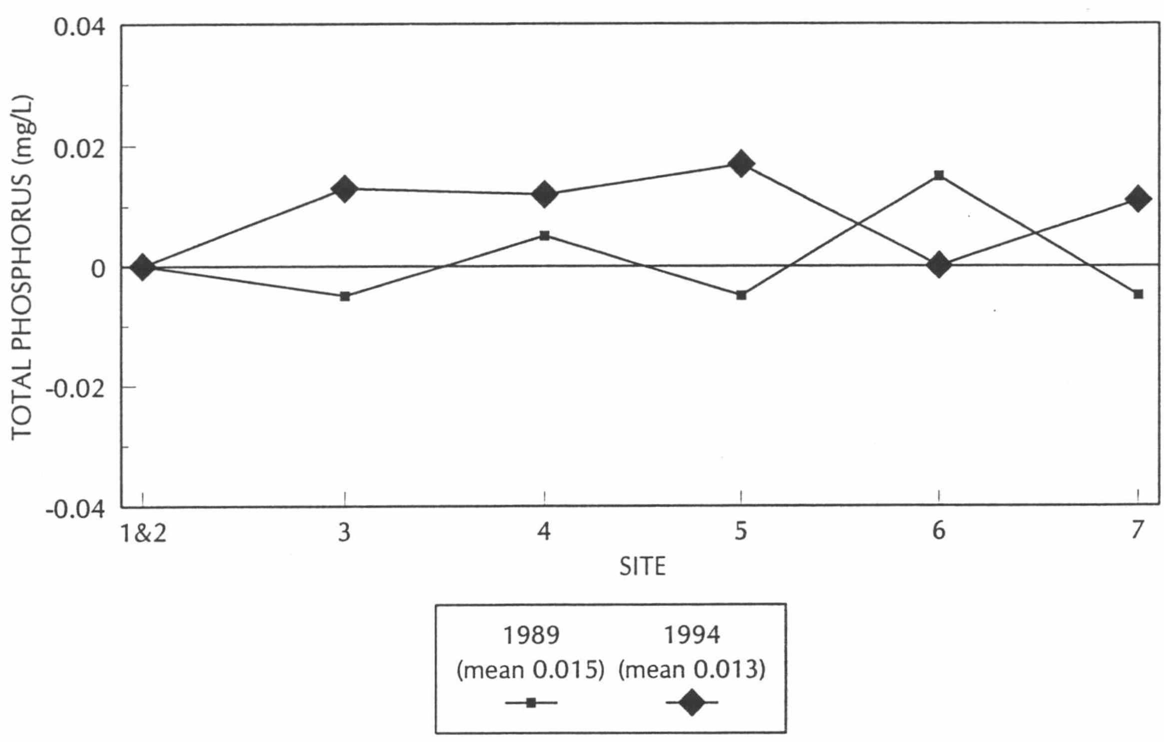




**Figure 7.** **True color and total phosphorus concentrations for downstream sites on the Athabasca River relative to mean of background Sites 1 and 2, fall 1994 compared to the pre-operational year (1989).**

Total suspended solids concentrations in ANC treated effluent were low, ranging from 10 to 14 mg/L, while in the Millar Western effluent it ranged 134 to 173 mg/L during the fall. The total suspended solids concentration at the site immediately below ANC and at the site below Millar Western was only marginally affected by effluent discharge. Total suspended solids concentrations were within both the AASWQIG and CWQG of an increase of 10 mg/L above background levels.

Phosphorus is generally regarded as the nutrient that limits productivity in freshwater ecosystems (Wetzel 1975). Total phosphorus (as P) concentrations at sites on the river ranged from 0.012 to 0.030 mg/L. The maximum total phosphorus concentration of 0.030 mg/L was recorded at Site 5 which is about 10 km below the ANC effluent outfall. All concentrations were below the AASWQIG of 0.05 mg/L total phosphorus. The mean total phosphorus concentration in the ANC treated effluent ranged from 4.9 to 7.2 mg/L, while in the Millar Western effluent it ranged from 0.55 to 3.36 mg/L. The increase in total phosphorus concentrations at downstream sites was likely due to phosphorus inputs from effluent discharges (ANC, Millar Western and the Whitecourt sewage treatment plant) and may also have been due to the McLeod River. The McLeod River is influenced by agricultural and municipal activity and/or the leaching of soils. A comparison of pre-operational (1989) and 1994 total phosphorus concentrations indicated that levels were slightly higher in 1994 than in 1989, except at Site 6 which was slightly lower (Figure 7). These increases may be due to land use practices, fluvial processes and/or effluent discharges. Total phosphorus values in 1994 were slightly higher at all downstream sites than at background sites, except at Site 6 which was similar to the background sites. In 1989 (pre-operational year) total phosphorus values fluctuated at downstream sites (slightly higher or slightly lower) compared to the background sites (Figure 7).

Total Kjeldahl nitrogen (TKN) concentrations were the same at all sites with a value of 0.1 mg/L. The mean monthly concentration of TKN in the ANC and Millar Western treated effluents ranged from 1.8 to 2.8 mg/L and 10.6 to 12.9 mg/L, respectively. Effluent discharge did not have any affect on TKN concentrations in the Athabasca River. All TKN values recorded during the survey were below the AASWQIG of 1.0 mg/L.

Total phenol concentrations were $<0.001$ mg/L at both background Site 2 and downstream Site 3. Phenol concentrations in ANC's treated effluent ranged from 0.020 to 0.040 mg/L. Effluent discharge from did not affect total phenol concentrations in the Athabasca River.

Phenolic compounds can occur naturally in the aquatic environment as decomposition products of aquatic plants and decaying vegetation (CCREM 1987). The total phenol values recorded during the survey at both sites were below the AASWQIG of 0.005 mg/L and the CWQG of 0.001 mg/L.

Total organic carbon concentrations showed were similar between the two sites. Total organic carbon values of 5 and 6 mg/L were recorded at Sites 2 and 3, respectively. No total organic carbon data is available for the ANC effluent.

Metals such as copper, manganese and iron exhibit a strong affinity to adsorb to suspended particulate matter. Metals are not generally considered to be a major component of pulp mill effluent. The concentrations recorded at both Sites 2 and 3 were below detection limits, except for iron, manganese and vanadium which were slightly above the values recorded at the background site. Metal concentrations were below both the AASWQIG and CWQG.

Neither resin or fatty acids were detected at Sites 2 and 3 during the fall survey. Dehydroabietic, abietic, pimaric, sandaracopimaric and neoabietic acids, commonly found in softwood pulp mill effluents (Taylor et al. 1988), were not detected during the survey. Most resin and fatty acids concentrations in ANC's treated effluent during the fall were below the detection limit of 0.010 mg/L. A linoleic acid concentration of 0.014 mg/L was recorded in October 1994 and a palmitic acid concentration of 0.011 mg/L was recorded in September 1994 in ANC's treated effluent. Total resin and fatty acids concentrations were below the AASWQIG of 0.1 mg/L.

## 3.3 PERIPHYTIC ALGAE

Mean chlorophyll a ranged between 29.2 and 635.8 mg/m$^2$ during the fall survey (Table 5). The lowest values occurred at background sites ranging between 29.2 and 65.0 mg/m$^2$, with a mean of 44.0 mg/m$^2$ for the three sites. The highest value of 635.8 mg/m$^2$ occurred at the first downstream site (Site 3A) and all other downstream sites ranged between 62.5 and 247.5 mg/m$^2$. Larger variability occurred between samples at downstream sites (confidence limits ranged between 53.5 and 162.8 mg/m$^2$) than at background sites (confidence limits ranged between 13.5 and 14.7 mg/m$^2$).

Table 5. **Periphytic algae chlorophyll *a* values per sample with means and 95% confidence limits (CL) per site, October 1994.**

| Site-Sample | Periphytic Algae Chlorophyll *a* (mg/m$^2$) |
|---|---|
| 1A-1 | 23.8 |
| 1A-2 | 28.8 |
| 1A-3 | 35.0 |
| Mean ± 95% CL | 29.2 ± 14.0 |
| 1-1 | 42.5 |
| 1-2 | 31.3 |
| 1-3 | 40.0 |
| Mean ± 95% CL | 37.9 ± 14.7 |
| 2-1 | 62.5 |
| 2-2 | 71.3 |
| 2-3 | 61.3 |
| Mean ± 95% CL | 65.0 ± 13.5 |
| 3A-1 | 697.5 |
| 3A-2 | 603.8 |
| 3A-3 | 606.3 |
| Mean ± 95% CL | 635.8 ± 132.7 |
| 3-1 | 71.3 |
| 3-2 | 98.8 |
| 3-3 | 56.3 |
| Mean ± 95% CL | 75.4 ± 53.5 |
| 4-1 | 320.0 |
| 4-2 | 230.0 |
| 4-3 | 192.5 |
| Mean ± 95% CL | 247.5 ± 162.8 |
| 5-1 | 171.3 |
| 5-2 | 222.5 |
| 5-3 | 136.3 |
| Mean ± 95% CL | 176.7 ± 107.8 |
| 6-1 | 78.8 |
| 6-2 | 100.0 |
| 6-3 | 8.8 |
| Mean ± 95% CL | 62.5 ± 118.6 |
| 7-1 | 56.3 |
| 7-2 | 117.5 |
| 7-3 | 97.5 |
| Mean ± 95% CL | 90.4 ± 77.6 |

There was an increase in chlorophyll *a* at Site 3A just downstream of the ANC effluent outfall when compared to the mean value of background sites (Figure 8). Chlorophyll *a* then decreased at Site 3 to a value similar to the mean background value, increased slightly at Site 4 and decreased slightly at Site 5. There was a further decrease in chlorophyll *a* at Site 6, which was downstream of the Millar Western effluent outfall and the McLeod River, to a value similar to the mean background value, and at Site 7 which was downstream of the Whitecourt sewage treatment effluent outfall, there was a small increase again.

ANOVA indicated that there was a significant difference in mean chlorophyll *a* between sites ($p < 0.05$) during the fall survey (Appendix D). The orthogonal contrasts showed that mean chlorophyll a was significantly higher at all downstream sites than at background sites and it was also significantly higher at near-field sites than at far-field sites ($p < 0.05$).

A comparison of chlorophyll a between the fall of 1993 and 1994 indicated generally less algal growth in the river (upstream and downstream of the ANC mill) during 1994 (Figure 9). This was likely a result of the lower than average summer and fall flows in the Athabasca River in 1993 which provided greater light penetration and less scour, therefore causing increased algal growth.

## 3.4 BENTHIC INVERTEBRATES

### 3.4.1 Basic Computations

A total of 138 taxa of benthic invertebrates has been identified (most to the generic level) from the 1989 to 1994 samples collected from the Athabasca River (Table 6). Of these, 75 taxa were identified from the October 1994 samples, of which two were new taxa not collected previously. The new taxa consisted of a Plecoptera (*Taeniopteryx* sp.) and a Chironomidae (a Chironominae *Stictochironomus* sp.).

As part of the QA/QC program, the re-sorting of sample residues was conducted on seven of the samples to determine the level of sorting efficiency. The sorting efficiency of the seven samples ranged between 94.9 and 97.4%, with an overall average of 96.4% (Appendix A). A high level of sorting efficiency was obtained even with the difficulty in sorting the samples with the larger amounts of algae. This level of sorting efficiency meets the EEM requirements of $\geq$ 95% recovery of all organisms.

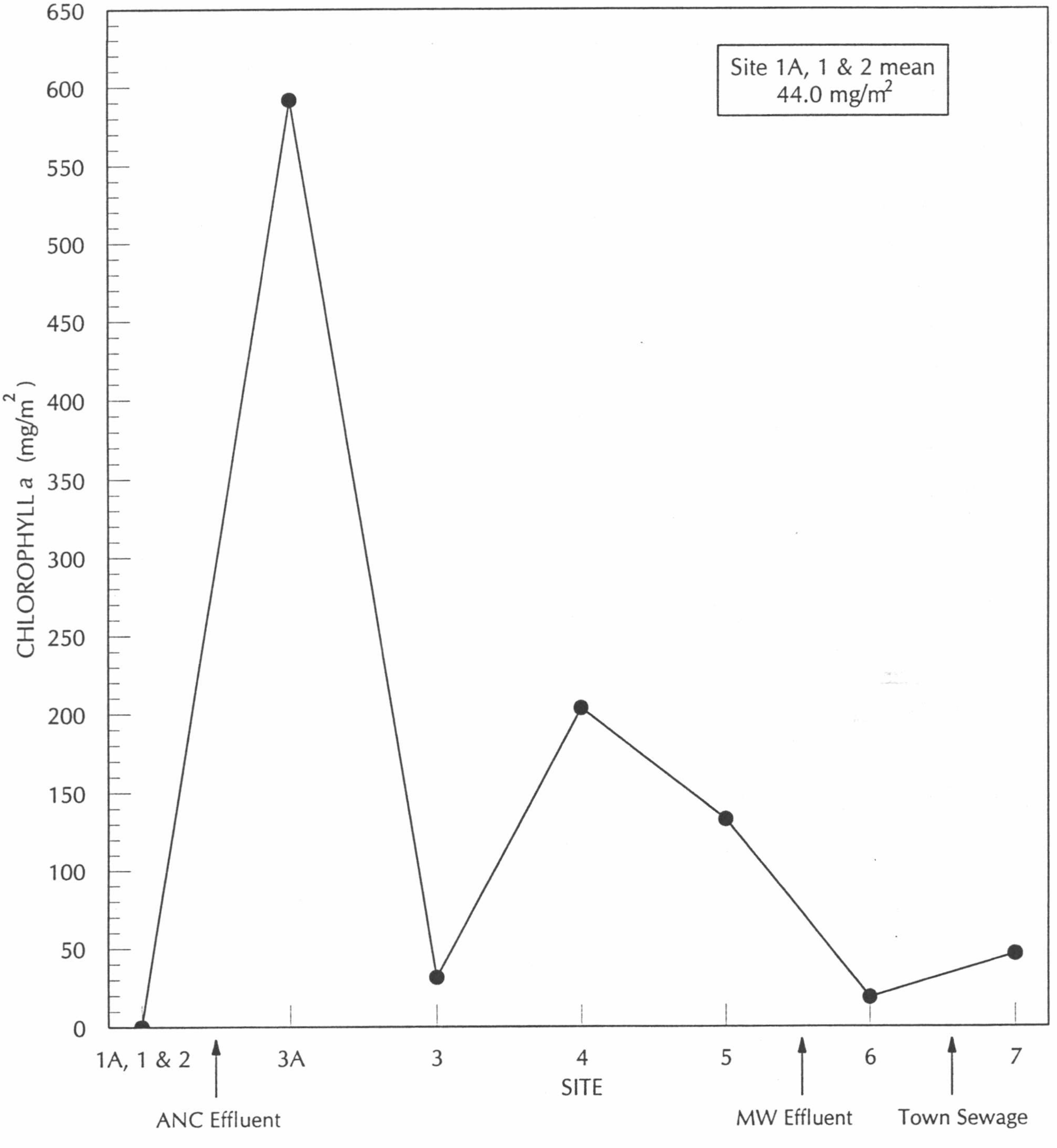



**Figure 8.** **Chlorophyll *a* for downstream sites on the Athabasca River relative to mean of background Sites 1A, 1 and 2, October 1994.**

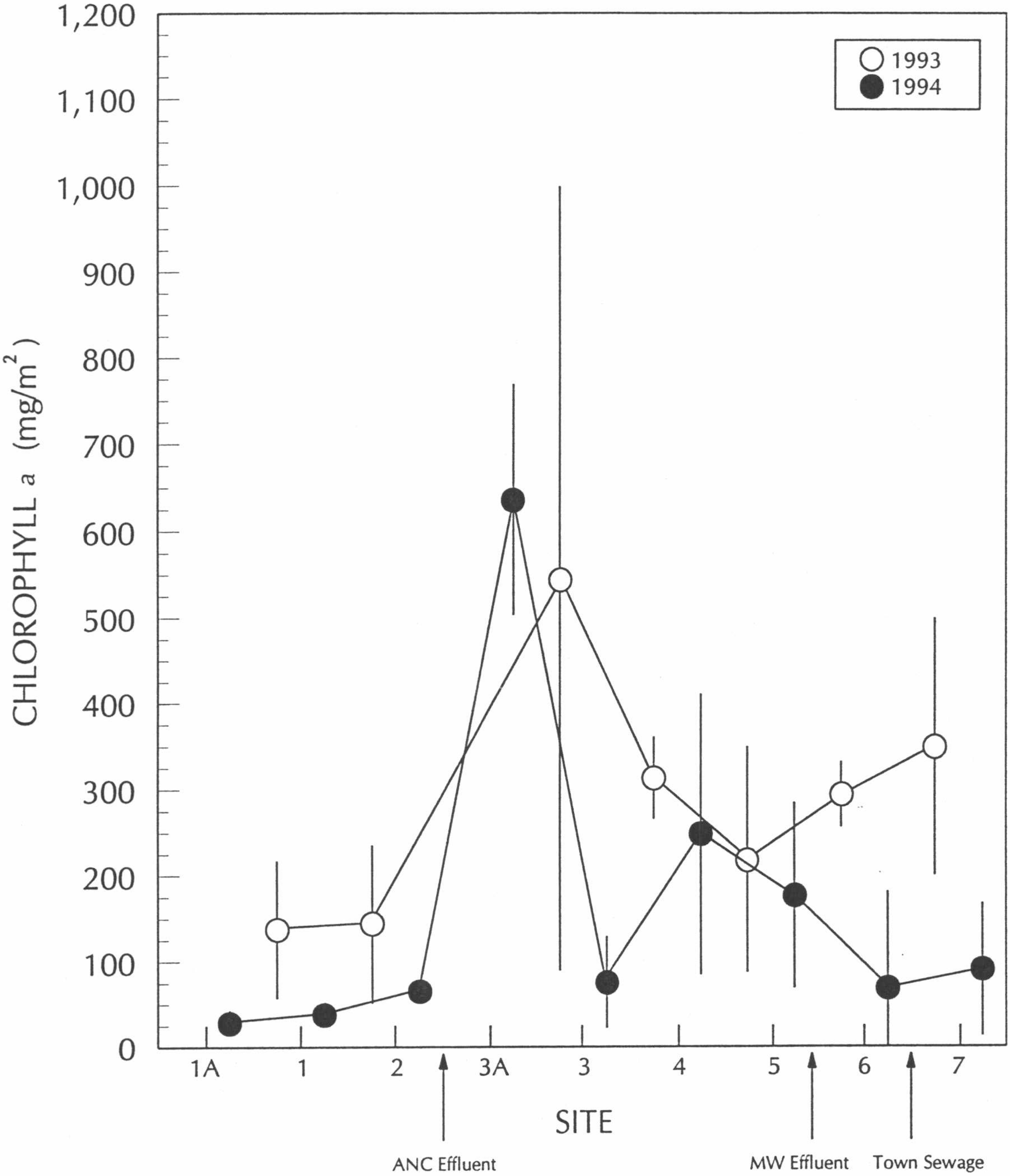



**Figure 9.** **Comparison of mean chlorophyll *a* with 95% confidence limits for sites on the Athabasca River for October 1993 and 1994.**

Table 6. **Benthic invertebrate species list with codes and functional feeding groups, 1994. Abbreviations for functional feeding groups as in Table 1.**

| Species Code | Taxa | Functional Feeding Group | Season* |
|---|---|---|---|
| | **ARTHROPODA** | | |
| | INSECTA | | |
| | Ephemeroptera (mayflies) | | |
| | Ametropodidae | | |
| 001 | *Ametropus neavei* | D | SF |
| | Baetidae | | |
| 002 | *Baetis* spp. | DH | SF |
| 003 | *Acentrella insignificans*[a] | DH | F |
| | Ephemerellidae | | |
| 096 | *Drunella coloradensis* | H | S |
| 004 | *Drunella doddsi* | H | SF |
| 114 | *Drunella grandis ingens* | H | SF |
| 005 | *Ephemerella inermis* | DH | SF |
| | Ephemeridae | | |
| 006 | *Ephemera* sp. | D | SF |
| | Heptageniidae | | |
| 007 | *Epeorus* sp. | DH | S |
| 008 | *Heptagenia* sp. | DH | SF |
| 009 | *Rhithrogena* sp. | DH | SF |
| 010 | *Stenonema* sp. | DH | F |
| 011 | Heptageniidae (early instar)** | DH | S |
| | Leptophlebiidae | | |
| 129 | *Leptophlebia* sp. | D | S |
| 012 | *Paraleptophlebia* sp. | DH | SF |
| | Metretopodidae | | |
| 013 | *Metretopus borealis* | C | S |
| | Siphlonuridae | | |
| 014 | *Ameletus* sp. | DH | SF |
| 130 | *Parameletus* sp. | DH | S |
| | Tricorythidae | | |
| 015 | *Tricorythodes* sp. | D | SF |
| | Trichoptera (caddisflies) | | |
| | Brachycentridae | | |
| 016 | *Brachycentrus* sp. | O | SF |
| | Glossosomatidae | | |
| 115 | *Glossosoma* sp. | H | F |

(continued)

Table 6. (continued)

| Species Code | Taxa | Functional Feeding Group | Season* |
|---|---|---|---|
| | Hydropsychidae | | |
| 017 | *Arctopsyche* sp. | O | SF |
| 018 | *Cheumatopsyche* sp. | O | SF |
| 019 | *Hydropsyche* spp. | O | SF |
| | Hydroptilidae | | |
| 020 | *Hydroptila* sp. | H | SF |
| 021 | *Stactobiella* sp. | DH | S |
| | Lepidostomatidae | | |
| 022 | *Lepidostoma* sp. | D | F |
| | Leptoceridae | | |
| 023 | *Oecetis* sp. | HC | SF |
| | Limnephilidae | | |
| 116 | *Apatania* sp | DH | SF |
| 097 | Limnephilidae (early instar)** | DH | F |
| | Polycentropodidae | | |
| 117 | *Neureclipsis* sp. | O | F |
| | Psychomyiidae | | |
| 024 | *Psychomyia* sp. | DH | SF |
| | Plecoptera (stoneflies) | | |
| 025 | Capniidae[b] | D | SF |
| | Chloroperlidae | | |
| | Chloroperlinae | | |
| 026 | *Haploperla brevis* | HC | SF |
| 098 | *Triznaka* sp. | C | S |
| 099 | Chloroperlinae (early instar)** | C | SF |
| | Nemouridae | | |
| 100 | *Nemoura sp.* | D | S |
| 111 | *Podmosta* sp. | D | S |
| 027 | *Zapada* sp. | D | SF |
| | Perlidae | | |
| 028 | *Claassenia sabulosa* | C | SF |
| 101 | *Hesperoperla pacifica* | C | F |
| | Perlodidae | | |
| 029 | *Cultus* sp. | C | SF |
| 030 | *Isogenoides* sp. | C | SF |
| 031 | *Isoperla* sp. | C | SF |
| 132 | *Skwala* sp. | C | F |
| 032 | Perlodidae (early instar)** | C | SF |
| | Pteronarcyidae | | |
| 033 | *Pteronarcella badia* | DH | SF |
| 034 | *Pteronarcys dorsata* | DH | SF |

(continued)

**Table 6.** (continued)

| Species Code | Taxa | Functional Feeding Group | Season* |
|---|---|---|---|
| | Taeniopterygidae | | |
| 035 | *Taenionema* sp. | H | SF |
| 137 | *Taeniopteryx* sp. | D | F |
| | Diptera (flies, midges) | | |
| | Athericidae | | |
| 036 | *Atherix* sp. | C | SF |
| | Blephariceridae | | |
| 118 | *Bibiocephala grandis* | H | F |
| | Ceratopogonidae | | |
| 037 | *Bezzia/Palpomyia gp.*[b] | C | SF |
| | Empididae | | |
| 038 | *Chelifera* sp. | CD | SF |
| 039 | *Hemerodromia* sp. | CD | SF |
| 119 | *Wiedemannia* sp. | C | F |
| | Simuliidae | | |
| 040 | *Simulium* sp. | O | S |
| | Tanyderidae | | |
| 120 | *Protanyderus* sp. | DH | F |
| | Tipulidae | | |
| 133 | *Antocha* sp. | D | F |
| 123 | *Dicranota* sp. | C | F |
| 041 | *Hexatoma* sp. | C | SF |
| 042 | *Limnophila* sp. | C | SF |
| 043 | Eriopterini Tribe | D | SF |
| | Chironomidae | | |
| | Chironominae | | |
| | Chironomini Tribe | | |
| 124 | *Chironomus* sp. | DH | F |
| 044 | *Cryptochironomus* sp. | C | SF |
| 134 | *Demicryptochironomus* sp. | D | F |
| 045 | *Microtendipes* sp. | D | SF |
| 046 | *Paracladopelma/Cyphomella* spp.[c] | D | SF |
| 047 | *Paralauterborniella nigrohalteralis* | D | SF |
| 112 | *Paratendipes* sp. | D | S |
| 125 | *Phaenopsectra* sp. | DH | F |
| 048 | *Polypedilum* spp. | DH | SF |
| 049 | *Robackia demeijerei* | D | SF |
| 050 | *Saetheria* sp. | D | S |
| 126 | *Stenochironomus* sp. | D | F |
| 138 | *Stictochironomus* sp. | DH | F |
| 051 | Chironomini (early instar)** | D | SF |

(continued)

Table 6. (continued)

| Species Code | Taxa | Functional Feeding Group | Season* |
|---|---|---|---|
| | Tanytarsini Tribe | | |
| 052 | *Cladotanytarsus* sp. | D | SF |
| 053 | *Constempellina* sp. | D | S |
| 054 | *Micropsectra* sp. | D | SF |
| 055 | *Rheotanytarsus* spp. | D | SF |
| 056 | *Stempellinella* sp. | DH | SF |
| 057 | *Sublettea* sp. | D | SF |
| 058 | *Tanytarsus* spp. | D | SF |
| 059 | Tanytarsini (early instar)** | D | S |
| | Diamesinae | | |
| | Diamesini Tribe | | |
| 102 | *Diamesa* sp. | D | SF |
| 060 | *Pagastia* sp. | D | F |
| 061 | *Potthastia gaedii* gp. | DH | SF |
| 127 | *Potthastia longimana* gp. | DH | F |
| 135 | *Pseudodiamesa* sp. | D | F |
| | Orthocladiinae | | |
| 103 | *Brillia* sp. | D | SF |
| 062 | *Cardiocladius* sp. | C | F |
| 104 | *Corynoneura* sp. | D | SF |
| 063 | *Cricotopus/Orthocladius* spp. | DH | SF |
| 064 | *Eukiefferiella* spp. | DH | SF |
| 105 | *Heleniella* sp. | D | F |
| 106 | *Heterotrissocladius* sp. | D | SF |
| 107 | *Krenosmittia* sp. | D | SF |
| 065 | *Nanocladius* sp. | D | SF |
| 108 | *Orthocladius (Symposiocladius) lignicola* | D | F |
| 066 | *Paracladius* sp. | D | F |
| 067 | *Parakiefferiella* spp. | D | SF |
| 068 | *Parametriocnemus* sp. | D | SF |
| 109 | *Psectrocladius* sp. | DH | S |
| 069 | *Rheocricotopus* sp. | DH | SF |
| 070 | *Synorthocladius* sp. | D | SF |
| 071 | *Thienemanniella* sp. | D | SF |
| 072 | *Tvetenia* spp. | D | SF |
| 073 | Orthocladiinae (early instar)** | D | SF |
| | Prodiamesinae | | |
| 074 | *Monodiamesa* sp. | D | SF |
| | Tanypodinae | | |
| | Macropelopiini Tribe | | |
| 113 | *Procladius* sp. | C | S |
| | Pentaneurini Tribe | | |
| 075 | *Larsia* sp. | C | SF |
| 131 | *Monopelopia* sp. | C | S |

(continued)

Table 6. (continued)

| Species Code | Taxa | Functional Feeding Group | Season* |
|---|---|---|---|
| 076 | *Nilotanypus* sp. | C | S |
| 077 | *Thienemannimyia* gp. | C | SF |
| 078 | Tanypodinae (early instar)** | C | F |
| | Coleoptera (beetles) | | |
| | Dytiscidae | | |
| 079 | *Oreodytes* sp. | C | F |
| | Elmidae | | |
| 080 | *Optioservus* sp. | DH | SF |
| 121 | Collembola (springtails) | DH | SF |
| | Hemiptera | | |
| | Corixidae (water boatmen) | | |
| 081 | *Callicorixa audeni* | C | SF |
| 122 | *Hesperocorixa atopodonta* | C | F |
| 082 | *Sigara* spp.[f] | DH | F |
| | Odonata (dragonflies) | | |
| | Gomphidae | | |
| 084 | *Ophiogomphus* sp. | C | SF |
| | Megaloptera (alderflies) | | |
| | Sialidae | | |
| 110 | *Sialis* sp. | C | S |
| | ARACHNIDA | | |
| 085 | Hydracarina (water mites) | C | SF |
| | CRUSTACEA | | |
| | Podocopa (seed shrimps) | | |
| | Candonidae[d] | | |
| 086 | *Candona* sp. | O | SF |

(continued)

Table 6. (continued)

| Species Code | Taxa | Functional Feeding Group | Season* |
|---|---|---|---|
| | **ANNELIDA** | | |
| | OLIGOCHAETA (aquatic earthworms) | | |
| | Haplotaxida | | |
| 087 | Enchytraeidae | D | SF |
| 088 | Naididae | D | SF |
| 089 | Tubificidae | D | SF |
| | Lumbriculida | | |
| 090 | Lumbriculidae | D | S |
| | HIRUDINEA (leeches) | | |
| | Rhynchobdellida | | |
| | Glossiphoniidae | | |
| 091 | *Helobdella stagnalis* | C | SF |
| 092 | **NEMATODA** (roundworms) | D | SF |
| | **MOLLUSCA** | | |
| | GASTROPODA (snails) | | |
| | Basommatophora | | |
| | Ancylidae | | |
| 136 | *Ferrissia* sp. | D | F |
| | Lymnaeidae | | |
| 093 | *Stagnicola catascopium*[e] | O | SF |
| | Planorbidae | | |
| 128 | *Gyraulus* sp. | DH | F |
| | PELECYPODA (clams) | | |
| | Heterodonta | | |
| | Sphaeriidae | | |
| 094 | *Pisidium* sp. | O | S |

(continued)

**Table 6.** **(concluded)**

| Species Code | Taxa | Functional Feeding Group | Season* |
|---|---|---|---|
| | **PLATYHELMINTHES** | | |
| | TURBELLARIA (flatworms) | | |
| | Tricladida (planarians) | | |
| | Planariidae | | |
| 095 | *Polycelis coronata* | CD | F |

* S - spring: F - fall

** The organisms indicated as early instars were too small to identify to the genus level.

a *Pseudocloeon* sp. has recently been placed into the *Acentrella* sp., along with the *Baetis* (*Laponica*) group (McCafferty and Waltz 1990).

b Definitive separation within the Capniidae family and the *Bezzia/Palpomyia* gp. is difficult with the keys presently available.

c *Cyphomella* sp. was previously (1989) identified as *Paracladopelma* sp. Definitive separation between these two genera is difficult with the present keys.

d *Candona* sp. has recently been moved from the Cypridae to the Candonidae family.

e *Stagnicola catascopium* was previously (1989-1991) identified as *Lymnaea* sp.

f The two species, *Sigara decoratella* and *Sigara solensis*, were combined as *Sigara* spp., since not all specimens could be identified to the species level.

The raw benthic data showing taxa identified and the number of organisms per sample for all sites are presented in Appendix E. Summary tables of the basic computations for each sample are presented in Appendix F. The total number of taxa, number of EPT taxa, total number of organisms, number of EPT and number of Chironomidae were log-transformed for statistical analyses.

The mean total number of taxa at sites ranged between 29 and 40 taxa (Figure 10). The mean number of taxa was slightly higher at all downstream sites (36 to 40), except at Site 3 (30 taxa), than at background sites (29 to 36). The mean number of EPT taxa ranged between 13 and 19 taxa, with slightly higher values at all downstream sites (16 to 19), except at Site 3 (14 taxa), than at background sites (13 to 16) (Figure 10).

ANOVA indicated that there were significant differences in the mean total number of taxa and the mean number of EPT taxa ($p < 0.05$) (Appendix G). *A priori* testing, using orthogonal contrasts, showed that both the total number of taxa and the number of EPT taxa were significantly higher at downstream sites than at background sites ($p < 0.05$). The total number of taxa was also significantly higher at far-field-sites than near-field sites ($p < 0.05$). However, there was no significant difference in the number of EPT taxa between far-field sites and near-field sites ($p > 0.05$).

The mean standing crop at sites ranged between 14,056 and 108,769 organisms/$m^2$ (Figure 11). The mean standing crop was higher at downstream Sites 3A, 3, 4 and 5 (32,962 to 108,769 organisms/$m^2$) than at background sites (14,056 and 26,953 organisms/$m^2$), while at downstream Sites 6 and 7 (25,280 and 21,442 organisms/$m^2$, respectively), it was similar to background sites.

ANOVA indicated that there was a significant difference in the mean total number of organisms (or standing crop) between sites ($p < 0.05$) (Appendix G). The orthogonal contrasts showed that the number of organisms was significantly higher at downstream sites than at background sites ($p < 0.05$) and it was also significantly higher at near-field sites than at far-field sites ($p < 0.05$).

The mean species diversity at sites ranged between 1.48 and 2.71 (Figure 12). The mean species diversity was lower at Sites 3A, 3 and 4 (1.48 to 1.65) than at background sites (2.03 to 2.48). At downstream Sites 5, 6 and 7 (2.23 to 2.71), the mean species diversity was

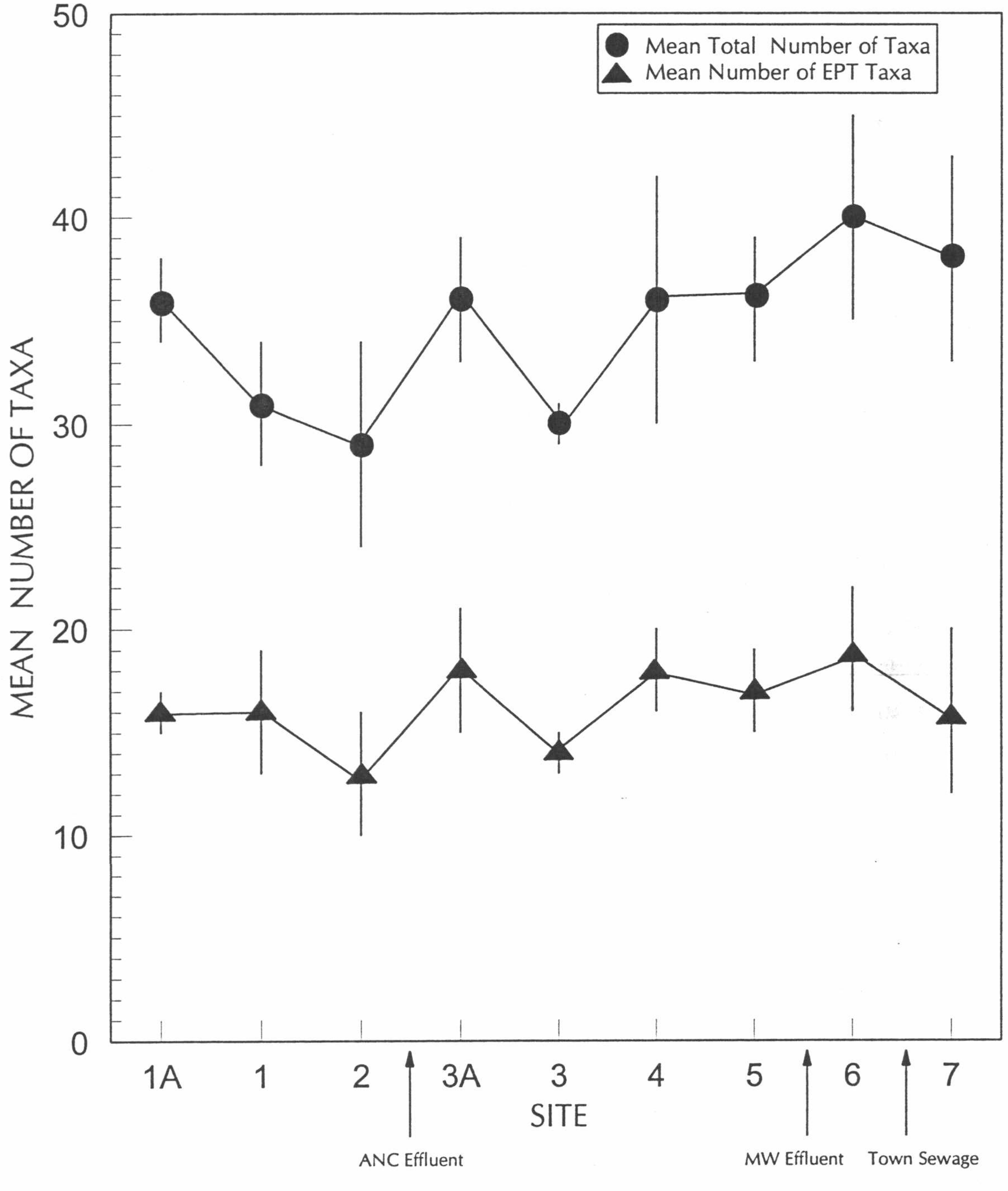



**Figure 10.** Mean total number of taxa and mean number of EPT taxa with 95% confidence limits for sites on the Athabasca River, October 1994.

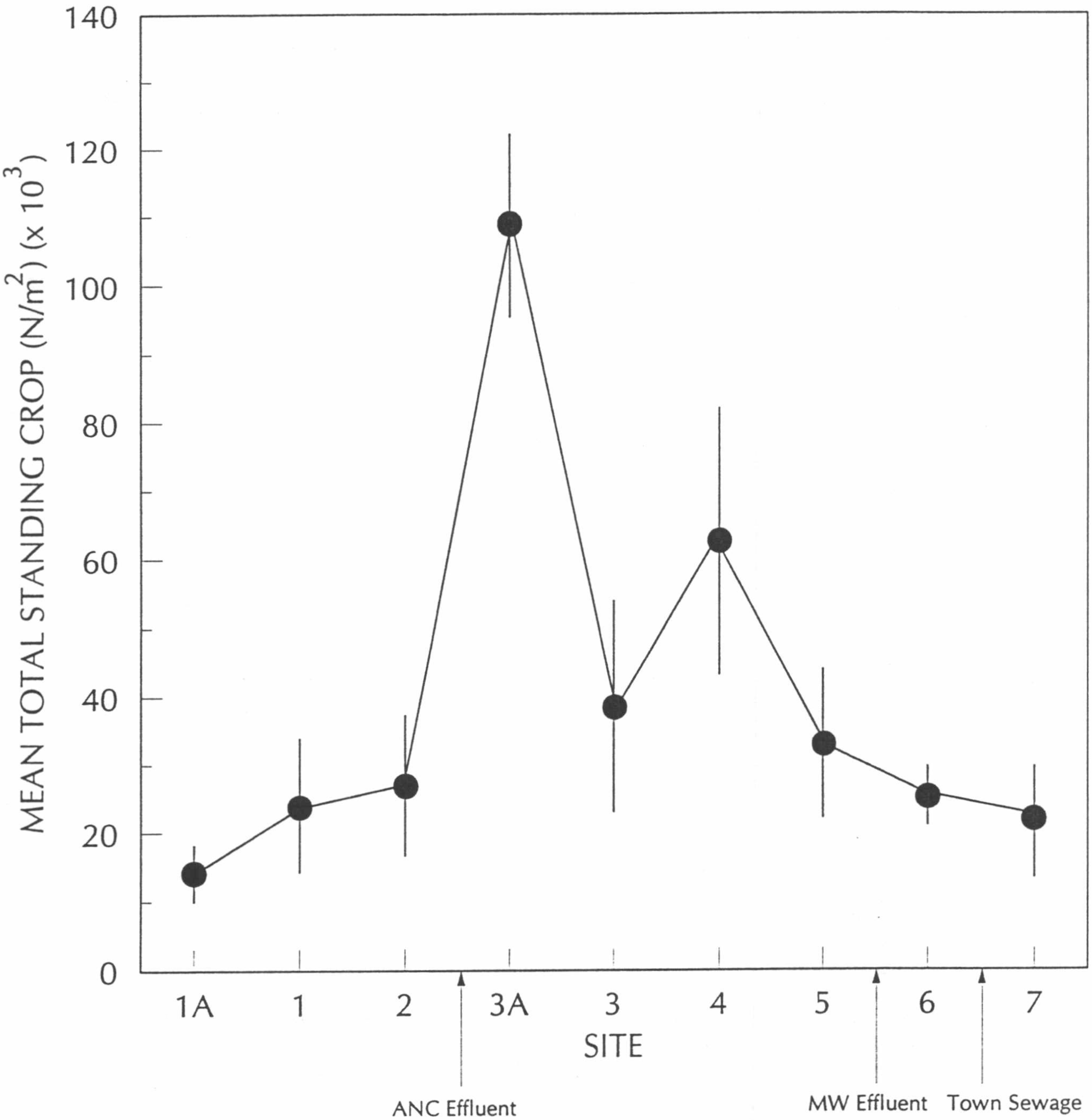



**Figure 11.** **Mean standing crop (number/m²) with 95% confidence limits for sites on the Athabasca River, October 1994.**

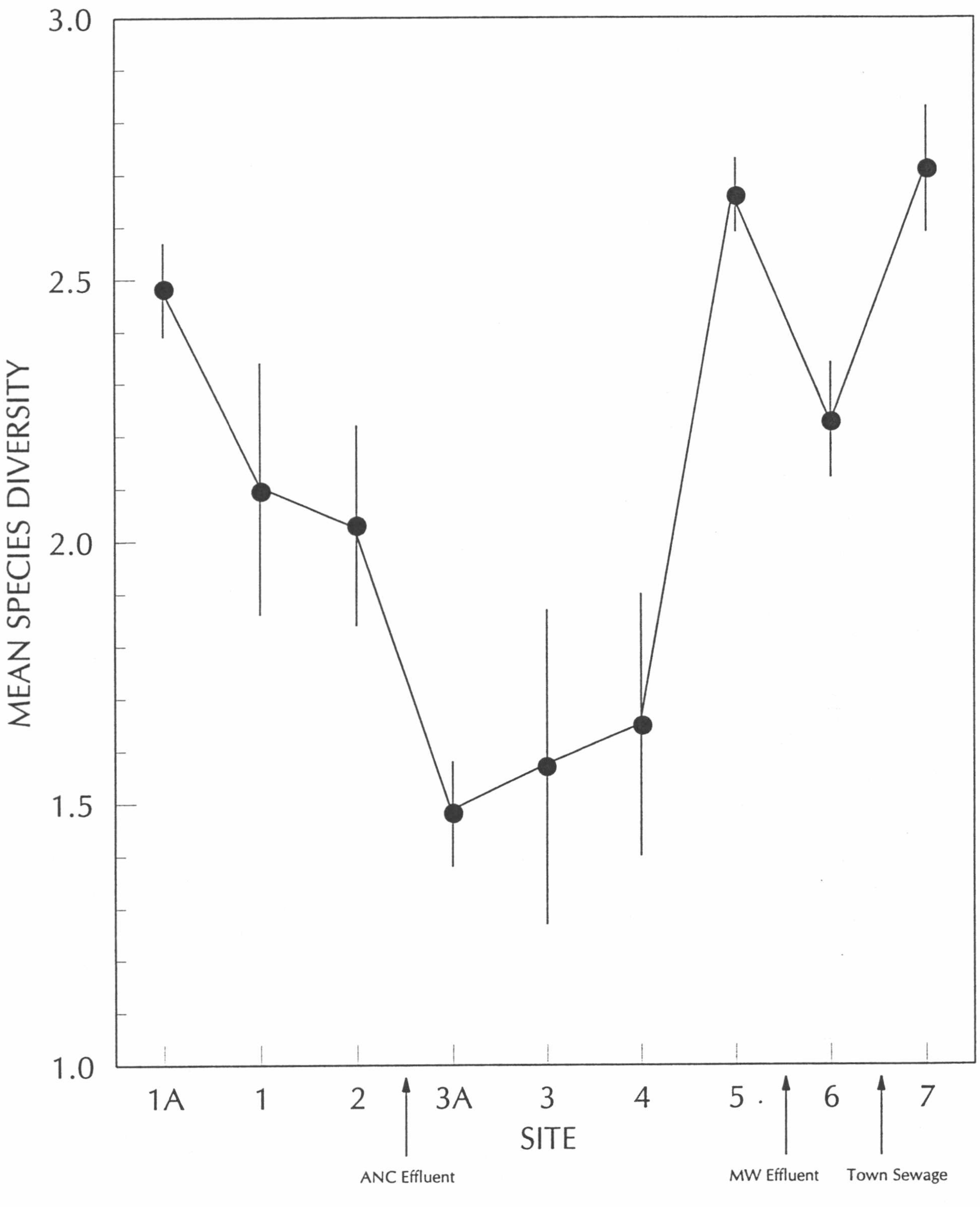



**Figure 12.** **Mean Shannon-Weaver species diversity with 95% confidence limits for sites on the Athabasca River, October 1994.**

similar to or slightly higher than at background sites. A low species diversity indicates that the majority of organisms present belong to only a few taxa and that other fauna are low in numbers, thus causing an uneven distribution.

The mean species diversity at all downstream sites (mean 2.05) was slightly lower than at background sites (mean 2.20). The mean species diversity at near-field sites (mean 1.84) was lower than at far-field sites (mean 2.47).

Chironomidae (midges) was the dominant taxonomic group at all sites, followed by Ephemeroptera (mayflies), Oligochaeta (aquatic worms) and remaining groups (fly larvae, beetles, water boatmen, dragonflies, water mites, seed shrimps, roundworms, snails and flatworms) (Figure 13). Trichoptera (caddisflies) and Plecoptera (stoneflies) were also present but in smaller numbers. The mean standing crop of Chironomidae was higher at all downstream sites, especially at Sites 3A, 3 and 4, than at background sites. The mean standing crop of Ephemeroptera was higher at Sites 3A, 4 and 5 than at background sites, while at all other downstream sites it was similar to background sites. The mean standing crop of Oligochaeta was highest at background Site 2 and downstream Site 4. At all other downstream sites, the mean standing crop of Oligochaeta was similar to or slightly higher than at background Sites 1A and 1. The mean standing crop of the remaining groups was highest at Site 3A, while at all other downstream sites it was similar to background sites. The mean standing crop of Trichoptera was higher at all downstream sites than at background sites, except at downstream Site 3 where it was similar. The mean standing crop of Plecoptera was similar at all downstream sites to background sites, except at Site 3A where it was higher.

ANOVA indicated that there were significant differences in the mean number (or standing crop) of EPT and the mean number of Chironomidae between sites ($p < 0.05$) (Appendix G). The orthogonal contrasts showed that the number of EPT and the number of Chironomidae were significantly higher at downstream sites than at background sites ($p < 0.05$). They were also significantly higher at near-field sites than at far-field sites ($p < 0.05$).

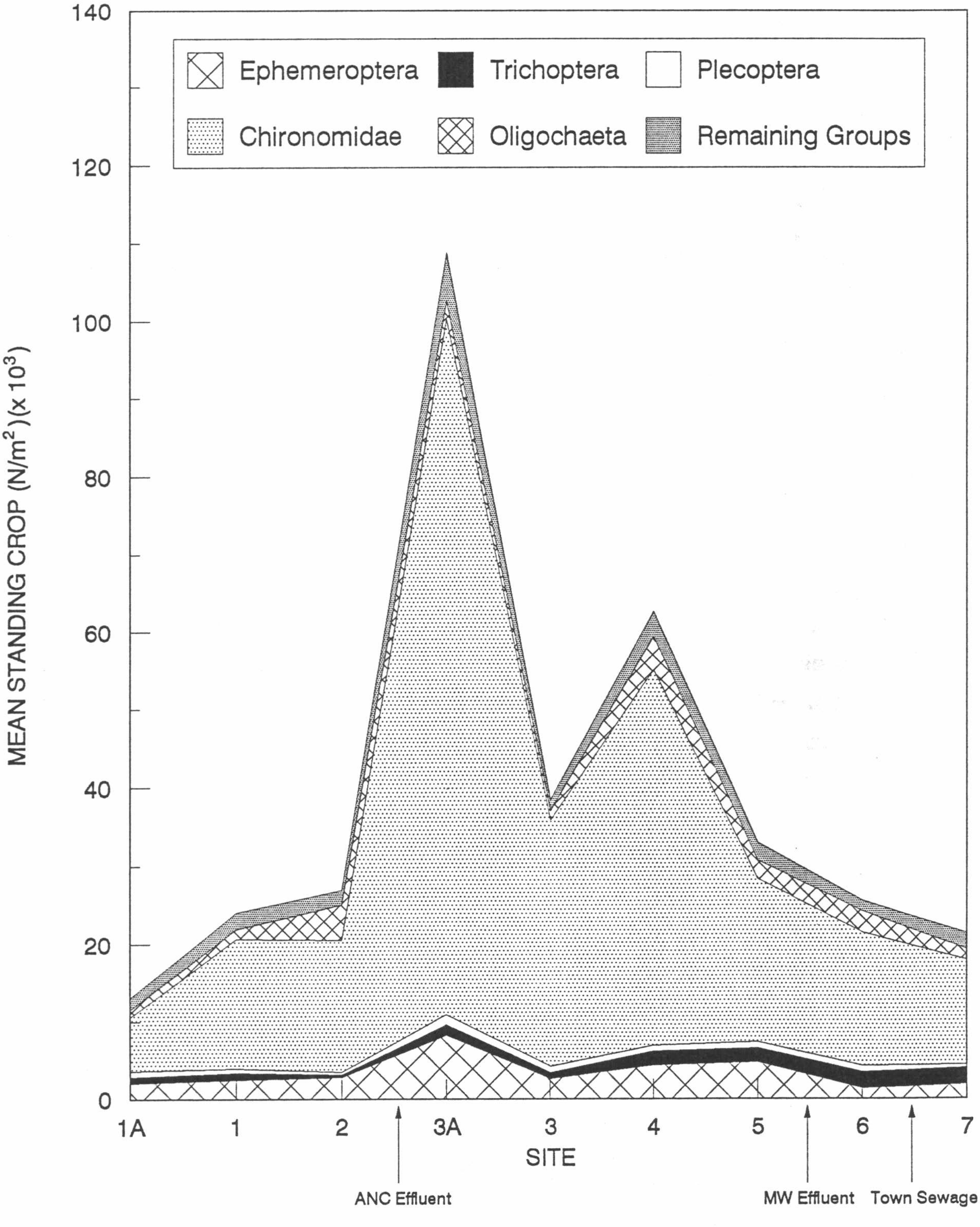



**Figure 13.** Mean cumulative standing crop (number/m$^2$) of the major taxonomic groups for sites on the Athabasca River, October 1994.

### 3.4.2 Community Analysis

The result of the RA analysis is shown as a species dominance distribution matrix for each sample site (Appendix H). This result was plotted as a two-axes (X and Y) ordination for site scores on a scale of 0 to 100 (ordination units) on each axis.

The site ordination indicated three sample clusters (Figure 14). Cluster I consisted of the main group of sites (Sites 1A, 1, 2, 3A, 3, 4 and 6), Cluster II of Site 7 and Cluster III of Site 5. A cluster of samples represents those which have similar benthic community assemblages. The degree of faunal homogeneity between samples within a cluster is represented by the closeness of the samples within the cluster.

The dominant benthic community assemblage characteristic of each cluster, in order of numerical dominance (Appendix H), was a follows:

Cluster I: *Cricotopus/Orthocladius* spp., *Rheotanytarsus* sp., Naididae, *Ephemerella inermis*, Hydracarina, *Brachycentrus* sp.

Cluster II: *Cricotopus/Orthocladius* spp., *Rheotanytarsus* sp., Hydracarina, *Ephemerella inermis*, Naididae, *Brachycentrus* sp.

Cluster III: *Cricotopus/Orthocladius* spp., *Rheotanytarsus* sp., *Eukiefferiella* sp., *Ephemerella inermis*

The mean standing crops (number/m$^2$) of the dominant taxa identified by RA for each site are shown in Figure 15.

A number of taxa have been found to respond to organic enrichment by increasing in numbers as a response to an increase in food availability, if oxygen is not limiting (Hynes 1960, Roback 1974, Godfrey 1978). Most of the dominant taxa within each cluster have been found to respond to organic enrichment from either natural or anthropogenic sources.

A gradient of organic enrichment appeared to exist between sites during the fall survey as indicated by the numbers of one chironomid, *Cricotopus/Orthocladius* spp. (Orthocladiinae) (Appendix H). This chironomid was dominant in all clusters with increasing numbers in samples across the X-axis from left to right (i.e. increased in abundance from samples in Cluster III to Cluster II to Cluster I) (Figure 14). Orthocladiinae,

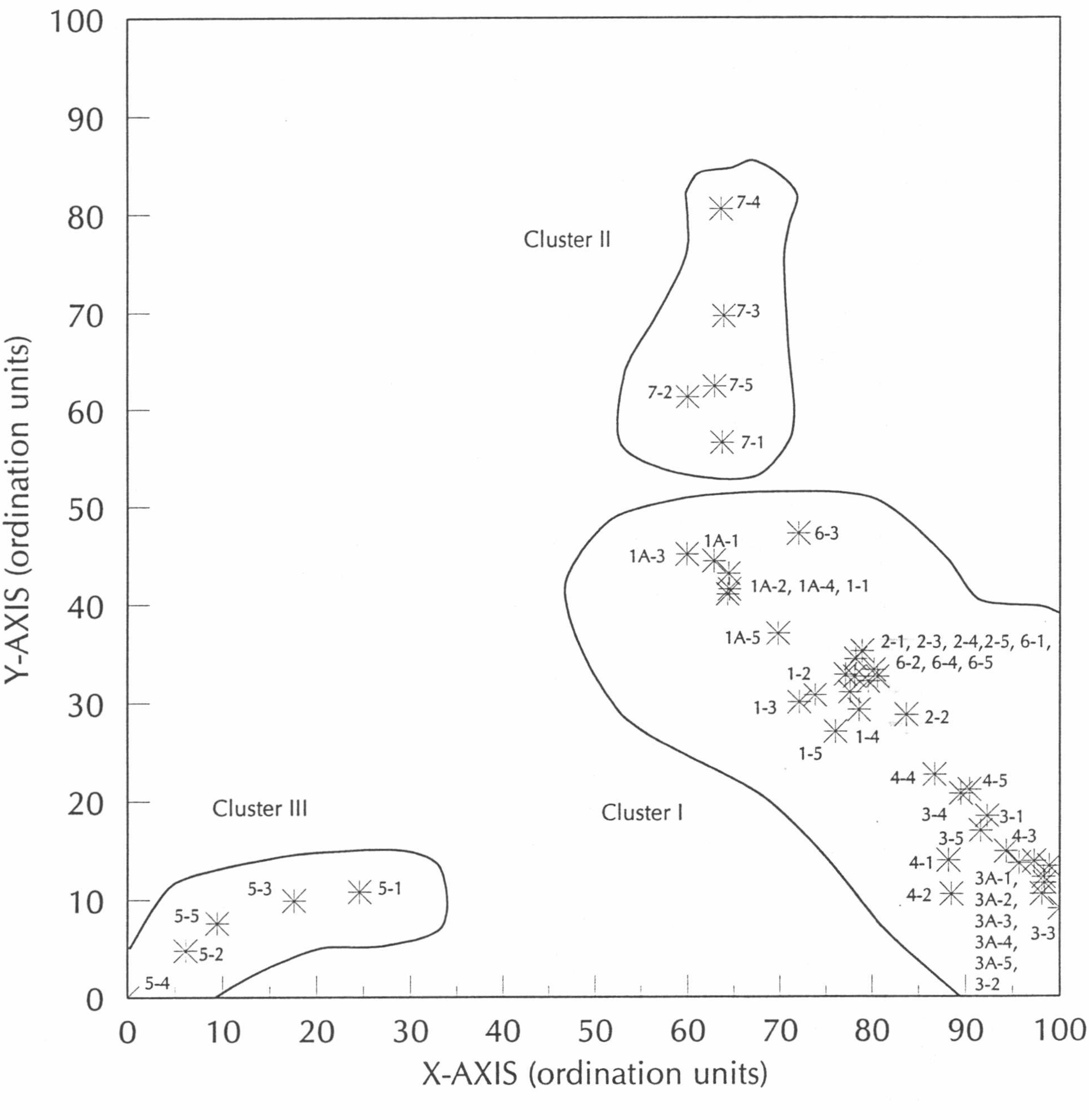



**Figure 14.** **Reciprocal averaging ordination of site scores, October 1994.**

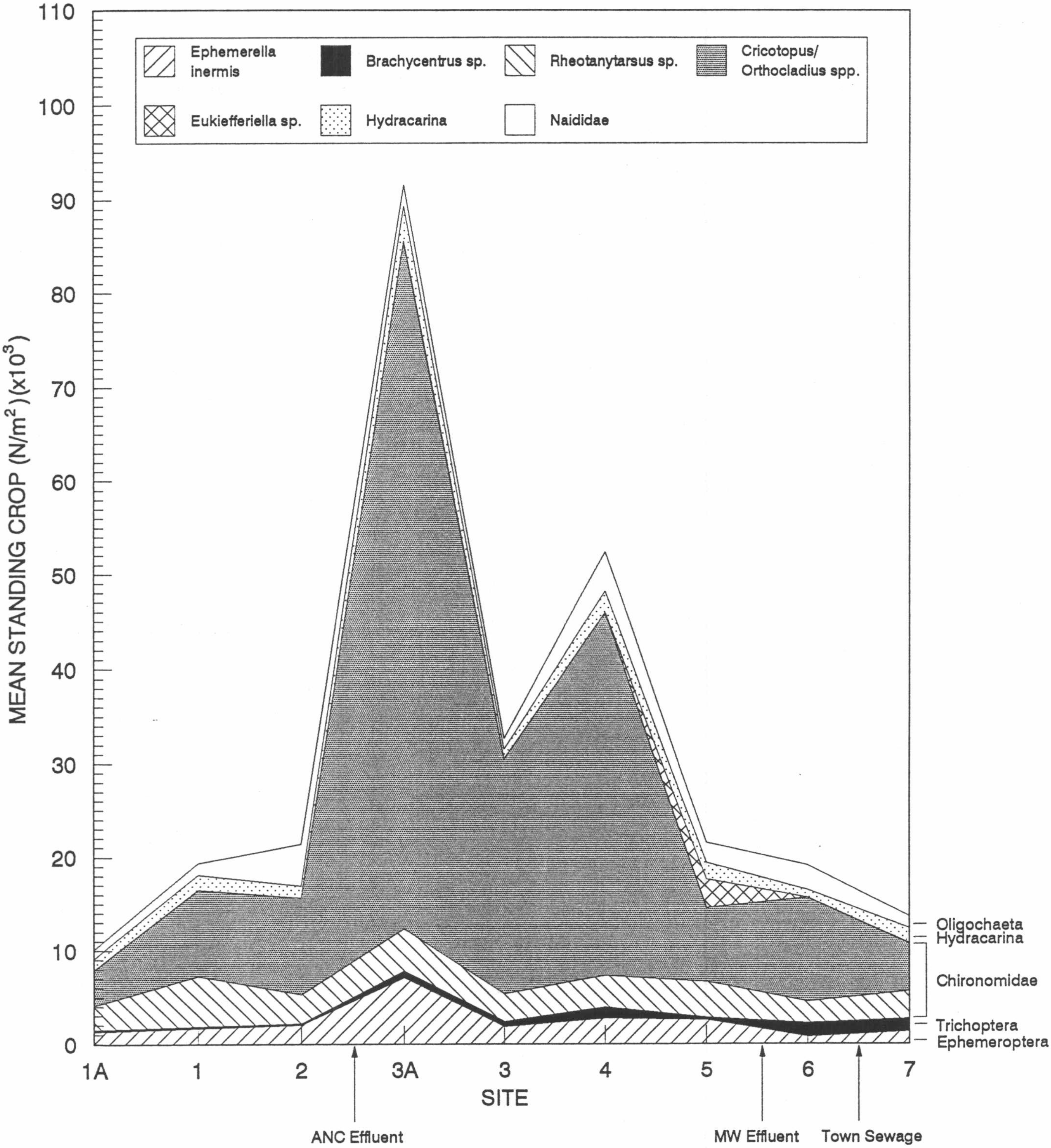



**Figure 15.** Mean cumulative standing crop (number/m$^2$) of the dominant taxa identified by RA for sites on the Athabasca River, October 1994.

such as *Cricotopus/Orthocladius* spp., have been found to respond to mild organic enrichment (Hynes 1960).

All downstream sites, except Site 5 (Cluster III) and Site 7 (Cluster II), had a similar benthic community structure to background sites (Cluster I). The main group of sites (Cluster I) was dominated by two chironomids (*Cricotopus/Orthocladius* spp. and a Chironominae, *Rheotanytarsus* sp. of the Tanytarsini Tribe), an Oligochaeta (Naididae), an Ephemeroptera (*Ephemerella inermis*), Hydracarina and a Trichoptera (*Brachycentrus* sp.). The separation of Site 7 (Cluster II) from the main group of sites indicated that there were some differences in the benthic community structure of Site 7 and the main group of sites. Site 7 was dominated by the same dominant taxa as the main group of sites, except that there was a shift in the dominance of Hydracarina and Naididae, so that Hydracarina was more dominant than Naididae at Site 7, whereas Naididae was more dominant than Hydracarina in the main group of sites.

The benthic community structure of downstream Site 5 (Cluster III) differed from all other sites. Site 5 was dominated by three of the six taxa dominant in the main group of sites and one additional taxa; three chironomids (*Cricotopus/Orthocladius* spp., *Rheotanytarsus* sp. and another Orthocladiinae, *Eukiefferiella* sp.) and an Ephemeroptera (*Ephemerella inermis*). The chironomid, *Eukiefferiella sp.* was dominant at Site 7 but was not dominant at any of the other sites.

Chironominae of the Tanytarsini Tribe (such as *Rheotanytarsus* sp.), like Orthocladiinae, have been found to respond to mild organic enrichment where oxygen levels are not seriously depressed (Hynes 1960). Most Ephemeroptera are grazers, feeding principally on algae and detrital materials (Merritt and Cummins 1984) and thus species, such as *Ephemerella inermis*, are suited to mild organic enrichment (Hynes 1960, Roback 1974). Trichopteran larvae construct various retreats, nets and cases which function as shelter and for food capture. *Brachycentrus* sp. (Bachycentridae) is a case builder and also a filter feeder, and has been reported to be more sensitive to organic loading than other Trichoptera, such as Hydropsychidae (Roback 1974). The Oligochaeta have been found to be reliable indicators of organic enrichment. The Naididae, in particular, have been found to thrive in organically enriched water, when a good supply of oxygen is provided by a current or turbulence (Hynes 1960). Hydracarina, which can be very numerous in both standing and running water, are active predators on small crustaceans or aquatic insect eggs and larvae (Clifford 1991).

During the fall 1994 survey, as in previous surveys (Luoma and Shelast 1991, 1992, 1993, 1994), the dominant benthic community structure of the background sites indicated the presence of some mild organic enrichment. The ANC effluent appeared to contribute additional organic enrichment to the river at Sites 3A, 4 and 5 (as indicated by the standing crop), however, there was a shift in the benthic community structure only at Site 5. This shift did not appear to have occurred at other downstream sites, where the benthic community structure was similar to background sites. The lower standing crop of organisms at Sites 6 and 7, and the similarity of their benthic community structure to background sites indicated that the Millar Western and Whitecourt sewage treatment effluents did not appear to contribute any additional organic enrichment to the river at these sites. Some recovery of the river may have been occurring at these two farthest dowstream sites.

### 3.4.3 Trophic Analysis

A trophic (feeding group) analysis of the benthic data was conducted to determine if there were any differences in benthic community trophic structure between sites. The availability of food is a factor which controls the occurrence and abundance of benthic invertebrates species (Hynes 1972). The percent of each functional group of the total number of organisms for all samples are presented in Appendix I.

The trophic analysis showed that all sites were dominated by detritivore/herbivores and detritivores (Figure 16). The detritivore/herbivores formed 36.3 to 77.4% and the detritivores formed 16.7 to 38.2 % of the total benthic fauna. A dominance of detritivore/herbivoress and detritivores is a common natural trait of streams in North America (Egglishaw 1964, Minshall 1967, Hynes 1972, Fisher and Likens 1972, Cummins et al. 1973). The carnivores formed 4.2 to 15.0% and the omnivores formed 0.9 to 9.5% of the total benthic fauna. All other groups formed less than 2% of the total benthic fauna.

The percent contribution of the dominant feeding groups for each cluster of sample sites (using individual samples) identified by RA was as follows:

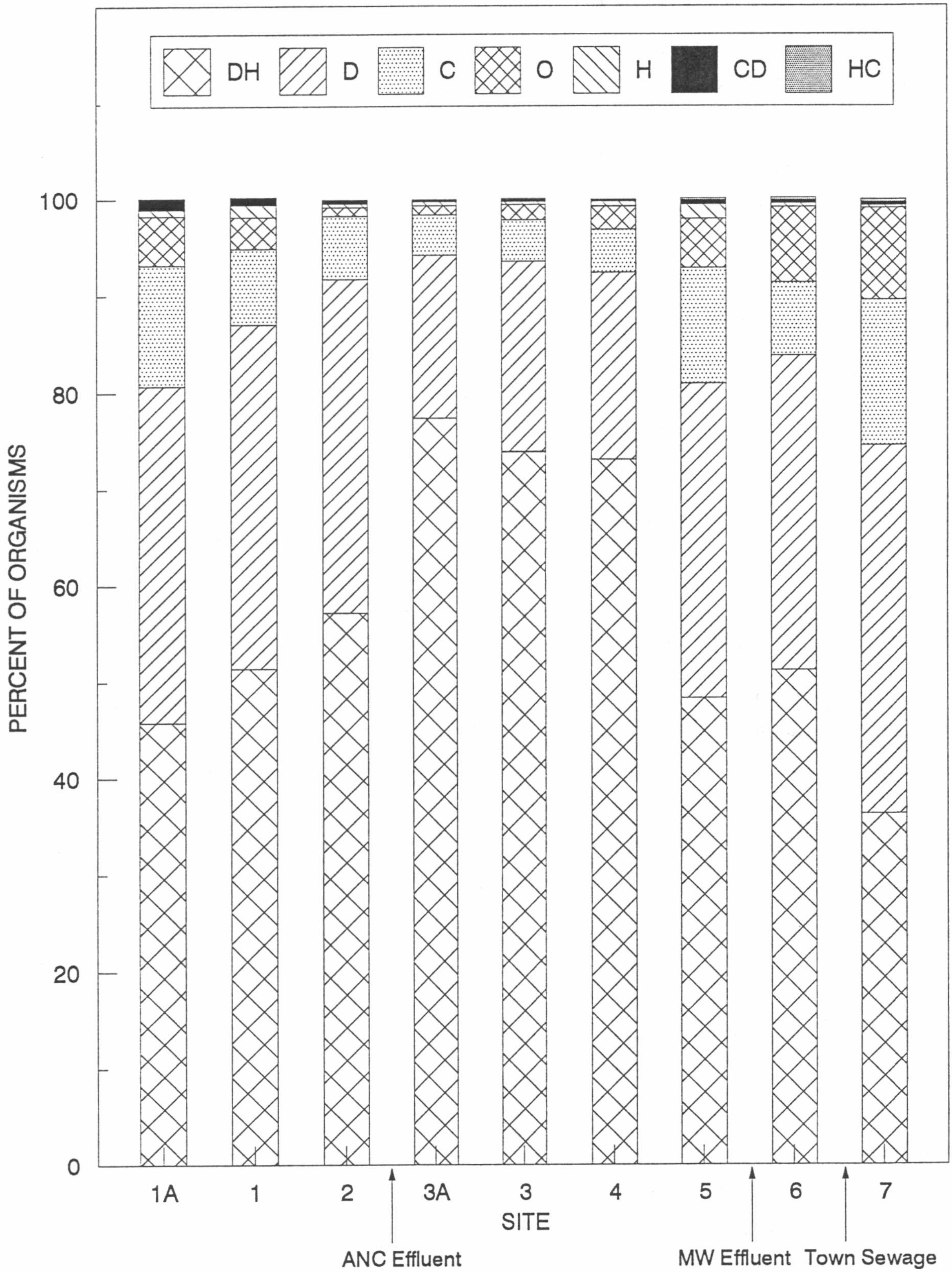



**Figure 16.** **Percent composition of benthic invertebrate functional feeding groups for sites on the Athabasca River, October 1994.**

| Cluster | DH | D | C | O |
|---|---|---|---|---|
| I (main group) | 41.5 - 82.2 | 12.8 - 39.5 | 1.9 - 14.7 | 0.3 - 13.2 |
| II (Site 7) | 32.1 - 40.2 | 35.5 - 42.9 | 10.9 - 20.5 | 6.5 - 11.3 |
| III (Site 5) | 46.0 - 50.9 | 30.4 - 35.1 | 10.9 - 14.3 | 2.3 - 7.3 |

The dominant detritivore/herbivores were *Cricotopus/Orthocladius* spp., *Eukiefferiella* sp. and *Ephemerella inermis*, the dominant detritivores were *Rheotanytarsus* sp. and Naididae, the dominant carnivore was Hydracarina and the dominant omnivore was *Brachycentrus* sp. Cluster I (main group of sites) had higher percentages of detritivore/herbivores than detritivores, followed by carnivores and omnivores. The higher percentages of detritivore/herbivores was the result of higher numbers of *Cricotopus/Orthocladius* spp. Cluster II (Site 7) had similar percentages of detritivore/herbivores and detritivores, followed by carnivores and then omnivores. The lower percentages of detritivore/herbivores in Cluster II compared to Cluster I was the result of lower numbers of *Cricotopus/Orthocladius* spp. and the higher percentages of carnivores was the result of higher numbers of Hydracarina (Figure 15). Cluster III (Site 5) had slightly higher percentages of detritivore/herbivores than detritivores, followed by carnivores and then omnivores. The lower percentages of detritivore/herbivores in Cluster III compared to Cluster I was the result of lower numbers of *Cricotopus/Orthocladius* spp., but the higher percentages in Cluster III compared to Cluster II was the result of higher numbers of *Eukiefferiella* sp. (Figure 15).

The trophic analysis indicated that there were some differences in feeding group structure between the groups of sites identified by the RA analysis. Increases or decreases in the numbers of detritivore/herbivores, detritivores, carnivores and omnivores caused shifts in the feeding group structure between sites. This occurred as a result of the change in the nature of the food supply caused by mild organic enrichment in this reach of the Athabasca River.

### 3.4.4 Organic Enrichment

Phosphorus is the nutrient that limits productivity in most freshwater ecosystems (Wetzel 1975). Increasing concentrations of phosphorus in streams often result in organic enrichment which increases biomass of algae, aquatic macrophytes and associated biota. Phosphorus inputs into the aquatic ecosystem can occur through either natural or anthropogenic sources. Natural sources of phosphorus include drainage from agricultural land, as well as leaching from soils that are high in phosphorus content (Hynes 1972). Effluents from pulp mills and sewage treatment plants can also elevate the phosphorus concentrations in receiving streams. Phosphorus is added to pulp mill effluents to enhance biological degradation of the pulping wastes. Benthic invertebrate enrichment has been reported downstream of pulp mills and sewage treatment plants as a result of organic loading from the effluents (Hynes 1972, Bothwell and Stockner 1980, Rabeni et al. 1985, Noton et al. 1989).

Organic enrichment usually results in a decrease in the number of taxa and an increase in the number of organisms (Lenat et al. 1980). Organic enrichment increases the food energy available in a system and in general, it is accompanied by an increased oxygen demand. This is a result of increased oxygen use by organisms (mainly bacteria) utilizing the additional food energy resources. The community structure may change such that organisms tolerant of low oxygen levels dominate the community and taxa intolerant of reduced oxygen conditions become eliminated over time. The additional food energy resources are available for use by tolerant taxa, such as Chironomidae (chironomids) and Oligochaeta (aquatic worms). They may be directly or indirectly used as a food resource and there may also be a reduction in predation and competition for the remaining species. In cases where organic enrichment does not result in a change in oxygen demand (such as for mild or moderate enrichment, or when oxygenation is maintained by a series of riffles in a lotic system), enrichment will tend to result in an increase in both the number of organisms and the number of taxa (Pearson and Rosenberg 1978, Rabeni et al. 1985, Noton et al. 1989).

The highest chlorophyll *a* value was found at Site 3A, which also had the highest standing crop of benthic invertebrates during the fall survey. A similar pattern of increases and decreases between sites occurred between chlorophyll *a* values and the standing crop of benthic invertebrates (Figures 9 and 11). The relationship between the amount of chlorophyll a and the standing crop of organisms (i.e. the higher the chlorophyll *a* value, the higher the standing crop) occurred at most sites (not at Sites 3, 5 and 7).

The increase in mean standing crop of benthic invertebrates at downstream Site 3A, and to a lesser extent at Sites 3, 4 and 5, in comparison to background sites, was likely the result of organic loading from the ANC effluent. Tolerant taxa, mainly Chironomidae, as well as intolerant taxa (Ephemeroptera and Trichoptera), increased in numbers at these sites, as a response to the organic enrichment. There was no decrease in the number of taxa at downstream sites, and in fact, there was a significant increase in the total number of taxa and the number of EPT taxa at downstream sites, indicating that only mild enrichment was occurring in the Athabasca River as a result of the organic loading from the ANC effluent.

### 3.4.5 Comparison of Pre-Operational and Operational Surveys

To assess the effects of pulp mill effluent on the benthic invertebrates of the Athabasca River, a comparison was made between the fall pre-operational and operational surveys. Pre-operational conditions existed in the fall of 1989, while start-up conditions existed in the fall of 1990. Operational conditions existed during the fall of 1991 to 1994.

The benthic community structure can differ between years as a result of numerous factors, such as hydraulic and other physical habitat conditions in the river. However, a comparison between pre-operational and operational data can be of importance in determining impact trends in the benthic community structure. A statistical test of whether the ANC discharge has affected benthic communities was conducted by comparing spatial differences or patterns before and after the mill became operational (i.e. combine temporal contrasts with spatial contrasts).

A repeated measures design was used to analyze five variables, consisting of total number of taxa, number of EPT taxa, total number of organisms (standing crop), number of EPT and number of Chironomidae (Table 7) (Appendix J). The total number of taxa, the number of EPT taxa, the total number of organsims, the number of EPT and the number of Chironomidae were log transformed.

The fall data for the five variables are represented in graphs which compare the background sites (Sites 1 and 2), near-field sites (Sites 3, 4 and 5) and far-field sites (Sites 6 and 7) between the six years (Figures 17 to 21). The mean species diversity was also graphed to show the trends over the six years (Figure 22). The two EEM sites (Sites 1A and 3A) were not included in these analyses since there are no pre-operational data for these sites.

There were no significant differences ($p > 0.05$) between downstream sites and background sites between the one pre-operational and five operational years, for any of the five variables during the fall. There were also no significant differences ($p > 0.05$) between

**Table 7.** **Results of repeated measures analyses of benthic community variables for fall samples, 1989 to 1994. Values are probabilities (p).**

| Contrast | | Variable | | | | |
|---|---|---|---|---|---|---|
| **Temporal** | **Spatial** | **Number of Taxa** | **Number of EPT Taxa** | **Number of Organisms** | **Number of EPT** | **Number of Chironomidae** |
| 1989, vs 1990, 1991 | BG vs DS | 0.152 | 0.170 | 0.455 | 0.204 | 0.547 |
| 1992, 1993, 1994 | NF vs FF | 0.720 | 0.698 | 0.105 | 0.588 | 0.065 |
| 1989 vs 1994 | BG vs DS | 0.142 | 0.521 | 0.908 | 0.380 | 0.834 |
| | NF vs FF | 0.816 | 0.514 | 0.016* | 0.060 | 0.012* |
| Year X Area Interaction | | 0.227 | 0.123 | 0.157 | 0.792 | 0.079 |

DS Downstream
BG Background
NF Near-Field
FF Far-Field
* These probabilities were significant ($p < 0.05$) (i.e. means are not the same). The p value is the probability under the null hypothesis (or the probability if the null hypothesis is true, i.e. means are the same) of obtaining a value as "unusual" as or more "unusual" than the one we actually obtained from the sample.

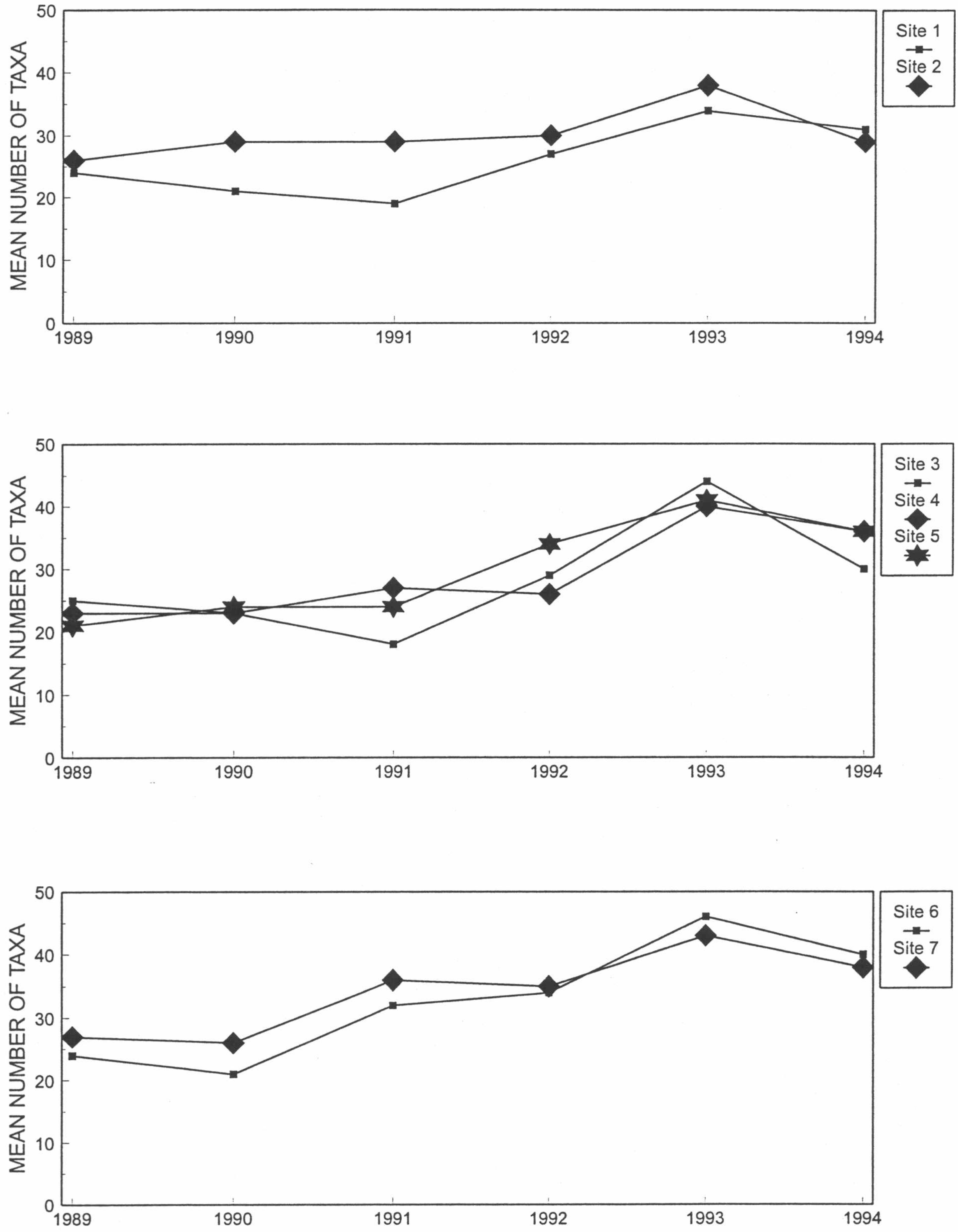



**Figure 17.** **Comparison of mean total number of taxa for background sites (Sites 1 and 2), near-field sites (Sites 3, 4 and 5) and far-field sites (Sites 6 and 7) from fall 1989 to 1994.**

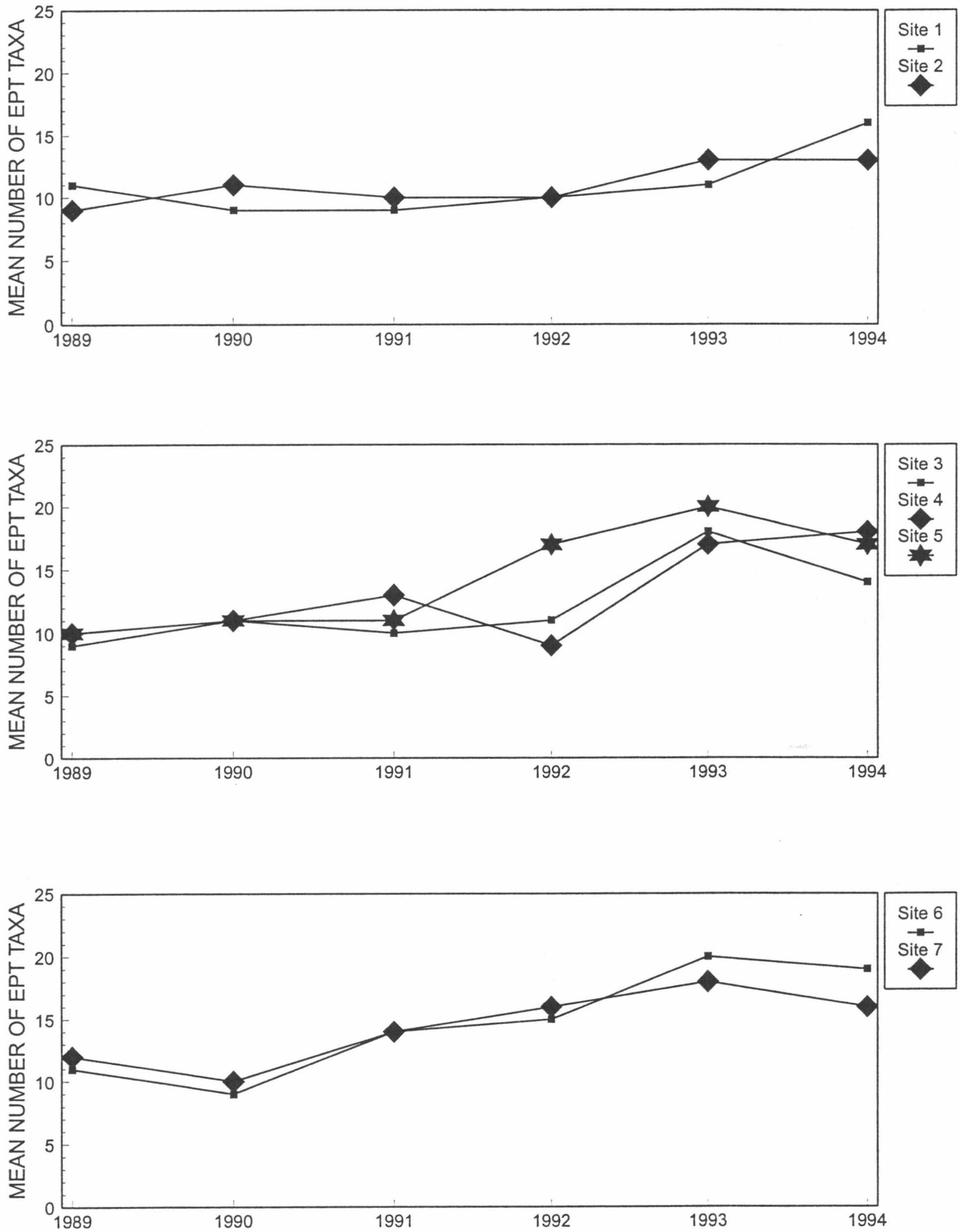



**Figure 18.** **Comparison of mean number of EPT taxa for background sites (Sites 1 and 2), near-field sites (Sites 3, 4 and 5) and far-field sites (Sites 6 and 7) from fall 1989 to 1994.**

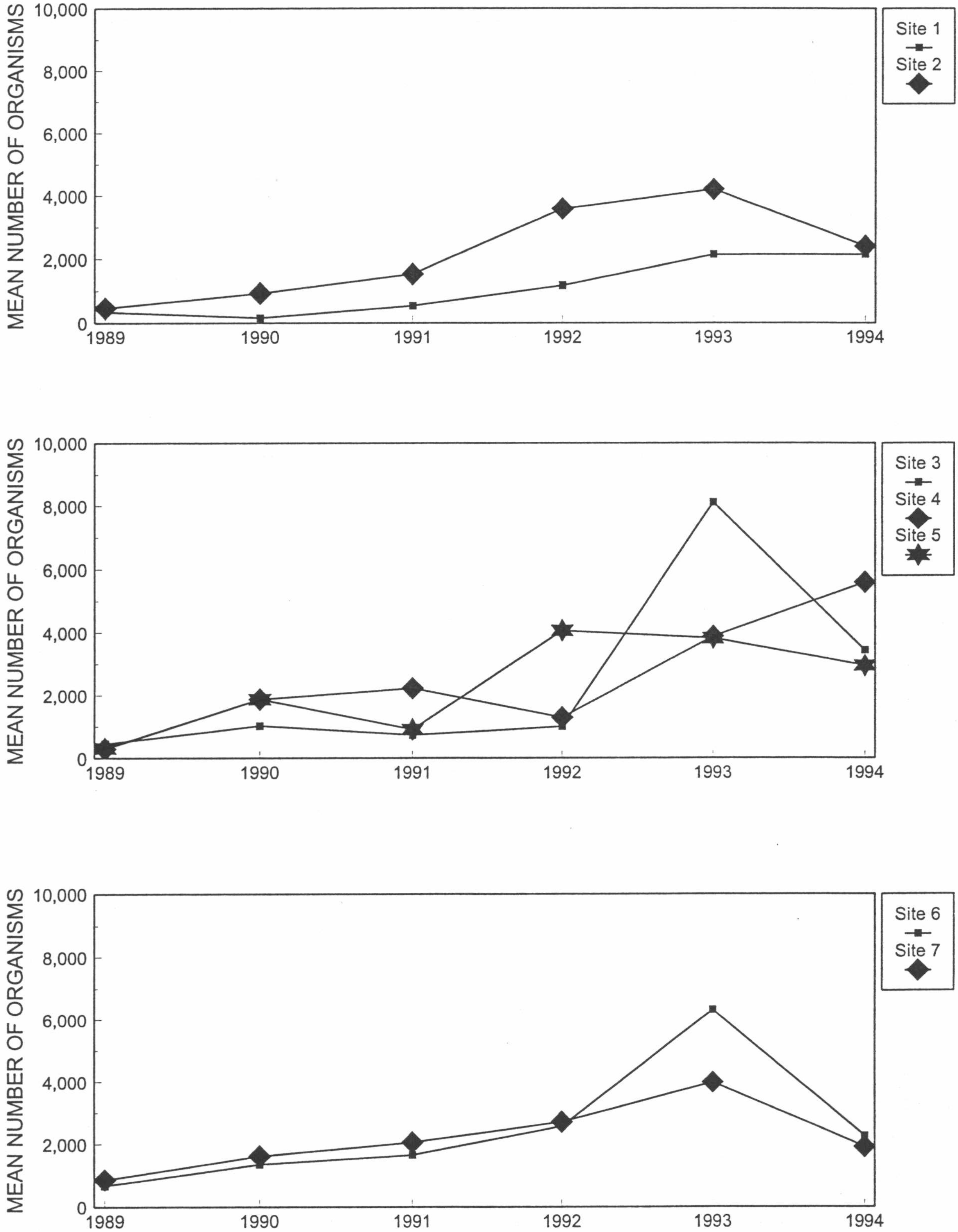



**Figure 19.** **Comparison of mean number of organisms for background sites (Sites 1 and 2), near-field sites (Sites 3, 4 and 5) and far-field sites (Sites 6 and 7) from fall 1989 to 1994.**

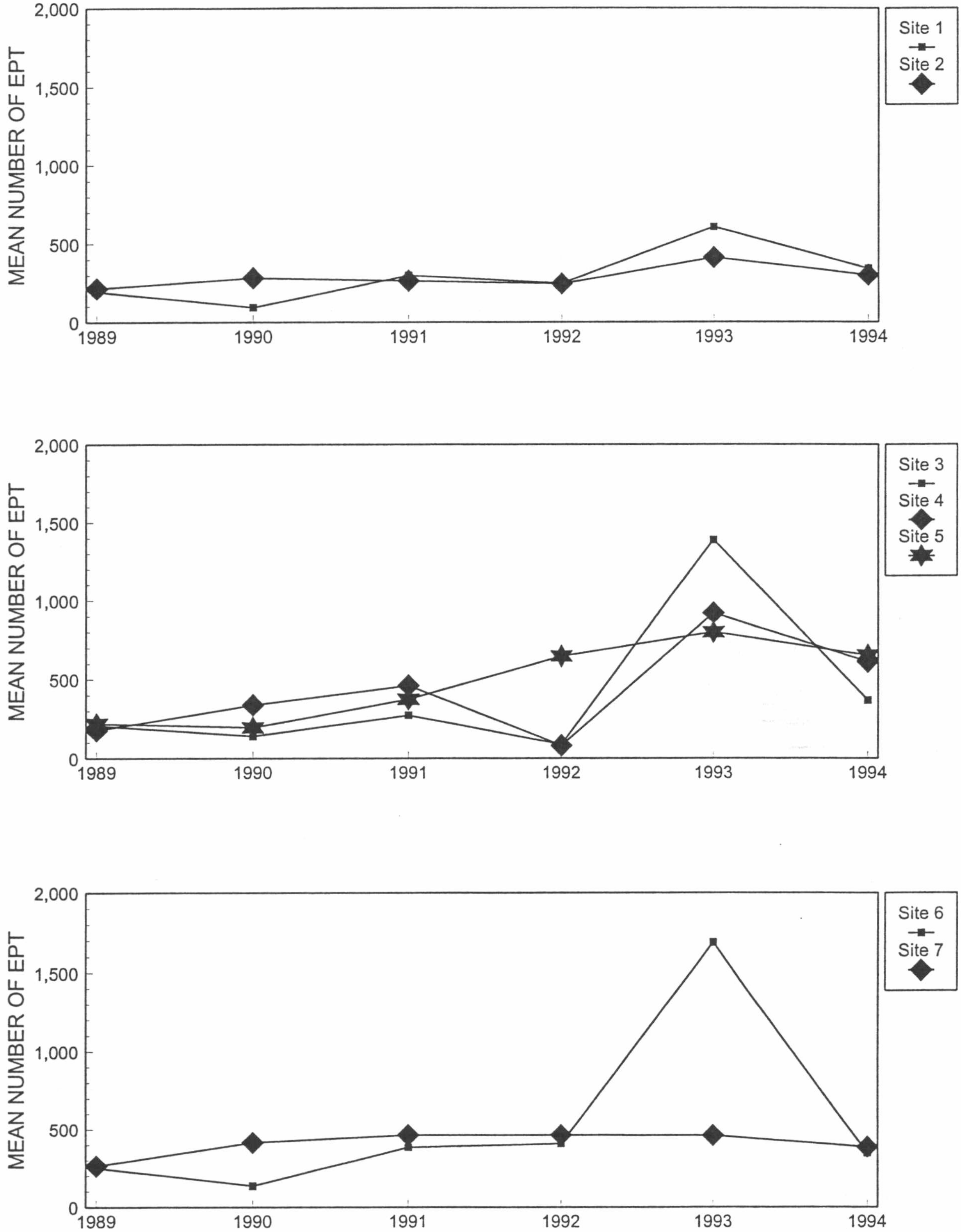



**Figure 20.** **Comparison of mean number of EPT for background sites (Sites 1 and 2), near-field sites (Sites 3, 4 and 5) and far-field sites (Sites 6 and 7) from fall 1989 to 1994.**

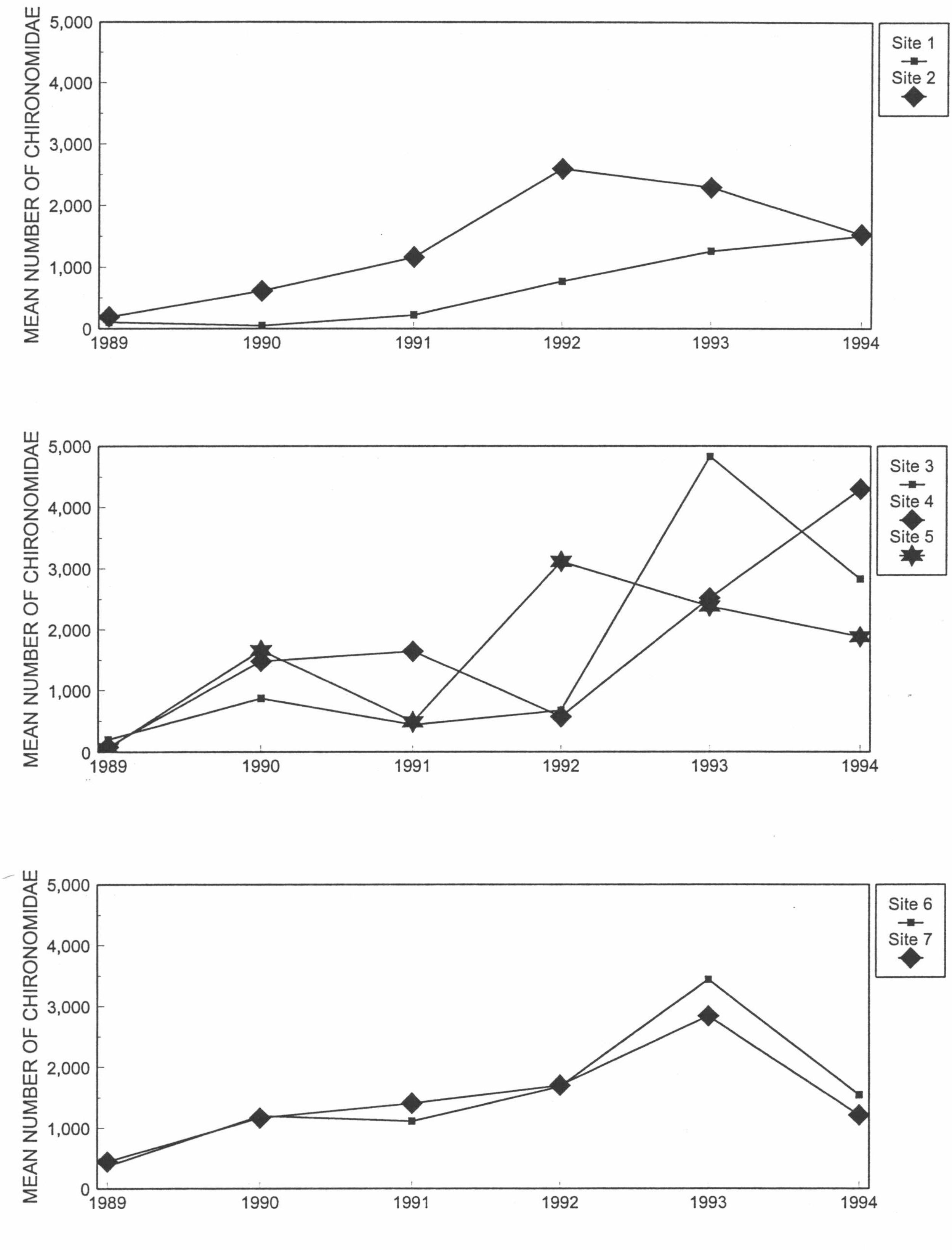



**Figure 21.** **Comparison of mean number of Chironomidae for background sites (Sites 1 and 2), near-field sites (Sites 3, 4 and 5) and far-field sites (Sites 6 and 7) from fall 1989 to 1994.**

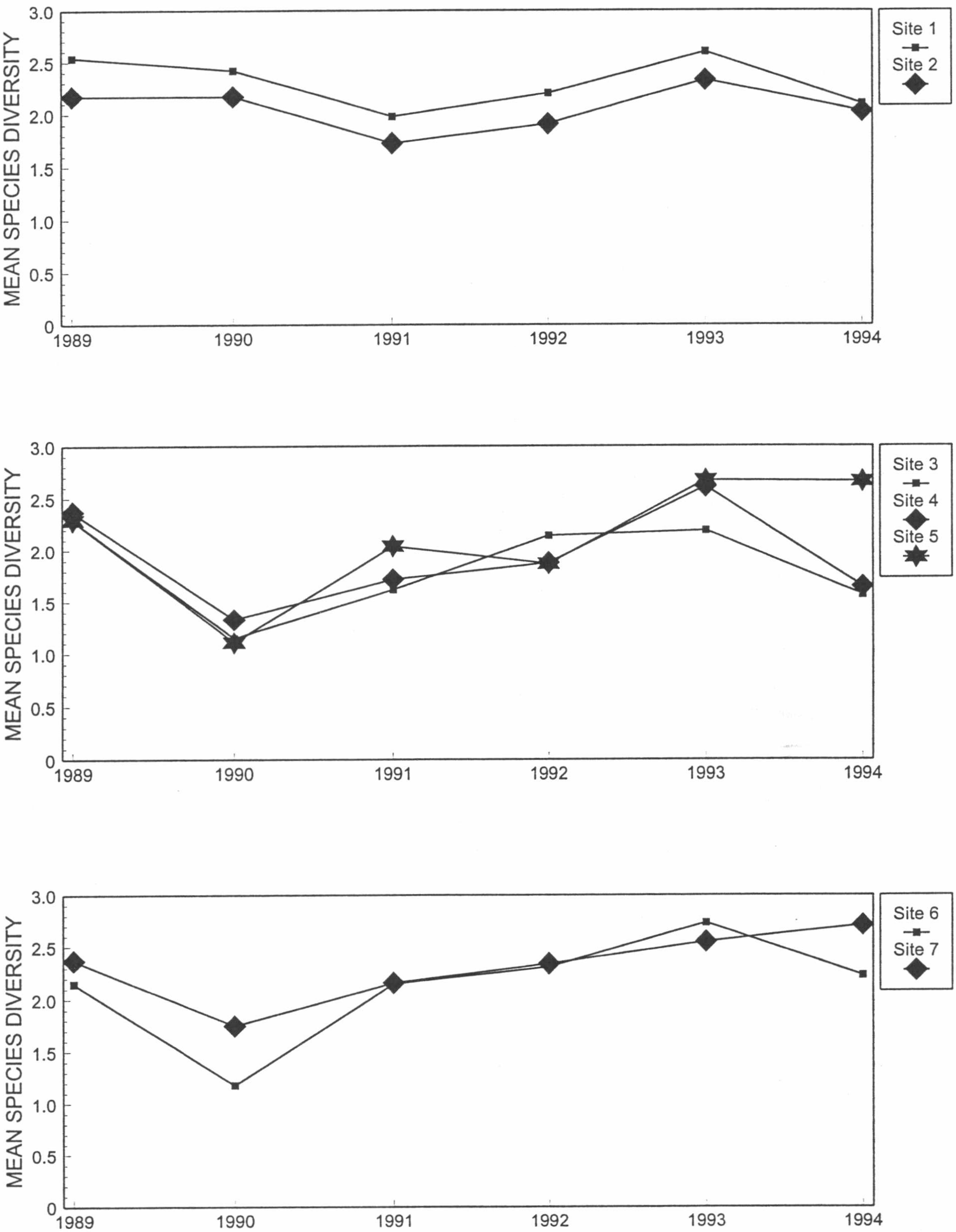



**Figure 22.** **Comparison of mean species diversity for background sites (Sites 1 and 2), near-field sites (Sites 3, 4 and 5) and far-field sites (Sites 6 and 7) from fall 1989 to 1994.**

near-field sites and far-field sites between the one pre-operational and five operational years, for any of the five variables.

When comparing 1994 with the pre-operational year (1989), there were no significant differences ($p > 0.05$) between downstream sites and background sites for any of the five variables. There were also no significant differences ($p > 0.05$) between near-field sites and far-field sites between 1989 and 1994 for the total number of taxa, the number of EPT taxa and the number of EPT, however the total number of organisms and the number of Chironomidae were significantly higher at near-field sites than far-field sites in 1994 than 1989.

The graphs showed that following a general trend of increases in most cases for the five variables from 1989 to 1993, there were decreases between 1993 and 1994 at most of the sites or in a few cases the values were similar between 1993 and 1994 (Figures 17 to 21). The number of EPT taxa, the number of organisms and the number of Chironomidae increased only at Sites 1 and 4 between 1993 and 1994 (Figures 18, 19 and 21).

The mean species diversity has fluctuated over the years. There was a decrease in mean species diversity between 1993 and 1994 at all sites, except at Site 5 where it remained the same and at Site 7 where it increased slightly.

These analyses indicated that there was no evidence of major effects on the benthic community of the river from the ANC discharge, when the impact over all downstream sites was compared between the one pre-operational and five operational years and when far-field effects were compared between the pre-operational and operational years. There was however, evidence of significant increases in the numbers of organisms at near-field sites as a result of organic enrichment from the ANC discharge, when the impact of far-field effects was compared between the pre-operational year (1989) and the operational year of 1994.

## 4.0 SUMMARY AND CONCLUSIONS

There were some variations in the physical characteristics of water velocity and substrate composition, but very little in water depth between sites. Water velocity differences between sites resulted from hydraulic and minor habitat differences between reaches of the river. Generally, these minor differences in physical characteristics do not likely cause any detectable differences in benthic community structure between sites.

The water quality data indicated that the Athabasca River was a well oxygenated, alkaline stream during the fall survey. Effluent discharge from the ANC mill did not affect pH, dissolved oxygen, biochemical oxygen demand, true color or total Kjeldahl nitrogen at downstream sites. Conductivity and total suspended solids concentration at sites below ANC appeared to be marginally affected by effluent discharge. Total phosphorus concentrations were higher at downstream sites than at background sites, likely as a result of effluent inputs.

Detailed water quality analyses at upstream Site 2 and downstream Site 3 indicated that most parameters were below detection limits and/or did not exceed provincial (AASWQIG) or federal (CWQG) guidelines. Metal concentrations, which are not generally a major component of pulp mill effluent, were below detection limits, except for iron, manganese and vanadium which were slightly above background values, but below the AASWQIG and CWQG. Neither resin or fatty acids were detected at Sites 2 or 3, and total resin and fatty acid concentrations in ANC's treated effluent were well below the AASWQIG of 0.1 mg/L.

There appeared to be an effect on periphytic chlorophyll *a* in the river from the ANC effluent. The highest chlorophyll *a* value was found at Site 3A, which also had the highest standing crop of benthic invertebrates during the fall survey. The relationship between the amount of chlorophyll *a* and the standing crop of organisms (i.e. the higher the chlorophyll *a*, the higher the standing crop) occurred at most sites. There was less algal growth in the river, both upstream and downstream of the ANC mill, in the fall of 1994 compared to 1993. This was likely a result of the lower than average summer and fall flows in the Athabasca River in 1993, which caused increased algal growth.

In 1994, the benthic invertebrates of the Athabasca River at downstream sites responded to mild organic enrichment. The increase in mean standing crop of benthic invertebrates at downstream Sites 3A, and to a lesser extent at Sites 3, 4 and 5, in comparison to background sites, was likely the result of organic loading from the ANC effluent. Tolerant taxa, mainly Chironomidae, as well as intolerant taxa (Ephemeroptera and Trichoptera), increased in numbers at these sites, as a response to organic enrichment. This is a typical response to organic enrichment. There was also no decrease in the total number of taxa at downstream sites, and in fact, there was a significant increase in the total number of taxa and the number of EPT taxa, indicating that only mild organic enrichment was occurring in the Athabasca River as a result of organic loading from the ANC effluent. Increases or decreases in the numbers of detritivore/herbivores, detritivores, carnivores and omnivores caused shifts in the feeding group structure between sites. This occurred as a result of the change in the nature of the food supply caused by mild organic enrichment. Mild organic enrichment, due to nutrient addition (phosphorus) from the ANC effluent, has apparently over the years caused an increase in the abundance of tolerant taxa, such as Chironomidae, but oxygen depletion has not been sufficient to cause a decrease in the more sensitive EPT taxa, which have also increased.

The lower standing crop of organisms at Sites 6 and 7, and the similarity of their benthic community structure to background sites indicated that the Millar Western and Whitecourt sewage treatment effluents did not appear to contribute any additional organic enrichment to the river at these sites. Some recovery of the river may have been occurring at these two farthest downstream sites.

The comparison of pre-operational and operational data for the fall indicated that there was no evidence of major effects on the benthic community of the river from the ANC discharge, when the impact over all downstream sites was compared between the one pre-operational and five operational years and when far-field effects were compared between the pre-operational and operational years. There was, however, evidence of significant increases in the numbers of organisms at near-field sites as a result of organic enrichment from the ANC discharge, when the impact of far-field effects was compared between the pre-operational year (1989) and the operational year of 1994.

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## 6.0 SENTAR QUALITY MANAGEMENT PROGRAM

This report, entitled "**A Benthic Invertebrate Monitoring Study on the Athabasca River, Whitecourt, Alberta, 1994**", was produced by the following individuals:

**Maire E. Luoma**
Name

Signature

**Bob M. Shelast**
Name

Signature

This report was reviewed by the following individual:

**Robert C. Scace**
Name

Signature

Approval to transmit to client:

**Robert C. Scace**
Office Manager/Senior Consultant

Signature

# APPENDICES

# APPENDIX A

# QA/QC

# STATEMENT OF SENTAR'S QUALITY ASSURANCE/QUALITY CONTROL

The basis of SENTAR's Quality Assurance/Quality Control (QA/QC) program is the adherence to a Quality Management Plan. SENTAR's QA/QC program is practiced for all types of studies. The QA program consists of externally imposed technical and management practices which ensure that the generation of quality and defensible data commensurate with the intended use of the data. The QC program consists of internal techniques which are used to measure and assess data quality and remedial actions to be taken when the data quality objectives are not realized. The assurance of adequate data is provided through Data Quality Objectives, which encompass all components of uncertainty in data generation.

SENTAR's QA/QC program follows the QA/QC described for conducting Environmental Effects Monitoring (EEM) studies, where appropriate (Environment Canada and Department of Fisheries and Oceans 1993).

## Objective

The objective of SENTAR's QA/QC program is to ensure that data generated for our clients is of known and defensible quality.

## Organization

Project Manager:

- Communicates committment to and delegates responsibility for quality assurance.
- Allocates funds and resources for effective quality assurance.
- Establishes Standard Operating Procedures (SOPs).

Quality Assurance Officer:

- Responsible for approval of all procedures.
- Authority for corrective action.
- Plans and evaluates QA/QC program.
- Reports any plans or problems of QA/QC to management.

Field Supervisor:

- Supervises compliance to QA/QC program.
- Helps establish SOPs.
- Follows approved field, sample and data analyses procedures and reporting of data as outlined in SOPs.

Field/Office Technicians:

- Have appropriate education and experience for the job.
- Follow approved field, sample and data analyses procedures and reporting of data as outlined in SOPs.

## Standard Operating Procedures

SOPs are developed to meet Data Quality Objectives. SENTAR's SOPs outline detailed protocols for sample collection, field procedures, laboratory procedures and reporting of data. Any changes to SOPs during a project are documented and justified.

All SOPs include meticulous record-keeping, proper collection of samples, adequate replication, preservation, shipping and storage of samples, instrument calibration and maintenance and the use of chain-of-custody forms to ensure sample continuity.

## Analytical Laboratories

The operations of any analytical laboratories used by SENTAR include the following Quality Control requirements as appropriate to the specific analysis: method blanks, laboratory duplicates, matrix spikes, analysis of reference materials, calibration control, surrogate spikes and internal standards.

**ALPHA LABORATORY SERVICES LTD.**

QA REPORT FOR: Sentar

ATTENTION: Ms. Maire Luoma

SAMPLE INFORMATION:
Project: 09-786-01-01
Date : 11-Oct

REFERENCE:
Client P.O.:
Alpha Job #: 6906

REPORT:
Date: 24-Oct-94
Verified By: LR
Filename: Cust16.rpt

| DESCRIPTION | DATE | QC CHECK | | | | DUPLICATE CHECK | | | SPIKE CHECK | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PARAMETER -- METHOD | ANALYSED | RESULT | MEAN | 95% CONFIDENCE LIMITS | | a | b | Diff. 95% C.L. | %RECOV. | MEAN | 95% CONFIDENCE LIMITS | |
| Total Phosphate - Stannous Chl( | 18-Oct | 0.16 | 0.14 | 0.11 | 0.17 | 0.03 | 0.02 | 0.02 | 135.00 | 112.32 | 84.96 | 139.68 |
| TKN - Ion Specific Electrode | 20-Oct | 0.24 | 0.25 | 0.22 | 0.28 | 0.66 | 0.70 | 0.04 | 90.00 | 90.63 | 70.80 | 110.47 |
| Color - Vision | 12-Oct | 15.00 | 15.00 | 15.00 | 15.00 | 10.00 | 10.00 | 0.00 | Spike Check Not Applicable | | | |
| Total Suspended Solids - Gravin | 19-Oct | 96.60 | 96.33 | 90.19 | 102.47 | 7.00 | 7.00 | 14.82 | Spike Check Not Applicable | | | |
| Sodium - ICP High Level | 13-Oct | 24.68 | 24.99 | 22.94 | 27.04 | 67.59 | 67.57 | 3.14 | 80.25 | 90.30 | 70.92 | 109.69 |
| B.O.D. - BOD5 | 12-Oct | 7.10 | 7.04 | 4.99 | 9.09 | 115.00 | 102.00 | 12.53 | Spike Check Not Applicable | | | |
| Phenol - Chloroform Extraction | 17-Oct | 24.50 | 24.89 | 22.36 | 27.42 | Duplicate Check Not Applicable | | | 87.50 | 93.10 | 79.20 | 107.00 |
| TOC - Autosampler | 12-Oct | 51.60 | 50.74 | 48.97 | 52.51 | 96.10 | 97.00 | 3.15 | 97.53 | 92.61 | 76.35 | 108.88 |
| Arsenic - Hydride | 21-Oct | 4.216 | 4.649 | 3.137 | 6.162 | 0.001 | 0.001 | 0.001 | 91.35 | 97.87 | 48.52 | 147.21 |
| Cadmium - ICP Low Level | 20-Oct | 0.047 | 0.051 | 0.046 | 0.057 | 0.001 | 0.001 | 0.001 | 90.50 | 94.10 | 74.10 | 114.09 |
| Chromium - ICP Low Level | 20-Oct | 0.049 | 0.053 | 0.047 | 0.059 | 0.004 | 0.004 | 0.005 | 92.35 | 96.56 | 78.43 | 114.69 |
| Cobalt - ICP Low Level | 20-Oct | 0.050 | 0.052 | 0.046 | 0.059 | 0.005 | 0.005 | 0.001 | 100.00 | 97.40 | 72.15 | 122.66 |
| Copper - ICP Low Level | 20-Oct | 0.052 | 0.049 | 0.045 | 0.054 | 0.004 | 0.003 | 0.006 | 105.50 | 97.38 | 76.28 | 118.48 |
| Lead - Graphite A.A. | 14-Oct | 0.027 | 0.024 | 0.020 | 0.029 | 0.001 | 0.001 | 0.001 | 61.00 | 92.08 | 43.49 | 140.68 |
| Mercury - Cold Vapor | 20-Oct | 3.360 | 3.548 | 2.937 | 4.160 | 0.001 | 0.001 | 0.000 | 101.24 | 97.65 | 78.75 | 116.55 |
| Molybdenum - ICP Low Level | 20-Oct | 0.048 | 0.056 | 0.045 | 0.066 | 0.004 | 0.004 | 0.007 | 87.50 | 95.30 | 58.28 | 132.32 |
| Nickel - ICP Low Level | 20-Oct | 0.044 | 0.051 | 0.040 | 0.061 | 0.006 | 0.006 | 0.002 | 89.50 | 91.14 | 61.54 | 120.74 |
| Selenium - Hydride | 21-Oct | 5.396 | 5.079 | 3.685 | 6.473 | 0.001 | 0.001 | 0.000 | 111.91 | 97.35 | 70.22 | 124.48 |
| Silver - ICP Low Level | 20-Oct | 0.047 | 0.048 | 0.041 | 0.055 | 0.003 | 0.003 | 0.001 | 95.50 | 81.06 | 58.97 | 103.15 |
| Vanadium - ICP Low Level | 20-Oct | 0.048 | 0.052 | 0.043 | 0.060 | 0.004 | 0.004 | 0.002 | 87.00 | 97.92 | 79.99 | 115.84 |
| Iron - ICP Low Level | 20-Oct | 0.049 | 0.052 | 0.042 | 0.062 | 0.008 | 0.006 | 0.045 | 100.40 | 105.82 | 82.55 | 129.09 |
| Manganese - ICP Low Level | 20-Oct | 0.055 | 0.051 | 0.045 | 0.056 | 0.012 | 0.013 | 0.062 | 102.00 | 98.57 | 81.42 | 115.72 |

**ALPHA LABORATORY SERVICES LTD.**

A REPORT FOR: Sentar

TTENTION: Ms. Maire Luoma

SAMPLE INFORMATION:
Project: 09-787-01-01
Date : 13-Oct

REFERENCE:
Client P.O.:
Alpha Job #: 6916

REPORT:
Date: 26-Oct-94
Verified By: [signature]
Filename: Cust16.rpt

| DESCRIPTION | DATE | QC CHECK | | | | DUPLICATE CHECK | | | SPIKE CHECK | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PARAMETER -- METHOD | ANALYSED | RESULT | MEAN | 95% CONFIDENCE LIMITS | | a | b | Diff. 95% C.L. | %RECOV. | MEAN | 95% CONFIDENCE LIMITS | |
| otal Phosphate - Stannous Chl | 18-Oct | 0.16 | 0.14 | 0.11 | 0.17 | 0.03 | 0.02 | 0.02 | 135.00 | 112.32 | 84.96 | 139.68 |
| KN - Ion Specific Electrode | 20-Oct | 0.24 | 0.25 | 0.22 | 0.28 | 0.66 | 0.70 | 0.04 | 90.00 | 90.63 | 70.80 | 110.47 |
| olor - Vision | 17-Oct | 15.00 | 15.00 | 15.00 | 15.00 | 10.00 | 10.00 | 0.00 | Spike Check Not Applicable | | | |
| otal Suspended Solids - Gravin | 24-Oct | 96.80 | 96.37 | 90.55 | 102.20 | 58.00 | 39.00 | 16.29 | Spike Check Not Applicable | | | |
| odium - ICP High Level | 20-Oct | 25.39 | 25.14 | 23.13 | 27.15 | 6.09 | 6.00 | 3.06 | 102.40 | 92.03 | 72.11 | 111.95 |
| .O.D. - BOD5 | 14-Oct | 8.20 | 7.08 | 5.07 | 9.09 | 63.00 | 65.00 | 12.53 | Spike Check Not Applicable | | | |
| henol - Chloroform Extraction | 18-Oct | 26.90 | 25.11 | 22.39 | 27.83 | Duplicate Check Not Applicable | | | 87.50 | 92.60 | 79.02 | 106.18 |
| OC - Autosampler | 17-Oct | 51.60 | 50.74 | 48.97 | 52.51 | 96.10 | 97.00 | 3.15 | 97.53 | 92.61 | 76.35 | 108.88 |
| rsenic - Hydride | 21-Oct | 4.216 | 4.649 | 3.137 | 6.162 | 0.001 | 0.001 | 0.001 | 91.35 | 97.87 | 48.52 | 147.21 |
| admium - ICP Low Level | 20-Oct | 0.047 | 0.051 | 0.046 | 0.057 | 0.001 | 0.001 | 0.001 | 90.50 | 94.10 | 74.10 | 114.09 |
| hromium - ICP Low Level | 20-Oct | 0.049 | 0.053 | 0.047 | 0.059 | 0.004 | 0.004 | 0.005 | 92.35 | 96.56 | 78.43 | 114.69 |
| obalt - ICP Low Level | 20-Oct | 0.050 | 0.052 | 0.046 | 0.059 | 0.005 | 0.005 | 0.001 | 100.00 | 97.40 | 72.15 | 122.66 |
| opper - ICP Low Level | 20-Oct | 0.052 | 0.049 | 0.045 | 0.054 | 0.004 | 0.003 | 0.006 | 105.50 | 97.38 | 76.28 | 118.48 |
| ead - Graphite A.A. | 14-Oct | 0.027 | 0.024 | 0.020 | 0.029 | 0.001 | 0.001 | 0.001 | 61.00 | 92.08 | 43.49 | 140.68 |
| ercury - Cold Vapor | 20-Oct | 3.360 | 3.548 | 2.937 | 4.160 | 0.001 | 0.001 | 0.000 | 101.24 | 97.65 | 78.75 | 116.55 |
| olybdenum - ICP Low Level | 20-Oct | 0.048 | 0.056 | 0.045 | 0.066 | 0.004 | 0.004 | 0.007 | 87.50 | 95.30 | 58.28 | 132.32 |
| ickel - ICP Low Level | 20-Oct | 0.044 | 0.051 | 0.040 | 0.061 | 0.006 | 0.006 | 0.002 | 89.50 | 91.14 | 61.54 | 120.74 |
| elenium - Hydride | 21-Oct | 5.396 | 5.079 | 3.685 | 6.473 | 0.001 | 0.001 | 0.000 | 111.91 | 97.35 | 70.22 | 124.48 |
| ilver - ICP Low Level | 20-Oct | 0.047 | 0.048 | 0.041 | 0.055 | 0.003 | 0.003 | 0.001 | 95.50 | 81.06 | 58.97 | 103.15 |
| anadium - ICP Low Level | 20-Oct | 0.048 | 0.052 | 0.043 | 0.060 | 0.004 | 0.004 | 0.002 | 87.00 | 97.92 | 79.99 | 115.84 |
| ron - ICP High Level | 20-Oct | 0.487 | 0.483 | 0.436 | 0.530 | 0.008 | 0.006 | 0.045 | 100.40 | 105.82 | 82.55 | 129.09 |
| anganese - ICP High Level | 20-Oct | 0.518 | 0.482 | 0.435 | 0.528 | 0.012 | 0.013 | 0.062 | 102.00 | 98.57 | 81.42 | 115.72 |

ETL Enviro·Test

A DIVISION OF ETL CHEMSPEC ANALYTICAL LIMITED

9936 - 67 Avenue, Edmonton, Alberta T6E 0P5 Telephone: (403) 434-9509 Fax: (403) 437-2311
Bay 118, 2370 Pegasus Way N.E., Calgary, Alberta T2E 8C3 Telephone: (403) 291-9897 Fax: (403) 291-0298
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## CHEMICAL ANALYSIS REPORT

SENTAR CONSULTANTS
SUITE 200, 1122 - 4 STREET S.W.
CALGARY, ALBERTA
T2R 1M1

Date: November 17, 1994

ATTN: MAIRE LUOMA

Lab Sample #: E4-10-268 Sampled By: CLIENT

Customer #: 09-787-01-01 Date Received: October 13, 1994

Sample Description: 2 water samples for resin and fatty acids analysis.

| LAB SAMPLE # | SAMPLE I.D. | RESULTS |
|---|---|---|
| E4-10-268-01A | SITE ANC 2 | Please see attached. |
| E4-10-268-02A | SITE ANC 3 | Please see attached. |

**RESIN AND FATTY ACID METHOD REFERENCE: Alberta Environment AE 129.0**
Analysis performed by Mahir Sidra, MSc., Chemist

**APPROVED BY:** [signature]
Detlef [Deib] Birkholz, MSc., ~~PhD~~.
Manager, Environmental Services
Pulp and Paper Division

ALL SAMPLES WILL BE DISPOSED OF AFTER 30 DAYS FOLLOWING ANALYSIS. PLEASE CONTACT THE LAB IF YOU REQUIRE ADDITIONAL SAMPLE STORAGE TIME.

RESIN AND FATTY ACIDS ANALYSIS REPORT
ENVIROTEST LABORATORIES
PULP AND PAPER DIVISION

PROJECT : SENTAR CONSULTANTS
MATRIX : WATER
LAB SAMPLE# : E4-10-268-01A
CLIENT I.D. : SITE ANC 2
SAMPLE SIZE : 800 mL

INSTRUMENT : HEWLETT PACKARD 5971A GC/MSD
ANALYSIS DATE : 19-Oct-94
ANALYST : Mahir Sidra M.Sc.

DETECTION LIMIT: 0.001 mg/L (ppm)

| | COMPOUND | CONCENTRATION mg/L (ppm) |
|---|---|---|
| FATTY ACIDS | ARACHIDIC ACID | ND |
| | LINOLEIC ACID | ND |
| | LINOLENIC ACID | ND |
| | MYRISTIC ACID | ND |
| | OLEIC ACID | ND |
| | PALMITIC ACID | ND |
| | STEARIC ACID | ND |
| | 9,10-DICHLOROSTEARIC ACID | ND |
| | TOTAL FATTY ACIDS : | ND |
| RESIN ACIDS | ABIETIC ACID | ND |
| | DEHYDROABIETIC ACID | ND |
| | ISOPIMARIC ACID | ND |
| | LEVOPIMARIC ACID | ND |
| | NEOABIETIC ACID | ND |
| | PALUSTRIC ACID | ND |
| | PIMARIC ACID | ND |
| | SANDARACOPIMARIC ACID | ND |
| | 12,14-DICHLORODEHYDROABIETIC ACID | ND |
| | 12-CHLORODEHYDROABIETIC ACID [#2] | ND |
| | 14-CHLORODEHYDROABIETIC ACID [#1] | ND |
| | TOTAL RESIN ACIDS : | ND |
| | TOTAL RESIN AND FATTY ACIDS : | ND |

NOTES:

1.) ND = Not Detected, less than detection limit listed.
2.) NDR = Not Detected due to incorrect ion ratios.
3.) The detection limit applies to all compounds listed.

QA/QC:

1.) To ensure resin acid extraction efficiency, the sample was fortified with a surrogate compound prior to extraction. Based on in-house data, the average % recovery for:

O-Methylpodocarpic Acid is: 95% ± 10%

2.) To ensure resin acid derivatization efficiency, the final extracts were fortified with tricosanoic acid prior to methylation with diazomethane. Based on in-house recovery data,the average % recovery for:

Tricosanoic Acid is: 103% ± 6.2%

# RESIN AND FATTY ACIDS ANALYSIS REPORT
## ENVIROTEST LABORATORIES
## PULP AND PAPER DIVISION

PROJECT : SENTAR CONSULTANTS
MATRIX : WATER
LAB SAMPLE# : E4-10-268-02A
CLIENT I.D. : SITE ANC 3
SAMPLE SIZE : 800 mL

INSTRUMENT : HEWLETT PACKARD 5971A GC/MSD
ANALYSIS DATE : 19-Oct-94
ANALYST : Mahir Sidra M.Sc.

DETECTION LIMIT: 0.001 mg/L (ppm)

| | COMPOUND | CONCENTRATION mg/L (ppm) |
|---|---|---|
| FATTY ACIDS | ARACHIDIC ACID | ND |
| | LINOLEIC ACID | ND |
| | LINOLENIC ACID | ND |
| | MYRISTIC ACID | ND |
| | OLEIC ACID | ND |
| | PALMITIC ACID | ND |
| | STEARIC ACID | ND |
| | 9,10-DICHLOROSTEARIC ACID | ND |
| | TOTAL FATTY ACIDS : | ND |
| RESIN ACIDS | ABIETIC ACID | ND |
| | DEHYDROABIETIC ACID | ND |
| | ISOPIMARIC ACID | ND |
| | LEVOPIMARIC ACID | ND |
| | NEOABIETIC ACID | ND |
| | PALUSTRIC ACID | ND |
| | PIMARIC ACID | ND |
| | SANDARACOPIMARIC ACID | ND |
| | 12,14-DICHLORODEHYDROABIETIC ACID | ND |
| | 12-CHLORODEHYDROABIETIC ACID [#2] | ND |
| | 14-CHLORODEHYDROABIETIC ACID [#1] | ND |
| | TOTAL RESIN ACIDS : | ND |
| | TOTAL RESIN AND FATTY ACIDS : | ND |

NOTES:

1.) ND = Not Detected, less than detection limit listed.
2.) NDR = Not Detected due to incorrect ion ratios.
3.) The detection limit applies to all compounds listed.

QA/QC:

1.) To ensure resin acid extraction efficiency, the sample was fortified with a surrogate compound prior to extraction. Based on in-house data, the average % recovery for:

O-Methylpodocarpic Acid is: 95% ± 10%

2.) To ensure resin acid derivatization efficiency, the final extracts were fortified with tricosanoic acid prior to methylation with diazomethane. Based on in-house recovery data, the average % recovery for:

Tricosanoic Acid is: 103% ± 6.2%

# CHEMEX Labs Alberta Inc.

Calgary : 2021 - 41st Avenue N.E., T2E 6P2. Telephone (403) 291-3077, FAX (403) 291-9468
Edmonton : 9331 - 48th Street, T6B 2R4, Telephone (403) 465-9877, FAX (403) 466-3332


SENTAR CONSULTANTS LTD
MAIRE LUOMA

DATE : October 24, 1994
CHEMEX PROJECT NO.: SENT010-0501-94-03354
CLIENT REFERENCE : ANC/MILLAR WESTERN
CLIENT JOB NO. : PROJ.#09-787-01-01/09-786-01-01

Analytical Data Reviewed By : ____________

QA/QC Reviewed By : ____________

The above signatures indicate that the individuals identified have reviewed the enclosed documents.

NOTE : Soil samples and water samples (for stable parameters) will be retained for a period of 60 days after completion of analysis.
Retention beyond this period can be arranged for a fee.

CHEMEX Labs Alberta Inc. is accredited by both the Canadian Association for Environmental Analytical Laboratories and the Standards Council of Canada for specific parameters registered with the Association and the Council.

## SORTING

**Project:** ANC - Athabasca River

**Project No.:** 09-787-00

**Sampling Date:** October 1994

| Site-Sample | Subsample Count in First 50 mL | Subsample Amount Sorted (mL)* | Subsample Fraction |
|---|---|---|---|
| 1A - 1 | 74 | 250 | X4 |
| 1A - 2 | 70 | 500 | X2 |
| 1A - 3 | 50 | 500 | X2 |
| 1A - 4 | 58 | 500 | X2 |
| 1A - 5 | 62 | 500 | X2 |
| Sorter: | Ela Grygorasz | | |

| Site-Sample | Subsample Count in First 50 mL | Subsample Amount Sorted (mL)* | Subsample Fraction |
|---|---|---|---|
| 1 - 1 | 46 | 500 | X2 |
| 1 - 2 | 170 | 125 | X8 |
| 1 - 3 | 86 | 250 | X4 |
| 1 - 4 | 90 | 250 | X4 |
| 1 - 5 | 128 | 200 | X5 |
| Sorter: | Rangathilakam Krishnaraj | | |

* Total subsample amount sorted from the 1 L sample.

## SORTING (Continued)

| Site-Sample | Subsample Count in First 50 mL | Subsample Amount Sorted (mL)* | Subsample Fraction |
|---|---|---|---|
| 2 - 1 | 78 | 250 | X4 |
| 2 - 2 | 162 | 125 | X8 |
| 2 - 3 | 110 | 200 | X5 |
| 2 - 4 | 104 | 200 | X5 |
| 2 - 5 | 116 | 200 | X5 |
| Sorter: | Ela Grygorasz | | |

| Site-Sample | Subsample Count in First 50 mL | Subsample Amount Sorted (mL)* | Subsample Fraction |
|---|---|---|---|
| 3A - 1 | 376 | 100 | X10 |
| 3A - 2 | 382 | 100 | X10 |
| 3A - 3 | 606 | 100 | X10 |
| 3A - 4 | 386 | 100 | X10 |
| 3A - 5 | 470 | 100 | X10 |
| Sorter: | Rangathilakam Krishnaraj | | |

| Site-Sample | Subsample Count in First 50 mL | Subsample Amount Sorted (mL)* | Subsample Fraction |
|---|---|---|---|
| 3 - 1 | 196 | 125 | X8 |
| 3 - 2 | 138 | 200 | X5 |
| 3 - 3 | 202 | 100 | X10 |
| 3 - 4 | 92 | 250 | X4 |
| 3 - 5 | 294 | 100 | X10 |
| Sorter: | Rangathilakam Krishnaraj | | |

* Total subsample amount sorted from the 1 L sample.

## SORTING (Continued)

| Site-Sample | Subsample Count in First 50 mL | Subsample Amount Sorted (mL)* | Subsample Fraction |
|---|---|---|---|
| 4 - 1 | 210 | 100 | X10 |
| 4 - 2 | 210 | 100 | X10 |
| 4 - 3 | 158 | 125 | X8 |
| 4 - 4 | 108 | 200 | X5 |
| 4 - 5 | 224 | 100 | X10 |
| Sorter: | Ela Grygorasz | | |

| Site-Sample | Subsample Count in First 50 mL | Subsample Amount Sorted (mL)* | Subsample Fraction |
|---|---|---|---|
| 5 - 1 | 160 | 125 | X8 |
| 5 - 2 | 134 | 200 | X5 |
| 5 - 3 | 218 | 100 | X10 |
| 5 - 4 | 98 | 250 | X4 |
| 5 - 5 | 90 | 250 | X4 |
| Sorter: | Ela Grygorasz | | |

| Site-Sample | Subsample Count in First 50 mL | Subsample Amount Sorted (mL)* | Subsample Fraction |
|---|---|---|---|
| 6 - 1 | 94 | 250 | X4 |
| 6 - 2 | 84 | 250 | X4 |
| 6 - 3 | 108 | 200 | X5 |
| 6 - 4 | 90 | 250 | X4 |
| 6 - 5 | 78 | 250 | X4 |
| Sorter: | Ela Grygorasz | | |

* Total subsample amount sorted from the 1 L sample.

## SORTING (Concluded)

| Site-Sample | Subsample Count in First 50 mL | Subsample Amount Sorted (mL)* | Subsample Fraction |
|---|---|---|---|
| 7 - 1 | 116 | 200 | X5 |
| 7 - 2 | 46 | 500 | X2 |
| 7 - 3 | 112 | 200 | X5 |
| 7 - 4 | 138 | 200 | X5 |
| 7 - 5 | 128 | 200 | X5 |
| Sorter: | Rrangathilakam Krishnaraj | | |

* Total subsample amount sorted from the 1 L sample.

# SORTING EFFICIENCY

**Project:** ANC - Athabasca River

**Project No.:** 09-787-00

**Sampling Date:** October 1994

**Re-Sorter:** Jack Zloty

| Site-Sample | Total Number of Organisms | | | | Percent Recovery | | |
|---|---|---|---|---|---|---|---|
| | Initial Sort | | Re-Sort | | | | |
| | Coarse | Fine | Coarse | Fine | Coarse | Fine | Total |
| 1A - 1 | 69 | 380 | 1 | 12 | 98.6 | 96.9 | 97.2 |
| 1 - 3 | 105 | 477 | 5 | 21 | 95.5 | 95.8 | 95.7 |
| 3A - 5 | 419 | 862 | 21 | 19 | 95.2 | 97.8 | 97.0 |
| 3 - 3 | 226 | 446 | 10 | 8 | 95.8 | 98.2 | 97.4 |
| 5 - 1 | 325 | 412 | 20 | 14 | 94.2 | 96.7 | 95.6 |
| 6 - 2 | 135 | 474 | 5 | 16 | 96.4 | 96.7 | 96.7 |
| 7 - 3 | 265 | 399 | 18 | 18 | 93.6 | 95.7 | 94.9 |
| Average | | | | | | | 96.4 |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
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## REFERENCE COLLECTION

**Project:** ANC

**Project No.:** 09-787-00

**Sampling Date:** October 1994

**Date Reference Collection Prepared:** June 1993

**Date Reference Collection Updated:** May 1995

**Location of Reference Collection:** SENTAR Consultants Ltd., Calgary, Alberta

**Reference Collection Prepared By:** Bob Saunders (1993)

**Reference Collection Updated By:** Jack Zloty (1995)

**Taxonomists:** Bob Saunders (1989 - 1993) and Jack Zloty (1992 - 1994)

# SENTAR
## CHAIN-OF-CUSTODY RECORD

Sampler: (Signature) Bob Shelast

Phone: 269-9300

Date Shipped: Oct. 11/94

Carrier: Greyhound

Weigh Bill No.:

SHIP TO: Alpha Labs
17212-106A Ave.
Edmonton, Alta

SEND RESULTS TO: SENTAR Consultants Ltd.
#200, 1122 - 4th Street SW
Calgary, AB T2R 1M1

ATTENTION: Marie Luoma

** Please quote SENTAR project number on results **

Project Name: ANC/Millar Western

Project No.: 09-786-01-01

| Relinquished by: (Signature) | Received by: (Signature) | Date | Time |
|---|---|---|---|
| Bob Shelast | S. Rumbolt | Oct. 11/94 | 8:30 P.M. |
| Relinquished by: (Signature) | Received at lab by: (Signature) | Date Oct. 12/94 | Time 10:00 Am |
| | | | |
| Discarded at lab by: (Signature) | Discard approved by: (Signature) | Date | Time |
| | | | |

### ANALYSIS REQUEST

| Sample ID No. | Sample Description | Date/Time Sampled | Analysis Requested | Sample Condition Upon Receipt |
|---|---|---|---|---|
| Site ANC 1 | Color/TSS | Oct 10/94 | | |
| " | BOD | " | | |
| " | Nutrients | " | | |
| Site ANC 2 | Color/TSS | Oct. 11/94 | | |
| " | BOD | " | | |
| " | Nutrients | " | | |
| " | Metals | " | | |
| " | Phenols | " | A. # 6166 | |

**NOTE:** DO NOT DISCARD SAMPLES UNTIL DISCARD APPROVED BY SENTAR.

Special Instructions/Comments:

Expected lab turn-around time: Rush (surcharge): ________ Standard: ✓ Full

*** PLEASE RETURN WHITE COPY TO SENTAR WITH FINAL RESULTS ***

# SENTAR
## CHAIN-OF-CUSTODY RECORD

Sampler: (Signature) [signature]

Phone: 

Date Shipped: Oct. 11/94

Project Name: MW/ANC

Project No.: 05-786-01-01

### ANALYSIS REQUEST

| Sample ID No. | Sample Description | Date/Time Sampled | Analysis Requested | Sample Condition Upon Receipt |
|---|---|---|---|---|
| Site ANC 2 | TOC | Oct. 11/94 | | |
| Site MW2A | Sodium | Oct. 9/94 | | |
| " | Color/TSS | " | | |
| " | Nutrients | " | | |
| Site MW3 | Color/TSS | " | | |
| " | Sodium | " | | |
| " | Nutrients | " | | |
| Site MW4 | Color/TSS | " | | |
| " | Sodium | " | | |
| " | Nutrients | " | | |
| Site MW5 | Color/TSS | Oct. 8/94 | | |
| " | Sodium | " | | |
| " | Nutrients | " | | |
| " | BOD | Oct. 10/94 | | |
| Site MW6 | Color/TSS | Oct. 8/94 | | |
| | Sodium | | | |
| | Nutrients | | | |
| MW Effluent #1 | Sodium | Oct. 8/94 | | |
| MW Effluent #2 | " | Oct. 9/94 | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

NOTE: DO NOT DISCARD SAMPLES UNTIL DISCARD APPROVED BY SENTAR.

Special Instructions/Comments: Site MW 5 = Site ANC 6

Expected lab turn-around time: Rush (surcharge): ______ Standard: ✓

Relinquished/Received (Initials): [initials] ______ ______

*** PLEASE RETURN WHITE COPY TO SENTAR WITH FINAL RESULTS ***

# SENTAR
# CHAIN-OF-CUSTODY RECORD

Sampler: (Signature) Bob Shelast

Phone: 269-9300

Date Shipped: Oct. 12/94

Carrier: Greyhound

Weigh Bill No.:

SHIP TO: Alpha Laboratories
17212 - 106 A Avenue
Edmonton, HLY9

SEND RESULTS TO: SENTAR Consultants Ltd.
#200, 1122 - 4th Street SW
Calgary, AB T2R 1M1

ATTENTION: Marie Lucma

** Please quote SENTAR project number on results **

Project Name: Miller Western/ANC

Project No.: 09-787-01-01

| Relinquished by: (Signature) | Received by: (Signature) | Date | Time |
|---|---|---|---|
| Bob Shelast | | Oct. 12/94 | 8:35 PM |
| **Relinquished by: (Signature)** | **Received at lab by: (Signature)** | **Date** | **Time** |
| | L Reinholt | Oct 13/94 | 9:00 AM |
| **Discarded at lab by: (Signature)** | **Discard approved by: (Signature)** | **Date** | **Time** |
| | | | |

## ANALYSIS REQUEST

File # 6916

| Sample ID No. | Sample Description | Date/Time Sampled | Analysis Requested | Sample Condition Upon Receipt |
|---|---|---|---|---|
| Site ANC 3 | River water | Oct. 12/94 | Metals | |
| " | " | " | TOC | |
| " | " | " | Phenols | |
| " | " | " | Nutrients | |
| " | " | " | Color/TSS | |
| " | " | " | BOD | |
| Site ANC 4 | " | " | BOD | |
| " | " | " | Color/TSS | |

**NOTE:** DO NOT DISCARD SAMPLES UNTIL DISCARD APPROVED BY SENTAR.

Special Instructions/Comments:

Expected lab turn-around time: Rush (surcharge): ______ Standard: ✓

*** PLEASE RETURN WHITE COPY TO SENTAR WITH FINAL RESULTS ***

# SENTAR
## CHAIN-OF-CUSTODY RECORD

Sampler: (Signature) Bob Skulast

Phone: 269-9300

Date Shipped: Oct 12/94

Project Name: MW/ANC

Project No.: 09-787-01-01

### ANALYSIS REQUEST

| Sample ID No. | Sample Description | Date/Time Sampled | Analysis Requested | Sample Condition Upon Receipt |
|---|---|---|---|---|
| Site ANC4 | River $H_2O$ | October 12/94 | Nutrients | |
| Site MW2 | " | " | TSS/Color | |
| " | " | " | BOD | |
| " | " | " | Nutrients | |
| " | " | " | Sodium | |
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NOTE: DO NOT DISCARD SAMPLES UNTIL DISCARD APPROVED BY SENTAR.

Special Instructions/Comments: Site MW2 = Site ANC 5

Expected lab turn-around time: Rush (surcharge): ________ Standard: ✓

Relinquished/Received (Initials): BH ________ ________ ________

*** PLEASE RETURN WHITE COPY TO SENTAR WITH FINAL RESULTS ***

Oct 26/94

**SENTAR**
**CHAIN-OF-CUSTODY RECORD**

Sampler: (Signature) BOB SHELAST

Phone: 269-9300

Date Shipped: Oct 13/1994

Carrier: PERSONAL

Weigh Bill No.: —

SHIP TO: ALPHA LABS

SEND RESULTS TO: SENTAR Consultants Ltd.
#200, 1122 - 4th Street SW
Calgary, AB T2R 1M1

ATTENTION: MAIRE Luoma

** Please quote SENTAR project number on results **

Project Name: MILLAR WESTERN / ANC

Project No.: 09-786-01-01 / 09-787-01-01

| Relinquished by: (Signature) | Received by: (Signature) | Date | Time |
|---|---|---|---|
| [signature] | [signature] | 94/10/13 | 7:20 p.m |

| Relinquished by: (Signature) | Received at lab by: (Signature) | Date | Time |
|---|---|---|---|
| | | | |

| Discarded at lab by: (Signature) | Discard approved by: (Signature) | Date | Time |
|---|---|---|---|
| | | | |

**ANALYSIS REQUEST**

| Sample ID No. | Sample Description | Date/Time Sampled | Analysis Requested | Sample Condition Upon Receipt |
|---|---|---|---|---|
| MW ~~1~~ | RIVER WATER | Oct 13/94 | NUTRIENTS | |
| " | " | " | TSS / COLOUR | |
| " | " | " | SODIUM | |
| MW7 | " | " | NUTRIENTS | |
| " | " | " | TSS / COLOUR | |
| " | " | " | BOD | |
| ~~" B~~ | ~~" B~~ | | | |
| MW Effluent #3 | Effluent | | Sodium | |

**NOTE:** DO NOT DISCARD SAMPLES UNTIL DISCARD APPROVED BY SENTAR.

Special Instructions/Comments: Site MW 7 = Site ANC 7

Expected lab turn-around time: Rush (surcharge): ______ Standard: X

*** PLEASE RETURN WHITE COPY TO SENTAR WITH FINAL RESULTS ***

2

**SENTAR**
**CHAIN-OF-CUSTODY RECORD**

Sampler: (Signature) Bob Shelast
Phone: 269-9300

Date Shipped: Oct.13/94
Carrier: IN PERSON
Weigh Bill No.: — E410268

SHIP TO: ENVIRO-TEST Edmonton

SEND RESULTS TO: SENTAR Consultants Ltd.
#200, 1122 - 4th Street SW
Calgary, AB T2R 1M1

ATTENTION: Maire Luoma

** Please quote SENTAR project number on results **

Project Name: ANC

Project No.: 09-787-01-01

| Relinquished by: (Signature) | Received by: (Signature) | Date | Time |
|---|---|---|---|
| Bob Shelast | Archie Lamg | Oct.13/94 | 7:45 |

| Relinquished by: (Signature) | Received at lab by: (Signature) | Date | Time |
|---|---|---|---|
| | W Hodges | OCT 14/94 | 0700 |

| Discarded at lab by: (Signature) | Discard approved by: (Signature) | Date | Time |
|---|---|---|---|
| | | | |

**ANALYSIS REQUEST**

| Sample ID No. | Sample Description | Date/Time Sampled | Analysis Requested | Sample Condition Upon Receipt | |
|---|---|---|---|---|---|
| Site ANC2 | River $H_2O$ | Oct.12/94 | R/F Acids | intact, cold | 01 |
| Site ANC3 | River $H_2O$ | Oct.12/94 | R/F Acids | " " | 02 |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
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**NOTE:** DO NOT DISCARD SAMPLES UNTIL DISCARD APPROVED BY SENTAR.

Special Instructions/Comments:

Expected lab turn-around time: Rush (surcharge): ________ Standard: ✓

*** PLEASE RETURN WHITE COPY TO SENTAR WITH FINAL RESULTS ***

# SENTAR
## CHAIN-OF-CUSTODY RECORD

RECEIVED

Sampler: (Signature) Bob Shelast

Phone: 269-9300

Date Shipped: October 17, 1994

Carrier: In Person

Weigh Bill No.:

SHIP TO: Chemex Labs Alberta Inc. 2021 - 41 Avenue N.E Calgary, Alberta

SEND RESULTS TO: SENTAR Consultants Ltd.
#200, 1122 - 4th Street SW
Calgary, AB T2R 1M1

ATTENTION: Maire Luoma

** Please quote SENTAR project number on results **

Project Name: ANC / Millar Western

Project No.: 09-786-01-01 (09-787-01-01)

| Relinquished by: (Signature) | Received by: (Signature) | Date | Time |
|---|---|---|---|
| Maire Luoma | [signature] | Oct. 17/94 | 12:22pm |
| **Relinquished by: (Signature)** | **Received at lab by: (Signature)** | **Date** | **Time** |
| | | | |
| **Discarded at lab by: (Signature)** | **Discard approved by: (Signature)** | **Date** | **Time** |
| | | | |

### ANALYSIS REQUEST

| Sample ID No. | Sample Description | Date/Time Sampled | Analysis Requested (FILTERS) | Sample Condition Upon Receipt |
|---|---|---|---|---|
| ANC 1-1 | Algae | 10/10/94; 5:30pm | Chlorophyll a | 3354-1 |
| ANC 1-2 | " | " " | " | 2 |
| ANC 1-3 | " | " " | " | 3 |
| ANC 1A-1 | Algae | 10/10/94; 1:00pm | Chlorophyll a. | 4 |
| ANC 1A-2 | " | " " | " | 5 |
| ANC 1A-3 | " | " " | " | 6 |
| ANC 2-1 | Algae | 11/10/94; 1:30pm | Chlorophyll a | 7 |
| ANC 2-2 | " | " | " | 8 |

**NOTE:** DO NOT DISCARD SAMPLES UNTIL DISCARD APPROVED BY SENTAR.

Special Instructions/Comments: Total 42 samples.

seq#1913
20%

Expected lab turn-around time: Rush (surcharge): ______ Standard: ✓

*** PLEASE RETURN WHITE COPY TO SENTAR WITH FINAL RESULTS ***

SENTAR
CHAIN-OF-CUSTODY RECORD

Sampler: (Signature) Bob Shelast
Phone: 269-9300

Date Shipped: Oct. 17/94
Project Name: ANC/Millar Western
Project No.: 09-787-01-01/09-786-01-01

ANALYSIS REQUEST

| Sample ID No. | Sample Description | Date/Time Sampled | Analysis Requested | Sample Condition Upon Receipt |
|---|---|---|---|---|
| ANC 2-3 | Algae | 11/10/94; 1:30pm | Chlorophyll a | 3354- 9 |
| ANC 3-1 | Algae | 12/10/94; 12:00pm | Chlorophylla | 10 |
| ANC 3-2 | " | " " | " | 11 |
| ANC 3-3 | " | " " | " | 12 |
| ANC 3A-1 | Algae | 11/10/94; 6:00pm | Chlorophylla | 13 |
| ANC 3A-2 | " | " " | " | 14 |
| ANC3A-3 | " | " " | " | 15 |
| ANC 4-1 | Algae | 12/10/94; 2:30pm | Chlorophylla | 16 |
| ANC 4-2 | " | " " | " | 17 |
| ANC 4-3 | " | " " | " | 18 |
| MW 1-1 | Algae | 13/10/94; 12:00pm | Chlorophylla | 19 |
| MW-1-2 | " | " " | " | 20 |
| MW 1-3 | " | " " | " | 21 |
| MW 2-1 | Algae | 12/10/94; 6:00pm | Chlorophylla | 22 |
| MW 2-2 | " | " " | " | 23 |
| MW 2-3 | " | " " | " | 24 |
| MW 2A-1 | Algae | 9/10/94; 5:00pm | Chlorophylla | 25 |
| MW 2A-2 | " | " " | " | 26 |
| MW 2A-3 | " | " " | " | 27 |
| MW 3-1 | Algae | 9/10/94; 2:00pm | Chlorophylla | 28 |
| MW 3-2 | " | " " | " | 29 |
| MW 3-3 | " | " " | " | 30 |
| MW 4-1 | Algae | 9/10/94; 11:30am | Chlorophylla | 31 |

**NOTE:** DO NOT DISCARD SAMPLES UNTIL DISCARD APPROVED BY SENTAR.

Special Instructions/Comments:

Expected lab turn-around time: Rush (surcharge): ________ Standard: ✓

Relinquished/Received (Initials): MK SS

*** PLEASE RETURN WHITE COPY TO SENTAR WITH FINAL RESULTS ***

# SENTAR
## CHAIN-OF-CUSTODY RECORD

Sampler: (Signature) Bob Shelast

Phone: 269-9300

Date Shipped: Oct. 17/94

Project Name: ANC/Millar Western

Project No.: 09-787-01-01/09-786-01-01

**ANALYSIS REQUEST**

| Sample ID No. | Sample Description | Date/Time Sampled | Analysis Requested | Sample Condition Upon Receipt |
|---|---|---|---|---|
| MW 4-2 | Algae | 9/10/94; 11:30am | Chlorophyll a | 3354-32 |
| MW 4-3 | " | " " | " | 33 |
| MW 5-1 | Algae | 8/10/94; 6:00pm | Chlorophyll a | 34 |
| MW 5-2 | " | " " | " | 35 |
| MW 5-3 | " | " " | " | 36 |
| MW 6-1 | Algae | 8/10/94; 3:00pm | Chlorophyll a | 37 |
| MW 6-2 | " | " " | " | 38 |
| MW 6-3 | " | " " | " | 39 |
| MW 7-1 | Algae | 13/10/94; 4:30pm | Chlorophyll a | 40 |
| MW 7-2 | " | " | " | 41 |
| MW 7-3 | " | " | " | 42 |

**NOTE:** DO NOT DISCARD SAMPLES UNTIL DISCARD APPROVED BY SENTAR.

Special Instructions/Comments: Site MW2 = Site ANC 5
Site MW 5 = Site ANC 6
Site MW7 = Site ANC 7

Expected lab turn-around time: Rush (surcharge): ______ Standard: ✓

Relinquished/Received (Initials): M.L. / S. ______ ______

*** PLEASE RETURN WHITE COPY TO SENTAR WITH FINAL RESULTS ***

**SENTAR**
**CHAIN-OF-CUSTODY RECORD**

Sampler: (Signature) [signature]

Phone: 269-9300

Date Shipped: Jan. 4, 1995

Carrier: In Person

Weigh Bill No.: –

SHIP TO: Jack Zloty
8527- 33 Avenue N.W.
Calgary, Alberta
T6X 2X9

SEND RESULTS TO: SENTAR Consultants Ltd.
#200, 1122 - 4th Street SW
Calgary, AB T2R 1M1

ATTENTION: Maire Luoma

** Please quote SENTAR project number on results **

Project Name: ANC

Project No.: 09787-00/02

| Relinquished by: (Signature) | Received by: (Signature) | Date | Time |
|---|---|---|---|
| [signature] | [signature] | Jan. 4, 1995 | 2:00 pm |
| Relinquished by: (Signature) | Received at lab by: (Signature) | Date | Time |
| | | | |
| Discarded at lab by: (Signature) | Discard approved by: (Signature) | Date | Time |
| | | | |

**ANALYSIS REQUEST**

| Sample ID No. | Sample Description | Date/Time Sampled | Analysis Requested | Sample Condition Upon Receipt |
|---|---|---|---|---|
| ANC Site 1-1 | Benthos | 10/10/94; 3:00 pm | Sorting and Identifications | |
| ANC Site 1-2 | Benthos | " " | | |
| ANC Site 1-3 | Benthos | " " | | |
| ANC Site 1-4 | Benthos | " " | | |
| ANC Site 1-5 | Benthos | " " | | |
| ANC Site 1A-1 | Benthos | 10/10/94; 10:30 am | | |
| ANC Site 1A-2 | Benthos | " " | | |
| ANC Site 1A-3 | Benthos | " " | | |

**NOTE:** DO NOT DISCARD SAMPLES UNTIL DISCARD APPROVED BY SENTAR.

Special Instructions/Comments:

Expected lab turn-around time: Rush (surcharge): ______ Standard: ✓

*** PLEASE RETURN WHITE COPY TO SENTAR WITH FINAL RESULTS ***

**SENTAR**
**CHAIN-OF-CUSTODY RECORD**

Sampler: (Signature) Bob Shelast

Phone: 269-9300

Date Shipped: Jan. 4, 1995
Project Name: ANC
Project No.: 09-787-00/02

**ANALYSIS REQUEST**

| Sample ID No. | Sample Description | Date/Time Sampled | Analysis Requested | Sample Condition Upon Receipt |
|---|---|---|---|---|
| ANC Site 1A-4 | ~~10/10/94~~ Benthos | 10/10/94; 10:30am | Sorting and Identifications | |
| ANC Site 1A-5 | Benthos | " " | | |
| ANC Site 2-1 | Benthos | 11/10/94; 10:30am | | |
| ANC Site 2-2 | Benthos | " " | | |
| ANC Site 2-3 | Benthos | " " | | |
| ANC Site 2-4 | Benthos | " " | | |
| ANC Site 2-5 | Benthos | " " | | |
| ANC Site 3-1 | Benthos | 12/10/94; 10:30am | | |
| ANC Site 3-2 | Benthos | " " | | |
| ANC Site 3-3 | Benthos | " " | | |
| ANC Site 3-4 | Benthos | " " | | |
| ANC Site 3-5 | Benthos | " " | | |
| ANC Site 3A-1 | Benthos | 11/10/94; 3:00pm | | |
| ANC Site 3A-2 | Benthos | " " | | |
| ANC Site 3A-3 | Benthos | " " | | |
| ANC Site 3A-4 | Benthos | " " | | |
| ANC Site 3A-5 | Benthos | " " | | |
| ANC Site 4-1 | Benthos | 12/10/94; 1:00pm | | |
| ANC Site 4-2 | Benthos | " " | | |
| ANC Site 4-3 | Benthos | " " | | |
| ANC Site 4-4 | Benthos | " " | | |
| ANC Site 4-5 | Benthos | " " | | |
| | | | | |

**NOTE:** DO NOT DISCARD SAMPLES UNTIL DISCARD APPROVED BY SENTAR.

Special Instructions/Comments: Total - 30 samples

Expected lab turn-around time: Rush (surcharge): ________ Standard: ✓

Relinquished/Received (Initials): BSh / BL ________ ________

*** PLEASE RETURN WHITE COPY TO SENTAR WITH FINAL RESULTS ***

# SENTAR
# CHAIN-OF-CUSTODY RECORD

Sampler: (Signature) [signature]
Phone: 269-9300

Date Shipped: Jan. 4, 1995
Carrier: In Person
Weigh Bill No.: —

SHIP TO: Jack Zloty
8527 - 33 Avenue N.W.
Calgary, Alberta
T6K 2X9

SEND RESULTS TO: SENTAR Consultants Ltd.
#200, 1122 - 4th Street SW
Calgary, AB T2R 1M1

ATTENTION: Maire Luoma

** Please quote SENTAR project number on results **

Project Name: ANC / MW

Project No.: 09-787-00 09-786-00

| Relinquished by: (Signature) | Received by: (Signature) | Date | Time |
|---|---|---|---|
| [signature] | [signature] | Jan. 4, 1995 | 2:00pm |
| Relinquished by: (Signature) | Received at lab by: (Signature) | Date | Time |
| | | | |
| Discarded at lab by: (Signature) | Discard approved by: (Signature) | Date | Time |
| | | | |

## ANALYSIS REQUEST

| Sample ID No. | Sample Description | Date/Time Sampled | Analysis Requested | Sample Condition Upon Receipt |
|---|---|---|---|---|
| MW Site 2-1 | Benthos | 12/10/94; 4:30 pm | Sorting and Identifications | |
| MW Site 2-2 | Benthos | " " | | |
| MW Site 2-3 | Benthos | " " | | |
| MW Site 2-4 | Benthos | " " | | |
| MW Site 2-5 | Benthos | " " | | |
| MW Site 5-1 | Benthos | 8/10/94; 5:00 pm | | |
| MW Site 5-2 | Benthos | " " | | |
| MW Site 5-3 | Benthos | " " | | |

NOTE: DO NOT DISCARD SAMPLES UNTIL DISCARD APPROVED BY SENTAR.

Special Instructions/Comments: MW Site 2 = ANC Site 5
MW Site 5 = ANC Site 6
MW Site 7 = ANC Site 7

Expected lab turn-around time: Rush (surcharge): ______ Standard: ✓

*** PLEASE RETURN WHITE COPY TO SENTAR WITH FINAL RESULTS ***

**SENTAR**
**CHAIN-OF-CUSTODY RECORD**

Sampler: (Signature) Bob Shelast

Phone: 269-9300

Date Shipped: Jan. 4, 1995

Project Name: ANC/MW

Project No.: 09-787-00/09-786-00

**ANALYSIS REQUEST**

| Sample ID No. | Sample Description | Date/Time Sampled | Analysis Requested | Sample Condition Upon Receipt |
|---|---|---|---|---|
| MW Site 5-4 | Benthos | 8/10/94; 5:00pm | Sorting and Identifications | |
| MW Site 5-5 | Benthos | " " | | |
| MW Site 7-1 | Benthos | 13/10/94; 3:00pm | | |
| MW Site 7-2 | Benthos | " " | | |
| MW Site 7-3 | Benthos | " " | | |
| MW Site 7-4 | Benthos | " " | | |
| MW Site 7-5 | Benthos | " " | | |

**NOTE:** DO NOT DISCARD SAMPLES UNTIL DISCARD APPROVED BY SENTAR.

Special Instructions/Comments: Total - 15 samples

Expected lab turn-around time: Rush (surcharge): ________ Standard: ✓

Relinquished/Received (Initials): [initials] / [initials]

*** PLEASE RETURN WHITE COPY TO SENTAR WITH FINAL RESULTS ***

# APPENDIX B

# PHYSICAL CHARACTERISTICS OF SAMPLE LOCATIONS, OCTOBER 1994

**Appendix B-1.** Water velocity and depth for each sample location (average of three measurements) with means and 95% confidence limits (CL) per site, October 1994.

| Site-Sample | Water Velocity (cm/s) | Water Depth (cm) |
|---|---|---|
| 1A-1 | 39 | 33 |
| 1A-2 | 32 | 35 |
| 1A-3 | 37 | 35 |
| 1A-4 | 33 | 34 |
| 1A-5 | 44 | 34 |
| Mean ± 95% CL | 37 ± 4 | 34 ± 1 |
| 1-1 | 39 | 35 |
| 1-2 | 38 | 34 |
| 1-3 | 42 | 34 |
| 1-4 | 52 | 34 |
| 1-5 | 45 | 35 |
| Mean ± 95% CL | 43 ± 5 | 34 ± 0 |
| 2-1 | 26 | 32 |
| 2-2 | 26 | 35 |
| 2-3 | 25 | 34 |
| 2-4 | 26 | 34 |
| 2-5 | 34 | 33 |
| Mean ± 95% CL | 27 ± 3 | 34 ± 1 |
| 3A-1 | 34 | 34 |
| 3A-2 | 31 | 35 |
| 3A-3 | 28 | 34 |
| 3A-4 | 27 | 36 |
| 3A-5 | 27 | 34 |
| Mean ± 95% CL | 29 ± 3 | 35 ± 1 |
| 3-1 | 30 | 34 |
| 3-2 | 30 | 34 |
| 3-3 | 30 | 35 |
| 3-4 | 24 | 34 |
| 3-5 | 28 | 34 |
| Mean ± 95% CL | 28 ± 2 | 34 ± 0 |
| 4-1 | 48 | 33 |
| 4-2 | 40 | 32 |
| 4-3 | 33 | 34 |
| 4-4 | 33 | 34 |
| 4-5 | 40 | 34 |
| Mean ± 95% CL | 39 ± 5 | 33 ± 1 |

(continued)

Appendix B-1. (concluded)

| Site-Sample | Water Velocity (cm/s) | Water Depth (cm) |
|---|---|---|
| 5-1 | 45 | 36 |
| 5-2 | 34 | 34 |
| 5-3 | 32 | 35 |
| 5-4 | 34 | 33 |
| 5-5 | 29 | 34 |
| Mean ± 95% CL | 35 ± 5 | 34 ± 1 |
| 6-1 | 41 | 33 |
| 6-2 | 42 | 36 |
| 6-3 | 40 | 34 |
| 6-4 | 37 | 35 |
| 6-5 | 37 | 35 |
| Mean ± 95% CL | 39 ± 2 | 35 ± 1 |
| 7-1 | 22 | 33 |
| 7-2 | 17 | 33 |
| 7-3 | 20 | 36 |
| 7-4 | 17 | 35 |
| 7-5 | 21 | 34 |
| Mean ± 95% CL | 19 ± 2 | 34 ± 1 |

**Appendix B-2.** **Substrate size distribution (percentage by weight) for each sample location with means and 95% confidence limits (CL) per site, October 1994.**

| Site-Sample | Cobble (64-256 mm) | Pebble (16-64 mm) | Large Gravel (4-16 mm) | Small Gravel (2-4 mm) | Coarse Sand (0.5-2 mm) |
|---|---|---|---|---|---|
| 1A-1 | 59.0 | 40.4 | 0.6 | - | - |
| 1A-2 | 42.1 | 57.4 | 0.6 | - | - |
| 1A-3 | 29.9 | 69.5 | 0.6 | - | - |
| 1A-4 | 39.2 | 60.8 | - | - | - |
| 1A-5 | 24.9 | 75.1 | - | - | - |
| Mean ± 95% CL | 39.0 ± 11.5 | 60.6 ± 11.7 | 0.4 ± 0.3 | - | - |
| 1-1 | 20.8 | 79.1 | 0.2 | - | - |
| 1-2 | 46.1 | 53.7 | 0.2 | - | - |
| 1-3 | 42.8 | 56.6 | 0.5 | 0.1 | - |
| 1-4 | 28.7 | 70.8 | 0.5 | - | - |
| 1-5 | 40.6 | 59.0 | 0.3 | - | - |
| Mean ± 95% CL | 35.8 ± 9.3 | 63.8 ± 9.4 | 0.3 ± 0.1 | <0.1 ± 0 | - |
| 2-1 | 52.6 | 47.4 | - | - | - |
| 2-2 | 53.3 | 46.7 | - | - | - |
| 2-3 | 62.2 | 37.7 | 0.1 | - | - |
| 2-4 | 84.0 | 16.0 | - | - | - |
| 2-5 | 62.2 | 37.8 | - | - | - |
| Mean ± 95% CL | 62.8 ± 11.1 | 37.1 ± 11.1 | <0.1 ± 0 | - | - |
| 3A-1 | 63.2 | 33.5 | 3.0 | 0.2 | <0.1 |
| 3A-2 | 58.0 | 40.5 | 1.4 | 0.1 | <0.1 |
| 3A-3 | 69.5 | 29.5 | 0.9 | 0.1 | <0.1 |
| 3A-4 | 72.4 | 27.3 | 0.3 | <0.1 | - |
| 3A-5 | 69.2 | 30.0 | 0.7 | <0.1 | - |
| Mean ± 95% CL | 66.4 ± 5.1 | 32.2 ± 4.6 | 1.3 ± 0.9 | 0.1 ± 0.1 | <0.1 ± 0 |
| 3-1 | 50.8 | 49.2 | - | - | - |
| 3-2 | 38.3 | 61.7 | - | - | - |
| 3-3 | 47.8 | 52.2 | - | - | - |
| 3-4 | 48.0 | 52.0 | - | - | - |
| 3-5 | 25.8 | 74.2 | - | - | - |
| Mean ± 95% CL | 42.1 ± 9.0 | 57.9 ± 9.0 | - | - | - |
| 4-1 | 50.1 | 49.9 | - | - | - |
| 4-2 | 21.8 | 78.2 | - | - | - |
| 4-3 | 43.6 | 56.4 | - | - | - |
| 4-4 | 49.6 | 50.3 | 0.1 | - | - |
| 4-5 | 57.0 | 43.0 | - | - | - |
| Mean ± 95% CL | 44.4 ± 11.8 | 55.6 ± 11.9 | <0.1 ± 0 | - | - |

(continued)

Appendix B-2. (concluded)

| Site-Sample | Cobble (64-256 mm) | Pebble (16-64 mm) | Large Gravel (4-16 mm) | Small Gravel (2-4 mm) | Coarse Sand (0.5-2 mm) |
|---|---|---|---|---|---|
| 5-1 | 49.4 | 50.6 | - | - | - |
| 5-2 | 59.2 | 40.8 | - | - | - |
| 5-3 | 62.6 | 37.4 | - | - | - |
| 5-4 | 56.2 | 43.8 | - | - | - |
| 5-5 | 30.5 | 69.5 | - | - | - |
| Mean ± 95% CL | 51.6 ± 11.2 | 48.4 ± 11.2 | - | - | - |
| | | | | | |
| 6-1 | 39.9 | 60.1 | - | - | - |
| 6-2 | 55.4 | 44.0 | 0.6 | - | - |
| 6-3 | 62.1 | 37.9 | <0.1 | - | - |
| 6-4 | 48.7 | 51.3 | - | - | - |
| 6-5 | 52.1 | 47.9 | - | - | - |
| Mean ± 95% CL | 51.6 ± 7.2 | 48.2 ± 7.3 | 0.1 ± 0.2 | - | - |
| | | | | | |
| 7-1 | 71.3 | 27.2 | 1.5 | <0.1 | - |
| 7-2 | 64.9 | 34.8 | 0.2 | - | - |
| 7-3 | 80.3 | 17.0 | 2.6 | - | - |
| 7-4 | 60.5 | 36.6 | 2.9 | - | - |
| 7-5 | 80.0 | 19.5 | 0.4 | - | - |
| Mean ± 95% CL | 71.4 ± 7.8 | 27.0 ± 7.7 | 1.5 ± 1.1 | <0.1 ± 0 | - |

# APPENDIX C

# AVERAGE MONTHLY CONCENTRATIONS OF SELECTED PARAMETERS FOR MILLAR WESTERN FINAL TREATED EFFLUENT, FALL 1994

**Appendix C.** **Average monthly concentrations of selected parameters for Millar Western final treated effluent, fall (August - October ) 1994.**

| Parameter* | August | September | October |
|---|---|---|---|
| Discharge ($m^3/d$) | 11,454 | 12,277 | 12,103 |
| pH (units) | 8.1 | 8.3 | 8.4 |
| Conductivity (µmhos/cm) | 6,328 | 6,480 | 6,667 |
| Dissolved Oxygen (mg/L) | 4.9 | 4.8 | 5.2 |
| Temperature (°C) | 34.8 | 33.6 | 32.9 |
| Biochemical Oxygen Demand (5 day) (ppm) | 97 | 66 | 52 |
| True Color (Pt-Co units) | 734 | 857 | 900 |
| Total Suspended Solids (mg/L) | 173 | 143 | 134 |
| Total Phosphorus (as P) (mg/L) | 3.36 | 0.55 | 2.83 |
| Total Kjeldahl Nitrogen (mg/L) | 11.4 | 10.6 | 12.9 |

Source: Millar Western Pulp Ltd. (unpublished data)

* All monthly averages were based on daily values, except for total phosphorus and total Kjeldahl nitrogen which were weekly values.

Pt-Co Platinum Cobalt

# APPENDIX D

## STATISTICAL ANALYSES RESULTS OF CHLOROPHYLL *a* DATA, OCTOBER 1994

**ANOVA on Chlorophyll *a* for Sites, October 1994**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Site | 8 | 8,90,600.0 | 111,300.00 | 78.00* | 0.0000 |
| Within | 18 | 25,690.6 | 1,427.26 | | |
| Total | 26 | 9,16,300.0 | | | |

**Orthogonal Contrasts**

Contrast Number 1 (Background/Downstream)

Contrast Coefficients: 6 6 6 -3 -3 -3 -3 -3 -3

| | |
|---|---|
| Contrast | -3,072.5 |
| SE (Contrast) | 277.62 |
| SS (Contrast) | 175,000 |
| T-Statistic | -11.07* |
| P (T-Statistic) | 0.0000 |

Contrast Number 2 (Near-field/Far-field)

Contrast Coefficients: 0 0 0 2 2 2 2 -4 -4

| | |
|---|---|
| Contrast | 1,659.2 |
| SE (Contrast) | 151.12 |
| SS (Contrast) | 172,000 |
| T-Statistic | 10.98* |
| P (T-Statistic) | 0.0000 |

* Significant ($p < 0.05$)
** Not Significant ($p > 0.05$)

# APPENDIX E

# SPECIES IDENTIFICATIONS AND NUMBERS PER SAMPLE, OCTOBER 1994

Site 1A - October 1994

| Species Code | Taxa | Number per Sample 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| | Ephemeroptera | | | | | |
| | Baetidae | | | | | |
| 002 | *Baetis* sp. | 60 | 9 | 33 | 28 | 24 |
| | Ephemerellidae | | | | | |
| 004 | *Drunella doddsi* | 0 | 0 | 0 | 1 | 0 |
| 005 | *Ephemerella inermis* | 103 | 55 | 213 | 101 | 104 |
| | Heptageniidae | | | | | |
| 008 | *Heptagenia* sp. | 5 | 4 | 12 | 2 | 2 |
| 009 | *Rhithrogena* sp. | 32 | 9 | 19 | 18 | 18 |
| | Leptophlebiidae | | | | | |
| 012 | *Paraleptophlebia* sp. | 1 | 0 | 2 | 0 | 0 |
| | Siphlonuridae | | | | | |
| 014 | *Ameletus* sp. | 2 | 5 | 2 | 1 | 3 |
| | Tricorythidae | | | | | |
| 015 | *Tricorythodes* sp. | 0 | 0 | 0 | 0 | 1 |
| | Trichoptera | | | | | |
| | Brachycentridae | | | | | |
| 016 | *Brachycentrus* sp. | 18 | 7 | 24 | 12 | 20 |
| | Glossosomatidae | | | | | |
| 115 | *Glossosoma* sp. | 1 | 0 | 1 | 2 | 1 |
| | Hydropsychidae | | | | | |
| 019 | *Hydropsyche* sp. | 72 | 36 | 36 | 33 | 53 |
| | Hydroptilidae | | | | | |
| 020 | *Hydroptila* sp. | 1 | 0 | 2 | 0 | 0 |
| | Lepidostomatidae | | | | | |
| 022 | *Lepidostoma* sp. | 16 | 1 | 7 | 0 | 4 |
| | Leptoceridae | | | | | |
| 023 | *Oecetis* sp. | 0 | 0 | 2 | 1 | 1 |
| | Limnephilidae | | | | | |
| 116 | *Apatania* sp. | 0 | 2 | 0 | 2 | 0 |
| | Plecoptera | | | | | |
| 025 | Capniidae | 34 | 14 | 48 | 20 | 18 |
| | Chloroperlidae | | | | | |
| 099 | Chloroperlinae (early instar) | 3 | 1 | 2 | 2 | 2 |
| | Perlodidae | | | | | |
| 029 | *Cultus* sp. | 55 | 10 | 29 | 28 | 22 |
| 030 | *Isogenoides* sp. | 1 | 1 | 1 | 0 | 1 |
| 031 | *Isoperla* sp. | 0 | 1 | 0 | 0 | 0 |
| 032 | Perlodidae (early instar) | 0 | 0 | 0 | 0 | 3 |
| | Taeniopterygidae | | | | | |
| 035 | *Taenionema* sp. | 4 | 2 | 20 | 2 | 6 |

(continued)

Site 1A - October 1994 (concluded)

| Species Code | Taxa | Number per Sample 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| | Diptera | | | | | |
| | Empididae | | | | | |
| 038 | *Chelifera* sp. | 0 | 5 | 2 | 1 | 2 |
| 039 | *Hemerodromia* sp. | 20 | 8 | 11 | 12 | 8 |
| | Tipulidae | | | | | |
| 041 | *Hexatoma* sp. | 4 | 1 | 4 | 2 | 1 |
| | Chironomidae | | | | | |
| | Chironominae | | | | | |
| | Chironomini Tribe | | | | | |
| 044 | *Cryptochironomus* sp. | 0 | 2 | 0 | 4 | 0 |
| 046 | *Paracladopelma/Cyphomella* spp. | 4 | 0 | 2 | 4 | 6 |
| 048 | *Polypedilum* spp. | 84 | 38 | 42 | 66 | 50 |
| | Tanytarsini Tribe | | | | | |
| 054 | *Micropsectra* sp. | 4 | 6 | 10 | 8 | 42 |
| 055 | *Rheotanytarsus* sp. | 304 | 196 | 212 | 254 | 176 |
| 057 | *Sublettea* sp. | 0 | 2 | 0 | 0 | 0 |
| 058 | *Tanytarsus* sp. | 0 | 0 | 4 | 0 | 8 |
| | Orthocladiinae | | | | | |
| 104 | *Corynoneura* sp. | 0 | 0 | 2 | 0 | 4 |
| 063 | *Cricotopus/Orthocladius* spp. | 368 | 234 | 224 | 318 | 544 |
| 064 | *Eukiefferiella* sp. | 4 | 4 | 2 | 10 | 14 |
| 067 | *Parakiefferiella* sp. | 12 | 14 | 10 | 18 | 44 |
| 070 | *Synorthocladius* sp. | 8 | 14 | 8 | 10 | 44 |
| 071 | *Thienemanniella* sp. | 16 | 2 | 8 | 2 | 2 |
| 072 | *Tvetenia* sp. | 9 | 9 | 10 | 20 | 14 |
| | Tanypodinae | | | | | |
| | Pentaneurini Tribe | | | | | |
| 077 | *Thienemannimyia* gp. | 16 | 14 | 12 | 11 | 10 |
| 085 | Hydracarina | 140 | 60 | 130 | 78 | 124 |
| | Podocopa | | | | | |
| | Candonidae | | | | | |
| 086 | *Candona* sp. | 4 | 0 | 0 | 0 | 0 |
| | Haplotaxida | | | | | |
| 087 | Enchytraeidae | 0 | 4 | 0 | 2 | 6 |
| 088 | Naididae | 172 | 60 | 56 | 43 | 90 |
| 089 | Tubificidae | 4 | 4 | 0 | 3 | 0 |
| 092 | Nematoda | 8 | 6 | 11 | 18 | 16 |
| | Basommatophora | | | | | |
| | Lymnaeidae | | | | | |
| 093 | *Stagnicola catascopium* | 0 | 0 | 1 | 0 | 1 |

**Site 1 - October 1994**

| Species Code | Taxa | Number per Sample 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| | Ephemeroptera | | | | | |
| | Baetidae | | | | | |
| 002 | *Baetis* sp. | 27 | 26 | 70 | 38 | 87 |
| | Ephemerellidae | | | | | |
| 005 | *Ephemerella inermis* | 154 | 171 | 152 | 102 | 156 |
| | Heptageniidae | | | | | |
| 008 | *Heptagenia* sp. | 10 | 8 | 16 | 13 | 6 |
| 009 | *Rhithrogena* sp. | 2 | 2 | 1 | 2 | 3 |
| | Siphlonuridae | | | | | |
| 014 | *Ameletus* sp. | 5 | 1 | 2 | 3 | 3 |
| | Trichoptera | | | | | |
| | Brachycentridae | | | | | |
| 016 | *Brachycentrus* sp. | 27 | 13 | 13 | 11 | 21 |
| | Glossosomatidae | | | | | |
| 115 | *Glossosoma* sp. | 0 | 9 | 0 | 1 | 5 |
| | Hydropsychidae | | | | | |
| 017 | *Arctopsyche* sp. | 0 | 1 | 0 | 0 | 0 |
| 019 | *Hydropsyche* sp. | 44 | 82 | 66 | 23 | 48 |
| | Hydroptilidae | | | | | |
| 020 | *Hydroptila* sp. | 1 | 1 | 5 | 4 | 6 |
| | Lepidostomatidae | | | | | |
| 022 | *Lepidostoma* sp. | 4 | 24 | 0 | 0 | 1 |
| | Leptoceridae | | | | | |
| 023 | *Oecetis* sp. | 0 | 1 | 1 | 0 | 7 |
| | Limnephilidae | | | | | |
| 116 | *Apatania* sp. | 2 | 0 | 0 | 0 | 0 |
| | Plecoptera | | | | | |
| 025 | Capniidae | 10 | 1 | 32 | 25 | 14 |
| | Chloroperlidae | | | | | |
| 099 | Chloroperlinae (early instar) | 4 | 1 | 2 | 0 | 0 |
| | Perlidae | | | | | |
| 028 | *Claassenia sabulosa* | 0 | 2 | 0 | 2 | 3 |
| | Perlodidae | | | | | |
| 029 | *Cultus* sp. | 4 | 0 | 0 | 0 | 0 |
| 030 | *Isogenoides* sp. | 2 | 4 | 4 | 0 | 3 |
| 031 | *Isoperla* sp. | 3 | 0 | 4 | 0 | 0 |
| 032 | Perlodidae (early instar) | 2 | 2 | 4 | 1 | 6 |
| | Taeniopterygidae | | | | | |
| 035 | *Taenionema* sp. | 2 | 52 | 21 | 0 | 30 |

(continued)

**Site 1 - October 1994 (concluded)**

| Species Code | Taxa | Number per Sample 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| | Diptera | | | | | |
| | Empididae | | | | | |
| 038 | *Chelifera* sp. | 0 | 16 | 7 | 10 | 6 |
| 039 | *Hemerodromia* sp. | 4 | 16 | 5 | 4 | 5 |
| | Tipulidae | | | | | |
| 041 | *Hexatoma* sp. | 3 | 1 | 1 | 1 | 6 |
| | Chironomidae | | | | | |
| | Chironominae | | | | | |
| | Chironomini Tribe | | | | | |
| 046 | *Paracladopelma/Cyphomella* spp. | 4 | 8 | 0 | 0 | 0 |
| 048 | *Polypedilum* spp. | 42 | 104 | 40 | 68 | 75 |
| 049 | *Robackia demeijerei* | 8 | 16 | 8 | 4 | 11 |
| | Tanytarsini Tribe | | | | | |
| 052 | *Cladotanytarsus* sp. | 0 | 0 | 0 | 4 | 0 |
| 054 | *Micropsectra* sp. | 4 | 0 | 4 | 12 | 5 |
| 055 | *Rheotanytarsus* sp. | 230 | 809 | 456 | 384 | 531 |
| 058 | *Tanytarsus* sp. | 0 | 0 | 4 | 0 | 0 |
| | Orthocladiinae | | | | | |
| 104 | *Corynoneura* sp. | 0 | 0 | 0 | 0 | 5 |
| 063 | *Cricotopus/Orthocladius* spp. | 245 | 1,156 | 778 | 815 | 1,125 |
| 064 | *Eukiefferiella* sp. | 0 | 0 | 4 | 0 | 0 |
| 065 | *Nanocladius* sp. | 2 | 0 | 0 | 0 | 0 |
| 067 | *Parakiefferiella* sp. | 2 | 0 | 0 | 4 | 0 |
| 070 | *Synorthocladius* sp. | 30 | 56 | 48 | 68 | 110 |
| 072 | *Tvetenia* sp. | 10 | 27 | 21 | 32 | 66 |
| | Prodiamesinae | | | | | |
| 074 | *Monodiamesa* sp. | 0 | 0 | 0 | 0 | 1 |
| | Tanypodinae | | | | | |
| | Pentaneurini Tribe | | | | | |
| 077 | *Thienemannimyia* gp. | 23 | 0 | 6 | 12 | 13 |
| 085 | Hydracarina | 111 | 161 | 132 | 128 | 185 |
| | Haplotaxida | | | | | |
| 087 | Enchytraeidae | 0 | 0 | 0 | 0 | 4 |
| 088 | Naididae | 110 | 120 | 96 | 148 | 101 |
| 092 | Nematoda | 4 | 16 | 10 | 21 | 92 |

Site 2 - October 1994

| Species Code | Taxa | Number per Sample | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| | Ephemeroptera | | | | | |
| | Baetidae | | | | | |
| 002 | *Baetis* sp. | 29 | 21 | 21 | 36 | 125 |
| | Ephemerellidae | | | | | |
| 005 | *Ephemerella inermis* | 140 | 139 | 141 | 227 | 260 |
| | Heptageniidae | | | | | |
| 008 | *Heptagenia* sp. | 9 | 0 | 5 | 16 | 15 |
| 009 | *Rhithrogena* sp. | 6 | 0 | 1 | 8 | 1 |
| | Leptophlebiidae | | | | | |
| 012 | *Paraleptophlebia* sp. | 0 | 0 | 0 | 0 | 1 |
| | Siphlonuridae | | | | | |
| 014 | *Ameletus* sp. | 0 | 0 | 1 | 0 | 0 |
| | Trichoptera | | | | | |
| | Brachycentridae | | | | | |
| 016 | *Brachycentrus* sp. | 8 | 10 | 9 | 13 | 22 |
| | Glossosomatidae | | | | | |
| 115 | *Glossosoma* sp. | 3 | 1 | 0 | 1 | 2 |
| | Hydropsychidae | | | | | |
| 019 | *Hydropsyche* sp. | 10 | 4 | 7 | 12 | 10 |
| | Hydroptilidae | | | | | |
| 020 | *Hydroptila* sp. | 1 | 10 | 1 | 4 | 2 |
| | Lepidostomatidae | | | | | |
| 022 | *Lepidostoma* sp. | 0 | 0 | 1 | 2 | 1 |
| | Limnephilidae | | | | | |
| 116 | *Apatania* sp. | 0 | 1 | 0 | 0 | 1 |
| | Psychomyiidae | | | | | |
| 024 | *Psychomyia* sp. | 1 | 0 | 0 | 0 | 0 |
| | Plecoptera | | | | | |
| 025 | Capniidae | 12 | 1 | 0 | 10 | 39 |
| | Chloroperlidae | | | | | |
| 099 | Chloroperlinae (early instar) | 0 | 3 | 5 | 2 | 1 |
| | Perlodidae | | | | | |
| 029 | *Cultus* sp. | 6 | 3 | 22 | 12 | 15 |
| 030 | *Isogenoides* sp. | 4 | 0 | 0 | 1 | 0 |
| 031 | *Isoperla* sp. | 0 | 0 | 1 | 0 | 0 |
| 032 | Perlodidae (early instar) | 0 | 0 | 0 | 5 | 1 |
| | Taeniopterygidae | | | | | |
| 035 | *Taenionema* sp. | 0 | 0 | 10 | 5 | 11 |

(continued)

Site 2 - October 1994 (concluded)

| Species Code | Taxa | Number per Sample 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| | Diptera | | | | | |
| | Empididae | | | | | |
| 038 | *Chelifera* sp. | 2 | 10 | 5 | 2 | 8 |
| 039 | *Hemerodromia* sp. | 5 | 9 | 0 | 1 | 6 |
| | Chironomidae | | | | | |
| | Chironominae | | | | | |
| | Chironomini Tribe | | | | | |
| 046 | *Paracladopelma/Cyphomella* spp. | 4 | 0 | 10 | 5 | 20 |
| 048 | *Polypedilum* spp. | 40 | 88 | 260 | 305 | 276 |
| | Tanytarsini Tribe | | | | | |
| 054 | *Micropsectra* sp. | 12 | 9 | 25 | 0 | 51 |
| 055 | *Rheotanytarsus* sp. | 201 | 314 | 305 | 248 | 313 |
| 058 | *Tanytarsus* sp. | 0 | 0 | 5 | 0 | 0 |
| | Diamesinae | | | | | |
| | Diamesini Tribe | | | | | |
| 127 | *Potthastia longimana* gp. | 0 | 26 | 20 | 15 | 35 |
| | Orthocladiinae | | | | | |
| 063 | *Cricotopus/Orthocladius* spp. | 511 | 1,063 | 916 | 869 | 1,245 |
| 067 | *Parakiefferiella* sp. | 0 | 0 | 5 | 20 | 15 |
| 070 | *Synorthocladius* sp. | 20 | 56 | 21 | 41 | 56 |
| 071 | *Thienemanniella* sp. | 4 | 0 | 0 | 0 | 0 |
| 072 | *Tvetenia* sp. | 0 | 10 | 42 | 16 | 25 |
| | Tanypodinae | | | | | |
| | Pentaneurini Tribe | | | | | |
| 077 | *Thienemannimyia* gp. | 4 | 26 | 20 | 15 | 48 |
| | Coleoptera | | | | | |
| | Dytiscidae | | | | | |
| 079 | *Oreodytes* sp. | 0 | 0 | 1 | 0 | 0 |
| 085 | Hydracarina | 60 | 103 | 120 | 161 | 147 |
| | Haplotaxida | | | | | |
| 087 | Enchytraeidae | 4 | 0 | 5 | 10 | 5 |
| 088 | Naididae | 223 | 490 | 495 | 259 | 535 |
| 092 | Nematoda | 1 | 17 | 30 | 31 | 125 |
| | Basommatophora | | | | | |
| | Lymnaeidae | | | | | |
| 093 | *Stagnicola catascopium* | 0 | 1 | 1 | 4 | 2 |

Site 3A - October 1994

| Species Code | Taxa | Number per Sample 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| | Ephemeroptera | | | | | |
| | Baetidae | | | | | |
| 002 | *Baetis* sp. | 90 | 78 | 73 | 58 | 82 |
| | Ephemerellidae | | | | | |
| 005 | *Ephemerella inermis* | 607 | 604 | 651 | 730 | 561 |
| | Heptageniidae | | | | | |
| 008 | *Heptagenia* sp. | 0 | 10 | 12 | 42 | 13 |
| 009 | *Rhithrogena* sp. | 0 | 0 | 1 | 0 | 0 |
| | Leptophlebiidae | | | | | |
| 012 | *Paraleptophlebia* sp. | 0 | 12 | 0 | 0 | 0 |
| | Siphlonuridae | | | | | |
| 014 | *Ameletus* sp. | 0 | 1 | 1 | 0 | 0 |
| | Tricorythidae | | | | | |
| 015 | *Tricorythodes* sp. | 0 | 0 | 2 | 0 | 0 |
| | Trichoptera | | | | | |
| | Brachycentridae | | | | | |
| 016 | *Brachycentrus* sp. | 21 | 60 | 92 | 134 | 33 |
| | Glossosomatidae | | | | | |
| 115 | *Glossosoma* sp. | 2 | 5 | 6 | 1 | 3 |
| | Hydropsychidae | | | | | |
| 017 | *Arctopsyche* sp. | 0 | 1 | 1 | 0 | 0 |
| 018 | *Cheumatopsyche* sp. | 0 | 0 | 0 | 1 | 0 |
| 019 | *Hydropsyche* sp. | 6 | 18 | 26 | 45 | 36 |
| | Hydroptilidae | | | | | |
| 020 | *Hydroptila* sp. | 5 | 15 | 9 | 4 | 4 |
| | Lepidostomatidae | | | | | |
| 022 | *Lepidostoma* sp. | 1 | 3 | 13 | 4 | 0 |
| | Leptoceridae | | | | | |
| 023 | *Oecetis* sp. | 4 | 14 | 14 | 27 | 2 |
| | Limnephilidae | | | | | |
| 116 | *Apatania* sp. | 2 | 5 | 1 | 1 | 2 |
| | Plecoptera | | | | | |
| 025 | Capniidae | 88 | 70 | 48 | 67 | 91 |
| | Chloroperlidae | | | | | |
| 099 | Chloroperlinae (early instar) | 1 | 3 | 5 | 0 | 6 |
| | Perlidae | | | | | |
| 028 | *Claassenia sabulosa* | 0 | 1 | 1 | 2 | 0 |
| | Perlodidae | | | | | |
| 029 | *Cultus* sp. | 1 | 0 | 3 | 3 | 2 |
| 030 | *Isogenoides* sp. | 1 | 1 | 1 | 1 | 1 |
| 031 | *Isoperla* sp. | 10 | 15 | 10 | 3 | 23 |

(continued)

## Site 3A - October 1994 (continued)

| Species Code | Taxa | Number per Sample 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| | Pteronarcyidae | | | | | |
| 033 | *Pteronarcella badia* | 1 | 1 | 0 | 3 | 0 |
| | Taeniopterygidae | | | | | |
| 035 | *Taenionema* sp. | 10 | 24 | 10 | 42 | 50 |
| | Diptera | | | | | |
| | Empididae | | | | | |
| 038 | *Chelifera* sp. | 4 | 14 | 3 | 13 | 4 |
| 039 | *Hemerodromia* sp. | 1 | 4 | 12 | 11 | 1 |
| | Tipulidae | | | | | |
| 041 | *Hexatoma* sp. | 0 | 0 | 10 | 0 | 0 |
| | Chironomidae | | | | | |
| | Chironominae | | | | | |
| | Chironomini Tribe | | | | | |
| 044 | *Cryptochironomus* sp. | 0 | 10 | 0 | 0 | 0 |
| 046 | *Paracladopelma/Cyphomella* spp. | 31 | 0 | 0 | 0 | 0 |
| 048 | *Polypedilum* spp. | 320 | 299 | 203 | 155 | 224 |
| 126 | *Stenochironomus* sp. | 10 | 0 | 0 | 0 | 0 |
| | Tanytarsini Tribe | | | | | |
| 052 | *Cladotanytarsus* sp. | 0 | 10 | 0 | 0 | 10 |
| 054 | *Micropsectra* sp. | 161 | 215 | 182 | 200 | 173 |
| 055 | *Rheotanytarsus* sp. | 710 | 420 | 370 | 190 | 305 |
| 057 | *Sublettea* sp. | 20 | 0 | 0 | 0 | 0 |
| 058 | *Tanytarsus* sp. | 10 | 0 | 10 | 0 | 10 |
| | Diamesinae | | | | | |
| | Diamesini Tribe | | | | | |
| 127 | *Potthastia longimana* gp. | 1 | 8 | 17 | 2 | 1 |
| | Orthocladiinae | | | | | |
| 104 | *Corynoneura* sp. | 0 | 0 | 0 | 0 | 10 |
| 063 | *Cricotopus/Orthocladius* spp. | 6,325 | 6,935 | 7,562 | 5,493 | 6,279 |
| 064 | *Eukiefferiella* spp. | 40 | 1 | 30 | 0 | 10 |
| 105 | *Heleniella* sp. | 10 | 0 | 0 | 0 | 0 |
| 067 | *Parakiefferiella* sp. | 30 | 13 | 0 | 10 | 20 |
| 070 | *Synorthocladius* sp. | 220 | 427 | 313 | 151 | 133 |
| 071 | *Thienemanniella* sp. | 570 | 176 | 152 | 244 | 168 |
| | Tanypodinae | | | | | |
| | Pentaneurini Tribe | | | | | |
| 077 | *Thienemannimyia* gp. | 35 | 46 | 52 | 42 | 80 |
| 085 | Hydracarina | 261 | 292 | 460 | 312 | 333 |
| | Podocopa | | | | | |
| | Candonidae | | | | | |
| 086 | *Candona* sp. | 0 | 0 | 20 | 10 | 0 |

(continued)

**Site 3A - October 1994 (concluded)**

| Species Code | Taxa | Number per Sample 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| | Haplotaxida | | | | | |
| 087 | Enchytraeidae | 20 | 30 | 0 | 0 | 0 |
| 088 | Naididae | 161 | 196 | 289 | 222 | 123 |
| 089 | Tubificidae | 1 | 0 | 0 | 0 | 0 |
| 092 | Nematoda | 196 | 210 | 158 | 192 | 245 |
| | Tricladida | | | | | |
| | Planariidae | | | | | |
| 095 | *Polycelis coronata* | 0 | 0 | 0 | 0 | 1 |

Site 3 - October 1994

| Species Code | Taxa | Number per Sample 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| | Ephemeroptera | | | | | |
| | Baetidae | | | | | |
| 002 | *Baetis* sp. | 25 | 8 | 5 | 28 | 44 |
| | Ephemerellidae | | | | | |
| 005 | *Ephemerella inermis* | 131 | 136 | 234 | 143 | 165 |
| | Heptageniidae | | | | | |
| 008 | *Heptagenia* sp. | 33 | 26 | 22 | 33 | 54 |
| 009 | *Rhithrogena* sp. | 2 | 4 | 2 | 0 | 0 |
| | Siphlonuridae | | | | | |
| 014 | *Ameletus* sp. | 5 | 4 | 5 | 8 | 13 |
| | Trichoptera | | | | | |
| | Brachycentridae | | | | | |
| 016 | *Brachycentrus* sp. | 25 | 18 | 71 | 43 | 91 |
| | Glossosomatidae | | | | | |
| 115 | *Glossosoma* sp. | 0 | 0 | 0 | 0 | 1 |
| | Hydropsychidae | | | | | |
| 017 | *Arctopsyche* sp. | 0 | 0 | 0 | 0 | 2 |
| 019 | *Hydropsyche* sp. | 3 | 2 | 3 | 3 | 2 |
| | Hydroptilidae | | | | | |
| 020 | *Hydroptila* sp. | 9 | 3 | 5 | 5 | 7 |
| | Lepidostomatidae | | | | | |
| 022 | *Lepidostoma* sp. | 12 | 1 | 2 | 0 | 13 |
| | Leptoceridae | | | | | |
| 023 | *Oecetis* sp. | 0 | 5 | 1 | 0 | 11 |
| | Limnephilidae | | | | | |
| 116 | *Apatania* sp. | 2 | 0 | 1 | 0 | 0 |
| | Plecoptera | | | | | |
| 025 | Capniidae | 27 | 31 | 25 | 37 | 85 |
| | Chloroperlidae | | | | | |
| 099 | Chloroperlinae (early instar) | 3 | 5 | 3 | 10 | 13 |
| | Perlidae | | | | | |
| 028 | *Claassenia sabulosa* | 0 | 5 | 0 | 8 | 0 |
| | Perlodidae | | | | | |
| 029 | *Cultus* sp. | 0 | 0 | 0 | 1 | 2 |
| 030 | *Isogenoides* sp. | 0 | 1 | 0 | 1 | 0 |
| 031 | *Isoperla* sp. | 16 | 12 | 25 | 10 | 34 |
| | Taeniopterygidae | | | | | |
| 035 | *Taenionema* sp. | 8 | 5 | 0 | 4 | 0 |
| | Diptera | | | | | |
| | Empididae | | | | | |
| 038 | *Chelifera* sp. | 2 | 1 | 2 | 13 | 1 |
| 039 | *Hemerodromia* sp. | 0 | 0 | 0 | 4 | 0 |

(continued)

Site 3 - October 1994 (concluded)

| Species Code | Taxa | Number per Sample 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| | Tipulidae | | | | | |
| 041 | *Hexatoma* sp. | 0 | 1 | 0 | 0 | 1 |
| | Chironomidae | | | | | |
| | Chironominae | | | | | |
| | Chironomini Tribe | | | | | |
| 046 | *Paracladopelma/Cyphomella* spp. | 8 | 0 | 0 | 0 | 0 |
| 048 | *Polypedilum* spp. | 120 | 50 | 60 | 40 | 50 |
| | Tanytarsini Tribe | | | | | |
| 052 | *Cladotanytarsus* sp. | 0 | 0 | 10 | 0 | 0 |
| 054 | *Micropsectra* sp. | 41 | 40 | 51 | 60 | 70 |
| 055 | *Rheotanytarsus* sp. | 432 | 155 | 150 | 176 | 412 |
| | Diamesinae | | | | | |
| | Diamesini Tribe | | | | | |
| 127 | *Potthastia longimana* gp. | 0 | 0 | 10 | 0 | 0 |
| | Orthocladiinae | | | | | |
| 063 | *Cricotopus/Orthocladius* spp. | 2,107 | 1,609 | 3,514 | 1,262 | 2,701 |
| 064 | *Eukiefferiella* sp. | 8 | 0 | 0 | 0 | 10 |
| 065 | *Nanocladius* sp. | 0 | 5 | 0 | 0 | 0 |
| 067 | *Parakiefferiella* sp. | 8 | 15 | 0 | 4 | 0 |
| 070 | *Synorthocladius* sp. | 176 | 80 | 100 | 72 | 100 |
| 071 | *Thienemanniella* sp. | 0 | 0 | 10 | 8 | 10 |
| 072 | *Tvetenia* sp. | 16 | 40 | 92 | 40 | 80 |
| | Prodiamesinae | | | | | |
| 074 | *Monodiamesa* sp. | 0 | 5 | 0 | 0 | 0 |
| | Tanypodinae | | | | | |
| | Pentaneurini Tribe | | | | | |
| 077 | *Thienemannimyia* gp. | 11 | 18 | 30 | 40 | 39 |
| 085 | Hydracarina | 120 | 30 | 93 | 64 | 141 |
| | Podocopa | | | | | |
| | Candonidae | | | | | |
| 086 | *Candona* sp. | 8 | 0 | 0 | 4 | 0 |
| | Haplotaxida | | | | | |
| 087 | Enchytraeidae | 1 | 0 | 0 | 0 | 0 |
| 088 | Naididae | 112 | 60 | 100 | 100 | 150 |
| 092 | Nematoda | 21 | 1 | 60 | 8 | 50 |
| | Tricladida | | | | | |
| | Planariidae | | | | | |
| 095 | *Polycelis coronata* | 0 | 0 | 0 | 4 | 0 |

**Site 4 - October 1994**

| Species Code | Taxa | Number per Sample 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| | Ephemeroptera | | | | | |
| | Baetidae | | | | | |
| 002 | *Baetis* sp. | 74 | 166 | 120 | 36 | 136 |
| | Ephemerellidae | | | | | |
| 004 | *Drunella doddsi* | 0 | 0 | 0 | 1 | 0 |
| 005 | *Ephemerella inermis* | 304 | 253 | 110 | 210 | 323 |
| | Heptageniidae | | | | | |
| 008 | *Heptagenia* sp. | 11 | 24 | 16 | 15 | 33 |
| 009 | *Rhithrogena* sp. | 1 | 32 | 8 | 2 | 0 |
| | Leptophlebiidae | | | | | |
| 012 | *Paraleptophlebia* sp. | 0 | 20 | 0 | 0 | 1 |
| | Siphlonuridae | | | | | |
| 014 | *Ameletus* sp. | 3 | 1 | 0 | 1 | 1 |
| | Tricorythidae | | | | | |
| 015 | *Tricorythodes* sp. | 0 | 0 | 1 | 0 | 0 |
| | Trichoptera | | | | | |
| | Brachycentridae | | | | | |
| 016 | *Brachycentrus* sp. | 117 | 124 | 72 | 62 | 176 |
| | Glossosomatidae | | | | | |
| 115 | *Glossosoma* sp. | 12 | 10 | 10 | 17 | 30 |
| | Hydropsychidae | | | | | |
| 017 | *Arctopsyche* sp. | 1 | 1 | 0 | 0 | 0 |
| 019 | *Hydropsyche* sp. | 31 | 36 | 12 | 11 | 36 |
| | Hydroptilidae | | | | | |
| 020 | *Hydroptila* sp. | 4 | 8 | 7 | 3 | 7 |
| | Lepidostomatidae | | | | | |
| 022 | *Lepidostoma* sp. | 1 | 3 | 6 | 5 | 3 |
| | Leptoceridae | | | | | |
| 023 | *Oecetis* sp. | 1 | 0 | 1 | 0 | 6 |
| | Limnephilidae | | | | | |
| 116 | *Apatania* sp. | 4 | 4 | 0 | 2 | 7 |
| | Plecoptera | | | | | |
| 025 | Capniidae | 44 | 17 | 28 | 63 | 35 |
| | Chloroperlidae | | | | | |
| 099 | Chloroperlinae (early instar) | 3 | 0 | 0 | 0 | 4 |
| | Perlidae | | | | | |
| 028 | *Claassenia sabulosa* | 0 | 4 | 1 | 1 | 1 |
| | Perlodidae | | | | | |
| 029 | *Cultus* sp. | 2 | 0 | 0 | 0 | 0 |
| 030 | *Isogenoides* sp. | 1 | 2 | 0 | 1 | 2 |
| 031 | *Isoperla* sp. | 24 | 9 | 13 | 15 | 7 |

(continued)

**Site 4 - October 1994 (continued)**

| Species Code | Taxa | Number per Sample 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| | Pteronarcyidae | | | | | |
| 033 | *Pteronarcella badia* | 0 | 0 | 0 | 1 | 0 |
| 034 | *Pteronarys dorsata* | 0 | 0 | 0 | 1 | 0 |
| | Taeniopterygidae | | | | | |
| 035 | *Taenionema* sp. | 33 | 3 | 1 | 0 | 4 |
| | Diptera | | | | | |
| | Blephariceridae | | | | | |
| 118 | *Bibiocephala grandis* | 1 | 0 | 0 | 0 | 0 |
| | Empididae | | | | | |
| 038 | *Chelifera* sp. | 1 | 4 | 6 | 8 | 18 |
| 039 | *Hemerodromia* sp. | 1 | 0 | 1 | 3 | 2 |
| 119 | *Wiedemannia* sp. | 0 | 1 | 0 | 1 | 2 |
| | Tipulidae | | | | | |
| 041 | *Hexatoma* sp. | 0 | 1 | 0 | 0 | 0 |
| | Chironomidae | | | | | |
| | Chironominae | | | | | |
| | Chironomini Tribe | | | | | |
| 044 | *Cryptochironomus* sp. | 0 | 0 | 0 | 0 | 10 |
| 046 | *Paracladopelma/Cyphomella* spp. | 0 | 0 | 0 | 5 | 10 |
| 048 | *Polypedilum* spp. | 100 | 150 | 408 | 195 | 410 |
| | Tanytarsini Tribe | | | | | |
| 052 | *Cladotanytarsus* sp. | 0 | 1 | 0 | 5 | 0 |
| 054 | *Micropsectra* sp. | 0 | 0 | 0 | 25 | 30 |
| 055 | *Rheotanytarsus* sp. | 113 | 316 | 341 | 261 | 475 |
| 058 | *Tanytarsus* sp. | 0 | 0 | 0 | 0 | 10 |
| | Diamesinae | | | | | |
| | Diamesini Tribe | | | | | |
| 127 | *Potthastia longimana* gp. | 0 | 1 | 2 | 0 | 4 |
| | Orthocladiinae | | | | | |
| 062 | *Cardiocladius* sp. | 1 | 4 | 1 | 0 | 3 |
| 063 | *Cricotopus/Orthocladius* spp. | 3,051 | 4,290 | 3,874 | 1,787 | 4,180 |
| 064 | *Eukiefferiella* sp. | 1 | 2 | 17 | 0 | 1 |
| 105 | *Heleniella* sp. | 0 | 0 | 0 | 0 | 1 |
| 065 | *Nanocladius* sp. | 0 | 0 | 0 | 0 | 2 |
| 067 | *Parakiefferiella* sp. | 10 | 30 | 40 | 10 | 70 |
| 070 | *Synorthocladius* sp. | 40 | 70 | 8 | 40 | 50 |
| 072 | *Tvetenia* sp. | 225 | 431 | 49 | 100 | 67 |
| | Tanypodinae | | | | | |
| | Pentaneurini Tribe | | | | | |
| 077 | *Thienemannimyia* gp. | 10 | 3 | 33 | 51 | 57 |
| | Coleoptera | | | | | |
| | Elmidae | | | | | |
| 080 | *Optioservus* sp. | 0 | 1 | 0 | 0 | 0 |

(continued)

Site 4 - October 1994 (concluded)

| Species Code | Taxa | Number per Sample 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| | Odonata | | | | | |
| | Gomphidae | | | | | |
| 084 | *Ophiogomphus* sp. | 1 | 0 | 0 | 0 | 0 |
| 085 | Hydracarina | 221 | 103 | 258 | 147 | 268 |
| | Haplotaxida | | | | | |
| 087 | Enchytraeidae | 21 | 3 | 0 | 0 | 2 |
| 088 | Naididae | 462 | 391 | 282 | 301 | 440 |
| 089 | Tubificidae | 0 | 0 | 0 | 0 | 11 |
| 092 | Nematoda | 105 | 47 | 84 | 88 | 94 |
| | Tricladida | | | | | |
| | Planariidae | | | | | |
| 095 | *Polycelis coronata* | 0 | 1 | 0 | 0 | 0 |

Site 5 - October 1994

| Species Code | Taxa | Number per Sample | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| | Ephemeroptera | | | | | |
| | Baetidae | | | | | |
| 002 | *Baetis* sp. | 150 | 150 | 269 | 118 | 97 |
| | Ephemerellidae | | | | | |
| 005 | *Ephemerella inermis* | 272 | 156 | 263 | 253 | 172 |
| | Heptageniidae | | | | | |
| 008 | *Heptagenia* sp. | 17 | 16 | 14 | 8 | 5 |
| 009 | *Rhithrogena* sp. | 6 | 23 | 9 | 8 | 19 |
| | Siphlonuridae | | | | | |
| 014 | *Ameletus* sp. | 12 | 10 | 7 | 7 | 15 |
| | Trichoptera | | | | | |
| | Brachycentridae | | | | | |
| 016 | *Brachycentrus* sp. | 28 | 28 | 25 | 34 | 16 |
| | Glossosomatidae | | | | | |
| 115 | *Glossosoma* sp. | 2 | 5 | 0 | 4 | 1 |
| | Hydropsychidae | | | | | |
| 017 | *Arctopsyche* sp. | 1 | 0 | 5 | 2 | 0 |
| 018 | *Cheumatopsyche* sp. | 1 | 2 | 1 | 0 | 0 |
| 019 | *Hydropsyche* sp. | 235 | 87 | 176 | 77 | 26 |
| | Hydroptilidae | | | | | |
| 020 | *Hydroptila* sp. | 0 | 1 | 2 | 0 | 0 |
| | Lepidostomatidae | | | | | |
| 022 | *Lepidostoma* sp. | 11 | 6 | 0 | 5 | 7 |
| | Leptoceridae | | | | | |
| 023 | *Oecetis* sp. | 18 | 10 | 0 | 3 | 1 |
| | Limnephilidae | | | | | |
| 116 | *Apatania* sp. | 1 | 0 | 3 | 2 | 5 |
| | Psychomyiidae | | | | | |
| 024 | *Psychomyia* sp. | 1 | 2 | 1 | 1 | 0 |
| | Plecoptera | | | | | |
| 025 | Capniidae | 17 | 27 | 23 | 24 | 22 |
| | Perlidae | | | | | |
| 028 | *Claassenia sabulosa* | 0 | 2 | 2 | 5 | 2 |
| | Perlodidae | | | | | |
| 029 | *Cultus* sp. | 0 | 0 | 1 | 2 | 0 |
| 030 | *Isogenoides* sp. | 4 | 8 | 10 | 5 | 0 |
| | Taeniopterygidae | | | | | |
| 035 | *Taenionema* sp. | 44 | 36 | 70 | 29 | 20 |

(continued)

**Site 5 - October 1994 (concluded)**

| Species Code | Taxa | Number per Sample 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| | Diptera | | | | | |
| | Ceratopogonidae | | | | | |
| 037 | *Bezzia/Palpomyia* gp. | 8 | 0 | 0 | 0 | 0 |
| | Empididae | | | | | |
| 038 | *Chelifera* sp. | 17 | 5 | 11 | 5 | 4 |
| 039 | *Hemerodromia* sp. | 0 | 0 | 20 | 4 | 0 |
| | Tipulidae | | | | | |
| 041 | *Hexatoma* sp. | 2 | 2 | 1 | 0 | 0 |
| | Chironomidae | | | | | |
| | Chironominae | | | | | |
| | Chironomini Tribe | | | | | |
| 046 | *Paracladopelma/Cyphomella* spp. | 0 | 5 | 0 | 0 | 0 |
| 048 | *Polypedilum* spp. | 8 | 15 | 50 | 28 | 0 |
| | Tanytarsini Tribe | | | | | |
| 052 | *Cladotanytarsus* sp. | 72 | 25 | 30 | 44 | 40 |
| 054 | *Micropsectra* sp. | 56 | 5 | 30 | 16 | 20 |
| 055 | *Rheotanytarsus* sp. | 409 | 387 | 421 | 264 | 224 |
| 057 | *Sublettea* sp. | 88 | 35 | 40 | 57 | 40 |
| | Diamesinae | | | | | |
| | Diamesini Tribe | | | | | |
| 127 | *Potthastia longimana* gp. | 0 | 1 | 0 | 0 | 0 |
| | Orthocladiinae | | | | | |
| 062 | *Cardiocladius* sp. | 152 | 155 | 170 | 144 | 88 |
| 063 | *Cricotopus/Orthocladius* spp. | 1,099 | 567 | 885 | 572 | 395 |
| 064 | *Eukiefferiella* sp. | 216 | 285 | 321 | 365 | 196 |
| 065 | *Nanocladius* sp. | 8 | 0 | 0 | 4 | 0 |
| 067 | *Parakiefferiella* sp. | 8 | 25 | 70 | 44 | 16 |
| 070 | *Synorthocladius* sp. | 32 | 10 | 51 | 28 | 16 |
| 071 | *Thienemanniella* sp. | 0 | 5 | 0 | 8 | 4 |
| 072 | *Tvetenia* sp. | 252 | 141 | 212 | 145 | 96 |
| | Tanypodinae | | | | | |
| | Pentaneurini Tribe | | | | | |
| 077 | *Thienemannimyia* gp. | 35 | 43 | 63 | 54 | 8 |
| 085 | Hydracarina | 192 | 170 | 170 | 93 | 160 |
| | Haplotaxida | | | | | |
| 087 | Enchytraeidae | 25 | 20 | 10 | 12 | 28 |
| 088 | Naididae | 88 | 170 | 370 | 180 | 140 |
| 092 | Nematoda | 34 | 24 | 35 | 24 | 13 |
| | Basommatophora | | | | | |
| | Lymnaeidae | | | | | |
| 093 | *Stagnicola catascopium* | 0 | 0 | 0 | 0 | 1 |

Site 6 - October 1994

| Species Code | Taxa | Number per Sample | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| | Ephemeroptera | | | | | |
| | Baetidae | | | | | |
| 002 | *Baetis* sp. | 66 | 24 | 39 | 18 | 20 |
| | Ephemerellidae | | | | | |
| 005 | *Ephemerella inermis* | 66 | 26 | 105 | 70 | 40 |
| | Ephemeridae | | | | | |
| 006 | *Ephemera* sp. | 0 | 1 | 0 | 2 | 0 |
| | Heptageniidae | | | | | |
| 008 | *Heptagenia* sp. | 4 | 4 | 5 | 2 | 2 |
| 009 | *Rhithrogena* sp. | 23 | 9 | 3 | 10 | 11 |
| | Siphlonuridae | | | | | |
| 014 | *Ameletus* sp. | 0 | 2 | 6 | 0 | 1 |
| | Tricorythidae | | | | | |
| 015 | *Tricorythodes* sp. | 1 | 0 | 0 | 0 | 0 |
| | Trichoptera | | | | | |
| | Brachycentridae | | | | | |
| 016 | *Brachycentrus* sp. | 99 | 61 | 308 | 134 | 83 |
| | Glossosomatidae | | | | | |
| 115 | *Glossosoma* sp. | 4 | 6 | 2 | 3 | 3 |
| | Hydropsychidae | | | | | |
| 017 | *Arctopsyche* sp. | 0 | 0 | 1 | 0 | 0 |
| 018 | *Cheumatopsyche* sp. | 0 | 0 | 5 | 0 | 0 |
| 019 | *Hydropsyche* sp. | 44 | 15 | 47 | 35 | 28 |
| | Hydroptilidae | | | | | |
| 020 | *Hydroptila* sp. | 4 | 4 | 1 | 0 | 0 |
| | Lepidostomatidae | | | | | |
| 022 | *Lepidostoma* sp. | 1 | 1 | 2 | 2 | 1 |
| | Leptoceridae | | | | | |
| 023 | *Oecetis* sp. | 3 | 8 | 7 | 6 | 5 |
| | Limnephilidae | | | | | |
| 116 | *Apatania* sp. | 4 | 5 | 6 | 3 | 3 |
| | Polycentropodidae | | | | | |
| 117 | *Neureclipsis* sp. | 3 | 0 | 4 | 0 | 0 |
| | Psychomyiidae | | | | | |
| 024 | *Psychomyia* sp. | 2 | 0 | 1 | 1 | 0 |
| | Plecoptera | | | | | |
| 025 | Capniidae | 23 | 26 | 50 | 22 | 28 |
| | Chloroperlidae | | | | | |
| 099 | Chloroperlinae (early instar) | 1 | 0 | 4 | 1 | 1 |
| | Perlidae | | | | | |
| 028 | *Claassenia sabulosa* | 2 | 1 | 1 | 1 | 2 |

(continued)

**Site 6 - October 1994 (continued)**

| Species Code | Taxa | Number per Sample 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| | Perlodidae | | | | | |
| 029 | *Cultus* sp. | 11 | 5 | 12 | 3 | 4 |
| 030 | *Isogenoides* sp. | 2 | 2 | 1 | 0 | 1 |
| 031 | *Isoperla* sp. | 1 | 0 | 0 | 0 | 0 |
| | Taeniopterygidae | | | | | |
| 035 | *Taenionema* sp. | 2 | 1 | 9 | 1 | 0 |
| | Diptera | | | | | |
| | Ceratopogonidae | | | | | |
| 037 | *Bezzia/Palpomyia* gp. | 0 | 0 | 1 | 0 | 0 |
| | Empididae | | | | | |
| 038 | *Chelifera* sp. | 6 | 1 | 1 | 5 | 2 |
| 039 | *Hemerodromia* sp. | 5 | 1 | 6 | 1 | 3 |
| | Tipulidae | | | | | |
| 041 | *Hexatoma* sp. | 0 | 0 | 1 | 0 | 2 |
| | Chironomidae | | | | | |
| | Chironominae | | | | | |
| | Chironomini Tribe | | | | | |
| 044 | *Cryptochironomus* sp. | 0 | 8 | 30 | 8 | 12 |
| 046 | *Paracladopelma/Cyphomella* spp. | 0 | 4 | 0 | 0 | 0 |
| 048 | *Polypedilum* spp. | 44 | 37 | 75 | 48 | 29 |
| 138 | *Stictochironomus* sp. | 0 | 4 | 0 | 0 | 0 |
| | Tanytarsini Tribe | | | | | |
| 052 | *Cladotanytarsus* sp. | 28 | 36 | 20 | 8 | 24 |
| 054 | *Micropsectra* sp. | 116 | 68 | 40 | 24 | 28 |
| 055 | *Rheotanytarsus* sp. | 156 | 176 | 310 | 208 | 164 |
| 057 | *Sublettea* sp. | 12 | 12 | 35 | 16 | 36 |
| 058 | *Tanytarsus* sp. | 0 | 4 | 0 | 0 | 0 |
| | Diamesinae | | | | | |
| | Diamesini Tribe | | | | | |
| 127 | *Potthastia longimana* gp. | 0 | 4 | 0 | 0 | 0 |
| | Orthocladiinae | | | | | |
| 062 | *Cardiocladius* sp. | 0 | 4 | 0 | 0 | 0 |
| 063 | *Cricotopus/Orthocladius* spp. | 1,080 | 968 | 995 | 998 | 910 |
| 064 | *Eukiefferiella* sp. | 0 | 4 | 0 | 0 | 0 |
| 065 | *Nanocladius* sp. | 12 | 20 | 35 | 16 | 36 |
| 067 | *Parakiefferiella* sp. | 8 | 12 | 5 | 0 | 0 |
| 070 | *Synorthocladius* sp. | 28 | 36 | 20 | 28 | 48 |
| 071 | *Thienemanniella* sp. | 4 | 8 | 10 | 4 | 12 |
| 072 | *Tvetenia* sp. | 28 | 66 | 37 | 65 | 51 |
| | Prodiamesinae | | | | | |
| 074 | *Monodiamesa* sp. | 4 | 0 | 0 | 0 | 0 |
| | Tanypodinae | | | | | |
| | Pentaneurini Tribe | | | | | |
| 077 | *Thienemannimyia* gp. | 79 | 57 | 80 | 89 | 46 |

(continued)

**Site 6 - October 1994 (concluded)**

| Species Code | Taxa | Number per Sample 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| 085 | Hydracarina | 52 | 89 | 70 | 93 | 81 |
| | Podocopa | | | | | |
| | Candonidae | | | | | |
| 086 | *Candona* sp. | 12 | 0 | 0 | 0 | 0 |
| | Haplotaxida | | | | | |
| 087 | Enchytraeidae | 12 | 1 | 20 | 12 | 14 |
| 088 | Naididae | 226 | 192 | 330 | 217 | 196 |
| 089 | Tubificidae | 0 | 0 | 1 | 5 | 0 |
| 092 | Nematoda | 17 | 18 | 33 | 30 | 57 |
| | Basommatophora | | | | | |
| | Lymnaeidae | | | | | |
| 093 | *Stagnicola catascopium* | 0 | 0 | 1 | 0 | 1 |

Site 7 - October 1994

| Species Code | Taxa | Number per Sample 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| | Ephemeroptera | | | | | |
| | Baetidae | | | | | |
| 002 | *Baetis* sp. | 41 | 30 | 40 | 25 | 37 |
| | Ephemerellidae | | | | | |
| 005 | *Ephemerella inermis* | 98 | 66 | 97 | 109 | 197 |
| | Heptageniidae | | | | | |
| 008 | *Heptagenia* sp. | 7 | 0 | 1 | 4 | 8 |
| 009 | *Rhithrogena* sp. | 8 | 2 | 2 | 6 | 6 |
| | Leptophlebiidae | | | | | |
| 012 | *Paraleptophlebia* sp. | 0 | 1 | 0 | 5 | 1 |
| | Siphlonuridae | | | | | |
| 014 | *Ameletus* sp. | 1 | 0 | 0 | 0 | 4 |
| | Tricorythidae | | | | | |
| 015 | *Tricorythodes* sp. | 1 | 0 | 0 | 0 | 0 |
| | Trichoptera | | | | | |
| | Brachycentridae | | | | | |
| 016 | *Brachycentrus* sp. | 114 | 71 | 181 | 147 | 118 |
| | Glossosomatidae | | | | | |
| 115 | *Glossosoma* sp. | 0 | 4 | 3 | 3 | 6 |
| | Hydropsychidae | | | | | |
| 019 | *Hydropsyche* sp. | 24 | 10 | 67 | 75 | 69 |
| | Lepidostomatidae | | | | | |
| 022 | *Lepidostoma* sp. | 1 | 0 | 0 | 1 | 1 |
| | Leptoceridae | | | | | |
| 023 | *Oecetis* sp. | 0 | 5 | 8 | 13 | 4 |
| | Limnephilidae | | | | | |
| 116 | *Apatania* sp. | 1 | 0 | 2 | 12 | 2 |
| | Polycentropodidae | | | | | |
| 117 | *Neureclipsis* sp. | 2 | 3 | 1 | 1 | 3 |
| | Psychomyiidae | | | | | |
| 024 | *Psychomyia* sp. | 0 | 0 | 0 | 1 | 1 |
| | Plecoptera | | | | | |
| 025 | Capniidae | 14 | 14 | 26 | 51 | 34 |
| | Chloroperlidae | | | | | |
| 099 | Chloroperlinae (early instar) | 2 | 0 | 0 | 1 | 2 |
| | Nemouridae | | | | | |
| 027 | *Zapada* sp. | 1 | 0 | 0 | 0 | 0 |
| | Perlidae | | | | | |
| 028 | *Claassenia sabulosa* | 2 | 0 | 0 | 0 | 0 |
| | Perlodidae | | | | | |
| 029 | *Cultus* sp. | 3 | 4 | 4 | 1 | 4 |
| 030 | *Isogenoides* sp. | 1 | 0 | 0 | 0 | 0 |

(continued)

**Site 7 - October 1994 (continued)**

| Species Code | Taxa | Number per Sample 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| | Taeniopterygidae | | | | | |
| 035 | *Taenionema* sp. | 10 | 2 | 0 | 0 | 1 |
| 137 | *Taeniopteryx* sp. | 1 | 0 | 0 | 0 | 1 |
| | Diptera | | | | | |
| | Ceratopogonidae | | | | | |
| 037 | *Bezzia/Palpomyia* gp. | 0 | 0 | 5 | 0 | 0 |
| | Empididae | | | | | |
| 038 | *Chelifera* sp. | 1 | 2 | 0 | 10 | 10 |
| 039 | *Hemerodromia* sp. | 5 | 2 | 0 | 0 | 0 |
| | Chironomidae | | | | | |
| | Chironominae | | | | | |
| | Chironomini Tribe | | | | | |
| 044 | *Cryptochironomus* sp. | 35 | 4 | 105 | 130 | 45 |
| 046 | *Paracladopelma/Cyphomella* spp. | 0 | 2 | 0 | 5 | 0 |
| 048 | *Polypedilum* spp. | 100 | 54 | 62 | 43 | 76 |
| | Tanytarsini Tribe | | | | | |
| 052 | *Cladotanytarsus* sp. | 60 | 34 | 45 | 40 | 35 |
| 054 | *Micropsectra* sp. | 85 | 38 | 75 | 190 | 145 |
| 055 | *Rheotanytarsus* sp. | 407 | 128 | 355 | 246 | 180 |
| 057 | *Sublettea* sp. | 0 | 0 | 0 | 0 | 5 |
| 058 | *Tanytarsus* sp. | 0 | 0 | 5 | 10 | 20 |
| | Diamesinae | | | | | |
| | Diamesini Tribe | | | | | |
| 127 | *Potthastia longimana* gp. | 4 | 0 | 2 | 1 | 25 |
| | Orthocladiinae | | | | | |
| 062 | *Cardiocladius* sp. | 5 | 0 | 0 | 0 | 0 |
| 104 | *Corynoneura* sp. | 0 | 0 | 0 | 5 | 0 |
| 063 | *Cricotopus/Orthocladius* spp. | 561 | 144 | 585 | 485 | 475 |
| 064 | *Eukiefferiella* sp. | 15 | 2 | 5 | 0 | 10 |
| 065 | *Nanocladius* sp. | 30 | 4 | 45 | 20 | 35 |
| 067 | *Parakiefferiella* sp. | 60 | 16 | 55 | 30 | 20 |
| 070 | *Synorthocladius* sp. | 90 | 26 | 35 | 60 | 30 |
| 071 | *Thienemanniella* sp. | 5 | 0 | 5 | 5 | 0 |
| 072 | *Tvetenia* sp. | 20 | 4 | 15 | 25 | 39 |
| | Tanypodinae | | | | | |
| | Pentaneurini Tribe | | | | | |
| 077 | *Thienemannimyia* gp. | 65 | 18 | 76 | 115 | 43 |
| | Hemiptera | | | | | |
| | Corixidae | | | | | |
| 081 | *Callicorixa audeni* | 13 | 2 | 12 | 23 | 18 |
| 085 | Hydracarina | 125 | 66 | 190 | 175 | 145 |

(continued)

**Site 7 - October 1994 (concluded)**

| Species Code | Taxa | Number per Sample 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| | Podocopa | | | | | |
| | Candonidae | | | | | |
| 086 | *Candona* sp. | 0 | 2 | 5 | 0 | 5 |
| | Haplotaxida | | | | | |
| 087 | Enchytraeidae | 10 | 11 | 5 | 0 | 25 |
| 088 | Naididae | 140 | 84 | 110 | 60 | 180 |
| 092 | Nematoda | 10 | 8 | 25 | 20 | 31 |
| | Basommatophora | | | | | |
| | Lymnaeidae | | | | | |
| 093 | *Stagnicola catascopium* | 2 | 2 | 1 | 8 | 1 |
| | Planorbidae | | | | | |
| 128 | *Gyraulus* sp. | 0 | 0 | 0 | 5 | 0 |

# APPENDIX F

# BASIC COMPUTATIONS OF BENTHIC INVERTEBRATE SAMPLES, OCTOBER 1994

Appendix F-1. Number (N) of taxa, number of EPT taxa, number of organisms, standing crop and species diversity of benthic invertebrate samples with means and 95% confidence limits (CL) per site, October 1994.

| Site-Sample | Number of Taxa | Number of EPT Taxa | Number of Organisms | Standing Crop (N/m²) | Species Diversity* |
|---|---|---|---|---|---|
| 1A-1 | 34 | 16 | 1,589 | 17,814 | 2.51 |
| 1A-2 | 35 | 15 | 840 | 9,417 | 2.43 |
| 1A-3 | 37 | 17 | 1,214 | 13,610 | 2.59 |
| 1A-4 | 35 | 15 | 1,137 | 12,747 | 2.43 |
| 1A-5 | 38 | 17 | 1,489 | 16,693 | 2.43 |
| Mean±95% | 36 ± 2 | 16 ± 1 | 1,254 ± 369 | 14,056 ± 4,141 | 2.48 ± 0.09 |
| 1-1 | 33 | 17 | 1,135 | 12,724 | 2.42 |
| 1-2 | 31 | 18 | 2,907 | 32,590 | 1.91 |
| 1-3 | 31 | 15 | 2,013 | 22,567 | 2.06 |
| 1-4 | 28 | 12 | 1,940 | 21,749 | 2.01 |
| 1-5 | 33 | 16 | 2,740 | 30,717 | 2.10 |
| Mean ± 95% CL | 31 ± 3 | 16 ± 3 | 2,147 ± 881 | 24,070 ± 9,876 | 2.10 ± 0.24 |
| 2-1 | 26 | 12 | 1,320 | 14,798 | 1.97 |
| 2-2 | 24 | 10 | 2,415 | 27,074 | 1.80 |
| 2-3 | 31 | 13 | 2,511 | 28,150 | 2.03 |
| 2-4 | 31 | 15 | 2,356 | 26,413 | 2.12 |
| 2-5 | 33 | 16 | 3,419 | 38,330 | 2.21 |
| Mean ± 95% CL | 29 ± 5 | 13 ± 3 | 2,404 ± 925 | 26,953 ± 10,367 | 2.03 ± 0.19 |
| 3A-1 | 38 | 16 | 9,987 | 111,962 | 1.57 |
| 3A-2 | 38 | 20 | 10,247 | 114,877 | 1.47 |
| 3A-3 | 38 | 21 | 10,823 | 121,334 | 1.39 |
| 3A-4 | 33 | 18 | 8,415 | 94,339 | 1.54 |
| 3A-5 | 34 | 15 | 9,039 | 101,334 | 1.42 |
| Mean ± 95% CL | 36 ± 3 | 18 ± 3 | 9,702 ± 1,199 | 108,769 ± 13,441 | 1.48 ± 0.10 |
| 3-1 | 30 | 14 | 3,492 | 39,148 | 1.62 |
| 3-2 | 31 | 16 | 2,376 | 26,637 | 1.47 |
| 3-3 | 28 | 14 | 4,686 | 52,534 | 1.22 |
| 3-4 | 30 | 13 | 2,233 | 25,034 | 1.87 |
| 3-5 | 29 | 15 | 4,352 | 48,789 | 1.66 |
| Mean ± 95% CL | 30 ± 1 | 14 ± 1 | 3,428 ± 1,385 | 38,428 ± 15,522 | 1.57 ± 0.30 |
| 4-1 | 36 | 19 | 5,035 | 56,446 | 1.65 |
| 4-2 | 38 | 18 | 6,567 | 73,621 | 1.51 |
| 4-3 | 30 | 15 | 5,810 | 65,135 | 1.43 |
| 4-4 | 34 | 18 | 3,474 | 38,946 | 1.94 |
| 4-5 | 42 | 18 | 7,029 | 78,800 | 1.73 |
| Mean ± 95% CL | 36 ± 6 | 18 ± 2 | 5,583 ± 1,740 | 62,590 ± 19,508 | 1.65 ± 0.25 |

(continued)

Appendix F-1. (concluded)

| Site-Sample | Number of Taxa | Number of EPT Taxa | Number of Organisms | Standing Crop ($N/m^2$) | Species Diversity* |
|---|---|---|---|---|---|
| 5-1 | 37 | 17 | 3,621 | 40,594 | 2.56 |
| 5-2 | 38 | 17 | 2,664 | 29,865 | 2.69 |
| 5-3 | 36 | 17 | 3,841 | 43,061 | 2.67 |
| 5-4 | 38 | 18 | 2,678 | 30,022 | 2.71 |
| 5-5 | 32 | 14 | 1,897 | 21,267 | 2.67 |
| Mean ± 95% CL | 36 ± 3 | 17 ± 2 | 2,940 ± 983 | 32,962 ± 11,021 | 2.66 ± 0.07 |
| 6-1 | 41 | 21 | 2,295 | 25,729 | 2.21 |
| 6-2 | 43 | 18 | 2,031 | 22,769 | 2.19 |
| 6-3 | 45 | 22 | 2,775 | 31,110 | 2.38 |
| 6-4 | 36 | 17 | 2,189 | 24,540 | 2.15 |
| 6-5 | 36 | 16 | 1,985 | 22,253 | 2.22 |
| Mean ± 95% CL | 40 ± 5 | 19 ± 3 | 2,255 ± 392 | 25,280 ± 4,398 | 2.23 ± 0.11 |
| 7-1 | 42 | 19 | 2,180 | 24,439 | 2.62 |
| 7-2 | 34 | 12 | 865 | 9,697 | 2.74 |
| 7-3 | 35 | 12 | 2,255 | 25,280 | 2.60 |
| 7-4 | 39 | 16 | 2,166 | 24,283 | 2.77 |
| 7-5 | 42 | 19 | 2,097 | 23,509 | 2.83 |
| Mean ± 95% CL | 38 ± 5 | 16 ± 4 | 1,913 ± 730 | 21,442 ± 8,188 | 2.71 ± 0.12 |

* Shannon-Weaver Index

**Appendix F-2.** **Number (N) of organisms for major taxonomic groups for each sample with total number, mean number and mean standing crop (SC) per site, October 1994.**

| Site-Sample | Number of Organisms | | | | | |
|---|---|---|---|---|---|---|
| | Ephemeroptera | Trichoptera | Plecoptera | Chironomidae | Oligochaeta | Others |
| 1A-1 | 203 | 108 | 97 | 829 | 176 | 176 |
| 1A-2 | 82 | 46 | 29 | 535 | 68 | 80 |
| 1A-3 | 281 | 72 | 100 | 546 | 56 | 159 |
| 1A-4 | 151 | 50 | 52 | 725 | 48 | 111 |
| 1A-5 | 152 | 79 | 52 | 958 | 96 | 152 |
| Total Number | 869 | 355 | 330 | 3,593 | 444 | 678 |
| Mean Number | 173.8 | 71.0 | 66.0 | 718.6 | 88.8 | 135.6 |
| Mean SC ($N/m^2$) | 1,948.4 | 796.0 | 739.9 | 8,056.1 | 995.5 | 1,520.2 |
| | | | | | | |
| 1-1 | 198 | 78 | 27 | 600 | 110 | 122 |
| 1-2 | 208 | 131 | 62 | 2,176 | 120 | 210 |
| 1-3 | 241 | 85 | 67 | 1,369 | 96 | 155 |
| 1-4 | 158 | 39 | 28 | 1,403 | 148 | 164 |
| 1-5 | 255 | 88 | 56 | 1,942 | 105 | 294 |
| Total Number | 1,060 | 421 | 240 | 7,490 | 579 | 945 |
| Mean Number | 212.0 | 84.2 | 48.0 | 1,498.0 | 115.8 | 189.0 |
| Mean SC ($N/m^2$) | 2,376.7 | 943.9 | 538.1 | 16,793.7 | 1,298.2 | 2,118.8 |
| | | | | | | |
| 2-1 | 184 | 23 | 22 | 796 | 227 | 68 |
| 2-2 | 160 | 26 | 7 | 1,592 | 490 | 140 |
| 2-3 | 169 | 18 | 38 | 1,629 | 500 | 157 |
| 2-4 | 287 | 32 | 35 | 1,534 | 269 | 199 |
| 2-5 | 402 | 38 | 67 | 2,084 | 540 | 288 |
| Total Number | 1,202 | 137 | 169 | 7,635 | 2,026 | 852 |
| Mean Number | 240.4 | 27.4 | 33.8 | 1,527.0 | 405.2 | 170.4 |
| Mean SC ($N/m^2$) | 2,695.1 | 307.2 | 378.9 | 17,118.8 | 4,542.6 | 1,910.3 |

(continued)

**Appendix F-2.** (continued)

| Site-Sample | Number of Organisms | | | | | |
|---|---|---|---|---|---|---|
| | Ephemeroptera | Trichoptera | Plecoptera | Chironomidae | Oligochaeta | Others |
| 3A-1 | 697 | 41 | 112 | 8,493 | 182 | 462 |
| 3A-2 | 705 | 121 | 115 | 8,560 | 226 | 520 |
| 3A-3 | 740 | 162 | 78 | 8,891 | 289 | 663 |
| 3A-4 | 830 | 217 | 121 | 6,487 | 222 | 538 |
| 3A-5 | 656 | 80 | 173 | 7,423 | 123 | 584 |
| Total Number | 3,628 | 621 | 599 | 39,854 | 1,042 | 2,767 |
| Mean Number | 725.6 | 124.2 | 119.8 | 7,970.8 | 208.4 | 553.4 |
| Mean SC ($N/m^2$) | 8,134.5 | 1,392.4 | 1,343.0 | 89,358.8 | 2,336.3 | 6,204.0 |
| 3-1 | 196 | 51 | 54 | 2,927 | 113 | 151 |
| 3-2 | 178 | 29 | 59 | 2,017 | 60 | 33 |
| 3-3 | 268 | 83 | 53 | 4,027 | 100 | 155 |
| 3-4 | 212 | 51 | 71 | 1,702 | 100 | 97 |
| 3-5 | 276 | 127 | 134 | 3,472 | 150 | 193 |
| Total Number | 1,130 | 341 | 371 | 14,145 | 523 | 629 |
| Mean Number | 226.0 | 68.2 | 74.2 | 2,829.0 | 104.6 | 125.8 |
| Mean SC ($N/m^2$) | 2,533.6 | 764.6 | 831.8 | 31,715.2 | 1,172.6 | 1,410.3 |
| 4-1 | 393 | 171 | 107 | 3,551 | 483 | 330 |
| 4-2 | 496 | 186 | 35 | 5,298 | 394 | 158 |
| 4-3 | 255 | 108 | 43 | 4,773 | 282 | 349 |
| 4-4 | 265 | 100 | 82 | 2,479 | 301 | 247 |
| 4-5 | 494 | 265 | 53 | 5,380 | 453 | 384 |
| Total Number | 1,903 | 830 | 320 | 21,481 | 1,913 | 1,468 |
| Mean Number | 380.6 | 166.0 | 64.0 | 4,296.2 | 382.6 | 293.6 |
| Mean SC ($N/m^2$) | 4,266.8 | 1,861.0 | 717.5 | 48,163.7 | 4,289.2 | 3,291.5 |

(continued)

**Appendix F-2.** **(concluded)**

| Site-Sample | Number of Organisms | | | | | |
|---|---|---|---|---|---|---|
| | Ephemeroptera | Trichoptera | Plecoptera | Chironomidae | Oligochaeta | Others |
| 5-1 | 457 | 298 | 65 | 2,435 | 113 | 253 |
| 5-2 | 355 | 141 | 73 | 1,704 | 190 | 201 |
| 5-3 | 562 | 213 | 106 | 2,343 | 380 | 237 |
| 5-4 | 394 | 128 | 65 | 1,773 | 192 | 126 |
| 5-5 | 308 | 56 | 44 | 1,143 | 168 | 178 |
| Total Number | 2,076 | 836 | 353 | 9,398 | 1,043 | 995 |
| Mean Number | 415.2 | 167.2 | 70.6 | 1,879.6 | 208.6 | 199.0 |
| Mean SC (N/$m^2$) | 4,654.7 | 1,874.4 | 791.5 | 21,071.8 | 2,338.6 | 2,230.9 |
| 6-1 | 160 | 164 | 42 | 1,599 | 238 | 92 |
| 6-2 | 66 | 100 | 35 | 1,528 | 193 | 109 |
| 6-3 | 158 | 384 | 77 | 1,692 | 351 | 113 |
| 6-4 | 102 | 184 | 28 | 1,512 | 234 | 129 |
| 6-5 | 74 | 123 | 36 | 1,396 | 210 | 146 |
| Total Number | 560 | 955 | 218 | 7,727 | 1,226 | 589 |
| Mean Number | 112.0 | 191.0 | 43.6 | 1,545.4 | 245.2 | 117.8 |
| Mean SC (N/$m^2$) | 1,255.6 | 2,141.3 | 488.8 | 17,325.1 | 2,748.9 | 1,320.6 |
| 7-1 | 156 | 142 | 34 | 1,542 | 150 | 156 |
| 7-2 | 99 | 93 | 20 | 474 | 95 | 84 |
| 7-3 | 140 | 262 | 30 | 1,470 | 115 | 238 |
| 7-4 | 149 | 253 | 53 | 1,410 | 60 | 241 |
| 7-5 | 253 | 204 | 42 | 1,183 | 205 | 210 |
| Total Number | 797 | 954 | 179 | 6,079 | 625 | 929 |
| Mean Number | 159.4 | 190.8 | 35.8 | 1,215.8 | 125.0 | 185.8 |
| Mean SC (N/$m^2$) | 1,787.0 | 2,139.0 | 401.3 | 13,630.0 | 1,401.3 | 2,083.0 |

APPENDIX G

STATISTICAL ANALYSES RESULTS OF BENTHIC DATA, OCTOBER 1994

## ANOVA on the Number of Taxa (Log Transformed) for Sites, October 1994

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Site | 8 | 0.10036 | 0.01255 | 8.26* | 0.0000 |
| Within | 36 | 0.05469 | 0.00152 | | |
| Total | 44 | 0.15505 | | | |

### Orthogonal Contrasts

Contrast Number 1 (Background/Downstream)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Contrast Coefficients: | 6 | 6 | 6 | -3 | -3 | -3 | -3 | -3 | -3 |

| | |
|---|---|
| Contrast | -0.9390 |
| SE (Contrast) | 0.2219 |
| SS (Contrast) | 0.0272 |
| T-Statistic | -4.23* |
| P (T-Statistic) | 0.0002 |

Contrast Number 2 (Near-field/Far-field)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Contrast Coefficients: | 0 | 0 | 0 | 2 | 2 | 2 | 2 | -4 | -4 |

| | |
|---|---|
| Contrast | -0.4595 |
| SE (Contrast) | 0.1208 |
| SS (Contrast) | 0.0220 |
| T-Statistic | -3.80* |
| P (T-Statistic) | 0.0005 |

* Significant ($p < 0.05$)
** Not Significant ($p > 0.05$)

**ANOVA on the Number of EPT Taxa (Log Transformed) for Sites, October 1994**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Site | 8 | 0.09682 | 0.01210 | 3.22* | 0.0073 |
| Within | 36 | 0.13542 | 0.00376 | | |
| Total | 44 | 0.23224 | | | |

## Orthogonal Contrasts

Contrast Number 1 (Background/Downstream)

Contrast Coefficients: 6 6 6 -3 -3 -3 -3 -3 -3

| | |
|---|---|
| Contrast | -0.9370 |
| SE (Contrast) | 0.3491 |
| SS (Contrast) | 0.0271 |
| T-Statistic | -2.68* |
| P (T-Statistic) | 0.0109 |

Contrast Number 2 (Near-field/Far-field)

Contrast Coefficients: 0 0 0 2 2 2 2 -4 -4

| | |
|---|---|
| Contrast | -0.0762 |
| SE (Contrast) | 0.1900 |
| SS (Contrast) | 0.000604 |
| T-Statistic | -0.40** |
| P (T-Statistic) | 0.6910 |

* Significant ($p < 0.05$)
** Not Significant ( $p > 0.05$)

## ANOVA on the Number of Organisms (Log Transformed) for Sites, October 1994

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Site | 8 | 2.88710 | 0.36089 | 21.67* | 0.0000 |
| Within | 36 | 0.59959 | 0.01666 | | |
| Total | 44 | 3.48668 | | | |

## Orthogonal Contrasts

Contrast Number 1 (Background/Downstream)

| Contrast Coefficients: | 6 | 6 | 6 | -3 | -3 | -3 | -3 | -3 | -3 |
|---|---|---|---|---|---|---|---|---|---|

| | |
|---|---|
| Contrast | -5.3360 |
| SE (Contrast) | 0.7346 |
| SS (Contrast) | 0.8788 |
| T-Statistic | -7.26* |
| P (T-Statistic) | 0.0000 |

Contrast Number 2 (Near-field/Far-field)

| Contrast Coefficients: | 0 | 0 | 0 | 2 | 2 | 2 | 2 | -4 | -4 |
|---|---|---|---|---|---|---|---|---|---|

| | |
|---|---|
| Contrast | 2.9510 |
| SE (Contrast) | 0.3999 |
| SS (Contrast) | 0.9071 |
| T-Statistic | 7.38* |
| P (T-Statistic) | 0.0000 |

* Significant ($p < 0.05$)
** Not Significant ($p > 0.05$)

ANOVA on the Number of EPT (Log Transformed) for Sites, October 1994

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Site | 8 | 1.34720 | 0.16840 | 8.10* | 0.0000 |
| Within | 36 | 0.74863 | 0.02080 | | |
| Total | 44 | 2.09583 | | | |

**Orthogonal Contrasts**

Contrast Number 1 (Background/Downstream)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Contrast Coefficients: | 6 | 6 | 6 | -3 | -3 | -3 | -3 | -3 | -3 |

| | |
|---|---|
| Contrast | -3.8921 |
| SE (Contrast) | 0.8208 |
| SS (Contrast) | 0.4675 |
| T-Statistic | -4.74* |
| P (T-Statistic) | 0.0000 |

Contrast Number 2 (Near-field/Far-field)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Contrast Coefficients: | 0 | 0 | 0 | 2 | 2 | 2 | 2 | -4 | -4 |

| | |
|---|---|
| Contrast | 1.9217 |
| SE (Contrast) | 0.4468 |
| SS (Contrast) | 0.3847 |
| T-Statistic | 4.30* |
| P (T-Statistic) | 0.0001 |

* Significant ($p < 0.05$)
** Not Significant ($p > 0.05$)

## ANOVA on the Number of Chironomidae (Log Transformed) for Sites, October 1994

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Site | 8 | 4.00772 | 0.50096 | 22.82* | 0.0000 |
| Within | 36 | 0.79040 | 0.02196 | | |
| Total | 44 | 4.79812 | | | |

### Orthogonal Contrasts

Contrast Number 1 (Background/Downstream)

| Contrast Coefficients: | 6 | 6 | 6 | -3 | -3 | -3 | -3 | -3 | -3 |
|---|---|---|---|---|---|---|---|---|---|

| | |
|---|---|
| Contrast | -6.4453 |
| SE (Contrast) | 0.8434 |
| SS (Contrast) | 1.2821 |
| T-Statistic | -7.64* |
| P (T-Statistic) | 0.0000 |

Contrast Number 2 (Near-field/Far-field)

| Contrast Coefficients: | 0 | 0 | 0 | 2 | 2 | 2 | 2 | -4 | -4 |
|---|---|---|---|---|---|---|---|---|---|

| | |
|---|---|
| Contrast | 3.4501 |
| SE (Contrast) | 0.4591 |
| SS (Contrast) | 1.2399 |
| T-Statistic | 7.51* |
| P (T-Statistic) | 0.0000 |

* Significant ($p < 0.05$)
** Not Significant ($p > 0.05$)

APPENDIX H

RESULTS OF RA ANALYSIS, OCTOBER 1994

**Appendix H.** **Species dominance distribution matrix for each sample, October 1994. The taxa represented by the species codes are listed in Table 6.**

| Site | 5 | 5 | 5 | 5 | 5 | 1 | 7 | 1 | 7 | 7 | 7 | 7 | 1 | 1 | 1 | 1 | 6 | 1 | 1 | 1 | 6 | 2 | 6 | 6 | 1 | 6 | 2 | 2 | 2 | 2 | 4 | 4 | 4 | 3 | 4 | 3 | 3 | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | A | | A | | | | | A | | A | A | | | | | | | | | | | | | | | | | | | | | | | | A | A | A | A | A | |
| Species Code / Sample | 4 | 2 | 5 | 3 | 1 | 3 | 2 | 1 | 5 | 4 | 1 | 3 | 4 | 1 | 2 | 5 | 3 | 3 | 2 | 5 | 5 | 1 | 2 | 4 | 4 | 1 | 5 | 3 | 4 | 2 | 4 | 1 | 2 | 4 | 5 | 5 | 1 | 3 | 2 | 4 | 1 | 3 | 5 | 2 | 3 |
| 062 | + | + | + | + | + | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | + | + | - | + | - | - | + | - | - | - | - | - | - | - |
| 064 | 1 | 1 | 1 | 1 | + | + | + | + | + | - | + | + | + | - | + | + | - | + | - | - | - | - | + | - | - | - | - | - | - | - | - | + | + | - | + | + | + | + | - | - | + | + | + | + | - |
| 057 | + | + | + | + | + | - | - | - | + | - | - | - | - | - | + | - | + | - | - | - | + | - | + | + | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - |
| 017 | + | - | - | + | + | - | - | - | - | - | - | - | - | - | - | - | + | - | + | - | - | - | - | - | - | - | - | - | - | - | - | + | + | - | - | + | - | - | - | - | - | + | - | + | - |
| 037 | - | - | - | - | + | - | - | - | - | - | - | + | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 018 | - | + | - | + | + | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - |
| 052 | + | + | + | + | + | - | + | - | + | + | + | + | - | - | - | - | + | - | - | - | + | - | + | + | + | + | - | - | - | - | + | - | + | - | - | - | - | - | - | - | - | - | + | + | + |
| 024 | + | + | - | + | + | - | - | - | + | + | - | - | - | - | - | - | + | - | - | - | - | + | - | + | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 035 | + | + | + | + | + | + | + | + | + | - | + | - | + | + | + | + | + | + | + | + | - | - | + | + | - | + | + | + | + | - | - | + | + | + | + | - | + | + | + | + | + | + | + | + | - |
| 014 | + | + | + | + | + | + | - | + | + | - | + | - | + | + | + | + | + | + | + | + | + | - | + | - | + | - | - | + | - | - | + | + | + | + | + | + | + | - | + | - | - | + | - | + | + |
| 030 | + | + | - | + | + | + | - | + | - | - | + | - | - | + | + | + | + | + | + | + | + | + | + | - | - | + | - | - | + | - | + | + | + | + | + | - | - | - | + | + | + | + | + | + | - |
| 087 | + | + | + | + | + | - | + | - | + | - | + | + | + | - | + | + | + | - | - | + | + | + | + | + | - | + | + | + | + | - | - | + | + | - | + | - | + | - | - | - | + | - | - | + | - |
| 019 | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + |
| 072 | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | - | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | - | - | - | - | - | + |
| 002 | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + |
| 067 | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | - | - | - | - | - | + | - | + | + | + | + | + | - | + | + | + | + | + | - | + | + | + | + | + | - | + | + | - |
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| 081 | - | - | - | - | - | - | + | - | + | + | + | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 137 | - | - | - | - | - | - | - | - | + | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 128 | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 027 | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
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| 055 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 1 | 2 | 2 | 2 | 2 | 3 | 1 | 1 | 3 | 3 | 2 | 1 | 2 | 1 | 1 | 2 | + | 1 | 1 | 1 | 1 | 1 | + | + | 1 | + | 1 | 1 | + | + | + | + | + | + | + | + |
| 085 | + | + | 1 | + | + | 1 | 1 | 1 | + | 1 | + | 1 | + | 1 | + | 1 | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + |
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(continued)

## Appendix H. (concluded)

| Site | 5 | 5 | 5 | 5 | 5 | 1 | 7 | 1 | 7 | 7 | 7 | 7 | 1 | 1 | 1 | 1 | 6 | 1 | 1 | 1 | 6 | 2 | 6 | 6 | 1 | 6 | 2 | 2 | 2 | 2 | 4 | 4 | 4 | 3 | 4 | 3 | 3 | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
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| Species Code / Sample | 4 | 2 | 5 | 3 | 1 | 3 | 2 | 1 | 5 | 4 | 1 | 3 | 4 | 1 | 2 | 5 | 3 | 3 | 2 | 5 | 5 | 1 | 2 | 4 | 4 | 1 | 5 | 3 | 4 | 2 | 4 | 1 | 2 | 4 | 5 | 5 | 1 | 3 | 2 | 4 | 1 | 3 | 5 | 2 | 3 |
| 032 | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | + | - | + | + | + | - | - | - | - | + | - | + | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
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| 015 | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | + | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | + | - | - | - |
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| 063 | 2 | 2 | 2 | 3 | 4 | 2 | 2 | 3 | 3 | 2 | 3 | 3 | 3 | 2 | 3 | 4 | 4 | 5 | 5 | 5 | 6 | 5 | 6 | 6 | 5 | 6 | 4 | 4 | 4 | 5 | 6 | 8 | 8 | 7 | 7 | 8 | 8 | 8 | 9 | 8 | 8 | 9 | 9 | 9 | 9 |
| 079 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
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| 074 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - |
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| 118 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 080 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - |
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| 095 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | + | - | - | - | - | - | - | - | - | + | - | - |
| 031 | - | - | - | - | - | - | - | - | - | - | - | - | - | + | + | - | - | + | - | - | - | - | - | - | - | + | - | + | - | - | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + |
| 033 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | + | + | - | - | + | - |
| 105 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | + | - | - | - | - |
| 126 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - |

+ present
- absent
1 to 9 weighted species abundance score

# APPENDIX I

# PERCENT COMPOSITION OF BENTHIC INVERTEBRATE FUNCTIONAL FEEDING GROUPS, OCTOBER 1994

Appendix I. Percent composition of benthic invertebrate functional feeding groups for each sample and site (pooled samples), October 1994.

| Site-Sample | Functional Feeding Group (percent) | | | | | | |
|---|---|---|---|---|---|---|---|
| | C | H | D | HC | DH | CD | O |
| 1A-1 | 13.8 | 0.4 | 37.2 | - | 41.5 | 1.3 | 5.9 |
| 1A-2 | 10.7 | 0.2 | 39.5 | - | 42.9 | 1.5 | 5.1 |
| 1A-3 | 14.7 | 1.9 | 32.0 | 0.2 | 45.2 | 1.1 | 5.0 |
| 1A-4 | 11.0 | 0.4 | 35.4 | 0.1 | 48.0 | 1.1 | 4.0 |
| 1A-5 | 10.9 | 0.5 | 31.9 | 0.1 | 51.0 | 0.7 | 5.0 |
| Pooled Sample | 12.4 | 0.7 | 34.9 | 0.1 | 45.8 | 1.1 | 5.1 |
| 1-1 | 13.4 | 0.3 | 36.8 | - | 42.9 | 0.4 | 6.3 |
| 1-2 | 5.9 | 2.1 | 37.0 | <0.1 | 50.5 | 1.1 | 3.3 |
| 1-3 | 7.6 | 1.3 | 33.7 | <0.1 | 52.8 | 0.6 | 3.9 |
| 1-4 | 7.4 | 0.3 | 36.2 | - | 53.7 | 0.7 | 1.8 |
| 1-5 | 7.9 | 1.5 | 34.3 | 0.3 | 53.1 | 0.4 | 2.5 |
| Pooled Sample | 7.8 | 1.3 | 35.6 | 0.1 | 51.4 | 0.7 | 3.3 |
| 2-1 | 5.6 | 0.3 | 36.4 | - | 55.8 | 0.5 | 1.4 |
| 2-2 | 5.6 | 0.5 | 37.1 | - | 55.4 | 0.8 | 0.6 |
| 2-3 | 6.7 | 0.4 | 37.6 | - | 54.4 | 0.2 | 0.7 |
| 2-4 | 8.3 | 0.4 | 27.2 | - | 62.6 | 0.1 | 1.2 |
| 2-5 | 6.2 | 0.4 | 34.7 | - | 57.3 | 0.4 | 1.0 |
| Pooled Sample | 6.5 | 0.4 | 34.5 | - | 57.2 | 0.4 | 0.9 |
| 3A-1 | 3.1 | 0.2 | 22.4 | <0.1 | 74.0 | 0.1 | 0.3 |
| 3A-2 | 3.6 | 0.4 | 17.3 | 0.1 | 77.6 | 0.2 | 0.8 |
| 3A-3 | 5.0 | 0.2 | 14.2 | 0.1 | 79.0 | 0.1 | 1.3 |
| 3A-4 | 4.3 | 0.6 | 15.2 | 0.3 | 77.1 | 0.3 | 2.3 |
| 3A-5 | 4.9 | 0.6 | 14.2 | <0.1 | 79.3 | 0.1 | 0.8 |
| Pooled Sample | 4.2 | 0.4 | 16.7 | 0.1 | 77.4 | 0.1 | 1.0 |
| 3-1 | 4.3 | 0.5 | 24.5 | - | 69.7 | 0.1 | 1.0 |
| 3-2 | 3.0 | 0.3 | 18.2 | 0.2 | 77.3 | <0.1 | 0.8 |
| 3-3 | 3.2 | 0.1 | 12.8 | <0.1 | 82.2 | <0.1 | 1.6 |
| 3-4 | 6.0 | 0.4 | 22.6 | - | 67.8 | 0.9 | 2.2 |
| 3-5 | 5.3 | 0.2 | 22.3 | 0.3 | 69.8 | <0.1 | 2.2 |
| Pooled Sample | 4.3 | 0.3 | 19.6 | 0.1 | 73.9 | 0.2 | 1.6 |
| 4-1 | 5.2 | 1.0 | 20.3 | <0.1 | 70.5 | <0.1 | 3.0 |
| 4-2 | 1.9 | 0.3 | 19.9 | - | 75.3 | 0.1 | 2.5 |
| 4-3 | 5.3 | 0.3 | 14.4 | <0.1 | 78.4 | 0.1 | 1.4 |
| 4-4 | 6.2 | 0.6 | 26.0 | - | 64.8 | 0.3 | 2.1 |
| 4-5 | 5.0 | 0.6 | 18.5 | 0.1 | 72.5 | 0.3 | 3.0 |
| Pooled Sample | 4.5 | 0.5 | 19.2 | <0.1 | 73.1 | 0.2 | 2.4 |

(continued)

Appendix I. (concluded)

| Site-Sample | Functional Feeding Group (percent) | | | | | | |
|---|---|---|---|---|---|---|---|
| | C | H | D | HC | DH | CD | O |
| 5-1 | 10.9 | 1.3 | 30.4 | 0.5 | 49.2 | 0.5 | 7.3 |
| 5-2 | 14.3 | 1.6 | 33.2 | 0.4 | 46.0 | 0.2 | 4.4 |
| 5-3 | 10.9 | 1.9 | 33.6 | - | 47.4 | 0.8 | 5.4 |
| 5-4 | 11.3 | 1.2 | 31.9 | 0.1 | 50.9 | 0.3 | 4.2 |
| 5-5 | 13.6 | 1.1 | 35.1 | 0.1 | 47.7 | 0.2 | 2.3 |
| Pooled Sample | 11.9 | 1.5 | 32.6 | 0.2 | 48.3 | 0.4 | 5.1 |
| 6-1 | 6.4 | 0.4 | 29.5 | 0.1 | 56.2 | 0.5 | 6.9 |
| 6-2 | 8.2 | 0.5 | 33.5 | 0.4 | 53.5 | 0.1 | 3.7 |
| 6-3 | 7.2 | 0.4 | 34.2 | 0.3 | 44.5 | 0.3 | 13.2 |
| 6-4 | 8.9 | 0.2 | 30.1 | 0.3 | 52.5 | 0.3 | 7.7 |
| 6-5 | 7.5 | 0.2 | 35.0 | 0.3 | 51.2 | 0.3 | 5.6 |
| Pooled Sample | 7.6 | 0.4 | 32.5 | 0.3 | 51.2 | 0.3 | 7.8 |
| 7-1 | 11.5 | 0.5 | 42.9 | - | 38.3 | 0.3 | 6.5 |
| 7-2 | 10.9 | 0.7 | 42.7 | 0.6 | 34.6 | 0.5 | 10.2 |
| 7-3 | 17.4 | 0.1 | 35.5 | 0.4 | 35.3 | - | 11.3 |
| 7-4 | 20.5 | 0.1 | 35.5 | 0.6 | 32.1 | 0.5 | 10.7 |
| 7-5 | 12.3 | 0.3 | 37.2 | 0.2 | 40.2 | 0.5 | 9.3 |
| Pooled Sample | 15.0 | 0.3 | 38.2 | 0.3 | 36.3 | 0.3 | 9.5 |

# APPENDIX J

## REPEATED MEASURES ANALYSES FOR PRE-OPERATIONAL AND OPERATIONAL DATA, 1989 TO 1994

**Repeated Measures Analysis on the Total Number of Taxa (Log Transformed), Fall 1989 to 1994**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Year | 5 | 1.509 | 0.302 | 22.336 | 0.000* |
| Year x Area | 10 | 0.197 | 0.020 | 1.458 | 0.227** |
| Error | 20 | 0.270 | 0.014 | | |
| **Temporal 1989 vs 1990 - 1994** | | | | | |
| Spatial BG vs DS | | | | | |
| Hypothesis | 1 | 0.038 | 0.038 | 3.128 | 0.152** |
| Error | 4 | 0.048 | 0.012 | | |
| Spatial NF vs FF | | | | | |
| Hypothesis | 1 | 0.002 | 0.002 | 0.148 | 0.720** |
| Error | 4 | 0.048 | 0.012 | | |
| **Temporal 1989 vs 1994** | | | | | |
| Spatial BG vs DS | | | | | |
| Hypothesis | 1 | 0.075 | 0.075 | 3.324 | 0.142** |
| Error | 4 | 0.091 | 0.023 | | |
| Spatial NF vs FF | | | | | |
| Hypothesis | 1 | 0.001 | 0.001 | 0.061 | 0.816** |
| Error | 4 | 0.091 | 0.023 | | |

* Significant ($p < 0.05$)
** Not Significant ($p > 0.05$)

**Repeated Measures Analysis on the Number of EPT Taxa (Log Transformed), Fall 1989 to 1994**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Year | 5 | 1.460 | 0.292 | 18.674 | 0.000* |
| Year x Area | 10 | 0.284 | 0.028 | 1.817 | 0.123** |
| Error | 20 | 0.313 | 0.016 | | |
| **Temporal 1989 vs 1990 - 1994** | | | | | |
| Spatial BG vs DS | | | | | |
| Hypothesis | 1 | 0.029 | 0.029 | 2.787 | 0.170** |
| Error | 4 | 0.041 | 0.010 | | |
| Spatial NF vs FF | | | | | |
| Hypothesis | 1 | 0.002 | 0.002 | 0.174 | 0.698** |
| Error | 4 | 0.041 | 0.010 | | |
| **Temporal 1989 vs 1994** | | | | | |
| Spatial BG vs DS | | | | | |
| Hypothesis | 1 | 0.005 | 0.005 | 0.493 | 0.521** |
| Error | 4 | 0.042 | 0.011 | | |
| Spatial NF vs FF | | | | | |
| Hypothesis | 1 | 0.005 | 0.005 | 0.512 | 0.514** |
| Error | 4 | 0.042 | 0.011 | | |

* Significant ($p < 0.05$)

** Not Significant ($p > 0.05$)

**Repeated Measures Analysis on the Total Number of Organisms (Log Transformed), Fall 1989 to 1994**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Year | 5 | 20.713 | 4.143 | 22.284 | 0.000* |
| Year x Area | 10 | 3.113 | 0.311 | 1.674 | 0.157** |
| Error | 20 | 3.718 | 0.186 | | |
| **Temporal 1989 vs 1990 - 1994** | | | | | |
| <u>Spatial BG vs DS</u> | | | | | |
| Hypothesis | 1 | 0.099 | 0.099 | 0.684 | 0.455** |
| Error | 4 | 0.581 | 0.145 | | |
| <u>Spatial NF vs FF</u> | | | | | |
| Hypothesis | 1 | 0.633 | 0.633 | 4.355 | 0.105** |
| Error | 4 | 0.581 | 0.145 | | |
| **Temporal 1989 vs 1994** | | | | | |
| <u>Spatial BG vs DS</u> | | | | | |
| Hypothesis | 1 | 0.002 | 0.002 | 0.015 | 0.908** |
| Error | 4 | 0.571 | 0.143 | | |
| <u>Spatial NF vs FF</u> | | | | | |
| Hypothesis | 1 | 2.330 | 2.330 | 16.328 | 0.016** |
| Error | 4 | 0.571 | 0.143 | | |

* Significant ($p < 0.05$)
** Not Significant ($p > 0.05$)

**Repeated Measures Analysis on the Number of EPT (Log Transformed), Fall 1989 to 1994**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Year | 5 | 8.163 | 1.633 | 6.205 | 0.001* |
| Year x Area | 10 | 1.589 | 0.159 | 0.604 | 0.792** |
| Error | 20 | 5.262 | 0.263 | | |
| **Temporal 1989 vs 1990 - 1994** | | | | | |
| Spatial BG vs DS | | | | | |
| Hypothesis | 1 | 0.078 | 0.078 | 2.303 | 0.204** |
| Error | 4 | 0.136 | 0.034 | | |
| Spatial NF vs FF | | | | | |
| Hypothesis | 1 | 0.012 | 0.012 | 0.347 | 0.588** |
| Error | 4 | 0.136 | 0.034 | | |
| **Temporal 1989 vs 1994** | | | | | |
| Spatial BG vs DS | | | | | |
| Hypothesis | 1 | 0.064 | 0.064 | 0.971 | 0.380** |
| Error | 4 | 0.265 | 0.066 | | |
| Spatial NF vs FF | | | | | |
| Hypothesis | 1 | 0.450 | 0.450 | 6.791 | 0.060** |
| Error | 4 | 0.265 | 0.066 | | |

* Significant ($p < 0.05$)
** Not Significant ($p > 0.05$)

**Repeated Measures Analysis on the Number of Chironomidae (Log Transformed), Fall 1989 to 1994**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Year | 5 | 30.232 | 6.046 | 18.441 | 0.000 |
| Year x Area | 10 | 6.798 | 0.680 | 2.073 | 0.079** |
| Error | 20 | 6.558 | 0.328 | | |
| **Temporal 1989 vs 1990 - 1994** | | | | | |
| Spatial BG vs DS | | | | | |
| Hypothesis | 1 | 0.142 | 0.142 | 0.431 | 0.547** |
| Error | 4 | 1.316 | 0.329 | | |
| Spatial NF vs FF | | | | | |
| Hypothesis | 1 | 2.110 | 2.110 | 6.413 | 0.065** |
| Error | 4 | 1.316 | 0.329 | | |
| **Temporal 1989 vs 1994** | | | | | |
| Spatial BG vs DS | | | | | |
| Hypothesis | 1 | 0.014 | 0.014 | 0.050 | 0.834** |
| Error | 4 | 1.100 | 0.275 | | |
| Spatial NF vs FF | | | | | |
| Hypothesis | 1 | 5.315 | 5.315 | 19.325 | 0.012* |
| Error | 4 | 1.100 | 0.275 | | |

* Significant ($p < 0.05$)
** Not Significant ($p > 0.05$)