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REPORT ON

REVIEW OF HISTORICAL BENTHIC INVERTEBRATE DATA FOR RIVERS AND STREAMS IN THE OIL SANDS REGION

Submitted to:

Regional Aquatic Monitoring Program Steering Committee

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EXECUTIVE SUMMARY

Purpose

The benthic invertebrate component of the Regional Aquatic Monitoring Program (RAMP) for the Oil Sands Region includes monitoring a number of key rivers and lakes to evaluate potential effects of oil sands developments on aquatic organisms. Previous benthic surveys have generated a large amount of data in these and other waterbodies throughout the Oil Sands Region. This review of available historical data was undertaken to facilitate refinement of the RAMP benthic monitoring program based on experience gained by previous studies and to summarize baseline data for future comparisons and assessments of trends. The objective of this report is to provide an overview of the available historical benthic invertebrate data (up to and including the 2001 RAMP survey), with an emphasis on the Athabasca River, its major tributaries and small streams.

Approach

Previous benthic studies were identified from a number of key sources. Studies were included in the review if they collected quantitative benthic community data using standard sampling devices and reported the raw data or provided a summary of the data. Characteristics of each study were summarized and the raw data for rivers and streams were entered into electronic spreadsheet files. Sites were mapped and renumbered to simplify future referencing. Although data sources and site locations for standing waters are provided in this report, data summaries are not provided.

The amount of historical data was summarized for the entire Oil Sands Region as the number of data sets available at the level of the sampling site (referred to as site data sets) within each major river, all small streams combined and standing waters north of Fort McMurray, and similarly for the area south of Fort McMurray. Habitat features, key benthic community variables, and seasonal and year-to-year variation in benthic community characteristics were summarized for studies that sampled natural substrates (i.e., the majority of studies) in the Athabasca River, its three major tributaries in the region (MacKay, Muskeg and Steepbank rivers), small streams north of Fort McMurray, and streams and rivers south of Fort McMurray. Species lists were also prepared.

The benthic invertebrate abundance data compiled to prepare this document are provided in a standardized spreadsheet format on the enclosed CD-ROM.

Overview of Historical Data

In total, 63 previous studies were identified, spanning a period of 32 years from 1970 to the end of 2001. About a quarter of the 50 studies considered potentially useful sampled the Athabasca River (a study was considered "useful" if it sampled using standard methods and reported the raw data, or provided a data summary). In the area north of Fort McMurray, 78 sites were sampled in the Athabasca River, compared to 52 sites in all major tributaries combined, 55 sites in small streams and 24 sites in standing waters. Many of these sites were sampled more than once, which has resulted in several hundred site data sets. South of Fort McMurray, 61 sites were sampled in rivers and streams, and 21 sites were sampled in lakes.

The most common sampling devices were the Ekman grab in depositional habitat, the Neill cylinder and Surber sampler in erosional habitat, and rock-filled basket-type artificial substrates in a variety of habitats. All of the data from major tributaries and most of the data from small streams were collected at reference sites. About two-thirds of the Athabasca River data were collected at reference sites. The data from standing waters are dominated by reservoirs, but also include a large proportion of reference site data. All of the data collected south of Fort McMurray were collected at reference sites.

The seasonal distribution of the historical data shows a bias toward fall sampling in the Athabasca River, with a lower level of effort in other months. There is no pronounced seasonal bias in other rivers, streams and standing waters north of Fort McMurray, which were sampled with similar effort in all months between May and October. The area south of Fort McMurray was sampled seasonally by the two large-scale studies in this area (Gulf 1979; Tripp and Tsui 1980) and in August or May by the two small-scale studies (Petro-Canada 2002; Rio Alto 2002), which resulted in the largest effort in August. Sampling in the winter and late fall was rare in the region and no samples were ever collected in April.

Athabasca River

The Athabasca River has been sampled at 78 sites by 13 studies from 1975 to 1997. Results of the most recent study (Jacques Whitford 2002) were not available for review. The majority of studies collected baseline data, or investigated the aquatic effects of Suncor Energy Inc. (Suncor, formerly Great Canadian Oil Sands Ltd.). A few regional-scale studies surveyed longer reaches within the lower Athabasca River. The greatest density of historical sites was between Shipyard Lake and Horseshoe Lake (i.e., the reach adjacent to Suncor and Syncrude Canada Ltd.).

Forty-five sites were sampled using depositional sampling methods (Ekman grab), twenty sites were sampled using erosional methods (Neill cylinder and Hess sampler) and 11 sites were sampled using both methods (but at different times). Forty-one sites were sampled using artificial substrates in combination with other methods and two sites were sampled using artificial substrates only (data collected using artificial substrates were not summarized).

Total benthic invertebrate abundance was variable but generally low in erosional habitat (usually <5,000 organism/m^2) and low to moderate in depositional habitat (≤20,000 organisms/m^2). Abundances were greater in September, especially in erosional habitat. Taxonomic richness (standardized to the family level) was less variable and generally low, usually between 10 and 20 families in erosional habitat and between 4 and 12 families in depositional habitat. Both abundance and richness tended to increase during the open water season in erosional habitat, with the maximum values in September. Seasonal trends were absent in depositional habitat. There were no consistent effects on abundance or richness in the reach adjacent to Suncor.

Chironomid midges were usually the dominant group in erosional habitats, constituting about 30 to 80% of total abundance at nearly all sites, in all months. Mayflies and oligochaete worms were also numerous, although more variable among months than chironomids. Depositional communities were usually dominated by chironomids and occasionally by other groups. Oligochaete worm dominance was found at four depositional sites adjacent to Suncor.

The variation in total invertebrate abundance among years was large, with a >10-fold variation at individual sites. Richness was less variable, with a close to two-fold maximum variation among years. Community composition varied considerably, even at the coarse level of major group. There are insufficient data for an analysis of time-trends in the erosional data set; no trends were apparent at depositional sites.

In total, 181 taxa were documented from the Athabasca River after standardizing the lowest taxonomic level to genus. The erosional data set included 130 taxa. The depositional data set was less diverse, with a total of 91 taxa. Nearly all common taxa reported from the Athabasca River are also common in other Alberta rivers.

MacKay River

Benthic communities of the MacKay River were sampled five times to the end of 2001 at a total of nine sites (the lowermost reach is being monitored by RAMP). The first two surveys collected baseline data and evaluated the potential effects of the Syncrude Mildred Lake facility. The two recent surveys were carried out as part of RAMP. All sampling was done in erosional habitat, which dominates the lower MacKay River. Specific habitat features varied moderately among sites and studies.

Total invertebrate abundance was low and variable (<10,000 organisms/m^2) during all fall surveys except in 1998 (higher), when river flows were unusually low during late summer and fall. Richness varied between 20 and 56 taxa per site based on genus level data. The composition of benthic communities at the level of major taxonomic group showed little consistency among sites and studies, with the exception of a moderate to large percentage of mayflies. Both total abundance and richness increased through the open-water season, with maximum values in August or September. Abundance and richness varied moderately among years, but without a trend over time.

A total of 106 taxa were documented from the MacKay River, based on genus as the lowest taxonomic level. All common taxa in this river are also common in erosional reaches of other Alberta rivers.

Muskeg River

Of all the major tributaries of the Athabasca River in the Oil Sands Region, the Muskeg River has been sampled the most intensively. Habitat distribution in the Muskeg River is unique in the Oil Sands Region because of an abrupt transition from erosional to predominantly depositional habitat at about 12 km from the mouth. Ten surveys were conducted over 22 years, which sampled a total of 12 sites. Both the lowermost erosional reach and the depositional reach are being monitored by RAMP. Seven surveys collected baseline data for a variety of planned oil sands developments and three surveys were done under RAMP as part of routine monitoring.

Total invertebrate abundance was low to moderate (1,000 to 22,000 organisms/m^2) during the fall in erosional habitat and highly variable (2,000 to 62,000 organisms/m^2) in depositional habitat. A number of studies reported higher taxonomic richness in this river than in other major rivers in the Oil Sands Region. Richness was higher and less variable in erosional habitat (34 to 77 taxa at the genus level) than in depositional habitat (13 to 72 taxa). Taxonomic composition of erosional communities was highly variable among sites and studies. Depositional communities were dominated by chironomids, although mollusks and oligochaetes were also common.

The variation in total invertebrate abundance among months in late summer to early fall was relatively low in the erosional reach. Seasonal variation in abundance tended to increase in an upstream direction in depositional habitat. Maximum abundance typically occurred in the fall, as was also observed in erosional habitat in the Athabasca and MacKay rivers. Richness was nearly constant from July to September at the erosional sites, but varied moderately at depositional sites. Community composition varied relatively little among seasons compared to the other major rivers in the region.

Year-to-year variation was considerable in total invertebrate abundance at the mouth of the river (with a ten-fold range) based on fall samples. Richness was similar in the three years with available data. Community composition at the level of major taxonomic group varied moderately among years.

Standardizing the lowest taxonomic level to genus yielded a total of 183 taxa, based on the data collected by quantitative studies. The high diversity of benthic invertebrates in this river relative to the Steepbank and MacKay rivers may be a reflection of the greater range of habitat variation in this river and, possibly, the larger number of samples collected from this river.

Steepbank River

The Steepbank River was sampled for benthic invertebrates five times to the end of 2001, at a total of nine sites. The lowermost reach is being monitored by RAMP. The objective of the first survey was to collect baseline data and investigate natural factors influencing benthic community characteristics. One survey was part of the baseline study for the Suncor Steepbank Mine and two recent surveys were done under RAMP. All sampling was done in erosional habitat, which dominates in the Steepbank River.

Estimates of total invertebrate abundance during the fall, based on the quantitative surveys, were low and variable (typically <10,000 organisms/m^2). The lowest abundance was reported from oil sands substrate. Richness varied moderately (35 to 68 taxa at the genus level) during the three recent studies that used consistent methods. Mayflies and chironomids dominated the communities at all sites, and mollusks, stoneflies and caddisflies were uncommon. Seasonal variation in total invertebrate abundance was moderate and generally lower than in the other rivers reviewed. Richness varied less among months with about two-fold ranges at each site. Neither of these variables showed a progressive increase through the open water season, as observed in the other major rivers. Based on semi-quantitative data, the composition of benthic communities showed no seasonal trends.

Year-to-year variation was moderate in total invertebrate abundance at the mouth of the river (with a six-fold range), based on fall samples. Richness was similar in the three years with data from the reach just upstream of the mouth. Community composition at the level of major taxonomic group varied moderately among years. Chironomids and mayflies were dominant in all years, while relative abundances of other dipterans and oligochaetes varied widely.

Standardizing the lowest taxonomic level to genus yielded a total of 98 taxa in this river, based on quantitative studies. As in the other major tributaries, the common taxa are also common in other rivers in the province.

Small Streams

A relatively large amount of data is available for small streams tributary to the major rivers discussed in previous sections. Descriptions of the small stream data collected in fall in the area north of Fort McMurray were organized by stream (if frequently sampled) or by basin. The small stream data represent a wide range of habitat conditions and, therefore, benthic community types as well. At the relatively coarse level of examination used in this report, the fauna of newly-created drainages (e.g., the West Interceptor Ditch) did not appear substantially different from natural communities. Studies in Poplar Creek documented some effects of the Poplar Creek Reservoir spillway on total abundance and community composition, but not on richness. Other effects of oil sands development were not apparent, which is not surprising considering that most of the data were collected before large-scale development in the region.

Standing Waters

Data for standing waters are not summarized in this report, but previous studies are listed and the amount of data collected is summarized. The standing waters are dominated by Ruth Lake, Poplar Creek Reservoir and Beaver Creek Reservoir. Data for reference lakes and wetlands, or waterbodies sampled during the reference period, form a relatively small proportion of the available data. The lake data are reasonably consistent in terms of sampling methods.

Streams and Lakes in the Southern Part of the Oil Sands Region

The southern Oil Sands Region was sampled by only four studies to the end of 2001. Within this document, this area is operationally defined as the area south of the Clearwater River to the Cold Lake Air Weapons Range. Three of these studies were of relatively large scale. The sampling mesh size used by these studies was larger (600 μm) compared to those typically used north of the Clearwater River (250 μm), resulting in lower abundance estimates. As in the northern part of the Oil Sands Region, the data from this area represent a wide range of habitat conditions and benthic community types.

Conclusions

This review provided an overview of historical benthic invertebrate data in the Oil Sands Region and described the benthic fauna of major rivers and small streams in the Oil Sands Region. The amount of potentially useful historical data is considerable, despite losses of the raw data collected by some of the early studies. Most of the historical data appear to be of acceptable quality and were collected using standard benthic sampling devices that are still widely used. The quantity and quality of supporting data (e.g., physical habitat data) varies by survey and compilation of a consistent supporting data set would require a large additional effort.

As a result of this review, the majority of the available historical data are now in electronic format for potential future analysis. Since no time-trends were apparent at sites sampled repeatedly over the past 25 years, the historical data are still applicable. Specific uses of the historical data have not been identified at this time, but may include use as baseline data in future assessments, refinement of monitoring design, characterizing year-to-year variability and baseline ranges for key benthic community variables, assessment of relationships between benthic community characteristics and environmental variables, and use of the historical data in an initial reference condition analysis.

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1 INTRODUCTION

The benthic invertebrate component of the Regional Aquatic Monitoring Program (RAMP) for the Oil Sands Region has been collecting data since 1997. During the spring of 2000, the Technical Subcommittee in charge of benthic invertebrate monitoring developed a draft outline for a monitoring program that focuses on a number of key rivers and lakes, including the Muskeg, Steepbank and MacKay rivers, Kearl Lake and Shipyard Lake. By 2002, this outline had expanded into a full monitoring component, incorporating scheduled sampling of all major tributaries of the Athabasca River in the Oil Sands Region and three lakes (Kearl, McClelland and Shipyard lakes).

The Technical Subcommittee is aware that previous benthic surveys in the Oil Sands Region have generated a large amount of potentially useful data. Therefore, a logical initial step in developing an appropriate monitoring program is to review the historical data. Accordingly, the major objective of this report is to provide an overview of the available historical benthic invertebrate data (including data collected by RAMP), with emphasis on the Athabasca River, its major tributaries and small streams. Its specific objectives are the following:

- to identify all historical benthic studies that generated data that may be useful for RAMP (specific criteria for identifying "useful" data are provided in the next section);
- to compile useful data in an accessible electronic format (i.e., Microsoft Excel® spreadsheets); and
- to summarize available data for the Athabasca River, its major tributaries (MacKay, Muskeg and Steepbank rivers) and small streams in the Oil Sands Region.

There are numerous potential uses of historical data, dependent largely upon the spatial coverage, frequency of sampling and data quality. The specific future uses of the historical data summarized in this report have not been decided.

The study area for which data were summarized in this report corresponds to the RAMP study area (i.e., the Regional Municipality of Wood Buffalo), which is an area of variable width (60 to 240 km) extending from the Cold Lake Air Weapons Range on the south to the Athabasca Delta on the north.

2 METHODS

2.1 SELECTION OF STUDIES

2.1.1 Data Sources

The initial scope of this review was as wide as possible to ensure that all previous studies were identified. The search for historical benthic invertebrate studies consisted of the following:

- reviewing reference lists of documents that summarized benthic invertebrate data from previous surveys (McCart and Mayhood 1980; O'Neil et al. 1982; Golder 1996a);
- reviewing lists of studies carried out during large-scale environmental research programs (e.g., Alberta Oil Sands Environmental Research Program [AOSERP], Northern River Basins Study [NRBS]);
- a computerized search of Biological Abstracts;
- searching the oil sands section of the Golder Associates Ltd. (Golder) in-house library; and
- soliciting input from members of the Technical Subcommittee.

2.1.2 Identification of Useful Studies

Once the initial search was complete and most studies were available in hardcopy format, each study was evaluated in terms of its usefulness for RAMP. A number of criteria were used to restrict the initial list of studies to those that were potentially useful. A study was considered useful if it had the following characteristics:

- it reported benthic community data as abundances of invertebrates (as opposed to providing life history information or contaminant concentrations);
- it collected quantitative or semi-quantitative data using standard sampling devices (e.g., Ekman grab, Neill cylinder, Surber sampler, artificial substrates [AS], standard kick sampling); and
- it provided raw data in some form (usually hardcopy), or at least provided a summary of the data as total abundance, richness and composition of the benthic community by major taxonomic groups.

Next, an overall summary table was prepared to provide an overview of the data collected by the studies considered useful (Appendix I). For each study, this table includes sampling times and locations (i.e., river or lake sampled), habitats sampled, number and type of sites (see definitions of site types below), pertinent details of sampling (e.g., device, bottom area, replication, mesh size), level of taxonomy, available supporting data and data format (hardcopy or electronic). Appendix I is intended to be a quick reference to the specifics of each study and was used to generate further summaries of the amount of available data.

2.2 SAMPLING SITE MAPPING AND CLASSIFICATION

2.2.1 Site Mapping

To illustrate the spatial coverage of the historical data, sites sampled by studies considered useful were mapped and renumbered to simplify future referencing. The simplest possible system was used to identify sites, consisting of consecutive integers, which resulted in each site having a unique identifier. In some instances, closely-spaced sites were differentiated by adding “a”, “b” or “c” to the end of the site number. A key (table of site codes) was developed that linked the original site codes to the new system (Appendix II). This table also includes the sampling methods used at each site, site type (see below) and the original study reference.

2.2.2 Site Classification

Site type was designated as “reference”, “potentially impacted” or “new” to allow estimation of the amount of historical reference site data. Reference sites were those sampled during baseline studies, or control/reference sites sampled during studies investigating effects on the benthic community due to a disturbance. Potentially impacted sites were those located below discharges and diversions, where previous studies reported biological effects, or where such effects are possible (e.g., below sewage treatment plants [STP]). Sites were designated as “new” if they were located in newly-created drainages or impoundments.

In the Athabasca River, sites were tentatively designated as potentially impacted if they were located between Tar Island Dyke and Saline Lake along the west bank (a 10 km reach), based on findings of Noton (1979) and Noton and Anderson (1982). In addition, sites along the west bank, within 10 km of the Fort McMurray STP discharge were also considered potentially impacted. All other sites in this river were considered to be reference sites, representing background conditions for the reach though the Oil Sands Region, though it is likely that they reflect the cumulative effects of upstream discharges and non-point sources.

In other waterbodies, potentially impacted sites included those below diversions, including Ruth Lake and the lower reaches of Beaver, Bridge and Poplar creeks (if sampled after the completion of Syncrude's diversions). Sites in newly-created drainages and impoundments included the West Interceptor Ditch (WID), Beaver Creek Reservoir, Poplar Creek Reservoir and Creek B1 (connects WID to Beaver Creek Reservoir).

2.3 DATA SUMMARY METHODS

2.3.1 Amount of Data

The amount of historical data was summarized in terms of the number of "site data sets" available for each waterbody (major rivers) or type of waterbody (i.e., small streams, lakes and rivers/lakes south of Fort McMurray). One site data set includes the data collected at one site during one sampling event, using one sampling method (= species list and abundances of taxa in a set of replicate samples). The amount of data was summarized separately for the following categories:

- each large river with a large data set (Athabasca, MacKay, Muskeg and Steepbank rivers);
- all remaining large rivers north of Fort McMurray combined;
- all small streams north of Fort McMurray combined;
- all lakes north of Fort McMurray combined;
- all rivers and streams south of Fort McMurray combined; and
- all lakes south of Fort McMurray combined.

The total number of site data sets in each of these groups was broken down by sampling method (corresponding to habitat type) and site type, and the number of site data sets was further broken down by month to show the seasonal distribution of sampling effort.

A separate summary was prepared to show the amount of reference site data collected using consistent sampling methods in the Athabasca River and in all other rivers/streams combined. The intent of this summary was to evaluate the amount of data available for multivariate analysis of the historical data, such as a reference condition analysis. Erosional and depositional data sets were summarized separately based on sampling methods (erosional: Neill, Hess, Surber; depositional: Ekman). Only the data collected using a relatively narrow range of common sieve mesh sizes (180 to 250 μm) were included in this summary. Level of taxonomy was not used to restrict the data included in this summary, because most studies provided data with a similar taxonomic resolution, with the exception of chironomid midges.

2.3.2 Data Entry and Preparation

The raw data for studies considered useful were entered manually into Microsoft Excel® spreadsheets, or electronic data files were obtained from benthos databases (BONAR, Ouellett and Cash 1996) and electronic project archives of consulting companies. Since the majority of the data had to be entered manually, which is a labour-intensive and costly procedure, data entry for streams and rivers was limited to samples collected from natural substrates using standard bottom sampling devices (Neill cylinder, Hess sampler, Surber sampler, Ekman grab, Ponar grab). Data collected using AS were not entered. Similarly, lake data were referenced in Appendices I and II but were not entered.

To minimize data entry errors, the entered data were checked for errors by comparing column totals with the originally reported totals for each sample. In cases of disagreement between these, all numbers were checked in the entered column. Since the originally reported column totals were frequently incorrect, this procedure resulted in checking a relatively large proportion of the data entered. Following data entry, spelling of taxonomic names was also checked and errors were corrected as necessary. A master taxon list including major taxon, family (plus subfamily/tribe for Chironomidae) and genus/species was developed based on all data in the electronic data files.

The amount and type of habitat-related data were inconsistent among studies, ranging from qualitative descriptions of flow characteristics and bottom substrates to detailed measurements of physical characteristics at each sample location. Therefore, an effort was not made to generate standardized electronic files of habitat data. Rather, the habitat-related data shown in the data summary tables were transcribed directly from the original hardcopy reports. It should be noted that a considerable amount of habitat data is available for rivers and streams in the Oil Sands Region in consultants' reports describing fisheries resources (e.g., Sekerak and Walder 1980), which could be entered into a database once a specific use of the historical benthic invertebrate data is identified. However, working with the available data revealed that development of a complete and standardized habitat data set would not be possible based on the information reported in the various study reports available.

To allow further analysis and preparation of species lists by river, data used for the summaries in this document were merged and sorted by habitat (erosional and depositional, based on sampling methods). In some cases, benthic sampling devices were used in habitats that were at the limit of their useful range (e.g., Neill cylinder in shifting sands and slow currents) and the resulting data may not be from “truly” erosional or depositional sites. However, because the aim of this review was to summarize as much of the available data as possible, marginal sites were not screened out.

After this procedure, the following data sets were available (these do not include data collected by studies that did not report the raw data):

- erosional and depositional data sets for the Athabasca River;
- erosional data set for the MacKay River;
- erosional and depositional data sets for the Muskeg River;
- erosional data set for the Steepbank River;
- erosional and depositional data sets for a number of other major rivers that have been sampled with a lower intensity;
- erosional and depositional data sets for small streams north of Fort McMurray; and
- erosional and depositional data sets for small streams south of Fort McMurray.

2.3.3 Summary Variables

Summary tables and graphs were prepared based on the data sets described above. Data collected during the entire open-water season were summarized for the Athabasca River to provide the maximum amount of information for this river, for decisions regarding future monitoring. The tributary and small stream data summaries concentrated on fall data (late August to November), which accounts for about half of the historical data for rivers and streams, because this season was selected for monitoring by RAMP. Seasonal variation in benthic community characteristics in major rivers was described based on selected studies that collected monthly data during the open-water season.

Data summaries included the following information for each site:

- Site location (as distance from mouth), habitat type (erosional/ depositional), sampling methods (sampling device, number of replicates, sieve mesh size), site characteristics in Athabasca River tributaries and small streams, where available (ranges in river width, depth, current velocity and substrate composition), and month and year sampled.
- Total abundance (as the mean number of organisms/m^2 at each site) and taxonomic richness (no. of families, genera or species). Taxonomic

richness (richness) was defined as the total number of taxa found in all samples collected at a site during one sampling event.

- Community composition at the level of major taxonomic group, expressed as percentages.
- Seasonal variation in the above benthic community variables at selected sites, either using all available data (Athabasca River) or results of individual studies that sampled on a monthly or seasonal basis (tributaries and small streams).
- Year-to-year variation in the above benthic community variables at selected sites, by combining results of studies that sampled the same sites in one season (typically fall) in different years using similar methods.
- Species lists and frequency of occurrence of each taxon in the Athabasca, MacKay, Muskeg and Steepbank rivers, and species lists for all small streams north of Fort McMurray combined and all small streams/rivers south of Fort McMurray combined. Frequency of occurrence was calculated as the percentage of the total site data sets in a river (or habitat within a river) where a taxon was present.

Summarizing the richness data collected by a large number of studies was complicated by different levels of sampling effort and taxonomic identification among studies. Richness defined as above tends to increase with the number of replicate samples collected. Therefore, differences in sampling effort among studies were discussed in the data summaries if they were of potential significance with regard to observed trends.

The level of taxonomic identification was typically genus for insects other than chironomid midges, family or a higher level for oligochaete worms, genus or a higher level for mollusks and crustaceans, and major taxon for other groups (e.g., Nematoda). Chironomids were identified to subfamily/tribe or genus, or were left at the family level. One conspicuous exception to the typical levels of identification is the study by Barton and Wallace (1980), which reported the majority of data at the species level (the raw data were not reported in this study; Dr. D.R. Barton, University of Waterloo, was contacted for the raw data files but was not able to provide them). To allow consistent summaries of richness in this report, Athabasca River richness data were converted to the family level. Richness data for other rivers were presented at the most common level of identification (typically genus), with notes on variation in the level of identification.

2.3.4 Ordination of Athabasca River Erosional Data

A large amount of data is available for erosional habitat in the Athabasca River. The erosional data set consists of 187 erosional site data sets, representing 29 sites, spanning 13 years (1981 to 1993) and six months during the open-water season (March and May to September). These data were collected using similar methods and most of the raw data were available from the original reports. In contrast, the available depositional data consisted of 49 data sets from 41 sites. Unfortunately, a large proportion of the depositional data were collected by studies that did not report the raw data (McCart et al. 1977; Barton and Wallace 1980) or used AS only (IEC Beak 1983).

To provide a more complete summary for this river than is possible using the summary variables described above, the erosional data were further analyzed using principal component analysis (PCA). PCA is an ordination technique that can reduce the dimensionality of multivariate data sets and is commonly used in exploratory analysis of benthic invertebrate data. It allows graphical representation of the among-site variation in a large number of taxa along two to three dimensions (referred to as principal components [PCs]), each representing a group of taxa that vary among sites in a similar manner. Scores on the principal components can be used for further analysis of relationships between benthic community structure and habitat variables.

Before analysis, the erosional data were converted to the family level to standardize the level of taxonomy and rare taxa were deleted. Rare taxa were defined as those together constituting <1% of the total number of invertebrates in the data set. This procedure reduced the number of taxa to 22, while retaining 99% of the original number of invertebrates. Deletion of rare taxa is a necessary step before ordination to reduce the number of variables in the analysis and eliminate potential outliers. The ordination was run on the correlation matrix generated from log-transformed site means. Relationships between PC scores, and time of sampling (month, year), location (east or west bank and upstream-downstream position), and site type (reference versus potentially impacted) were examined as scatter-plots.

3 DATA REVIEW

3.1 GENERAL OVERVIEW

Historical studies reviewed in this document span a period of 32 years (1970 to 2001; Table 1), with a gap of about five years with no sampling activity in the late 1980s and early 1990s. A total of 63 studies were identified, 50 of which were considered potentially useful according to the criteria listed in Section 2. The potentially useful studies span 28 years (1974 to 2001). The majority were funded by AOSERP, Suncor, Syncrude and Alberta Environment (AENV). About a quarter of the potentially useful studies (14) sampled the Athabasca River. Four of the early studies did not report the raw data, which represents an unrecoverable loss. The following discussion is limited to the studies considered useful and includes those that did not report the raw data.

Table 1 Historical Benthic Invertebrate Studies in the Oil Sands Region (1970 to 2001)

Survey Year	Waterbody (research program, funding industry)	Reference	Comment
Benthic Studies Considered Useful for RAMP			
1974	Ruth Lake, Poplar Creek (Syncrude)	Syncrude (1975)	no comment
1975	Ruth Lake, Poplar Creek (Syncrude)	Noton and Chymko (1977)	drift study of Poplar Creek also done
1975	Athabasca River (Syncrude)	McCart et al. (1977)	raw data not reported
1977	Beaver Creek, Beaver Creek Reservoir, Ruth Lake, Poplar Creek, Poplar Creek Reservoir (Syncrude)	Noton and Chymko (1978)	drift study of Poplar Creek also done
1976-1977	Jackpine (then Hartley) Creek (AOSERP)	Hartland-Rowe et al. (1979)	raw data not reported; drift studies of Jackpine Creek also done
1976-1977	Athabasca River, Muskeg and Steepbank River basins (AOSERP)	Barton and Wallace (1980), Barton and Lock (1979)	semi-quantitative sampling in Muskeg and Steepbank river basins; raw data not reported
1977	MacKay River (Syncrude)	McCart et al. (1978)	drift studies of MacKay River also done
1977	WID, Lower Beaver Creek, unnamed streams	Tsui et al. (1978)	examined colonization of WID; drift study of an unnamed stream also done
1978	Athabasca River (Suncor, then GCOS)	Noton (1979)	no comment
1978	Christina River, Hangingstone River, Gregoire River, Gregoire Lake, Algar Lake, other streams south of Fort McMurray (AOSERP)	Tripp and Tsui (1980)	drift study of Hangingstone River also done
1978	Cottonwood Creek, Meadow Creek, Kinosis Creek, Kettle River, South Kettle River, unnamed streams, High Lake, Low Lake, Gull Lake (Gulf)	Gulf (1979)	qualitative sampling in streams; samples sorted without magnification
1979	Muskeg River (AOSERP)	Crowther and Lade (1980)	no comment
1979	Poplar Creek (Syncrude)	Retallack (1980)	raw data not reported

Table 1 Historical Benthic Invertebrate Studies in the Oil Sands Region (continued)

Survey Year	Waterbody (research program, funding industry)	Reference	Comment
1980	Poplar Creek (Syncrude)	Retallack (1981a)	raw data not reported
1981	Athabasca River (Suncor)	Noton and Anderson (1982)	no comment
1981	Athabasca River (Alberta Environment)	Boerger (1983a), Walder and Mayhood (1985)	Walder and Mayhood (1985) reanalyzed data of Boerger (1983a)
1981	Jackpine Creek and other streams, ponds and lakes in Muskeg River basin (SandAlta)	O'Neil et al. (1982)	no comment
1981	Poplar Creek (Syncrude)	Retallack (1981b)	report not available
1982	Athabasca River (Suncor)	IEC Beak (1983), Beak (1988)	no comment
1982	Poplar Creek (Syncrude)	Boerger (1983b)	no comment
1983	Athabasca River (Alberta Environment)	Corkum (1984 unreleased)	no comment
1983-1987	Athabasca River (Alberta Environment)	Anderson (1991)	no comment
1984	Beaver Creek Reservoir, Ruth Lake, Poplar Creek Reservoir, MacKay River, Dover River, Poplar Creek, Beaver Creek, small streams in Beaver Creek basin (Syncrude)	RL&L and AA Aquatic Research (1985)	no comment
1985	Muskeg River, Kearl Lake, small streams in Muskeg River basin (OSLO)	Beak (1986)	no comment
1986	Athabasca River (Suncor)	EVS (1986)	no comment
1987	Athabasca River (Alberta Environment)	AENV data listed by Ouellett and Cash (1996)	no comment
1988	Muskeg River, Kearl Lake, small streams in Muskeg River basin (OSLO)	RL&L (1989)	no comment
1993	Athabasca River (NRBS)	Dunnigan and Millar (1993)	no comment
1995	Athabasca River, Steepbank River (Aurora/Steepbank baseline)	EVS (1996)	no comment
1995	Muskeg River, Kearl Lake and small streams in Muskeg River basin (Aurora/Steepbank baseline)	Golder (1996a)	no comment
1996	Shipyard Lake (Suncor)	Golder (1996b)	no comment
1996	Reference wetlands (CT wetlands study, Suncor)	Golder (1997)	no comment
1996?	Unnamed wetlands (Suncor)	Bendell-Young et al. (1977)	no comment
1997	Athabasca River (RAMP)	Golder (1998a)	no comment
1997	Muskeg River and Wapasu Creek (Mobil)	Komex (1997)	no comment
1998	McLean Creek (Suncor)	Golder (1998b)	no comment
1998	Meadow Creek, Cottonwood Creek, Kettle River (Gulf)	Gulf (2001)	no comment
1998	MacKay River, Muskeg River, Steepbank River (RAMP)	Golder (1999a)	no comment
1999	Fort Creek (Koch)	Golder (2000a)	no comment

Table 1 Historical Benthic Invertebrate Studies in the Oil Sands Region (continued)

Survey Year	Waterbody (research program, funding industry)	Reference	Comment
2000	Susan Lake outlet Creek and Creek A (TrueNorth)	TrueNorth (2001)	drift studies of Fort and Susan creeks, and unnamed creek A also done
2000	MacKay River, Muskeg River, Steepbank River, Shipyard Lake (RAMP)	Golder (2001)	no comment
2000	Isadore's Lake (Shell)	Shell (unpublished data)	no comment
1999-2000	Ells River (PERD)	Cash and Culp (in prep.)	report not available
2001	Jackpine, Muskeg, Khahago and Shelley creeks (Shell)	Shell (2002)	no comment
2001	Clearwater, MacKay, Muskeg, Steepbank rivers, Fort Creek, Kearl and Shipyard lakes (RAMP)	Golder (2002a)	no comment
2001	Calumet, Ells, Tar rivers, Calumet and Lillian lakes (CNRL)	CNRL (2002)	drift study of Tar River also done
2001	Maqua and Surmont lakes, three unnamed lakes (Petro-Canada)	Petro-Canada (2001)	no comment
2001	Wiau Lake and four unnamed lakes, one unnamed stream (Rio Alto)	Rio Alto (2002)	no comment
2001	Muskeg River and Stanley, Iyinimin, Wesukemina and Blackfly creeks (Syncrude)	Golder (2002b)	no comment
2001	Athabasca River (Suncor)	Jacques Whitford (2002)	report not available
Benthic Studies Considered Not Useful for RAMP			
1970	Beaver Creek (Alberta Fish and Wildlife)	Robertson (1970)	quantitative sampling, but data not reported
1971	Beaver Creek (Syncrude)	Syncrude (1973)	quantitative sampling, but details of methods and raw data not reported; drift study also done
1972	Large number of rivers in oil sands area (Alberta Fish and Wildlife)	Griffiths (1973)	qualitative sampling only, coarse level taxonomy
1973?	Jackpine (then Hartley) Creek	Dames and Moore (1973)	qualitative sampling only
1975	Athabasca River (AOSERP)	Flannagan (1977)	life history data; no community data collected
1978	Ells River, MacKay River, Hangingstone River, Steepbank River, Muskeg River	Crowther and Griffing (1979)	qualitative sampling, no taxonomic classification
1979	Small streams in Firebag, Muskeg, Steepbank, MacKay and Ells river basins (AOSERP)	Sekerak and Walder (1980)	qualitative sampling only, coarse level taxonomy
1983	Athabasca River (Suncor)	Beak (1988)	trace elements in sediment and benthos
1994	Athabasca River (Suncor)	Golder (1994)	small-scale survey, qualitative sampling only
1999	Wetlands in Oil Sands Region (Suncor, in part)	Whelly (1999)	quantitative samples not processed
1999	McLean and Wood creeks	Golder (1999b)	drift studies only
2000	McLean Creek	Golder (2000b)	drift study only
2001	Muskeg and Shelley creeks	Golder (2002c)	drift studies only

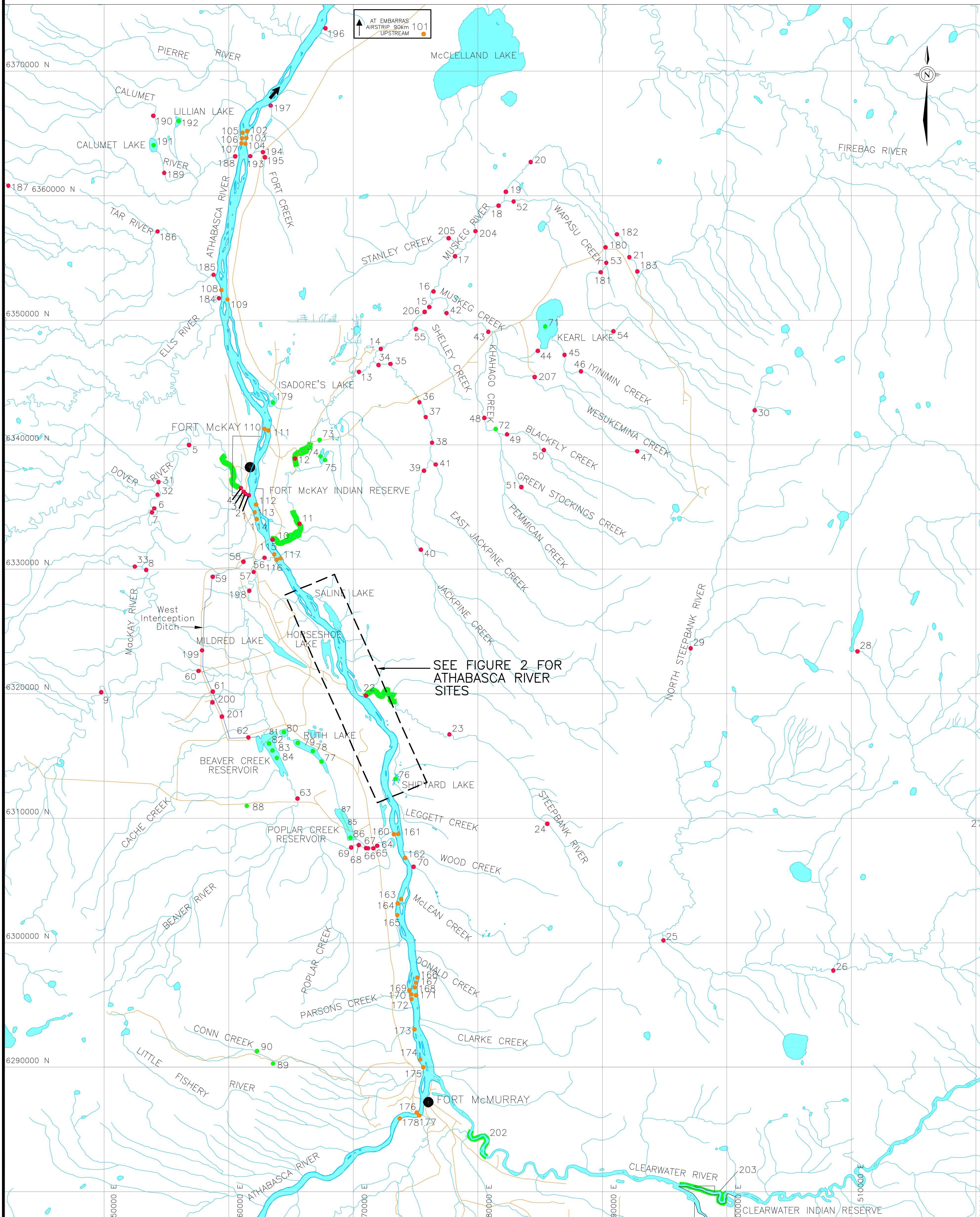
Benthic invertebrate studies conducted in the area north of Fort McMurray since 1974 have sampled 78 sites in the Athabasca River, 52 sites in major tributaries (Calumet, Clearwater, Ells, MacKay, Muskeg, Steepbank and Tar rivers), 55 sites in small streams, and 23 sites in lakes, ponds and wetlands (Figures 1 and 2; Tables II-1 to II-4 in Appendix II). Many of these sites were sampled more than once, as shown by multiple site codes and study references for individual sites in the site code keys in Appendix II.

The amount of data for the region south of Fort McMurray is smaller, consisting of 61 sites in all rivers and streams combined, and 21 sites in standing waters (Figure 3; Tables II-4 and II-5 in Appendix II).

The amount of historical data is summarized in units of site data sets in Table 2 (reaches sampled by RAMP were counted as individual sites). The Athabasca River has been sampled the most, with a total of 519 site data sets. The remainder of the data is dominated by small streams, with 166 site data sets in major tributaries, 383 sets in small streams and 207 sets in standing waters in the area north of Fort McMurray. Most of the data collected south of Fort McMurray are from rivers and small streams. These numbers represent the total amount of data collected by all studies using all sampling methods; however, a number of studies did not report the raw data, which means that the amount of data available for analysis is actually lower (see the sections for individual rivers or basins for the amount of available data).

The most common sampling devices were the Ekman grab in depositional habitats and lakes, the Neill cylinder and Surber sampler in erosional habitat, and rock-filled basket-type AS (Table 2 and Table I-1, Appendix I). All of these devices were commonly used in the Athabasca River (Table 2). Natural substrates in the MacKay and Steepbank rivers were sampled largely using erosional sampling devices (Neill cylinder, Surber sampler, kicknet), corresponding to the largely erosional nature of these rivers. Artificial substrates, which are not restricted by habitat type, were also used in the MacKay River and one small stream (Poplar Creek). The Muskeg River was sampled with both erosional (lower reach) and depositional (mid to upper reaches) techniques, reflecting the abrupt change in the character of this river at about 12 km from its mouth. Small streams were sampled largely using erosional sampling devices and the majority of standing waters were sampled with an Ekman grab.

R:\CAD\2300\022-2301\6340\ Drawing file: study-area.dwg Dec 16, 2003 – 2:40pm



LEGEND

- ROADWAYS
- RIVERS AND STREAMS
- 12 SITES IN TRIBUTARIES AND SMALL STREAMS
- 74 SITES IN LAKES, PONDS AND WETLANDS
- 114 SITES IN ATHABASCA RIVER
- REACHES SAMPLED IN 2000 AND 2001

5 0 5

SCALE KILOMETRES

NOTES:

1. SEE TABLE ___ FOR SITE CODES AND STUDY REFERENCES

REFERENCE

DIGITAL DATA SETS 74D, 74E, 74I, 84A AND 84H FROM RESOURCE DATA DIVISION ALBERTA ENVIRONMENTAL PROTECTION 1997. DATUM: NAD83. PROJECTION: UTM ZONE 12.

PROJECT

RAMP

TITLE

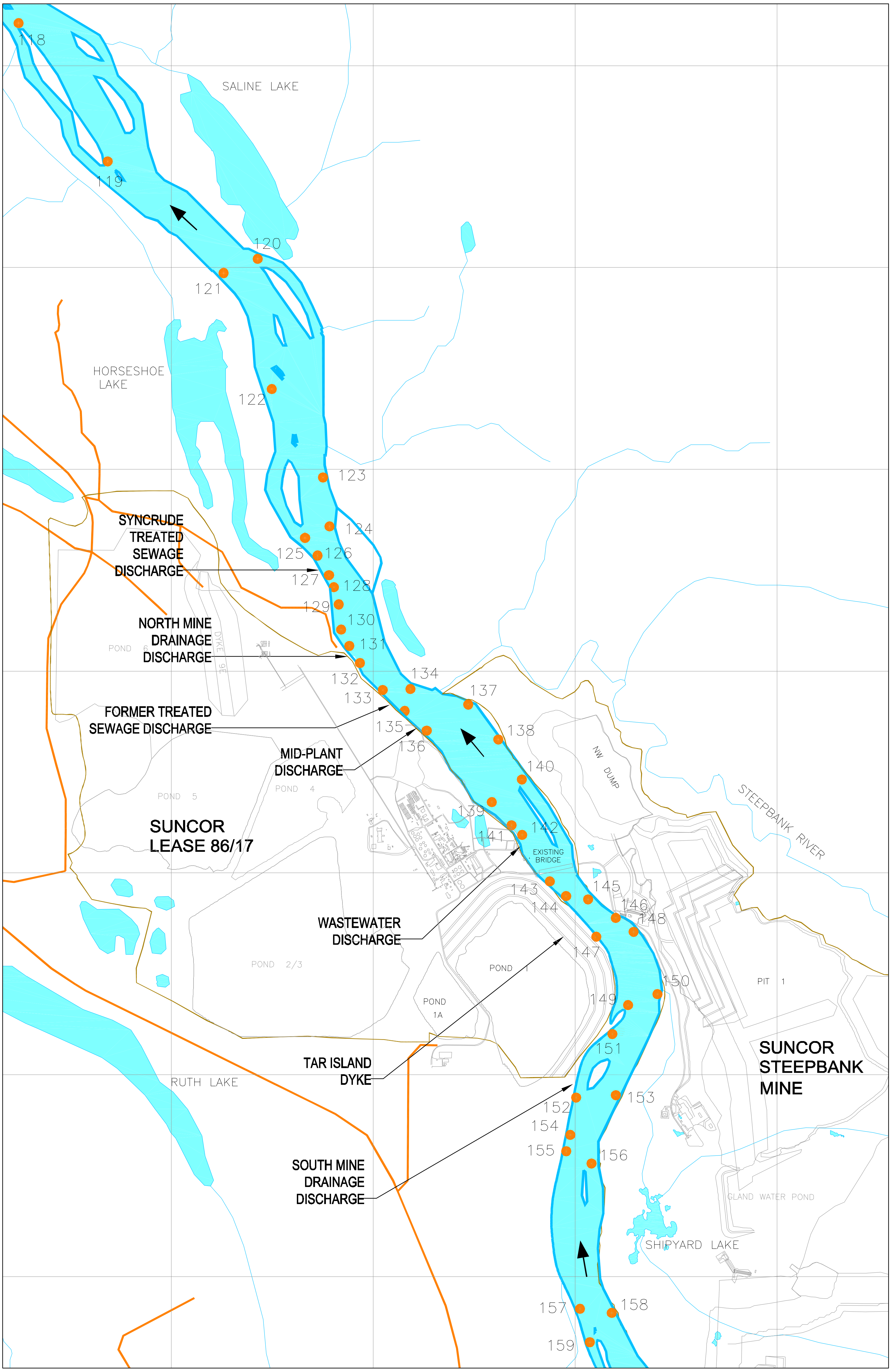
HISTORICAL BENTHIC INVERTEBRATE SAMPLING LOCATIONS IN THE OIL SANDS REGION NORTH OF FORT McMURRAY (1974-2001)

Golder Associates
Calgary, Alberta

PROJECT No. 022-2301.6340		FILE No. study-area.dwg	
DESIGN	ZK	07/08/02	SCALE AS SHOWN REV. 0
CADD	JEF	20/08/03	
CHECK	ZK	15/11/03	
REVIEW	ZK	15/11/03	

FIGURE: 1

R:\Archive\CALGARY\2000\2300\002-2309\CAD\6340\sampling-pts.dwg



LEGEND

ROADWAYS
RIVERS AND STREAMS
156 SAMPLING SITES (118–159)

NOTES:

1. SEE APPENDIX II FOR SITE CODES AND STUDY REFERENCES

REFERENCE

DIGITAL DATA SETS 74D, 74E, 74I, 84A AND 84H FROM RESOURCE DATA DIVISION ALBERTA ENVIRONMENTAL PROTECTION 1997. DATUM: NAD83. PROJECTION: UTM ZONE 12.

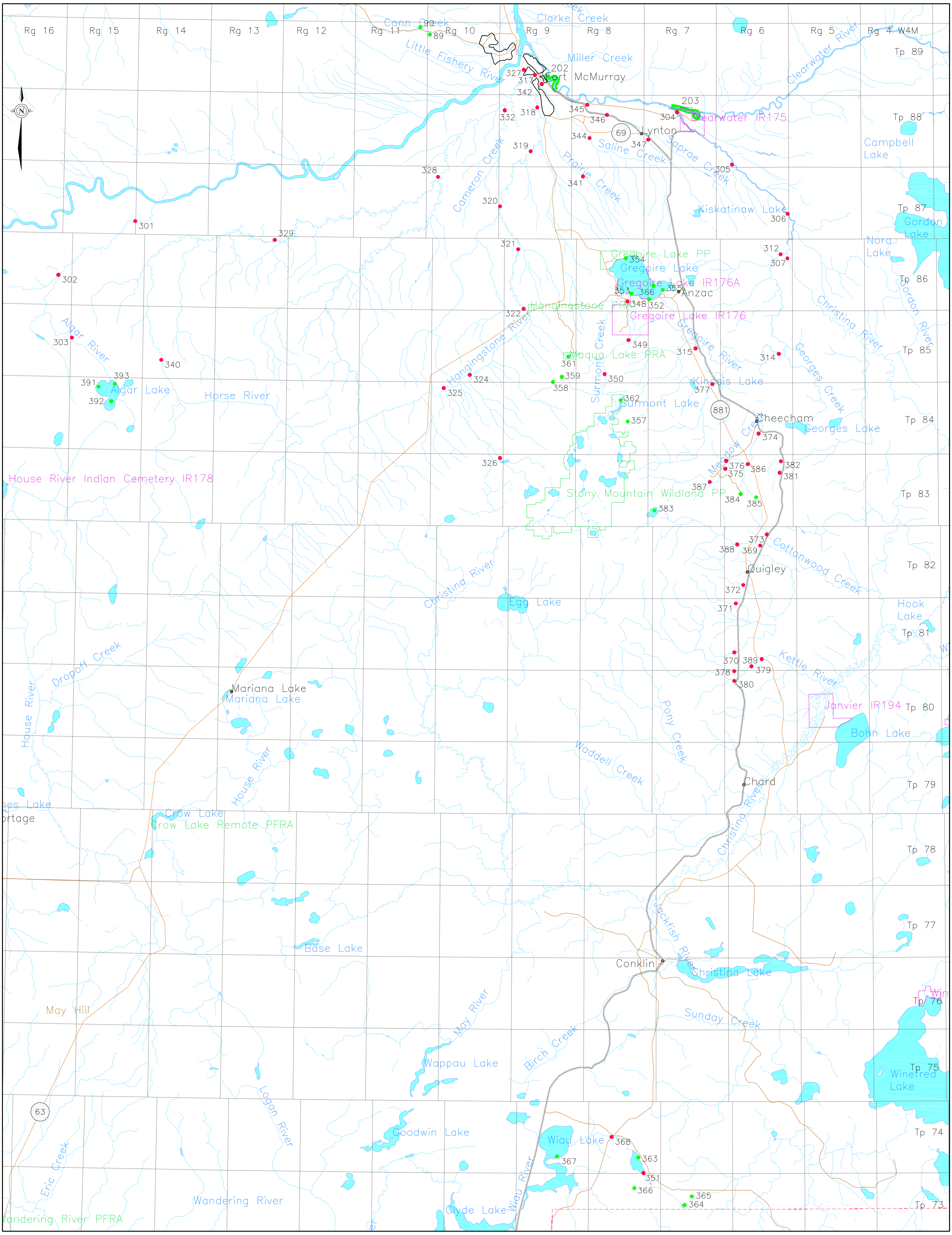
0 0.5 1 1.5 2 2.5km
SCALE: 50,000

Golder Associates

HISTORICAL BENTHIC INVERTEBRATE SAMPLING LOCATIONS IN THE ATHABASCA RIVER IN THE SUNCOR/SYNCRUDE REACH

DRAWN: RFM	APPROVED:	DATE: 04 May 2001
PROJECT: 002-2309.6340		FIGURE: 2

Revision No.: 04



LEGEND

- ROADWAYS
- RIVERS AND STREAMS
- SITES IN TRIBUTARIES AND SMALL STREAMS
- SITES IN LAKES, PONDS AND WETLANDS
- REACHES SAMPLED IN 2000 AND 2001

10 0 10
SCALE KILOMETRES

REFERENCE

ALBERTA NTDB DATA SUPPLIED BY GEOMATICS CANADA, AUGUST 2001. NAD 83 ZONE 12. SHEETS 74D, E AND 74L IN NAD 27 ZONE 12. SASKATCHEWAN NTDB DATA SUPPLIED BY ISC, AUG. 2001. NAD 83 ZONE 13. ALL DATA CONVERTED TO NAD 83 UTM ZONE 12. OIL & GAS AND ENVIRONMENTAL DATA PROVIDED BY VERITAS GeoSERVICES LTD., CURRENT AS OF MAY 2001.

PROJECT
RAMP

TITLE
HISTORICAL BENTHIC INVERTEBRATE SAMPLING LOCATIONS IN THE OIL SANDS REGION SOUTH OF FORT McMURRAY (1974-2001)

Golder Associates
Calgary, Alberta

PROJECT No. 022-2301.6340			FILE No. Historical Benthic-rev
DESIGN	DJ	16/08/02	SCALE AS SHOWN REV. 1
CADD	JEF	20/08/03	
CHECK	ZK	15/11/03	FIGURE: 3
REVIEW	ZK	15/11/03	

Table 2 Summary of the Number of Site Data Sets in the Historical Database (1974 to 2001)

Waterbody/ Sample Type	Grand Total	Imp[(a)]	New[(a)]	Ref[(a)]	Site Data Sets								
					Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Athabasca River													
Ekman	160	69	0	91	0	0	0	21	21	21	72	25	0
Neill/Hess/ Surber	203	30	0	173	1	0	57	40	38	38	29	0	0
AS (basket)	126	65	0	61	0	0	0	21	21	22	47	15	0
airlift	30	10	0	20	0	0	0	6	6	6	6	6	6
Total	519	174	0	345	1	0	57	88	86	87	154	46	6
Major Athabasca River Tributaries													
MacKay River													
Neill/Surber	32	0	0	32	0	0	3	7	7	3	12	0	0
AS (basket)	15	0	0	15	0	0	3	3	3	3	3	0	0
Total	47	0	0	47	0	0	6	10	10	6	15	0	0
Muskeg River													
Ekman	34	0	0	34	0	0	8	0	0	9	6	11	0
Neill	14	0	0	14	0	0	0	0	3	3	8	0	0
Kicknet	16	0	0	16	0	0	4	0	8	0	0	4	0
Total	64	0	0	64	0	0	12	0	11	12	14	15	0
Steepbank River													
Neill/Surber	18	0	0	18	0	0	0	1	2	3	10	2	0
Kicknet	28	0	0	28	0	0	7	0	14	0	0	7	0
Total	46	0	0	46	0	0	7	1	16	3	10	9	0
Other Rivers													
Ekman	7	0	0	7	0	0	0	0	0	0	2	5	0
Neill	2	0	0	2	0	0	0	0	0	0	0	2	0
Total	9	0	0	9	0	0	0	0	0	0	2	7	0
Small Streams North of Fort McMurray													
Ekman	100	0	15	85	0	0	20	7	11	18	19	23	2
Neill/Hess/ Surber	226	9	50	167	6	0	28	42	39	29	44	26	12
Kicknet	8	0	0	8	0	0	2	0	4	0	0	2	0
AS (basket)	29	0	15	14	0	0	0	4	13	4	4	4	0
PIBS [(b)]	20	0	10	10	0	0	0	4	4	4	4	4	0
Total	383	9	90	284	6	0	50	57	71	55	71	59	14
Lakes North of Fort McMurray													
Ekman	194	19	82	93	6	0	25	29	33	44	39	12	6
core	13	10	0	3	0	0	0	0	0	13	0	0	0
Total	207	29	82	96	6	0	25	29	33	57	39	12	6

Table 2 Summary of the Number of Site Data Sets in the Historical Database (1974 to 2001) (continued)

Waterbody/ Sample Type	Grand Total	Imp[a]	New[a]	Ref[a]	Site Data Sets								
					Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Rivers and Small Streams South of Fort McMurray													
Ekman	39	0	0	39	0	0	11	4	5	15	0	4	0
Surber	105	0	0	105	0	0	23	18	9	37	0	18	0
Total	144	0	0	144	0	0	34	22	14	52	0	22	0
Lakes South of Fort McMurray													
Ekman	28	0	0	28	0	0	13	0	3	12	0	0	0

[a] Imp = potentially impacted sites; New = sites in man-made channels or impoundments; Ref = reference sites.

[b] PIBS = portable invertebrate box sampler.

All of the data from major tributaries fall in the reference category, and most of the small stream data were collected at reference locations (Table 2). About two-thirds of the Athabasca River data were collected at reference locations. Data from standing waters are dominated by reservoir samples (Beaver and Poplar Creek reservoirs) and reference site data. All of the data collected south of Fort McMurray are from reference sites. The preponderance of reference site data in the historical data set reflects the relatively recent increase in the spatial scale of oil sands development in the region.

The seasonal distribution of the historical data shows a bias toward fall (September) sampling in the Athabasca River, with a lower level of effort in other months (Table 2). There is no pronounced bias in other rivers, streams and standing waters north of Fort McMurray, which were sampled with similar effort in all months from May to October. The area south of Fort McMurray was sampled from May to August and October, with the largest effort in August. Sampling in the winter (March) and late fall was rare and no samples were ever collected in April, presumably because of high flows or unsafe conditions during snow melt.

The reference site data were further examined to evaluate the amount of data available for a reference condition approach (RCA) analysis of the river data. The southern data set is unlikely to be of use in this type of analysis because the mesh size used during most studies in this area (600 µm) was larger than the most commonly used mesh sizes used by the majority of other studies in the region (180 to 250 µm). Additionally, one of the major studies in the southern area (Gulf 1979) used qualitative sampling and sample sorting methods, and large mesh sizes (600 to 850 µm), suggesting their data are not comparable with the data collected by other studies. The remainder of the southern data are from small-scale studies, and would be insufficient for even an initial RCA analysis.

An RCA analysis would require a reference site data set that is consistent in terms of sampling and sample processing methods, but represents a range of stream sizes. Therefore, the possibilities for this type of analysis in the Oil Sands Region include separate analyses for erosional and depositional habitat because they have traditionally been sampled using different methods. Additionally, the Athabasca River data and the data for smaller rivers/streams would have to be analyzed separately because of the great difference in habitat between these data sets. This yields four possible subsets of the historical data: (1) erosional, and (2) depositional habitat in the Athabasca River; as well as (3) erosional, and (4) depositional habitat in all smaller rivers and streams combined.

To arrive at the amount of data that would be useful for this analysis, the summary table in Appendix I was reduced by deleting the following sites:

- non-reference sites;
- sites in lakes/ponds/wetlands and in the southern part of the Oil Sands Region;
- sites with no raw data;
- sites sampled using other than 180 to 250 µm mesh collecting nets; and
- sites sampled using devices other than the Neill, Hess or Surber samplers (erosional habitat) or the Ekman grab (depositional habitat).

The numbers of site data sets at the remaining sites are summarized in Table 3. Considering that the minimum number of sites for an RCA analysis is about 50 to 60 (Reynoldson and Rosenberg 1996), this initial assessment suggests that there are sufficient reference site data sets for this type of analysis in erosional habitat in the Athabasca River and both habitat types in smaller rivers and streams. However, since seasonal changes in benthic communities tend to interfere with RCA assessments, the data should be restricted further to the most commonly sampled season (usually the fall). Based on the amount of fall data (September to November) sufficient data may be available for a preliminary analysis of tributary river and small stream data.

The benthic invertebrate abundance data compiled to prepare this document are provided in a standardized spreadsheet format on the enclosed CD-ROM.

The following sections summarize historical studies in the Athabasca River, its major tributaries with multiple years of data (MacKay, Muskeg and Steepbank rivers), small streams north of Fort McMurray and rivers/streams south of Fort McMurray.

Table 3 Summary of the Number of Reference Site Data Sets Generated Using Consistent Methods (1974 to 2001)

River/Habitat	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Total	Fall[(a)]
Athabasca River											
Depositional	0	0	0	0	0	0	30	0	0	30	30
Erosional	1	0	50	33	31	32	22	0	0	169	22
Other Rivers and Small Streams											
Depositional	0	0	21	2	4	20	20	35	0	102	55
Erosional	0	0	7	12	14	8	37	11	1	90	49

(a) Fall = September, October and November.

3.2 ATHABASCA RIVER

3.2.1 Studies Reviewed

The Athabasca River has been sampled by 13 studies from 1975 to 1997 (Table 4; the report describing the 2001 study [Jacques Whitford 2002] was not available for review). The first studies collected baseline data for a planned Syncrude discharge (McCart et al. 1977) and for major rivers in the Oil Sands Region as part of AOSERP (Barton and Wallace 1980). About half of the remaining studies (Noton 1979; Noton and Anderson 1982; IEC Beak 1983; Corkum 1984 unreleased; EVS 1986, 1996) investigated the aquatic effects of Suncor, formerly the Great Canadian Oil Sands Ltd. within the relatively short reach of river shown in Figure 2. Part of one study (AENV data listed by Ouellett and Cash 1996) focussed on the Fort McMurray sewage treatment plant discharge. A few of the studies were more regional in scope. Boerger (1983a) and Corkum (1984 unreleased) investigated the reach between Fort McMurray and the Ells River; Golder (1998a) sampled upstream and downstream of existing and planned oil sands developments; and Anderson (1991) sampled two long-term monitoring sites in the lower Athabasca River, which were part of the provincial long-term river monitoring network. A single site upstream of Fort McMurray was sampled during the Northern River Basins Study (Dunnigan and Millar 1993).

Of all the studies conducted to the end of 2001, Boerger (1983a) collected by far the largest amount of data: 16 sites were sampled seven times from May to August 1981, which accounts for about 60% of the available erosional data for this river. The data collected by Boerger (1983a) were re-analyzed by Walder and Mayhood (1985), who pointed out that because a non-random procedure was used to select samples retained for laboratory analysis, results of a statistical analysis should be considered tentative or inconclusive. However, the data are useful for an exploratory analysis focussing on community composition, as applied in this report (Section 3.2.2.1).

Table 4 Details of Athabasca River Studies

Reference	Number of Sites	Habitat	Sampling Method and Replication (sieve mesh size)	Year	Month
McCart et al. (1977)	15	depositional	Ekman, AS (basket) 3 replicates (600 µm)	1975	June-Oct (monthly)
Barton and Wallace (1980)	10	depositional (6), erosional (4)	Ekman, Surber 3 replicates (202 µm)	1976-77	Sept, Oct
	6	depositional	Ekman, airlift 3-10 replicates (202 µm)	1977	June-Oct (monthly, plus May at 1 site)
Noton (1979)	10	depositional	Ekman, AS (basket) 9 or 3 replicates (250 µm)	1978	Sept/Oct
Boerger (1983a)	16	erosional	Hess 3 replicates (250 µm)	1981	May-Aug (every 2 weeks, exc. Aug)
Noton and Anderson (1982)	10	depositional	Ekman, AS (basket) 5 and 3 replicates (250 µm)	1981	Sept
IEC Beak (1983), Beak (1988)	7	depositional	AS (basket) 6 replicates (250 µm)	1982	Aug/Sept
Corkum (1984 unreleased)	17	erosional	Neill 3 replicates (210 µm)	1983	May, Sept
Anderson (1991)	2	erosional	Neill 5 replicates (210 µm)	1983-87	May/June, Aug/Sept
EVS (1986)	6	erosional	Neill, AS (basket) 5 replicates (250 µm)	1986	June, July
AENV data listed by Ouellett and Cash (1996)	9	depositional (5), erosional (4)	Ekman, Neill 10 repl. (depositional) 5 repl. (erosional) (210 µm)	1987	Aug, Sept
Dunnigan and Millar (1993)	1	erosional	Neill 10 replicates (210 µm)	1993	March
EVS (1996)	12	depositional	Ekman, AS (basket) 1 composite of 3 samples (Ekman), 3 replicates (AS) (250 µm)	1995	Sept/Oct
Golder (1998a)	12	depositional	Ekman 6 replicates (250 µm)	1997	Sept

In total, 78 sites were sampled by the above studies, with about half (42) in the intensively sampled reach shown in Figure 2. The spacing of sites was variable, and despite the large number of studies, few sites were sampled by more than two studies. The greatest density of sites was between Shipyard Lake and Horseshoe Lake (Figure 2). Spatial coverage of the river was still relatively dense for some distance upstream and downstream of this reach. The maximum distance between adjacent sites was about 5 km from the MacKay River to Fort McMurray. Relatively few sites were sampled downstream of the MacKay River.

All depositional samples were collected using a 15 cm Ekman grab (Table I-1 in Appendix I). Erosional samples were collected using a Neill cylinder, Hess sampler, or Surber sampler. Both habitats were sampled using AS (rock-filled baskets) and one study (Barton and Wallace 1980) used an airlift (suction) sampler.

The number of sites sampled using exclusively depositional sampling methods (45) was greater than those sampled using erosional methods (20) (Table II-1 in Appendix II), which reflects the generally depositional, shifting sand substrates in the lower Athabasca River. Eleven sites were sampled using both methods. Forty-one sites were sampled using AS in combination with other methods and two sites were sampled using AS only. Because of the limited working depth of erosional sampling devices (usually ≤60 cm), erosional sampling was usually restricted to the narrow band of shallow water within a few metres of the shoreline (e.g., Corkum 1984 unreleased). Depositional sites were usually farther from shore, in deeper water (e.g., 1 to 2 m depth; Golder 1998a).

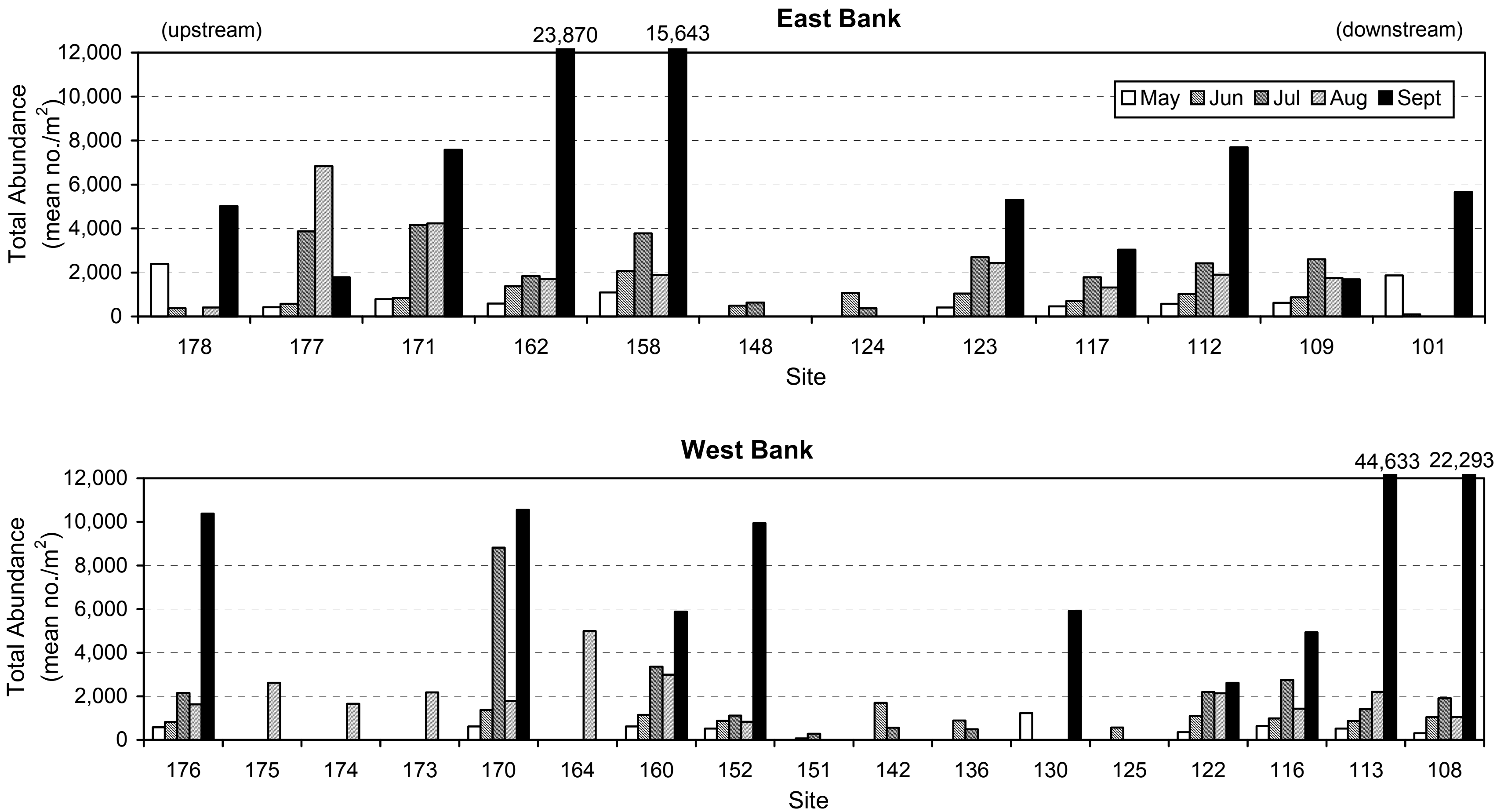
3.2.2 Summary of Historical Data

3.2.2.1 Erosional Habitat

Total benthic invertebrate abundance expressed as the mean number of organisms per square metre was variable but generally low along both banks of the Athabasca River. Due to river stage fluctuations, some of the variation in abundance at erosional sites (usually located in shallow, near-shore areas) may have been due to sampling previously exposed areas. Numbers were usually <5,000 organism/m^2, except in September, when total abundances were considerably larger (Figure 4). There was a relatively consistent seasonal trend at most sites. Abundance tended to increase during the open water season, with maximum numbers in September.

The reach immediately downstream of the Suncor discharge (Sites 125 to 142 along the west bank) was not as intensively sampled using erosional methods as most other sites, presumably because of its largely depositional character. Total invertebrate abundance was not unusual at erosional sites in this reach.

Figure 4 Total Invertebrate Abundance at Erosional Sites in the Athabasca River



Taxonomic richness (standardized to the family level) was less variable than total abundance (Figure 5), which is typical of benthic invertebrate data. Richness was generally between 10 and 15 families along the east bank. A number of sites along the west bank had richness values above this range in July and August. At sites with monthly data, richness tended to increase over time during the open-water season, though the trends were less pronounced than those observed for total abundance (Figure 5). There was no indication of an effect on richness downstream of the Suncor discharge.

Composition of benthic communities at the level of major taxon showed some degree of consistency at erosional sites (Tables 5 and 6). Chironomid midges (Chironomidae) were usually the dominant group, constituting about 30 to 80% of total abundance at nearly all sites, in all months. Mayflies (Ephemeroptera) and oligochaete worms (Oligochaeta) were also numerous, although more variable among months than chironomids. Stoneflies (Plecoptera) were abundant in May and August samples from the east bank. Together, these four groups usually accounted for about 60 to 100% of total abundance. Roundworms (Nematoda), caddisflies (Trichoptera) and other invertebrates were minor constituents of erosional communities.

On average, 68% of the total abundance at erosional sites represented depositional taxa (Chironomidae and Oligochaeta). This may have resulted from settling of drifting invertebrates and fine sediments from depositional areas, which represent the dominant habitat type in the lower Athabasca River.

Availability of data for evaluation of year-to-year variation or long-term trends is limited because few sites were sampled by more than two studies and the available data were distributed over a number of months. Therefore groups of closely-spaced sites (representing <5 km reaches) were selected for an initial evaluation. Additional criteria for selecting sites included availability of data for the same season in at least three years. The only erosional sites satisfying these requirements were Sites 178 (upstream of Fort McMurray), 101 (far downstream, at Embarras) and Sites 151 and 152 (upstream of Suncor) (Figures 1 and 2). Sites 178 and 101 were sampled repeatedly during the same monitoring program (Anderson 1991) using standardized methods, which renders them appropriate for an evaluation of year-to-year variation.

Figure 5 Taxonomic Richness (number of families) at Erosional Sites in the Athabasca River

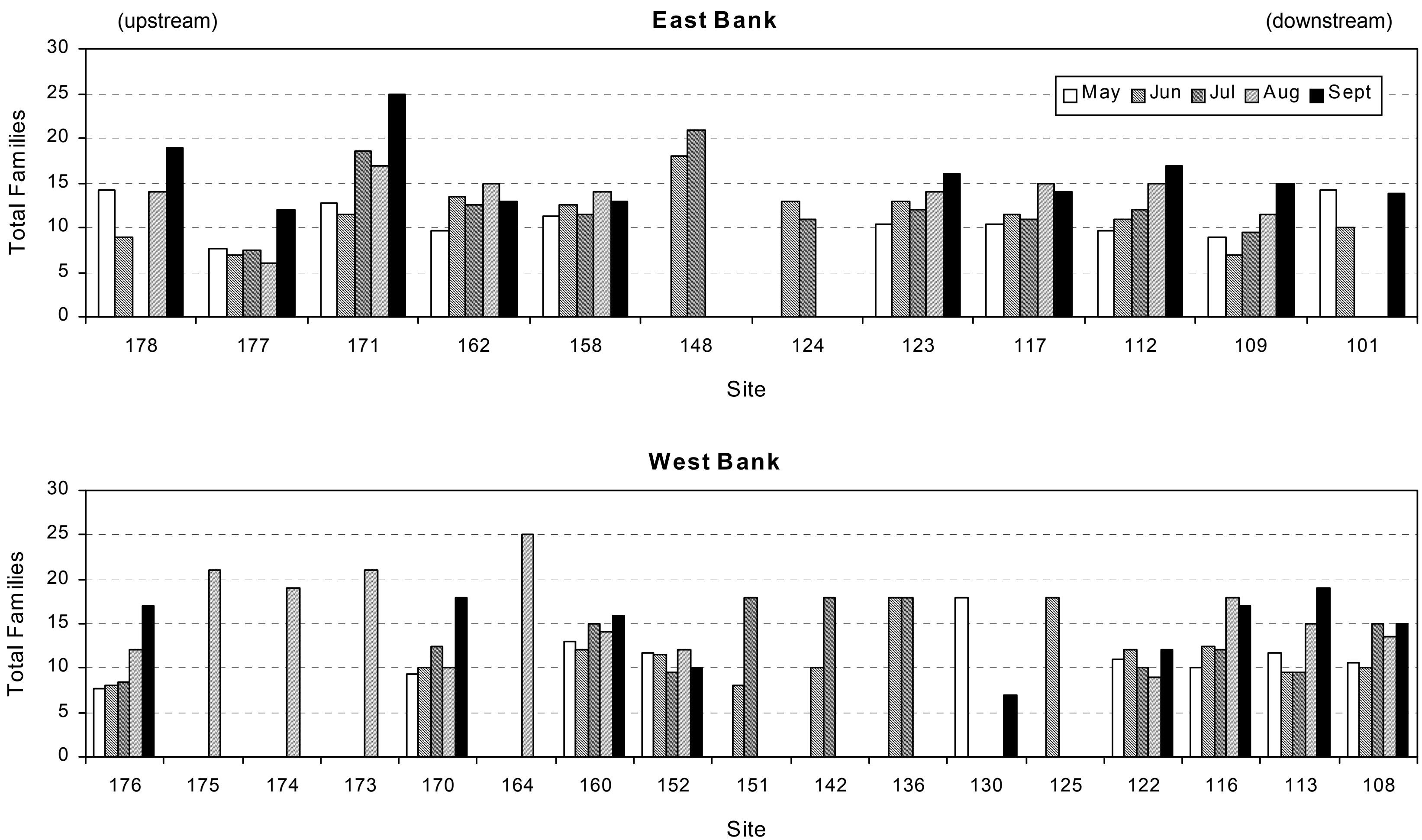


Table 5 Benthic Community Composition at Erosional Sites Along the West Bank of the Athabasca River

Site	Month	Year(s)	Nema-toda (%)	Oligo-chaeta (%)	Epheme-roptera (%)	Plecop-tera (%)	Trichop-tera (%)	Chirono-midae (%)	Other (%)
178	May	1983-86	32.2	33.6	1.2	0.4	0.3	30.7	1.5
	June	1987	40.3	18.3	2.2	0.0	2.2	36.6	0.5
	Aug	1987	13.8	45.3	18.2	3.0	2.5	12.3	4.9
	Sept	1983-86	4.4	13.5	3.9	1.0	2.3	71.3	3.5
177	May	1981, 1983	4.8	7.2	5.1	7.7	0.5	72.3	2.4
	June	1981	0.0	34.3	3.5	0.0	0.9	58.8	2.6
	July	1981	0.0	27.5	1.4	0.0	0.0	69.9	1.1
	Aug	1981	0.0	12.6	0.1	0.0	0.0	87.2	0.1
	Sept	1983	22.2	45.8	2.6	0.4	0.2	24.7	4.1
171	May	1981, 1983	2.4	30.1	9.8	4.4	0.3	46.9	6.1
	June	1981	0.0	5.0	50.7	2.4	0.0	38.4	3.6
	July	1981	0.0	14.0	38.1	0.0	0.3	45.1	2.4
	Aug	1981	0.0	5.2	18.5	0.0	0.9	69.7	5.7
	Sept	1983	6.2	20.1	27.6	1.9	1.0	38.2	5.0
162	May	1981, 1983	6.6	4.5	19.7	1.3	0.2	63.6	4.1
	June	1981	0.0	7.2	55.6	2.2	1.8	31.0	2.2
	July	1981	0.0	16.9	30.4	0.0	0.5	48.1	4.1
	Aug	1981	0.0	22.9	18.6	0.4	5.3	46.5	6.4
	Sept	1983	14.0	6.4	0.5	0.0	0.0	72.7	6.3
158	May	1981, 1983	4.8	5.9	4.4	0.8	0.4	79.2	4.6
	June	1981	0.0	27.3	39.0	0.6	0.0	30.4	2.6
	July	1981	0.0	24.6	20.8	0.0	0.2	52.3	2.1
	Aug	1981	0.0	15.2	21.7	0.5	2.1	57.8	2.6
	Sept	1983	22.1	26.0	0.5	0.0	0.0	46.2	5.2
148	June	1986	2.0	8.4	10.4	2.0	16.1	55.8	5.2
	July	1986	28.5	22.8	21.8	0.3	1.9	17.7	7.0
124	June	1986	17.4	18.3	11.4	0.4	0.2	50.1	2.2
	July	1986	50.5	8.1	8.6	0.0	1.1	26.3	5.4
123	May	1981, 1983	1.9	28.9	10.1	5.4	0.5	50.4	2.7
	June	1981	0.0	4.3	50.6	9.1	2.1	29.8	4.2
	July	1981	0.0	21.5	16.6	0.3	0.3	59.0	2.3
	Aug	1981	0.0	16.4	28.9	3.6	10.0	34.5	6.6
	Sept	1983	4.0	50.8	12.9	1.4	1.8	17.7	11.4
117	May	1981, 1983	0.5	17.6	10.0	9.8	0.2	57.3	4.6
	June	1981	0.0	11.1	43.4	5.2	0.0	34.9	5.4
	July	1981	0.0	3.2	51.0	0.6	0.8	42.6	1.8
	Aug	1981	0.0	9.4	31.1	3.3	5.8	44.8	5.6
	Sept	1983	34.3	14.7	9.3	0.5	0.0	37.1	4.0
112	May	1981, 1983	1.6	3.7	8.9	12.3	0.0	69.5	4.1
	June	1981	0.0	30.3	25.4	0.5	0.0	35.1	8.6
	July	1981	0.0	8.5	56.3	0.0	0.2	33.2	1.8
	Aug	1981	0.0	9.4	11.7	0.6	1.7	71.2	5.4
	Sept	1983	14.2	29.2	8.1	0.1	0.2	34.9	13.2
109	May	1981, 1983	0.2	34.0	14.3	10.2	0.4	33.7	7.3
	June	1981	0.0	70.2	3.8	0.2	0.0	23.3	2.5
	July	1981	0.0	36.4	24.3	0.0	2.5	35.7	1.1
	Aug	1981	0.0	16.5	13.8	5.7	3.0	56.6	4.4
	Sept	1983	4.1	55.9	12.0	0.6	0.4	10.6	16.3
101	May	1983-86	4.9	11.9	5.5	7.1	0.2	66.7	3.8
	June	1987	11.1	15.6	17.8	0.0	0.0	53.3	2.2
	Sept	1983-87	11.3	8.7	1.5	0.3	0.1	71.0	7.2

Table 6 Benthic Community Composition at Erosional Sites Along the East Bank of the Athabasca River

Site	Month	Year(s)	Nema-toda (%)	Oligo-chaeta (%)	Epheme-roptera (%)	Plecop-tera (%)	Trichop-tera (%)	Chirono-midae (%)	Other (%)
176	May	1981, 1983	3.3	7.7	3.1	8.3	1.2	48.9	27.6
176	Jun	1981	0.0	26.1	10.7	1.6	1.2	58.3	2.1
176	Jul	1981	0.0	25.6	3.3	0.5	1.1	69.0	0.5
176	Aug	1981	0.0	19.2	8.8	1.0	4.5	65.5	1.0
176	Sept	1983	2.8	3.7	1.3	0.3	0.1	89.6	2.3
175	Aug	1987	1.8	38.2	4.7	7.7	0.5	41.4	5.8
174	Aug	1987	2.4	4.6	7.1	13.2	1.4	69.7	1.6
173	Aug	1987	2.8	13.9	23.3	24.3	1.8	31.4	2.5
170	May	1981, 1983	2.9	15.7	6.1	9.1	0.0	60.8	5.4
170	Jun	1981	0.0	10.3	14.2	1.3	0.7	73.1	0.4
170	Jul	1981	0.0	32.9	8.5	0.2	0.7	57.1	0.5
170	Aug	1981	0.0	0.4	14.7	0.7	3.9	78.9	1.3
170	Sept	1983	2.1	28.8	18.7	3.4	0.3	41.3	5.3
164	Aug	1987	2.2	16.4	16.7	9.4	2.3	47.2	5.8
160	May	1981, 1983	2.7	6.4	11.8	18.4	0.4	51.9	8.4
160	Jun	1981	0.0	9.6	16.2	3.0	0.1	70.0	1.0
160	Jul	1981	0.0	15.9	23.9	0.0	0.9	58.3	1.0
160	Aug	1981	0.0	5.9	12.4	0.9	1.3	74.7	4.8
160	Sept	1983	6.4	22.5	14.9	2.3	0.3	39.8	13.9
152	May	1981, 1983	1.5	17.5	11.2	11.4	1.1	52.6	4.7
152	Jun	1981	0.0	16.0	49.4	3.4	1.5	26.0	3.6
152	Jul	1981	0.0	27.7	16.1	0.2	0.0	51.9	4.2
152	Aug	1981	0.0	0.0	23.5	2.0	8.5	59.9	6.1
152	Sept	1983	8.0	16.5	0.5	0.0	0.0	71.3	3.8
151	Jun	1986	8.6	31.4	5.7	0.0	0.0	37.1	17.1
151	Jul	1986	12.1	5.0	17.7	0.0	3.5	36.9	24.8
142	Jun	1986	3.2	9.1	0.6	0.0	0.1	86.0	0.9
142	Jul	1986	18.2	9.6	25.0	2.9	5.0	33.9	5.4
136	Jun	1986	2.3	8.6	20.3	5.2	27.3	31.8	4.5
136	Jul	1986	38.4	4.5	14.0	0.0	13.6	22.7	6.6
130	May	1983	1.1	9.2	1.9	19.8	0.0	60.7	7.3
130	Sept	1983	6.1	35.4	0.5	0.0	0.0	55.9	2.1
125	Jun	1986	5.3	6.4	22.3	3.2	0.4	52.4	10.1
122	May	1981, 1983	0.9	1.9	7.8	21.3	0.3	59.9	7.8
122	Jun	1981	0.0	15.5	46.3	2.7	0.9	32.1	2.4
122	Jul	1981	0.0	17.9	21.6	0.0	0.6	59.2	0.7
122	Aug	1981	0.0	13.8	19.6	6.5	0.8	57.3	2.0
122	Sept	1983	18.6	12.0	1.5	0.0	0.3	65.3	2.3
116	May	1981, 1983	1.9	10.9	6.6	28.5	0.2	43.6	8.3
116	Jun	1981	0.0	23.6	48.6	5.3	0.2	17.5	4.8
116	Jul	1981	0.0	14.5	28.4	0.3	0.5	54.2	2.1
116	Aug	1981	0.0	5.6	34.0	10.7	4.4	39.2	6.1
116	Sept	1983	7.7	17.2	17.2	4.4	0.5	43.8	9.4
113	May	1981, 1983	1.7	7.0	5.5	12.3	0.0	62.3	11.1
113	Jun	1981	0.0	42.3	17.7	4.6	0.2	32.7	2.5
113	Jul	1981	0.0	6.3	35.1	0.0	0.0	56.7	2.0
113	Aug	1981	0.0	6.2	20.4	4.3	1.8	58.5	8.7
113	Sept	1983	9.6	20.7	0.7	0.0	0.1	66.5	2.3
108	May	1981, 1983	1.5	16.8	9.1	13.1	0.7	51.1	7.7
108	Jun	1981	0.0	61.2	8.1	3.8	0.0	20.3	6.5
108	Jul	1981	0.0	16.3	24.5	0.0	0.6	51.2	7.4
108	Aug	1981	0.0	13.1	17.7	4.1	3.3	56.7	5.1
108	Sept	1983	9.0	24.4	0.4	0.1	0.0	62.7	3.5

The variation in total invertebrate abundance among years was large, with a maximum range of about 500 to nearly 15,000 organisms/m^2 at Site 178 (a nearly 30-fold variation) (Figure 6). Richness was less variable among years, with a maximum range of 10 to 23 families at Site 101 (a close to two-fold variation). Community composition also varied considerably, even at the coarse level of major group (Figure 7). For example, the relative abundance of chironomids ranged from 12 to 87% of total abundance at Site 178. Both abundance and richness at Site 178, and abundance at Site 101 appeared to decline over the five-year period with available data (Figure 6). However, despite these potential trends, there are insufficient data for an analysis of time-trends in the erosional data set.

Figure 6 Year-to-year Variation in Total Invertebrate Abundance at Selected Erosional Sites in the Athabasca River

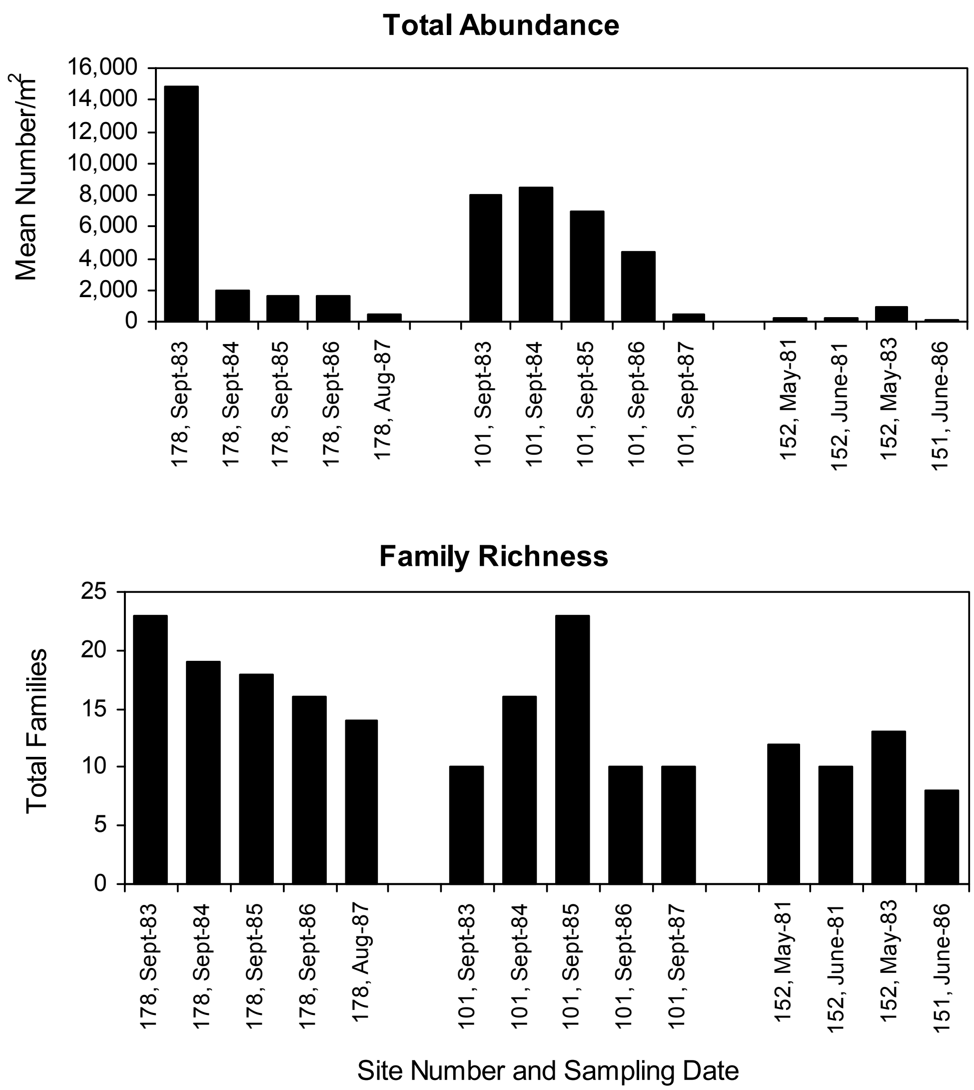
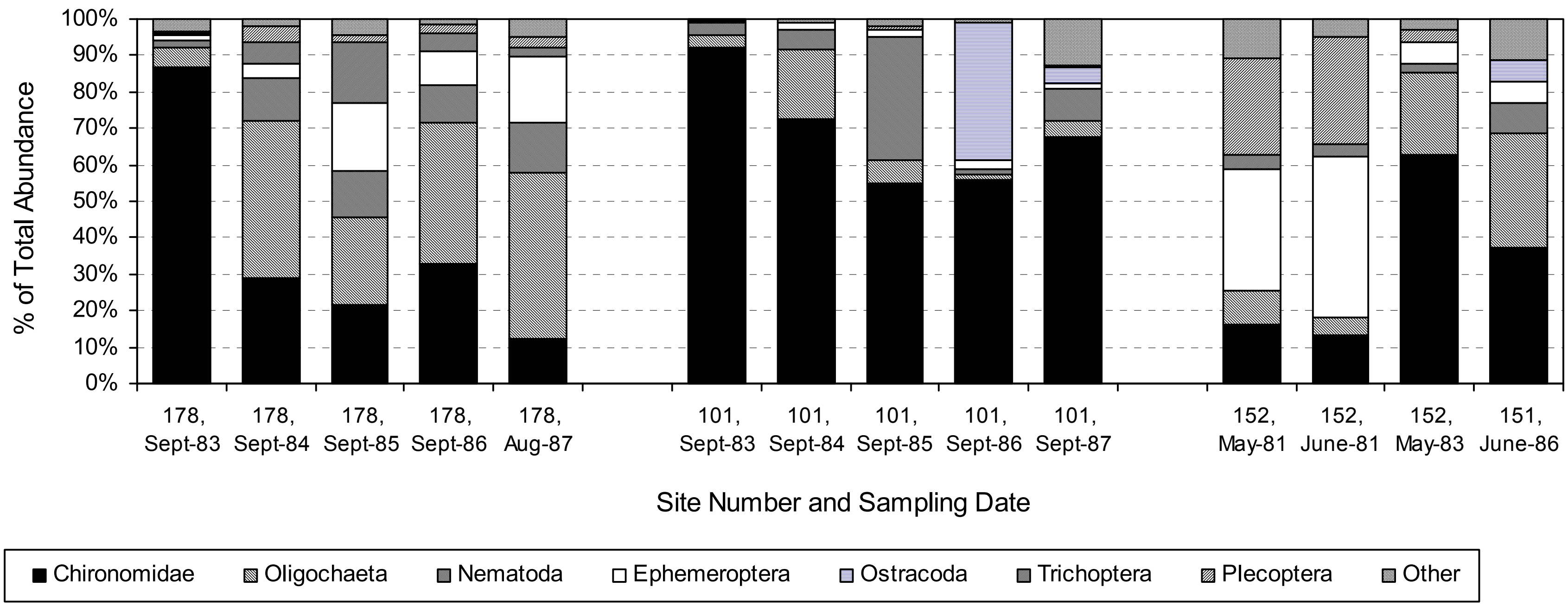


Figure 7 Year-to-year Variation in Benthic Community Composition at Selected Erosional Sites in the Athabasca River



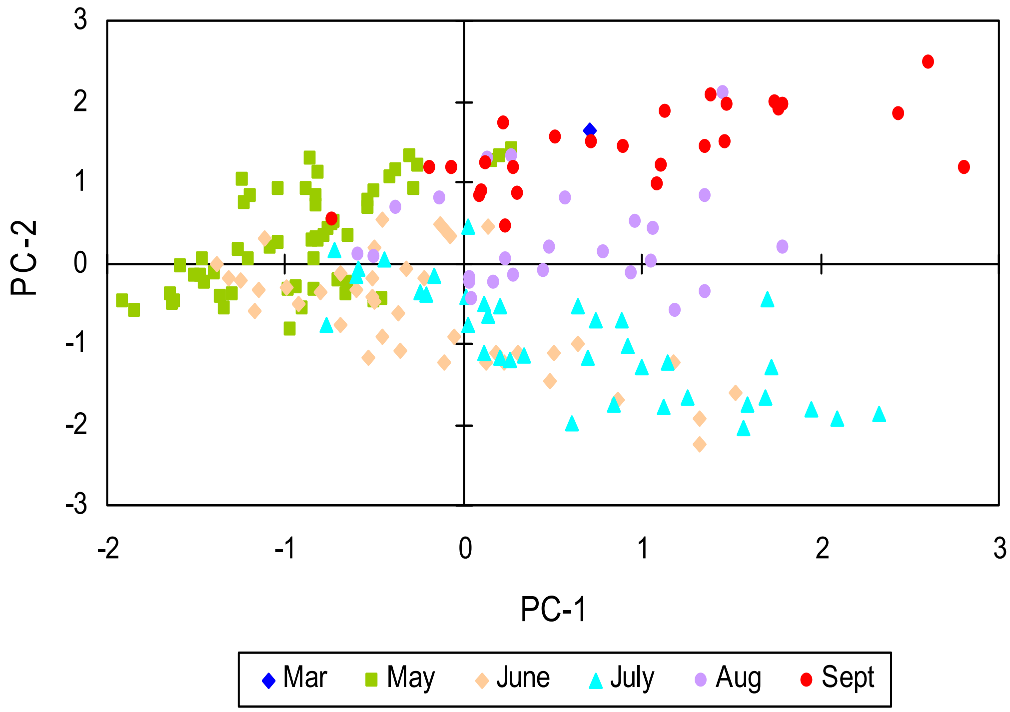
Results of the ordination suggest that the time of sampling has considerable influence on the taxonomic composition of benthic samples. The first three principal components (PCs) explained 47% of the total variance in the erosional data (Table 7). Families or higher taxa within the numerically dominant invertebrate groups (e.g., chironomids, oligochaetes and common mayfly families) had high positive loadings on the first principal component (PC-1), suggesting that high scores on PC-1 in Figure 8 are indicative of higher abundances of these taxa. Graphical examination of ordination plots showed grouping of sites sampled in the same month (Figure 8). No grouping or trends were found with respect to position along the river, bank sampled, year of sampling, or position relative to the Suncor discharge. Results of this analysis stress the importance of considering seasonal variation in the design of future monitoring studies in the Athabasca River.

Table 7 Summary of PCA Results for Erosional Sites in the Athabasca River

Taxon	PC-1	PC-2	PC-3
Component Loadings[(a)]			
Tricorythidae	**0.796**	-0.289	-0.091
Heptageniidae	**0.731**	-0.313	0.402
Baetidae	**0.715**	-0.177	0.186
Chironomidae	**0.702**	0.283	-0.329
Gomphidae	**0.656**	-0.090	0.184
Oligochaeta	**0.644**	0.243	-0.384
Leptophlebiidae	**0.548**	0.237	0.090
Isonychiidae	**0.513**	-0.416	-0.152
Hydropsychidae	**0.511**	0.032	0.444
Ostracoda	**0.508**	0.295	-0.462
Nematoda	0.197	**0.793**	-0.241
Empididae	0.350	**0.704**	0.220
Caenidae	0.451	**-0.669**	-0.143
Perlodidae	-0.145	0.306	**0.743**
Ephemerellidae	0.250	0.418	**0.531**
Ceratopogonidae	0.375	0.361	-0.147
Ametropodidae	0.124	-0.173	0.086
Simuliidae	-0.156	-0.209	-0.101
Ameletidae	0.336	-0.426	0.049
Metretopodidae	-0.246	-0.368	0.164
Acarina	0.022	0.294	0.102
Siphlonuridae	-0.385	0.143	-0.261
Eigenvalue	5.052	3.146	2.045
Variance Explained (%)	23.0	14.3	9.3

[(a)] Component loadings >0.5 are bolded.

Figure 8 Ordination Plot of Erosional Sites in the Athabasca River



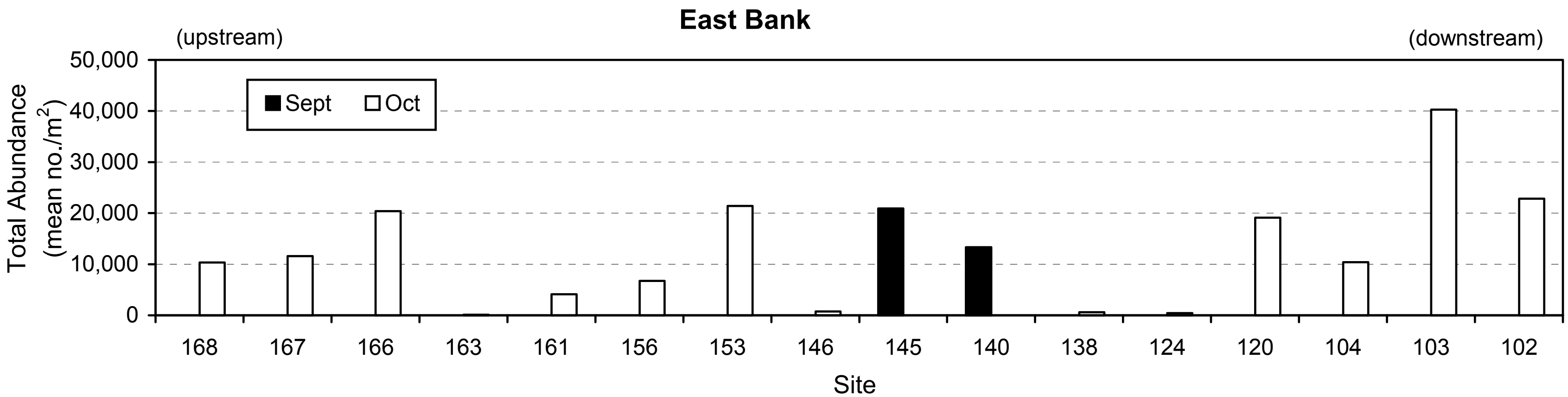
3.2.2.2 Depositional Habitat

Total benthic invertebrate abundance was variable and in the low to moderate range in absolute terms (≤20,000 organisms/m^2) at depositional sites, with the exception of September 1981 results from the reach adjacent to Suncor along the west bank (Sites 127 to 149 in Figure 9). The highest abundance values were reported from this reach by Noton and Anderson (1982) and Ouellett and Cash (1996). In contrast, a previous, October 1978 survey (Noton 1979) reported some of the lowest total abundances from this reach.

Total invertebrate abundances were reported by two other surveys (Figures 10 and 11), which were not included in Figure 9 because the raw data were not available (Barton and Wallace 1980; McCart et al. 1977). Abundances documented by these studies were in similar ranges as those shown in Figure 9. These studies found no appreciable differences between the sites adjacent to Suncor (Sites 130 and 131 in Figure 10; Sites 126 and 142 in Figure 11) and other sites.

Taxonomic richness was less variable than total abundance (Figure 12), but more variable (with several-fold ranges along both banks) than richness values reported from erosional sites (Figure 5). The typical richness values in

Figure 9 Total Invertebrate Abundance at Depositional Sites in the Athabasca River



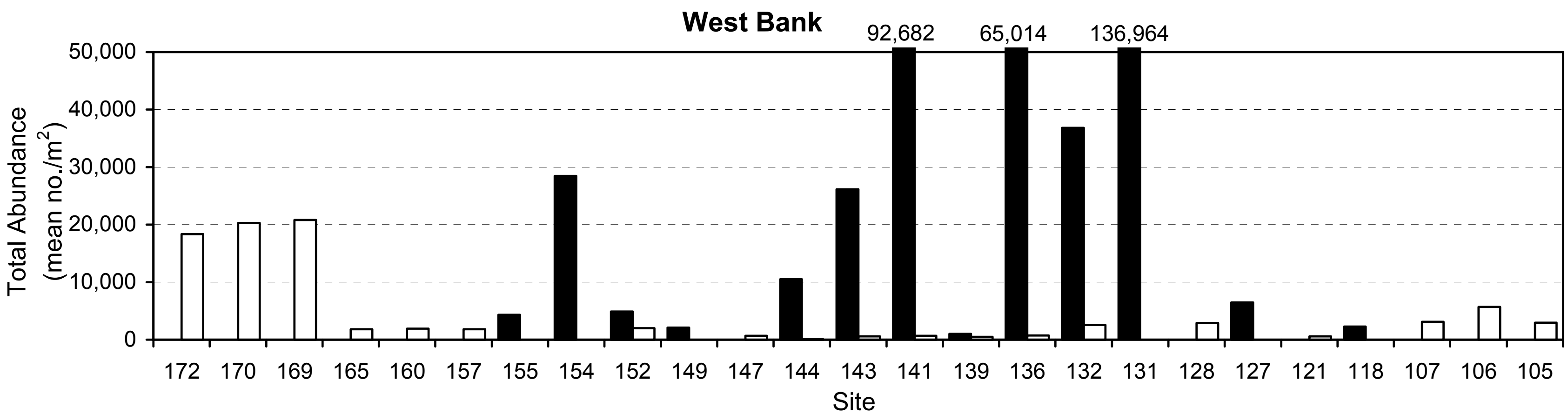


Figure 10 Seasonal Variation in Benthic Community Characteristics at Selected Depositional Sites in the Athabasca River in 1975 (data from McCart et al. 1977)

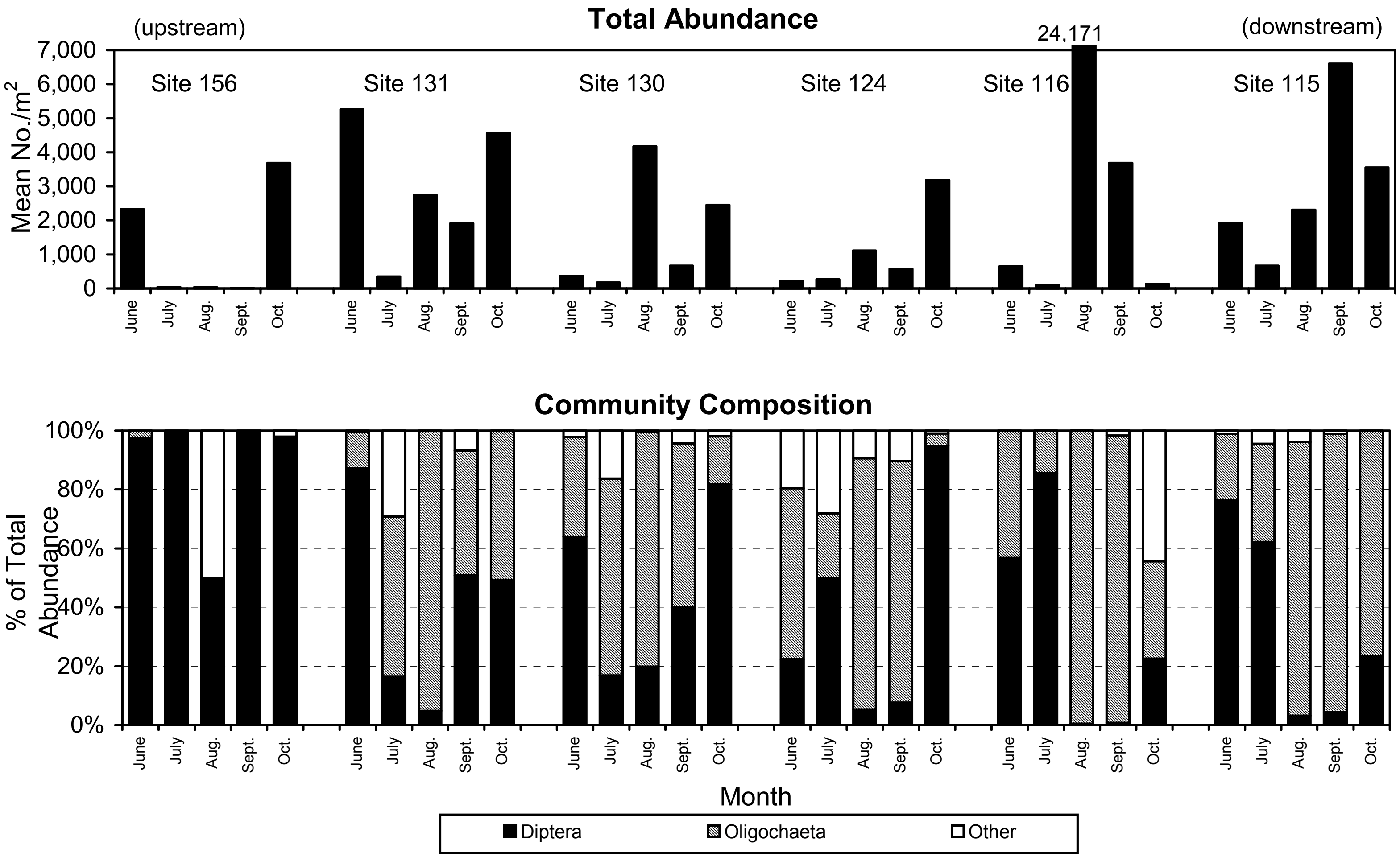


Figure 11 Seasonal Variation in Benthic Community Characteristics at Selected Depositional Sites in the Athabasca River in 1977 (data from Barton and Wallace 1980)

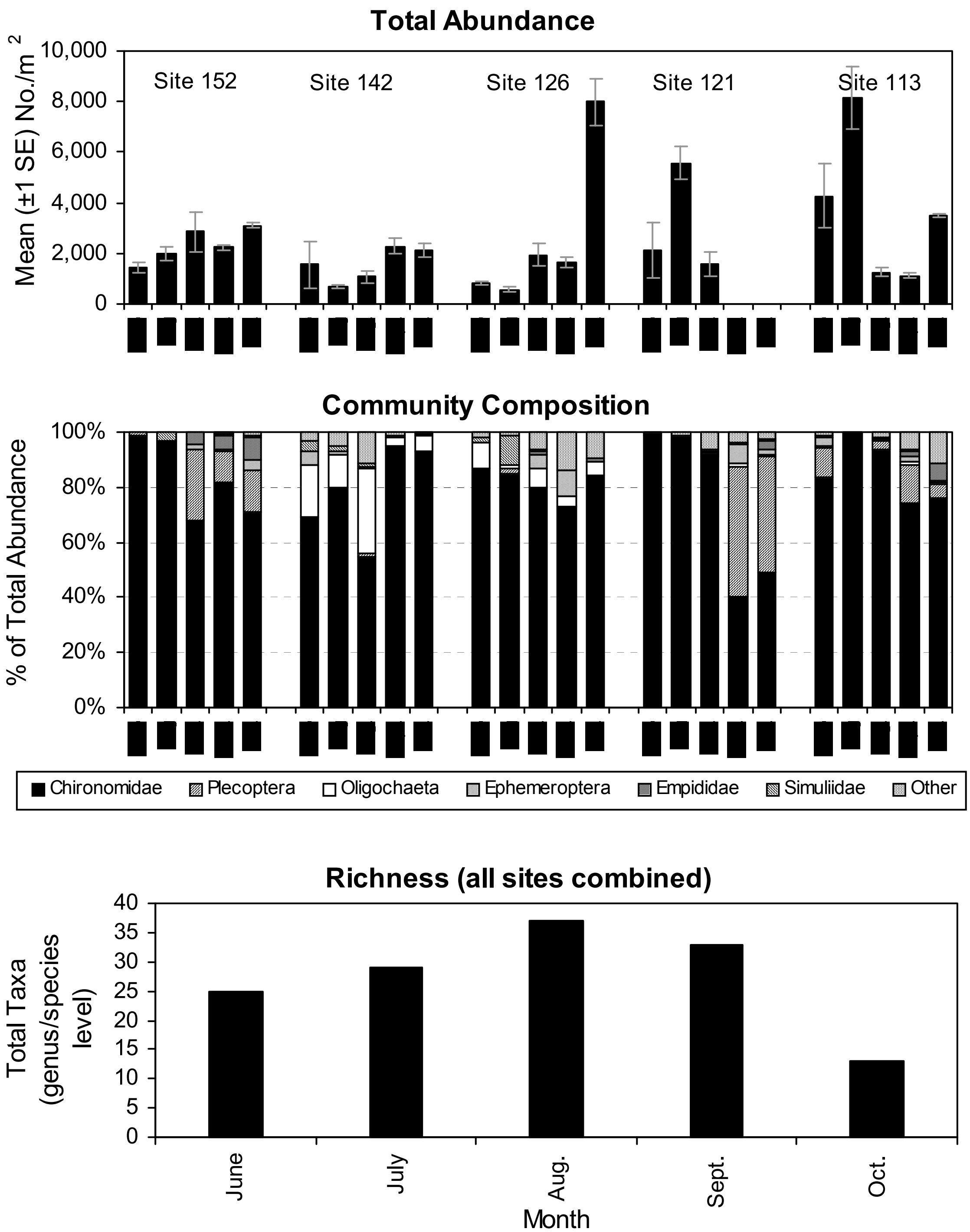
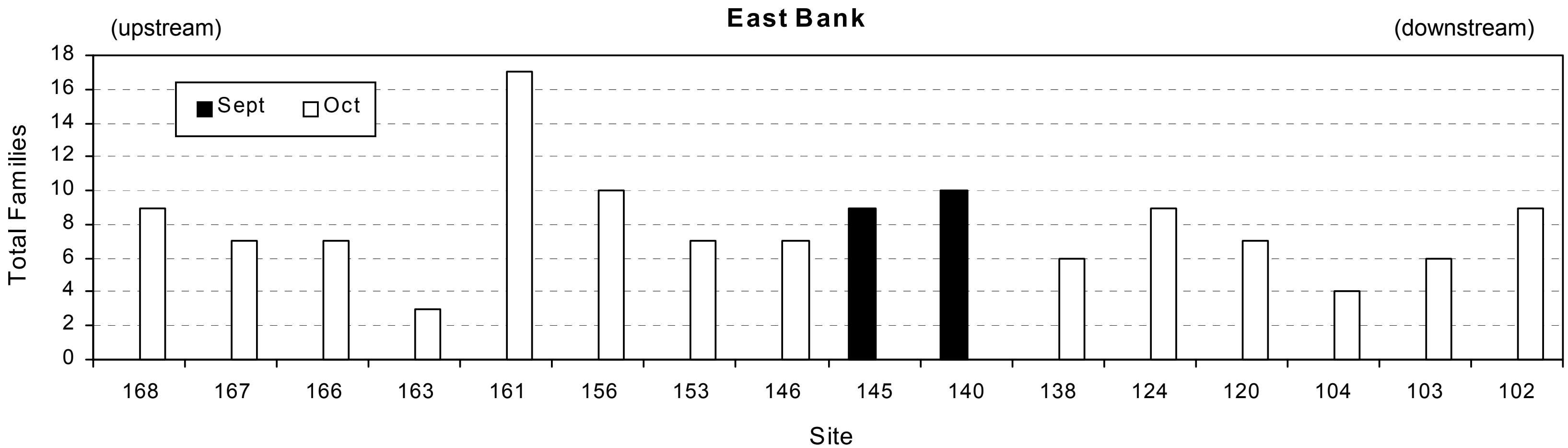
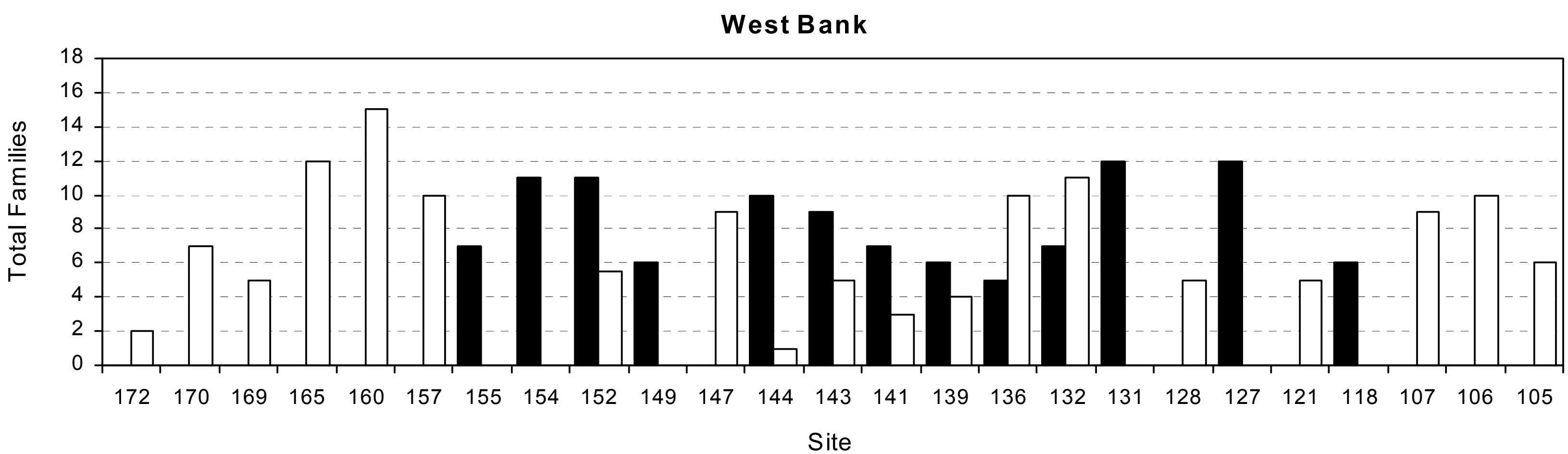


Figure 12 Taxonomic Richness (number of families) at Depositional Sites in the Athabasca River





depositional habitat (4 to 12 families) were lower than those in erosional habitat (10 to 20), as may be expected based on habitat differences. The spatial trend in the October data along the west bank suggests a potential reduction in richness below Suncor's Tar Island Dyke (TID) (at Site 144) with recovery within a 2.5 km distance downstream (at Site 136). However, the September data did not show a similar trend. Overall, there were no consistent effects on richness in the reach adjacent to Suncor, as also found for the abundance data.

Benthic communities were usually dominated by chironomids and occasionally by other groups (Plecoptera and Trichoptera) (Table 8). Oligochaete worm dominance was found at four sites adjacent to Suncor (143, 139, 136, 132), also suggesting the potential for community alteration in this area.

Table 8 Benthic Community Composition at Depositional Sites Along the Athabasca River

Site	Month	Year	Nema-toda (%)	Oligo-chaeta (%)	Epheme-roptera (%)	Plecop-tera (%)	Trichop-tera (%)	Chirono-midae (%)	Other (%)
East Bank									
168	Oct	1997	23.8	3.3	0.4	1.2	0.4	67.9	2.9
167	Oct	1997	2.2	4.1	0.7	0.0	0.0	91.1	1.9
166	Oct	1997	1.3	1.1	0.2	0.0	0.0	96.4	1.1
163	Oct	1995	0.0	14.3	28.6	0.0	0.0	57.1	0.0
161	Oct	1995	1.0	2.8	5.6	20.6	0.7	59.8	9.4
156	Oct	1995	0.2	0.4	0.9	0.4	0.0	86.7	11.4
153	Oct	1978	0.0	0.6	0.5	0.1	0.0	97.8	0.9
146	Oct	1995	0.0	0.0	11.5	25.0	0.0	46.2	17.3
145	Sept	1981	34.1	3.3	0.1	0.0	0.0	59.2	3.3
140	Sept	1981	42.8	1.8	0.2	0.1	0.1	52.6	2.4
138	Oct	1978	0.0	1.7	4.3	0.9	0.9	87.8	4.3
124	Oct	1995	0.0	0.0	26.7	30.0	16.7	16.7	10.0
120	Oct	1995	0.3	27.0	0.3	0.0	0.0	60.1	12.3
104	Oct	1997	1.7	33.1	0.0	0.0	0.0	62.8	2.5
103	Oct	1997	7.7	3.4	0.0	0.4	0.0	86.8	1.7
102	Oct	1997	10.4	2.6	0.8	0.2	0.0	84.2	1.9
West Bank									
172	Oct	1997	0.0	0.0	0.0	0.0	0.0	99.8	0.2
170	Oct	1997	1.7	1.7	0.0	3.6	0.0	90.2	2.8
169	Oct	1997	3.7	3.7	0.0	0.0	0.0	90.5	2.1
165	Oct	1995	0.8	7.9	1.6	22.8	0.8	55.1	11.0
160	Oct	1995	5.3	8.4	3.1	0.0	1.5	37.4	44.3
157	Oct	1978	0.0	0.5	1.9	3.5	0.3	92.1	1.6
155	Sept	1987	17.6	3.2	2.9	0.0	0.0	75.0	1.4
154	Sept	1981	0.2	10.9	0.1	0.0	0.4	84.6	3.8
152	Sept	1981	0.7	21.3	3.2	5.0	55.7	13.3	0.7
	Oct	1978	0.0	2.6	2.9	0.0	0.0	92.6	1.9
		1995	1.8	0.0	5.5	20.0	0.0	69.1	3.6
149	Sept	1987	11.0	6.5	2.5	0.0	0.0	79.6	0.4

Table 8 Benthic Community Composition at Depositional Sites Along the Athabasca River (continued)

Site	Month	Year	Nema-toda (%)	Oligo-chaeta (%)	Epheme-roptera (%)	Plecop-tera (%)	Trichop-tera (%)	Chirono-midae (%)	Other (%)
147	Oct	1995	0.0	2.1	19.1	63.8	8.5	4.3	2.1
144	Sept	1981	1.7	7.2	0.2	0.0	0.2	90.2	0.6
	Oct	1978	0.0	0.0	0.0	0.0	0.0	100.0	0.0
143	Sept	1981	1.4	27.1	0.0	0.0	0.2	69.2	2.1
	Oct	1978	0.0	85.1	6.6	2.5	0.0	5.0	0.8
141	Sept	1981	5.6	36.4	0.0	0.0	0.0	56.7	1.3
	Oct	1978	0.0	32.1	5.0	0.0	0.0	62.9	0.0
139	Sept	1981	0.9	0.0	2.6	0.9	0.0	71.1	24.6
	Oct	1978	0.0	87.5	3.1	0.0	0.0	8.3	1.0
136	Sept	1981	0.1	57.7	0.0	0.0	0.0	41.6	0.5
	Oct	1978	1.4	10.4	21.5	1.4	0.0	56.9	8.3
132	Sept	1981	0.1	17.1	0.0	0.0	0.0	81.4	1.4
	Oct	1978	0.0	50.0	1.3	0.8	0.2	44.9	2.8
131	Sept	1987	13.3	21.4	0.0	0.0	0.0	64.7	0.5
128	Oct	1995	0.0	18.3	0.0	4.0	0.0	70.8	6.9
127	Sept	1987	6.0	13.5	0.1	0.0	0.1	78.2	2.1
121	Oct	1995	0.0	2.5	5.0	37.5	0.0	52.5	2.5
118	Sept	1987	0.8	2.1	0.6	0.2	0.2	96.2	0.0
107	Oct	1997	8.3	16.7	0.0	5.6	2.8	27.8	38.9
106	Oct	1997	6.1	25.8	3.0	0.0	1.5	47.0	16.7
105	Oct	1997	2.9	29.4	0.0	2.9	0.0	53.0	11.8

Seasonal trends in benthic community characteristics were examined using results of Barton and Wallace (1980) and McCart et al. (1977). Total invertebrate abundance varied without trends at the six sites sampled monthly during 1975 by McCart et al. (1977) (Figure 10). The only consistent feature of the abundance data was the low numbers reported at all sites in July, which may have resulted from scouring caused by a "short-term flood" in late June and early July (McCart et al. 1977). Seasonal variation in total abundance was less pronounced at the sites sampled by Barton and Wallace (1980) in 1977 (Figure 11). This study also did not report consistent trends in abundance during the open-water season, but highlighted the importance of substrate composition and the variation in substrate characteristics in determining the abundance and composition of benthic communities in the lower Athabasca River.

Variation in richness (Figure 11), reported by Barton and Wallace (1980) as total taxa at all sites combined, was relatively small on substrates dominated by organic debris. Since data were combined for all sites in Figure 11, the month-to-month variation is lower than would be expected for individual sites.

The composition of depositional benthic communities was highly variable among months when examined at the coarse level of major taxonomic groups (Figures 10 and 11). Barton and Wallace (1980) related the variation in community composition through the open-water season to changes in bottom sediment characteristics caused by redistribution of fine sediments by changing current velocities and local flow patterns. They concluded that the lower Athabasca River represents a dynamic benthic environment, which results in a continuous and substantial variation in the abundance and composition of benthic communities.

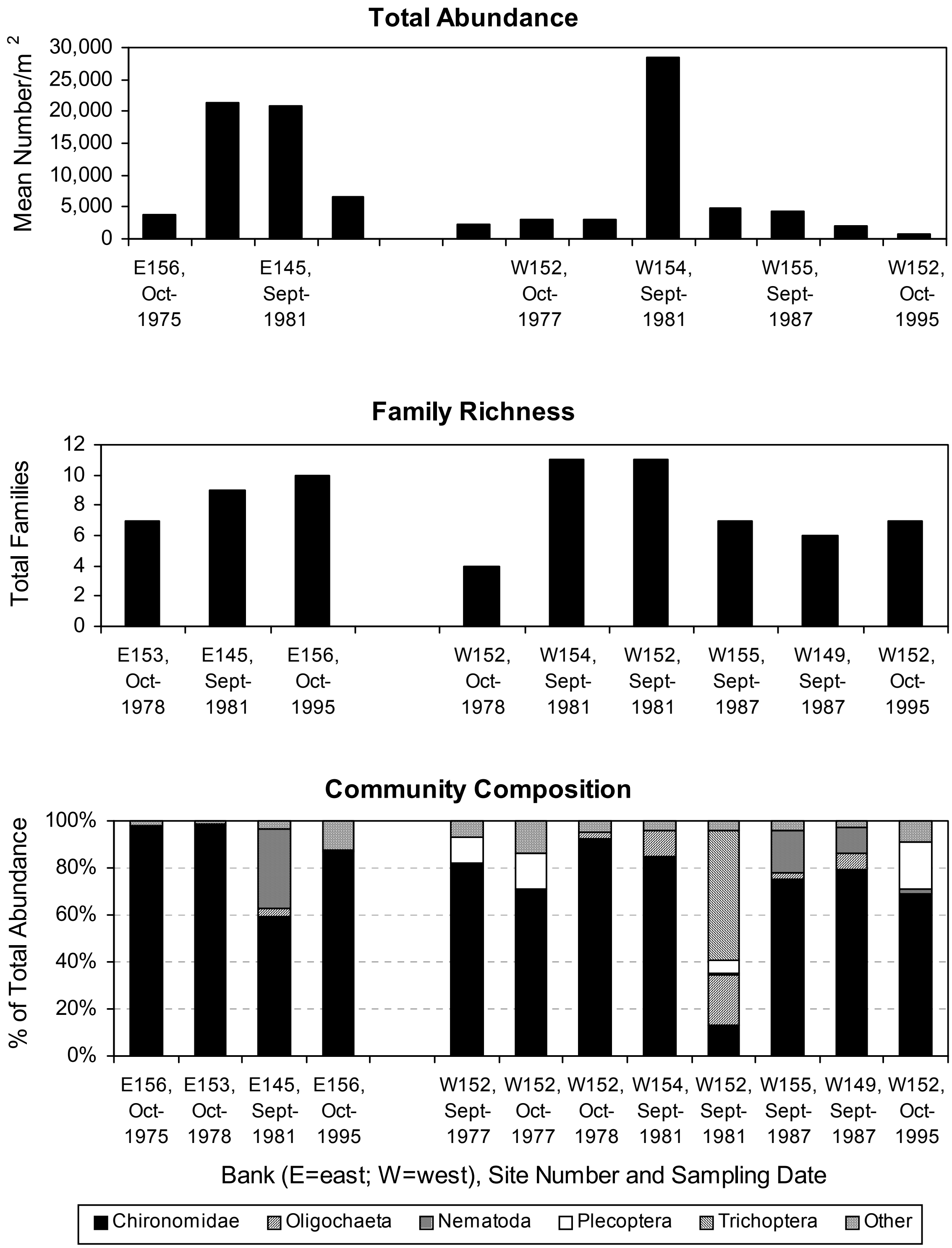
The approach used to summarize depositional data for describing year-to-year variation and long-term trends was outlined in the previous section (i.e., sites within 5 km reach; same season; three years minimum). Results for the two groups of sites that satisfied the selection criteria show high variation in total invertebrate abundance and moderate variation in richness. Community composition in the reach across from TID (Sites 145, 153, 156) was similar in three of the four years with data (Figure 13). Upstream of Suncor on the west bank (Sites 149, 152, 154, 155), communities were strongly dominated by chironomids at nearly all sites and in all years, except Site 152 in 1981, when caddisflies and oligochaetes were present in greater proportions than chironomids. Trends over time were not apparent in benthic community variables based on this preliminary evaluation.

3.2.2.3 Species List

In total, 306 taxa were reported from the Athabasca River, most at the genus and species level (Table III-1 in Appendix III). Standardizing the lowest taxonomic level to genus resulted in a total of 181 taxa in the entire data set (see summary at the end of the species list in Table III-1). For discussions of common taxa in this report, common taxa were operationally defined as those present in 25% or more site data sets based on the quantitative data.

The erosional data set included 130 taxa, based on genus as the lowest taxonomic level (Table III-1; see summary at end of table). Common taxa included roundworms, oligochaetes (as a group), ostracods, the mayflies *Baetis*, *Cloeon*, *Caenis*, *Ephemerella*, *Heptagenia*, *Metretopus* and *Tricorythodes*, the dragonfly *Ophiogomphus*, perlodid stoneflies (as a group), the caddisfly *Hydropsyche*, Ceratopogonidae (as a group), a number of chironomid genera, Empididae (as a group) and Simuliidae (as a group). With the exception of the mayflies *Cloeon* and *Metretopus*, all of these taxa are common in erosional reaches of Alberta rivers. There were no conspicuous differences in species lists or frequencies of occurrence between the east and west banks. The largest number of taxa was reported within the Ephemeroptera (26) and Chironomidae (30).

Figure 13 Year-to-year Variation in Benthic Community Characteristics within Short (<5 km) Depositional Reaches in the Athabasca River



The depositional data set was less diverse, with a total of 91 taxa reported by the quantitative studies (Table III-1). This may partially reflect the fewer depositional site data sets (102) relative to erosional habitat (187). The common depositional taxa included roundworms, oligochaetes (as a group), unidentified dipterans and chironomids, and the chironomid genus *Polypedilum*. The number of taxa and frequencies within the EPT (Ephemeroptera, Plecoptera, Trichoptera) insect orders were considerably lower than in the erosional habitat. The chironomid fauna was richer in depositional habitat (37 taxa) relative to erosional habitat (30 taxa), despite the lower depositional sampling intensity. There were conspicuous differences between banks in the frequency of *Polypedilum* occurrence and in frequencies for a number of less common invertebrates (e.g., Tubificidae, *Ametropus*, *Gomphus* and a number of dipterans). However, because the two banks were sampled with unequal effort, the observed differences may be artifacts.

3.3 MACKAY RIVER

3.3.1 Studies Reviewed

Benthic communities of the MacKay River were sampled five times to the end of 2001 (Table 9). The available data span 25 years, with large gaps between the first three studies. The objectives of the first two surveys were to collect baseline data (McCart et al. 1978) and to evaluate what changes, if any, had occurred since the Syncrude Mildred Lake facility began operating in 1978 (RL&L and AA Aquatic Research 1985). The three recent surveys of the lower reach of this river (Golder 1999a, 2001, 2002a) were carried out as part of RAMP and continued annual monitoring is planned under RAMP until 2004. After 2004, monitoring frequency may be adjusted based on evaluation of collected information as well as in consideration of development schedules of nearby oil sands projects.

The first two surveys sampled on a monthly or seasonal basis and the three recent surveys sampled during the fall (Table 9). All sampling was done in erosional habitat, which dominates the lower MacKay River. Accordingly, samples from natural substrates were collected using a Surber sampler or a Neill cylinder. McCart et al. (1978) also used rock-filled basket-type AS. The abundance data collected by the last four surveys are comparable among studies because sampling and sample processing methods were similar. The first survey (McCart et al. 1978) used a coarse sampling mesh (600 µm) that would be expected to result in lower abundance of smaller-sized taxa such as chironomids, oligochaete worms and early instar mayflies.

Table 9 Study Details and Sampling Site Characteristics in the MacKay River

Reference	Site Locations[a]	Sampling Method and Replication (sieve mesh size)	Habitat Type and Site Characteristics	Month/Year Sampled
McCart et al. (1978)	3 sites; 2 km (Site 4), 32 km (Site 7) and 60 km (Site 9) from mouth	Surber and AS (basket) 3 replicates (600 µm)	erosional: width: 9-13 m; mean depth: 0.4-0.8 m; substrate: gravel and smaller particles at mouth (2 km), cobble/boulder upstream	May to Sept 1977 (monthly)
RL&L and AA Aquatic Research (1985)	4 sites; 0.7 km (Site 3), 14 km (Site 5), 29 km (Site 6) and 40 km (Site 8) from mouth	Neill 3 replicates (250 µm)	erosional: width: 27-45 m; mean depth: 0.7 m; current vel.: 0.3-0.6 m/s; substrate: sand/gravel/ cobble, bitumen at MR-B3	June, July, Sept 1984
RAMP Golder (1999a)	3 sites near mouth (Sites 1, 2, 3)	Neill 5 replicates (250 µm)	erosional: width: 15-60 m; mean depth: 0.2-0.3 m; current vel.: 0.2-0.3 m/s; substrate: sand/gravel/cobble	Sept 1998
RAMP Golder (2001)	5 km reach beginning at mouth	Neill 15 samples (250 µm)	erosional: width: 30-42 m; depth: 0.3-0.4 m; current vel.: 0.5-1.0 m/s; substrate: cobble/gravel	Oct 2000
RAMP Golder (2002a)	5 km reach beginning at mouth	Neill 15 samples (250 µm)	erosional: width: 21-36 m; depth: 0.3-0.5 m; current vel.: 0.3-1.4 m/s; substrate: cobble/gravel	Sept 2001

[a] Site locations are shown in Figure 1.

The number of sites sampled by each study was relatively few, ranging from three to four from 1977 to 1998 (Table 9). The 2000 and 2001 RAMP surveys used a reach approach, by distributing sampling effort along the first 5 km of the river from its mouth. Spacing of sites has also varied among studies. As a result, only the lowermost area near the mouth was sampled by all five studies.

3.3.2 Summary of Historical Data

Although all sites sampled in the MacKay River were erosional, specific habitat features varied moderately among sites and studies. The first two studies sampled in deeper water (0.4 to 0.8 m) than the RAMP surveys (0.2 to 0.5 m) (Table 9). Current velocity ranged between 0.2 and 1.4 m/s overall, though the ranges within individual studies were usually lower. Substrate composition was similar during all studies. River discharge was unusually low during the 1998 RAMP survey.

Total invertebrate abundance was low and variable (<10,000 organisms/m^2) during all fall surveys except in 1998 (Table 10), which may reflect the unusually low flows during late summer and fall 1998. The abundances reported for fall 1977 are not directly comparable to those reported by the other studies due to the coarse mesh sampling net used.

Table 10 Summary of Historical Benthic Invertebrate Data for the MacKay River (September/October data)

Reference [year sampled]	Site (distance from mouth)	Mean Total Abundance (no./m²)	Richness (total taxa)	Community Composition (%)[a]						
				M (%)	O (%)	E (%)	P (%)	T (%)	C (%)	Ot (%)
McCart et al. (1978) [1977] *(coarse mesh – 600 µm)*	Site 4 (2 km)	858	23	0	7	71	7	5	10	1
	Site 7 (32 km)	1,457	20	0	2	49	13	4	31	1
	Site 9 (60 km)	1,887	31	0	0	25	4	59	7	4
RL&L and AA Aquatic Research (1985) [1984]	Site 3 (0.7 km)	2,860	23[b]	<1	28	17	4	<1	35	15
	Site 5 (14 km)	142	16[b]	0	38	49	10	0	3	0
	Site 6 (29 km)	542	20[b]	1	53	27	1	0	8	9
	Site 8 (40 km)	7,115	23[b]	<1	20	30	<1	0	43	6
RAMP Golder (1999a) [1998]	Site 1 (250 m)	6838	46	<1	10	23	<1	<1	61	4
	Site 2 (500 m)	11,482	47	<1	15	18	2	<1	57	8
	Site 3 (1 km)	24,675	46	0	4	30	3	<1	56	6
RAMP Golder (2001) [2000]	mouth to 5 km upstream	6,817	56	<1	30	21	5	<1	34	9
RAMP Golder (2002a) [2001]	mouth to 5 km upstream	3,825	55	<1	13	18	5	3	40	22

[a] M = mollusks; O = Oligochaeta; E = Ephemeroptera; P = Plecoptera; T = Trichoptera; C = Chironomidae; Ot = Other.
[b] Oligochaeta and Chironomidae were not identified to lower taxonomic levels.

Richness varied between 20 and 56 taxa based on the studies with similar taxonomic resolution (Table 10). The increasing trend in total richness over time is likely an artifact, resulting from the larger number of samples collected in 1998 (5) and subsequent years (15) relative to previous years (3), and the greater spatial coverage in 2000 and 2001 relative to 1998.

The composition of benthic communities at the level of major taxonomic group showed little consistency among sites and studies, with the exception of moderate to large percentages of mayflies in all years (Table 10). The low percentages of chironomids and oligochaetes in 1977 relative to other years is a likely result of the larger mesh size used in that year. Percentages of oligochaetes and chironomids were highly variable among studies. Mollusks, stoneflies, caddisflies and "other" groups were minor components of the communities with one conspicuous exception in 1977, when caddisflies were the numerically dominant group.

Seasonal trends in total abundance and richness in the MacKay River resembled those observed at erosional sites in the Athabasca River. Based on results of McCart et al. (1978), both variables increased through the open-water season at all sites, with maximum values in August or September (Figure 14). The increases in abundance were in some cases close to an order of magnitude, whereas the increase in richness was at most four-fold. There were some seasonal trends in community composition as well, but they were less clear. The percentage of oligochaetes declined though the open-water season; mayfly relative abundance peaked in July or August; and the percentage of caddisflies increased substantially at one site in August and September relative to the previous months.

Year-to-year variation and trends over time were examined in the reach near the mouth, which was sampled by all five studies. The 2000 and 2001 data represent the lower 5 km reach of the river, whereas other studies sampled individual sites. Three closely-spaced sites were sampled near the mouth in 1998. Total abundance was in the low to moderate range in absolute terms and varied without a distinct trend over time (Figures 15 and 16). Total invertebrate abundance was lowest in 1977, but was not comparable to results of other studies because of mesh size differences. As noted above, the higher abundances in 1998 may have been the result of unusually low river discharge. Variation in total richness at the family level has been lower among years. The apparent increasing trend in richness over time is an artifact of the varying spatial resolution of the studies summarized (i.e., greater spatial coverage in 2000 and 2001 resulted in documenting more taxa). The variation in abundances of insects in the EPT orders and chironomid midges resembled the pattern in total abundance. None of the variables showed potential long-term trends.

In total, 137 taxa were reported from the MacKay River (Table III-2 in Appendix III). Standardizing the lowest taxonomic level to genus yielded a total of 108 taxa. Common taxa included roundworms, oligochaetes (as a group), Sphaeriidae (as a group), Hydracarina, the mayflies *Baetis*, *Pseudocloeon*, *Caenis*, *Heptagenia*, *Rhithrogena* and *Tricorythodes*, the dragonfly *Ophiogomphus*, the stonefly *Pteronarcys*, the caddisfly *Hydropsyche*, Ceratopogonidae, a small number of chironomid genera and black flies (Simuliidae; as a group). All of these taxa are common in erosional reaches of Alberta rivers. The highest number of taxa within a major group was found in the Chironomidae (44). The total number of taxa found in the MacKay River (108) was comparable to that reported from the Steepbank River (100), but was considerably lower than the number reported from the Muskeg River (194, based on quantitative studies). The higher number of taxa in the Muskeg River may in part reflect the greater historical sampling effort in this river. The distribution of the total number of taxa in the major groups was similar in the MacKay and Steepbank rivers.

Figure 14 Seasonal Variation in Benthic Community Characteristics in the MacKay River in 1977 (data from McCart et al. 1978)

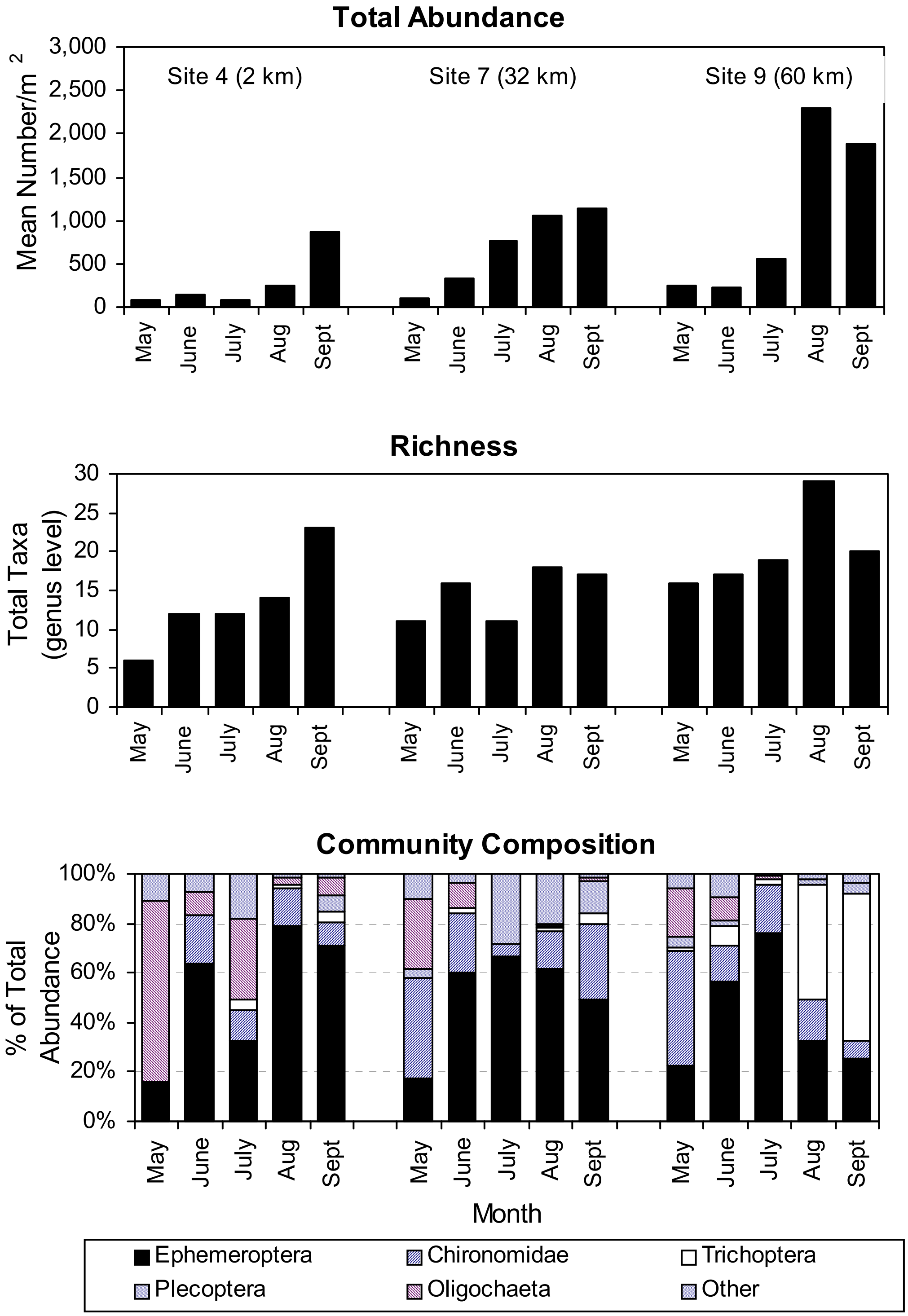


Figure 15 Year-to-year Variation in Total Invertebrate Abundance, Richness and Oligochaeta Abundance in the Lower Reach of the MacKay River

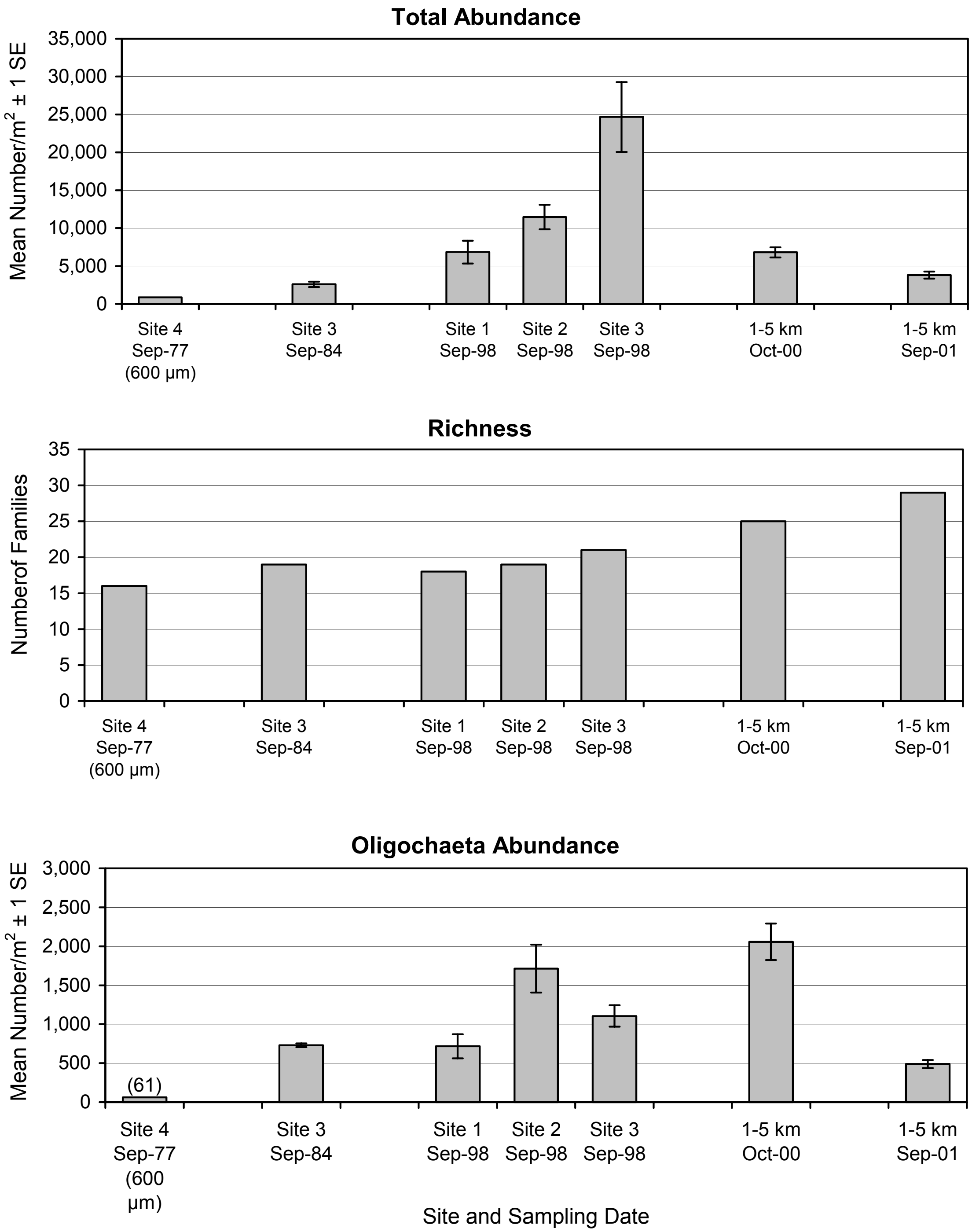
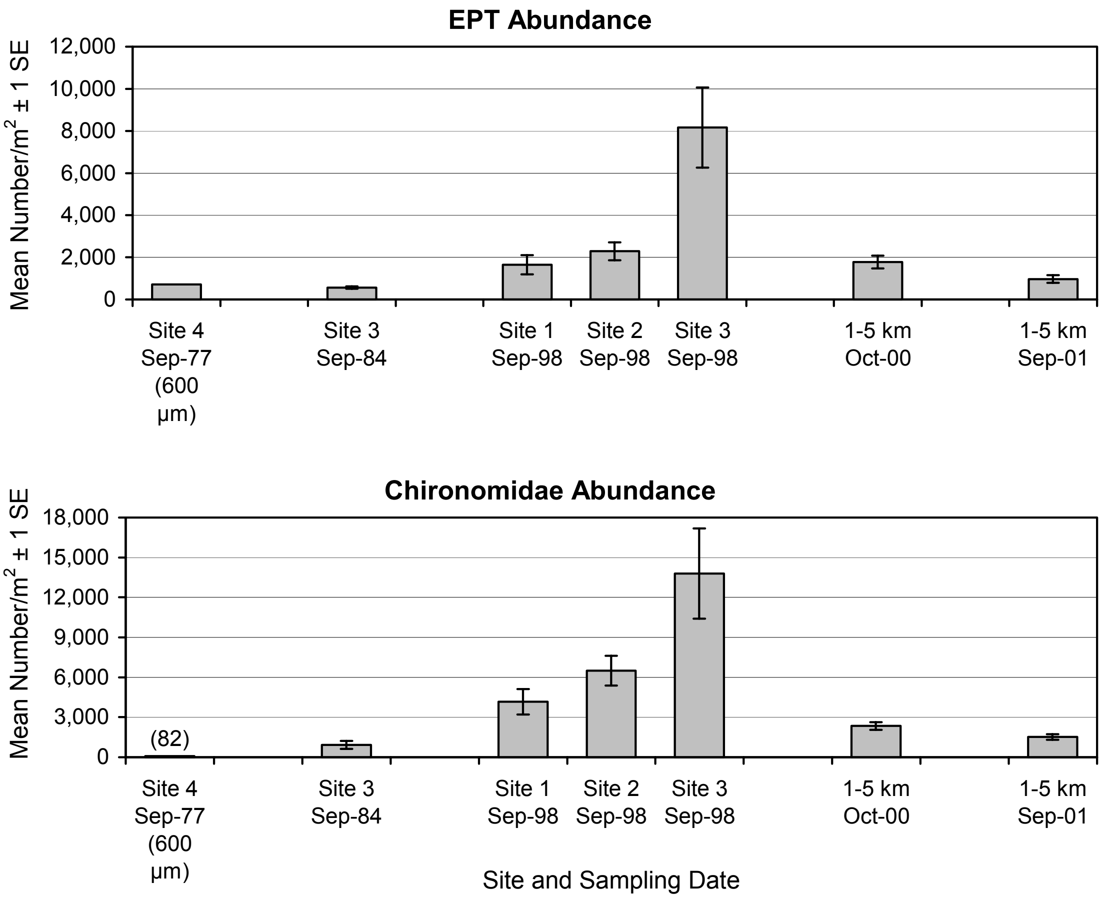


Figure 16 Year-to-year Variation in EPT Abundance and Chironomidae Abundance in the Lower Reach of the MacKay River



3.4 MUSKEG RIVER

3.4.1 Studies Reviewed

Of all the major tributaries of the Athabasca River in the Oil Sands Region, the Muskeg River has been sampled the most intensively. Ten surveys were conducted over 22 years, beginning in 1980 (Table 11). All studies sampled in the fall, with the exception of Komex (1997). The first six surveys collected baseline data for a variety of planned oil sands developments. Three surveys (Golder 1999a, 2001, 2002a) were done under RAMP as part of routine monitoring. The remaining recent survey (Golder 2002b) collected baseline data for the Syncrude Aurora South Mine development area. Some activities related to oil sands extraction were already in progress in the Muskeg River basin at the time of the recent surveys (e.g., muskeg dewatering for the Syncrude Aurora Mine and mine camp construction). Continued annual monitoring of the lowest reaches is planned under RAMP until 2004, after which monitoring frequency may be adjusted to suit development schedules of nearby oil sands developments. Tributaries of the Muskeg River have been sampled by a number of surveys as well; results of those studies are summarized in Section 3.6.

Table 11 Study Details and Sampling Site Characteristics in the Muskeg River

Reference	Site Locations[(a)]	Sampling Method and Replication (sieve mesh size)	Habitat Type and Site Characteristics	Month/Year Sampled
Barton and Wallace (1980)	4 sites, from mouth to upper reaches (Sites 10, 12, 20, 21)	Kicknet one 15-min. sample (500 μm)	erosional (Sites 10 and 12); width: 20 m; mean depth: 0.4 m; current vel.: 0.6 m/s; substrate: cobble/gravel depositional (Sites 20 and 21); width: 5-8 m; mean depth: 0.8 m; current vel.: 0.03-0.05 m/s; substrate: fines/organic	July, Oct 1976 May, July 1977
Crowther and Lade (1980)	3 sites; 5 km (Site 11), 15 km (Site 12) and 40 km (Site 15) upstream from mouth	Neill 10 replicates (250 μm)	erosional; width: 8-24 m; mean depth: 0.2-0.9 m; substrate: cobble/gravel	July, Aug, Sept 1979
Beak (1986)	5 sites, from 35 to 65 km upstream of mouth (Sites 14, 15, 16, 18, 19)	Ekman 3 replicates (180 μm)	depositional; mean depth: 0.6-1.5 m; current vel.: 0-0.1 m/s; substrate: sand/gravel/ organic	Oct 1985
RL&L (1989)	6 sites, from 30 to 65 km upstream of mouth (Sites 13, 14, 15, 16, 18, 19)	Ekman 3 replicates (180 μm)	depositional; width: 7-14 m; mean depth: 0.4-0.7 m; current vel.: 0.1-0.7 m/s; substrate: fines/organic	May, Aug, Oct 1988
Golder (1996a)	3 sites; at mouth (Site 10) and 30 km (Site 13) and 55 km (Site 17) upstream from mouth	Neill (Site 10) Ekman (Sites 13 and 17) 3 replicates (250 μm)	erosional (Site 10); mean depth: 0.5 m; current vel.: 0.9 m/s; substrate: cobble/gravel depositional (Sites 13 and 17); mean depth: 0.7->2 m; current vel.: 0-0.03 m/s; substrate: fines/organic	Sept-Oct 1995
Komex (1997)	3 sites just downstream of headwaters	Ekman 5 replicates (mesh size n/a[(b)])	depositional mean depth: >1 m; current vel.: n/a; substrate: organic/sand gravel/cobble	May and August 1997
RAMP Golder (1999a)	3 sites near mouth (10a, 10b, 10c)	Neill 5 replicates (250 μm)	erosional; mean depth: 0.2-0.3 m; current vel.: 0.3-0.5 m/s; substrate: cobble/gravel	Sept 1998

Table 11 Study Details and Sampling Site Characteristics in the Muskeg River (continued)

Reference	Site Locations[a]	Sampling Method and Replication (sieve mesh size)	Habitat Type and Site Characteristics	Month/Year Sampled
RAMP Golder (2001)	5 km reach beginning at mouth and 3 km reach beginning ~15 km upstream from mouth	Neill (near mouth) Ekman (15 km from mouth) 15 samples/ reach (250 µm)	erosional (near mouth); width: 17-25 m; depth: 0.3-0.4 m; current vel.: 0.5-1.0 m/s; substrate: cobble/gravel depositional (10 km from mouth); width: 14-28 m; depth: 0.3-2 m; current vel.: 0.1-0.5 m/s; substrate: sand/silt/clay	Oct 2000
RAMP Golder (2002a)	5 km reach beginning at mouth and 3 km reach beginning ~15 km upstream from mouth	Neill (near mouth) Ekman (15 km from mouth) 15 samples/ reach (250 µm)	erosional (near mouth); width: 11-23 m; depth: 0.3-0.6 m; current vel.: 0.2-1.1 m/s; substrate: cobble/gravel depositional (10 km from mouth); width: 6-14 m; depth: 0.3-1.5 m; current vel.: 0-0.04 m/s; substrate: sand	Sept 2001
Golder (2002b)	2 sites, at 37 km and 57 m from mouth	Ekman 5 replicates (250 µm)	depositional; mean depth: 0.5-1.1 m; current vel.: 0 m/s; substrate: sand/silt	Sept/Oct 2001

[a] Site locations are shown in Figure 1.
[b] n/a = not available.

Habitat distribution in the Muskeg River is unique in the Oil Sands Region because of the abrupt transition from erosional to predominantly depositional habitat about 12 km from the mouth (there are occasional riffles in the middle to upper reaches). Most studies sampled the middle to upper depositional reaches of the river.

The first investigators (Barton and Wallace 1980) used a 500 µm mesh kicknet to collect semi-quantitative samples from four widely-spaced sites (Table 11). Subsequent surveys were done using quantitative sampling techniques. The Neill cylinder was used in erosional habitat and the Ekman grab was used in depositional areas. Two of the studies used a 180 µm mesh sampling net and sieves, while all others used 250 µm mesh for sampling and sample processing (Table 11). Mesh size was not reported by one study (Komex 1997). The variation in mesh size may be reflected to a minor degree in abundance estimates and community composition reported by the various studies.

Thirteen sites were sampled by quantitative methods, from the mouth to just below headwater streams, upstream of Wapasu Creek (Figure 1). The RAMP surveys used a reach approach, by distributing sampling effort within two reaches to allow characterization of both major habitat types. These were: (1) the first 5 km of the river, beginning at its mouth (erosional); and (2) the reach between two small tributaries, from about 15 to 18 km from the mouth (Figure 1). Combining all studies, spacing of sites was variable, with larger gaps below Jackpine Creek than in the upper reaches. The lowermost reach near the mouth was sampled a number of times using consistent methods.

3.4.2 Summary of Historical Data

Erosional sites sampled in the lower Muskeg River were generally shallow (<0.6 m), with moderate currents (0.5 to 1 m/s) and cobble/gravel substrates (Table 11). Slower current velocities were measured during the 1998 RAMP survey, which was done during a period of very low river discharge. Habitat variation was greater among depositional sites. Depth varied from 0.3 to 2 m; current velocity ranged from zero to 0.7 m/s; and substrates comprised various combinations of sand, silt, clay and organic detritus (Table 11).

The semi-quantitative study by Barton and Wallace (1980) provided the most detailed information regarding the taxonomic composition of benthic communities in the Muskeg River, but because the data for all sampling events at a site were pooled, the information on seasonal variation is not available. This study documented up to 166 taxa from single sampling sites (Table 12; many at the species level), which is the largest number of taxa reported from a site by any single study in the Oil Sands Region. The highest richness was found in erosional habitat at the mouth (Table 12). The two depositional sites sampled by Barton and Wallace (1980) were similar in terms of richness. Chironomids, mayflies and "other" taxa dominated the erosional Site 10; chironomids, oligochaetes and "other" taxa dominated the depositional sites.

Total invertebrate abundance during the fall, based on the quantitative surveys, was low to moderate (1,000 to 22,000 organisms/m^2) in erosional habitat and highly variable (2,000 to 62,000 organisms/m^2) in depositional habitat (Table 12). RL&L (1989) found a progressive increase in total abundance at depositional sites through the middle and upper reaches (Table 12).

Richness was higher and less variable at erosional sites than in depositional habitat, which may partly reflect the lower number of replicates (typically 3) collected during depositional surveys relative to erosional surveys (5 or greater). The RAMP surveys of both habitats sampled with equal effort in both habitats and found one to nine more taxa in erosional habitat. Pooling chironomids at the family level (i.e., the richness values in parentheses in Table 12) to standardize for the variable taxonomic detail for this group showed that on average, there were twice as many non-chironomid taxa in erosional habitat than in depositional habitat before the RAMP surveys. The two RAMP surveys found only slightly more non-chironomid taxa in erosional habitat.

Table 12 Summary of Historical Benthic Invertebrate Data for the Muskeg River (September/October data, except where noted otherwise)

Reference [year sampled]	Site (distance from mouth)	Mean Total Abundance (no./m^2)	Richness (total taxa)[a]	Community Composition[b]						
				M (%)	O (%)	E (%)	P (%)	T (%)	C (%)	Ot (%)
All Habitats										
Barton and Wallace (1980) (kicknet survey) [1976 to 1977] *(data were combined for all samples collected over a 1-year period)*	Site 10 (mouth)	-[c]	166	5	4	12	4	7	58	10
	Site 20 (68 km)	-	81	6	11	<1	0	0	55	27
	Site 21 (82 km)	-	78	3	27	1	0	2	31	36
Erosional Reach (mouth to 12 km upstream and isolated reaches upstream)										
Crowther and Lade (1981) [1979]	Site 11 (5 km)	8,952	43 (40)	1	<1	7	4	27	51	9
	Site 12 (15 km)	7,493	46 (43)	5	2	12	9	25	11	35
Golder (1996a) [1995]	Site 10 (mouth)	1,284	34 (29)	<1	42	11	6	2	9	30
Golder (1999a) [1998]	Site 10a (100 m)	13,149	59 (41)	3	18	13	2	1	39	24
	Site 10b (200 m)	21,844	58 (38)	12	9	12	3	<1	28	34
	Site 10c (400 m)	17,200	57 (36)	12	5	12	6	3	32	30
Golder (2001) [2000]	mouth to 5 km upstream	10,180	77 (45)	1	2	50	6	<1	31	10
Golder (2002a) [2001]	mouth to 5 km upstream	5,026	73 (49)	3	7	28	5	9	23	25
Depositional Reach (>12 km from mouth)										
Beak (1986) [1985]	Site 14 (35 km)	32,838	32 (32)	0	3	6	<1	<1	88	2
	Site 15 (38 km)	30,415	42 (21)	<1	2	1	0	<1	93	3
	Site 16 (43 km)	41,524	31 (15)	<1	5	<1	0	<1	93	2
	Site 18 (63 km)	15,638	22 (8)	3	15	<1	0	0	74	8
	Site 19 (65 km)	37,912	31 (14)	6	38	3	0	0	49	4
RL&L (1989) [1988]	Site 13 (30 km)	2,021	18 (14)	18	18	<1	1	0	54	8
	Site 14 (35 km)	3,039	21 (18)	6	15	3	5	15	12	44
	Site 15 (38 km)	9,976	30 (25)	2	10	<1	0	<1	67	21
	Site 16 (43 km)	5,332	20 (15)	13	16	4	<1	0	61	5
	Site 18 (63 km)	15,996	15 (12)	29	1	<1	0	0	67	3
	Site 19 (65 km)	17,687	23 (18)	14	3	5	0	<1	74	4
Golder (1996a) [1995]	Site 13 (30 km)	17,438	34 (28)	3	14	<1	0	1	63	19
	Site 17 (54 km)	5,081	13 (9)	3	19	0	0	0	73	5
Golder (2001) [2000]	15 to 18 km from mouth	58,297	68 (42)	5	13	<1	<1	<1	76	6
Golder (2002a) [2001]	15 to 18 km from mouth	62,098	72 (41)	4	2	<1	<1	<1	86	6
Golder (2002b) [2001]	Site 206 (37 km)	8,600	33 (21)	15	3	<1	0	0	31	51
	Site 204 (57 km)	15,729	45 (23)	7	3	8	0	<1	68	15

[a] Numbers in parentheses show richness with chironomids at the family level.
[b] M = mollusks; O = Oligochaeta; E = Ephemeroptera; P = Plecoptera; T = Trichoptera; C = Chironomidae; Ot = Other.
[c] - = not applicable; qualitative data only; results were not reported for Site 12.

Taxonomic composition of erosional communities was highly variable among sites and studies, based on fall data (Table 12). Percentages of mayflies and chironomids varied over the same range (about 10 to 50% of total abundance), but chironomids were usually more numerous. Relative abundances of most other major invertebrate groups ranged from nearly absent to between 10 and 40%. Stoneflies were the exception, occurring at low percentages at all sites and all years. Depositional communities were usually dominated by chironomids (Table 12) although mollusks and oligochaetes were also common.

Variation among months in late summer to early fall in total invertebrate abundance was relatively low in the erosional reach (Sites 11 and 12 in Figure 17) (Crowther and Lade 1981). Differences in abundance between seasons tended to increase through the middle to upstream reaches in depositional habitat (Figure 18) (RL&L 1989). As well, maximum abundance typically occurred in the fall. This trend was also observed in erosional habitat in the Athabasca and MacKay rivers. Richness was nearly constant from July to September at the erosional sites (Figure 17). Variation in richness among seasons at depositional sites was moderate (up to 5-fold), without an upstream-downstream trend (Figure 18). Composition of erosional communities remained similar from July to August at the two sites with available data (Sites 11 and 12; Figure 17). Depositional community composition varied relatively little among seasons (Figure 18) compared to other rivers.

Year-to-year variation and trends over time were examined in the reach near the mouth, which was sampled in the same season (fall) by all five studies. The 2000 and 2001 data represent the lower 6 km reach of the river, whereas other studies sampled individual sites. Three closely-spaced sites were sampled near the mouth in 1998. Year-to-year variation was considerable in total invertebrate abundance at the mouth of the river (with a ten-fold range) based on fall samples (Figure 19). Richness at the family level was similar in all years, with a slight increasing trend due to differences in sampling design among studies (Figure 19). Abundances of oligochaete worms, EPT taxa and chironomids varied among years without apparent trends (Figures 19 and 20).

In total, 265 taxa were reported from the Muskeg River by quantitative studies and 280 taxa were found by Barton and Wallace (1980) (Table III-2 in Appendix III). The number of taxa reported by Barton and Wallace (1980) may be an overestimate for the mainstem, because it is unclear whether it includes all streams sampled during their kicknet survey in the Muskeg River basin (i.e., it may include Muskeg Creek and Wesukemina Creek). Standardizing the lowest taxonomic level to genus yielded a total of 194 taxa (quantitative studies) and 213 taxa (Barton and Wallace 1980).

Figure 17 **Seasonal Variation in Benthic Community Characteristics at Erosional Sites in the Muskeg River in 1979 (data from Crowther and Lade 1980)**

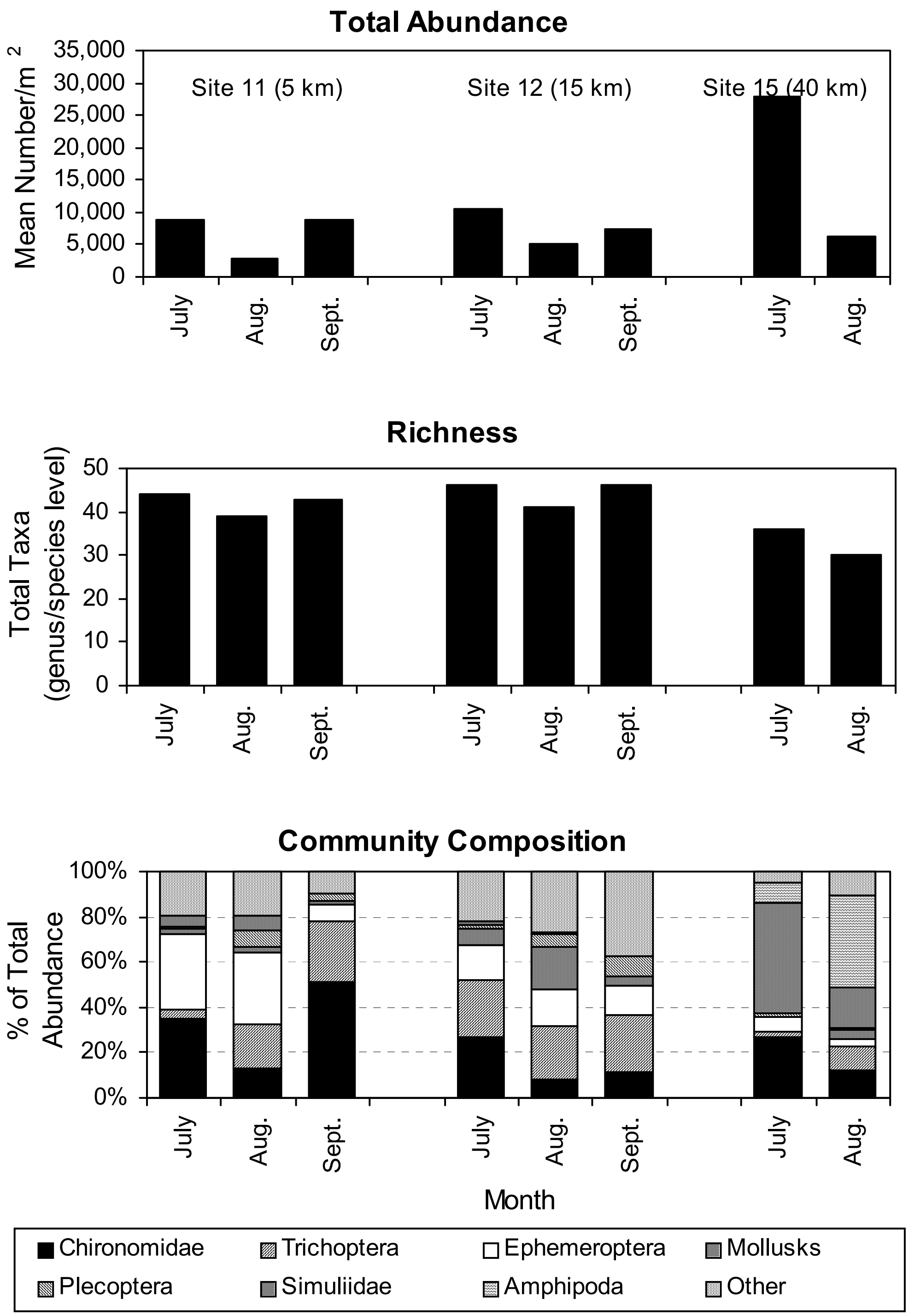


Figure 18 Seasonal Variation in Benthic Community Characteristics at Depositional Sites in the Muskeg River in 1988 (data from RL&L 1989)

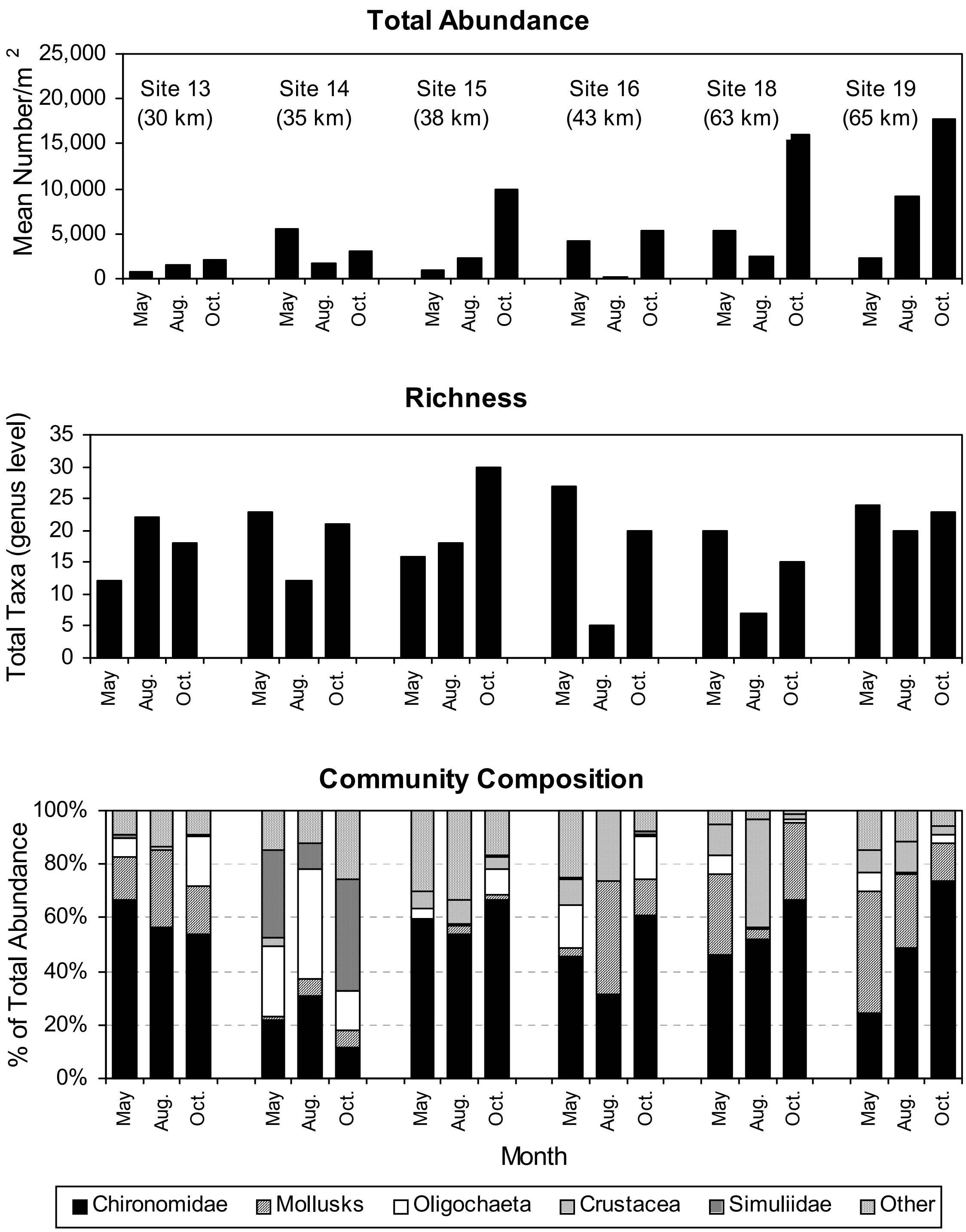


Figure 19 Year-to-year Variation in Total Invertebrate Abundance, Richness and Oligochaeta Abundance at the Mouth of the Muskeg River

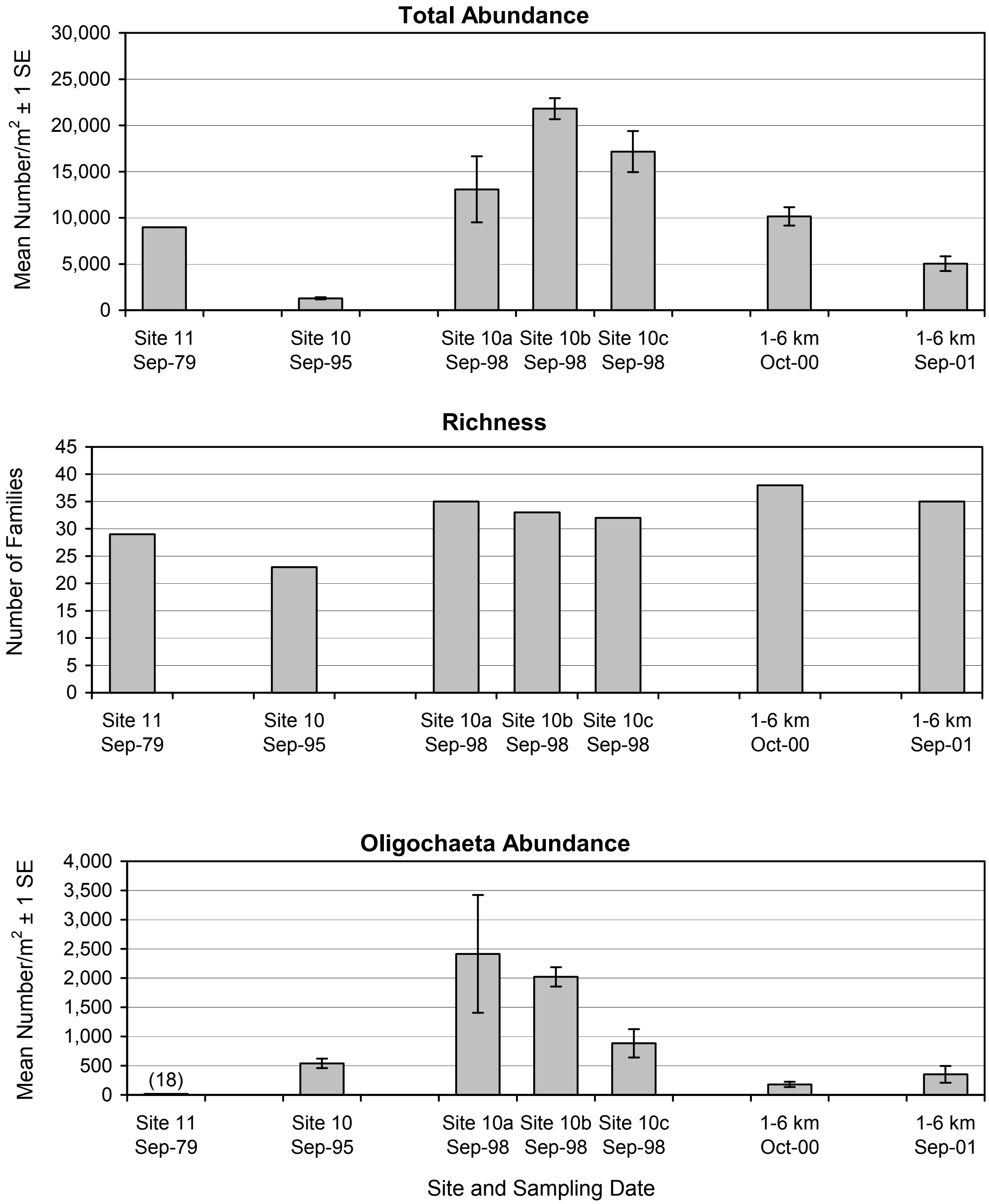
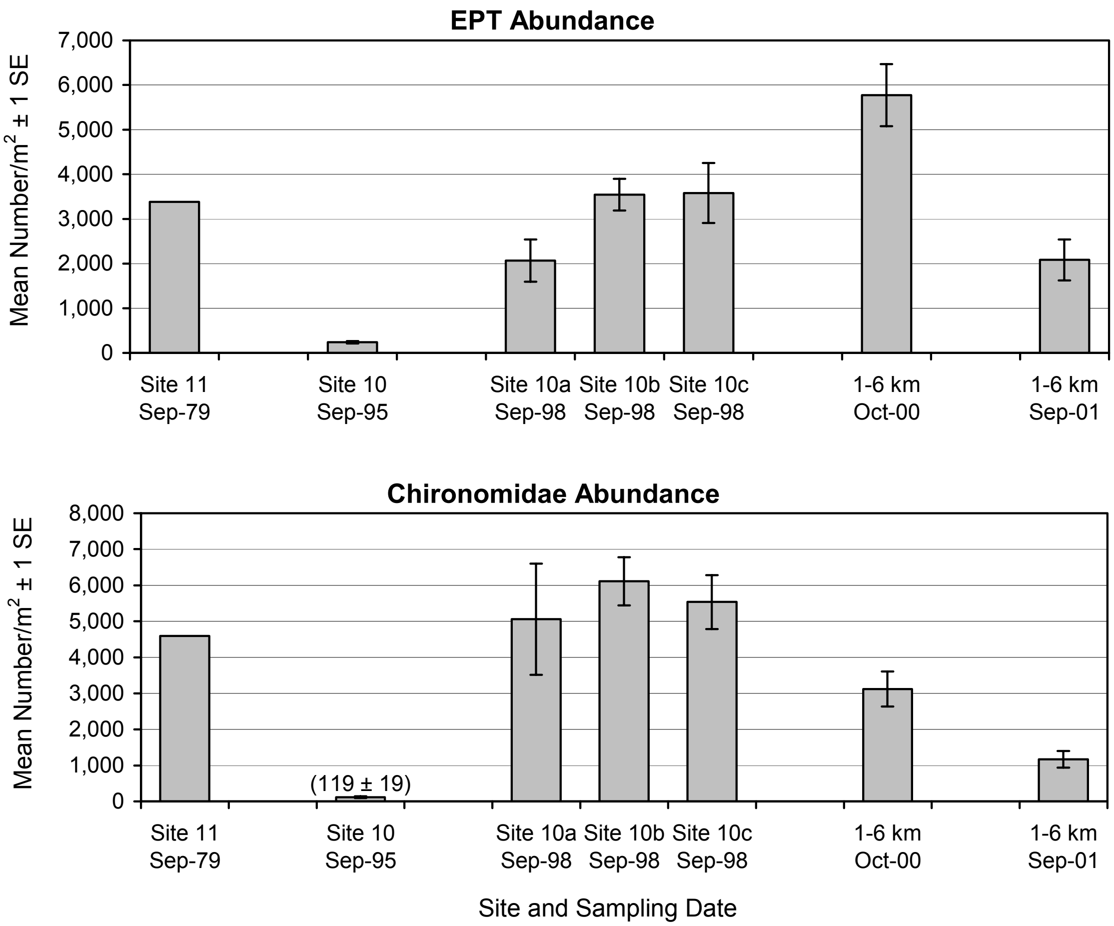


Figure 20 Year-to-year Variation in EPT Abundance and Chironomidae Abundance at the Mouth of the Muskeg River



Common taxa in this river included Nematoda, the oligochaete families Naididae and Tubificidae, the leach *Helobdella*, the gastropods *Ferrissia* and *Gyraulus*, the fingernail clams *Pisidium* and *Sphaerium*, Hydracarina, ostracods (as a group), four mayfly genera (*Baetis*, *Ephemerella*, *Stenonema*, *Leptophlebia*), the stonefly *Isoperla*, the caddisfly *Lepidostoma*, Ceratopogonidae (as a group and both common genera in this family), five chironomid subfamilies or tribes and two chironomid genera, the empidid fly *Hemerodromia*, the black fly *Simulium* and the tipulid fly *Dicranota*. The highest number of genera within a major group was found in the Chironomidae (50 genera). The high diversity of benthic invertebrates in this river relative to the Steepbank and MacKay rivers may be a reflection of the greater range of habitat variation relative to other major tributaries and, possibly, the larger number of samples collected.

3.5 STEEPBANK RIVER

3.5.1 Studies Reviewed

The Steepbank River was sampled for benthic invertebrates five times to the end of 2001 (Table 13). The available data span 26 years, with a large gap between the first study (1976 to 1977) and the other four studies (1995 to 2001). The objective of the first survey was to collect baseline data and investigate natural factors influencing benthic community characteristics, including the presence and amount of oil sands in the substrate (Barton and Wallace 1980). The first of the three recent surveys (EVS 1996) was part of the baseline study for the Suncor Steepbank Mine. The last three surveys (Golder 1999a, 2001, 2002a) were done under RAMP as part of routine monitoring to strengthen the baseline database. Continued annual monitoring of the lowest reach is planned by RAMP until 2004, after which monitoring frequency may be adjusted to suit development schedules of nearby oil sands developments.

Table 13 Study Details and Sampling Site Characteristics in the Steepbank River

Reference	Site Locations[(a)]	Sampling Method and Replication (sieve mesh size)	Habitat Type and Site Characteristics	Month/Year Sampled
Barton and Wallace (1980)	7 sites from mouth to headwaters (Sites 22d, 25, 26, 27, 28, 29, 30; includes 2 sites in N. Steepbank R.)	Kicknet one 15-min. sample (500 µm)	<u>mostly erosional</u>; width: 3-20 m; mean depth: 0.3-0.8 m; current vel.: 0.03-1 m/s; substrate: variable, mostly coarse	July, Oct 1976 May, July 1977
	2 sites near mouth (Sites 22c, 22d)	Surber 1-4 replicates (202 µm)	<u>variable</u> at lower site dep. on Athabasca R flows; <u>erosional</u> at upper site, in eroding oil sands and cobble	June to Oct 1977 (monthly)
EVS (1996)	3 sites; at mouth (Site 22b), 10 km upstream (Site 23) and 24 km upstream (Site 24)	Neill 5 replicates (250 µm)	<u>erosional;</u> mean depth: 0.2-0.5 m; current vel.: 0.2-1.4 m/s; substrate: cobble/gravel	Oct 1995
RAMP Golder (1999a)	3 sites near mouth (Sites 22a, 22b, 22c)	Neill 5 replicates (250 µm)	<u>erosional;</u> width: 8-11 m; mean depth: 0.2-0.3 m; current vel.: 0.4-0.6 m/s; substrate: cobble/gravel	Sept 1998
RAMP Golder (2001)	5 km reach beginning at the mouth	Neill 15 samples (250 µm)	<u>erosional;</u> width: 17-31 m; depth: 0.2-0.5 m; current vel.: 0.6-1.0 m/s; substrate: cobble/gravel	Oct 2000
RAMP Golder (2002a)	5 km reach beginning at the mouth	Neill 15 samples (250 µm)	<u>erosional;</u> width: 10-26 m; depth: 0.2-0.5 m; current vel.: 0.2-1.0 m/s; substrate: cobble/gravel	Sept 2001

[(a)] Site locations are shown in Figure 1; for the data summary, Site 22 was divided into four sites as follows: Site 22a = 100 m from mouth; Site 22b = 250 m from mouth; Site 22c = 400 m from mouth; Site 22d = 1 km from mouth.

The first survey (Barton and Wallace 1980) used two different approaches to address different objectives. Semi-quantitative kicknet sampling was used to describe the benthic fauna of widely distributed sites in the Steepbank and North Steepbank rivers (Table 13). Quantitative Surber samples were collected at two sites near the mouth to study habitat associations in detail as well as community responses to varying amounts of naturally-occurring oil sands in the substrate. The mesh size of the kicknet was relatively large (500 µm), which is likely reflected in differences in taxonomic composition from those reported by the other studies. The Surber sampler had a finer (202 µm) mesh than those used in later surveys (250 µm); however, the smaller mesh was not sufficiently different to cause an appreciable disparity in abundances and taxonomic composition among surveys.

Barton and Wallace (1980) sampled monthly (Surber samples) or at selected times (kicknet surveys), while all three recent surveys sampled during the fall (Table 13). All sampling was done in erosional habitat, which dominates in the Steepbank River. Sampling methods and mesh sizes used by the recent surveys were identical, but the level of replication and spatial coverage of the river varied among studies (Table 13).

The number of sites sampled by quantitative studies was relatively few, ranging from two to three per study (Table 13). As in the MacKay and Muskeg rivers, the 2000 and 2001 RAMP surveys used a reach approach, by distributing sampling effort within the first 5 km of the river from its mouth. Spacing of sites has also varied among studies. As a result, only the lowermost reach near the mouth was sampled by all five studies.

3.5.2 Summary of Historical Data

All sites sampled in the Steepbank River were erosional, characterized by coarse substrates. Nevertheless, specific habitat features varied moderately among sites and studies. The kicknet survey by Barton and Wallace (1980) covered the greatest range in habitat characteristics (Table 13). The quantitative surveys sampled similar habitats in terms of depth and substrate characteristics. Current velocity varied widely among the sites sampled by EVS (1996), while the three RAMP surveys were reasonably similar in terms of depth, velocity and substrate characteristics.

Results of the semi-quantitative study by Barton and Wallace (1980) provided the most detailed information on taxonomic composition in the Steepbank River, but because the data for all sampling events at a site were pooled, the information on seasonal variation is not available. This study documented up to 140 taxa from single sampling sites (Table 14), many at the species level. The lowest richness of 81 taxa was found at the mouth, but there was no trend in richness with distance from the mouth. All sites were dominated by chironomids. There were some progressive changes in community composition from the mouth to the headwaters. The percentage of mayflies declined from the mouth to the headwaters and there was a slight increase in the percentage of mollusks (Table 14). Percentages of other taxa either remained low and similar at all sites (oligochaetes and stoneflies), or varied moderately without an upstream trend (caddisflies and chironomids).

Table 14 Summary of Historical Benthic Invertebrate Data for the Steepbank River (September/October data, except where noted otherwise)

Reference [year sampled]	Site (distance from mouth)	Mean Total Abundance (no./m²)	Richness (total taxa)	Community Composition (%)[a]						
				M (%)	O (%)	E (%)	P (%)	T (%)	C (%)	Ot (%)
Barton and Wallace (1980) (kicknet survey) [1976-1977] *(data were combined for all samples collected over a 1-year period)*	Site 22d (1 km)	-[b]	81	<1	3	29	1	<1	46	19
	Site 25 (50 km)	-	118	1	5	24	5	20	36	9
	Site 26 (75 km)	-	105	1	9	11	5	7	53	14
	Site 27 (110 km)	-	113	3	4	16	4	13	51	9
	Site 28 (130 km)	-	119	18	4	3	0	3	42	30
	Site 29[c](140 km)	-	140	10	3	5	3	6	61	12
	Site 30[c](170 km)	-	103	10	9	1	<1	1	56	22
Barton and Wallace (1980) (Surber survey) [1977]	Site 22c-cobble (0.4 km)	2,137-3,685	-	-	-	-	-	-	-	-
	Site 22c-oil sands	550	-	-	-	-	-	-	-	-
	Site 22d (1 km)	4,145-6,015	18	0	0	35	4	0	28	33
EVS (1996) [1995]	Site 22b (~250 m)	1,422	40	<1	2	45	5	<1	14	34
	Site 23 (10 km)	3,104	60	<1	11	32	2	9	31	15
	Site 24 (24 km)	6,010	67	<1	2	13	2	15	51	17
RAMP Golder (1999a) [1998]	Site 22a (100 m)	4,411	35	0	7	26	<1	<1	63	5
	Site 22b (250 m)	11,539	39	0	2	58	<1	1	24	15
	Site 22c (400 m)	6,827	43	<1	6	55	<1	1	25	12
RAMP Golder (2001) [2000]	mouth to 5 km upstream	2,355	68	<1	34	42	1	<1	15	7
Golder (2002a) [2001]	mouth to 5 km upstream	3,209	56	<1	13	52	<1	<1	25	10

[a] M = mollusks; O = Oligochaeta; E = Ephemeroptera; P = Plecoptera; T = Trichoptera; C = Chironomidae; Ot = Other.
[b] - = not applicable: qualitative data only, or insufficient information.
[c] North Steepbank River.

Estimates of total invertebrate abundance during the fall, based on the quantitative surveys, were low and variable (typically <10,000 organisms/m^2; Table 14). The lowest abundance was reported from oil sands substrate. Richness varied moderately (35 to 68 taxa at the genus level) during the four recent studies that used consistent methods. Mayflies and chironomids dominated the communities at all sites, and mollusks, stoneflies and caddisflies were uncommon.

Seasonal variation in total invertebrate abundance (Figure 21) was moderate and generally lower than that observed in the other rivers reviewed (Figure 14). Richness varied less among months with about two-fold ranges at each site. Neither of these variables showed the progressive increase through the open water season observed for the Athabasca (erosional habitat only) and MacKay rivers. Based on the semi-quantitative data collected by Barton and Wallace (1980), the composition of benthic communities showed no seasonal trends.

Year-to-year variation and trends over time were examined in the reach near the mouth, which was sampled by consistent methods by four of the five studies. The 2000 and 2001 data represent the lower 5 km reach of the river, whereas other studies sampled individual sites. Three closely-spaced sites were sampled near the mouth in 1998. Year-to-year variation was moderate in total invertebrate abundance at the mouth of the river (with a six-fold range), based on fall samples (Figure 22). Richness was similar in 1995, 1998 and 2001, but was higher in 2000. Oligochaeta abundance was variable and EPT and chironomid abundances reflected total abundance (Figures 22 and 23). None of the benthic community variables exhibited long-term trends.

In total, 123 taxa were reported from the Steepbank River by quantitative studies and 237 taxa were found by Barton and Wallace (1980) (Table III-2 in Appendix III). The number of taxa reported by Barton and Wallace (1980) may be an overestimate for the mainstem, because it likely includes the North Steepbank River. Standardizing the lowest taxonomic level to genus yielded a total of 100 taxa (quantitative studies) and 188 taxa (Barton and Wallace 1980). The large difference between these data sources is probably due to the relatively small quantitative sampling effort in this river, compared to the intensive surveys of Barton and Wallace (1980) in 1976 and 1977.

Based on available quantitative data, most of the taxa reported from this river are considered common, which may have resulted from sampling a relatively narrow range of habitats. As in the other major tributaries, the highest number of taxa within a major group was found in the Chironomidae (36 taxa).

Figure 21 Seasonal Variation in Benthic Community Characteristics in the Steepbank River in 1976 and 1977 (data from Barton and Wallace 1980)

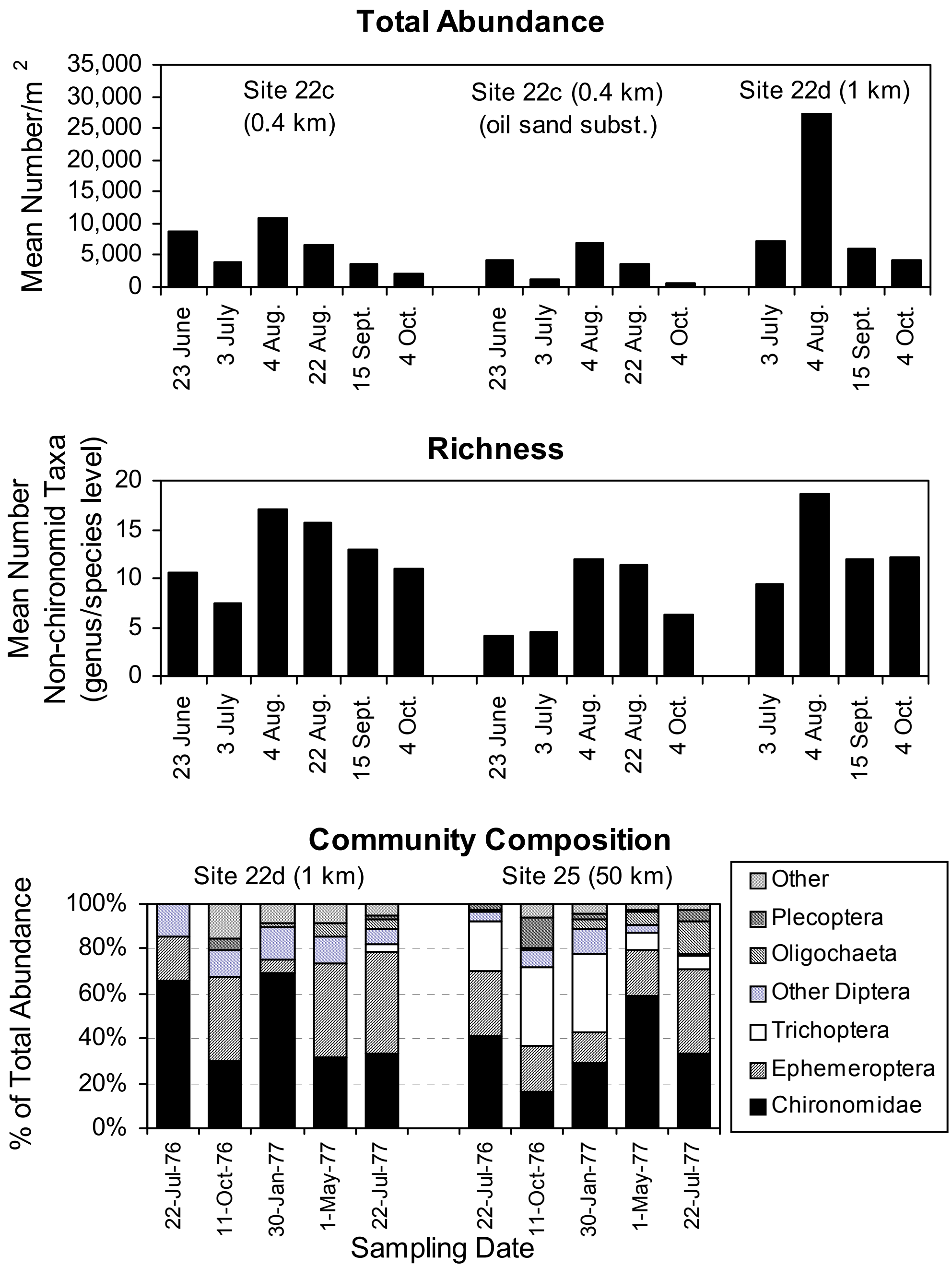


Figure 22 Year-to-year Variation in Total Invertebrate Abundance, Richness and Oligochaeta Abundance at the Mouth of the Steepbank River

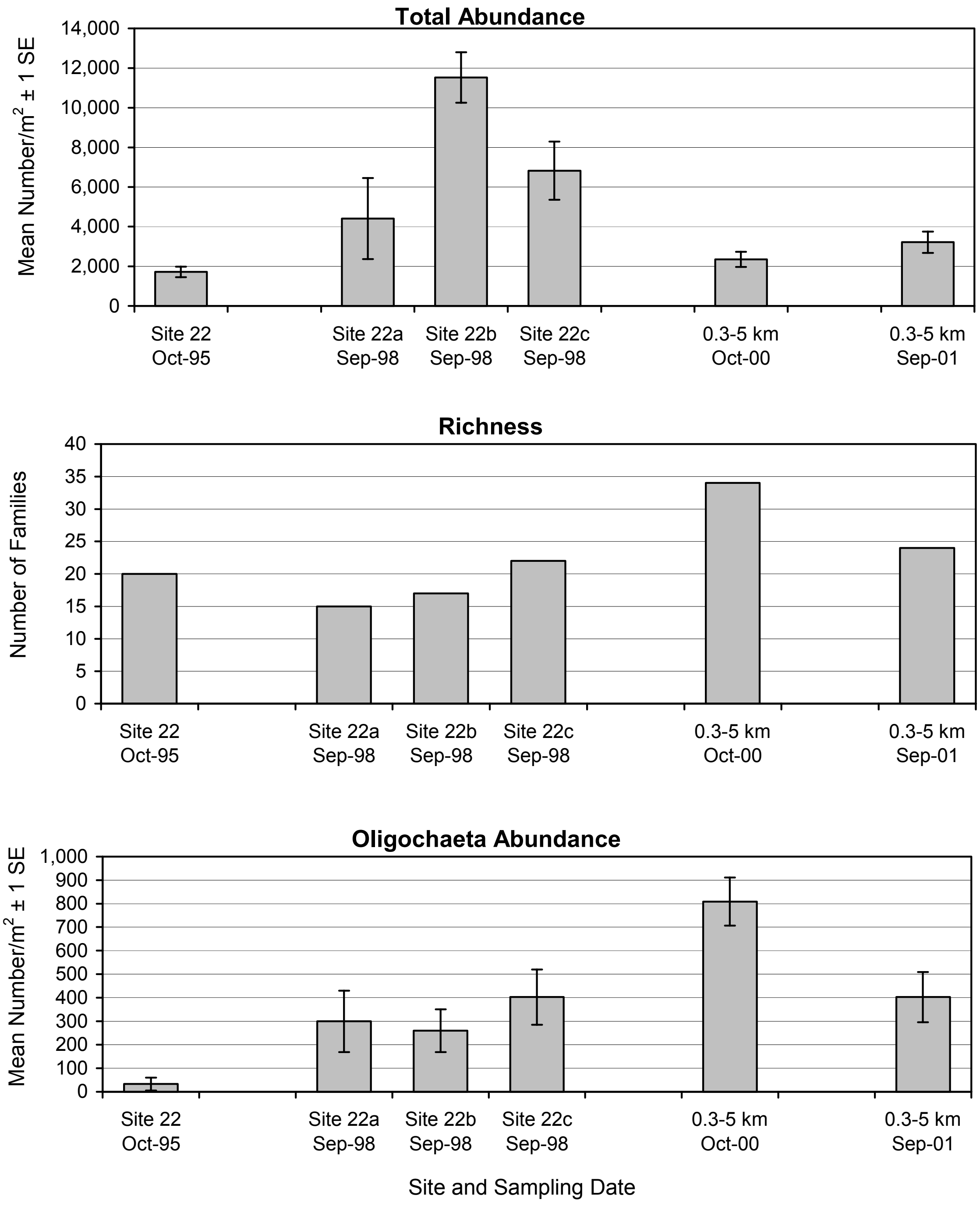
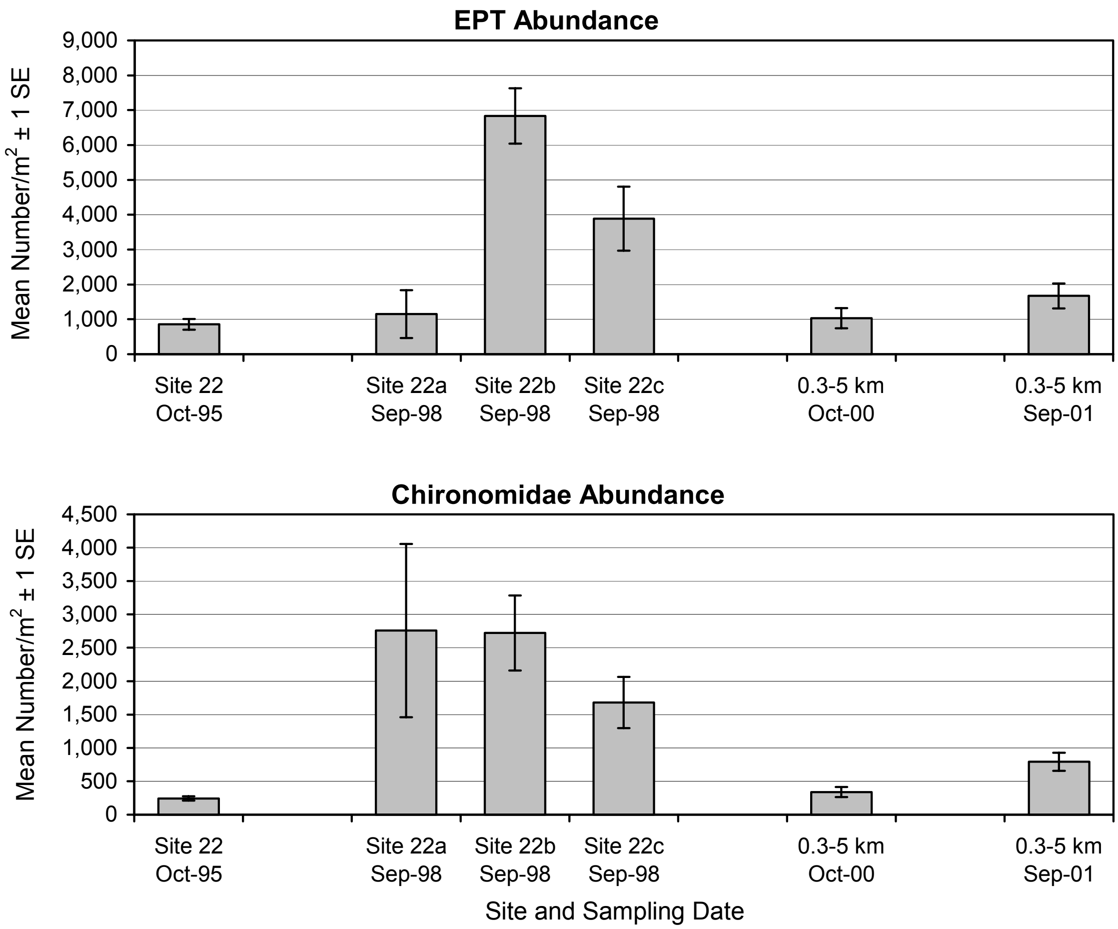


Figure 23 Year-to-year Variation in EPT Abundance and Chironomidae Abundance at the Mouth of the Steepbank River



3.6 SMALL STREAMS NORTH OF FORT MCMURRAY

3.6.1 Introduction

A relatively large amount of data is available for small streams tributary to the major rivers discussed above. Benthic invertebrate abundance data from small streams are in electronic format (on the attached CD-ROM) and are thus available for analysis. Habitat related data were not compiled electronically, because measurement of habitat attributes varied greatly among studies and habitat-related data were not reported in a standard format.

In the sections that follow, descriptions of the small stream data are organized by stream if frequently sampled (Poplar Creek), or by basin (Beaver, Jackpine, Muskeg and Wapasu Creek basins). Data were not summarized for a number of small streams that were infrequently sampled (i.e., once or twice), or at one to a few sites (Shelley, McLean and Fort creeks, Susan Lake outlet, Creek A and streams in MacKay River basin). The data summary was not restricted to natural streams. Available data for the WID were summarized to provide an indication of communities that develop in man-made streams, which will be a common feature of the reclaimed landscape after the life of oil sands developments.

3.6.2 Beaver Creek Basin

3.6.2.1 Studies Reviewed

Available data for the Beaver Creek basin include samples taken during 1977 (Noton and Chymko 1978; Tsui et al. 1978) and again in 1984 (RL&L and AA Aquatic Research 1985) (Table 15). These sources provided data for two seasons, eight years apart. The objective of Noton and Chymko (1978) was to obtain baseline data for Upper Beaver Creek (i.e., the reach upstream of Beaver Creek Reservoir). Tsui et al. (1978) described colonization in the newly-created WID, and the fauna of Lower Beaver Creek (i.e., the reach downstream of the Syncrude Mildred Lake Mine area) and two small tributaries of the WID. The objective of RL&L and AA Aquatic Research (1984) was to characterize current conditions of Upper and Lower Beaver Creek and the WID, as well as document changes since earlier studies.

The first study (Noton and Chymko 1978) sampled one site in Upper Beaver Creek on a seasonal basis (spring, summer and fall) in depositional habitat (Table 15). Tsui et al. (1978) sampled monthly at four sites along the WID (one erosional and three depositional sites), two depositional sites in tributaries of the WID and at one erosional site in Lower Beaver Creek. RL&L and AA Aquatic Research (1985) sampled seasonally at locations in both Upper and Lower Beaver Creek, and in the WID, at both erosional and depositional sites.

The first two studies used mesh sizes of 600 µm for samples taken with both the Ekman grab and the Surber sampler, while the last study used 250-µm mesh nets with the Ekman grab and the Neill cylinder (Table 15).

Table 15 Study Details and Sampling Site Characteristics in the Beaver Creek Basin

Reference	Site Locations[a]	Sampling Method and Replication (sieve mesh size)	Habitat Type and Site Characteristics	Month/ Year Sampled
Noton and Chymko (1978)	Upper Beaver Creek: 1 site; 2 km upstream of Beaver Creek Reservoir (Site 63)	Ekman 3 replicates (5 replicates in Oct) (600 µm)	depositional; depth: 2 m at midstream; current vel.: slow; substrate: sand/silt	May, July, Oct 1977
Tsui et al. (1978)	Lower Beaver Creek: 1 site; 6.25 km upstream of Athabasca R (Site 198) WID: 4 sites; 6.2 km (Site 59), 13 km (Site 199), 16.9 km (Site 61), 18.3 km (Site 201) upstream of Athabasca R (Site 198) WID tributaries: 2 sites; (Sites 60 and 200)	Surber, Ekman 3 replicates (600µm)	erosional; depth: 18-25 cm; width 8-12 m; substrate: gravel/cobble depositional; depth: 12-30 cm; width: 1-12 m; current vel.: slow; substrate: mud and organic material	May to Sept 1977
RL&L and AA Aquatic Research (1985)	Upper Beaver Creek: 1 site; 2 km upstream of Beaver Creek Reservoir (Site 63) Lower Beaver Creek: 3 sites; 1.2 km (Site 56), 3.3 km (Sites 57 and 58, in different channels) upstream of Athabasca R. WID: 3 sites; 6.2 (Site 59), 16.9 (Site 61), 22.0 (Site 62) km upstream of Athabasca R. WID tributaries: 1 site; (Site 60)	Ekman, Neill 3 replicates (250 µm)	erosional; substrate: cobble with gravel depositional; substrate: sand/silt and organic material	June, July, Sept 1985

[a] Site locations are shown in Figure 1.

3.6.2.2 Summary of Historical Data

Habitat characteristics vary considerably in the Beaver Creek basin. Upper Beaver Creek samples were taken in sand/silt substrate in 2 m of water with slow currents (Table 15). Stream flows averaged 0.44 m^3/s in 1977 (Noton and Chymko 1978) and ranged between 0.1 and 0.5 m^3/s in 1984 (RL&L and AA Aquatic Research 1985). Habitat sampled in Lower Beaver Creek and the WID by Tsui et al. (1978) was variable, from sand/silt or predominately organic substrates, and slow-flowing water to more erosional conditions with gravel and cobble substrates. Sites sampled along the WID by RL&L and AA Aquatic Research (1985) had cobble and gravel substrate with low flows ranging from 0.10 m^3/s in June to 0.06 m^3/s in September.

Mean total abundance was low (usually <10,000) during the fall at most sites (Table 16) and a consistent seasonal trend was absent at sites sampled monthly in 1977 (Figure 24). Mean total abundance was, however, >20,000 at Sites 59 and 61 in the WID in fall 1984 (Table 16). Generally, abundances were greater in 1984 than in 1977, which might be an artifact of using sampling devices with finer mesh nets in 1984 (Table 15). Richness was low in all streams in the Beaver Creek basin, with about half of the sites having fewer than ten families during fall sampling (Table 16). The number of families was also generally greater in 1984 than in 1977.

Community composition at the major taxon level was variable within the Beaver Creek basin (Table 16). Plecoptera and Trichoptera were absent, or present at low percentages at all sites. Upper Beaver Creek was dominated by chironomids, and mayflies or oligochaetes, depending on the year sampled. Oligochaete worms dominated the fauna of Lower Beaver Creek in both years, except at Site 56 (closest to the mouth), where chironomids were dominant. Small tributaries of the WID (Creeks W3 and W5) were dominated by either blackflies (Simuliidae) or chironomids.

The benthic fauna of the WID differed between the two years with data, most likely reflecting a combination of habitat variability among sites and successional changes in the benthic community over time. In 1977, communities were dominated by chironomids and, at one site, mayflies. Mayflies, oligochaete worms and other taxa (typically dipterans other than chironomids) were also common. In contrast, the 1984 study found mostly chironomid midges (70 to 97% of total abundance) despite sampling erosional habitat (as implied by the sampling method used: Neill cylinder). In 1977, seasonal variation in community composition was considerable, but inconsistent among sites (Figure 24).

Year-to-year variability in community structure was also large, as illustrated by a comparison of the data between 1977 and 1984 for sites in Upper Beaver Creek and the WID sites with data available for both years (Figure 25). The community in Upper Beaver Creek was similar in both years in terms of abundance, but richness was lower, mayflies were less numerous and oligochaete worms were more abundant in 1984. The data for Sites 59 and 61 in the WID showed consistent differences among years. Both abundance and richness increased in 1984, but chironomid dominance was much more pronounced in 1984. Since the WID was completed only about a year before the 1977 survey, the changes in community structure at these sites may reflect successional changes following initial colonization.

There were 90 taxa in the Beaver Creek basin during the fall, with 75 taxa at the genus level. A species list for all small streams sampled north of Fort McMurray is provided in Table III-3 (Appendix III) based on data from all seasons.

Table 16 Summary of Historical Benthic Invertebrate Data Collected during the Fall in the Beaver Creek Basin

Stream	Reference [year sampled]	Site (distance from mouth)	Habitat	Mean Total Abundance (no./m^2)	Richness (total families)	Community Composition (%)[a] O (%)	E (%)	P (%)	T (%)	S (%)	C (%)	Ot (%)
Upper Beaver Creek	Noton and Chymko (1978) [1977]	63 (2 km upstream of Beaver Creek Reservoir)	depositional	14,068	24	2	23	0	<1	0	62	13
	RL&L and AA Aquatic Research (1985) [1984]	63 (2 km upstream of Beaver Creek Reservoir)	depositional	11,810	6	17	7	0	0	0	70	5
Lower Beaver Creek	Tsui et al. (1978) [1977]	198 (6.3 km)	erosional	667	2	97	0	0	0	0	0	3
	RL&L and AA Aquatic Research (1985) [1984]	56 (1.2 km)	erosional	2,307	13	19	2	15	4	0	57	3
		57 (3.3 km)	erosional	3,537	14	60	<1	0	<1	0	28	11
		58 (3.3 km)	erosional	83	5	80	0	0	4	0	4	12
WID	Tsui et al. (1978) [1977]	59 (6.2 km)	erosional	2,305	7	0	11	0	0	1	51	37
		61 (16.9 km)	depositional	1,351	7	20	7	0	0	0	35	38
		199 (13.0 km)	depositional	4,401	9	1	19	0	0	0	51	29
		201 (18.3 km)	depositional	2,050	10	2	54	0	0	<1	24	19
	RL&L and AA Aquatic Research (1985) [1984]	59 (6.2 km)	erosional	24,047	23	<1	<1	0	<1	0	97	2
		61 (16.9 km)	erosional	22,200	10	4	0	0	0	0	94	1
		62 (22.0 km)	erosional	2,047	19	4	5	0	3	1	79	8
Creek W3	Tsui et al. (1978) [1977]	60 (0.4 km)	depositional	329	5	28	0	0	0	15	53	5
	RL&L and AA Aquatic Research (1985) [1984]	60 (0.4 km)	depositional	3,612	7	17	2	0	0	0	62	18
Creek W5	Tsui et al. (1978) [1977]	200 (0.4 km)	depositional	1,202	12	12	2	0	4	71	7	5

[a] O = Oligochaeta; E = Ephemeroptera; P = Plecoptera; T = Trichoptera; C = Chironomidae; S = Simuliidae; Ot = Other.

Figure 24 Seasonal Variation in Total Abundance, Richness and Community Composition in Lower Beaver Creek and the WID (data from Tsui et al. (1978)

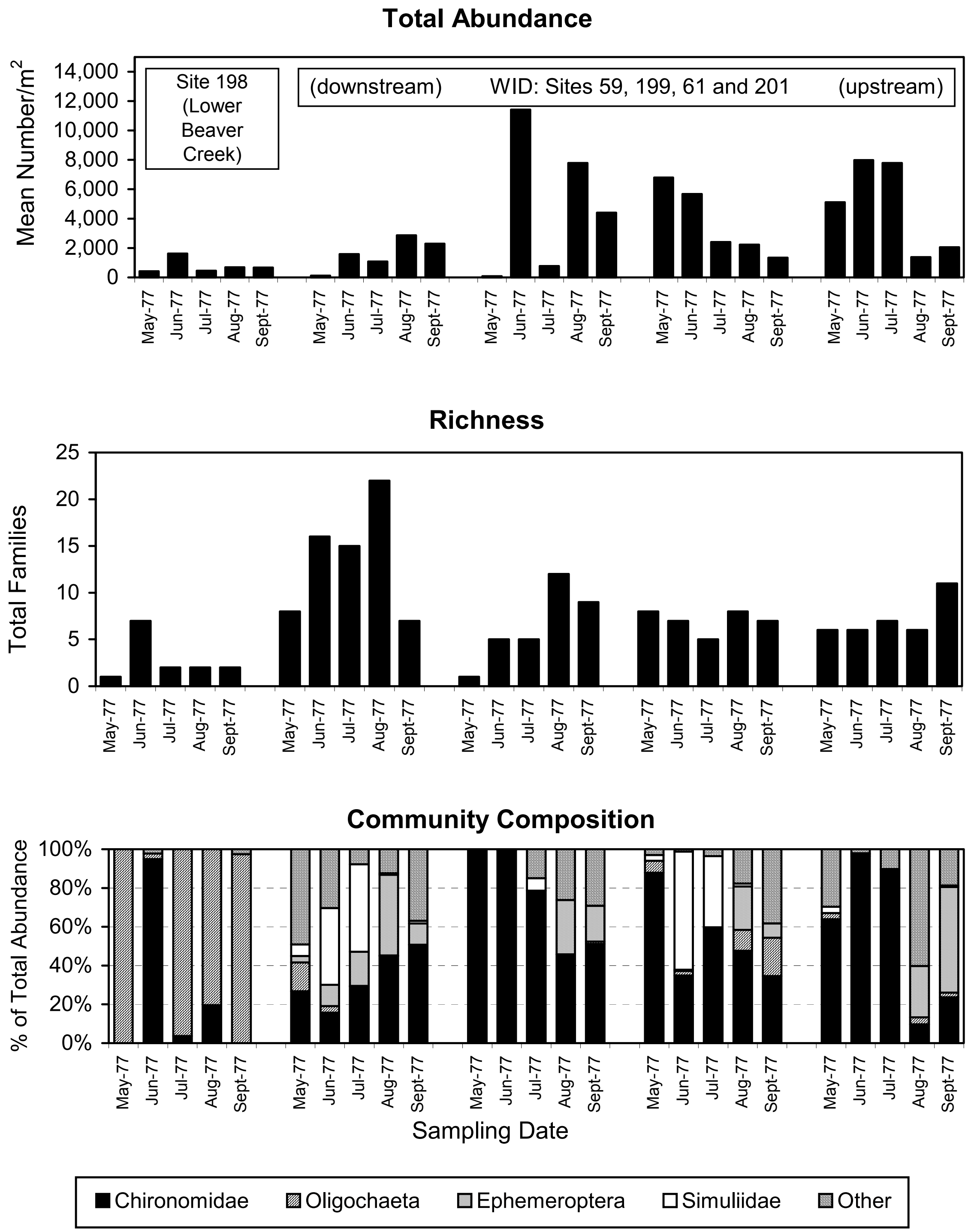
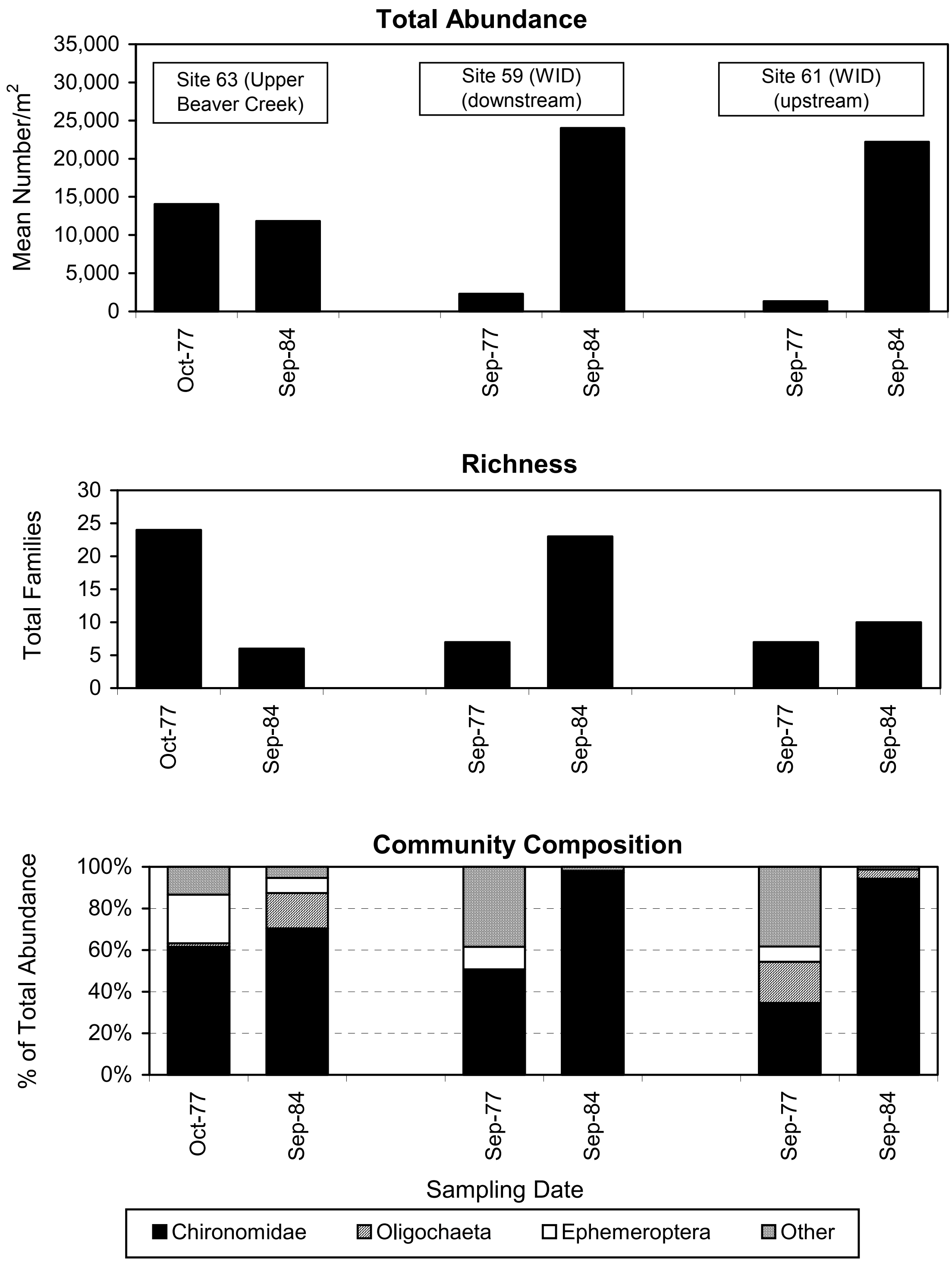


Figure 25 Differences in Total Abundance, Richness and Community Composition between 1977 and 1984 in Upper Beaver Creek and the WID (data from Noton and Chymko 1978, and RL&L and AA Aquatic Research 1985)



3.6.3 Poplar Creek

3.6.3.1 Studies Reviewed

There were eight studies of benthic communities in the Poplar Creek basin between 1974 and 1984 (Table 17). Details regarding habitat sampled are limited, because reporting of habitat data was not consistent among studies and some studies did not collect detailed habitat data. A number of studies used AS to monitor invertebrates, resulting in a data set that is not consistent over time.

Four general areas were sampled by historical studies in Poplar Creek. These include two areas upstream from the Poplar Creek Reservoir spillway (Sites 68a/b and 69, corresponding to historical Sites PC3 and PC4, respectively) and two areas downstream (at or immediately downstream of spillway: Sites 65b, 66 and 67 [historical Site PC2]; at some distance downstream from spillway: Sites 64 and 65a [historical Site PC1]). Previous site designations are provided in Table II-3, Appendix II. Each of the studies included two to four of these areas; however, sampling sites within these areas varied. Objectives of the first two studies (Syncrude 1975 and Noton and Chymko 1977) were to describe baseline conditions, while the 1978 and later studies evaluated impact of water discharges from the spillway.

The first four studies collected samples at least monthly, from March or May through fall (Table 17). The upstream sampling locations were in erosional habitats, but the downstream sites were depositional. Prior to the second study, Site 67 (PC2), located immediately downstream from the spillway was considered erosional. Construction of the spillway (completed in summer 1976) resulted in silt deposition in Poplar Creek downstream of the outfall, changing the habitat from erosional to depositional.

Sampling methods also differed among studies. Portable Invertebrate Box Sampler (PIBS), Surber, Hess or Neill cylinder samplers were used in erosional habitat and the Ekman grab was used in depositional habitat. Retallack (1980, 1981a, and 1981b) and Boerger (1983b) used basket-type AS to sample invertebrates. Retallack (1980) utilized a Surber sampler with a 1,024 µm mesh to collect instream invertebrates when a Portable Invertebrate Box Sampler (PIBS) (300 µm mesh) did not appear to sample adequately and used a 1,000 µm mesh net to retrieve AS samplers. The remaining samples were taken with sampling meshes of 300 µm or smaller (Table 17). Because of these differences in methods there is little consistency in the data available for this stream.

The data summary presented in the following section includes data collected in June and July, which was the only period sampled by all studies. In addition to data from natural substrates, AS data were also summarized because they accounted for a large proportion of the available data set for this stream.

Table 17 Study Details and Sampling Site Characteristics in Poplar Creek

Reference	Site Locations[a]	Sampling Method and Replication (sieve mesh size)	Habitat Type and Site Characteristics	Month/ Year Sampled
Syncrude (1975)	4 sites; 2.8 km (Site 65a), 3.8 km (Site 67), 4.2 km (Site 68b),4.9 km (Site 69) from mouth.	Surber 3 replicates 300 µm Ekman (one site) 8 replicates (600 µm)	erosional; (Sites 67, 68b, 69) width: 5-6 m; mean depth: 0.1-0.3 m; current vel.: 0.5-1 m/s; substrate: cobble with gravel base depositional; (Site 65a) mean depth: 0.2-0.3 m; current vel.: 0.2-0.3 m/s; substrate: sand/silt	March; May to Sept 1994 (monthly)
Noton and Chymko (1977)	3 sites; 2.8 km (Site 65a), 3.8 km (Site 67), 4.9 km (Site 69) from mouth.	Surber 1 sample 300 µm Ekman (one site) 8 replicates (600 µm)	(stream discharge reported for all sites and changes in substrate over the monitoring period reported at one site)	May to November 1975 (biweekly)
Noton and Chymko (1978)	3 sites; 2.3 km (Site 64), 3.5 km (Site 66), 4.9 km (Site 69) from mouth.	Hess 3 replicates (250 µm)	erosional; width: 5-18 m; mean depth: 0.1-0.3 m; substrate: sand/silt with some cobble and boulder	May to November 1977 (monthly)
Retallack (1980)	4 sites; 2.3 km (Site 64), 3.1 km (Site 65b), 4.5 km (Site 68b), 4.9 km (Site 69) from mouth.	AS (basket) PIBS (200 µm) Surber (1024 µm) 3 replicates	erosional; mean depth: 0.1-0.3 m	May to October 1979 (monthly)
Retallack (1981a)	3 sites; 2.3 km (Site 64), 3.1 km (Site 65b), 4.4 km (Site 68b) from mouth.	AS (basket, brick) (1000 µm) 3 replicates	(not reported)	June, July and Sept 1980
Retallack (1981b)	2 sites; 2.3 km (Site 64) and 4.4 km (Site 68b) from mouth.	AS (basket) 2-3 replicates	(report not available)	
Boerger (1983b)	4 sites; 2.3 km (Site 64), 3.1 km (Site 65b), 4.4 km (Site 68b), 4.9 km (Site 69) from mouth.	AS (basket) 3 replicates (250 µm)	erosional; current vel.: 0.2-0.3 m/s; substrate: sand/silt with some cobble and boulder	July 1982
RL&L and AA Aquatic Research (1985)	4 sites; 2.3 km (Site 64), 3.1 km (Site 65b), 4.2 km (Site 68a), 4.9 km (Site 69) from mouth.	Neill (210 µm) Dip net (250 µm) Ekman (250 µm) 3 replicates (all)	(stream discharge and gradient reported) upstream sites (Sites 68a and 69): width: 5-8 m; mean depth: 0.1-1.5 m; current vel.: 0-0.2 m/s	June, July and Sept 1984

[a] Site locations are shown in Figure 1.

3.6.3.2 Summary of Historical Data

Sampling methods have varied among studies, making it difficult to compare their results. Studies of natural substrates reported low total invertebrate abundances (up to 3,130 organisms/m^2) before the discharge from the spillway (i.e., 1974 and 1975), or at the two upstream reference sites (Table 18, Figure 26). After the spillway began to discharge in July 1976 (Boerger 1983b), total abundance has increased considerably at sites located downstream from the spillway (Sites 64 to 66) due to habitat alteration that resulted from the deposition of fine sediments. Examination of the AS data in Table 18 reveals no effect in (1980), or the potential for effects of much lower magnitude (1979, 1981, 1982), as may be expected during studies that controlled substrate composition.

Richness was similar among studies that sampled natural substrates (usually 10 to 17 families) and was higher in studies using AS (14 to 25 families) (Table 18). There were no temporal trends in richness, and an effect of the spillway on richness was not observed (Figure 26).

The benthic community was dominated by mayflies and chironomids on natural substrates at reference sites and before discharges from the spillway began (Table 18). The assemblages sampled by AS also had high proportions of these taxa, but filter-feeders (caddisflies and, occasionally, black flies) were also abundant. After 1976, communities downstream of the spillway had lower percentages of mayflies (Sites 65b to 67) and greater percentages of black flies (Sites 64 and 65a) and hydras (Figure 26). These changes likely reflected suspended sediment inputs, which reduced habitat suitability for mayflies and provided food for black flies. Similar changes were not observed at the upstream reference sites, thereby confirming the effects of the spillway discharges.

A species list for all small streams sampled north of Fort McMurray is provided in Table III-3 (Appendix III) based on data from all seasons.

3.6.4 Muskeg River Basin

3.6.4.1 Studies Reviewed

The Muskeg River has a large drainage area including the sub-basins of Jackpine Creek, Muskeg Creek (with several tributaries), Shelley Creek, Wapasu Creek and Stanley Creek, and a number of other, unnamed small streams. Most surveys of benthic communities were undertaken to obtain baseline data on biological resources, in support of planned oil sands developments. One study (O'Neil et al. 1982) intended to describe the impact of the Hartley Creek Diversion on

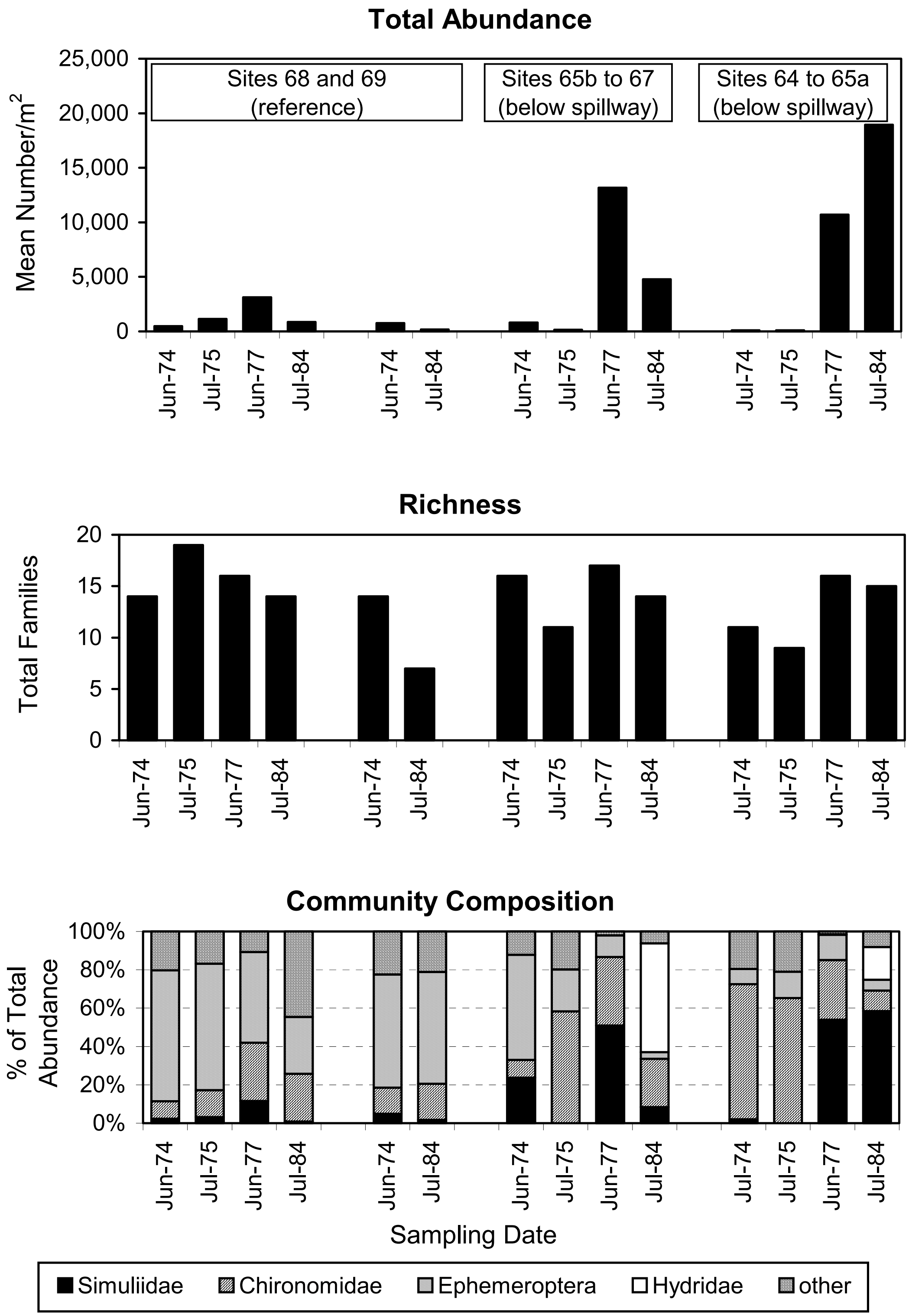
Jackpine Creek (then Hartley Creek). Available data span a period of approximately 25 years, with a number of gaps.

Table 18 Summary of Historical Benthic Invertebrate Data for Poplar Creek Based on June and July Data (erosional habitat)

Reference [year sampled]	Site[a] (distance from mouth)	Mean Total Abundance (no/m²)	Richness (total families)	Community Composition (%)[b]						
				O (%)	E (%)	P (%)	T (%)	C (%)	S (%)	Ot (%)
Natural Substrates										
Syncrude (1975) [1974]	Site 64	102	11	2	8	4	0	71	2	14
	Site 67	813	16	<1	55	<1	4	9	24	7
	Site 68b	769	14	9	59	3	2	14	5	8
	Site 69	474	14	0	68	<1	9	9	2	11
Noton and Chymko (1977) [1975]	Site 65a	95	9	3	14	0	3	65	0	15
	Site 67	156	11	7	22	1	3	58	0	8
	Site 69	1,134	19	<1	66	2	6	14	3	9
Noton and Chymko (1978) [1977]	Site 64	10,700	16	<1	13	<1	<1	31	54	<1
	Site 66	13,166	17	<1	11	<1	<1	36	51	<1
	Site 69	3,130	16	<1	47	1	8	30	12	1
RL&L and AA Aquatic Research (1985) [1984]	Site 64	18,951	15	<1	6	0	3	11	58	21
	Site 65b	4,776	14	5	3	0	1	25	8	57
	Site 68a	175	7	11	58	9	0	19	2	2
	Site 69	874	14	4	30	32	1	25	<1	7
Artificial Substrates										
Retallack (1980) [1979]	Site 64 (AS)	1,337	17	<1	12	0	16	20	50	2
	Site 65b (AS)	259	14	0	8	<1	<1	70	18	3
	Site 68b (AS)	38	14	0	50	0	24	13	0	13
	Site 69 (AS)	180	14	0	35	0	47	8	7	3
Retallack (1981a) [1980]	Site 64 (AS)	211	16	0	55	<1	13	25	<1	6
	Site 65b (AS)	381	20	0	12	0	15	62	0	11
	Site 68b (AS)	362	22	<1	38	1	8	46	<1	6
Retallack (1981b) [1981]	Site 64 (AS)	4,324	17	<1	12	<1	52	26	7	<1
	Site 68b (AS)	3,203	20	<1	30	8	38	14	6	2
Boerger (1983b) [1982]	Site 64 (AS)	5,387	21	0	10	<1	5	18	66	1
	Site 65b (AS)	1,829	25	<1	24	0	3	51	6	16
	Site 68b (AS)	1,491	20	0	37	1	<1	55	<1	5
	Site 69 (AS)	533	21	<1	27	<1	<1	57	<1	14

[a] AS in parentheses indicates that samples were collected using AS.
[b] O = Oligochaeta; E = Ephemeroptera; P = Plecoptera; C = Chironomidae; S = Simuliidae; Ot = Other.

Figure 26 **Total Abundance, Richness and Community Composition in Poplar Creek Based on Samples from Natural Substrates (data from sources identified in Table 18)**



The first study in the Muskeg Creek basin sampled in July and October 1976 and in January, May and July 1977 (Barton and Wallace 1980) using a 500-µm mesh kicknet in mostly depositional habitat (Table 19; abundance and richness data are not included here, because the raw data are unavailable). The next three studies were progressively smaller in scope, utilizing consistent sampling techniques in both erosional and depositional habitats (Beak 1986; RL&L 1989; Golder 1996a). The two recent studies (Golder 2002b; Shell 2002) were intended to provide an update on the status of benthic invertebrate communities at selected locations in the fall of 2001, primarily in depositional habitat.

Four studies in the Muskeg Creek basin (Beak 1986; Golder 1996a, 2002b; Shell 2002) sampled during the fall. Barton and Wallace (1980) sampled in spring and summer, with one winter sample, and RL&L (1989) sampled spring, summer and fall (Table 19). Numerous sites were sampled more than once. However, only Beak (1986) and RL&L (1989) sampled the same group of sites (Sites 42, 43, 44, 48, 50 and 51). Three of the locations (Sites 42, 44 and 51) investigated by both Beak (1986) and RL&L (1989) were sampled using different methods: Beak (1986) used a Neill cylinder, while RL&L (1989) used an Ekman grab. Thus, evaluation of trends over time may be unreliable for some sites. Sites were widely spaced in many of the tributaries of this stream.

Eight sites were investigated in the Jackpine Creek basin (Table 20). All studies were small-scale, with three or fewer sites in the basin and only three sites (Sites 34, 36 and 38) were sampled by more than one study. Sites were relatively evenly spaced along the mainstem of Jackpine Creek (Figure 1) and both erosional and depositional habitats were sampled.

In the Jackpine Creek basin, the first study sampled monthly, the next two sampled seasonally and the last two sampled only during the fall (Table 20). Hartland-Rowe et al. (1979) utilized various sampling methods, including Neill and Surber samplers, an Ekman grab and an airlift sampler. It was difficult to standardize the bottom area and amount of sediment collected with the airlift sampler, making comparisons of airlift data with other data problematic. The remaining studies used an Ekman grab in depositional habitat, and a Hess sampler or a Neill cylinder in erosional habitat.

Unfortunately, much of the data collected by Hartland-Rowe et al. (1979) is not useful for comparisons with data generated by other studies. Hartland-Rowe et al. (1979) did not report richness and did not report abundance in a consistent manner. Furthermore, the raw data were also not reported, and the community composition data only included numbers of Ephemeroptera, Plecoptera and Trichoptera.

Table 19 Study Details and Sampling Site Characteristics in the Muskeg Creek Basin

Reference	Site Locations[a]	Sampling Method and Replication (sieve mesh size)	Habitat Type and Site Characteristics	Month/ Year Sampled
Barton and Wallace (1980)	Muskeg Creek: 1 site; 13 km upstream of Muskeg River (Site 44) Wesukemina Creek: 1 site; 26 km upstream of Muskeg River (Site 47)	Kicknet one sample (500 μm)	depositional; width: 1-4 m; max depth: 0.7-1.0 m; current vel.: <0.01-0.2 m/s; substrate: sand/organic debris	July, Oct 1976, Jan, May, Jul 1977
Beak (1986)	Muskeg Creek: 3 sites; 3 km (Site 42), 7 km (Site 43), 13 km (Site 44) upstream of Muskeg River Iyinimin Creek: 1 site; 16 km upstream of Muskeg River (Site 45) Khahago Creek: 1 site; 15 km upstream of Muskeg River (Site 48) Blackfly Creek: 1 site; 22 km upstream of Muskeg River (Site 50) Green Stockings Creek: 1 site; 23 km upstream of Muskeg River (Site 51)	Ekman, Neill 3 replicates (180 μm)	erosional; mean depth 0.2 m; mean current vel.: 0.46 m/s; substrate: cobble/pebble depositional; mean depth: 1.18-1.3 m; mean current vel.: <0.1 m/s; substrate: sand/organic material	Oct 1985
RL&L (1989)	Muskeg Creek: 3 sites; 3 km (Site 42), 7 km (Site 43), 13 km (Site 44) upstream of Muskeg River Iyinimin Creek: 1 site; 19 km upstream of Muskeg River (Site 46) Khahago Creek: 1 site; 15 km upstream of Muskeg River (Site 48) Blackfly Creek: 1 site; 22 km upstream of Muskeg River (Site 50) Green Stockings Creek: 1 site; 23 km upstream of Muskeg River (Site 51)	Ekman, Neill 3 replicates (180 μm)	erosional; substrate: gravel/cobble depositional; substrate: organic/sand	May, Aug, Sept 1989
Golder (1996a)	Muskeg Creek: 1 site; 13 km upstream of Muskeg River (Site 44) Iyinimin Creek: 1 site; 19 km upstream of Muskeg River (Site 46) Khahago Creek: 1 site; 15 km upstream of Muskeg River (Site 48) Blackfly Creek: 1 site; 18 km upstream of Muskeg River (Site 49)	Ekman, Neill 3 replicates (250 μm)	erosional; depth: 0.2-0.4 m; current vel.: 0.2-0.4 m/s; substrate: gravel/cobble with sand/silt/clay depositional; depth: 0.4-1.3 m; current vel.: 0.01-0.1 m/s; substrate: sand/silt/clay	Sept 1995
Golder (2002b)	Iyinimin Creek: 1 site; 19 km upstream of Muskeg River (Site 46) Blackfly Creek: 1 site; 22 km upstream of Muskeg River (Site 50) Wesukemina Creek: 1 site; 13 km upstream of Muskeg River (Site 207)	Ekman 5 replicates (250 μm)	depositional; width 1.5-3.2 m; depth 0.3-0.8 m; current vel.: <0.1 m/s	Oct 2001
Shell (2002)	Muskeg Creek: 1 site; 7 km upstream of Muskeg River (Site 43) Muskeg Creek: 1 site; 13 km upstream of Muskeg River (Site 44) Khahago Creek: 1 site; 15 km upstream of Muskeg River (Site 48)	Ekman 5 replicates (250 μm)	depositional; depth: 0.5-1.4 m; width 3-8 m; current vel.: <0.1; substrate: sand/silt/clay	Sept 2001

[a] Site locations are shown in Figure 1.

Table 20 Study Details and Sampling Site Characteristics in Jackpine Creek

Reference	Site Locations[a]	Sampling Method and Replication (sieve mesh size)	Habitat Type and Site Characteristics	Month/ Year Sampled
Hartland-Rowe et al. (1979)	3 sites: 1.5 km (Site 35), 7 km (Site 36), 8 km (Site 37) from Muskeg River	Neill, Surber, Ekman, Airlift 3-9 replicates (250 μm)	erosional; depth: 0.3-0.5 m; width: 5-10 m; substrate: cobble/gravel/ boulder depositional; depth 0.4 m; width: 10 m; substrate: sand	May to Nov 1976 and Feb to Nov 1977, monthly
O'Neil et al. (1982)	3 sites: 7 km (Site 36), 11 km (Site 38), 21 km (Site 40) from Muskeg Creek	Hess, Ekman 3 replicates (250 μm)	erosional; substrate: gravel, cobble, boulders depositional; substrate: sand/silt	May, July, Sept 1981
RL&L (1989)	3 sites: 550 m (Site 34), 13 km (Site 39), 13 km (Site 41; in East Jackpine Creek) from Muskeg River	Ekman 3 replicates (180 μm)	depositional; mean width: 3.5-9.5 m; max depth: 1-2 m; flow: placid; substrate: organic/sand	May, Aug, Sept 1989
Golder (1996a)	2 sites: 550 m (Site 34), 11 km (Site 38) from Muskeg River	Neill 3 replicates (250 μm)	erosional; mean depth: 0.3-0.4 m; current vel.: 0.15-0.45 m/s; substrate: gravel/cobble	Sept 1995
Shell (2002)	2 sites: 565 m (Site 34), 7 km (Site 36) from Muskeg River	Neill, Ekman 5 replicates (250 μm)	erosional; width: 10.2 m; mean depth 0.3 m; current vel.: 0.3 m/s; substrate: gravel/cobble depositional; width: 9 m; mean depth 0.3 m; current vel: 0.2 m/s; substrate: sand	Sept 2001

[a] Site locations are shown in Figure 1.

Five sites were sampled by the three previous studies in the Wapasu Creek basin, two of which (Sites 52 and 53) were sampled during more than one investigation (Table 21). Spacing of these sites has been inconsistent, with three sites in close proximity to one another, one close to the mouth and one in the headwaters (Figure 1). Samples were collected in the fall by the first study (Beak 1986), seasonally by the second (RL&L 1989), and in the spring and late summer by the most recent survey (Komex 1997). Beak (1986) sampled in both erosional and depositional habitats. The two subsequent studies each sampled a single habitat type only.

Table 21 Study Details and Sampling Site Characteristics in Wapasu Creek

Reference	Site Locations[a]	Sampling Method and Replication (sieve mesh size)	Habitat Type and Site Characteristics	Month/ Year Sampled
Beak (1986)	2 sites: 800 m (Site 52), 12 km (Site 53) from Muskeg River	Hess, Ekman 3 replicates (180 μm)	erosional; depth: 0.2 m; current vel.: 0.7 m/s; substrate: cobble/ gravel depositional; depth 0.5 m; current vel.: <0.1 m/s; substrate: sand /organic material	October 1985
RL&L (1989)	3 sites: 800 m (Site 52), 12 km (Site 53), 20 km (Site 54) from Muskeg River	Ekman 3 replicates (180 μm)	depositional; width 3.5-8 m; depth: shallow to >0.8 m; current vel.: low; substrate: sand/organic	May, Aug, Sept 1989
Komex (1997)	2 sites: 11 km (Site 180), 13 km (Site 181) from Muskeg River	Neill 5 replicates (250 μm)	erosional; substrate: silt, wood debris, cobble/boulder	May, Aug 1997

[a] Site locations are shown in Figure 1.

3.6.4.2 Summary of Historical Data

Muskeg Creek Basin

Sites sampled in Muskeg and Khahago creeks were mostly depositional (Table 22), reflecting the relatively low gradients in these streams. Sites sampled in headwater streams of Muskeg and Khahago creeks (Blackfly, Iyinimin, Green Stockings and Wesukemina creeks) were mostly erosional. In Jackpine and Wapasu creeks, depositional sites were slightly more frequently sampled than erosional sites.

Total benthic invertebrate abundance was widely variable in the Muskeg Creek basin during the fall, without a consistent difference between erosional and depositional sites (Table 22). Richness usually varied between 10 and 26 families (Table 22). However, at the erosional Site 42, Beak (1986) recorded 35 families. Richness appeared slightly higher at erosional sites, as would be expected. The benthic communities sampled in the Muskeg Creek basin were usually dominated by chironomid midges, with higher proportions of stoneflies and caddisflies occasionally observed at erosional sites.

Based on data collected by RL&L (1989) at three sites in Muskeg Creek (Figure 27), seasonal variation in community characteristics was low to moderate, but the frequently observed increase in total abundance over the open water season was only seen at one site (Site 44). Long-term trends were not apparent at sites with a minimum of three years of data (Figure 28), with the possible exception of community composition at Sites 44 and 46, where opposite trends were found in the proportion of the community consisting of Chironomidae.

Table 22 Summary of Fall Historical Benthic Invertebrate Data for the Muskeg Creek Basin

Creek	Reference [year sampled]	Site (distance from mouth)	Habitat	Mean Total Abundance (no/m²)	Richness (total families)	Community Composition (%)[a]						
						O (%)	E (%)	P (%)	T (%)	C (%)	S (%)	Ot (%)
Muskeg	Barton and Wallace (1980) [1976-1977]	44 (13 km)	all	n/a[b]	n/a	48	<1	0	1	30	0	21
	Beak (1986) [1985]	42 (3 km)	erosional	85,543	35	<1	1	<1	<1	85	0	11
		43 (7 km)	depositional	44,749	14	4	1	0	<1	92	0	3
		44 (13 km)	erosional	21,230	20	2	<1	0	<1	95	<1	3
	RL&L (1989) [1988]	42 (3 km)	depositional	3,125	26	9	6	9	34	12	<1	31
		43 (7 km)	depositional	2,078	15	13	1	1	0	68	0	17
		44 (13 km)	depositional	17,343	23	9	<1	0	2	69	<1	20
	Golder (1996a) [1995]	44 (13 km)	depositional	25,146	11	5	0	0	0	71	0	24
	Shell (2002) [2001]	43 (7 km)	depositional	7,585	18	7	<1	0	<1	86	0	6
		44 (13 km)	depositional	4,223	6	0	0	0	0	25	0	75
Khahago	Beak (1986) [1985]	48 (15 km)	depositional	9,331	12	5	0	0	0	80	0	15
	RL&L (1989) [1988]	48 (15 km)	depositional	12,484	17	2	3	0	<1	84	0	11
	Golder (1996a) [1995]	48 (15 km)	depositional	9,515	13	8	<1	0	1	78	0	12
	Shell (2002) [2001]	48 (15 km)	depositional	7,585	18	<1	14	0	<1	74	0	11
Blackfly	Beak (1986) [1985]	50 (22 km)	erosional	44,352	19	1	2	13	13	57	8	6
	RL&L (1989) [1988]	50 (22 km)	erosional	453	12	1	1	6	36	29	6	21
	Golder (1996a) [1995]	49 (18 km)	erosional	5,942	20	6	3	<1	3	68	<1	20
	Golder (2002b) [2001]	50 (22 km)	depositional	10,208	9	3	0	0	0	85	<1	12
Iyinimin	Beak (1986) [1985]	45 (17 km)	erosional	24,413	24	9	<1	37	2	49	0	3
	RL&L (1989) [1988]	46 (19 km)	erosional	537	14	1	4	63	20	5	1	6
	Golder (1996a) [1995]	46 (19 km)	erosional	652	14	4	2	19	0	61	<1	13
	Golder (2002b) [2001]	46 (19 km)	depositional	22,738	11	6	0	0	<1	89	0	5
Green Stockings	Beak (1986) [1985]	51 (23 km)	erosional	12,419	19	7	<1	3	5	82	<1	3
	RL&L (1989) [1988]	51 (23 km)	depositional	16,412	14	4	0	0	<1	84	0	12
Wesukemina	Barton and Wallace (1980) [1976-1977]	47 (26 km)	all	n/a	n/a	12	2	3	1	59	0	23
	Golder (2002b) [2001]	207 (15 km)	depositional	62,496	21	<1	2	0	<1	71	0	26

(a) O = Oligochaeta; E = Ephemeroptera; P = Plecoptera; T = Trichoptera; C = Chironomidae; S = Simuliidae; Ot = Other.

(b) n/a = not available.

Figure 27 Seasonal Variation in Total Abundance, Richness and Community Composition at Three Sites in Muskeg Creek (data from RL&L 1989)

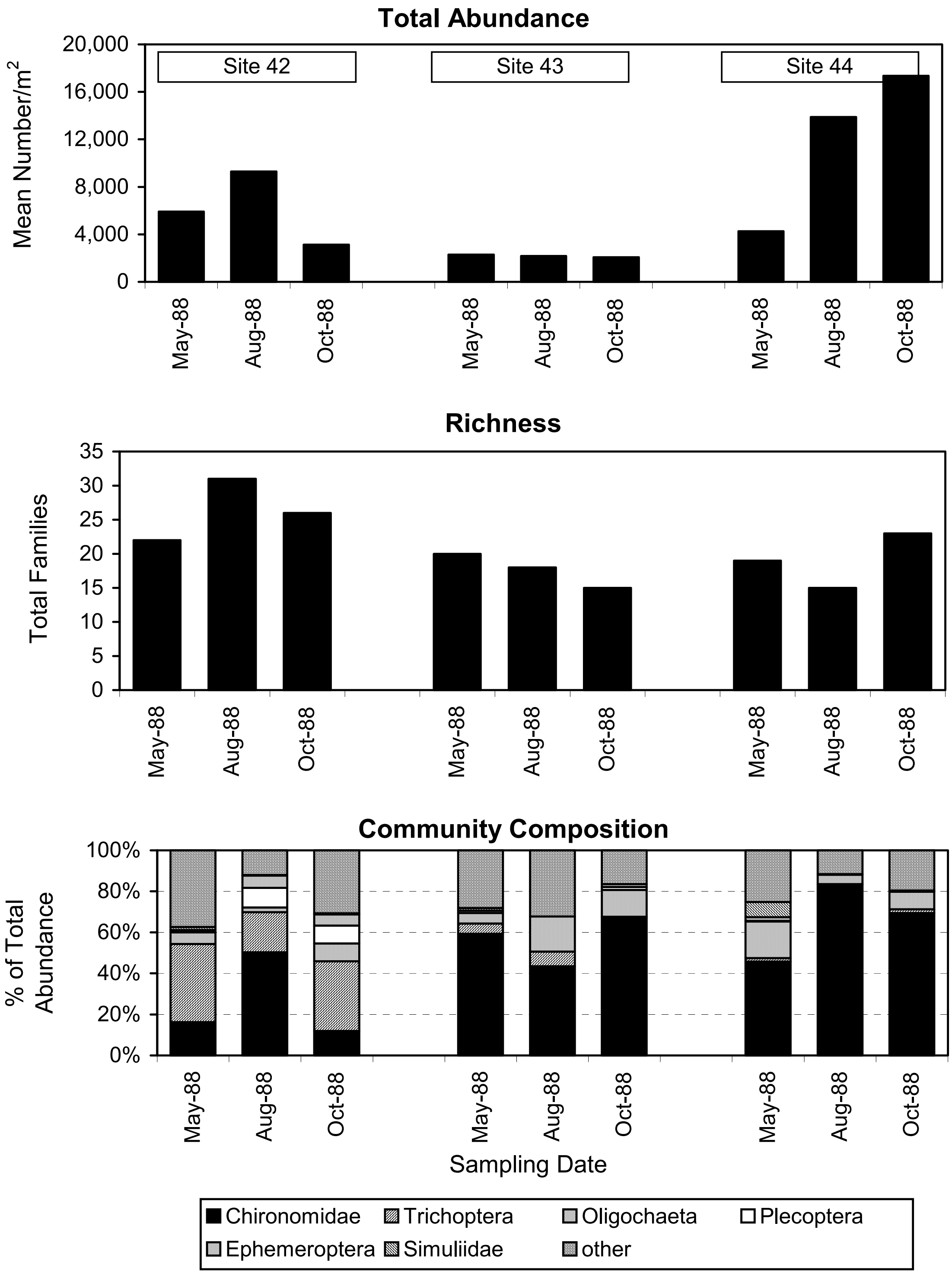
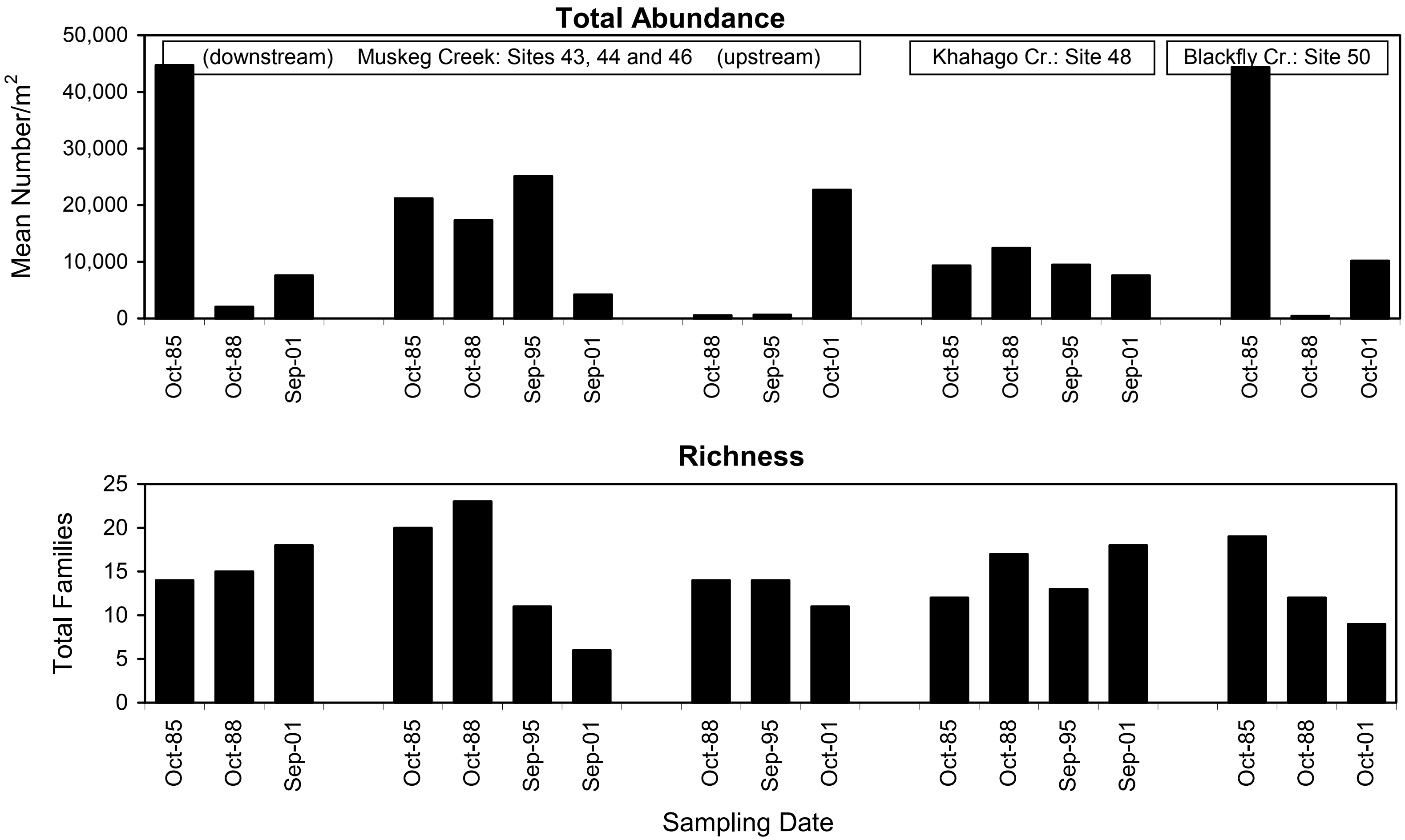
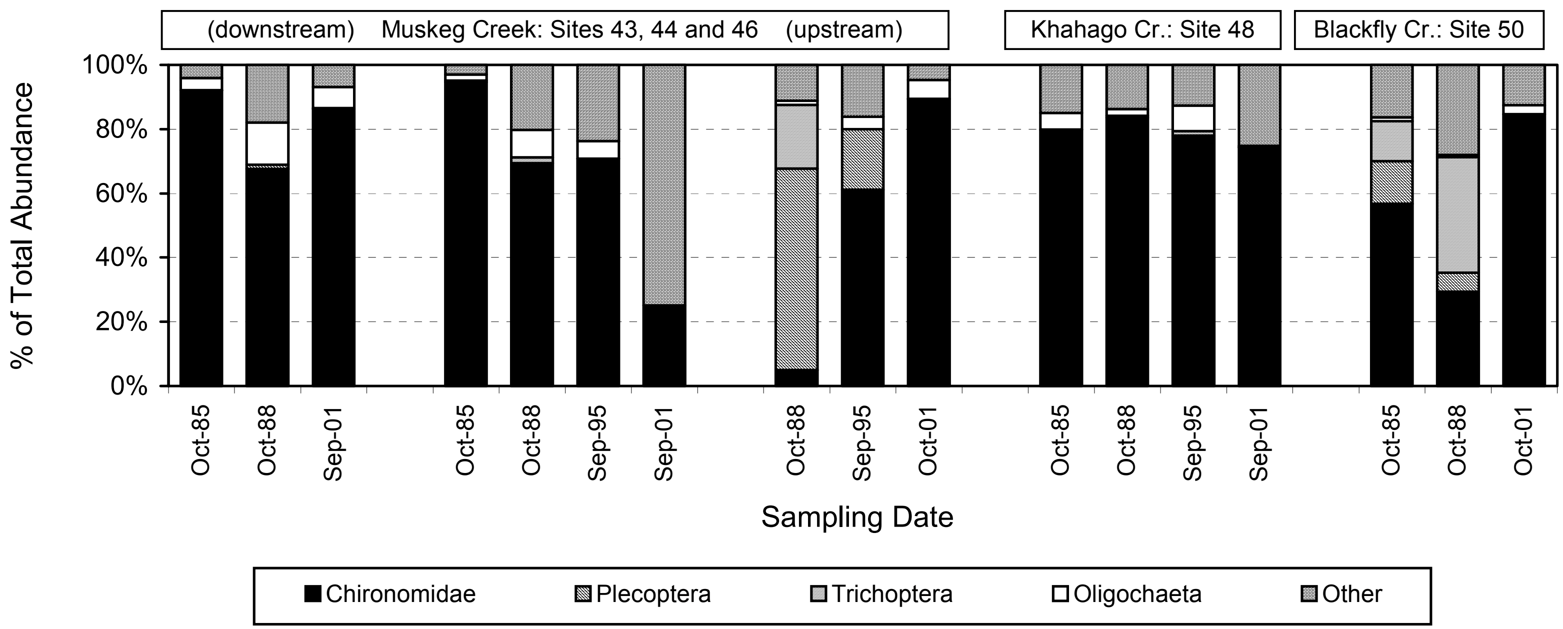


Figure 28 Variation Over Time in Benthic Community Characteristics at Five Sites in the Muskeg Creek Basin (data from sources identified in Table 22)



Note: Black bars = depositional habitat; white bars = erosional habitat

Figure 28 Variation Over Time in Benthic Community Characteristics at Five Sites in the Muskeg Creek Basin (continued)



Jackpine Creek

Total invertebrate abundance was highly variable in Jackpine Creek based on fall data, with a nearly 100-fold range overall (Table 23). Although both the minimum and maximum abundance values were at depositional sites, erosional sites were also characterized by high variability. Richness exhibited an approximately two fold range overall, and erosional sites clearly supported more diverse communities. Chironomid dominance was pronounced at depositional sites and, occasionally, at erosional sites as well, although erosional sites tended to support higher proportions of non-chironomid taxa. The combined proportion of EPT orders was higher at erosional sites, as expected. However, this group only made up a small proportion of the overall community. Minor taxa combined in the "other" category were more abundant in erosional habitat, accounting for the greater richness in this habitat.

All three sites sampled seasonally by RL&L (1989) were characterized by an increase in abundance over the open-water season (Figure 29). A consistent seasonal trend was not apparent in richness or community composition. There are insufficient data to evaluate long-term trends in Jackpine Creek at most sites. The limited available data suggest a decrease over time in abundance, no consistent change in richness and a decline in the proportion of chironomids (Figure 30).

Wapasu Creek

Limited data are available for Wapasu Creek, the major headwater tributary of the Muskeg River (Table 24). Total abundance reported from this stream during the fall was generally low (<10,000 organisms/m^2), except at sites sampled by Beak (1986), where 21,000 to >110,000 organisms/m^2 were found. Apart from the Beak (1996) data, there was little difference in abundance between samples collected from erosional and depositional sites. Richness was consistently higher in erosional habitat than at depositional sites. Chironomids were the dominant group at most locations. However, in the investigation by Beak (1986), the erosional site (Site 53) was dominated by blackflies (Simuliidae). One depositional site (Site 52) had a higher proportion of oligochaetes relative to other sites. There are insufficient data to evaluate long-term trends in Wapasu Creek.

Number of Taxa

At erosional sites in small streams in the Muskeg River basin, 153 taxa were reported during the fall, with 129 taxa at the genus level. Common groups included Nematoda, Oligochaeta, Chironomidae (as a group) *Baetis*, *Brachycentrus*, *Hydropsychidae* and *Optioservus*. There were 170 taxa at depositional sites, with 149 at the genus level. Common groups in this habitat included Nematoda, Oligochaeta (as a group), Sphaeriidae (as a group) Ostracoda and Chironomidae (as a group), all normally found in depositional habitats. A species list for all small streams sampled north of Fort McMurray is provided in Table III-3 (Appendix III) based on data from all seasons.

Table 23 Summary of Fall Historical Benthic Invertebrate Data for Jackpine Creek

Reference [year sampled]	Site (distance from mouth)	Habitat	Mean Total Abundance (no/m²)	Richness (total families)	Community Composition (%)[a]						
					O (%)	E (%)	P (%)	T (%)	C (%)	S (%)	Ot (%)
O'Neil et al. (1982) [1981]	36 (7 km)	erosional	26,227	28	6	7	1	6	73	0	7
	38 (11 km)	depositional	91,057	20	4	1	0	<1	84	0	11
	40 (21 km)	depositional	103,888	14	1	2	0	<1	92	0	4
RL&L (1989) [1988]	34 (565 m)	depositional	4,071	15	10	7	0	0	71	0	11
	39 (13 km)	depositional	13,588	17	<1	<1	0	<1	88	0	10
	41 (13 km)	depositional	19,737	14	1	0	0	<1	93	0	6
Golder (1996a) [1995]	34 (565 m)	erosional	2,684	29	5	11	<1	2	51	0	31
	38 (11 km)	erosional	1,926	27	12	15	5	5	29	<1	34
Shell (2002) [2001]	34 (565 m)	depositional	1,256	17	6	9	1	1	38	1	43
	36 (7 km)	erosional	2,451	30	4	31	6	13	19	0	26

[a] O = Oligochaeta; E = Ephemeroptera; P = Plecoptera; T = Trichoptera; C = Chironomidae; S = Simuliidae; Ot = Other.

Table 24 Summary of Fall Historical Benthic Invertebrate Data for Wapasu Creek

Reference [year sampled]	Site (distance from mouth)	Habitat	Mean Total Abundance (no/m²)	Richness (total families)	Community Composition (%)[a]						
					O (%)	E (%)	P (%)	T (%)	C (%)	S (%)	Ot (%)
Beak (1986) [1985]	52 (788 m)	depositional	21,213	10	34	0	0	<1	30	0	36
	53 (12 km)	erosional	113,817	20	<1	<1	<1	18	17	64	1
RL&L (1989) [1988]	52 (788 m)	depositional	7,539	17	9	5	0	<1	67	0	19
	53 (12 km)	depositional	6,163	13	<1	<1	0	0	77	0	22
	54 (20 km)	depositional	215	5	0	7	0	0	73	0	20
Komex (1997) [1997]	180 (11 km)	erosional	4,561	18	5	5	0	2	54	0	35
	181 (13 km)	erosional	6,519	23	3	2	0	3	61	<1	31

[a] O = Oligochaeta; E = Ephemeroptera; P = Plecoptera; T = Trichoptera; C = Chironomidae; S = Simuliidae; Ot = Other.

Figure 29 Seasonal Variation in Total Abundance, Richness and Community Composition at Three Sites in Jackpine Creek (data from RL&L 1989)

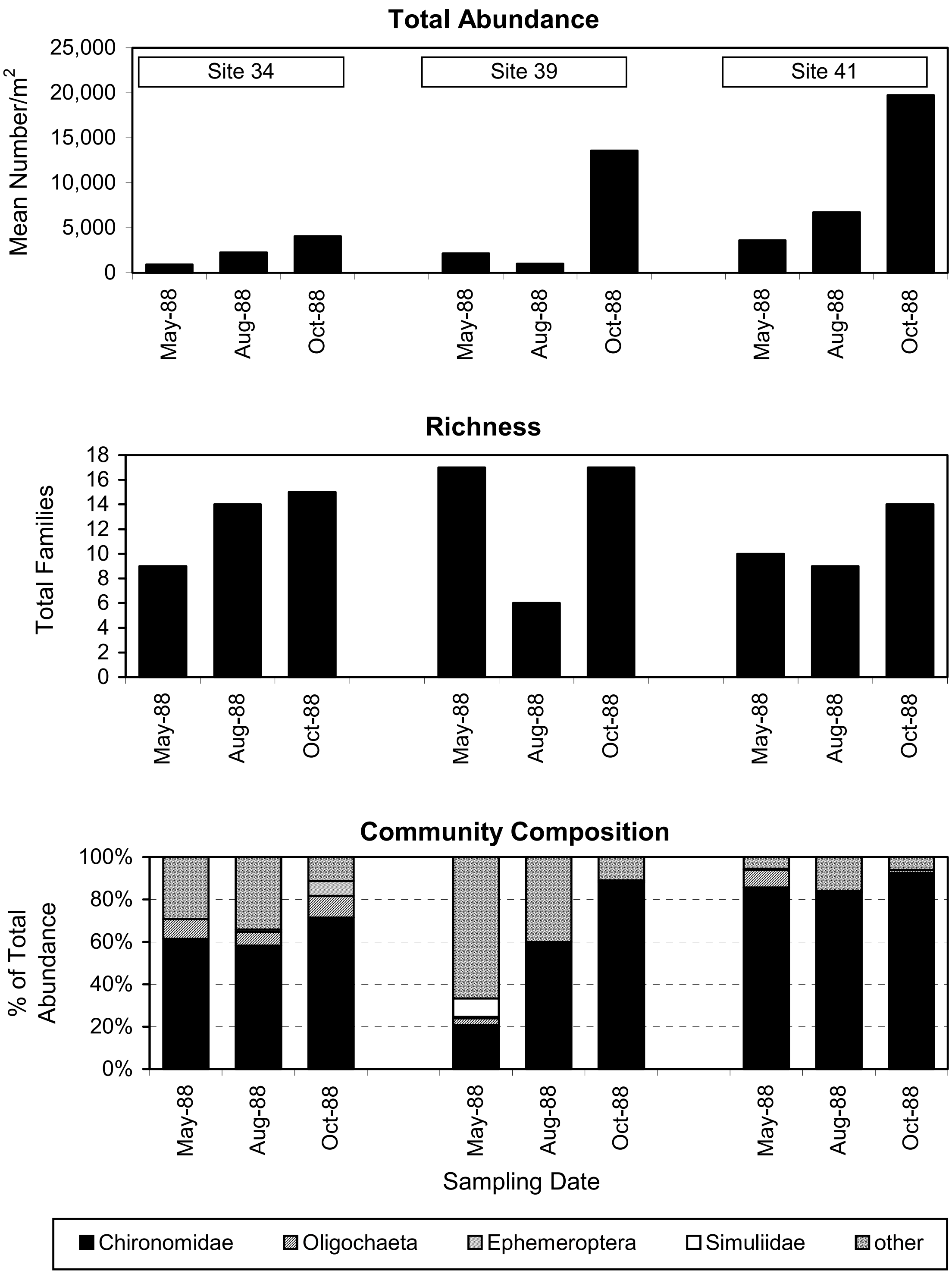
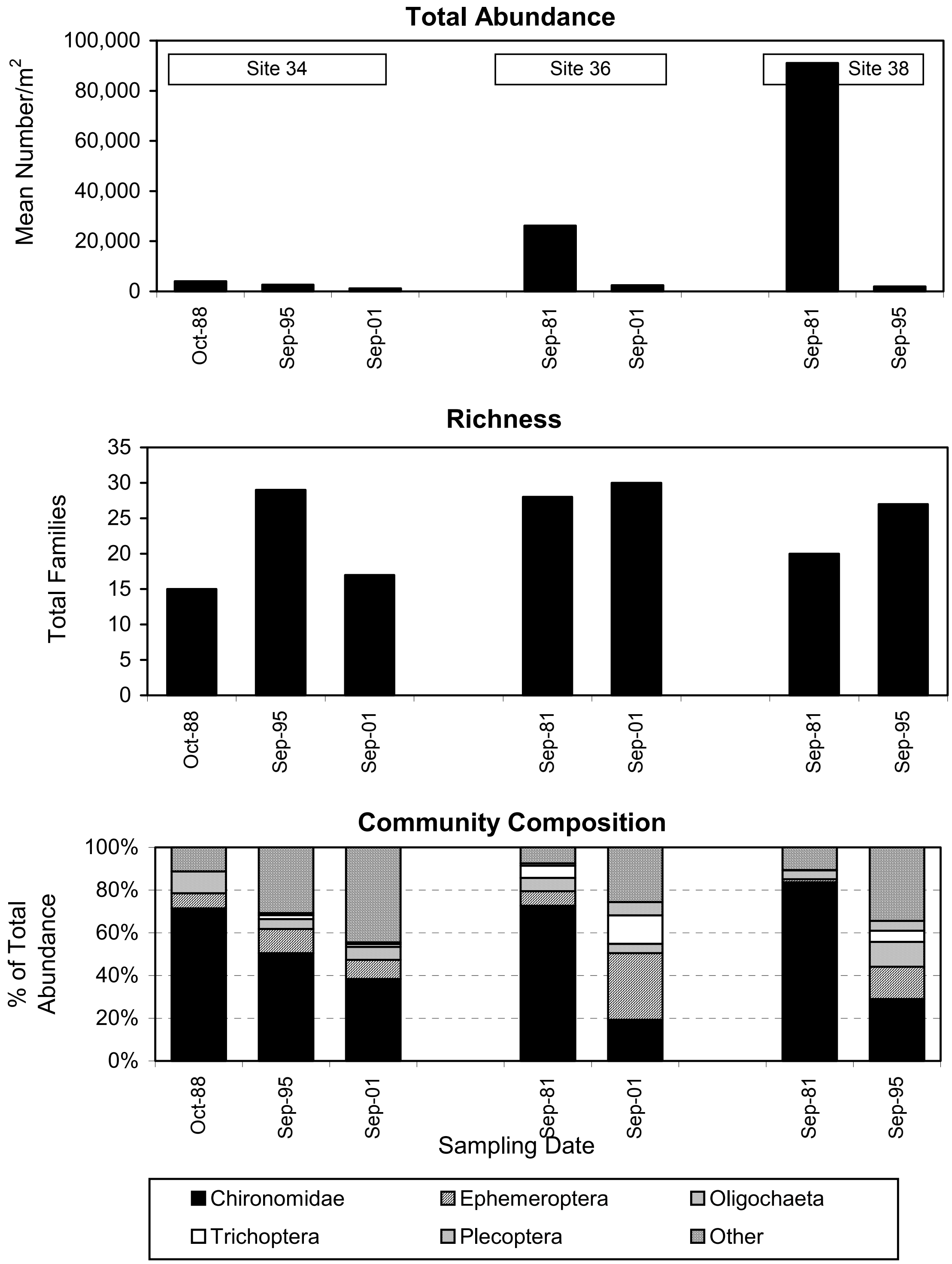


Figure 30 Variation Over Time in Benthic Community Characteristics at Three Sites in Jackpine Creek (data from sources identified in Table 23)



3.6.5 Other Small Streams

Compared to the streams described in preceding sections, other small streams received relatively little effort during previous studies, consisting mostly of occasional sampling at one or two sites per stream. Due to the relatively small amount of data available for these streams, no summaries are provided in this report, but general characteristics of studies and sampling locations are provided in Appendices I and II, and Figure 1.

3.7 RIVERS AND SMALL STREAMS SOUTH OF FORT McMURRAY

3.7.1 Introduction

Relatively few surveys of benthic invertebrates have been conducted in the southern Oil Sands Region. Within this document, this area is operationally defined as the area south of the Clearwater River to the Cold Lake Air Weapons Range. The four studies that sampled rivers and streams in this region to the end of 2001 include Tripp and Tsui (1980), Gulf (1979, 2001) and Rio Alto (2002). Three of these studies (Tripp and Tsui 1980; Gulf 1979; Rio Alto 2002) plus Petro–Canada (2002) also sampled standing waters. Site locations are shown in Figure 3; study details and study references for each site are provided in Appendices I and II.

In the sections that follow, benthic invertebrate data were summarized for August, which was the only month sampled by all of the three large-scale studies (Tripp and Tsui 1980; Gulf 1979, 2001). Rio Alto (2002) only sampled in May.

3.7.2 Hangingstone River

3.7.2.1 Studies Reviewed

The Hangingstone River and its tributaries, Saline and Prairie Creeks, were sampled by Tripp and Tsui (1980) in the spring, summer and fall of 1978 (Table 25). The objective of this investigation was to collect baseline data as part of AOSERP, to facilitate assessments of the effects of future development in the Oil Sands Region.

Nine erosional sites were sampled in the Hangingstone River and two in Saline Creek, using a Surber sampler. One depositional site was sampled in Prairie Creek using an Ekman grab. Samples were screened though a 600-μm mesh sieve, which is coarser than the sampling mesh (250 μm) typically used in the region north of Fort McMurray. Thus, caution should be used when comparing data from the two sub-regions.

Table 25 Study Details and Sampling Site Characteristics in the Hangingstone River Basin (data from Tripp and Tsui 1980)

Reference	Site Locations[(a)]	Sampling Method and Replication (sieve mesh size)	Habitat Type and Site Characteristics	Month/ Year Sampled
Tripp and Tsui (1980)	Hangingstone River: 1 km (Site 317) 7 km (Site 318) 15 km (Site 319) 33 km (Site 320) 42 km (Site 321) 59 km (Site 322) 63 km (Site 324) 69 km (Site 325) 81 km (Site 326) 98 km (Site 340) Prairie Creek: 13 km (Site 341) Saline Creek: 1 km (Site 342) 18 km (Site 344)	Surber, Ekman 3 replicates (600 μm)	erosional; width: 5-32 m; depth: 0.16-0.54 m; vel: 0.1-0.5 m/s; substrate: cobble and boulder with sand and gravel depositional; width: 1.6 m; depth: 0.5 m; vel: <0.1 m; substrate: sand/silt with organic material.	June, August and October 1978

[(a)] Site locations are shown in Figure 3; distances represent distance from mouth.

3.7.2.2 Summary of Historical Data

Substrates sampled in the Hangingstone basin were predominately coarse, consisting of cobble and boulders, or cobble with gravel and sand (Trip and Tsui 1980, Table 25). Habitat characteristics were similar at all sites, and the variation in depth and velocity was low, even between the widest (32 m) and narrowest (5 m) sites. Substrates at the single depositional site consisted mostly of sand and silt, with a large organic component.

Total invertebrate abundance was relatively low (<3,000 organisms/m^2), likely reflecting the large mesh size used. The most abundant community was observed at Site 317 (Table 26, Figure 31), the farthest downstream site on the Hangingstone River. There was no difference in abundance between the single depositional site in Prairie Creek and the erosional sites. Both sites on Saline Creek were characterized by low total abundance (<200 organisms/m^2).

Richness expressed as the total number of families was generally low and variable among sites (Figure 31). The number of families ranged from three at

Site 342 on Saline Creek to over 15 at three sites in the Hangingstone River. The number of families (9) at the depositional site on Prairie Creek was only slightly below the average of all sites (11) in the Hangingstone River basin (Table 26).

Community composition was variable among sites in the Hangingstone River basin (Figure 30). Chironomidae were dominant at Site 325 where sand was the dominant substrate component. Chironomidae and Oligochaeta together made up over 97 percent of the total abundance at Site 317, representing one of the wider reaches in this river. The EPT group was dominant at the other erosional sites. At the only depositional site on Prairie Creek, the "other" group, consisting mostly of fingernail clams (*Pisidium*), was the largest component of the community.

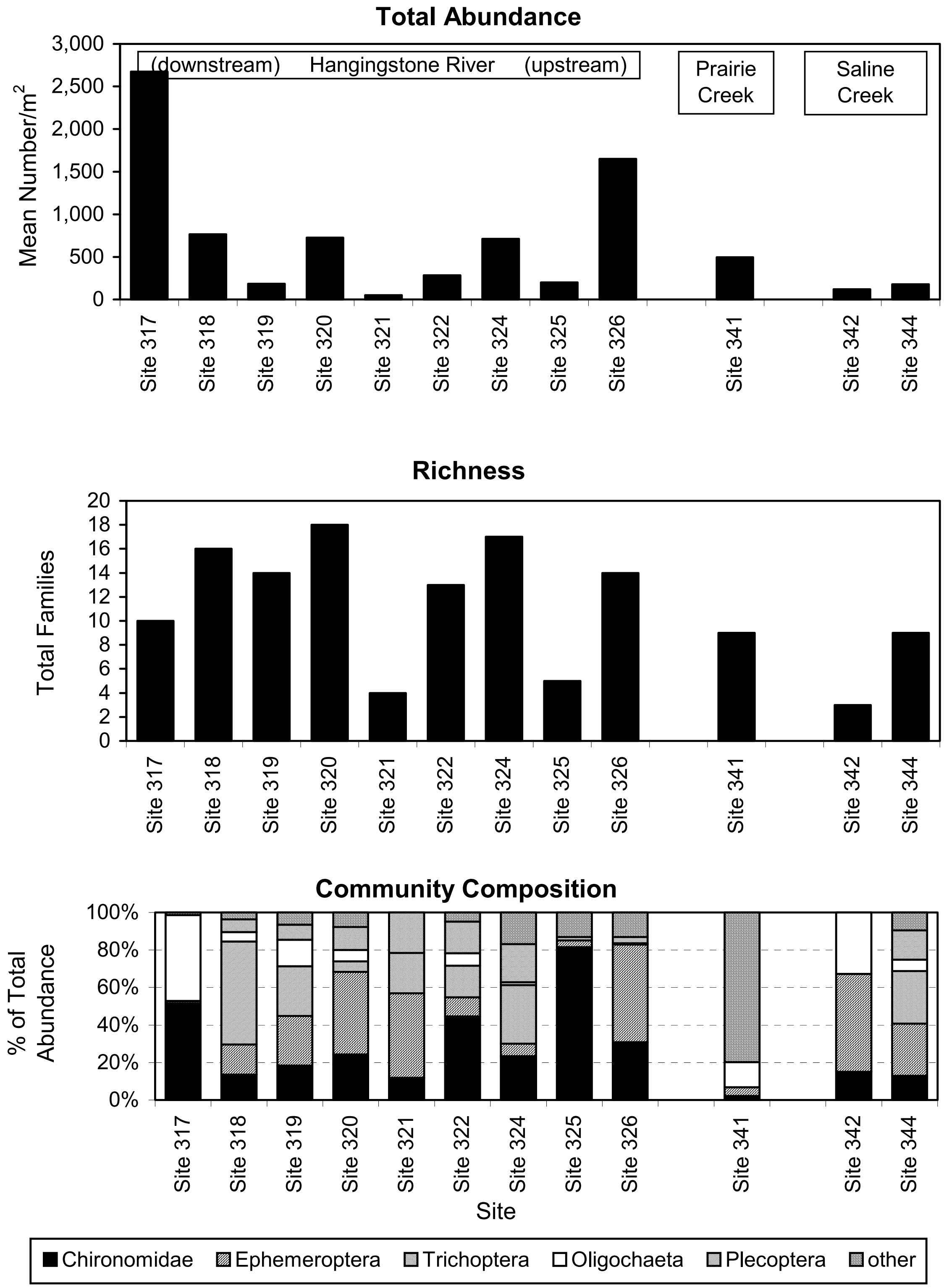
In total, 89 taxa were found in the Hangingstone River basin in August, with 81 taxa at the genus level. The Chironomidae was the richest group with 31 genera, followed by Ephemeroptera (11 genera), Plecoptera (9 genera) and Trichoptera (7 genera). Common taxa included the midge *Cricotopus*, the mayflies *Baetis* and *Heptagenia*, the caddisfly family Hydropsychidae (as a group) and genus *Brachycentrus*, and Plecoptera (as a group). A species list for all small streams sampled south of Fort McMurray is provided in Table III-4 (Appendix III) based on data from all seasons.

Table 26 Summary of Historical Benthic Invertebrate Data for the Hangingstone River Basin (data from Tripp and Tsui 1980)

Stream	Site (distance from mouth)	Habitat	Mean Total Abundance (no/m^2)	Richness (total families)	Community Composition (%)[a]						
					O (%)	E (%)	P (%)	T (%)	C (%)	S (%)	Ot (%)
Hangingstone River	Site 317 (1 km)	erosional	2,675	10	46	1	0	<1	52	0	1
	Site 318 (7 km)	erosional	767	16	5	16	7	55	14	1	2
	Site 319 (15 km)	erosional	185	14	14	26	8	26	18	0	6
	Site 320 (33 km)	depositional	726	18	6	44	12	6	24	3	5
	Site 321 (42 km)	erosional	51	4	0	45	22	22	12	0	0
	Site 322 (59 km)	erosional	285	13	7	10	17	17	45	0	5
	Site 324 (63 km)	erosional	712	17	2	7	20	31	23	<1	16
	Site 325 (69 km)	erosional	200	5	0	4	0	2	82	0	13
	Site 326 (81 km)	depositional	1,651	14	<1	52	3	0	31	0	13
	Site 340 (98 km)	erosional	1,424	15	<1	14	7	57	21	0	<1
Prairie Creek	Site 341 (13 km)	depositional	498	9	13	5	0	0	2	0	80
Saline Creek	Site 342 (1 km)	erosional	119	3	33	52	0	0	15	0	0
	Site 344 (18 km)	erosional	179	9	6	28	16	28	13	6	3

Source: Tripp and Tsui (1980); August 1978 data were summarized.
[a] O = Oligochaeta; E = Ephemeroptera; P = Plecoptera; T = Trichoptera; C = Chironomidae; S = Simuliidae; Ot = Other.

Figure 31 Total Abundance, Richness and Community Composition in the Hangingstone River Basin



3.7.3 Christina River Basin

3.7.3.1 Studies Reviewed

The Christina River and its tributaries were sampled three times, by two different studies in 1978 (Gulf 1979; Tripp and Tsui 1980) and once in 1998 (Gulf 2001) (Table 27). Two of these studies (Gulf 1979, 2001) collected baseline data for an *in situ* oil sands development in the Surmont Creek area. Tripp and Tsui (1980) collected baseline data as part of AOSERP.

Table 27 Study Details and Sampling Site Characteristics in the Christina River Drainage

Reference	Site Locations[(a)]	Sampling Method and Replication (sieve mesh size)	Habitat Type and Site Characteristics	Month/ Year Sampled
Gulf (1979)	Cottonwood Creek: 23 km (Site 369) 35 km (Site 370) 32 km (Site 371) 32 km (Site 372) 22 km (Site 373) Meadow Creek: 43 km (Site 374) 52 km (Site 375) Kinosis Creek: 40 km (Site 377) Kettle River basin: 16 km (Site 378) 14 km (Site 379) 20 km (Site 380) Unnamed tributaries: 31 km (Site 381) 30 km (Site 382)	Surber used as kicknet (850 µm) 3 replicates	erosional; depth: 0.2-0.3 m; substrate: gravel/cobble with sand depositional; depth: 0.9-1 m: substrate: silt/organic material	May, July and August 1978
Tripp and Tsui (1980)	Christina River: 1 km (Site 304) 11 km (Site 305) 21 km (Site 306) 27 km (Site 307) Gregoire River: 2 km (Site 312) 18 km (Site 314) 32 km (Site 315) Surmont Creek: 1 km (Site 348) 13 km (Site 349) 23 km (Site 350)	Surber Ekman 3 replicates (600 µm)	erosional; width: 6-65 m; depth: 0.2->0.5 m; current vel.:<0.1-0.6 m/s; substrate: gravel/cobble and cobble/boulder depositional; width: 3-13 m; depth: 0.2-0.5 m; current vel.: 0.1-0.3 m/s; substrate: sand/silt and organic material	June, August and October 1978

Table 27 Study Details and Sampling Site Characteristics in the Christina River Drainage (continued)

Reference	Site Locations[(a)]	Sampling Method and Replication (sieve mesh size)	Habitat Type and Site Characteristics	Month/ Year Sampled
Gulf (2001)	Cottonwood Creek: 23 km (Site 369) 26 km (Site 388) Meadow Creek: 48 km (Site 386) 55 km (Site 387) Kettle River: 12 km (Site 389)	Surber 3 replicates (250 µm)	erosional; substrate: silt/sand/ gravel	August 1998

(a) Site locations are shown in Figure 3; distances represent distance from mouth.

In the first study (Gulf 1979), a Surber sampler was used as a kicknet, rather than to sample a defined bottom area. The sampler mesh size was relatively large (850 µm) and samples were sorted without a microscope. For these reasons, results of this study are considered qualitative and total abundance was not calculated on a square metre basis.

Tripp and Tsui (1980) sampled with a Surber sampler and an Ekman grab. The mesh size used during this study was 600 µm. Tripp and Tsui (1980) also provided relatively detailed habitat tables. The third study (Gulf 2001) used a Surber sampler with a mesh size of 250 µm.

3.7.3.2 Summary of Historical Data

Most of the sites sampled in the Christina River basin were erosional (Table 28). However, there was considerable variability in habitat, ranging from predominantly sandy sites to gravel and boulder-dominated sites. Tripp and Tsui (1980) covered the largest geographical range and the widest range of habitats. Sites sampled by Gulf (2001) were generally similar in terms of habitat characteristics.

Total abundance was relatively low (<5,000 organisms/m^2) at the ten sites sampled by Tripp and Tsui (1980) in the northern part of the Christina River basin (Table 28, Figure 32), which likely resulted from the large mesh sampling net used. Among the Surmont Creek sites, the depositional site (Site 348) yielded a much higher abundance of benthic invertebrates than the two erosional sites (Sites 349 and 350). Based on the limited available data for sites in the southern portion of the basin (Gulf 2001), total abundance was also highly variable there (Table 28, Figure 33), ranging from close to 5,000 organisms/m^2 to >40,000 organisms/m^2. The higher abundances at most of the sites sampled by Gulf (2001) were most likely the result of the smaller mesh size used during the 1998 survey.

Table 28 Summary of Historical Benthic Invertebrate Data for the Christina River Basin

Reference [year sampled]	River/Stream	Site (distance from mouth)	Habitat	Mean Total Abundance (no/m²)	Richness (total families)	Community Composition (%)[a]						
						O (%)	E (%)	P (%)	T (%)	C (%)	S (%)	Ot (%)
Gulf (1979) [1978]	Cottonwood Creek basin	Site 369 (23 km)	erosional	-[b]	16	<1	1	20	3	64	0	11
		Site 370 (35 km)	erosional	-	13	2	2	17	<1	71	<1	7
		Site 371 (32 km)	erosional	-	17	1	24	39	11	10	1	13
		Site 372 (32 km)	erosional	-	7	21	3	24	3	44	0	5
		Site 373 (22 km)	depositional	-	7	11	0	0	26	37	0	26
	Meadow Creek	Site 374 (43 km)	erosional	-	18	<1	14	5	29	7	0	46
		Site 375 (52 km)	erosional	-	20	<1	42	48	3	5	<1	2
	Kinosis Creek	Site 377 (40 km)	depositional	-	2	0	0	0	0	95	0	5
	Kettle River basin	Site 378 (16 km)	erosional	-	17	<1	6	16	52	10	0	14
		Site 379 (14 km)	erosional	-	4	0	17	17	0	33	0	33
		Site 380 (20 km)	erosional	-	16	0	6	3	49	23	4	15
	unnamed tributaries of Christina River	Site 381 (31 km)	depositional	-	3	0	0	0	0	88	0	12
		Site 382 (30 km)	depositional	-	2	0	0	0	0	50	0	50
Tripp and Tsui (1980) [1978]	Christina River	Site 304 (1 km)	erosional	1,373	14	<1	35	10	9	43	0	2
		Site 305 (11 km)	erosional	1,109	15	<1	10	2	22	61	0	4
		Site 306 (21 km)	erosional	2,111	16	<1	7	3	28	40	0	21
		Site 307 (27 km)	erosional	643	12	<1	30	4	18	33	0	7
	Gregoire River	Site 312 (2 km)	erosional	312	14	7	40	22	11	8	0	13
		Site 314 (18 km)	depositional	486	7	0	5	5	14	50	0	27
		Site 315 (32 km)	depositional	513	11	3	2	2	80	10	0	2
	Surmont Creek	Site 348 (1 km)	depositional	4,128	8	2	2	0	<1	94	0	2
		Site 349 (13 km)	erosional	213	11	0	14	56	6	25	0	0
		Site 350 (23 km)	erosional	592	15	9	6	3	18	58	0	6

Table 28 Summary of Historical Benthic Invertebrate Data for Sites in the Christina River Basin (continued)

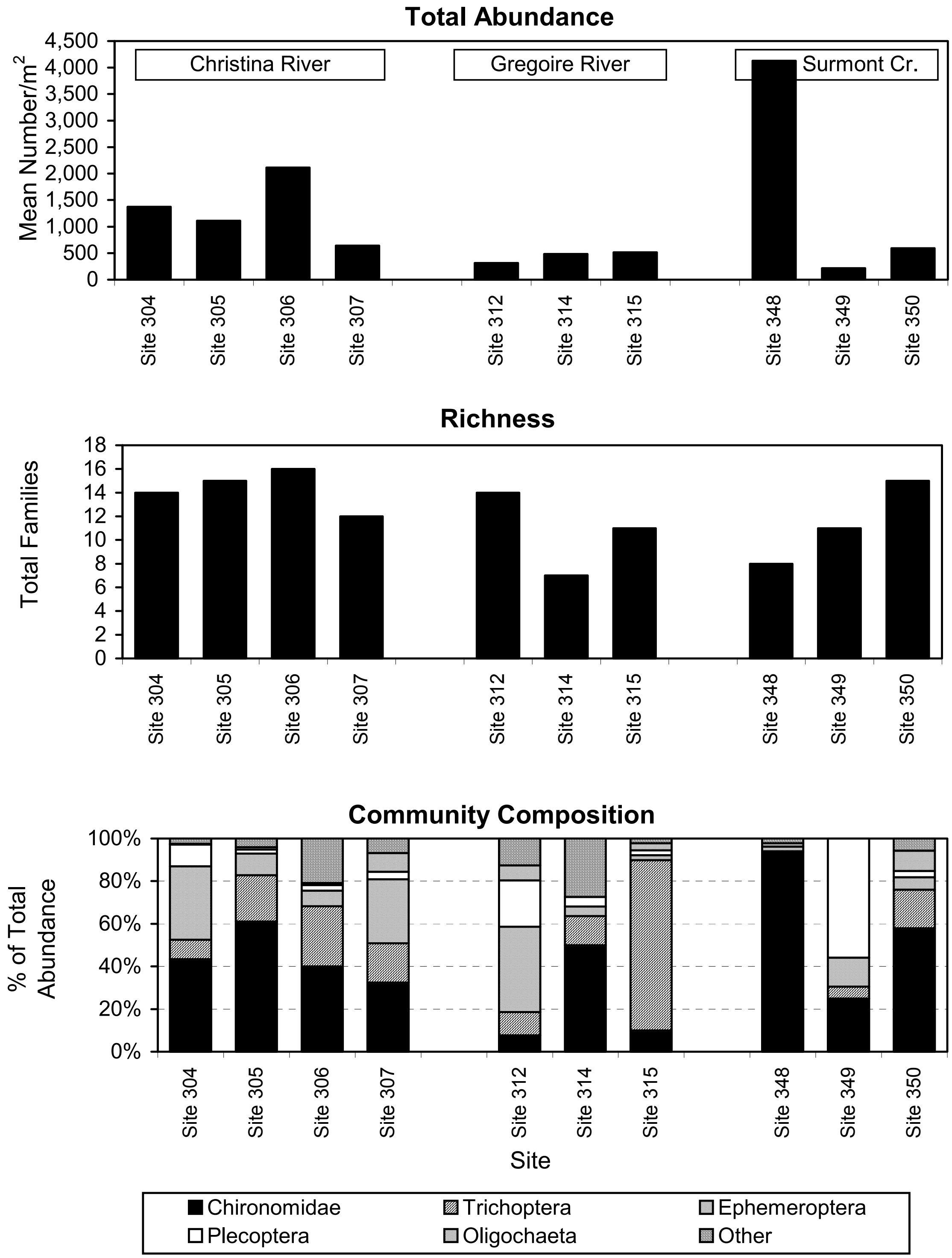
Reference [year sampled]	River/Stream	Site (distance from mouth)	Habitat	Mean Total Abundance (no/m^2)	Richness (total families)	Community Composition (%)[a]						
						O (%)	E (%)	P (%)	T (%)	C (%)	S (%)	Ot (%)
Gulf (2001) [1998]	Cottonwood Creek	Site 369 (23 km)	erosional	4,768	28	2	21	3	23	37	<1	14
		Site 388 (26 km)	erosional	21,051	26	4	32	6	28	21	<1	9
	Meadow Creek	Site 386 (48 km)	erosional	40,609	26	<1	2	0	<1	77	13	7
		Site 387 (55 km)	erosional	11,315	31	<1	25	16	50	5	1	4
	Kettle River	Site 389 (12 km)	erosional	36,742	20	<1	<1	<1	<1	96	0	3

Note: August data are shown.

[a] O = Oligochaeta; E = Ephemeroptera; P = Plecoptera; T = Trichoptera; C = Chironomidae; S = Simuliidae; Ot = Other.

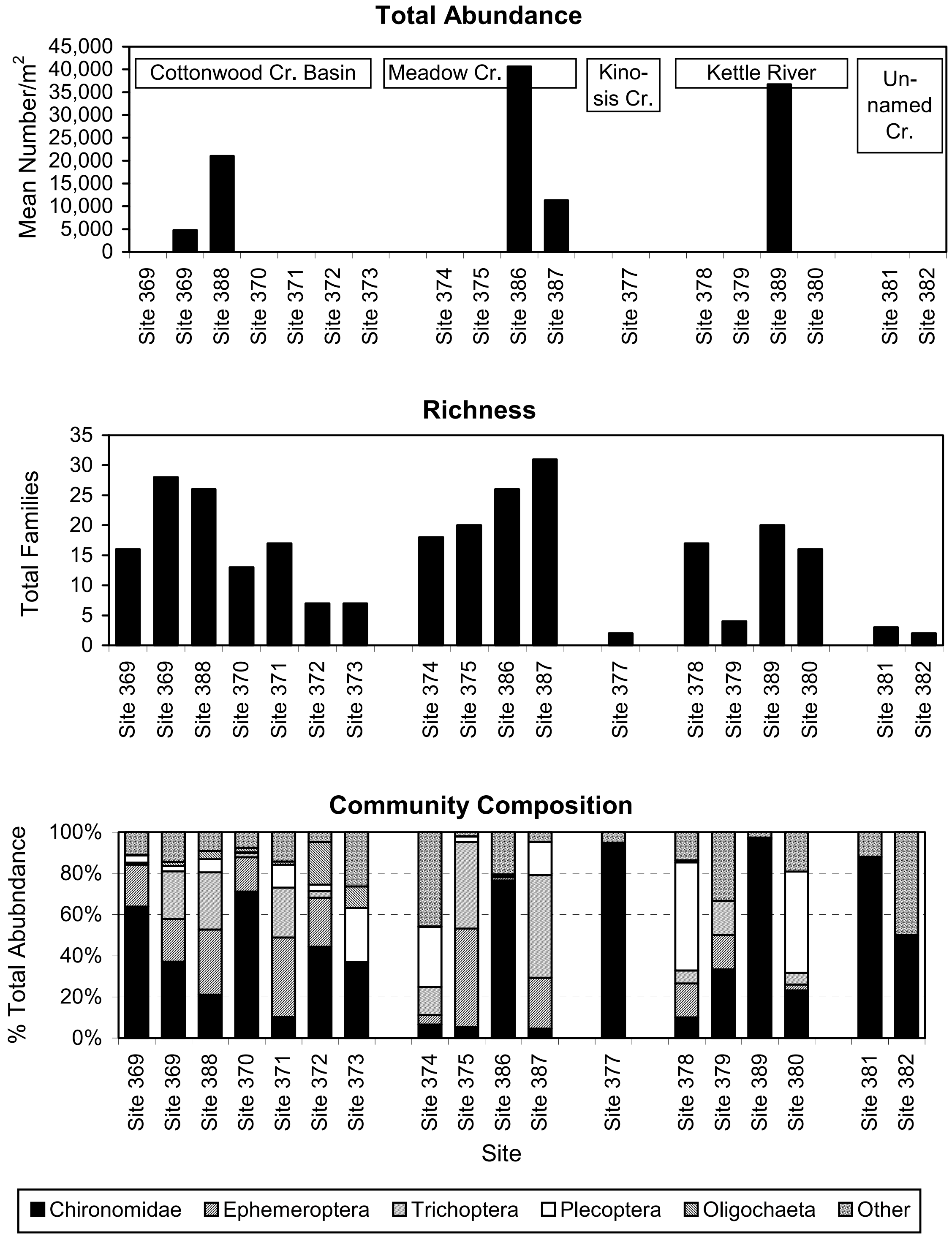
[b] Total abundance could not be calculated because only qualitative data were collected.

Figure 32 Total Abundance, Richness and Community Composition in the Northern Part of the Christina River Basin (data from Tripp and Tsui 1980)



Note: August data are shown; sites are ordered downstream to upstream in each river/stream.

Figure 33 Total Abundance, Richness and Community Composition in the Southern Part of the Christina River Basin (data from Gulf 1979 and 2001)



Note: August data are shown; sites are ordered downstream to upstream in each river/stream.

Richness was more variable in the southern part of the Christina River basin compared to the northern part (Table 28, Figures 32 and 33). The number of families ranged between seven and 16 at the northern sites sampled by Tripp and Tsui (1980). The number of families reported in the southern tributaries ranged from two to 31, with four sites having less than five families. Three of these four sites were erosional, which is unexpected in light of the greater diversity typically encountered in erosional habitat. Of the six sites that had 20 or more families, five were sampled by Gulf (2001), suggesting mesh size differences and different levels of taxonomic identification among studies contributed to the variation in richness.

Community composition was highly variable among sites in the northern part of the Christina River basin, with the exception of the Christina River (Figure 32). The percentage of Chironomidae appeared lower than usually observed in the region, which may also reflect the large mesh sampling net used by Tripp and Tsui (1980). At the southern sites, community composition ranged from extreme chironomid dominance (Sites 377 and 389) to relatively well balanced communities (e.g., Cottonwood Creek) (Figure 33).

There were few apparent trends in benthic community characteristics with distance upstream from the mouth of rivers and streams. Richness increased in an upstream direction in Surmont Creek (Figure 32) and Meadow Creek (Figure 33).

In total, 150 taxa were reported in the Christina River basin during late summer, with 132 taxa at the genus level. Frequently encountered taxa included oligochaete worms, chironomid midges, the mayflies *Baetis* and *Heptagenia*, and the caddisflies *Glossosoma*, *Brachycentrus* and *Hydropsyche*. A species list for all small streams sampled south of Fort McMurray is provided in Table III-4 (Appendix III) based on data from all seasons.

3.7.4 Other Basins

3.7.4.1 Studies Reviewed

Rivers and streams in other basins south of Fort McMurray were sampled by Tripp and Tsui (1980) in various tributaries of the Clearwater River, and by Rio Alto (2002) in a small stream draining to Wiau Lake (Table 29). Tripp and Tsui (1980) characterized the baseline state of the aquatic environment as part of AOSERP and Rio Alto (2002) collected baseline data for an *in situ* oil sands development.

Table 29 Study Details and Sampling Site Characteristics for Rivers and Streams Draining to the Clearwater River and Wiau Lake

Reference	Site Locations[a]	Sampling Method and Replication (sieve mesh size)	Habitat Type and Site Characteristics	Month/ Year Sampled
Tripp and Tsui (1980)	Algar River: 5 km (Site 301) 28 km (Site 302) 50 km (Site 303) Horse River: 1 km (Site 327) 28 km (Site 328) 88 km (Site 329) 140 km (Site 340) Cameron Creek: 0.5 km (Site 332) Saprae Creek: 1 km (Site 345) 5 km (Site 346) 15 km (Site 347)	Surber, Ekman 3 replicates (600 µm)	erosional: width: 2-30 m; depth: 0.1-0.5 m; current vel.: >0.1-0.6 m/s; substrate: gravel/cobble/ boulder depositional: width: 3-16 m; depth: 0.2-1.3 m; current vel.: non-measurable to 0.3 m/s; substrate: sand/silt/organic	June, August and October 1978
Rio Alto (2002)	unnamed stream upstream of Wiau Lake: 1.6 km (Site 351) 7 km (Site 368)	Ekman 3 replicates (500 µm)	depositional: highly ponded due to beaver activity.	May 2002

[a] Site locations are shown in Figure 3.

Trip and Tsui (1980) sampled four streams in June, August and October of 1978, with up to four sites in each stream (Table 29). Sampling was done mostly in erosional habitat, except for two sites in the Algar River, where depositional habitat was predominant. An Ekman grab was used at the two depositional sites and a Surber sampler was used at the erosional sites. The second study (Rio Alto 2002) sampled two depositional sites upstream of Wiau Lake in May 2002 using an Ekman grab. Mesh sizes used by these studies were comparable, at 600 and 500 µm.

3.7.4.2 Summary of Historical Data

The erosional sites had variable substrates (Table 29). Samples were taken in gravel and cobble with some boulders; however, a few sites were dominated by sand and silt. Substrates at the two depositional sites in the Algar River consisted of relatively high amounts of organic detritus (Tripp and Tsui 1980). The unnamed stream that drains to Wiau Lake runs through predominantly muskeg terrain and was highly ponded due to beaver activity. Substrates were predominantly fine at these sites and stream flow was non-measurable to very low (Rio Alto 2002).

Total invertebrate abundance was relatively low at these sites (≤3,000 organisms/m^2), in part reflecting the large mesh sizes used by these studies (Table 30, Figure 34). Richness ranged from three families (Site 302 in the Algar River) to 18 families (Site 328 in the Horse River and Site 347 in Saprae Creek). Community composition was variable. Communities were usually dominated by caddisflies, chironomid midges and oligochaete worms, although mayflies were occasionally abundant.

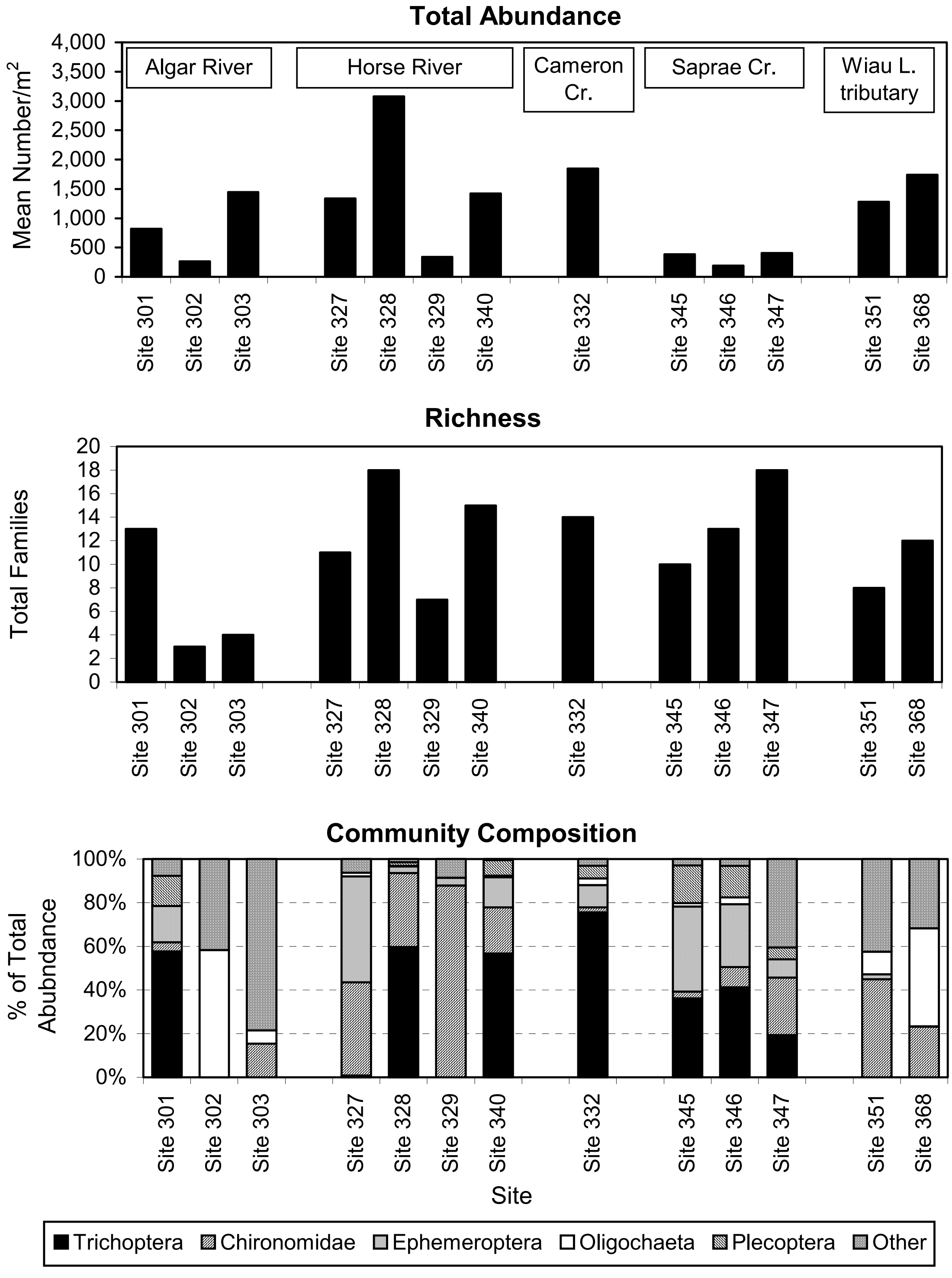
In total, 88 taxa were reported from these sites, with 92 at the level of genus. Common taxa included oligochaete worms, chironomids, the mayflies *Baetis, Heptagenia*, and the caddisflies *Brachycentrus* and *Hydropsyche*. The most diverse group was the Chironomidae, with 32 genera. A species list for all small streams sampled south of Fort McMurray is provided in Table III-4 (Appendix III) based on data from all seasons.

Table 30 Summary of Historical Benthic Invertebrate Data for Rivers and Streams Draining to the Clearwater River and Wiau Lake

Reference [year sampled]	River/Stream	Site (distance from mouth)	Habitat	Mean Total Abundance (no/m²)	Richness (total families)	Community Composition (%)[a]						
						O (%)	E (%)	P (%)	T (%)	C (%)	S (%)	Ot (%)
Tripp and Tsui (1980) [1978]	Algar River	Site 301 (5 km)	erosional	817	13	0	17	14	58	4	<1	7
		Site 302 (28 km)	depositional	266	3	58	0	0	0	0	0	42
		Site 303 (50 km)	depositional	1,443	4	6	0	0	0	15	0	78
	Horse River	Site 327 (1 km)	erosional	1,337	11	2	49	0	<1	43	2	5
		Site 328 (28 km)	erosional	3,079	18	<1	3	2	60	34	<1	1
		Site 329 (88 km)	depositional	338	7	0	4	0	0	88	0	9
		Site 340 (140 km)	erosional	1,424	15	<1	14	7	57	21	0	<1
	Cameron Creek	Site 332 (0.5 km)	erosional	1,848	14	3	10	6	76	2	0	3
	Saprae Creek	Site 345 (1 km)	erosional	387	10	2	39	17	36	3	0	3
		Site 346 (5 km)	erosional	194	13	3	29	14	41	9	0	3
		Site 347 (15 km)	depositional	407	18	0	8	5	19	26	8	32
Rio Alto (2002) [2002]	unnamed tributary of Wiau Lake	Site 351 (0.1 km)	depositional	1,280	8	10	2	0	0	45	0	42
		Site 368 (7 km)	depositional	1,742	12	45	<1	0	0	23	0	32

Note: August data are shown for Tripp and Tsui (1980); Rio Alto (2002) sampled in May.
[a] O = Oligochaeta; E = Ephemeroptera; P = Plecoptera; T = Trichoptera; C = Chironomidae; S = Simuliidae; Ot = Other.

Figure 34 Total Abundance, Richness and Community Composition in Rivers and Streams Draining to the Clearwater River and Wiau Lake (data from Tripp and Tsui (1980) and Rio Alto (2002)



Note: August data are shown for the Algar and Horse rivers, and for Cameron and Saprae creeks; May data are shown for Wiau Lake tributary; sites are ordered downstream to upstream in each river/stream.

4 SUMMARY AND CONCLUSIONS

This review provided an overview of historical benthic invertebrate data in the Oil Sands Region and described the fauna of four major rivers and a large number of small streams in the Oil Sands Region. The amount of potentially useful historical data is considerable, despite losses of the raw data collected by some of the early studies. Most of the historical data appear to be of good quality and were collected using standard benthic sampling devices that are still widely used. The amount and quality of supporting environmental data varies greatly by survey. Site-specific supporting data collected by a number of the earlier studies are very limited. Therefore, compilation of a consistent supporting data set would require a large additional effort and it may not be possible to generate a complete environmental data set.

The majority of the historical data was collected at reference sites or during the pre-development period. Sampling sites are relatively evenly distributed among the different types of surface waters (major rivers, small streams, lakes) in the region. Based on sampling methods used in natural substrates and type of waterbody sampled, the data can be grouped into two major riverine habitat types: erosional and depositional. The seasonal distribution of the historical data shows a bias toward fall sampling in the Athabasca River. There is no pronounced bias in other rivers and streams, which were sampled with similar effort in all months between May and October.

Summaries of available data for major rivers revealed that benthic invertebrate abundance tends to be low in erosional habitat (<20,000 organisms/m^2). Abundances of depositional communities are higher on average, but also considerably more variable. Taxonomic richness is usually higher in erosional habitat. The total number of taxa collected in a river by studies using standard quantitative sampling methods ranged from about 100 (MacKay and Steepbank rivers) to about 180 (Athabasca and Muskeg rivers), using genus as the lowest level of identification. The rivers with greater numbers of taxa encompass wider ranges in habitat features, but were also sampled with greater effort in the past. Composition of benthic communities varied widely within and among rivers, and usually displayed the typical distinction between erosional (diverse) and depositional (chironomid dominated) communities. A number of studies reported increases in abundance and richness through the open-water season; clear seasonal trends in community composition were not apparent. There were no obvious long-term trends in benthic community characteristics at sites sampled repeatedly over the past 25 years, although in some cases changes in sampling design have resulted in lack of comparability among years.

As a result of this review, the majority of the available historical data for rivers and streams is now in electronic format for potential future analysis (see attached CD-ROM for all raw data summarized in this report). Since long-term trends were not found in benthic community variables, the historical data are still applicable.

Specific uses of the historical data have not been identified at this time, but may include the following:

- use as baseline data in future assessments of the effects of specific disturbances (i.e., in conventional before/after effects assessments);
- refinement of the sampling designs of future monitoring, by
  - selecting sites that have been successfully sampled in the past;
  - selecting the appropriate habitat to be monitored and the corresponding sampling technique;
  - evaluating seasonal trends and selecting the appropriate monitoring season;
  - estimating the number of samples required for collecting representative data from a site;
  - conducting power analysis to determine the required number of replicate sampling units for future studies comparing sites or reaches; and
  - estimating ecologically significant effect sizes for statistical analysis of monitoring data;
- characterizing year-to-year variability and establishing baseline ranges for key benthic community variables;
- assessment of relationships between benthic community characteristics and key environmental variables (e.g., flow-related variables); and
- possible use of the historical data in an initial RCA-type analysis; this type of analysis would require generating a consistent supporting environmental data set, including key variables that have been successfully used in the past to assign historical sites to specific reference conditions.

5 CLOSURE

We trust the above meets your present requirements. If you have any questions or require additional details, please contact the undersigned.

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APPENDIX I

SUMMARY OF THE AMOUNT AND TYPE OF HISTORICAL BENTHIC INVERTEBRATE DATA

Table I-1 Summary of the Amount and Type of Historical Benthic Invertebrate Data in the Oil Sands Region by River and Lake (1974 to 2001) (continued)

Reference	Research program/ funder	Waterbody	Survey year	Survey month	Habitat	Total number of sites	Number of potentially impacted sites	Number of sites in man-made channels or impoundments	Number of reference sites	Number of reference sites sampled by month: Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Sampling device (type/bottom area as m^2)	Number of replicates/ site	Mesh size (µm)	Typical level of taxonomy	Supporting data	Raw data availability	Comment
Athabasca River																									
Ouellet and Cash (1996)	Alberta Envt.	Athabasca R	1987	Sep	depositional	5	2		3							3			Ekman (0.0231)	10	210	genus	field WQ, substrate, sample depth	BONAR[(a)]	
Ouellet and Cash (1996)	Alberta Envt.	Athabasca R	1987	Aug	erosional	4	2		2						2				Neill (0.1)	5	210	genus	field WQ, substrate, sample depth	BONAR	
Anderson (1991)	Alberta Envt.	Athabasca R	1983	May, Sep	erosional	2			2			2				2			Neill (0.1)	5	210	genus	field WQ, substrate, sample depth	BONAR	
Anderson (1991)	Alberta Envt.	Athabasca R	1984	May, Sep	erosional	2			2			2				2			Neill (0.1)	5	210	genus	field WQ, substrate, sample depth	BONAR	
Anderson (1991)	Alberta Envt.	Athabasca R	1985	May, Sep	erosional	2			2			2				2			Neill (0.1)	5	210	genus	field WQ, substrate, sample depth	BONAR	
Anderson (1991)	Alberta Envt.	Athabasca R	1986	May, Sep	erosional	2			2			2				2			Neill (0.1)	5	210	genus	field WQ, substrate, sample depth	BONAR	
Anderson (1991)	Alberta Envt.	Athabasca R	1987	Jun, Aug/Sep	erosional	2			2				2		2				Neill (0.1)	5	210	genus	field WQ, substrate, sample depth	BONAR	
Barton and Wallace (1980)	AOSERP	Athabasca R	1976	Oct	depositional	4			4								4		Ekman (0.0232)	6-10	202	genus/ species	substrate, depth	n/a	no raw data (richness only)
Barton and Wallace (1980)	AOSERP	Athabasca R	1977	Sep	depositional	2			2							2			Ekman (0.0232)	3	202	genus/ species	substrate, depth	n/a	no raw data (richness only)
Barton and Wallace (1980)	AOSERP	Athabasca R	1977	Sep	erosional	4			4							4			Surber (0.09)	3	202	genus/ species	substrate, depth	n/a	no raw data (richness only)
Barton and Wallace (1980)	AOSERP	Athabasca R	1977	Jun-Oct (monthly, plus May at 1 site)	depositional	6	2		4				4	4	4	4	4		Ekman (0.0232), airlift	3	202	genus/ species	monthly discharge	n/a	no raw data (summary info only); AS attempt failed
Boerger (1983a)	Alberta Envt.	Athabasca R	1981	May-Aug (every 2 wks, exc. Aug)	erosional	16	2		14			28	28	28	18				Hess (0.1)	3	250	genus exc. chironomids	depth, current, discharge, some WQ, field WQ,	hardcopy	
Corkum (1984, unreleased)	Alberta Envt.	Athabasca R	1983	May, Sep	erosional	17	3		14			14				14			Neill (0.1)	3	210	genus exc. chironomids	WQ, depth, current, field WQ, substrate	hardcopy	
Dunnigan and Millar (1993)	NRBS	Athabasca R	1993	Mar	erosional	1			1	1									Neill (0.1)	10	210	genus	WQ, current, depth, substrate, periphyton	BONAR	
EVS (1986)	Suncor	Athabasca R	1986	Jun, Jul	erosional?	6	3 (2 AS)		3				3	3					Neill (0.1), AS (basket)	5	250	genus	current, field WQ, periphyton	hardcopy	some AS samplers lost
EVS (1996)	Suncor	Athabasca R	1995	Sep/Oct	depositional	12	2		10							10			Ekman (0.0232), AS (basket)	1, 3	250	genus	field WQ, WQ, current, depth, substrate	electronic	AS samplers lost from 1 reference site
Golder (1998a)	RAMP	Athabasca R	1997	Sep	depositional	12	3		9							9			Ekman (0.0232)	6	250	genus	field WQ, WQ, current, depth, substrate	electronic	
IEC Beak (1983), Beak (1988)	Suncor	Athabasca R	1982	Aug/Sep	depositional	7	5		2						2				AS (baskets)	6	250	genus	field WQ, some WQ, current velocity, substrate, total depth, sampler depth, detritus weight	hardcopy	
Jacques Whitford (2002)	Suncor	Athabasca R	2001	Sep	depositional	n/a													Ekman (0.0232)	n/a	n/a	n/a	n/a	n/a	report not available
McCart et al. (1977)	Syncrude	Athabasca R	1975	Jun-Oct (monthly)	depositional	15	7		8				8	7	7	7	6		Ekman (0.0232), AS (basket)	3	600	genus	WQ, periphyton	n/a	no raw data; pooled data for all months, (summary info only)
Noton (1979)	GCOS (now Suncor)	Athabasca R	1978	Sep/Oct	depositional	10	6		4							4			Ekman (0.0225), AS (basket)	9, 3	250	genus exc. chironomids	depth, field WQ, WQ, TOC	hardcopy	
Noton and Anderson (1982)	Suncor	Athabasca R	1981	Sep	depositional	10	6		4							4			Ekman (0.0225), AS (basket)	5, 3	250	genus	depth, field WQ, WQ, substrate, current velocity	hardcopy	
Major Athabasca River Tributaries - MacKay River																									
Golder (1999)	RAMP	MacKay R	1998	Sep	erosional	3			3							3			Neill (0.093)	5	250	genus	field WQ, WQ, stream width, current, depth, substrate, periphyton	electronic	
Golder (2001)	RAMP	MacKay R	2000	Sep	erosional	1 reach			1 reach							1 reach			Neill (0.093)	15	250	genus	field WQ, stream width, current, depth, substrate, periphyton	electronic	
Golder (2002a)	RAMP	MacKay R	2001	Sep	erosional	1 reach			1 reach							1 reach			Neill (0.093)	15	250	genus	field WQ, stream width, current, depth, substrate, periphyton	electronic	
McCart et al. (1978)	Syncrude	Mackay R	1977	May-Sep (monthly)	erosional	3			3			3	3	3	3	3			Surber (0.093), AS (basket)	3	600	genus	stream width, depth, substrate, WQ, periphyton	hardcopy	drift study also done
RL&L and AA Aquatic Res. (1985)	Syncrude	MacKay R	1984	Jun, Jul, Sep	erosional	4			4				4	4		4			Neill (0.1)	3	250	genus exc. chironomids	discharge, stream order, depth, current, some WQ	hardcopy	qualitative kicknet samples also collected
Major Athabasca River Tributaries - Muskeg River																									
Barton and Wallace (1980)	AOSERP	Muskeg R	1976	Jul, Oct	all (kicknet)	4			4					4			4		15 min kicknet samples (500)	1	500	genus/ species	stream width, depth, current	n/a	no raw data (summary info only)
Barton and Wallace (1980)	AOSERP	Muskeg R	1977	May, Jul	all (kicknet)	4			4			4		4					15 min kicknet samples (500)	1	500	genus/ species	stream width, depth, current	n/a	no raw data (summary info only)
Beak (1986)	OSLO	Muskeg R	1985	Oct	depositional	5			5								5		Ekman (0.0232)	3	180	genus	field WQ, WQ, current, depth, periphyton, width, substrate	hardcopy	
Crowther and Lade (1980)	AOSERP	Muskeg R	1979	Jul, Aug, Sep	erosional	3			3					3	3	2			Neill (0.0707)	10	250	genus/ species	depth, substrate	hardcopy	site means only
Golder (1996a)	Syncrude	Muskeg R	1995	Sep/Oct	depositional	2			2							2			Ekman (0.0232)	3	250	genus	field WQ, WQ, depth, substrate	electronic	
Golder (1996a)	Syncrude	Muskeg R	1995	Sep/Oct	erosional	1			1							1			Neill (0.093)	3	250	genus	field WQ, WQ, depth, substrate	electronic	
Golder (1999)	RAMP	Muskeg R	1998	Sep	erosional	3			3							3			Neill (0.093)	5	250	genus	field WQ, WQ, stream width, current, depth, substrate, periphyton	electronic	
Golder (2001)	RAMP	Muskeg R	2000	Sep	erosional	1 reach			1 reach							1 reach			Neill (0.093)	15	250	genus	field WQ, stream width, current, depth, substrate, periphyton	electronic	
Golder (2001)	RAMP	Muskeg R	2000	Sep	depositional	1 reach			1 reach							1 reach			Ekman (0.0232)	15	250	genus	field WQ, stream width, current, depth, substrate, periphyton	electronic	
Golder (2002a)	RAMP	Muskeg R	2001	Sep	erosional	1 reach			1 reach							1 reach			Neill (0.093)	15	250	genus	field WQ, stream width, current, depth, substrate, periphyton	electronic	
Golder (2002a)	RAMP	Muskeg R	2001	Sep	depositional	1 reach			1 reach							1 reach			Ekman (0.0232)	15	250	genus	field WQ, stream width, current, depth, substrate, periphyton	electronic	
Golder (2002b)	Syncrude	Muskeg R	2001	Sep	depositional	2			2							2			Ekman (0.0232)	5	250	genus	field WQ, WQ, SQ, depth, width, current, depth, substrate	electronic	
Komex (1997)	Mobil	Muskeg R	1997	May, Aug	depositional	3			3			2			3				Ekman (0.0232)	5	not reported	genus exc. chironomids	field WQ, current, depth, discharge, substrate	hardcopy	
RL&L (1989)	OSLO	Muskeg R	1988	May/Jun, Aug, Oct	depositional	6			6			6			6		6		Ekman (0.0232)	3	180	genus exc. chironomids	field WQ, WQ, current, depth, substrate	hardcopy	

Table I-1 Summary of the Amount and Type of Historical Benthic Invertebrate Data in the Oil Sands Region by River and Lake (1974 to 2001) (continued)

Reference	Research program/ funder	Waterbody	Survey year	Survey month	Habitat	Total number of sites	Number of potentially impacted sites	Number of sites in man-made channels or impoundments	Number of reference sites	Number of reference sites sampled by month									Sampling device (type/bottom area as m^2)	Number of replicates/ site	Mesh size (µm)	Typical level of taxonomy	Supporting data	Raw data availability	Comment
										Mar	Apr	May	June	July	Aug	Sept	Oct	Nov							
Major Athabasca River Tributaries - Steepbank River and North Steepbank River																									
Barton and Wallace (1980)	AOSERP	North Steepbank R	1976	Jul, Oct	all (kicknet)	2			2					2			2		15 min kicknet samples (500)	1	500	genus/ species	stream width, depth, current	n/a	no raw data (summary info only)
Barton and Wallace (1980)	AOSERP	North Steepbank R	1977	May, Jul	all (kicknet)	2			2			2		2					15 min kicknet samples (500)	1	500	genus/ species	stream width, depth, current	n/a	no raw data (summary info only)
Barton and Wallace (1980)	AOSERP	Steepbank R	1976	Jul, Oct	all (kicknet)	5			5					5			5		15 min kicknet samples (500)	1	500	genus/ species	stream width, depth, current	n/a	no raw data (summary info only)
Barton and Wallace (1980)	AOSERP	Steepbank R	1977	May, Jul	all (kicknet)	5			5			5		5					15 min kicknet samples (500)	1	500	genus/ species	stream width, depth, current	n/a	no raw data (summary info only)
Barton and Wallace (1980)	AOSERP	Steepbank R	1977	Jun-Oct (monthly; twice in Aug)	erosional	2			2				1	2	3	2	2		Surber (0.09)	1-4	202	genus/ species	stream width, depth, current, substrate	n/a	no raw data (summary info only)
EVS (1996)	Suncor	Steepbank R	1995	Sep/Oct	erosional	3			3							3			Neill (0.086)	5	250	genus	field WQ, WQ, current, depth, substrate	electronic	
Golder (1999)	RAMP	Steepbank R	1998	Sep	erosional	3			3							3			Neill (0.093)	5	250	genus	field WQ, WQ, stream width, current, depth, substrate, periphyton	electronic	
Golder (2001)	RAMP	Steepbank R	2000	Sep	erosional	1 reach			1 reach							1 reach			Neill (0.093)	15	250	genus	field WQ, stream width, current, depth, substrate, periphyton	electronic	
Golder (2002a)	RAMP	Steepbank R	2001	Sep	erosional	1 reach			1 reach							1 reach			Neill (0.093)	15	250	genus	field WQ, stream width, current, depth, substrate, periphyton	electronic	
Major Athabasca River Tributaries - Ells River																									
Cash and Culp (in prep.)	PERD	Ells River	1999, 2000	?	erosional	5			5										U-net (0.1)	3	400	genus	n/a	n/a	report not available
CNRL (2002)	CNRL	Ells River	2001	Oct	depositional	1			1								1		Ekman (0.0232)	5	250	genus	field WQ, stream width, current, depth, substrate	electronic	
Major Athabasca River Tributaries - Clearwater River																									
Golder (2002a)	RAMP	Clearwater R	2001	Sep	depositional	2 reaches			2 reaches							2 reaches			Ekman (0.0232)	15	250	genus	field WQ, stream width, current, depth, substrate	electronic	
Major Athabasca River Tributaries - Tar River																									
CNRL (2002)	CNRL	Tar R	2001	Oct	erosional	2			2								2		Neill (0.093)	5	250	genus	field WQ, stream width, current, depth, substrate, periphyton	electronic	drift study also done
CNRL (2002)	CNRL	Tar R	2001	Oct	depositional	1			1								1		Ekman (0.0232)	5	250	genus	field WQ, stream width, current, depth, substrate	electronic	
Major Athabasca River Tributaries - Calumet River																									
CNRL (2002)	CNRL	Calumet R	2001	Oct	depositional	3			3								3		Ekman (0.0232)	5	250	genus	field WQ, stream width, current, depth, substrate	electronic	
Small Streams North of Fort McMurray																									
Barton and Wallace (1980)	AOSERP	Muskeg Cr	1976	Jul, Oct	all (kicknet)	1			1					1			1		15 min kicknet samples (500)	1	500	genus/ species	stream width, depth, current	n/a	no raw data (summary info only)
Barton and Wallace (1980)	AOSERP	Muskeg Cr	1977	May, Jul	all (kicknet)	1			1			1		1					15 min kicknet samples (500)	1	500	genus/ species	stream width, depth, current	n/a	no raw data (summary info only)
Barton and Wallace (1980)	AOSERP	Wesukemina Cr	1976	Jul, Oct	all (kicknet)	1			1					1			1		15 min kicknet samples (500)	1	500	genus/ species	stream width, depth, current	n/a	no raw data (summary info only)
Barton and Wallace (1980)	AOSERP	Wesukemina Cr	1977	May, Jul	all (kicknet)	1			1			1		1					15 min kicknet samples (500)	1	500	genus/ species	stream width, depth, current	n/a	no raw data (summary info only)
Beak (1986)	OSLO	Blackfly Cr	1985	Oct	erosional	1			1								1		Neill (0.0892)	3	180	genus	field WQ, WQ, current, depth, periphyton, width, substrate	hardcopy	
Beak (1986)	OSLO	Green Stockings Cr	1985	Oct	erosional	1			1								1		Neill (0.0892)	3	180	genus	field WQ, WQ, current, depth, periphyton, width, substrate	hardcopy	
Beak (1986)	OSLO	Iyinimin Cr	1985	Oct	erosional	1			1								1		Neill (0.0892)	3	180	genus	field WQ, WQ, current, depth, periphyton, width, substrate	hardcopy	
Beak (1986)	OSLO	Khahago Cr	1985	Oct	depositional	1			1								1		Ekman (0.0232)	3	180	genus	field WQ, WQ, current, depth, periphyton, width, substrate	hardcopy	
Beak (1986)	OSLO	Muskeg Cr	1985	Oct	depositional	1			1								1		Ekman (0.0232)	3	180	genus	field WQ, WQ, current, depth, periphyton, width, substrate	hardcopy	
Beak (1986)	OSLO	Muskeg Cr	1985	Oct	erosional	2			2								2		Neill (0.0892)	3	180	genus	field WQ, WQ, current, depth, periphyton, width, substrate	hardcopy	
Beak (1986)	OSLO	Wapasu Cr	1985	Oct	depositional	1			1								1		Ekman (0.0232)	3	180	genus	field WQ, WQ, current, depth, periphyton, width, substrate	hardcopy	
Beak (1986)	OSLO	Wapasu Cr	1985	Oct	erosional	1			1								1		Neill (0.0892)	3	180	genus	field WQ, WQ, current, depth, periphyton, width, substrate	hardcopy	
Boerger (1983b)	Syncrude	Poplar Cr	1982	Jul	erosional?	4		2	2					2					AS (basket)	3	250	genus exc. chironomids	n/a	hardcopy	
Golder (1996a)	Syncrude	Blackfly Cr	1995	Sep/Oct	erosional	1			1							1			Neill (0.093)	3	250	genus	field WQ, WQ, depth, substrate	electronic	
Golder (1996a)	Syncrude	Iyinimin Cr	1995	Sep/Oct	erosional	1			1							1			Neill (0.093)	3	250	genus	field WQ, WQ, depth, substrate	electronic	
Golder (1996a)	Syncrude	Jackpine Cr	1995	Sep/Oct	erosional	2			2							2			Neill (0.093)	3	250	genus	field WQ, WQ, depth, substrate	electronic	
Golder (1996a)	Syncrude	Khahago Cr	1995	Sep/Oct	depositional	1			1							1			Ekman (0.0232)	3	250	genus	field WQ, WQ, depth, substrate	electronic	
Golder (1996a)	Syncrude	Muskeg Cr	1995	Sep/Oct	depositional	1			1							1			Ekman (0.0232)	3	250	genus	field WQ, WQ, depth, substrate	electronic	
Golder (1998b)	Suncor	McLean Cr	1998	Sep	depositional	1			1							1			Ekman (0.0232)	5	250	genus	field WQ, WQ, depth, substrate	electronic	
Golder (2000)	TrueNorth	Fort Cr	1999	Oct	erosional	2			2								2		Surber (0.093)	3-5	250	genus	field WQ, current, depth, periphyton, substrate	electronic	drift study also done
Golder (2000)	TrueNorth	Fort Cr	1999	Oct	depositional	1			1								1		Ekman (0.0232)	2	250	genus	field WQ, current, depth, substrate	electronic	
Golder (2002a)	RAMP	Fort Cr	2001	Oct	depositional	1 reach			1 reach								1 reach		Ekman (0.0232)	5	250	genus	field WQ, WQ, current, depth, substrate	electronic	
Golder (2002b)	Syncrude	Blackfly Cr	2001	Oct	depositional	1			1								1		Ekman (0.0232)	5	250	genus	field WQ, WQ, SQ, depth, width, current, depth, substrate	electronic	
Golder (2002b)	Syncrude	Iyinimin Cr	2001	Oct	depositional	1			1								1		Ekman (0.0232)	5	250	genus	field WQ, WQ, SQ, depth, width, current, depth, substrate	electronic	

Table I-1 Summary of the Amount and Type of Historical Benthic Invertebrate Data in the Oil Sands Region by River and Lake (1974 to 2001) (continued)

										Number of reference sites sampled by month															
Reference	Research program/ funder	Waterbody	Survey year	Survey month	Habitat	Total number of sites	Number of potentially impacted sites	Number of sites in man-made channels or impoundments	Number of reference sites	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Sampling device (type/bottom area as m^2)	Number of replicates/ site	Mesh size (µm)	Typical level of taxonomy	Supporting data	Raw data availability	Comment
Golder (2002b)	Syncrude	Stanley Cr	2001	Oct	depositional	1			1								1		Ekman (0.0232)	5	250	genus	field WQ, WQ, SQ, depth, width, current, depth, substrate	electronic	
Golder (2002b)	Syncrude	Wesukemina Cr	2001	Oct	depositional	1			1								1		Ekman (0.0232)	5	250	genus	field WQ, WQ, SQ, depth, width, current, depth, substrate	electronic	
Hartland-Rowe et al. (1979)	AOSERP	Jackpine Cr	1976	May	depositional	1			1			1							Ekman (0.0529)	5	250	genus/ species	depth, current, substrate, field WQ	n/a	no raw data (summary info only), also collected airlift samples
Hartland-Rowe et al. (1979)	AOSERP	Jackpine Cr	1976	May-Nov (monthly)	erosional	5			5			5	5	5	5	5	5	5	Surber (0.093), Neill (0.0707)	3, 5	250	genus/ species	depth, current, substrate, field WQ	n/a	no raw data (summary info only), also collected airlift and "single rock" samples; drift study also done
Hartland-Rowe et al. (1979)	AOSERP	Jackpine Cr	1977	May-Sep (monthly)	erosional	4			4			4	4	4	4	4			Surber (0.093), Neill (0.0707)	3, 5	250	genus/ species	depth, current, substrate, field WQ	n/a	no raw data (summary info only), also collected airlift and "single rock" samples
Komex (1997)	Mobil	Wapasu Cr	1997	May, Aug	erosional	2			2			2			2				Neill (0.093)	5	not reported	genus exc. chironomids	field WQ, current, depth, discharge, substrate	hardcopy	
Noton and Chymko (1977)	Syncrude	Poplar Cr	1975	May-Nov (every 2 weeks)	erosional	3			3			6	6	4	4	4	4	4	Surber (0.19)	1	300	genus	depth, current, substrate, field WQ	hardcopy	drift study also done
Noton and Chymko (1977)	Syncrude	Poplar Cr	1975	Jul-Nov (every 2 weeks)	depositional				1					1	2	2	2	2	Ekman (0.0232)	8	600	genus	depth, current, substrate, field WQ	hardcopy	
Noton and Chymko (1978)	Syncrude	Poplar Cr	1977	Mar, May-Nov (monthly)	erosional	3		2	1			2	1	1	1	1	1	1	Hess (0.093)	3	250	genus exc. chironomids	depth, field WQ, substrate	hardcopy	drift study also done
Noton and Chymko (1978)	Syncrude	Upper Beaver Cr	1977	May, Jul, Oct	depositional	1			1			1		1			1		Ekman (0.0232)	12	600	genus	depth, field WQ, substrate	hardcopy	
O'Neil et al. (1982)	SandAlta	Jackpine Cr	1981	May, Jul, Sep	depositional	2			2			2		2		2			Ekman (0.0232)	5	250	genus	stream width, current, substrate (qualitative) depth, field WQ, WQ, benthic algae	hardcopy	
O'Neil et al. (1982)	SandAlta	Jackpine Cr	1981	May, Jul, Sep	erosional	1			1			1		1		1			Neill (0.1)	3	250	genus	stream width, current, substrate (qualitative) depth, field WQ, WQ, benthic algae	hardcopy	
Retallack (1980)	Syncrude	Poplar Cr	1979	May-Oct (monthly)	erosional	4		2	2				2	2	2	1 (2 AS)	2		Surber (0.093), PIBS, AS (basket)	3	200 (PIBS), 1024 (Surber), 212 (lab)	genus exc. chironomids	current, discharge, some WQ, field WQ,	n/a	no raw data (summary info only); drift study also done; subset of data reported by Boerger (1983b)
Retallack (1981a)	Syncrude	Poplar Cr	1980	Jul	erosional?	3		2	1					1					AS (basket)	3	1000	genus exc. chironomids	n/a	n/a	report not available; subset of data reported by Boerger (1983b)
Retallack (1981b)	Syncrude	Poplar Cr	1981	Jul	erosional?	2		1	1					1					AS (basket)	2-3	not reported	genus exc. chironomids	n/a	n/a	report not available; subset of data reported by Boerger (1983b)
RL&L (1989)	OSLO	Blackfly Cr	1988	May/Jun, Aug, Oct	erosional	1			1			1			1		1		Neill (0.1)	3	180	genus exc. chironomids	field WQ, WQ, periphyton, current, depth, substrate	hardcopy	
RL&L (1989)	OSLO	Green Stockings Cr	1988	May/Jun, Aug, Oct	depositional	1			1			1			1		1		Ekman (0.0232)	3	180	genus exc. chironomids	field WQ, WQ, periphyton, current, depth, substrate	hardcopy	
RL&L (1989)	OSLO	Iyinimin Cr	1988	May/Jun, Aug, Oct	erosional	1			1			1			1		1		Neill (0.1)	3	180	genus exc. chironomids	field WQ, WQ, periphyton, current, depth, substrate	hardcopy	
RL&L (1989)	OSLO	Jackpine Cr	1988	May/Jun, Aug, Oct	depositional	3			3			3			3		3		Ekman (0.0232)	3	180	genus exc. chironomids	field WQ, WQ, periphyton, current, depth, substrate	hardcopy	
RL&L (1989)	OSLO	Khahago Cr	1988	May/Jun, Aug, Oct	depositional	1			1			1			1		1		Ekman (0.0232)	3	180	genus exc. chironomids	field WQ, WQ, periphyton, current, depth, substrate	hardcopy	
RL&L (1989)	OSLO	Muskeg Cr	1988	May/Jun, Aug, Oct	depositional	3			3			3			3		3		Ekman (0.0232)	3	180	genus exc. chironomids	field WQ, WQ, periphyton, current, depth, substrate	hardcopy	
RL&L (1989)	OSLO	Wapasu Cr	1988	May/Jun, Aug, Oct	depositional	3			3			3			3		3		Ekman (0.0232)	3	180	genus exc. chironomids	field WQ, WQ, periphyton, current, depth, substrate	hardcopy	
RL&L and AA Aquatic Res. (1985)	Syncrude	Bridge Cr	1984	Jun, Jul, Sep	erosional	1	1												Neill (0.1)	3	250	genus exc. chironomids	discharge, stream order, depth, current, some WQ	hardcopy	qualitative kicknet samples also collected
RL&L and AA Aquatic Res. (1985)	Syncrude	Cr B1 (channelized)	1984	Jun, Jul, Sep	erosional	1		1											Neill (0.1)	3	250	genus exc. chironomids	discharge, stream order, depth, current, some WQ	hardcopy	qualitative kicknet samples also collected
RL&L and AA Aquatic Res. (1985)	Syncrude	Cr M2	1984	Jun, Jul, Sep	erosional	1			1				1	1		1			Neill (0.1)	3	250	genus exc. chironomids	discharge, stream order, depth, current, some WQ	hardcopy	qualitative kicknet samples also collected
RL&L and AA Aquatic Res. (1985)	Syncrude	Cr M6	1984	Jun, Jul, Sep	erosional	1			1				1	1		1			Neill (0.1)	3	250	genus exc. chironomids	discharge, stream order, depth, current, some WQ	hardcopy	qualitative kicknet samples also collected
RL&L and AA Aquatic Res. (1985)	Syncrude	Cr W3	1984	Jun, Jul, Sep	depositional	1			1				1	1		1			Ekman (0.0232)	3	250	genus exc. chironomids	discharge, stream order, depth, current, some WQ	hardcopy	qualitative kicknet samples also collected
RL&L and AA Aquatic Res. (1985)	Syncrude	Dover R	1984	Jun, Jul, Sep	erosional	1			1				1	1		1			Neill (0.1)	3	250	genus exc. chironomids	discharge, stream order, depth, current, some WQ	hardcopy	qualitative kicknet samples also collected
RL&L and AA Aquatic Res. (1985)	Syncrude	Lower Beaver Cr	1984	Jun, Jul, Sep	erosional	2	2												Neill (0.1)	3	250	genus exc. chironomids	discharge, stream order, depth, current, some WQ	hardcopy	qualitative kicknet samples also collected
RL&L and AA Aquatic Res. (1985)	Syncrude	Poplar Cr	1984	Jun, Jul, Sep	erosional	4		2	2				2	2		2			Neill (0.1)	3	250	genus exc. chironomids	discharge, stream order, depth, current, some WQ	hardcopy	qualitative kicknet samples also collected
RL&L and AA Aquatic Res. (1985)	Syncrude	Upper Beaver Cr	1984	Jun, Jul, Sep	depositional	1			1				1	1		1			Ekman (0.0232)	3	250	genus exc. chironomids	discharge, stream order, depth, current, some WQ	hardcopy	qualitative kicknet samples also collected
RL&L and AA Aquatic Res. (1985)	Syncrude	West Interceptor Ditch	1984	Jun, Jul, Sep	depositional	1		1											Neill (0.1) (dep. habitat)	3	250	genus exc. chironomids	discharge, stream order, depth, current, some WQ	hardcopy	qualitative kicknet samples also collected
RL&L and AA Aquatic Res. (1985)	Syncrude	West Interceptor Ditch	1984	Jun, Jul, Sep	erosional	1		1											Neill (0.1)	3	250	genus exc. chironomids	discharge, stream order, depth, current, some WQ	hardcopy	qualitative kicknet samples also collected
Shell (2002)	Shell	Jackpine Cr	2001	Sep	erosional	1			1							1			Neill (0.093)	5	250	genus	field WQ, periphyton, current, depth, substrate	electronic	
Shell (2002)	Shell	Jackpine Cr	2001	Sep	depositional	1			1							1			Ekman (0.0232)	5	250	genus	field WQ, current, depth, substrate	electronic	
Shell (2002)	Shell	Khahago Cr	2001	Sep	depositional	1			1							1			Ekman (0.0232)	5	250	genus	field WQ, depth, substrate	electronic	
Shell (2002)	Shell	Muskeg Cr	2001	Sep	depositional	2			2							2			Ekman (0.0232)	5	250	genus	field WQ, depth, substrate	electronic	drift study also done
Shell (2002)	Shell	Shelley Cr	2001	Oct	depositional	1			1							1			Ekman (0.0232)	5	250	genus	depth, field WQ, substrate	electronic	drift study also done

Table I-1 Summary of the Amount and Type of Historical Benthic Invertebrate Data in the Oil Sands Region by River and Lake (1974 to 2001) (continued)

Reference	Research program/ funder	Waterbody	Survey year	Survey month	Habitat	Total number of sites	Number of potentially impacted sites	Number of sites in man-made channels or impoundments	Number of reference sites	Number of reference sites sampled by month: Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Sampling device (type/bottom area as m²)	Number of replicates/ site	Mesh size (µm)	Typical level of taxonomy	Supporting data	Raw data availability	Comment
Syncrude (1975)	Syncrude	Poplar Cr	1974	Jul-Sep (monthly)	depositional	1			1					1	1	1			Surber (0.186) and Ekman (0.0232)	3, 8	300, 600	genus	depth, current, substrate, field WQ	hardcopy	
Syncrude (1975)	Syncrude	Poplar Cr	1974	Mar, May-Sep (monthly)	erosional	3			3	3		3	3	2	2	2			Surber (0.186)	3	300	genus	depth, current, substrate, field WQ	hardcopy	
TrueNorth (2001)	TrueNorth	Creek A	2000	Jun	erosional	1			1				1						Surber (0.093)	5	250	genus	field WQ, current, depth, periphyton, substrate	electronic	drift study also done
TrueNorth (2001)	TrueNorth	Susan Lake outlet	2000	Jun	erosional	1			1				1						Surber (0.093)	5	250	genus	field WQ, current, depth, periphyton, substrate	electronic	drift study also done
Tsui et al. (1978)	Syncrude	Lower Beaver Cr	1977	May, Jun, July, Aug, Sep	erosional	1		1											Surber (0.093)	3	600	genus	depth, width, current, temperature, substrate, bank characteristics	hardcopy	
Tsui et al. (1978)	Syncrude	Unnamed stream	1977	May, Jun, July, Aug, Sep	depositional	1			1			1	1	1	1	1			Ekman (0.0232)	3	600	genus	depth, width, current, temperature, substrate, bank characteristics	hardcopy	drift study also done (Stn 7)
Tsui et al. (1978)	Syncrude	Unnamed stream	1977	May, Jun, July, Aug, Sep	depositional	1			1			1	1	1	1	1			Ekman (0.0232)	3	600	genus	depth, width, current, temperature, substrate, bank characteristics	hardcopy	
Tsui et al. (1978)	Syncrude	West Interceptor Ditch	1977	May, Jun, July, Aug, Sep	erosional	1		1											Surber (0.093)	3	600	genus	depth, width, current, temperature, substrate, bank characteristics	hardcopy	
Tsui et al. (1978)	Syncrude	West Interceptor Ditch	1977	May, Jun, July, Aug, Sep	depositional	3		3											Ekman (0.0232)	3	600	genus	depth, width, current, temperature, substrate, bank characteristics	hardcopy	
Lakes, Reservoirs, Ponds and Wetlands North of Fort McMurray																									
(unpublished data)	Shell (Albian)	Isadore's L	2000	Sept	lake	1			1							1			Ekman (0.0232)	10	250	genus	field WQ, depth, substrate	electronic	
Beak (1986)	OSLO	Kearl L	1985	Oct	lake	1			1								1		Ekman (0.0232)	3	180	genus	field WQ, WQ, depth, vegetation	hardcopy	
Bendell-Young et al. (1997)	Suncor	Unnamed wetlands	1996?	n/a	wetland	7	6		1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	corer (0.00159)	30	n/a	major taxon	n/a	hardcopy	reference wetland location unknown; non-standard sampling method
CNRL (2002)	CNRL	Calumet L	2001	Oct	lake	1			1								1		Ekman (0.0232)	10	250	genus	field WQ, WQ, depth, substrate, vegetation	electronic	
CNRL (2002)	CNRL	Lillian L	2001	Oct	lake	1			1								1		Ekman (0.0232)	9	250	genus	field WQ, WQ, depth, substrate, vegetation	electronic	
Golder (1996a)	Suncor	Kearl L	1995	Sept/Oct	lake	1			1							1			Ekman (0.0232)	3	250	genus	field WQ, WQ, depth, substrate	electronic	
Golder (1996b)	Suncor	Shipyard L	1995	Aug	wetland	3			3						3				Ekman (0.0232)	3	250	genus	field WQ, WQ, depth, substrate	electronic	
Golder (1997)	Suncor	Unnamed wetlands	1997	Aug	wetland	13	10		3						3				four 6.5 cm diam. cores per sample (0.0133)	3	250	genus	field WQ, WQ, depth, substrate	electronic	non-standard sampling method
Golder (2001)	RAMP	Kearl L	2000	Sept	lake	1			1							1			Ekman (0.0232)	10	250	genus	field WQ, WQ, depth, substrate, vegetation	electronic	
Golder (2001)	RAMP	Shipyard L	2000	Sept	wetland	1			1							1			Ekman (0.0232)	10	250	genus	field WQ, depth, substrate	electronic	
Golder (2002a)	RAMP	Kearl L	2001	Sept	lake	1			1							1			Ekman (0.0232)	10	250	genus	field WQ, WQ, depth, substrate, vegetation	electronic	
Golder (2002a)	RAMP	Shipyard L	2001	Sept	wetland	1			1							1			Ekman (0.0232)	10	250	genus	field WQ, depth, substrate	electronic	
Noton and Chymko (1977)	Syncrude	Ruth L	1975	May-Sep (every 2 weeks)	lake	3			3			6	6	6	6	6			Ekman (0.0232)	1	600	genus	depth, field WQ, macrophytes	hardcopy	
Noton and Chymko (1978)	Syncrude	Beaver Cr Res	1977	Mar, May-Nov (monthly)	reservoir	2		2											Ekman (0.0232)	3	600	genus	depth, field WQ, substrate	hardcopy	
Noton and Chymko (1978)	Syncrude	Beaver Cr Res	1977	Aug	reservoir	10		10											Ekman (0.0232)	3	600	genus	depth, field WQ, substrate	hardcopy	colonization study
Noton and Chymko (1978)	Syncrude	Poplar Cr Res	1977	Mar, May-Nov (monthly)	reservoir	2		2											Ekman (0.0232)	3	600	genus	depth, field WQ, substrate	hardcopy	
Noton and Chymko (1978)	Syncrude	Poplar Cr Res	1977	Aug	reservoir	10		10											Ekman (0.0232)	3	600	genus	depth, field WQ, substrate	hardcopy	colonization study
Noton and Chymko (1978)	Syncrude	Ruth L	1977	Mar, May-Nov (monthly)	lake	2	2												Ekman (0.0232)	3	600	genus	depth, field WQ, substrate	hardcopy	
O'Neil et al. (1982)	SandAlta	Unnamed ponds/lakes	1981	May, Jul, Sep	pond	4			4			4		4		4			Ekman (0.0232)	5	600	genus	depth, field WQ, WQ	hardcopy	
RL&L (1989)	OSLO	Kearl L	1988	May/June, Aug, Oct	lake	3			3			3			3		3		Ekman (0.0232)	3	180	genus exc. chironomids	field WQ, WQ, depth, substrate	hardcopy	
RL&L and AA Aquatic Res. (1985)	Syncrude	Beaver Cr Res.	1984	Jun, Jul, Sep	reservoir	5		5											Ekman (0.0232)	3	250	genus exc. chironomids	depth, substrate, macrophytes	hardcopy	qualitative dipnet samples also collected
RL&L and AA Aquatic Res. (1985)	Syncrude	Poplar Cr Res.	1984	Jun, Jul, Sep	reservoir	5		5											Ekman (0.0232)	3	250	genus exc. chironomids	depth, substrate, macrophytes	hardcopy	qualitative dipnet samples also collected
RL&L and AA Aquatic Res. (1985)	Syncrude	Ruth L	1984	Jun, Jul, Sep	lake	1	1												Ekman (0.0232)	3	250	genus exc. chironomids	depth, substrate, macrophytes	hardcopy	qualitative dipnet samples also collected
Syncrude (1975)	Syncrude	Ruth L	1974	May-Sep (every 2 weeks)	lake	3			3			6	6	6	6	6			Ekman (0.0232)	1	600	genus	depth, field WQ, macrophytes	hardcopy	
Rivers and Small Streams South of Fort McMurray																									
Gulf (1979)	Gulf	Cottonwood Cr	1978	May, Jul, Aug	erosional	1			1			1		1	1				Kicknet	3	850 (No. 20)	genus exc. chironomids	physical site characteristics, substrate, macrophytes	hardcopy	Surber used as kicknet; samples sorted without microscope
Gulf (1979)	Gulf	Creek 225.3	1978	May, Jul, Aug	erosional	1			1			1		1	1				Kicknet	3	850 (No. 20)	genus exc. chironomids	physical site characteristics, substrate, macrophytes	hardcopy	Surber used as kicknet; samples sorted without microscope
Gulf (1979)	Gulf	Creek 229.2	1978	May, Jul, Aug	erosional	1			1			1		1	1				Kicknet	3	850 (No. 20)	genus exc. chironomids	physical site characteristics, substrate, macrophytes	hardcopy	Surber used as kicknet; samples sorted without microscope
Gulf (1979)	Gulf	Creek 230.8	1978	May, Jul, Aug	erosional	1			1			1		1	1				Kicknet	3	850 (No. 20)	genus exc. chironomids	physical site characteristics, substrate, macrophytes	hardcopy	Surber used as kicknet; samples sorted without microscope
Gulf (1979)	Gulf	Creek 235.4	1978	May, Jul, Aug	depositional	1			1			1		1	1				Kicknet	3	850 (No. 20)	genus exc. chironomids	physical site characteristics, substrate, macrophytes	hardcopy	Surber used as kicknet; samples sorted without microscope
Gulf (1979)	Gulf	Creek 241	1978	May, Jul, Aug	depositional	1			1			1		1	1				Kicknet	3	850 (No. 20)	genus exc. chironomids	physical site characteristics, substrate, macrophytes	hardcopy	Surber used as kicknet; samples sorted without microscope
Gulf (1979)	Gulf	Creek 242	1978	May, Jul, Aug	depositional	1			1			1		1	1				Kicknet	3	850 (No. 20)	genus exc. chironomids	physical site characteristics, substrate, macrophytes	hardcopy	Surber used as kicknet; samples sorted without microscope
Gulf (1979)	Gulf	Kettle R	1978	May, Jul, Aug	erosional	2			2			2		2	2				Kicknet	3	850 (No. 20)	genus exc. chironomids	physical site characteristics, substrate, macrophytes	hardcopy	Surber used as kicknet; samples sorted without microscope

Table I-1 Summary of the Amount and Type of Historical Benthic Invertebrate Data in the Oil Sands Region by River and Lake (1974 to 2001) (continued)

Reference	Research program/ funder	Waterbody	Survey year	Survey month	Habitat	Total number of sites	Number of potentially impacted sites	Number of sites in man-made channels or impoundments	Number of reference sites	Number of reference sites sampled by month: Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Sampling device (type/bottom area as m^2)	Number of replicates/ site	Mesh size (µm)	Typical level of taxonomy	Supporting data	Raw data availability	Comment
Gulf (1979)	Gulf	Kinosis Cr	1978	May, Jul, Aug	depositional	1			1			1		1	1				Kicknet	3	850 (No. 20)	genus exc. chironomids	physical site characteristics, substrate, macrophytes	hardcopy	Surber used as kicknet; samples sorted without microscope
Gulf (1979)	Gulf	Meadow Cr	1978	May, Jul, Aug	erosional	2			2			2		2	2				Kicknet	3	850 (No. 20)	genus exc. chironomids	physical site characteristics, substrate, macrophytes	hardcopy	Surber used as kicknet; samples sorted without microscope
Gulf (1979)	Gulf	Meadow Cr	1978	May, Jul, Aug	depositional	1			1			1		1	1				Kicknet	3	850 (No. 20)	genus exc. chironomids	physical site characteristics, substrate, macrophytes	hardcopy	Surber used as kicknet; samples sorted without microscope
Gulf (1979)	Gulf	South Kettle R	1978	May, Jul, Aug	erosional	1			1			1		1	1				Kicknet	3	850 (No. 20)	genus exc. chironomids	physical site characteristics, substrate, macrophytes	hardcopy	Surber used as kicknet; samples sorted without microscope
Gulf (2001)	Conoco	Cottonwood Cr	1998	Aug	erosional	2			2						2				Surber (0.093)	3	250	genus	depth, current, substrate (qualitative) field WQ	electronic	
Gulf (2001)	Conoco	Kettle R	1998	Aug	erosional	1			1						1				Surber (0.093)	3	250	genus	depth, current, substrate (qualitative) field WQ	electronic	
Gulf (2001)	Conoco	Meadow Cr	1998	Aug	erosional	2			2						2				Surber (0.093)	3	250	genus	depth, current, substrate (qualitative) field WQ	electronic	
Rio Alto (2002)	Rio Alto	Unnamed stream	2001	May	depositional	2			2			2							Ekman (0.0232)	3	500	genus	depth, field WQ, substrate	electronic	
Tripp and Tsui (1980)	AOSERP	Algar R	1978	Aug	depositional	2			2						2				Ekman (0.0225)	3	600	genus	stream width, depth, current, substrate, field WQ, periphyton	hardcopy	kick samples also collected
Tripp and Tsui (1980)	AOSERP	Algar R	1978	Aug	erosional	1			1						1				Surber (0.093)	3	600	genus	stream width, depth, current, substrate, field WQ, periphyton	hardcopy	kick samples also collected
Tripp and Tsui (1980)	AOSERP	Cameron Cr	1978	Aug	erosional	1			1						1				Surber (0.093)	3	600	genus	stream width, depth, current, substrate, field WQ, periphyton	hardcopy	kick samples also collected
Tripp and Tsui (1980)	AOSERP	Christina R	1978	Jun, Aug, Oct	erosional	4			4				4		4		4		Surber (0.093)	3	600	genus	stream width, depth, current, substrate, field WQ, periphyton	hardcopy	kick samples also collected
Tripp and Tsui (1980)	AOSERP	Gregoire R	1978	Aug	depositional	2			2						2				Ekman (0.0225)	3	600	genus	stream width, depth, current, substrate, field WQ, periphyton	hardcopy	kick samples also collected
Tripp and Tsui (1980)	AOSERP	Gregoire R	1978	Aug	erosional	1			1						1				Surber (0.093)	3	600	genus	stream width, depth, current, substrate, field WQ, periphyton	hardcopy	kick samples also collected
Tripp and Tsui (1980)	AOSERP	Hangingstone R	1978	May, Jun, Aug, Oct	depositional	2			2			2	2		2		2		Ekman (0.0225)	3	600	genus	stream width, depth, current, substrate, field WQ, periphyton	hardcopy	kick samples also collected
Tripp and Tsui (1980)	AOSERP	Hangingstone R	1978	May, Jun, Aug, Oct	erosional	7			7			7	7		7		7		Surber (0.093)	3	600	genus	stream width, depth, current, substrate, field WQ, periphyton	hardcopy	kick samples also collected; drift study also done
Tripp and Tsui (1980)	AOSERP	Horse R	1978	May, Jun, Aug, Oct	depositional	1			1			1	1		1		1		Ekman (0.0225)	3	600	genus	stream width, depth, current, substrate, field WQ, periphyton	hardcopy	kick samples also collected
Tripp and Tsui (1980)	AOSERP	Horse R	1978	May, Jun, Aug, Oct	erosional	3			3			3	3		3		3		Surber (0.093)	3	600	genus	stream width, depth, current, substrate, field WQ, periphyton	hardcopy	kick samples also collected
Tripp and Tsui (1980)	AOSERP	Prairie Cr	1978	Aug	depositional	1			1						1				Ekman (0.0225)	3	600	genus	stream width, depth, current, substrate, field WQ, periphyton	hardcopy	kick samples also collected
Tripp and Tsui (1980)	AOSERP	Saline Cr	1978	May, Jun, Aug, Oct	erosional	2			2			2	2		2		2		Surber (0.093)	3	600	genus	stream width, depth, current, substrate, field WQ, periphyton	hardcopy	kick samples also collected
Tripp and Tsui (1980)	AOSERP	Saprae Cr	1978	Aug	depositional	1			1						1				Ekman (0.0225)	3	600	genus	stream width, depth, current, substrate, field WQ, periphyton	hardcopy	kick samples also collected
Tripp and Tsui (1980)	AOSERP	Saprae Cr	1978	Aug	erosional	2			2						2				Surber (0.093)	3	600	genus	stream width, depth, current, substrate, field WQ, periphyton	hardcopy	kick samples also collected
Tripp and Tsui (1980)	AOSERP	Surmont Cr	1978	May, Jun, Aug, Oct	depositional	1			1			1	1		1		1		Ekman (0.0225)	3	600	genus	stream width, depth, current, substrate, field WQ, periphyton	hardcopy	kick samples also collected
Tripp and Tsui (1980)	AOSERP	Surmont Cr	1978	May, Jun, Aug, Oct	erosional	2			2			2	2		2		2		Surber (0.093)	3	600	genus	stream width, depth, current, substrate, field WQ, periphyton	hardcopy	kick samples also collected
Lakes, Reservoirs, Ponds and Wetlands South of Fort McMurray																									
Gulf (1979)	Gulf	Gull L	1978	May, Jul, Aug	lake	1			1			1		1	1				Ekman (0.0232)	3	600 (No. 30)	genus exc. chironomids	physical site characteristics, substrate, macrophytes	hardcopy	
Gulf (1979)	Gulf	High L	1978	May, Jul, Aug	lake	1			1			1		1	1				Ekman (0.0232)	3	600 (No. 30)	genus exc. chironomids	physical site characteristics, substrate, macrophytes	hardcopy	
Gulf (1979)	Gulf	Low L	1978	May, Jul, Aug	lake	1			1			1		1	1				Ekman (0.0232)	3	600 (No. 30)	genus exc. chironomids	physical site characteristics, substrate, macrophytes	hardcopy	
Gulf (2001)	Conoco	Engstrom L	1998	Aug	lake	1			1						1				Ekman (0.0232)	3	250	genus	depth, current, substrate (qualitative) field WQ	electronic	
Petro-Canada (2002)	Petro-Canada	Lake L10	2001	May	lake	1			1			1							Ekman (0.0232)	3	500	genus	depth, field WQ, substrate	electronic	
Petro-Canada (2002)	Petro-Canada	Lake L11	2001	May	lake	1			1			1							Ekman (0.0232)	3	500	genus	depth, field WQ, substrate	electronic	
Petro-Canada (2002)	Petro-Canada	Lake L12	2001	May	lake	1			1			1							Ekman (0.0232)	3	500	genus	depth, field WQ, substrate	electronic	
Petro-Canada (2002)	Petro-Canada	Lake L8	2001	May	lake	1			1			1							Ekman (0.0232)	3	500	genus	depth, field WQ, substrate	electronic	
Petro-Canada (2002)	Petro-Canada	Surmont L	2001	May	lake	1			1			1							Ekman (0.0232)	3	500	genus	depth, field WQ, substrate	electronic	
Rio Alto (2002)	Rio Alto	Unnamed lake 1	2001	May	lake	1			1			1							Ekman (0.0232)	3	500	genus	depth, field WQ, substrate	electronic	
Rio Alto (2002)	Rio Alto	Unnamed lake 3	2001	May	lake	1			1			1							Ekman (0.0232)	3	500	genus	depth, field WQ, substrate	electronic	
Rio Alto (2002)	Rio Alto	Unnamed lake 4	2001	May	lake	1			1			1							Ekman (0.0232)	3	500	genus	depth, field WQ, substrate	electronic	
Rio Alto (2002)	Rio Alto	Unnamed lake 7	2001	May	lake	1			1			1							Ekman (0.0232)	3	500	genus	depth, field WQ, substrate	electronic	
Rio Alto (2002)	Rio Alto	Wiau L	2001	May	lake	1			1			1							Ekman (0.0232)	3	500	genus	depth, field WQ, substrate	electronic	
Tripp and Tsui (1980)	AOSERP	Algar L	1978	Aug	lake	3			3						3				Ekman (0.0232)	3	600	genus	depth, substrate, field WQ	hardcopy	
Tripp and Tsui (1980)	AOSERP	Gregoire L	1978	Aug	lake	5			5						5				Ekman (0.0232)	3	600	genus	depth, substrate, field WQ	hardcopy	

Notes: n/a = not available; WQ = water quality; SQ = sediment quality.

[(a)] BONAR = Benthos of Northern Alberta Rivers database (Ouellet and Cash 1996).

APPENDIX II

SITE CODE KEYS FOR FIGURES 1 TO 3

Table II-1 Site Code Key for the Athabasca River in Figures 1 and 2

Site Number	Original Site Code	Site Type[(a)]	Sampling Methods[(b)]	Reference
101	00AL07DD0650	Ref	Neill	Anderson (1991)
102	ATR-B-A1	Ref	Ekman	Golder (1998a)
103	ATR-B-A2	Ref	Ekman	Golder (1998a)
104	ATR-B-A3	Ref	Ekman	Golder (1998a)
105	ATR-B-A4	Ref	Ekman	Golder (1998a)
106	ATR-B-A5	Ref	Ekman	Golder (1998a)
107	ATR-B-A6	Ref	Ekman	Golder (1998a)
108	1W	Ref	Hess, Neill	Boerger (1983a), Corkum (1984, unreleased)
109	1E	Ref	Hess, Neill	Boerger (1983a), Corkum (1984, unreleased)
110	15	Ref	Ekman, AS	McCart et al. (1977)
111	6	Ref	Ekman, airlift	Barton and Wallace (1980)
112	2E	Ref	Hess, Neill	Boerger (1983a), Corkum (1984, unreleased)
113	2W	Ref	Hess, Neill	Boerger (1983a), Corkum (1984, unreleased)
	5	Ref	Ekman, airlift	Barton and Wallace (1980)
114	14	Ref	Ekman, AS	McCart et al. (1977)
115	13	Ref	Ekman, AS	McCart et al. (1977)
116	3W	Ref	Hess, Neill	Boerger (1983a), Corkum (1984, unreleased)
	12	Ref	Ekman, AS	McCart et al. (1977)
117	3E	Ref	Hess, Neill	Boerger (1983a), Corkum (1984, unreleased)
118	401370	Ref	Ekman	Ouellett and Cash (1996)
119	11	Ref	Ekman, AS	McCart et al. (1977)
120	AB012	Ref	Ekman, AS	EVS (1996)
121	AB011	Ref	Ekman, AS	EVS (1996)
	4	Ref	Ekman, airlift	Barton and Wallace (1980)
122	10	Imp	Ekman, AS	McCart et al. (1977)
	4W	Ref	Hess, Neill	Boerger (1983a), Corkum (1984, unreleased)
123	4E	Ref	Hess, Neill	Boerger (1983a), Corkum (1984, unreleased)
124	9	Ref	Ekman, AS	McCart et al. (1977)
	6	Ref	Neill, AS	EVS (1986)
	AB010	Ref	Ekman, AS	EVS (1996)
125	8	Imp	Ekman, AS	McCart et al. (1977)
	7	Imp	Neill, AS	EVS (1986), IEC Beak (1983)
126	3	Imp	Ekman, airlift	Barton and Wallace (1980)
127	401220	Imp	Ekman	Ouellett and Cash (1996)
128	7	Imp	Ekman, AS	McCart et al. (1977)
	AB009	Imp	Ekman, AS	EVS (1996)
129	6	Imp	Ekman, AS	McCart et al. (1977)

Table II-1 Site Code Key for the Athabasca River in Figures 1 and 2 (continued)

Site Number	Original Site Code	Site Type[(a)]	Sampling Methods[(b)]	Reference
130	5	Imp	Ekman, AS	McCart et al. (1977)
	PW	Imp	Neill	Corkum (1984, unreleased)
131	4	Imp	Ekman, AS	McCart et al. (1977)
	401210	Imp	Ekman	Ouellett and Cash (1996)
132	W1	Imp	Ekman, AS	Noton (1979), Noton and Anderson (1982)
133	6	Imp	AS	IEC Beak (1983)
134	3	Ref	Ekman, AS	McCart et al. (1977)
135	2	Imp	Ekman, AS	McCart et al. (1977)
136	W2	Imp	Ekman, AS	Noton (1979), Noton and Anderson (1982)
	5	Imp	Neill, AS	IEC Beak (1983), EVS (1986)
137	4	Ref	Neill, AS	EVS (1986)
138	E1	Ref	Ekman, AS	Noton (1979)
139	W3	Imp	Ekman, AS	Noton (1979), Noton and Anderson (1982)
140	E1	Ref	Ekman, AS	Noton and Anderson (1982)
141	W4	Imp	Ekman, AS	Noton (1979), Noton and Anderson (1982)
142	2	Imp	Ekman, airlift	Barton and Wallace (1980)
	4	Imp	AS	IEC Beak (1983)
	3	Imp	Neill, AS	EVS (1986)
143	W5	Imp	Ekman, AS	Noton (1979), Noton and Anderson (1982)
144	W6	Imp	Ekman, AS	Noton (1979), Noton and Anderson (1982)
	3	Imp	AS	IEC Beak (1983)
145	E2	Ref	Ekman, AS	Noton and Anderson (1982)
146	AB008	Ref	Ekman, AS	EVS (1996)
147	AB007	Imp	Ekman, AS	EVS (1996)
148	2a	Ref	Neill, AS	EVS (1986)
149	400985	Imp	Ekman	Ouellett and Cash (1996)
150	2	Ref	Neill, AS	EVS (1986)
151	1	Ref	Neill, AS	EVS (1986)
152	1	Ref	Ekman, airlift	Barton and Wallace (1980)
	W7	Ref	Ekman, AS	Noton (1979), Noton and Anderson (1982)
	2	Ref	AS	IEC Beak (1983)
	5W	Ref	Hess, Neill	Boerger (1983a), Corkum (1984, unreleased)
	AB005	Ref	Ekman, AS	EVS (1996)
153	E2	Ref	Ekman, AS	Noton (1979)
154	W8	Ref	Ekman, AS	Noton and Anderson (1982)
155	400980	Ref	Ekman	Ouellett and Cash (1996)

Table II-1 Site Code Key for the Athabasca River in Figures 1 and 2 (continued)

Site Number	Original Site Code	Site Type[(a)]	Sampling Methods[(b)]	Reference
156	1	Ref	Ekman, AS	McCart et al. (1977)
	AB006	Ref	Ekman, AS	EVS (1996)
157	W8	Ref	Ekman, AS	Noton (1979)
158	5E	Ref	Hess, Neill	Boerger (1983a), Corkum (1984, unreleased)
159	1	Ref	AS	IEC Beak (1983)
160	6W	Ref	Hess, Neill	Boerger (1983a), Corkum (1984, unreleased)
	AB003	Ref	Ekman, AS	EVS (1996)
161	AB004	Ref	Ekman, AS	EVS (1996)
162	6E	Ref	Hess, Neill	Boerger (1983a), Corkum (1984, unreleased)
163	AB002	Ref	Ekman, AS	EVS (1996)
164	400820	Ref	Neill	Ouellett and Cash (1996)
165	AB001	Ref	Ekman, AS	EVS (1996)
166	ATR-B-B3	Ref	Ekman	Golder (1998a)
167	ATR-B-B2	Ref	Ekman	Golder (1998a)
168	ATR-B-B1	Ref	Ekman	Golder (1998a)
169	ATR-B-B4	Imp	Ekman	Golder (1998a)
170	ATR-B-B5	Imp	Ekman	Golder (1998a)
	7W	Imp	Hess, Neill	Boerger (1983a), Corkum (1984, unreleased)
171	7E	Ref	Hess, Neill	Boerger (1983a), Corkum (1984, unreleased)
172	ATR-B-B6	Imp	Ekman	Golder (1998a)
173	400630	Imp	Neill	Ouellett and Cash (1996)
174	400620	Imp	Neill	Ouellett and Cash (1996)
175	400610	Imp	Neill	Ouellett and Cash (1996)
176	8W	Ref	Hess, Neill	Boerger (1983a), Corkum (1984, unreleased)
177	8E	Ref	Hess, Neill	Boerger (1983a), Corkum (1984, unreleased)
	00AL07CC0500	Ref	Neill	Anderson (1991)
178	12V (km 291.5)	Ref	Neill	Dunnigan and Millar (1993)

(a) Ref = reference site, Imp = potentially impacted site.

(b) Airlift = airlift sampler; AS = artificial substrates; Ekman = Ekman grab; Hess = Hess sampler; Neill = Neill cylinder.

Table II-2 Site Code Key for Major Tributaries of the Athabasca River North of Fort McMurray in Figure 1

Site Number	Original Site Code	Site Type[(a)]	Sampling Methods[(b)]	Reference
Clearwater River				
202	3 km reach upstream of Fort McMurray (CLR-D-1 to CLR-D-15)	Ref	Ekman	Golder (2002a)
203	5 km reach upstream of Christina River (CLR-D-16 to CLR-D-30)	Ref	Ekman	Golder (2002a)
Calumet River				
188	CR-1	Ref	Ekman	CNRL (2002)
189	CR-3	Ref	Ekman	CNRL (2002)
190	CR-4	Ref	Ekman	CNRL (2002)
Dover River				
32	DR-B	Ref	Neill	RL&L and AA Aquatic Res. (1985)
Ells River				
184	ER-2	Ref	Ekman	CNRL (2002)
MacKay River				
mouth to 5 km upstream (MAR-E)		Ref	Neill	Golder (2001, 2002a)
1 (200 m upstream)	MAC-1	Ref	Neill	Golder (1999)
2 (400 m upstream)	MAC-2	Ref	Neill	Golder (1999)
3 (1 km upstream)	MAC-3	Ref	Neill	Golder (1999)
	MR-B1	Ref	Neill	RL&L and AA Aquatic Res. (1985)
4	Lower	Ref	Surber, AS	McCart et al. (1978)
5	MR-B2	Ref	Neill	RL&L and AA Aquatic Res. (1985)
6	MR-B3	Ref	Neill	RL&L and AA Aquatic Res. (1985)
7	Middle	Ref	Surber, AS	McCart et al. (1978)
8	MR-B4	Ref	Neill	RL&L and AA Aquatic Res. (1985)
9	Upper	Ref	Surber, AS	McCart et al. (1978)
Muskeg River				
mouth to 5 km upstream (MUR-E)		Ref	Neill	Golder (2001, 2002a)
12 km to 15 km upstream from mouth (MUR-D)		Ref	Ekman	Golder (2001, 2002a)
10a (50 m upstream)	M1	Ref	Kicknet	Barton and Wallace (1980)
	30	Ref	Neill	Golder (1996a)
	MUR-1	Ref	Neill	Golder (1999)

Table II-2 Site Code Key for Major Tributaries of the Athabasca River North of Fort McMurray in Figure 1 (continued)

Site Number	Original Site Code	Site Type[a]	Sampling Methods[b]	Reference
10b (200 m upstream)	MUR-2	Ref	Neill	Golder (1999)
10c (400 m upstream)	MUR-3	Ref	Neill	Golder (1999)
11	1	Ref	Neill	Crowther and Lade (1981)
12	M1A	Ref	Kicknet	Barton and Wallace (1980)
	2	Ref	Neill	Crowther and Lade (1981)
13	18	Ref	Ekman	RL&L (1989), Golder (1996a)
14	5	Ref	Ekman	Beak (1986), RL&L (1989)
206	MUR 4	Ref	Ekman	Golder (2002b)
15	3	Ref	Neill	Crowther and Lade (1981)
	4	Ref	Ekman	Beak (1986), RL&L (1989)
16	3	Ref	Ekman	Beak (1986), RL&L (1989)
17	35	Ref	Ekman	Golder (1996a)
204	MUR-USC	Ref	Ekman	Golder (2002b)
18	2	Ref	Ekman	Beak (1986), RL&L (1989)
19	1	Ref	Ekman	Beak (1986), RL&L (1989)
20	M2	Ref	Kicknet	Barton and Wallace (1980)
182	5	Ref	Ekman	Komex (1997)
21	M3	Ref	Kicknet	Barton and Wallace (1980)
	4 (Lower)	Ref	Ekman	Komex (1997)
183	3 (Upper)	Ref	Ekman	Komex (1997)
Steepbank River (and North Steepbank River)				
mouth to 5 km upstream (STR-E)		Ref	Neill	Golder (2001, 2002a)
22a (100 m upstream)	STR-1	Ref	Neill	Golder (1999)
	S7	Ref	Kicknet	Barton and Wallace (1980)
22b (300 m upstream)	SB003	Ref	Neill	EVS (1996)
	STR-2	Ref	Neill	Golder (1999)
	LS2	Ref	Surber	Barton and Wallace (1980)
22c (500 m upstream)	STR-3	Ref	Neill	Golder (1999)
22d (1 km upstream)	LS1	Ref	Kicknet, Surber	Barton and Wallace (1980)
23	SB002	Ref	Neill	EVS (1996)
24	SB001	Ref	Neill	EVS (1996)
25	S6	Ref	Kicknet	Barton and Wallace (1980)
	US	Ref	Kicknet	Barton and Wallace (1980)
26	S5	Ref	Kicknet	Barton and Wallace (1980)
27	S4	Ref	Kicknet	Barton and Wallace (1980)

Table II-2 Site Code Key for Major Tributaries of the Athabasca River North of Fort McMurray in Figure 1 (continued)

Site Number	Original Site Code	Site Type[(a)]	Sampling Methods[(b)]	Reference
28	S3	Ref	Kicknet	Barton and Wallace (1980)
29	S2	Ref	Kicknet	Barton and Wallace (1980)
30	S1	Ref	Kicknet	Barton and Wallace (1980)
Tar River				
185	TR-1	Ref	Ekman	CNRL (2002)
186	TR-2	Ref	Surber	CNRL (2002)
187	TR-7	Ref	Surber	CNRL (2002)

(a) Ref = reference site.

(b) AS = artificial substrates; Ekman = Ekman grab; Neill = Neill cylinder; Surber = Surber sampler.

Table II-3 Site Code Key for Small Streams North of Fort McMurray in Figure 1

Site Number	Original Site Code	Site Type[(a)]	Sampling Methods[(b)]	Reference
MacKay River Basin				
31	M2-B	Ref	Neill	RL&L and AA Aquatic Res. (1985)
33	M6-B	Ref	Neill	RL&L and AA Aquatic Res. (1985)
Muskeg River Basin				
Jackpine Creek Drainage				
34	17	Ref	Ekman, Neill	RL&L (1989), Golder (1996a)
	JAC-1	Ref	Ekman	Shell (2002)
35	1	Ref	Surber, Neill	Hartland-Rowe et al. (1979)
36	5	Ref	Surber, Neill, single rock	Hartland-Rowe et al. (1979)
	L4	Ref	Hess	O'Neil et al. (1982)
	JAC-2	Ref	Neill	Shell (2002)
37	8	Ref	Surber, Neill, airlift, Ekman	Hartland-Rowe et al. (1979)
38	L5	Ref	Ekman	O'Neil et al. (1982)
	S4	Ref	Neill	Golder (1996a)
39	16	Ref	Ekman	RL&L (1989)
40	L6	Ref	Ekman	O'Neil et al. (1982)
41	15	Ref	Ekman	RL&L (1989)
Muskeg Creek Drainage				
42	11	Ref	Neill, Ekman	Beak (1986), RL&L (1989)
43	10	Ref	Ekman	Beak (1986), RL&L (1989)
	MUC-1	Ref	Ekman	Shell (2002)
44	M4	Ref	Kicknet	Barton and Wallace (1980)
	9	Ref	Neill, Ekman	Beak (1986), RL&L (1989), Golder (1996a)
	MUC-2	Ref	Ekman	Shell (2002)
45	8	Ref	Neill	Beak (1986)
46	8	Ref	Neill	RL&L (1989), Golder (1996a)
	IYC-HS	Ref	Ekman	Golder (2002b)
47	M5	Ref	Kicknet	Barton and Wallace (1980)
48	14	Ref	Ekman	Beak (1986), RL&L (1989), Golder (1996a)
	KHC-1	Ref	Ekman	Shell (2002)
49	55	Ref	Neill	Golder (1996a)
50	12	Ref	Neill	Beak (1986), RL&L (1989)
	BLC-HS	Ref	Ekman	Golder (2002b)
51	13	Ref	Neill, Ekman	Beak (1986), RL&L (1989)
207	WEC-SKL	Ref	Ekman	Golder (2002b)
Wapasu Creek Drainage				
52	7	Ref	Ekman	Beak (1986), RL&L (1989)
53	6	Ref	Neill, Ekman	Beak (1986), RL&L (1989)
54	19	Ref	Ekman	RL&L (1989)
180	1 (Lower)	Ref	Neill	Komex (1997)
181	2 (Upper)	Ref	Neill	Komex (1997)

Table II-3 Site Code Key for Small Streams North of Fort McMurray in Figure 1 (continued)

Site Number	Original Site Code	Site Type[a]	Sampling Methods[b]	Reference
Shelley Creek				
55	SHC-1	Ref	Ekman	Shell (2002)
Stanley Creek				
205	STC-HS	Ref	Ekman	Golder (2002b)
Beaver Creek Basin				
56	LBC-B1	Imp	Neill	RL&L and AA Aquatic Res. (1985)
57	LBC-B2	Imp	Neill	RL&L and AA Aquatic Res. (1985)
198	1	Imp	Surber	Tsui et al. (1978)
58	BRC-B	Imp	Neill	RL&L and AA Aquatic Res. (1985)
59	WID-B1	New	Neill	RL&L and AA Aquatic Res. (1985)
	2	New	Surber	Tsui et al. (1978)
199	3	New	Ekman	Tsui et al. (1978)
201	5	New	Ekman	Tsui et al. (1978)
60	W3-B	Ref	Ekman	RL&L and AA Aquatic Res. (1985)
	6	Ref	Ekman	Tsui et al. (1978)
61	WID-B2	New	Neill	RL&L and AA Aquatic Res. (1985)
	4	New	Ekman	Tsui et al. (1978)
200	7	Ref	Ekman	Tsui et al. (1978)
62	B1-B	New	Neill	RL&L and AA Aquatic Res. (1985)
63	UBC	Ref	Ekman	Noton and Chymko (1978)
	UBC-B	Ref	Ekman	RL&L and AA Aquatic Res. (1985)
Poplar Creek				
64	PC-1	New	Hess	Noton and Chymko (1978)
	PC1	New	AS, PIBS, Surber	Retallack (1980, 1981a, 1981b), Boerger (1983b)
	PC-B1	New	Neill	RL&L and AA Aquatic Res. (1985)
65a (down-stream)	B1	Ref	Surber, Ekman	Syncrude (1975), Noton and Chymko (1977)
65b (up-stream)	PC2	New	AS, PIBS, Surber	Retallack (1980, 1981a), Boerger (1983b)
	PC-B2	New	Neill	RL&L and AA Aquatic Res. (1985)
66	PC-2	New	Hess	Noton and Chymko (1978)
67	B2	Ref	Surber	Syncrude (1975), Noton and Chymko (1977)
68a (down-stream)	PC-B3	Ref	Neill	RL&L and AA Aquatic Res. (1985)
68b (up-stream)	B3	Ref	Surber	Syncrude (1975)
	PC3	Ref	AS, PIBS, Surber	Retallack (1980, 1981a, 1981b), Boerger (1983b)
69	B4	Ref	Surber	Syncrude (1975), Noton and Chymko (1977)
	PC-B4	Ref	Hess	Noton and Chymko (1978)
	PC4	Ref	AS, PIBS, Surber	Retallack (1980), Boerger (1983b)
	PC-B4	Ref	Neill	RL&L and AA Aquatic Res. (1985)

Table II-3 Site Code Key for Small Streams North of Fort McMurray in Figure 1 (continued)

Site Number	Original Site Code	Site Type[(a)]	Sampling Methods[(b)]	Reference
McLean Creek				
70	MCC-1	Ref	Ekman	Golder (1998b)
Fort Creek Area				
193 (Fort Creek)	FOC-D	Ref	Ekman	Golder (2002a)
	FOC	Ref	Surber	Golder (2000)
194 (Fort Creek)	FOC-MID	Ref	Surber	Golder (2000)
195 (Fort Creek)	FOC-MID	Ref	Ekman	Golder (2000)
196	Creek A	Ref	Surber	TrueNorth (2001)
197	Susan L. outlet cr.	Ref	Surber	TrueNorth (2001)

[(a)] Ref = reference site, Imp = potentially impacted site; New = site in man-made channel or impoundment.

[(b)]AS = artificial substrates; Ekman = Ekman grab; Hess = Hess sampler; Neill = Neill cylinder; PIBS = portable invertebrate box sampler; Surber = Surber sampler.

Table II-4 Site Code Key for Lakes, Reservoirs, Ponds and Wetlands in Figures 1 and 3

Site Number	Original Site Code	Site Type[(a)]	Sampling Methods[(b)]	Reference
NORTH OF FORT McMURRAY				
Calumet Lake				
191	CL-1	Ref	Ekman	CNRL (2002)
Lillian Lake				
192	LL-1	Ref	Ekman	CNRL (2002)
Muskeg River Basin				
71 (Kearl Lake)	Kearl L.	Ref	Ekman	Beak (1986)
	20	Ref	Ekman	RL&L (1989)
	80	Ref	Ekman	Golder (1996a)
	KEL	Ref	Ekman	Golder (2001, 2002a)
72	L8	Ref	Ekman	O'Neil et al. (1982)
73	L12	Ref	Ekman	O'Neil et al. (1982)
74	L3	Ref	Ekman	O'Neil et al. (1982)
75	L2	Ref	Ekman	O'Neil et al. (1982)
Isadore's Lake				
179	ISL	Ref	Ekman	Shell (unpublished data)
Shipyard Lake				
76	AW020	Ref	Ekman	Golder (1996b)
	AW021	Ref	Ekman	Golder (1996b)
	AW022	Ref	Ekman	Golder (1996b)
	SHL	Ref	Ekman	Golder (2001, 2002a)
Ruth Lake				
77	1	Ref	Ekman	Syncrude (1975), Noton and Chymko (1977)
78	2	Ref	Ekman	Syncrude (1975), Noton and Chymko (1977)
	RL-2	Imp	Ekman	Noton and Chymko (1978)
79	3	Ref	Ekman	Syncrude (1975), Noton and Chymko (1977)
	RL-3	Imp	Ekman	Noton and Chymko (1978)
	RL-B	Imp	Ekman	RL&L and AA Aquatic Res. (1985)
Beaver Creek Reservoir				
80	BCR-B1	New	Ekman	RL&L and AA Aquatic Res. (1985)
81	1 to 10 (transect)	New	Ekman	Noton and Chymko (1978)
82	BCR-B2	New	Ekman	RL&L and AA Aquatic Res. (1985)
	BCR-B3	New	Ekman	RL&L and AA Aquatic Res. (1985)
	BCR-1	New	Ekman	Noton and Chymko (1978)
83	BCR-B5	New	Ekman	RL&L and AA Aquatic Res. (1985)
84	BCR-B4	New	Ekman	RL&L and AA Aquatic Res. (1985)
	BCR-2	New	Ekman	Noton and Chymko (1978)
Poplar Creek Reservoir				
85	PCR-2	New	Ekman	Noton and Chymko (1978)
	8	New	Ekman	Noton and Chymko (1978)

Table II-4 Site Code Key for Lakes, Reservoirs, Ponds and Wetlands in Figures 1 and 3 (continued)

Site Number	Original Site Code	Site Type[(a)]	Sampling Methods[(b)]	Reference
86	PCR-1	New	Ekman	Noton and Chymko (1978)
	1 to 10 (transect)	New	Ekman	Noton and Chymko (1978)
	BCR-B1 to BCR-B5 (transect)	New	Ekman	RL&L and AA Aquatic Res. (1985)
87	6 to 10 (transect)	New	Ekman	Noton and Chymko (1978)
Wetlands (reference wetlands only)				
88	AOSTRA	Ref	6.5 cm diameter corer	Golder (1997)
89	Spruce	Ref	6.5 cm diameter corer	Golder (1997)
90	Tower	Ref	6.5 cm diameter corer	Golder (1997)
SOUTH OF FORT McMURRAY				
Algar Lake				
391	1	Ref	Ekman	Tripp and Tsui (1980)
392	2	Ref	Ekman	Tripp and Tsui (1980)
393	3	Ref	Ekman	Tripp and Tsui (1980)
Christina River Basin				
383	High Lake	Ref	Ekman	Gulf (1979)
384	Low Lake	Ref	Ekman	Gulf (1979)
385	Gull Lake	Ref	Ekman	Gulf (1979)
Gregoire Lake				
352	1	Ref	Ekman	Tripp and Tsui (1980)
353	2	Ref	Ekman	Tripp and Tsui (1980)
354	3	Ref	Ekman	Tripp and Tsui (1980)
355	4	Ref	Ekman	Tripp and Tsui (1980)
356	5	Ref	Ekman	Tripp and Tsui (1980)
Hangingstone River Basin				
358	L10	Ref	Ekman	Petro Canada (2001)
361	Maqua Lake	Ref	Ekman	Petro Canada (2001)
Surmont Creek Basin				
362	Surmont Lake	Ref	Ekman	Petro Canada (2001)
357	L8	Ref	Ekman	Petro Canada (2001)
359	L11	Ref	Ekman	Petro Canada (2001)
Wiau Lake Basin				
363	Unnamed Lake 1	Ref	Ekman	Rio Alto (2002)
364	Unnamed Lake 3	Ref	Ekman	Rio Alto (2002)
365	Unnamed Lake 4	Ref	Ekman	Rio Alto (2002)
366	Unnamed Lake 7	Ref	Ekman	Rio Alto (2002)
367	Wiau Lake	Ref	Ekman	Rio Alto (2002)

(a) Ref = reference site, Imp = potentially impacted site; New = site in man-made channel or impoundment.
(b) Ekman = Ekman grab.

Table II-5 Site Code Key for Streams South of Fort McMurray in Figure 3

Site Number	Original Site Code	Site Type[(a)]	Sampling Methods[(b)]	Reference
Algar River				
301	1	Ref	Surber/Ekman/Kick[(c)]	Tripp and Tsui (1980)
302	2	Ref	Surber/Ekman/Kick	Tripp and Tsui (1980)
303	3	Ref	Surber/Ekman/Kick	Tripp and Tsui (1980)
Cameron Creek				
332	1	Ref	Surber/Ekman/Kick	Tripp and Tsui (1980)
Christina River				
304	1	Ref	Surber/Ekman/Kick	Tripp and Tsui (1980)
305	2	Ref	Surber/Ekman/Kick	Tripp and Tsui (1980)
306	3	Ref	Surber/Ekman/Kick	Tripp and Tsui (1980)
307	4	Ref	Surber/Ekman/Kick	Tripp and Tsui (1980)
Christina River Tributaries				
369	Cottonwood Cr.	Ref	qualitative kick sampling	Gulf (1979)
	C2	Ref	Surber	Gulf (2001)
370	Creek 225.3	Ref	qualitative kick sampling	Gulf (1979)
371	Creek 229.2	Ref	qualitative kick sampling	Gulf (1979)
372	Creek 230.8	Ref	qualitative kick sampling	Gulf (1979)
373	Creek 235.4	Ref	qualitative kick sampling	Gulf (1979)
374	Meadow Cr. No.1	Ref	qualitative kick sampling	Gulf (1979)
375	Meadow Cr. No.2	Ref	qualitative kick sampling	Gulf (1979)
376	Meadow Cr. No.4	Ref	qualitative kick sampling	Gulf (1979)
377	Kinosis Cr.	Ref	qualitative kick sampling	Gulf (1979)
378	Kettle R. No.1	Ref	qualitative kick sampling	Gulf (1979)
379	Kettle R. No.2	Ref	qualitative kick sampling	Gulf (1979)
380	S. Kettle River	Ref	qualitative kick sampling	Gulf (1979)
381	Creek 241	Ref	qualitative kick sampling	Gulf (1979)
382	Creek 242	Ref	qualitative kick sampling	Gulf (1979)
386	M1	Ref	Surber	Gulf (2001)
387	M3	Ref	Surber	Gulf (2001)
388	C12	Ref	Surber	Gulf (2001)
389	K1	Ref	Surber	Gulf (2001)
Gregoire River				
312	1	Ref	Surber/Ekman/Kick	Tripp and Tsui (1980)
314	3	Ref	Surber/Ekman/Kick	Tripp and Tsui (1980)
315	4	Ref	Surber/Ekman/Kick	Tripp and Tsui (1980)
Hangingstone River				
317	1	Ref	Surber/Ekman/Kick	Tripp and Tsui (1980)
318	2	Ref	Surber/Ekman/Kick	Tripp and Tsui (1980)
319	3	Ref	Surber/Ekman/Kick	Tripp and Tsui (1980)
320	4	Ref	Surber/Ekman/Kick	Tripp and Tsui (1980)
321	5	Ref	Surber/Ekman/Kick	Tripp and Tsui (1980)

Table II-5 Site Code Key for Streams South of Fort McMurray in Figure 3 (continued)

Site Number	Original Site Code	Site Type[(a)]	Sampling Methods[(b)]	Reference
322	6	Ref	Surber/Ekman/Kick	Tripp and Tsui (1980)
324	8	Ref	Surber/Ekman/Kick	Tripp and Tsui (1980)
325	9	Ref	Surber/Ekman/Kick	Tripp and Tsui (1980)
326	10	Ref	Surber/Ekman/Kick	Tripp and Tsui (1980)
Horse River				
327	1	Ref	Surber/Ekman/Kick	Tripp and Tsui (1980)
328	2	Ref	Surber/Ekman/Kick	Tripp and Tsui (1980)
329	3	Ref	Surber/Ekman/Kick	Tripp and Tsui (1980)
340	4	Ref	Surber/Ekman/Kick	Tripp and Tsui (1980)
Prairie Creek				
341	3	Ref	Surber/Ekman/Kick	Tripp and Tsui (1980)
Saline Creek				
342	1	Ref	Surber/Ekman/Kick	Tripp and Tsui (1980)
344	3	Ref	Surber/Ekman/Kick	Tripp and Tsui (1980)
Saprae Creek				
345	1	Ref	Surber/Ekman/Kick	Tripp and Tsui (1980)
346	2	Ref	Surber/Ekman/Kick	Tripp and Tsui (1980)
347	3	Ref	Surber/Ekman/Kick	Tripp and Tsui (1980)
Surmont Creek				
348	1	Ref	Surber/Ekman/Kick	Tripp and Tsui (1980)
349	2	Ref	Surber/Ekman/Kick	Tripp and Tsui (1980)
350	3	Ref	Surber/Ekman/Kick	Tripp and Tsui (1980)
Wiau Lake Basin				
368	ST1	Ref	Ekman	Rio Alto (2002)
351	ST2	Ref	Ekman	Rio Alto (2002)

[(a)] Ref = reference site, Imp = potentially impacted site; New = site in man-made channel or impoundment.
[(b)] Ekman = Ekman grab; Surber = Surber sampler.
[(c)] Sampling device used by Tripp and Tsui (1980) was not specified.

APPENDIX III

SPECIES LISTS AND FREQUENCY OF OCCURRENCE

Table III-1 Frequency of Occurrence by Each Taxon in the Athabasca River

Notes: Percentages are based on studies that reported raw data and represent the percent of the total site data sets where a taxon was present.
P = present | C = common | LA = locally abundant
I = infrequent | R = restricted to lower reaches | F = frequently collected
A = abundant | (?) = taxonomic identification is uncertain | - = not identified to level shown

Major Taxon	Family (Subfamily/Tribe)	Genus/Species	Erosional Habitat (%)			Depositional Habitat (%)				All Habitats
			Total n=187	East bank n=99	West bank n=88	Total n=102	East bank n=26	West bank n=76	McCart et al. (1977)	Barton and Wallace (1980)
Hydrozoa	-	-	1	2						
	Hydridae	-	6	5	7					
		Hydra	0.5	1		1		1		I
Turbellaria	-	-	1	1	1	1		1	P	
Nemertea	-	-	0.5		1					
Nematoda	-	-	38	41	34	32	42	29	P	F
Oligochaeta	-	-	82	82	83	60	38	67	P	
	Aelosomatidae	-	2	1	3					
		Aelosoma								I
	Enchytraeidae	-	10	10	10	3	4	3		F, LA
	Lumbriculidae	-	0.5		1					
	Naididae	-	9	12	5	16	23	13		
		Amphichaeta leydigi	3	1	6					
		Amphichaeta americana								F
		Nais alpina	0.5	1						
		Nais behningi	3	2	5					F
		Nais communis	3	2	3					
		Nais variabilis	1	1	1					
		Nais simplex								C
		Pristina aequiseta	2	2	2					
		Specaria josinae	2	2	1					
	Sparganophilidae	-	1		2					
	Tubificidae	-	14	15	14	24	38	18		
		Limnodrilus profundicola	5	3	7					
		Limnodrilus hoffmeisteri								I
		Limnodrilus claparedianus								I
Hirudinea	-	-	1	1	1				P	
	Erpobdellidae	*Nephelopsis*	1	1	1					
	Glossiphoniidae	*Placobdella*	0.5		1					
Ostracoda	-	-	36	38	34	15	23	12		I
Amphipoda	-	-	0.5		1					
	Talitridae	*Hyalella azteca*				2		3	P	
Arachnida	-	-	7	8	7					
(Araneae)	-	-	3	1	5					
(Acarina)	-	-	13	18	8	4	8	3		
(Acarina - Prostigmata)	-	-	5	3	7					
(Acarina - Hydracarina)	-	-	10	12	7	3	12		P	
Gastropoda	-	-	2		3					
	Ancylidae	*Ferrissia*	0.5	1		1		1		
	Lymnaeidae	*Lymnaea*	0.5	1					P	
	Planorbidae	*Gyraulus*	1	1	1					
Pelecypoda	-	-	2	3	1					
	Sphaeriidae	-	3	5	1	2	4	1		
		Sphaerium	1	1	1	1		1	P	C
		Sphaerium striatinum				1	4			
		Pisidium	2	3	1	8		11		
Collembola	-	-	13	12	15	1		1		
	Hypogastruridae	-	0.5		1					
	Isotomidae	-	2	2	2					
	Onychiuridae	-	2	2	1					
	Sminthuridae	-	2	2	1					
Ephemeroptera	-	-	5	9	1	17		22		
	Acanthametropodidae	*Analetris*	7	7	7					
		Analetris eximia								R
	Ameletidae	*Ameletus*	17	15	19				P	R
	Ametropodidae	*Ametropus*	21	20	22	22	35	17	P	
		Ametropus neavei				4	12	1		P
	Baetidae	-	22	24	19	3		4		
		Baetis	67	66	68	2	4	1	P	F
		Baetis tricaudatus				2		3		
		Centroptilum	17	16	18					
		Cloeon	35	38	31					
		Cloeon implicatum								I
		Pseudocloeon	21	21	22				P	
	Baetiscidae	*Baetisca*	4	3	6					

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Major Taxon	Family (Subfamily/Tribe)	Genus/Species	Erosional Habitat (%) Total n=187	Erosional Habitat (%) East bank n=99	Erosional Habitat (%) West bank n=88	Depositional Habitat (%) Total n=102	Depositional Habitat (%) East bank n=26	Depositional Habitat (%) West bank n=76	Depositional Habitat (%) McCart et al. (1977)	All Habitats Barton and Wallace (1980)
Ephemeroptera (continued)	Caenidae	-				1		1		
		Caenis	28	27	30	2		3		I
		Brachycercus	11	13	9				P	
	Ephemerellidae	*Ephemerella*	52	52	52	5	4	5	P	
		Ephemerella inermis/infrequens				6	15	3		
		Ephemerella inermis								F
	Ephemeridae	*Ephemera*	4	2	6					
		Ephemera simulans								I
		Hexagenia	1	1	1				P	I
		Hexagenia limbata				1	4			
	Heptageniidae	-	13	15	11	3	4	3		
		Cinygmula	1	2					P	
		Epeorus	0.5		1				P	
		Heptagenia	83	82	85	10	15	8	P	C
		Rhithrogena	15	15	15				P	C
		Pseudiron								I
		Stenonema	6	7	6					
	Isonychiidae	*Isonychia*	24	27	20				P	I
	Leptophlebiidae	-	1	2						
		Leptophlebia	17	16	17	3	8	1	P	
		Leptophlebia cupida								I
		Leptophlebia nebulosa								I
		Paraleptophlebia	2	2	1				P	I
	Metretopodidae	*Metretopus*	29	25	33					
	Polymitarcyidae	*Ephoron*	0.5	1						
	Siphlonuridae	-	11	14	7					
		Siphlonurus	9	10	8					
		Siphloplecton	3	3	3				P	
	Tricorythidae	-	0.5	1						
		Tricorythodes	41	46	34					
		Tricorythodes minutus				1	4			I(?)
Odonata	-	-	1	2						
Odonata - Anisoptera	-	-	1	2						
	Aeshnidae	*Aeshna*	1	1	1	1		1		
	Corduliidae	*Epitheca*				1		1		
		Somatochlora				2	4	1		
	Gomphidae	-	2	1	2				P	
		Gomphus	1		2	8	15	5	P	
		Gomphus notatus								I(?)
		Ophiogomphus	64	59	70	10	8	11	P	
		Ophiogomphus colubrinus								C
		Stylurus				2	8			
Plecoptera	-	-	6	3	9	15		20		
	Capniidae	-	1		2	3	4	3		
		Capnia vernalis								C
	Chloroperlidae	-	12	14	10					
		Alloperla							P	
		Haploperla	1	1	1					
		Hastaperla brevis								C, LA
	Nemouridae	-	0.5		1					
		Nemoura	1	1	1					
		Nemoura (Shipsa) rotunda								I
	Peltoperlidae	-	2	1	2					
	Perlidae	*Acroneuria*							P	
		Acroneuria abnormis								C
		Claassenia	0.5	1						
		Hesperoperla	0.5		1					
	Perlodidae	-	64	58	72	13	19	11	P	
		Arcynopteryx	1	1	1					
		Isogenoides	4	3	5	3	4	3		
		Isogenoides frontalis								F, LA
		Isoperla	15	15	15	12	19	9		
		Isoperla longiseta								F, A
		Isoperla sordida								I(?)
	Pteronarcyidae	*Pteronarcella*	0.5		1					
		Pteronarcella regularis								I
		Pteronarcys	4	4	3	2	4	1	P	
		Pteronarcys dorsata								C, LA
	Taeniopterygidae	*Taenionema*	0.5	1		5	12	3	P	
		Taeniopteryx	1	2		2	8			
		Oemopteryx fosketti								C

Table III-1 Frequency of Occurrence by Each Taxon in the Athabasca River

Major Taxon	Family (Subfamily/Tribe)	Genus/Species	Erosional Habitat (%)			Depositional Habitat (%)				All Habitats
			Total n=187	East bank n=99	West bank n=88	Total n=102	East bank n=26	West bank n=76	McCart et al. (1977)	Barton and Wallace (1980)
Hemiptera	-	-	2	1	2					
	-	(adult)	2	1	2					
	Corixidae	-	12	16	7				P	
		(adult)	6	2	11					
		Callicorixa				5		7		
		Callicorixa audeni				3		4		I, LA
		Sigara				3	4	3		
		Sigara conocephala								I, LA
		Sigara lineata								I
		Sigara solensis								I
		Sigara trilineata								I
(Homoptera)	-	-	4	5	3	4	4	4		
Trichoptera	-	-	3	3	2	1		1		
	Brachycentridae	-	0.5		1					
		Brachycentrus	12	7	17	2	4	1	P	F
		Brachycentrus occidentalis				3		4		
		Micrasema								I
	Glossosomatidae	*Glossosoma*	1	1	1				P	
	Hydropsychidae	-	17	16	17	1		1		
		Arctopsyche	2	1	2					I
		Cheumatopsyche	7	10	5	4	8	3	P	F, LA
		Cheumatopsyche speciosa								A
		Hydropsyche	35	28	42	10	12	9	P	C, LA
		Hydropsyche bifida								C
	Hydroptilidae	-	4	6	1					
		Hydroptila	3	5	1					
		Mayatrichia	2	1	2					
		Neotrichia	1	1	1					I
		Oxyethira							P	
	Leptoceridae	-	3	3	3					
		Nectopsyche	0.5	1						
		Oecetis	9	8	9					
		Oecetis avara								C
		Ceraclea				1	4			
		Ceraclea tarsipunctata								R
		Triaenodes								I
	Limnephilidae	-				1		1	P	
		Limnephilus	0.5	1						
		Onocosmoecus				1		1		
	Lepidostomatidae	*Lepidostoma*							P	I
	Polycentropodidae	-	1	2		1		1		
		Neureclipsis	7	8	7				P	
		Polycentropus flavus								I
		Polycentropus remotus								I
	Psychomyiidae	-	0.5	1						
		Psychomyia	0.5	1						
Lepidoptera	-	-	5	3	7					
	Pyralidae	*Nymphula*								I
Coleoptera	-	-	3	5		1		1		
	-	(adult)	5	4	6					
	Dytiscidae	-	3	2	3	1		1		
	Elmidae	-	3	3	2	1		1		
		Dubiraphia				1		1		
		Optioservus fastiditus								I
	Gyrinidae	-							P	
	Haliplidae	*Haliplus*				1		1		
Diptera	-	-	10	12	8	30	38	28		
(Brachycera)	-	-				1		1		
	Athericidae	-	0.5		1					
		Atherix pachypus								I
		Atherix variegata							P	
	Ceratopogonidae	-	56	59	52	22	15	24	P	C
		Bezzia	6	3	9					
		Dasyhelea				1	4			
	(Ceratopogoninae)	-				13	27	8		
	Chironomidae	-	82	82	83	36	12	45		
	(Chironominae)	-	2	1	3	2		3		

Table III-1 Frequency of Occurrence by Each Taxon in the Athabasca River

Major Taxon	Family (Subfamily/Tribe)	Genus/Species	Erosional Habitat (%) Total n=187	Erosional Habitat (%) East bank n=99	Erosional Habitat (%) West bank n=88	Depositional Habitat (%) Total n=102	Depositional Habitat (%) East bank n=26	Depositional Habitat (%) West bank n=76	Depositional Habitat (%) McCart et al. (1977)	All Habitats Barton and Wallace (1980)
Diptera (continued)	(Chironomini)	-	29	36	22	20	23	18		
		Acalcarella	0.5		1					
		Beckiella tethys								F
		Chernovskiia				2	4	1		
		Chernovskiia orbicus								F
		Chironomus	4	2	6	12	19	9	P	
		Chironomus fluviatilis group								I, LA
		Chironomus salinarius group								I
		Cryptochironomus	2	1	3	18	27	14	P	F
		Cryptochironomus cf. rolli				3	4	3		C
		Cryptotendipes				5		7		I
		Cyphomella	2	2	2					
		Cyphomella cf. gibbera								C, LA
		Demicryptochironomus				6	8	5	P	I
		Dicrotendipes				1		1		
		Endochironomus cf. subtendens								I
		Harnischia				1		1		
		Harnischia complex				12	27	7		
		Microtendipes cf. pedellus								I
		Paracladopelma				18	23	16		C, A
		Paralauterborniella	2	1	3	20	31	16		I
		Paratendipes				3	4	3	P	C
		Phaenopsectra	1		2	2	4	1		I
		Polypedilum	6	4	9	30	50	24	P	F
		Polypedilum breviantennatum group								F, A
		Polypedilum fallax group								I
		Polypedilum scalaenum group								F
		Robackia				1		1		
		Robackia claviger								F, A
		Robackia demeijerei								F, A
		Sergentia	0.5		1					
		Stenochironomus				1		1		I
		Stictochironomus				3		4		C
	(Corynoneurini)	-	1	2						
	(Diamesinae)	-	1	2		1	4			
		Monodiamesa	2	2	2	15	27	11		
		Monodiamesa cf. tuberculata								C
		Potthastia				2	4	1		
		Potthastia longimana Gr.				1		1		
		Potthastia longimanus type								I
		Pseudodiamesa								I
	(Orthocladiinae)	-	29	32	25	23	19	24	P	
		Brillia				4	4	4		C
		Bryophenocladius	1	1	1					
		Corynoneura	2	1	2					I
		Cricotopus/Orthocladius	4	3	5	2	4	1		
		Cricotopus bicinctus								I
		Cricotopus cylindraceus group								I
		Cricotopus juscus group								I
		Eukiefferiella				3		4		C
		Eukiefferiella cf. claripennis								I
		Eukiefferiella/Tvetenia	3	3	3					
		Heterotrissocladius				5	15	1	P	
		Heterotrissocladius cf. latilaminus								I
		Limnophyes	1	1	1					I
		Lopescladius				2	4	1		
		Nanocladius	2	1	3	7	8	7		
		Nanocladius cf. rectinervis								C
		Orthocladius complex				1	4			
		Parakiefferiella								I
		Parametriocnemus				1		1		
		Psectrocladius	1	1	1	1		1		
		Rheosmittia	4	3	5	4	4	4		
		Rheocricotopus								I
		Synorthocladius								I
		Thienemanniella	1	1	1					I
	(Prodiamesinae)	-	6	7	5	5		7		

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			Erosional Habitat (%)			Depositional Habitat (%)				All Habitats
Major Taxon	**Family (Subfamily/Tribe)**	**Genus/Species**	**Total n=187**	**East bank n=99**	**West bank n=88**	**Total n=102**	**East bank n=26**	**West bank n=76**	**McCart et al. (1977)**	**Barton and Wallace (1980)**
Diptera (continued)	(Tanypodinae)	-	29	35	23	10	4	12		
		Ablabesmyia	0.5		1	6	15	3	P	
		Derotanypus	1	1	1					
		Nilotanypus								I
		Larsia								I
		Procladius	1		2	17	23	14	P	I, LA
		Thienemannimyia	4	2	6	3	4	3		
		Thienemannimyia group				6	8	5		F
	(Tanytarsini)	-	30	35	24	7		9		
		Cladotanytarsus	3	2	3	2	4	1		C
		Micropsectra	0.5	1		17	38	9		C
		Parapsectra/Micropsectra	0.5		1					
		Rheotanytarsus	3	2	3	7	15	4		F
		Stempellina				2		3		
		Stempellinella				11	15	9		
		Tanytarsus	2	3	1	4	8	3	P	C
		Zavrelia	2	1	3					C
	Dolichopodidae	*Dolichopodidae*								I
		Rhaphium				1		1		
		-	0.5	1						
	Empididae	-	35	31	40	13		17	P	
		Chelifera	0.5	1						I
		Hemerodromia	9	10	7	4	12	1		C
		Wiedemannia								I
	Ptychopteridae	-				1		1		
	Simuliidae	-	25	20	30	17		22	P	
		Simulium				3	4	3		
		Simulium arcticum								F, A
		Simulium tuberosum complex								C, A
		Simulium venustum complex								C
	Stratiomyidae	-	0.5	1						
	Tabanidae	-	3	4	2				P	
	Tipulidae	-	2		3	1		1	P	
		Dicranota				1		1		
		Eriocera								I
		Hexatoma	0.5		1					
Total taxa (All studies/habitats combined: 306)			179	156	153	126	77	116	57	119
Total taxa (genus as lowest level) (All studies/habitats combined: 181)			130	111	115	91	63	83	54	98
Total taxa in major taxonomic groups (genus as lowest level)		Oligochaeta	9	7	9	3	3	3	0	5
		Mollusca	6	6	4	4	2	4	2	1
		Ephemeroptera	26	25	24	9	8	7	15	15
		Odonata	3	2	3	6	4	5	2	2
		Plecoptera	13	10	10	6	6	5	5	9
		Trichoptera	13	13	10	6	4	5	8	11
		Coleoptera	2	2	2	3	0	3	1	1
		Chironomidae	30	24	28	37	27	36	9	40
		Other Diptera	9	7	6	7	4	6	6	8
		Other	19	15	19	10	5	9	6	6

Table III-2 Frequency of Occurrence by Each Taxon in the MacKay, Muskeg and Steepbank Rivers

Notes: Percentages are based on studies that reported raw data and represent the percent of the total site data sets where a taxon was present.
I = infrequent R = restricted to lower reaches F = frequently collected
A = abundant LA = locally abundant - = not identified to level shown
C = common (?) = taxonomic identification is uncertain

Major Taxon	Family (Subfamily/Tribe)	Genus/Species	MacKay R. (%) n=32	Muskeg R. (%) n=42	Steepbank R. (%) n=8	Barton and Wallace (1980) Muskeg R.	Barton and Wallace (1980) Steepbank R.
Porifera	-	*Spongilla*	0	0	0	C	C
Hydrozoa	Hydridae	*Hydra*	6	17	0	C	C
Turbellaria - Tricladida	-	-	0	2	0		
	-	*Allocoela*	0	0	0	I	
	-	*Dugesia tigrina*	0	0	0	I(?)	
Nematoda	-	-	44	67	100	F	F
Nematomorpha	-	-	0	0	0	F	F
Bryozoa	-	-	0	0	0	I	I
Oligochaeta	-	-	75	5	0		
	Enchytraeidae	-	16	19	100	I	F
	Lumbricidae	-	0	7	0		
	Lumbriculidae	-	0	14	13		
		Lumbriculus variegatus	0	0	0	C	I
	Naididae	-	16	81	100		
		Arcteonais lomondi	0	0	0	I	
		Chaetogaster diaphanus	0	0	0	C	I
		Chaetogaster langi	0	0	0	I	
		Dero digitata	0	0	0	I	
		Nais behningi	0	0	0	C, LA	F
		Nais communis/variabilis	0	0	0	C	C
		Nais pardalis	0	0	0	C	
		Nais pseudobtusa	0	0	0	I	I
		Nais simplex	0	0	0	C	C
		Pristina breviseta	0	0	0	I	F
		Pristina foreli	0	0	0	I	I
		Pristina longiseta	0	0	0	C	
		Slavina appendiculata	0	0	0	C	C
		Specaria josinae	0	0	0	I	
		Stylaria lacustris	0	0	0	I	I
		Uncinais uncinata	0	0	0	I	C
		Vejdovskyella comata	0	0	0	I	I
	Tubificidae	-	16	74	100	F, LA	F, LA
		Limnodrilus claparedianus	0	0	0	I	
		Limnodrilus hoffmeisteri	0	0	0	I	I
		Peloscolex	0	0	0	C	I
		Tubifex tubifex	0	0	0		I
Hirudinea	-	-	0	10	0		
	Erpobdellidae	-	0	5	0		
		Dina	0	0	0	I(?)	I(?)
		Dina parva	0	5	0		
		Dina/Moorebdella	0	5	0		
		Erpobdella punctata	0	2	0	C	I
		Mooreobdella fervida	0	2	0		
		Nephelopsis obscura	0	7	0		I
	Glossiphoniidae	*Glossiphonia complanata*	3	17	0	I	C
		Glossiphonia heteroclita	0	0	0	I	
		Helobdella stagnalis	0	40	0	C	C
		Placobdella ornata	0	2	0		
		Placobdella papillifera	0	2	0	I(?)	
	Hirudinidae	*Haemopsis grandis*	0	0	0	I	I
	Piscicolidae	*Piscicola*	0	0	0	I	I
Mollusca	-	-	3	0	0		
Gastropoda	-	-	0	2	0		
	-	*Ferrissia*	0	0	0	I	
	Ancylidae	*Ferrissia rivularis*	22	31	75		
	Hydrobiidae	-	0	5	13		
		Amnicola limosa	0	0	0	I(?)	
		Probythinella	0	2	0		
	Lymnaeidae	-	0	2	0		
		Lymnaea	0	7	0	I, LA	I
		Stagnicola	0	2	0		
	Physidae	*Physa*	0	14	0	C	F

Table III-2 Frequency of Occurrence by Each Taxon in the MacKay, Muskeg and Steepbank Rivers

Major Taxon	Family (Subfamily/Tribe)	Genus/Species	MacKay R. (%) n=32	Muskeg R. (%) n=42	Steepbank R. (%) n=8	Barton and Wallace (1980)	
						Muskeg R.	Steepbank R.
Gastropoda (continued)	Planorbidae	*Gyraulus*	6	29	25		
		Gyraulus parvus	0	0	0	C	?
		Helisoma	0	7	0	I	I
	Planorbidae	*Promenetus*	0	2	0	I	
		Promenetus evacuous	0	2	0		
	Valvatidae	*Valvata*	3	0	0		
		Valvata lewisii	0	2	0	C(?)	C(?)
		Valvata sincera	0	26	0		
		Valvata tricarinata	0	5	0		
Pelecypoda	Sphaeriidae	-	28	48	13		
		Musculium	0	19	0	C	C
		Pisidium	3	52	0	F	F
		Pisidium/Sphaerium	0	2	0		
		Sphaerium	0	36	0	C	F
	Unionidae	-	3	0	0		
		Lampsilis	0	0	0	I	
		Lampsilis radiata	0	2	0		
		Lasmigona complanata	0	2	0		
Acari - Hydracarina	-	-	38	52	100		
	Hygrobatidae	*Hygrobates*	0	2	0		
	Lebertiidae	*Lebertia*	0	10	0		
Copepoda - Harpacticoida	-	-	0	7	0		
Ostracoda	-	-	6	45	50	F	F
	Candonidae	*Candona*	6	10	25		
	Cyclocypridae	*Cyclocypris*	0	2	0		
	Cypridae	-	0	2	0		
Amphipoda	-	-	0	14	0		
	Gammaridae	*Gammarus lacustris*	0	29	0	C, LA	I
	Talitridae	*Hyalella azteca*	3	33	0	C, LA	C, LA
Collembola	-	-	13	21	50		
	Isotomidae	*Isotomus*	0	2	0		
Ephemeroptera	Ameletidae	*Ameletus*	19	0	25	I, LA	F
		Ameletus subnotatus	3	2	25		
	Ametropodidae	*Ametropus neavei*	0	0	0		C, LA
	Baetidae	-	28	2	0		
		Acentrella	0	2	25		
		Baetis	50	40	63	C, LA	F, LA
		Baetis sp. 1	31	0	0		
		Baetis sp. 2	44	0	0		
		Baetis tricaudatus	0	0	38		
		Baetisca	0	2	0		
		Callibaetis	0	2	0		
		Callibaetis coloradensis	0	0	0	I	C
		Centroptilum	13	2	0	I	F
		Diphetor hageni	0	0	13		
		Cloeon	0	0	0	I	
		Pseudocloeon	28	0	0	I	C
	Baetiscidae	*Baetisca*	6	2	13		
		Baetisca columbiana	0	0	0	I(?)	I(?)
		Baetisca obesa	0	0	0	I	C
	Caenidae	*Brachycercus*	6	0	0	C, LA	I
		Caenis	31	12	0	I	I
		Caenis sp.1	0	12	0		
		Caenis sp.2	0	2	0		
	Ephemerellidae	-	3	5	13		
		Drunella grandis	0	2	50		
		Ephemerella	25	26	63		
		Ephemerella (drunella)	13	0	0		
		Ephemerella aurivilli	0	12	0	I	
		Ephemerella grandis ingens	0	2	0		
		Ephemerella inermis/infrequens	0	0	38		
		Ephemerella inermis	0	0	0	I	C
		Ephemerella lita	0	19	0		
		Ephemerella marginata	0	0	0	I	I
		Ephemerella simplex	0	0	0	I, C	C
		Ephemerella spinifera	0	2	0	I	F, A
		Ephemerella tibialis	0	0	0	I	C
	Ephemeridae	*Ephemera cf. simulans*	0	0	0	I	
		Hexagenia	0	19	0		

Table III-2 Frequency of Occurrence by Each Taxon in the MacKay, Muskeg and Steepbank Rivers

Major Taxon	Family (Subfamily/Tribe)	Genus/Species	MacKay R. (%) n=32	Muskeg R. (%) n=42	Steepbank R. (%) n=8	Barton and Wallace (1980) Muskeg R.	Barton and Wallace (1980) Steepbank R.
Ephemeroptera (continued)	Heptageniidae	-	34	5	75		
		Epeorus albertae	0	0	0		I(?)
		Heptagenia	84	14	88	R, LA	F, A
		Rhithrogena	31	0	88	R	I
		Stenonema	16	31	13		
		Stenonema vicarium	0	0	0	R	C
		Stenacron interpunctatum	0	0	0	I	
	Isonychiidae	*Isonychia*	0	0	0	I	
	Leptophlebiidae	-	0	12	0		
		Leptophlebia	13	50	13		
		Leptophlebia cupida	0	0	0	F, A	C
		Leptophlebia nebulosa	0	0	0	F, A	C
		Paraleptophlebia	16	5	13	I	F
	Metretopodidae	*Metretopus borealis*	0	0	0	I, LA	
	Siphlonuridae	-	0	2	0		
		Parameletus	0	2	0		
		Siphlonurus	3	5	0	C	I
		Siphlonurus alternatus	0	0	0	C	I
		Siphloplecton	0	5	0		
		Siphloplecton basale	0	0	0	I, LA	I
	Tricorythidae	*Tricorythodes*	50	12	25		
		Tricorythodes minutus	0	0	0	C, LA(?)	C(?)
Odonata	-	-	0	12	0		
Odonata - Anisoptera	Aeshnidae	*Aeshna*	0	5	0		
		Aeshna eremita	0	0	0	C	C
		Aeshna interupta	0	7	0	I	I
		Aeshna umbrosa	0	0	0	C(?)	C(?)
	Corduliidae	*Cordulia shurtleffi*	0	0	0	I	
		Epitheca canis	0	5	0	I	
		Somatochlora	0	2	0		
		Somatochlora minor	0	0	0	I	F
	Gomphidae	*Gomphus*	0	2	0		
		Ophiogomphus	56	19	75		
		Ophiogomphus colubrinus	0	0	0	R, LA	C, A
	Libellulidae	*Leucorrhinia hudsonica*	0	0	0	I	
Odonata - Zygoptera	Calopterygidae	*Calopteryx aequabilis*	0	5	0		
	Coenagrionidae	-	0	2	0		
		Agrion aequabile	0	0	0	I	I
		Ceoenagrion resolutum	0	0	0	I	I
		Enallagma boreale	0	2	0	I	
		Ischnura	0	0	0	I	
Plecoptera	-	-	16	10	13		
	Capniidae	-	0	2	63		
		Capnia vernalis	0	0	0	I	C
	Chloroperlidae	-	13	14	63		
		Hastaperla	9	7	0		
		Hastaperla brevis	0	10	0	R, LA	F
		Paraperla	0	2	0		
	Leuctridae	*Leuctra cf. sara*	0	0	0	I(?)	F(?)
	Nemouridae	-	3	0	0		
		Malenka	0	0	13		
		Amphinemura linda	0	0	0	I	I
		Shipsa rotunda	0	0	0	C, LA	C, A
		Nemoura	0	17	0		
		Nemoura arctica	0	0	0	R, LA	I
		Zapada	0	7	25		
		Zapada cinctipes	0	0	25	F	
	Perlidae	-	3	0	0		
		Acroneuria	6	10	0		
		Acroneuria lycorias	0	0	0	I	
		Claassenia sabulosa	0	21	25	R, A?	C?
		Paragnetina	0	7	0		
	Perlodidae	*Arcynopteryx*	0	2	0	R, LA	F
		Isogenoides	16	5	0		
		Isogenoides frontalis	0	0	0	I	I
		Isoperla	25	38	75		
		Isoperla fulva	0	0	0	I	
		Isoperla fusca	0	0	0	R, LA(?)	I(?)
		Skwala	0	2	50		

Table III-2 Frequency of Occurrence by Each Taxon in the MacKay, Muskeg and Steepbank Rivers

Major Taxon	Family (Subfamily/Tribe)	Genus/Species	MacKay R. (%) n=32	Muskeg R. (%) n=42	Steepbank R. (%) n=8	Barton and Wallace (1980)	
						Muskeg R.	Steepbank R.
Plecoptera (continued)	Pteronarcyidae	*Pteronarcella dorsata*	0	14	0		
		Pteronarcella regularis	0	0	0		C
		Pteronarcys	25	12	0		
		Pteronarcys dorsata	0	0	38	R, A	C, A
	Taeniopterygidae	*Taenionema*	0	0	13		
		Taeniopteryx	25	17	63		
		Taeniopteryx nivalis	0	2	0	C, LA	C
		Taeniopteryx parvula	0	0	0	I	
Hemiptera	Corixidae	-	6	10	0		
		Callicorixa	3	2	13		
		Callicorixa audeni	0	0	0		F, A
		Hesperocorixa atopodonta	0	0	0	C	C
		Hesperocorixa michiganensis	0	0	0	I	F
		Hesperocorixa minorella	0	0	0		I
		Sigara	6	10	25		
		Sigara alternata	0	0	0	I, LA	I, LA
		Sigara bicoloripennis	0	0	0	I	C
		Sigara conocephala	0	0	0	I	C
		Sigara decoratella	0	0	0	I	C
		Sigara grossolineata	0	0	0		I
		Sigara mullettensis	0	0	0	I	I
		Sigara penniensis	0	0	0	I	I
		Sigara solensis	0	0	0	I, LA	C
		Sigara washingtonensis	0	0	0		I
		Trichocorixa naias	0	0	0	I	
		Trichocorixa verticalis interiores	0	0	0		I
Megaloptera	Sialidae	*Sialis*	0	2	0	I	C
Lepidoptera	-	-	0	0	13		
	Pyralidae	*Nymphula*	0	2	0		
Trichoptera	-	-	6	7	13		
	Brachycentridae	-	0	2	0		
		Brachycentrus	16	19	0	R, LA	F, A
		Brachycentrus americanus	0	10	13	R, LA	F, A
		Brachycentrus occidentalis	0	0	13		
		Micrasema	0	10	25	R, LA	F, A
	Glossosomatidae	-	0	2	0		
		Agapetus	0	2	0	I	I
		Glossosoma	13	24	38	R, LA	F
		Protoptila	0	2	13	I	I
	Helicopsychidae	*Helicopsyche*	0	12	0		
		Helicopsyche borealis	0	5	0	R	
	Hydropsychidae	-	13	7	25		
		Arctopsyche	19	0	0	I	C
		Arctopsyche grandis	0	0	13		
		Arctopsyche ladogensis	0	7	0		
		Cheumatopsyche	3	21	25	C, LA	F
		Cheumatopsyche annalis	0	10	0		
		Hydropsyche	38	21	88	R, LA	F
		Hydropsyche betteni	0	19	0		
		Hydropsyche bifida	0	19	0	C	C
		Hydropsyche recurvata	0	12	0		
		Hydropsyche simulans	0	19	0		
		Hydropsyche slossonae	0	19	0	C	C
		Potamyia flava	0	7	0		
	Hydroptilidae	-	0	12	25		
		Agraylea	0	0	0	I	I
		Dibusa	0	0	0	I	
		Hydroptila	0	5	75	I	
		Mayatrichia	6	0	0	I	I
		Ochrotrichia	0	5	13	I	I(?)
		Neotrichia	0	2	13		
		Oxyethira	3	10	0	R, LA	C
	Lepidostomatidae	*Lepidostoma*	3	33	38	R, LA	F, A
	Leptoceridae	*Ceraclea*	3	21	25		
		Ceraclea annulicornis	0	0	0	I	C
		Ceraclea tarsipunctata	0	0	0	I	C
		Nectopsyche	0	0	0	I	
		Oecetis	9	17	0		
		Oecetis avara	0	0	0	I	I

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Major Taxon	Family (Subfamily/Tribe)	Genus/Species	MacKay R. (%) n=32	Muskeg R. (%) n=42	Steepbank R. (%) n=8	Barton and Wallace (1980)	
						Muskeg R.	Steepbank R.
Trichoptera (continued)	Limnephilidae	-	0	2	0		
		Anabolia bimaculata	0	0	0	I	
		Asynarchus	0	0	0	C	I
		Glyphopsyche irrorata	0	0	0	I	C
		Drusinus	6	0	0		
		Grammotaulius	0	2	0	I	
		Hesperophylax	0	0	0	I	C
		Limnephilus	0	14	0	C	F
	Limnephilidae	*Limnephilus minusculus*	0	0	0	I	
		Moselyana	0	2	0		
		Nemotaulius	0	12	0		
		Nemotaulius hostilis	0	0	0	I	
		Oncosmoecus	0	0	0		I
		Psychoglypha subborealis	0	0	0	I	C
		Pycnopsyche	0	0	0		R
	Philopotamidae	-	3	0	0		
		Wormaldia gabriella	0	14	0	R, LA	I
		Chimarra	0	2	0		
	Phryganeidae	*Agrypnia*	0	2	0	I	
		Phryganea	0	0	0	I	
		Ptilostomis	0	5	0		
		Ptilostomis semifasciata	0	2	0	I	F
	Polycentropodidae	*Neureclipsis*	3	2	0		
		Polycentropus	0	10	0		
		Polycentropus cinereus	0	0	0	I	
		Polycentropus flavus	0	0	0	I	
		Polycentropus plexus	0	2	0		
	Psychomyiidae	*Psychomyia*	0	7	13		
		Psychomyia flavida	0	5	0		
	Rhyacophilidae	*Rhyacophila*	6	2	13	I	I
Coleoptera	Chrysomelidae	*Donacia*	0	2	0		
	Dytiscidae	-	3	0	0		
		Agabus	0	2	0	I	I
		Agabus seriatus	0	0	0	I	
		Carrhydrus crassipes	0	0	0	I	
		Deronectes	0	0	0		I
		Dytiscus harrissi	0	0	0	I	
		Hydaticus	0	0	0		I
		Hydroporus	3	0	0		I
		Ilybius	0	2	0	I	
		Liodessus	3	5	0		
		Neoscutopterus	0	0	0		I
	Elmidae	-	3	7	0		
		Dubiraphia	0	17	0		
		Dubiraphia robusta	0	0	0	I	
		Optioservus	3	21	0		
		Optioservus fastidatus	0	19	0	R, LA	I
		Stenelmis	0	2	0		
	Gyrinidae	-	0	2	0		
		Gyrinus affinis	0	0	0	C, LA	
		Gyrinus maculiventris	0	0	0	I	I
		Gyrinus minutus	0	0	0	I	
		Gyrinus opacus	0	0	0		C(?)
		Gyrinus pectoralis	0	0	0	I	
	Haliplidae	*Brychius*	0	5	0	I	I, LA
		Haliplus	0	12	0	I	C
	Hydrophilidae	-	0	0	0	C	
	Heteroceridae	-	0	2	0		
Diptera	-	-	6	2	25		
	Athericidae	-	9	0	0		
		Atherix	0	19	63		
		Atherix pachypus	0	0	0	R, LA	C
	Ceratopogonidae	-	28	38	63	F	F
		Atrichopogon	0	0	0	I	
		Bezzia	0	5	0		
		Bezzia/Probezzia	0	43	0		
		Palpomyia tibialis	0	5	0		
	Chironomidae	-	38	21	13		
	(Chironominae)	-	0	19	0		
	(Chironomini)	-	16	60	63		
		Chironomus	9	7	13		
		Chironomus annularis group	0	0	0	I	
		Chironomus cf. decorus	0	0	0	C	

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Major Taxon	Family (Subfamily/Tribe)	Genus/Species	MacKay R. (%) n=32	Muskeg R. (%) n=42	Steepbank R. (%) n=8	Barton and Wallace (1980)	
						Muskeg R.	Steepbank R.
Diptera (continued)	(Chironomini)	*Chironomus fluviatilis group*	0	0	0	C	I
		Chironomus plumosus group	0	7	0	I	I
		Chironomus salinarius group	0	0	0	I	I
		Chironomus thumni group	0	5	0	I, LA	
		Cladopelma	0	7	0	C	I
		Cryptochironomus	19	29	75	C	F
		Cryptocladopelma	0	0	0	I	I
		Cryptotendipes	3	5	0	I	I
		Demicryptochironomus	13	10	50		
		Dicrotendipes	0	14	0		
		Dicrotendipes cf. fumidus	0	0	0	C	C
		Dicrotendipes cf. modestus	0	0	0	I	
		Dicrotendipes cf. neomodestus	0	0	0	I	
		Dicrotendipes cf. nervosus	0	0	0	I	I
		Endochironomus	3	0	0		
		Endochironomus cf. subtendens	0	0	0	C	I
		Glyptotendipes	0	0	0	I	I
		Kiefferulus	0	0	0		I
		Microtendipes	19	26	50		
		Microtendipes cf. pedellus	0	0	0	C	C
		Nilothauma	0	2	0		
		Pagastiella	0	5	0		
		Parachironomus	0	10	0	C	I
		Paracladopelma	3	5	0	I	I
		Paralauterborniella	3	5	0	I	I
		Paratendipes	6	12	0	I	C
		Phaenopsectra	3	14	13	C	F
		Polypedilum	34	26	100	C	F
		Polypedilum breviantennatum group	0	0	0	I	F
		Polypedilum fallax group	0	0	0	I	C
		Robackia	6	0	0		
		Saetheria	16	10	63		
		Stictochironomus	3	12	0	C	F
		Tribelos	0	5	0		
		Xenochironomus xenolabis	0	0	0	I	
	(Corynoneurini)	-	0	12	0		
	(Diamesinae)	-	0	5	0		
		Diamesa	0	2	0	I	I
		Potthastia	9	17	50		
		Potthastia cf. gaedi	0	0	0	I	
		Potthastia longimanus type	3	5	13	I	C
		Protanypus	0	0	0	I	
		Pseudodiamesa	0	0	0	I	
	(Orthocladiinae)	-	13	43	100		
		Orthocladiinae A	0	0	0	I, LA	C
		Orthocladiinae D	0	0	0		I
		Acricotopus cf. senex	0	0	0	C	I
		Brillia	0	14	38	C	C
		Cardiocladius	9	0	0	C	C
		Chaetocladius	0	0	13		
		Corynoneura	16	26	88	F	F
		Cricotopus	25	0	0		
		Cricotopus/Nostococladius	0	0	13		
		Cricotopus/Orthocladius	9	26	63		
		Cricotopus bicinctus	0	0	0	C, A	C, A
		Cricotopus cylindraceus group	0	0	0	I	I
		Cricotopus juscus group	0	0	0		I
		Cricotopus tremulus group	0	0	0	C, A	C, A
		Cricotopus nr. curtus	0	0	0	I	I
		Cricotopus cf. triannulatus	0	0	0		C
		Cricotopus trifascia group	0	0	0	I	
		Cricotopus nostocicola	0	0	0	I	C
		Cricotopus cf. laetus	0	0	0		I
		Diplocladius cf. cultriger	0	0	0	C	F
		Eukiefferiella	13	5	100	C	F, A
		Eukiefferiella cf. brevicalcar	0	0	0	I	I
		Eukiefferiella cg. claripennis	0	0	0	I, LA	C
		Eurycnemus	0	0	0	I	
		Euryhapsis	0	2	0		
		Heterotrissocladius	3	21	0		
		Heterotrissocladius cf. latilaminus	0	0	0	C	F

Table III-2 Frequency of Occurrence by Each Taxon in the MacKay, Muskeg and Steepbank Rivers

Major Taxon	Family (Subfamily/Tribe)	Genus/Species	MacKay R. (%) n=32	Muskeg R. (%) n=42	Steepbank R. (%) n=8	Barton and Wallace (1980) Muskeg R.	Barton and Wallace (1980) Steepbank R.
Diptera (continued)	(Orthocladiinae)	*Krenosmittia*	0	5	38	I	I
		Limnophyes	0	0	0	I	I
		Lopescladius	13	12	38		
		Metriocnemus	0	0	0	I	
		Nanocladius	3	12	13		
		Nanocladius cf. balticus	0	0	0		I
		Nanocladius cf. distinctus	0	0	0	C	
		Nanocladius cf. rectinervis	0	0	0		F
		Orthocladius	25	0	0	I	F
		Orthocladius complex	0	0	38		
		Parakiefferiella	6	21	25	C	F
		Parametriocnemus	3	12	50	C	F
		Parametriocnemus cf. graminicola	0	0	0		I
		Parametriocnemus cf. lundbecki	0	0	0	I	C
		Paraphanocladius	0	0	0		C
		Paratrichocladius	0	0	0	I, LA	
		Psectrocladius	9	5	0	C	C
		Psectrocladius cf. simulans	0	0	0	I	I
		Pseudosmittia	0	0	0	I	
		Rheocricotopus	0	2	25	I, LA	C
		Rheocricotopus nr. kenorensis	0	0	0	I, LA	
		Rheosmittia	3	5	13		
		Smittia	6	0	0		
		Synorthocladius	13	7	63	I	F
		Thienemanniella	13	17	63	C	F
		Tvetenia	16	12	100		
		?Genus acutilabis	0	0	0		C
	(Orthocladiinae/Diamesinae)	-	0	36	0		
	(Pentaneurini)	-	0	5	13		
	(Podonominae)	*Trichotanypus posticalis*	0	0	0	R	
	(Tanypodinae)	-	0	67	25		
		Ablabesmyia	13	21	38	F	F
		Conchapelopia	16	0	0	I	C
		Labrundinia	0	0	0	I	I
		Larsia	3	5	13	C	C
		Nilotanypus	6	12	50	R, C	C
		Paramerina	0	0	25	I	C
		Pentaneura	0	0	13		
		Procladius	9	21	0	F	F
		Rheopelopia	0	0	0	I	
		Thienemannimyia	3	12	50	I	
		Thienemannimyia complex	13	12	50	C	F
	(Tanytarsini)	-	3	45	50		
		Cladotanytarsus	28	19	50	C	F
		Constempellina	0	0	0		I
		Micropsectra	41	26	100	F, A	F, A
		Paratanytarsus	0	21	13	C	I
		Rheotanytarsus	41	17	100	C, A	F, A
		Stempellina	13	12	0	C, LA	F
		Stempellinella	6	17	25		
		Sublettea	3	0	0		
		Tanytarsus	28	19	13	F, A	F, A
		Tanytarsus/Micropsectra	0	5	0		
		Zavrelia	0	0	0	C	F
	Dixidae	-	0	5	0		
		Paradixa	0	0	0	I	
	Dolichopodidae	-	0	5	0		C
		Rhaphium	0	2	0		
	Empididae	-	19	0	0		
		Chelifera	3	12	88	C	C
		Hemerodromia	16	38	100	C	F
		Hemerodromia rogatoris	0	0	0	C	
		Oreogeton	0	2	0		
		Rhamphomyia	0	2	0	LA	LA
		Wiedemannia	0	0	25		C
	Ephydridae	*Psilopa*	0	0	0	I	I
	Psychodidae	*Pericoma*	0	0	13		I
		Telmatoscopus	0	0	0	I	I
		Psychoda	0	7	0		
	Muscidae	*Limnophora*	0	0	0		I

Table III-2 Frequency of Occurrence by Each Taxon in the MacKay, Muskeg and Steepbank Rivers

Major Taxon	Family (Subfamily/Tribe)	Genus/Species	MacKay R. (%) n=32	Muskeg R. (%) n=42	Steepbank R. (%) n=8	Barton and Wallace (1980) Muskeg R.	Barton and Wallace (1980) Steepbank R.
Diptera (continued)	Simuliidae	-	38	5	0		
		Simulium	16	38	88		
		Simulium arcticum	0	0	0	I	
		Simulium prob. aureum	0	0	0	C	
		Simulium decorum	0	0	0	C	C
		Simulium euryadminiculum	0	0	0	I	
		Simulium tuberosum complex	0	0	0	C, A	C, A
		Simulium venustum complex	0	0	0		C
	Stratiomyidae	*Stratiomyia*	0	0	0		I
	Syrphidae	*Helophilus*	0	0	0	I	I
	Tabanidae	*Chrysops*	0	19	0	I	C
		Tabanus	0	10	25		
	Tipulidae	-	3	0	13		
		Antocha	0	0	13	I	I
		Dicranota	6	40	75	R, LA	F
		Eriocera	0	12	0	R, LA	C
		Hexatoma	0	19	13		
		Holorusia	0	0	0	I	
		Limnophila	0	12	0		
		Prionocera	0	0	0		I
		Tipula	0	2	0	I	I
Total taxa			137	265	123	280	237
Total taxa (genus as lowest level)			108	194	100	213	188
Total taxa in major taxonomic groups (genus as lowest level)		Oligochaeta	3	5	4	14	12
		Mollusca	5	14	4	12	8
		Ephemeroptera	15	19	13	22	19
		Odonata	1	7	1	10	5
		Plecoptera	7	14	9	14	13
		Trichoptera	14	29	14	33	25
		Coleoptera	3	11	0	10	9
		Chironomidae	44	50	36	61	57
		Other Diptera	7	20	12	16	20
		Other	9	25	7	21	20

Table III-3 Benthic Invertebrate Taxon List for Small Streams North of Fort McMurray

Major Taxon	Family	Subfamily/Tribe	Genus/Species
Hydrozoa	Hydridae	-	*Hydra*
Turbellaria	-	-	-
	-	-	*Polycelis coronata*
Nematoda	-	-	-
Oligochaeta	-	-	-
	Enchytraeidae	-	-
	Lumbricidae	-	-
	Lumbriculidae	-	-
	Naididae	-	-
		-	*Nais*
		-	*Pristina*
		-	*Pristinella*
	Tubificidae	-	-
Hirudinea (Hirudinoidea)	-	-	-
	Erpobdellidae	-	-
		-	*Dina parva*
		-	*Dina/Moorebdella*
		-	*Erpobdella punctata*
		-	*Nephelopsis obscura*
	Glossiphoniidae	-	-
		-	*Glossiphonia complanata*
		-	*Glossiphonia heteroclita*
		-	*Helobdella*
		-	*Helobdella fusca*
		-	*Helobdella stagnalis*
		-	*Placobdella*
		-	*Theromyzon*
	Hirudinidae	-	-
		-	*Haemopsis grandis*
Gastropoda	-	-	-
	Ancylidae	-	*Ferrissia*
		-	*Ferrissia rivularis*
	Hydrobiidae	-	*Probythinella*
	Lymnaeidae	-	-
		-	*Lymnaea*
		-	*Stagnicola*
	Physidae	-	-
		-	*Physa*
	Planorbidae	-	-
		-	*Armiger crista*
		-	*Gyraulus*
		-	*Helisoma*
		-	*Menetus cooperi*
		-	*Promenetus*
		-	*Promenetus evacuous*
	Valvatidae	-	*Valvata*
		-	*Valvata lewisii*
		-	*Valvata sincera*
		-	*Valvata sincera helicoidea*
		-	*Valvata sincera sincera*
Pelecypoda	-	-	-
	Sphaeriidae	-	-
		-	*Musculium*
		-	*Pisidium*
		-	*Pisidium/Sphaerium*
		-	*Sphaerium*
	Unionidae	-	*Lasmigona complanata*
Tardigrada	-	-	-

Table III-3 Benthic Invertebrate Taxon List for Small Streams North of Fort McMurray

Major Taxon	Family	Subfamily/Tribe	Genus/Species
Acari	-	-	-
Acari - Hydrachnidia	-	-	-
Acari - Hydracarina	-	-	-
	Hygrobatidae	-	*Hygrobates*
	Lebertiidae	-	*Lebertia*
	Sperchonidae	-	*Sperchon*
Cladocera	-	-	-
	Bosminidae	-	*Bosmina*
	Chydoridae	-	-
	Moinidae	-	-
Copepoda	-	-	-
Copepoda - Cyclopoida	-	-	-
Copepoda - Harpacticoida	-	-	-
Ostracoda	-	-	-
	Candonidae	-	*Candona*
	Cyclocypridae	-	*Cyclocypris*
	Cypridae	-	-
Amphipoda	Gammaridae	-	*Gammarus lacustris*
	Talitridae	-	*Hyalella azteca*
Collembola	-	-	-
	Entomobryidae	-	-
	Isotomidae	-	*Isotomus*
Ephemeroptera	-	-	-
	Ameletidae	-	*Ameletus*
	Baetidae	-	-
		-	*Baetis*
		-	*Baetis pygmaeus*
		-	*Baetis/Pseudocloeon*
		-	*Callibaetis*
		-	*Centroptilum*
		-	*Pseudocloeon*
	Baetiscidae	-	*Baetisca*
	Caenidae	-	*Caenis*
	Ephemerellidae	-	*Drunella*
		-	*Drunella grandis*
		-	*Ephemerella*
		-	*Ephemerella (drunella)*
		-	*Ephemerella attenuata*
		-	*Ephemerella spinifera*
	Ephemeridae	-	*Ephemera*
	Heptageniidae	-	-
		-	*Cinygma*
		-	*Cinygmula*
		-	*Epeorus*
		-	*Heptagenia*
		-	*Rhithrogena*
		-	*Stenacron*
		-	*Stenonema*
	Leptophlebiidae	-	-
		-	*Leptophlebia*
		-	*Paraleptophlebia*
	Metretopodidae	-	*Metretopus*
	Siphlonuridae	-	-
		-	*Parameletus*
		-	*Siphloplecton*
	Tricorythidae	-	*Tricorythodes*

Table III-3 Benthic Invertebrate Taxon List for Small Streams North of Fort McMurray

Major Taxon	Family	Subfamily/Tribe	Genus/Species
Odonata - Anisoptera	-	-	-
	Aeshnidae	-	*Aeshna*
		-	*Anax*
	Corduliidae	-	*Cordulia shurtleffi*
		-	*Epitheca*
		-	*Somatochlora*
	Gomphidae	-	*Gomphus*
		-	*Ophiogomphus*
	Libellulidae	-	-
		-	*Libellula*
		-	*Macrothemis*
		-	*Perithemis*
Odonata - Zygoptera	Ceoenagrionidae	-	-
		-	*Ischnura*
		-	*Enallagma*
	Lestidae	-	*Lestes*
Plecoptera	-	-	-
	Capniidae	-	-
		-	*Capnia*
		-	*Capnia complex*
		-	*Isocapnia*
	Chloroperlidae	-	-
		Chloroperlinae	-
		-	*Alloperla*
		-	*Alloperla/Hastaperla*
		-	*Chloroperla*
		-	*Neaviperla/Suwallia/Sweltsa/Triznaka*
	Leuctridae	-	-
	Nemouridae	-	-
		-	*Amphinemura*
		-	*Malenka*
		-	*Nemoura*
		-	*Nemoura arctica*
		-	*Zapada*
	Perlidae	-	-
		-	*Acroneuria*
		-	*Claassenia*
		-	*Claassenia sabulosa*
	Perlodidae	-	-
		-	*Arcynopteryx*
		-	*Isogenus (Isogenoides)*
		-	*Isogenus/Diura*
		-	*Isoperla*
		-	*Skwala*
	Pteronarcyidae	-	*Pteronarcella*
		-	*Pteronarcys*
	Taeniopterygidae	-	*Brachyptera*
		-	*Taeniopteryx*
Hemiptera	-	-	-
	Corixidae	-	-
		-	*Callicorixa*
		-	*Sigara*
	Gerridae	-	*Gerris*
	Mesoveliidae	-	-
Homoptera	-	-	-
Megaloptera	Sialidae	-	*Sialis*
Trichoptera	-	-	-
	Brachycentridae	-	*Amiocentrus*
		-	*Amiocentrus/Micrasema*
		-	*Brachycentrus*
		-	*Micrasema*

Table III-3 Benthic Invertebrate Taxon List for Small Streams North of Fort McMurray

Major Taxon	Family	Subfamily/Tribe	Genus/Species
Trichoptera (continued)	Glossosomatidae	-	-
		-	*Anagapetus*
		-	*Glossosoma*
	Hydropsychidae	-	-
		-	*Arctopsyche*
		-	*Cheumatopsyche*
		-	*Hydropsyche*
		-	*Hydropsyche bifida*
		-	*Hydropsyche slossonae*
	Hydroptilidae	-	-
		-	*Hydroptila*
		-	*Ochrotrichia*
		-	*Oxyethira*
		-	*Stactobiella*
	Lepidostomatidae	-	*Lepidostoma*
	Leptoceridae	-	-
		-	*Ceraclea*
		-	*Oecetis*
	Limnephilidae	-	-
		-	*Clostoeca*
		-	*Hesperophylax*
		-	*Limnephilus*
		-	*Nemotaulius*
	Philopotamidae	-	-
		-	*Wormaldia*
	Phryganeidae	-	*Agrypnia*
		-	*Ptilostomis*
	Polycentropodidae	-	*Neureclipsis*
		-	*Polycentropus*
	Psychomyiidae	-	-
		-	*Psychomyia*
	Rhyacophilidae	-	-
		-	*Rhyacophila*
Lepidoptera	-	-	-
	Cossidae	-	*Prionoxystus*
	Noctuidae	-	-
	Pyralidae	-	*Nymphula*
Coleoptera	-	-	-
	Chrysomelidae	-	-
		-	*Donacia*
		-	*Galerucella*
		-	*Pyrrhalta*
	Dytiscidae	-	-
		-	*Agabus*
		-	*Bidessus*
		-	*Deronectes*
		-	*Dytiscus*
		-	*Rhantus*
	Elmidae	-	-
		-	*Dubiraphia*
		-	*Heterlimnius*
		-	*Narpus*
		-	*Optioservus*
		-	*Stenelmis*
	Gyrinidae	-	*Gyrinus*
	Haliplidae	-	-
		-	*Brychius*
		-	*Haliplus*
	Notonectidae	-	*Notonecta*

Table III-3 Benthic Invertebrate Taxon List for Small Streams North of Fort McMurray

Major Taxon	Family	Subfamily/Tribe	Genus/Species
Diptera - Brachycera	-	-	-
Diptera	Anthomyiidae	-	-
		-	*Limnophora*
	Athericidae	-	*Atherix*
		-	*Atherix variegata*
	Ceratopogonidae	-	-
		Ceratopogoninae	-
			Bezzia
			Bezzia/Palpomyia
			Bezzia/Probezzia
			Culicoides
			Palpomyia
		Dasyheleinae	*Dasyhelea*
		Forcipomyiinae	*Atrichopogon*
			Forcipomyia
	Chaoboridae	-	*Chaoborus*
	Chironomidae	-	-
		Chironominae	-
		Chironomini	-
			Chironomus
			Chironomus plumosus grp.
			Chironomus thumni grp.
			Cladopelma
			Cladopelma
			Cryptotendipes
			Demicryptochironomus
			Dicrotendipes
			Endochironomus
			Glyptotendipes
			Harnischia
			Limnochironomus (Dicrotendipes)
			Microtendipes
			Parachironomus
			Paracladopelma
			Paralauterborniella
			Paratendipes
			Phaenopsectra
			Polypedilum
			Saetheria
			Stenochironomus
			Stictochironomus
		Tanytarsini (Calopsectrini)	-
			Calopsectra (Tanytarsus)
			Cladotanytarsus
			Constempellina
			Micropsectra
			Paratanytarsus
			Rheotanytarsus
			Stempellina
			Stempellinella
			Sublettea
			Tanytarsus
			Tanytarsus/Micropsectra
			Zavrelia
		Diamesinae	-
			Diamesa
			Pagastia
			Potthastia
			Potthastia (gaedii type)
			Potthastia (longimanus type)
			Pseudodiamesa

Table III-3 Benthic Invertebrate Taxon List for Small Streams North of Fort McMurray

Major Taxon	Family	Subfamily/Tribe	Genus/Species
Diptera (continued)		Orthocladiinae	-
			-
			Corynoneura
			Thienemanniella
			Acricotopus
			Brillia
			Cardiocladius
			Chaetocladius
			Cricotopus
			Cricotopus trifasciatus
			Cricotopus/Orthocladius
			Diplocladius
			Doncricotopus
			Eukiefferiella
			Euryhapsis
			Heterotrissocladius
			Hydrobaenus
			Krenosmittia
			Lopescladius
			Metriocnemus
			Microcricotopus (Nanocladius)
			Nanocladius
			Parakiefferiella
			Parametriocnemus
			Psectrocladius
			Pseudosmittia
			Rheocricotopus
			Rheosmittia
			Smittia
			Stilocladius
			Synorthocladius
			Trichocladius
			Tvetenia
		Prodiamesinae	*Monodiamesa*
			Odontomesa
		Tanypodinae	-
			Ablabesmyia
			Alotanypus
			Clinotanypus
			Larsia
			Natarsia
			Nilotanypus
			Procladius
			Psectrotanypus
			Tanypus
			Thienemannimyia
			Thienemannimyia complex
			Trissopelopia
			Zavrelimyia
	Culicidae	Culicinae	-
	Dixidae	-	-
		-	*Dixella*
	Dolichopodidae	-	-
		-	*Rhaphium*
	Empididae	-	-
		-	*Chelifera*
		-	*Clinocera*
		-	*Hemerodromia*
		-	*Oreogeton*
		-	*Wiedemannia*

Table III-3 Benthic Invertebrate Taxon List for Small Streams North of Fort McMurray

Major Taxon	Family	Subfamily/Tribe	Genus/Species
Diptera (continued)	Ephydridae	-	*Ephydra*
	Muscidae	-	-
	Psychodidae	-	-
		-	*Pericoma*
	Ptychopteridae	-	*Ptychoptera*
	Rhagionidae	-	-
	Simuliidae	-	-
		-	*Prosimulium*
		-	*Simulium*
	Stratiomyidae	-	-
		-	*Odontomyia*
	Tabanidae	-	-
		-	*Chrysops*
		-	*Tabanus*
	Tipulidae	-	-
		Limoniinae	-
		-	*Antocha*
		-	*Dicranota*
		-	*Hexatoma*
		-	*Limnophila*
		-	*Tipula*
		-	*Triogma*
Terrestrial	-	-	-

Note: - = not identified to level shown.

Table III-4 Benthic Invertebrate Taxon List for Streams and Rivers in the Southern Oil Sands Region

Major Taxon	Family	Subfamily/Tribe	Genus/Species
Nematoda	-	-	-
Oligochaeta	-	-	-
	Tubificidae	-	-
Hirudinea (Hirudinoidea)	-	-	-
	Erpobdellidae	-	-
		-	*Dina parva*
		-	*Erpobdella punctata*
		-	*Nephelopsis obscura*
	Glossiphoniidae	-	*Glossiphonia complanata*
		-	*Helobdella*
		-	*Helobdella stagnalis*
	Hirudinidae	-	*Haemopsis*
Gastropoda	-	-	-
	Ancylidae	-	*Ferrissia*
	Lymnaeidae	-	*Lymnaea*
	Physidae	-	*Physa*
	Planorbidae	-	*Armiger*
		-	*Gyraulus*
		-	*Gyraulus parvus*
		-	*Helisoma*
	Valvatidae	-	*Valvata*
		-	*Valvata sincera*
Pelecypoda	Sphaeriidae	-	-
		-	*Pisidium*
Araneae	-	-	-
Acari - Hydrachnidia	-	-	-
Acari - Hydracarina	-	-	-
Cladocera	-	-	-
	Chydoridae	-	-
Copepoda - Calanoida	-	-	-
Copepoda - Cyclopoida	-	-	-
Ostracoda	-	-	-
Amphipoda	-	-	-
	-	-	*Gammarus*
	Gammaridae	-	*Gammarus lacustris*
		-	*Hyalella*
	Talitridae	-	*Hyalella azteca*
Collembola	-	-	-
Ephemeroptera	Ameletidae	-	*Ameletus*
	Baetidae	-	-
		-	*Baetis*
		-	*Callibaetis*
		-	*Centroptilum*
		-	*Pseudocloeon*
	Caenidae	-	*Brachycercus*
		-	*Caenis*
	Ephemerellidae	-	-
		-	*Drunella*
		-	*Ephemerella*
		-	*Ephemerella inermis*
		-	*Ephemerella spinifera*
		-	*Serratella*
	Ephemeridae	-	*Hexagenia*
	Heptageniidae	-	-
		-	*Cinygma*
		-	*Cinygmula*
		-	*Epeorus*
		-	*Heptagenia*
		-	*Rhithrogena*
		-	*Stenonema*

Table III-4 Benthic Invertebrate Taxon List for Streams and Rivers in the Southern Oil Sands Region

Major Taxon	Family	Subfamily/Tribe	Genus/Species
Ephemeroptera (continued)	Leptophlebiidae	-	*Leptophlebia*
		-	*Paraleptophlebia*
	Metretopodidae	-	*Metretopus*
		-	*Metretopus borealis*
	Siphlonuridae	-	-
		-	*Parameletus*
		-	*Siphlonurus*
	Tricorythidae	-	*Tricorythodes*
		-	*Tricorythodes minutus*
Odonata	-	-	-
Odonata - Anisoptera	Aeshnidae	-	*Aeshna interupta*
	Corduliidae	-	*Somatochlora*
	Gomphidae	-	*Ophiogomphus*
Plecoptera	-	-	-
	Capniidae	-	*Capnia*
		-	*Capnia/Eucapnopsis*
	Capniidae/Leuctridae	-	-
	Chloroperlidae	-	-
		-	*Alloperla/Hastaperla*
		-	*Hastaperla*
	Leuctridae	-	*Leuctra*
	Nemouridae	-	*Nemoura*
		-	*Nemoura cinctipes*
		-	*Zapada*
	Perlidae	-	*Acroneuria*
		-	*Claassenia*
		-	*Claassenia sabulosa*
	Perlodidae	-	-
		-	*Arcynopteryx*
		-	*Isogenoides*
		-	*Isoperla*
		-	*Skwala*
	Pteronarcyidae	-	*Pteronarcella*
		-	*Pteronarcella regularis*
		-	*Pteronarcys*
		-	*Pteronarcys dorsata*
	Taeniopterygidae	-	*Taeniopteryx*
Hemiptera	Corixidae	-	-
		-	*Sigara*
		-	*Sigara washingtonensis*
Megaloptera	Sialidae	-	*Sialis*
Trichoptera	-	-	-
	Apataniidae	-	*Apatania*
	Brachycentridae	-	*Amiocentrus*
		-	*Brachycentrus*
		-	*Micrasema*
	Glossosomatidae	-	-
		-	*Glossosoma*
	Hydropsychidae	-	-
		-	*Arctopsyche*
		-	*Cheumatopsyche*
		-	*Hydropsyche*
	Hydroptilidae	-	-
		-	*Agraylea*
		-	*Hydroptila*
		-	*Neotrichia*
		-	*Orthotrichia*
		-	*Oxyethira*

Table III-4 Benthic Invertebrate Taxon List for Streams and Rivers in the Southern Oil Sands Region

Major Taxon	Family	Subfamily/Tribe	Genus/Species
Trichoptera (continued)	Lepidostomatidae	-	*Lepidostoma*
	Leptoceridae	-	-
		-	*Ceraclea*
		-	*Oecetis*
	Limnephilidae	-	-
		-	*Glyphopsyche irrorata*
		-	*Hesperophylax*
		-	*Lenarchus*
		-	*Limnephilus*
		-	*Onocosmoecus*
		-	*Psychoglypha*
		-	*Pycnopsyche*
	Philopotamidae	-	*Wormaldia*
	Phryganeidae	-	*Ptilostomis*
	Polycentropodidae	-	*Neureclipsis*
		-	*Nyctiophylax*
		-	*Polycentropus*
	Psychomyiidae	-	*Psychomyia*
		-	*Psychomyia flavida*
	Rhyacophilidae	-	*Rhyacophila*
Lepidoptera	-	-	-
	Pyralidae	-	*Nymphula*
Coleoptera	Dytiscidae	-	-
		-	*Agabus*
		-	*Laccophilus*
		-	*Oreodytes*
	Elmidae	-	-
		-	*Dubiraphia*
		-	*Optioservus*
	Gyrinidae	-	*Gyrinus*
	Haliplidae	-	*Brychius*
		-	*Haliplus*
Diptera	Anthomyiidae	-	-
		-	*Limnophora*
		-	*Lispe*
	Athericidae	-	*Atherix*
	Ceratopogonidae	-	-
		Ceratopogoninae	-
			Bezzia/Palpomyia
			Culicoides
			Palpomyia
	Chaoboridae	-	*Chaoborus*
	Chironomidae	-	-
		Chironominae	-
		Chironomini	-
			Chironomus
			Cladopelma
			Cladopelma
			Demicryptochironomus
			Glyptotendipes
			Harnischia
			Microtendipes
			Parachironomus
			Paracladopelma
			Paralauterborniella
			Phaenopsectra
			Polypedilum
			Polypedilum fallax
			Stictochironomus

Table III-4 Benthic Invertebrate Taxon List for Streams and Rivers in the Southern Oil Sands Region

Major Taxon	Family	Subfamily/Tribe	Genus/Species
Diptera (continued)		Tanytarsini	-
			Cladotanytarsus
			Micropsectra
			Paratanytarsus
			Rheotanytarsus
			Tanytarsus
			Zavrelia
		Diamesinae	*Diamesa*
			Potthastia
			Pseudodiamesa
		Orthocladiinae	-
			Corynoneura
			Thienemanniella
			Brillia
			Cricotopus
			Eukiefferiella
			Heterotrissocladius marcidus
			Metriocnemus
			Nanocladius
			Orthocladius
			Parakiefferiella
			Parametriocnemus
			Paratrichocladius
			Psectrocladius
			Pseudosmittia
			Rheocricotopus
			Syncricotopus
			Synorthocladius
		Prodiamesinae	*Monodiamesa*
			Odontomesa
			Prodiamesa
		Tanypodinae	-
			Ablabesmyia
			Labrundinia
			Nilotanypus
			Procladius
			Thienemannimyia
	Culicidae	Culicinae	-
	Dixidae	-	*Dixa*
	Dolichopodidae	-	-
		-	*Rhaphium*
	Empididae	-	-
		-	*Chelifera*
		-	*Hemerodromia*
		-	*Oreogeton*
		-	*Wiedemannia*
	Ephydridae	-	-
	Psychodidae	-	*Pericoma*
	Ptychopteridae	-	-
	Simuliidae	-	-
		-	*Simulium*
	Stratiomyidae	-	-
	Tabanidae	-	-
		-	*Chrysops*
		-	*Tabanus*
	Tipulidae	-	-
		-	*Antocha*
		-	*Dicranota*
		-	*Hexatoma*
		-	*Limnophila*
		-	*Ormosia*
		-	*Pseudolimnophila*
		-	*Tipula*
Terrestrial	-	-	-

Note: - = not identified to level shown.