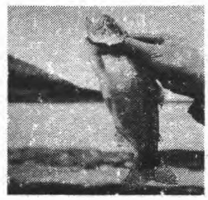
Canada Alberta Northwest Territories

Northern River Basins Study





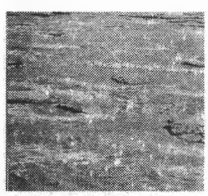






NORTHERN RIVER BASINS STUDY PROJECT REPORT NO. 123

AN ASSESSMENT OF THE UTILITY OF BENTHIC MACROINVERTEBRATE AND FISH COMMUNITY STRUCTURE IN BIOMONITORING, PEACE, ATHABASCA AND SLAVE RIVER BASINS






Prepared for the
Northern River Basins Study
under Project 5211-D1/E1

by

Kevin J. Cash, Mark S. J. Ouellett, Fred J. Wrona
National Hydrology Research Institute

and

Greg Wagner
Consultant

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PREFACE:

The Northern River Basins Study was initiated through the "Canada-Alberta-Northwest Territories Agreement Respecting the Peace-Athabasca-Slave River Basin Study, Phase II - Technical Studies" which was signed September 27, 1991. The purpose of the Study is to understand and characterize the cumulative effects of development on the water and aquatic environment of the Study Area by coordinating with existing programs and undertaking appropriate new technical studies.

This publication reports the method and findings of particular work conducted as part of the Northern River Basins Study. As such, the work was governed by a specific terms of reference and is expected to contribute information about the Study Area within the context of the overall study as described by the Study Final Report. This report has been reviewed by the Study Science Advisory Committee in regards to scientific content and has been approved by the Study Board of Directors for public release.

It is explicit in the objectives of the Study to report the results of technical work regularly to the public. This objective is served by distributing project reports to an extensive network of libraries, agencies, organizations and interested individuals and by granting universal permission to reproduce the material.

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Whereas the above publication is the result of a project conducted under the Northern River Basins Study and the terms of reference for that project are deemed to be fulfilled,
IT IS THEREFORE REQUESTED BY THE STUDY OFFICE THAT;
this publication be subjected to proper and responsible review and be considered for release to the public.

(Dr. Fred J. Wrona, Science Director) — 16 May 96 (Date)

Whereas it is an explicit term of reference of the Science Advisory Committee "to review, for scientific content, material for publication by the Board",
IT IS HERE ADVISED BY THE SCIENCE ADVISORY COMMITTEE THAT;
this publication has been reviewed for scientific content and that the scientific practices represented in the report are acceptable given the specific purposes of the project and subject to the field conditions encountered.
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(Dr. P. A. Larkin, Ph.D., Chair) — May 10/96 (Date)

Whereas the Study Board is satisfied that this publication has been reviewed for scientific content and for immediate health implications,
IT IS HERE APPROVED BY THE BOARD OF DIRECTORS THAT;
this publication be released to the public, and that this publication be designated for: **[ ] STANDARD AVAILABILITY [ ] EXPANDED AVAILABILITY**

(Lucille Partington, Co-chair) — May 9/96 (Date)

(Robert McLeod, Co-chair) — May 21/96 (Date)

BENTHIC MACROINVERTEBRATE AND FISH COMMUNITY STRUCTURE WITHIN THE NORTHERN RIVER BASINS: AN ASSESSMENT OF THEIR UTILITY IN BIOMONITORING

STUDY PERSPECTIVE

Some of the primary goals of the Northern River Basins Study are to provide a scientifically sound information base for use in monitoring, predicting and assessing cumulative effects of development and the general health of these aquatic ecosystems. Data on benthic macroinvertebrate and fish community structure are widely recognized as being very useful in cumulative assessment and issues of ecosystem health and integrity. Benthic macroinvertebrates are bottom-dwelling organisms (primarily insect larvae) that can be very sensitive to environmental change and are considered good indicators of aquatic ecosystem health. Measurements of aquatic community structure have been made periodically within the Peace, Athabasca and Slave River systems for much of the past 30 years, but the collections were not standardized nor coordinated between years and locations. These data sets have not been analyzed with the specific objective of determining the appropriateness of the monitoring data collected, nor for the purpose of assessing the general state of the aquatic ecosystem.

Related Study Questions

13a) What predictive tools are required to determine the cumulative effects of man-made discharges on the water and aquatic environment?

13b) What are the cumulative effects of man-made discharges on the water and aquatic environment?

14) What long term monitoring programs and predictive models are required to provide an ongoing assessment of the state of the aquatic ecosystems?

This project report describes efforts to assess the nature and quality of long-term data sets measuring benthic invertebrate and fish community structure and effluent loading within the Peace, Athabasca and Slave River drainages. Information was collated and standardized to assess the utility of applying current biomonitoring techniques to these data. In turn, recommendations were made on the most appropriate approaches to use in a long-term cumulative effects monitoring plan.

Because of a lack of sufficient data and the problems associated with quantifying fish community structure, it was found, except for specific components, that fish community data could not be used effectively as a biomonitoring tool in the northern river basins. Existing long-term data sets of benthic invertebrate and fish community structure were compiled into a single standardized master database, resulting in a quick and efficient query system to produce overviews of basin-wide changes in community structure. Measures of invertebrate communities in areas upstream and downstream of pulp mills provided the greatest insight into the effects these effluents, and were generally a function of changes in relative abundance of different invertebrate groups. Results from more than 100 separate multivariate analyses demonstrated significant year to year and between season (spring versus fall) variation in macroinvertebrate community structure upstream and downstream of all mills. Both qualitative (rapid bioassessment) and qualitative (multivariate statistics) approaches to biomonitoring stress the need to collect habitat or environmental data in addition to community data. These approaches represent the only methods by which natural variation in these rivers can be distinguished from man-made stressors.

This study recommends a biomonitoring approach that combines qualitative and quantitative approaches to biomonitoring using macroinvertebrate communities. These techniques are capable of assessing current ecosystem condition and of providing information on long-term trends within the ecosystem. They also evaluate community structure in the light of environmental data. Although this approach could be extended to other aquatic communities, fish communities should not be included in this approach. In addition, a significant database has been developed that will greatly assist future monitoring efforts by government and industry.

REPORT SUMMARY

The purpose of this project (**Project 5211-D1: Quantitative analysis of benthic macroinvertebrate and fish community structure - a critique and comparison of biomonitoring techniques**) consisted of two objectives. In the first instance the nature and quality of long-term data sets measuring benthic macroinvertebrate and fish community structure within the Peace, Athabasca and Slave river systems was assessed. These data were then compiled into a single standardized and accessible master database. The master database now exists in electronic format as a relational database (in Microsoft Access) and is accompanied by a manual explaining its use. The second objective of this project involved statistical analyses on the standardized master database and the application of several currently employed biomonitoring and bio-assessment techniques to the same database. These analyses were performed in order to address the following specific questions: (1) Are the data currently being collected within the northern river basins of sufficient quality and quantity to permit application of widely used biomonitoring and bio-assessment techniques? (2) What (if any) additional information, or modifications in data collection, are required before these techniques can be successfully applied within the northern river basins? (3) Do current biomonitoring techniques adequately identify and capture changes in benthic macroinvertebrate and/or fish community structure caused by changes in anthropogenic effluent loadings (particularly pulp mill effluent) within this system? (4) What are the strengths and weaknesses of each technique when applied to this master data set and are results obtained from the application of different techniques comparable? (5) Which technique or group of techniques would best fulfil the Northern River Basins Study (NRBS) objective of identifying those monitoring programs necessary for ongoing assessment of cumulative effects and aquatic ecosystem integrity.

One of the primary objectives of the NRBS has been to construct a baseline data set describing ecological structure and function within these systems. By combining and standardizing the hundreds of different studies measuring benthic community structure into a single database this study has made considerable progress toward that goal. More importantly, it is possible to use this master database to quickly and efficiently produce overviews of basin-wide changes in benthic macroinvertebrate community structure, or to sort through the data and extract relevant subsets of data for more detailed examination. The database has been constructed so as to maintain maximum flexibility and could easily be updated on a regular basis allowing it to serve as a single and current repository for all such data collected within the basins. The database can also accommodate information collected over a much broader spatial scale and can be linked to other electronic data sets even if those data sets exist in different formats. The ability to form direct links between separate data sets containing information on for example, benthic macroinvertebrate community structure, water quality, hydrologic records and climatic data would be of great value to researchers and environmental managers within these regions.

Although considerable time and effort has been invested in the collection and analysis of data relating to population and community structure within these basins there still exist major information gaps, particularly with respect to fish community structure. This lack of data is a

consequence of historical bias and logistical difficulties in sampling. For these and other reasons, it was decided that measures of entire fish community structure are not available and could not be effectively used as an biomonitoring tool in the northern river basins. This does not suggest that particular components or populations within that community could not serve as valuable biomonitoring tools. As with fish community structure, there were significant gaps in available data measuring benthic macroinvertebrate community structure. In particular, there was insufficient data available to assess benthic macroinvertebrate community structure at a basin-wide scale. This lack of information seriously constrains our ability to properly assess the general state and function of these ecosystems.

Measures of benthic macroinvertebrate community structure in the areas immediately above and below pulp mills indicated that communities both above and below the pulp mills were numerically dominated by chironomids (Orthocladiinae and Chironominae), oligochaete worms (Naididae and Tubificidae) and mayflies (Baetidae, Ephemerellidae and Heptageniidae). Stoneflies (Perlodidae, Capniidae, Taeniopterygidae) and caddisflies (Hydropsychidae and Polycentropodidae) were also abundant at certain sites and at certain times. Observed differences between sites upstream (u/s) and downstream (d/s) of any particular pulp mill were generally a function of changes in relative abundance of taxa rather than a result of the disappearance or addition of specific taxa. Results from over 100 separate multivariate analyses demonstrated significant year to year and between season (spring (March to May) and autumn (September to November)) variation in benthic macroinvertebrate community structure upstream and downstream of all mills. However, these analyses did not serve to consistently separate upstream reference sites from downstream impact sites nor do these analyses provide evidence to argue that changes in benthic community structure downstream of the pulp mills result from the loss of taxa. Thus, while effluent from the pulp mills affects benthic macroinvertebrates, these affects act primarily at the level of the individual (i.e., body size) and with respect to overall macroinvertebrate densities, and do not produce significant and consistent changes in overall community structure. The fact that the multivariate analyses described in this report fail to consistently and predictably separate impact from reference sites does not imply that these techniques are incapable of detecting shifts but rather, given the available data, that there were no consistent shifts to detect. More importantly, these observations serve to demonstrate the importance of collecting "high quality" environmental data at the same site from which benthic invertebrate collections are taken.

Biomonitoring programs, particularly those operating on the scale required by the NRBS are both expensive and labour intensive. Benthic macroinvertebrates are more commonly used in the assessment and monitoring of aquatic ecosystems than are any other group of organisms and have been shown to be one of the most cost-effective biomonitoring tools available. However, it is not sufficient to collect data on benthic macroinvertebrate community structure alone. Rather, there is a great and urgent need to construct a "quality" data set for the northern river basins that contains information not only on the structure and function of the benthic community at a given site but also characterizes the site in terms of physical, chemical and habitat variables. Both the qualitative (rapid bioassessment) and quantitative (multivariate statistics) approaches to biomonitoring stress the need to collect habitat or environmental data of this type and represent the only methods by which natural variation can be distinguished from anthropogenically induced stress.

We thus recommend a biomonitoring approach that combines rapid assessment protocols and multivariate statistical approaches to biomonitoring. These techniques are capable of assessing current ecosystem condition and of providing information on long-term trends within the ecosystem. They also evaluate community structure in the light of environmental data. We would further suggest that this approach be extended to other aquatic and riparian communities, but that fish communities not be included in this approach.

Combining qualitative and quantitative approaches to bioassessment is one way to reduce overall biomonitoring costs but these costs could be further reduced by better coordinating current sampling efforts within the basins. Pulp mills currently conduct their own monitoring studies and will be increasingly responsible for monitoring under the Federal Environmental Effects Monitoring (EEM) legislation. If industry becomes responsible for monitoring in the areas upstream and downstream of the pulp mills, government agencies could redirect their efforts to monitoring those reaches of the river between the mills.

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We thank Alberta Environmental Protection (AEP), Dr. Patricia Chambers (Environment Canada), Dr. Garry Scrimgeour (University of Alberta), Weldwood of Canada Ltd., Alberta Newsprint Co., Millar Western Pulp Ltd., Slave Lake Pulp Corp., Alberta Pacific Corp., Weyerhaeuser Canada Ltd. and Peace River Pulp Co. for access to monitoring data. We also thank Dr. Anne-Marie Anderson and Maurice Drouin of AEP for useful discussions. Mr. Tom Boag (EnviResources) and Mr. D. Mayhood (AEP) assisted in the identification of fish studies. Mr. Erik Ellehoj (NRBS Study Office) kindly assisted in the preparation of Figure 1. This report was improved by the comments of several reviewers.

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1.0 INTRODUCTION

1.1 GENERAL BACKGROUND

One of the primary objectives of the Northern River Basins Study (NRBS) is to identify those long-term monitoring programs and predictive models required to provide ongoing assessments of cumulative effects and the general health/integrity of these aquatic ecosystems (NRBS 1994). Indeed, NRBS Guiding Questions 13 and 14 (Appendix A) are directly related to the development of appropriate biomonitoring tools that could be applied within these basins following the conclusion of NRBS.

Data relating to benthic macroinvertebrate and/or fish community structure are widely recognized as providing valuable insight into cumulative impact assessment and issues such as aquatic ecosystem health/integrity. Benthic macroinvertebrate data have been used extensively for this purpose and are currently the organisms most widely employed in the assessment of water quality (Resh *et al.* 1995). Measurements of aquatic community structure have been collected periodically within the Peace, Athabasca and Slave river systems for much of the past 30 years, and in particular over the last 15 years. With the onset of the Federally legislated Environmental Effects Monitoring (EEM) program (Environment Canada and Department of Fisheries and Oceans 1991), these types of collections will continue and expand, particularly in areas immediately adjacent to point source discharges such as pulp mills.

The general purpose of this project (**Project 5211-D1: Quantitative analysis of benthic macroinvertebrate and fish community structure - a critique and comparison of biomonitoring techniques**) can be divided into two primary objectives. In the first instance, we collected and assessed the nature and quality of long-term data sets measuring benthic macroinvertebrate and fish community structure within the Peace, Athabasca and Slave river systems. Within the logistic and financial limitations of the project, we then compiled these existing databases into a single standardized and accessible master database. The master database now exists in electronic format as a relational database (in Microsoft Access) and is accompanied by a manual (Ouellette and Cash 1995) explaining its use. We feel that this database will prove valuable to researchers and managers (representing Federal and Provincial governments as well as industry) within these basins and will also contribute in a significant way to the NRBS goal of creating a baseline data set describing the general ecology of the Peace, Slave and Athabasca river basins.

The second component of this project involved statistical analyses of the standardized master database and the application of several currently employed biomonitoring and bio-assessment techniques to the same database. These analyses were performed in order to address the following specific questions: (1) Are the data currently being collected within the northern river basins of sufficient quality and quantity to permit application of widely used biomonitoring and bio-assessment techniques? (2) What (if any) additional information, or modifications in data collection, are required before these techniques can be successfully applied within the northern river basins? (3) Do current biomonitoring techniques adequately identify and capture changes in benthic macroinvertebrate and/or fish community structure caused by changes in anthropogenic effluent loadings (particularly pulp mill effluent) within this system? (4) What are the strengths and weaknesses of each technique when applied to this master data set and are results obtained from the application of different techniques comparable? (5) Which technique or group of techniques would best fulfil the NRBS objective of identifying those monitoring programs necessary for ongoing assessment of cumulative effects and aquatic ecosystem integrity (Study Question 14, Appendix A)?

A more detailed description of this project and its objectives may be found in the terms of reference (Appendix B).

1.2 REPORT STRUCTURE

The terms of reference for this project were finalized in August 1994 (Appendix B) and required the submission of interim reports on November 1, 1994 (Cash *et al.* 1994) and March 31, 1995 (Cash *et al.* 1995) as well as the submission of a final report. For simplicity, the final report has been subdivided into two documents, the first dealing with study objectives as described above, and the second (Ouellette and Cash 1995), a manual describing access to and use of the standardized master database. The final report has been divided in this fashion so as to provide a stand alone database manual for those researchers or managers that may be interested only in the summarization and standardization of data collected within these basins. As will be discussed below, it is our hope that this database will not only serve the objectives of this project but will also constitute an information resource that can be utilized and expanded by researchers on these basins. The database itself will accompany the final report and will be provided in electronic (i.e., Microsoft Access) format.

This document is further divided into four primary sections. The first section describes data sources and sampling locations, criteria for data inclusion in the master database, and the nature and structure of the master database itself. The second section examines issues relating to the examination and analyses of aquatic community structure within the northern river basins. This section includes the results of multivariate analyses (Principal Component Analysis) performed on the data. The third section examines the data in light of commonly employed biomonitoring techniques to determine first, if these techniques can be applied to data collected within these basins and second, if these techniques appropriately describe observed changes within the study area. In the final section we provide a series of recommendations concerning the design of an aquatic community structure monitoring program that could be employed in the northern river basins.

2.0 DATA SOURCES AND STRUCTURE

2.1 MACROINVERTEBRATE COMMUNITY STRUCTURE

2.1.1 Data Sources

Data sets measuring macroinvertebrate community structure within the northern river basins were identified with the assistance of Dr. Anne-Marie Anderson (Alberta Environmental Protection), Dr. Garry Scrimgeour (Post-Doctoral Fellow, University of Alberta, National Hydrology Research Institute), personnel from the NRBS study office and by representatives of industries (primarily pulp mills) operating within these basins. The majority of data were already available in electronic format (generally QuatroPro or Lotus spreadsheets). In those cases in which the data were only available in hard-copy format, they were converted to electronic format. All data were first compiled in standardized QuatroPro spreadsheets before being imported into the larger data base (see below). QuatroPro files are not included as part of the final report, however electronic copies of these files were submitted to the NRBS study office as part of Cash *et al.* (1995) and are available from that source.

Although macroinvertebrate community structure data have been collected throughout the basins, by a variety of agencies and/or consultants, and for a variety of purposes, this study is primarily concerned with long-term changes in aquatic community structure occurring within the mainstems and major tributaries of these basins. For these reasons, it was decided that not all studies conducted within the basins would be suitable for inclusion in the larger database. For example, a number of studies have been conducted within the northern river basins in areas other than along the mainstems of the Peace, Athabasca or Slave rivers, or along their major tributaries. These studies were performed both in lakes and in smaller streams and rivers and were often concerned with the ecological consequences of specific anthropogenic activities such as coal mining. Unfortunately, it was far beyond the scope of this project to collect all of these data (most of which existed only in hard copy format) and properly synthesize it within the context of this study. More importantly, since most of the data consisted of short-term studies they did not directly address the objectives of this project.

It was decided that for data from a specific study to be included in the larger, or master, database the study was required to meet several criteria including:

1. The study must provide *quantitative* measurements of benthic macroinvertebrate community structure.

2. The study must have been conducted on the mainstem of the Peace, Athabasca or Slave rivers, or on one of the major tributaries of these rivers.

3. The study must contain long-term (i.e., more than one year) monitoring data, or contain sampling sites that overlap with other studies that do.

Between 10 and 15 of the identified studies conducted on the mainstem or major tributaries of the Peace, Athabasca or Slave rivers failed to meet all of these criteria and have not been included in the final database.

2.1.2 Sampling Locations

Over 94 separate benthic macroinvertebrate monitoring studies have been identified as meeting the selection criteria described above. These studies vary in duration, from as little as one year to ongoing studies now in their 35th year, and represent data from 328 different sites within the Athabasca and Peace rivers, as well as their major tributaries (Lesser Slave, Smoky and Wapiti rivers).

Unfortunately, we were unable to identify data sets collected within that section of the Slave River within the NRBS study area that satisfy the criteria for inclusion in the master data set. This lack of data suggests that the Slave River, relative to the Peace and Athabasca rivers, has received less attention historically. While this may be understandable, particularly in light of the degree of direct anthropogenic impact on the Slave relative to the Peace and Athabasca rivers, it also suggests our baseline understanding of ecological structure and function may be particularly limited in this region of the northern river basins.

Despite the lack of data from the Slave River we nevertheless feel that ecological conclusions and management recommendations emerging from an examination of data from the Peace and Athabasca rivers, as well as their major tributaries, should also prove relevant to the mainstem of the Slave River. Any such extrapolation however, will not serve to fill the knowledge gap that exists with respect to our basic understanding of the ecological structure and function of this River. This gap must be filled before a successful management program can be implemented for the Slave River.

Following the identification of the 328 different sampling locations an attempt was made to determine the Global Imaging System (GIS) codes associated with each sampling location. Although not part of the deliverables for this project, it was felt that such an undertaking would significantly increase the usefulness of the database, both within the context of this study and for any other researchers or managers who may choose to make use of the information contained in the master database.

In some cases, GIS codes were already available. In other cases, such as Alberta Environmental Protection's (AEP) practice of using NAQUDAT or ENVIRODAT codings, available codings that could be readily converted to GIS codes were already available for sampling sites. In some cases, however, codes had to be calculated by first determining the exact sampling site locations from topographic maps and then converting latitude - longitude information to GIS scores. A third group of (primarily older) studies provided little specific information regarding site location, in these cases it was not always possible to assign an accurate GIS code. Where possible and logistically feasible, GIS codes were provided for each sampling location within the master database. The location for all sampling sites for which GIS codes were determined is given in Figure 1. Details concerning sampling locations and specific projects included in the master database and the format of those files is provided in Appendix C of this report.

2.1.3 Standardization and Taxonomic Resolution

Any attempt to synthesize and harmonize data collected from a large number of sources, collected in a variety of locations and covering a period of over three and a half decades will clearly pose a variety of logistical problems.

First, and perhaps most importantly, although there is now considerable effort directed toward the standardization of sample collections and analyses (i.e., Quality Assurance/Quality Control, or QA/QC procedures), such has not been the case historically. Within streams and rivers, Hess and Neill type samplers are among the most commonly used benthic macroinvertebrate samplers in riffle habitat (Resh and McElravy 1993). While this is also true of the northern river basins, other techniques including artificial substrates and air samplers have also been employed (Anderson 1990). Depositional areas have not typically been sampled within these basins, but in those cases where they were sampled, Ponar or Ekman type grab samplers have generally been used (see below). Unfortunately, differences in observed benthic macroinvertebrate community structure arising from differences in sampling technique are difficult and often impossible to evaluate. Indeed, comparisons cannot even be addressed unless several different types of samplers are used in the same location, a situation that did not occur in the available studies.

Similarly, the specific characteristics (species diversity, density, total abundance etc.) of the benthic macroinvertebrate community observed will depend greatly on the size and number of samples taken at a given site. This is of particular concern when trying to insure that rare species are included in the sample, when comparisons among or between sites are to be made, or when the researcher wishes to detect an effect (e.g., change in density of selected taxa), if present. As will be discussed in subsequent sections, spatial and temporal variation in the distribution and abundance of benthic macroinvertebrates is often considerable, even in the absence of any disturbance (Norris and Georges 1993). It is therefore important that environmental variability and its effects on sampling accuracy and precision be accounted for both in study design and in data analyses.

The past 15 years have witnessed considerable progress in several areas of study design and data collection. More recent monitoring studies carried out in these basins employ stratified sampling (i.e., all samples are taken from "similar" riffle habitats) and tend to collect approximately five samples at each sampling location. While this approach may serve as a good "rule of thumb" there

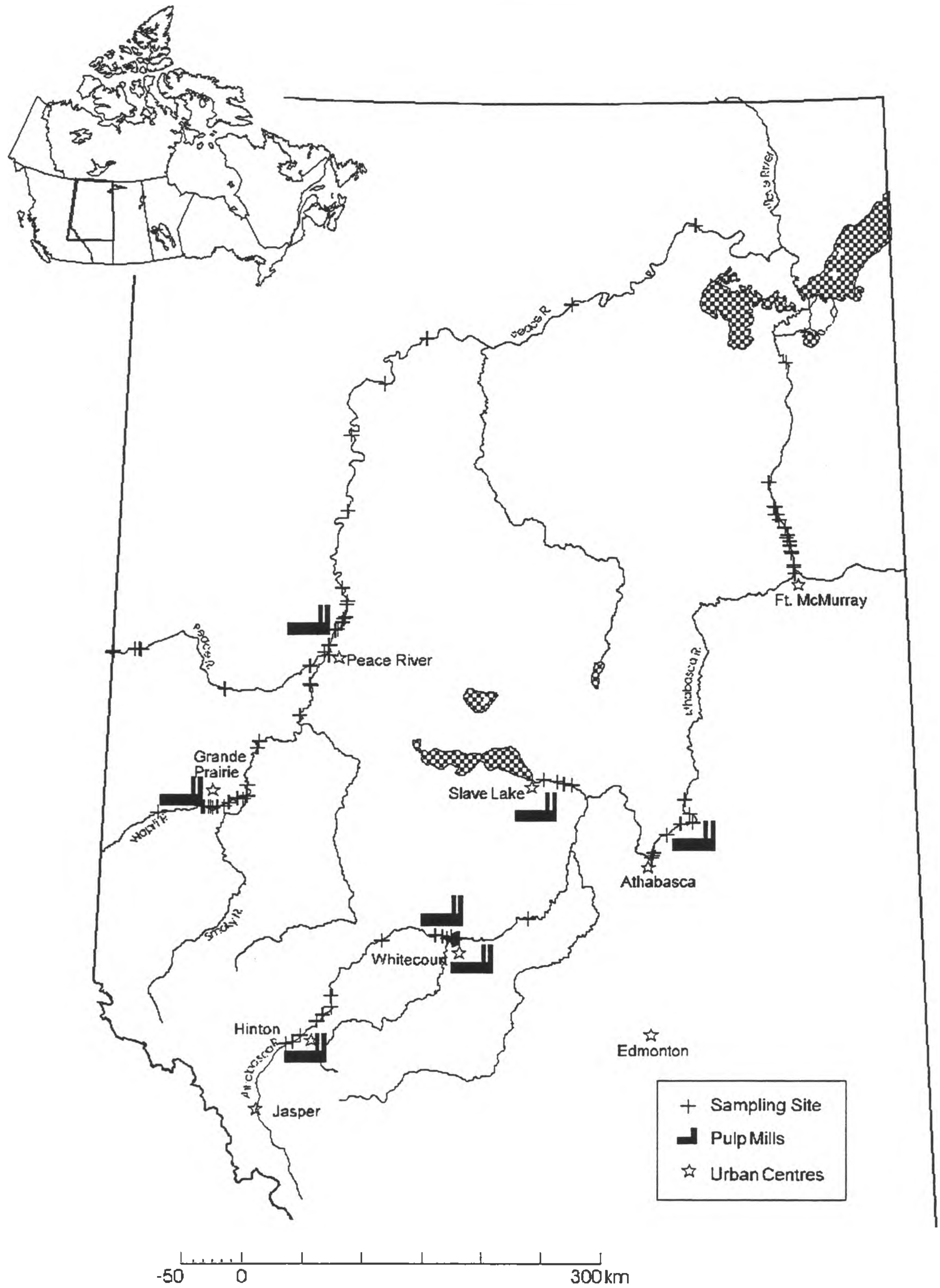

Figure 1. Benthic Invertebrate Sampling Sites on the Athabasca, Lesser Slave, Wapiti, Smoky and Peace Rivers.

is no *a priori* reason to suggest that this level of sampling effort is adequate. Only an explicit statement of the size of the effect (effect size) one wishes to detect followed by preliminary sampling and power analysis can provide researchers with precise information as to required sample size and sampling intensity.

Given that preliminary sampling is usually not possible, the five sample "rule of thumb" approach does represent a considerable advance over earlier studies that often collected fewer than five samples per site. In long-term studies, power analysis could be employed in the first few years of the monitoring program to determine adequate sampling efforts thereafter. Among those studies included in the master database, there are some that collected up to ten samples per site while in other cases only means or total abundances and no information as to sampling effort or sample number were provided.

For the purposes of this study, we have chosen to express all benthic macroinvertebrate community structure data in terms of density (number of individuals per m^2), ignoring differences in sampling technique and/or effort. In those cases in which a number of samples were collected at a given site at the same time, mean densities were calculated and are used in all analyses. We recognize that this approach almost certainly introduces some biases to the database and that, in some cases, observed differences in measured community structure may be a consequence of differences in sampling technique rather than true differences among communities. However, we feel any such biases are unavoidable and are balanced by the opportunity to consider and analyze the much larger data set.

Aside from long-term, basin-wide analyses we have attempted, where ever possible, to restrict our analyses to those times and locations that used similar sampling techniques and protocols. Complete and detailed descriptions of sampling techniques and protocols are included in the final database for the information of any researchers making use of the data (see Ouellette and Cash 1995).

The second problem associated with a synthesis of data from a large number of sources arises from a lack of standardization in taxonomic resolution. The ability to provide more detailed identifications of macroinvertebrates has generally increased with the improvement in, and more widespread distribution of, good quality taxonomic keys. Cost of sample processing however, remains one of the greatest constraints on taxonomic resolution (and sampling intensity), a situation unlikely to change in the foreseeable future (but see rapid assessment protocols, described below). In recent years several agencies, including AEP (Anderson 1990), have provided recommendations as to acceptable levels of taxonomic resolution and have instituted more rigorous QA/QC procedures to ensure proper taxonomic identification. These recommendations have resulted in much more standardized studies and data that is more accurate and precise however, the potential for differences arising solely as a consequence of differences in collection protocols and taxonomic skills remains a concern.

For the purposes of this study, we have generated a list of all aquatic benthic macroinvertebrate taxa that could potentially occur within samples collected from these basins. This master taxonomic list is provided in Appendix D and contains 884 separate entries. This list obviously includes far more taxa than would be found in any one sample or any one site; however, by including all taxa and by providing a high degree of taxonomic resolution the database can easily accommodate new entries and retains maximum flexibility. Moreover, because all data are ultimately contained within a relational database (see below, Ouellette and Cash 1995) a longer taxonomic list results in a negligibly larger database that can be used in a much more efficient manner. When working with the final database researchers will be able to "lump" or "split" organisms to any desired taxonomic level (eg. order, family, genus, etc.) and will be able to generate data matrices (in ASCII or spreadsheet format) containing only those taxa present at the site(s) and/or year(s) of interest.

With respect to the analyses described in this report, the actual level of taxonomic resolution employed will vary as a function of the locations/years being analyzed and taxonomic resolution employed by the agency/contractor that identified the taxa. Certain taxonomic groups, such as the Ephemeroptera or Trichoptera, are routinely identified to the level of genus or species while others, such as the Chironomidae, are usually identified only to the level of sub-family or tribe. In cases where taxonomic resolution differs because of the source, taxa in studies with higher resolution were "lumped" upward to allow comparisons with other studies conducted in the same area. In all analyses taxonomic resolution meet or exceed the guidelines laid out by Alberta Environmental Protection (Anderson 1990).

In the case of the multivariate analyses reported below, the selected level of taxonomic resolution was further complicated by the existence of rare taxa. Taxa, regardless of level, were excluded from the analysis if they occurred in fewer than 5% of the samples being analyzed *and* accounted for fewer than 1% of the total individuals in any one sample. Rare taxa are generally excluded from multivariate analyses using these or similar criteria as they have the potential to bias the results toward rare taxa and away from dominant ones (Gauch 1983; Reynoldson *et al.* 1995). In many cases in this report, taxa that would have been otherwise excluded from the analysis because they were rare, were "lumped" upward into a higher taxonomic criteria that did meet the criteria and were thus retained in the analysis.

The final problem associated with compiling and synthesising these studies arises from a lack of consistent format in data presentation. Even within a single study, on a single river, and within a single year, a single consultant may format data from different sites in different ways. This in no way affects the quality of the data but the time and effort required to standardize all samples from all locations and all years has been considerable. It is hoped that programs such as the Federal Government's Environmental Effects Monitoring (EEM) Program (Environment Canada and Department of Fisheries and Oceans 1991) will help to standardize reporting procedures in the future. It is also possible that the data format developed for this project could be adopted by AEP as a standard for future work. Such a decision would provide two immediate advantages: (1) Having already transferred all available data (including AEP's own studies) to this format, AEP could then ensue that all of its information, past and future, would exist in the same standardized format. (2) Any additional information reported using this format could be readily incorporated into the master Microsoft Access database (see below).

2.1.4 Master Database

Monitoring of biological systems in general, and macroinvertebrate community structure in particular, typically generates large amounts of data. For any productive use of this information to occur, a system for identifying and extracting specific data points and/or data sets must be available. Standard techniques involve storage of information in spreadsheet files, where the data can be easily manipulated, and from which extracts can be made for analyses. This approach to data storage has been the historical standard employed by agencies, industries and consultants collecting macroinvertebrate data within the northern river basins. However, when environmental monitoring involves management of very large amounts of data, spreadsheets are no longer an adequate means for storing and manipulating the information. In these instances, data are generally stored in a *database*.

Databases are designed to store large amounts of information and facilitate retrieval of this information based on specific criteria. Traditional (or flat) databases store all the information associated with one data point in a single line called a *record*. Although this permits retrieval of all the information associated with a particular piece of data, it generally results in a database that contains large amounts of repetitive information. For example, a database containing information on species occurrence would contain the information on sample site, sample time, sampling technique, *etc.* for *every* taxa, *and* every replicate. This can result in the same information being repeated dozens or hundreds of times. If for example, later information results in a change in the description of a site, each occurrence of that site must be located and changed individually. This repetition greatly increases the time required to develop and maintain the database, increases the probability of entry errors, and adds no new real information to the database.

Traditional databases also tend to be large and somewhat cumbersome to use because of this replication of data. The need to repeat the entry of information also increases the likelihood of data entry errors, and results in increased time to extract information. For most users, databases are employed for data storage, but manipulation and analysis of the data generally occurs in spreadsheet or other programs. The inclusion of all the repeated information means additional "clean-up" time must be spent in the other programs. Clearly, traditional databases are simply incapable of handling the volume of information present in the master database in an efficient manner and are thus not appropriate for this project. Indeed, electronic spreadsheet versions of the data currently exists in over 1,000 separate files on nine high density disks. Electronic copies of these spreadsheets (QuatroPro Version 5.0) were included in an interim report for this project (Cash *et al.* 1995) and are available upon request from the NRBS study office. A hard copy version of this data would exceed 1,300 pages in total length (see Appendix C) and is not included as part of the final report.

Relational databases differ from the more traditional forms in that repetitive information (e.g., location information, sampling technique etc.) is stored in a separate location, or table, and referenced as required. This saves space, increases the speed at which information can be extracted, reduces the probability of errors in the database and facilitates changes in the data when corrections or expansions are required.

By establishing links or *relationships* between information stored in different tables, all the information can be extracted from the database, just as if it were all contained in every record. If only partial information is required (e.g., just the descriptions of the sampling locations, or only selected taxa), this information can be quickly extracted from the appropriate table without searching the entire database. This makes summarizing the supporting information a quick and straightforward process.

After considering a variety of database options (e.g., Environment Canada's Ecological Effects Monitoring Electronic Reporting System or EEMERS, D-base Software, Fortran Software, FoxPro), we chose to employ Microsoft Access, a relational database management system, to compile the master database. Although there are several database programs capable of relational data management, Microsoft Access is one of the few in which the relationships in the information are built into the structure of the database. For this and other reasons including cost, availability, ease of use and compatibility with other software, we chose to use Microsoft Access as our data management system.

Microsoft Access is a networkable, Windows based, relational database program. It allows the efficient storage and retrieval of information, is inexpensive, and is compatible with other database programs such as D-Base, Paradox and FoxPro. Because it is a Windows based application novice users can quickly learn the software and use it to add information to the database or extract the information required.

Microsoft Access can import and export spreadsheet or ASCII files and can import files from other database programs. Microsoft Access can also link directly to data stored in other database programs without importing this data, reading and writing directly to the original file. This assures that users always have access to the most current version of the data. This approach also eliminates the problems associated with multiple copies of the same data. Data can be entered using *forms* which can be structured to mimic existing paper forms. This facilitates entry of data into the database. Data can be presented in presentation quality *reports*, and can be conveniently manipulated for export to other computer packages (such as statistical or graphical programs). Importantly, Microsoft Access can also easily link with other databases, including those employing other types of software such as D-base. This feature would allow researchers to link the macroinvertebrate information in this database to other databases containing relevant information. For example, this technique could be used to link information from macroinvertebrate sampling data to water quality data collected at the same location and stored in a different database.

The utility of the master database created for this project will depend largely on the ease with which researchers and managers can reorganize subsets of data within the larger database, and then extract the desired information. Different types of analyses may require data only from certain sites or reaches of particular interest, may involve only certain taxa or taxonomic levels, or may involve some subset of years or seasons. Clearly, any useful database management system must allow for this type of data manipulation and extraction and at the same time remain relatively inexpensive and relatively easy to use. Microsoft Access is easily learned, is able to rapidly perform the type of data manipulations required and will readily export the results of these manipulations to a number of statistical, graphical, word processing or spreadsheet software packages.

In order to facilitate the use of the master database by researchers and managers we have generated a manual (Ouellette and Cash 1995) which will accompany the database. The manual and database are both part of the final report but constitute separate components. In this way, individuals interested only in using the master database will have ready access to it. It is not the intention of the manual to duplicate material already adequately described in the manuals for Microsoft Access. Consequently, it is advisable for users to have available to them a copy of the Microsoft Access User's Guide to provide more detailed information on some of the features discussed in our manual, and to expand their use of the database beyond the features discussed in the manual.

2.2 FISH COMMUNITY STRUCTURE

2.2.1 Data Sources

Data sets measuring fish population and/or community structure within the northern river basins were identified with the assistance of Mr. Tom Boag of EnviResources and Mr. D. Mayhood of Alberta Fish and Wildlife. A total of approximately 1,800 reports concerning fish population/community structure within the Peace, Athabasca and Slave river systems were identified and briefly reviewed. Included in these reports are data collected as long ago as 1925 and as recently as 1994.

2.2.2 Data Evaluation

The total number of available monitoring studies that measured fish population or fish community structure within the northern river basins greatly exceeded that available for benthic macroinvertebrate community structure, both in terms of the volume of data available and the period over which that data was collected. Unfortunately, this data set, particularly in its current form, presents several practical as well theoretical difficulties. As such, it is unlikely to provide much utility for the current project.

First, despite a great deal of time and effort expended in measuring fish *populations* within these basins there has been considerably less attention devoted to measuring fish *community structure* within the same areas. The reasons for this lack of information on entire fish community structure are both historical and understandable. In contrast to those studying benthic macroinvertebrate community structure, fisheries biologists and managers have more often been concerned with only one species or one group of species, rather than the entire fish community. In most cases, the mandate of the fisheries biologists has required the collection of data relating only to those species considered important to the sport, commercial or sustenance fisheries. This bias in study objectives is reflected in the available data and suggests a lack of studies whose aim was to gather information on species and/or life-history stages not directly relevant to some aspect of the above mentioned fisheries.

Biomonitoring techniques that rely on fish community structure measures (e.g., the Index of Biotic Integrity (Dionne and Karr 1992; Karr 1991, 1992)) require the sampling of a fish of species of all size classes and occupying different habitats within the river (e.g., bottom dwellers *versus* those that live in the water column). However, as a consequence of historical priorities in fisheries biology, there have been few attempts to capture all fish species of all size classes within a given site at a given time. Indeed, despite advances in sampling techniques, for example the common use of electrofishing, sampling all fish species in all size classes within a given location remains a considerable logistical challenge, particularly in rivers as large and as difficult to work in as those in the northern river basins. Any attempt to measure fish community structure in these rivers would probably require the simultaneous deployment of a variety of sampling techniques within a given reach of the river. In other words, although there exists a large body of data collected on fish populations within these basins, data relating to fish community structure are rare, incomplete and of insufficient quantity and quality to be of value to this project.

In addition to logistical or practical challenges relating to the adequate sampling of a fish community in large northern rivers, there remains the considerable difficulty of defining what actually constitutes a fish community. An ecological community can be defined as a group of interacting populations (Ricklefs 1979); measures of community must thus include all species belonging to that community and important to those interactions. In the case of benthic macroinvertebrates, their small size and restricted movements allow entire communities to be sampled with ease. Similarly, in small wadeable streams, fish communities can typically be sampled by simply blocking off a section of the stream and electrofishing or netting all fish in that area. However, in large rivers, such as those considered here, logistical difficulties complicate sampling, moreover, individual fish of certain species may move hundreds of river kilometres in the course of a single year while individuals of other species may live their entire lives within an area of a few square meters. Finally, within a single species, individuals of different life-history stages may have significantly different habitat requirements and may seldom co-occur in the same habitat.

Given the different ecologies, habitat requirements, movement patterns and life-history strategies of the individual species that constitute fish communities within these rivers, it would clearly not be possible to adequately describe fish community structure by sampling a restricted area during a single season. Rather, extensive and intensive sampling would have to occur over a much broader spatial and temporal scale involving long stretches of river and different seasons. If fish community structure were to be used as a biomonitoring tool the precise scale of sampling would have to be determined only after a consideration of the movement patterns and basic ecology of those species comprising the community. Even establishing the appropriate temporal and spatial scale of sampling required to describe the fish community represents a considerable investment of time and effort and would probably be well beyond the scope of most monitoring programs.

Provided the fish community could be properly defined and adequately sampled, the next challenge facing managers and researchers would be to identify and distinguish among or between impact and reference fish communities. Ideally, impact and reference fish communities should not overlap spatially, and should be separated by the point source of interest. Within the northern river basins system, it seems likely that the home range of many members of the fish community, particularly species important to the commercial, sustenance and sports fisheries, extend both above and below one or more point sources of interest (typically a pulp mill). In other words, a single fish community would very likely span sections of the river both upstream and downstream of any single point source of interest. Given the size of some species' home ranges, potential "reference" communities may be so far removed from the identified "impact" community that any observed differences between the two might be more a function of changes in environmental parameters or general riverine habitat than a consequence of exposure to of any point source, anthropogenic impact.

It may be possible to replace measures of the entire fish community with measures of some subset of the same community (e.g., all those species caught in a particular size of net, set for a standardized period of time). Movement patterns of species within such a subset may be more consistent and better understood simplifying data interpretation. However, if such a subset of the community were to be used, the ecology and distribution of all life-stages of the selected taxa would have to be well understood as would the ability to extrapolate from results based on community subsets to the community as a whole.

It should be noted that the concerns described above relate to measures of fish community structure only, and need not apply to individuals or populations within that community. Individual- (e.g., growth, fecundity, morophometrics and meristics) and population- (e.g., distribution, age/size-class structure, rate of increase) based measures taken on a variety of fish species are commonly used ecological indicators and provide valuable insight into the ecological structure and integrity of riverine systems (Plafkin *et al.* 1986). More sessile fish species within those communities may provide both reference and impact populations that could be used as effective indicators of anthropogenic impact. Similarly, if some rapid physiological response was to be measured (e.g., changes in sex steroid levels or induction of mixed function oxidase activity *sensu* Munkittrick *et al.* 1991, 1992), it might be appropriate to sample above and below the point source, provided the movement patterns of the species sampled were such that captured individuals were likely to have been in the area from which they were collected for the preceding several days or weeks.

Additional difficulties identified among the studies reviewed relate to considerable differences in sampling techniques employed. Fish within these basins have been sampled using a variety of methodologies, including gill nets, seines, set lines and electrofishing. The efficacy of these techniques changes dramatically as a function of the habitat in which they are employed and comparisons among studies using different techniques or even the same technique in different habitats would present significant challenges. In a significant portion of identified studies, the situation is further complicated by a lack of measures of sampling effort (i.e., catch per unit effort, or CPUE).

A final, but serious, complication arises from the fact that the data contained in almost all of the fish population/community studies identified as having occurred within these basins are available only in hard copy format. While an electronic version of this database would no doubt be useful, the task of collecting all identified studies, standardizing the information with respect to format and content and finally transposing the data into a standardized electronic form would likely require several person years, a major undertaking that is clearly far beyond the capacities and mandate of this project.

For all of the reasons described above, it has been decided that the currently available database measuring fish community structure within the northern river basins is neither appropriate nor amenable to statistical investigation. The information identified thus far would also not serve as an adequate database with which to test current biomonitoring techniques; indeed we argue that it is neither useful nor possible to employ fish community structure as a biomonitoring tool within large northern river systems. Measures of fish community structure are widely employed in other ecosystems (Plafkin *et al.* 1989) but in these cases, their use has been confined to small (by NRBS standards) streams and rivers in which many of the difficulties discussed above do not apply.

3.0 MACROINVERTEBRATE COMMUNITY STRUCTURE

3.1 GENERAL CONSIDERATIONS

Benthic macroinvertebrates are more commonly used in the assessment and monitoring of aquatic ecosystems than are any other group of organisms (Resh *et al.* 1995). The advantages of using benthic macroinvertebrates in monitoring freshwater systems are numerous and have been well documented (see summaries in Plafkin *et al.* 1989; Rosenberg and Resh 1993). These advantages include the fact that: (1) they are a diverse and widely distributed group that can be found in virtually all aquatic ecosystems; (2) because they are relatively sessile, they integrate, and are representative of, conditions present in the area in which they are sampled; (3) they are sensitive to environmental stresses (both natural and anthropogenic) and show a wide variety of responses to such stress; (4) with some notable exceptions (e.g., Chironomidae, Oligochaeta) their taxonomy is generally well understood.

Despite the many advantages of using benthic macroinvertebrates as a biomonitoring tool it is also necessary to be aware of any difficulties associated with this approach. Among the challenges involved in the effective use of benthic macroinvertebrates in biomonitoring is the need to: (1) obtain sufficiently precise and accurate measures of benthic macroinvertebrate community structure at a variety of locations; (2) relate observed changes in benthic macroinvertebrate community structure to the environmental parameters responsible for those changes and; (3) successfully distinguish natural variation in benthic macroinvertebrate community structure from those changes induced by anthropogenic stress.

In the context of the NRBS, environmental managers and researchers are faced with the added complication of trying to develop an adequate understanding of benthic macroinvertebrate community ecology and structure within the basins while *simultaneously* assessing the impact of anthropogenic activities on those communities. The importance of understanding the natural structure and function of ecological communities cannot be over emphasised. It is this understanding that determines our view of the system and provides a standard against which anthropogenic activities are measured, and a context within which all management priorities and objectives are developed.

Ideally, environmental monitoring programs would have at their disposal accurate and complete information as to the basic ecology of the ecosystems being monitored. Such a database could be used to identify the most appropriate bioindicators, and to identify those ecosystem components most sensitive to perturbation as well as the manner in which different components within the system interact (Cash 1995). Unfortunately, limitations on human and financial resources as well as on our ability to understand complex ecological processes preclude this possibility. These challenges are in no way unique to the NRBS but may be particularly acute in a system as large and as difficult to work on as this one.

3.1.1 Natural *versus* Anthropogenic Variation in Community Structure

One of the major goals of any aquatic biomonitoring program employing measures of benthic macroinvertebrate community structure is to use the patterns of distribution and abundance of organisms observed within the ecosystem to determine the state of the ecosystem and to detect change within that system. The extent to which this goal is met is thus dependent on the ability to:

1. Identify those components of the community that require measurement.

2. Properly measure and describe those components.

3. Compare and contrast those measures at a variety of spatial and temporal scales.

4. Relate these observed patterns to corresponding patterns in physicochemical variables so as to identify the underlying causes responsible for changes in community structure.

The development of appropriate study designs is critical to this process and will facilitate management objectives by assuring the proper collection of relevant data, the elimination of confounding effects and the selection of appropriate analyses (Norris and Georges 1993).

Spatial and temporal variation in the distribution and abundance of organisms, particularly benthic macroinvertebrates, is often considerable, even in the absence of any anthropogenic disturbance. It is therefore important that environmental variability and its effects on sampling accuracy and precision be accounted for both in terms of study design and in data analyses. The past two decades have witnessed considerable progress in several areas of study design and data collection and while more progress is required, there have been major improvements in, and greater standardization of, field sampling and collection techniques (Downing 1979; Cuffney *et al.* 1993a,b; Gibbons *et al.* 1993; Meador *et al.* 1993a,b; Porter *et al.* 1993; Resh and McElravy 1993). It is also now generally recognized that even small habitat differences among sites can be a major source of natural variation. Sampling protocols should thus include habitat characterization and measurements of all important and relevant physicochemical variables (Norris and Georges 1993).

The preceding discussion has several important implications for the interpretation of the database compiled for this project. A more explicit consideration of these points will serve to illustrate both the strengths and weaknesses of the master database and will hopefully provide direction as to the most appropriate design of any future biomonitoring program to be employed in these basins.

First, the master database created for this project does not constitute a single study. Rather, as described above, it consists of 94 separate studies presented in a standardized format. Obviously, studies of benthic macroinvertebrates within the northern river basins have been carried out for a variety of purposes and have employed a variety of study designs. As discussed above, differences in collection techniques probably led to biases within the master database but such biases are unavoidable and cannot be quantified. Differences in precision among studies are also present but, at least in the last 10 - 15 years, greater standardization in study design should serve to reduce variance among studies.

Second, and of greater concern is the fact that most studies did not include detailed habitat characterization or measurements of all relevant physicochemical variables. This omission has two important consequences: (1) although we possess information concerning benthic community structure there is no context in which observed differences in community structure can be examined; and (2) the process of distinguishing between natural and anthropogenically induced variation in community structure is greatly complicated. If, for example, an analysis reveals that within a given year, community structure downstream of a point source differs from that observed above the point source it is tempting to assume that any such differences are attributable to the presence of the point source. In fact, the observed differences could be due to any number of differences between the sites, including subtle habitat differences and the fact that they are separated by the point source.

By obtaining more detailed measures of habitat and physicochemical variables researchers would be better able to "tease" apart community structure differences arising as a result of natural variation (e.g., differences in water quality, substrate size, embededness, channel character, current, etc.) from those resulting from the point source (e.g., pulp mill effluent). Moreover, direct, quantitative, comparisons of variables such as water quality measurements between reference and impacted sites can provide insight into the factors responsible for any observed changes in community structure and may also help to distinguish between naturally and anthropogenically induced changes in structure.

The above example illustrates challenges associated with differences observed on a spatial scale but similar challenges exist on a temporal scale. That systems such as these are highly variable is well known (Cash 1995). As a consequence, even at undisturbed or reference sites, benthic community structure will vary considerably across seasons and years (see below). Given that this is the case, observed changes at impact sites could be indicative of long term changes within the basin (e.g. changes in global weather patterns), a consequence of cumulative exposure to anthropogenic activity (e.g., long-term exposure to pulp mill effluent) or an expression of the extreme natural variation within this system (e.g. yearly variation in spring flood levels, ambient light, temperature, etc). Detailed habitat characterizations and measurements of relevant physical and chemical variables allow managers to "tease" apart the various causes of the observed variation in community structure and to assess the impact of anthropogenic activities on those communities.

3.1.2 Scale

Issues of scale in the analysis of benthic macroinvertebrate community structure are closely related to those of appropriate sampling design. Scale (spatial, temporal and organizational) is an important consideration, not only from the perspective of adequately describing and sampling a system as large the Peace, Athabasca and Slave river basins, but also from the perspective of interpreting and identifying spatial, temporal, and organizational pattern in the data once they are collected. Indeed, a growing number of ecological researchers have argued that the problem of pattern and scale is rapidly emerging as one of the central problems in population ecology and ecosystem science (Fox 1992; O'Neill *et al.* 1992). These researchers also argue that issues of scale and pattern represent an important bridge between theoretical and applied ecology (Levin 1992), and should play an important role in the ongoing monitoring and assessment of ecosystem health and in the development of biomonitoring programs.

The problem of deciding the most appropriate scale at which to observe pattern is further complicated by the effect of scale on the interpretation of pattern once observed. Because each species or group of species experiences the environment at a unique range of scales, the scale of observation chosen by the researcher or manager will influence the description of pattern. It is thus necessary to ensure that researchers are careful to chose a scale of observation appropriate to the question being asked (Levin 1992). In other words, specific patterns observed within the environment are largely a function of the scale at which workers choose to make observations and a change in the choice of scale may well change the pattern observed.

Issues of scale and pattern will continue to complicate the interpretation of biomonitoring data and are clearly deserving of further investigation. Problems arising from the misinterpretation of biomonitoring data can be minimized if issues relating to scale are explicitly recognized both in the design of studies and in the interpretation of results. Confusion resulting from scale-related problems may also be minimized by: (1) giving careful consideration to the scale or scales of relevance for a particular question, (2) collecting observations from a variety of different spatial, temporal, and organizational scales, (3) being sensitive to the potential difficulties in extrapolating between scales (Cooper and Barmuta 1993), and (4) being aware of the fact that the causal mechanisms producing the observed pattern often occur at a scale below that at which the pattern is observed (Levin 1992).

With respect to the NRBS, perhaps the most important scale-related issues are spatial and relate to the contrast between attempts to assess the local impact of anthropogenic activity (e.g., a particular pulp mill) and attempts to characterize the broader, basin-wide effects (see below). Additional scale issues relate to the timing of sampling and the need to assess long-term ecological changes within these basins.

3.1.3 Potential Limitations of Traditional Biomonitoring Techniques

Traditional aquatic biomonitoring programs employing measures of benthic macroinvertebrate community structure were largely developed to examine the potential effects of organic pollutants on the environment (Metcalfe-Smith 1994). However, aquatic organisms in nature are routinely exposed to a great variety of different stresses, both organic and inorganic, simultaneously. Common stressors include organic pollution (nutrients, sewage), heavy metals, dioxons, furans, and organochlorines to name a few (Costan *et al.* 1993). In some cases, as with pulp mills, a single effluent may contain nutrients (e.g., nitrogen and phosphorus), well known contaminants (e.g., dioxons and furans), and are thought to contain other important contaminants that are yet to be identified.

The historical bias in the use of benthic macroinvertebrate community structure to detect the effects of organic pollutants on the environment has important implications for the northern river basins. First, it may be necessary to develop new indicators in order to detect community exposure to nonorganic pollution (e.g., heavy metals). Indeed, benthic macroinvertebrates may not ultimately prove to be the most reliable and cost-effective indicators of these types of pollution. Second, some of the most commonly used macroinvertebrate monitoring techniques (e.g., Plafkin *et al.* 1989) are based on the assumption that the addition of pollutants such as nutrients will result in eutrophication, the loss of pollution tolerant taxa and a possible reduction of macroinvertebrate density and/or diversity. Such a response to anthropogenic stress is common and has been well documented in numerous river and lakes (Metcalfe-Smith 1994). However, in nutrient limited, oligotrophic systems, such as the northern river basins, introduction of nutrients may actually lead to an increase in algal production and eventually, an increase in macroinvertebrate density and diversity (see below). An increase in macroinvertebrate density and diversity of this type can be thought of as resulting from a "fertilizing" of the river followed by general increases in numbers of rare taxa generally not present in samples from the reference site become so common as to be captured by samples from the impacted site.

The important consequence for this study, and for the NRBS, is that an unconsidered application of certain widely used biomonitoring tools will result in the conclusion that impacted sites are more "pristine" than reference, or undisturbed sites. The reason for this apparent contradiction rests with the assumption that anthropogenic impacts always result in a loss of taxa (Plafkin *et al.* 1989) and to effectively ignore impacts that result in an increase in macroinvertebrate density or diversity.

It is tempting to consider increases in abundance and diversity as being beneficial or positive changes in the ecosystem but such a view is extremely dangerous. If the objective of the monitoring program is to detect and quantify impacts of anthropogenic activity then it is important to recognize that *any* significant change in density or diversity, regardless of direction, represents anthropogenic impacts and shifts away from the "natural" state. It may be that governments and the public consider increases in density and diversity to be positive changes but it must also be appreciated that these are strictly, subjective, societal valuations and have no basis in scientific or ecological theory. In other words, any increase in density and diversity is no less an impact than a decrease in density and diversity. Any decision to view these changes in a different light is a purely cultural and nonscientific one.

The lesson for the NRBS is to carefully consider the types of information required and the ability of various biomonitoring techniques to supply that information. Techniques designed for other locales and pollution issues may not meet the specific concerns and needs of a monitoring program within the northern river basins.

3.1.4 Conclusions

The concerns outlined in the previous sections should not be interpreted as a criticism of the individual studies that constitute the master database (or of biomonitoring tools that have been successfully applied in other regions). Historically, studies concerned with benthic macroinvertebrate community structure in these basins have not directly and quantitatively related their results to environmental (i.e., habitat, physical, chemical) measures collected at the same time. Only in recent years, have detailed habitat measures become a routine component of such studies. Detailed environmental measures are now integral to programs such as the US Environmental Protection Agency (EPA) Rapid Bioassessment Protocols (Plafkin *et al.* 1989), the UK, **R**iver **I**n**V**ertebrate **P**rediction **A**nd **C**lassification **S**ystem (RIVPACS) program (Wright *et al.* 1984, 1988; Wright 1995), the Great Lakes **BE**nthic **A**ssessment of **S**edimen**T** (the BEAST approach (Reynoldson *et al.* 1995) and a variety of rapid assessment techniques (Resh *et al.* 1995).

Moreover, in the majority of studies carried out in these basins the objective was to compare benthic community structure upstream of a point source to that observed in a variety of downstream locations. It was not the intent of these studies either to compare a variety of locations throughout the basins (i.e. basin-wide comparisons) or to construct long-term data sets for specific locations.

Although environmental data may not traditionally have been analyzed in a quantitative manner, sampling standardization has served to control, at least in part, for spatial variation and a lack of habitat characterization within this system. For example, almost all samples included in the master database were collected from within riffle habitat. This stratification of sampling (i.e. choosing to sample only one type of habitat) reduces observed variation among samples. Likewise, most collections were obtained at similar depths and from habitats with similar cobble further reducing habitat differences between impact and reference sites. By selecting impact and reference sampling locations that differ from one another as little as possible, researchers and managers reduce or account for much of the natural variation observed in the samples and can have greater confidence that any observed differences in community structure are a consequence of anthropogenic activity. Such stratification also allows for preliminary comparisons over larger spatial and temporal scales even if the data involved in these comparisons come from several different studies.

In the analyses presented in the following sections the reader is asked to be aware of both the strengths and limitations of the data set as discussed above. Perhaps the greatest benefit of summarizing and standardizing all the data collected within these basins is to explicitly identify information gaps and to provide direction as to what types of data should be collected in the future.

3.2 DATA ANALYSIS

Benthic community structure was analyzed primarily through the use of multivariate ordination techniques. More specifically, Principal Component Analysis (PCA) was used to distinguish among sampling locations throughout the basins and within single reaches over time. All analyses presented here were conducted using the PRINCOMP procedure of SAS (SAS Institute 1988).

Ideally, the results of each PCA would be considered separately and the associated eigenvectors (and hence significant taxa) thoroughly discussed. However, this study is based on almost 200 separate analyses, over 100 of which are presented in this report. A complete discussion of each analysis would add greatly to the length of this report and might well serve to obscure more general trends contained within the data. For these reasons, the results of PCA will be presented and discussed in general rather than specific terms, and will be primarily used to illustrate overall trends in the data. Results of all multivariate analyses are presented graphically in Appendix E of this report. Where appropriate, results of specific analyses are also presented in the text. The proportion of total variation explained by each of the principal component axes (PRIN) is given in parentheses following the axis label. Only those axes that explained at least 15% of the total variation are presented in this report. Eigenvectors for individual taxa are not presented, however taxa whose absolute value >0.25, were considered significant contributors to the relevant principal component axis.

Densities of individual taxa collected within each sample and replicate are available in the master database. However, to present complete taxonomic lists and accompanying densities for each sample analyzed in this report would add hundreds of pages to its length and would contribute little to its quality. For these reasons, taxonomic lists have not been included for each of the analyses described in subsequent sections. In almost all cases and at almost all locations within these basins, benthic invertebrate communities were numerically dominated by members of the Chironomidae (midges), Oligochaeta (worms), Ephemeroptera (mayflies), Trichoptera (caddisflies), and/or Plecoptera (stoneflies). Observed shifts in community structure discussed below, relate to changes in the relative numbers of of these taxa rather than the elimination of certain taxa. Readers interested in more specific abundance or taxonomic details are referred to the database included in this report.

Rapid assessment metrics were analyzed following the protocols laid out by the US EPA (see Plafkin *et al.* 1989). The only significant deviations from those protocols are:

1. Metrics presented are based on counts of entire samples rather than on subsamples

2. In those cases where samples from more than one reference site or category of impact site where available, the values presented are based on the mean for all reference sites or for all sites within each impact site category.

3.3 BASIN-WIDE ANALYSES

3.3.1 Introduction

Despite the considerable investment of time and money devoted to the examination of benthic community structure within these basins there has never been a study whose primary purpose was to assess macroinvertebrate community structure at a basin-wide level. This omission represents an important gap in our available knowledge of the basic ecology and structure of these ecosystems. However, this gap is understandable in light of historical considerations described below.

First, the vast majority of individual studies conducted within these basins were designed to examine the near- to mid-field (0 km - 100 km downstream) effects of point source activities on benthic community structure. In other words, the focus has been on local effects of specific activities such as pulp mill operations, usually as part of the Provincial licensing agreement for those operations. A concentration of sampling effort near point sources is appropriate since aquatic communities in these areas are probably at greatest risk from anthropogenic activity, but the unfortunate consequence is a lack of information on large stretches of river lying between point sources.

The second consideration relates to the considerable logistic and financial challenges presented by any attempt to sample (at least on a spatial scale) a system as large as the northern river basins. Even if sampling were restricted to the mainstems of those portions of the Peace, Athabasca and Slave rivers found within the study area, researchers would have to sample more than 2500 river km. Clearly, any attempt to sample such an area would be expensive, would require considerable coordination of effort (at Federal, Provincial/Territorial, local and industry levels) and historically has been beyond the scope and mandate of studies carried out in these basins.

As a consequence of this focus on point source activities, the data required to examine changes in benthic community structure at a basin-wide level is simply not available. However, it may be possible to gain some insight into general community structure by comparing data from reference sites in different reaches collected in the same year and during the same season. The results of such an analysis are presented below.

3.3.2 Results and Discussion

As discussed above, an analysis of basin-wide changes in community structure would ideally involve a large number of sites distributed throughout the basin, sampled in the same season and repeated over a number of years. Unfortunately, most samples were collected in close proximity to pulp mills and while data were collected in each year of operation, different mills were sampled in different seasons. As a result there are few year/season combination in which there are data adequate to compare a number of different pulp mills. Indeed, the autumn of 1992 is the only period in which the available data allows for a comparison of samples taken in different reaches in the basin.

More specifically, data measuring benthic macroinvertebrate community structure were available from five sets of reference sites (three along the Athabasca River and two along the Peace River), including the areas upstream of: (1) the Weldwood mill at Hinton, (2) the Alberta Newsprint Corporation (ANC) mill at Whitecourt, (3) the Alberta Pacific (ALPAC) mill at Athabasca, (4) the Weyerhaeuser mill at Grande Prairie and, (5) the Daishowa mill at Peace River. Analysis of impact sites included the Millar Western mill at Whitecourt but excluded ALPAC as available data did not include the operational period for this mill. Samples obtained in the vicinity of the Slave Lake Pulp Corporation at Slave Lake are not included in the analyses. Surveys in this area employed different sampling techniques (i.e. grab samplers) in a different habitat type (i.e. depositional sites) and thus, results are not directly comparable to surveys conducted in riffle habitat using Neill type samplers.

The basin-wide analysis of benthic community structure consisted of three steps. (1) Reference sites above pulp mills were compared across the basins in order to examine changes in community structure independent of anthropogenic activity. (2) A comparison of sites below, but within 20 km of the mills was conducted. (3) In the third step, the results of the two analyses were compared to evaluate the effect of the mills on the overall pattern of community structure.

Results of the basin-wide analysis of reference sites are presented in Figure 2 and reveal some interesting trends. First, with respect to samples from Weldwood, Weyerhaeuser and Daishowa, collections within the same reach tend to be plotted close to one another in ordination space. This suggests variation in community structure within these reaches was relatively low. Second, within-reach variation above ANC and ALPAC mills was significantly greater than that observed above the other mills. Third, despite the ANC and ALPAC outliers there was no strong tendency for sites to separate into different groups. The first two axes of the PCA explained only 45% of the total observed variation in benthic macroinvertebrate community structure. The first axis (PRIN1) represents a general increase in macroinvertebrate taxa and in particular, certain members of Mollusca, Trichoptera and Plecoptera. The second axis does not reflect a change in overall numbers but does suggest a decrease in relative abundance of Oligochaeta, Chironomini and Trichoptera.

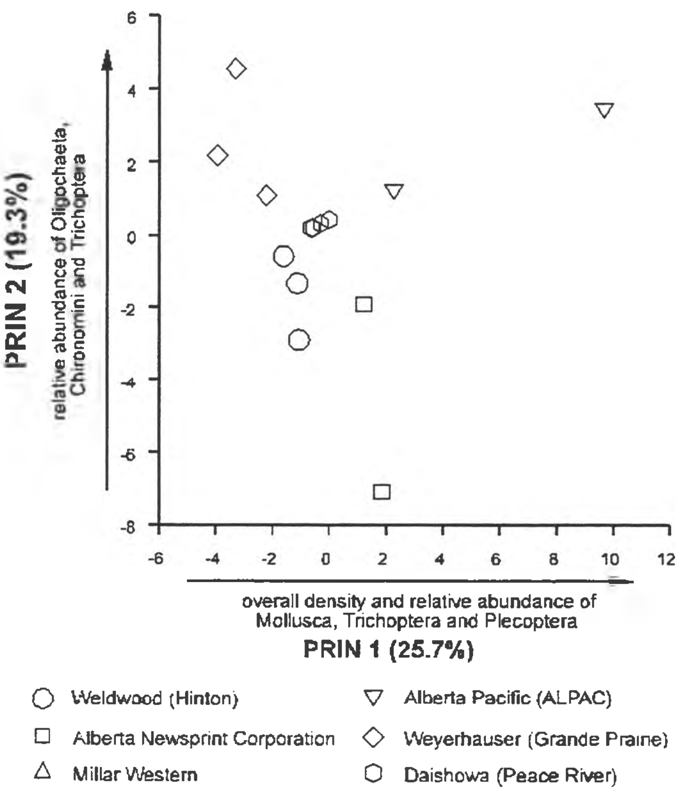

Figure 2. Principal Component Analysis of Reference Sites in the NRBS Area for the Autumn of 1992.

The fact that distinct groupings are not apparent in this analysis suggests that reference sites in different parts of the basins do not differ greatly with respect to the relative abundance of invertebrate taxa. Indeed, variation among samples collected above some mills (e.g., ANC and ALPAC) is greater than that observed between different mills.

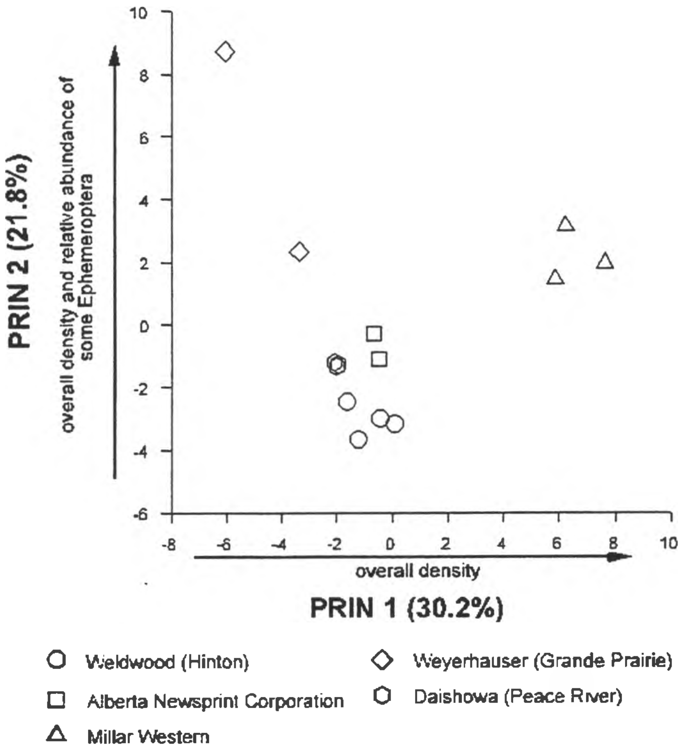

Figure 3. Principal Component Analysis of Impact Sites in the NRBS Area for the Autumn of 1992.

In contrast to the analysis of reference sites, a similar analysis of impact sites (Figure 3) serves to separate Millar Western impact sites from impact sites below other mills along the first PCA axis. This separation is not strongly driven by changes in specific taxa (as determined by eigenvector values) but rather, is reflective of higher total numbers at the Millar Western sites. The second PCA axis helps to separate at least one of the Weyerhaeuser sites from the remaining samples. As with the first axis, the second axis is not reflective of dramatic shifts in any single taxa other than Siphlonuridae (Ephemeroptera). As with the first analysis, there is also a strong tendency for sites within a given reach to be plotted close to one another in ordination space indicating lower variance in community structure within a reach than among reaches. The absolute eigenvectors associated with both these analyses are all quite low (<0.30) indicating that the different groupings of impact sites reflect a series of minor shifts in relative abundance rather than major shifts in important taxa. It should also be noted that, for reasons that will be discussed below, caution should be used when interpreting any results pertaining to observations made in the vicinity of the Daishowa mill.

At a more important level, it is difficult to draw conclusions as to basin-wide changes in community structure on the basis of relatively few, widely separated samples collected in one season of one year. Clearly, any attempt to assess benthic macroinvertebrate community structure on a basin-wide level would require a number of elements. First, a coordination of sampling efforts by individual mills would ensure that all samples collected above and below mills were obtained in the same season. Second, samples would have to be collected between mills so as to sample adequately the scale of interest. Third all sampling would have to be standardized with respect to sampling technique and stratification. Fourth, relevant environmental data would need to be collected in conjunction with the macroinvertebrate samples. Finally, while samples need not be collected within each season and in each year, there would be a need for regular basin-wide sampling to assess the role of natural year-to-year variation in benthic community structure within these basins.

Rather than concentrate on basin-wide analyses the remainder of this Chapter will summarize results of analyses comparing reference and impact sites at specific mills over time. Within these analyses each year/season combination is analyzed separately. The reason for this stratification is simply that the natural year-to-year and among season variation in community structure would quickly "swamp" and obscure anthropogenically induced variation, particularly in any analysis that simultaneously considered all years and seasons as well as impact and reference sites. By considering each year/season combination separately we are able to "tease" apart natural and anthropogenically induced variation and thereby form a clearer understanding of the effect of human activities on this system. Multivariate analyses involving data collected in all years within a single season (i.e. spring or autumn) have been conducted. However, these analyses fail to demonstrate any consistent pattern and more importantly, fail to explain a sizeable portion of the observed variation in community structure. For these reasons, such analyses are not included in this report.

3.4 WELDWOOD OF CANADA LTD.

3.4.1 Introduction

The Weldwood of Canada Ltd. mill began operations in 1957, employs a Kraft-type process, is located on the Athabasca River at Hinton and is the longest-running pulp mill on this river. The master database contains data from the area surrounding the Weldwood mill that spans a period of 33 years (from 1960 until 1993). Fourteen separate year/season combinations were deemed appropriate for analyses in this report (see Appendix E-1). For the purposes of this report, benthic macroinvertebrate community samples collected from the Athabasca River around the Weldwood mill were placed into one of four categories: (1) the area upstream of the pulp mill outfall, (2) the area between 0 and 5 km downstream of the pulp mill outfall, (3) the area between 5 and 20 km downstream of the pulp mill outfall, and (4) the area between 20 and 50 km downstream of the pulp mill outfall.

3.4.2 Results and Discussions

The results of a series of PCAs examining benthic invertebrate community structure above and below the Weldwood Mill are provided in Appendix E-1. In general, communities both above and below the mill were numerically dominated by chironomids (Orthocladiinae and Chironominae), mayflies (Baetidae, Ephemerellidae and Heptageniidae) and, particularly in earlier years, oligochaete worms (Naididae and Tubificidae). Observed differences among sites were generally a function of changes in relative numbers of taxa rather than a result of the disappearance or addition of specific taxa (see master database).

A year by year inspection of the data and results of multivariate analyses reveals important differences in sampling techniques employed and hence conclusions generated concerning benthic community structure. During the period between 1972 and 1979 artificial substrate samplers were used in this area, whereas Surber (1960) or Neill (1984 to present) samplers were most often used (and were the only sampling techniques to be analyzed) at other times.

Artificial substrate samplers have the advantage of allowing researchers to control for substrate differences among sites, however their use requires at least two visits to the sampling location (one to set the sampler and the second to recover it and collect the macroinvertebrates) and, because of differences among taxa in the tendency to drift and colonize new habitat, artificial substrate samplers are biased toward that subset of taxa most likely to move on to the artificial substrate. In other words, in the absence of a colonization history (i.e. which taxa are most likely to colonize the sampler and when) such samplers may provide inaccurate measures of community structure (Cairns and Pratt 1993). This bias in data collection complicates the interpretation of results and could lead to inaccurate or misleading conclusions. For these reasons the use of artificial substrate samplers is no longer common within these basins and will not be considered further in the context of this report.

In the spring 1960 collection the single reference site is separated from the impact sites along the first PCA axis which explains 38% of the total variation in community structure and reflects a general increase numbers in taxa other than chironomids and oligochaetes, suggesting these "pollution tolerant" taxa were relatively more abundant at downstream sites. These observations are consistent with what might be predicted downstream of the pulp mill but it is important to note that this analysis involved only one reference site and may not accurately reflect community structure upstream of the mill.

In the remaining Weldwood samples there is no strong tendency for reference sites to be plotted close to one another in ordination space or to be plotted in an area removed from impact sites. Exceptions to this trend can be found in the spring of 1989 and in the spring of 1991. However, in the spring of 1989 reference sites were separated only along the second PCA axis which accounted for only 15% of the total variation and was driven (based on eigenvector values) by increasing relative abundance of relatively rare taxa including (in order of relative importance): Hexatoma (Tipulidae), Heptageniidae (Ephemeroptera), Enchytraeidae (Oligochaeta) and Chironomini (Chironominae) and decreasing relative abundance of Orthocladiinae and Perlodidae (Plecoptera). In the spring of 1991, the separation of reference sites again occurred along the second PCA. In this case, the axis accounted for 22% of the total measured variation and the only eigenvectors along the axis that were greater than 0.25 were once again related to rare taxa (Nematoda and brachycentrid Trichoptera).

An examination of the results of multivariate analyses given in Appendix E-1 also indicates that sample sites immediately downstream of the Weldwood mill tend to be plotted further from one another in ordination space than are sites in any other reach. This observation indicates that the variability in benthic macroinvertebrate community structure immediately downstream of the mill is greater than that observed in other reaches; there are at least two possible explanations for this observation. First, the higher variability in community structure in this reach could be a direct consequence of exposure to pulp mill effluent. Greater variability in benthic macroinvertebrate community structure is often used as an indicator of community instability and could be higher in this section of the river because at this point the pulp mill effluent has not yet been diluted and is thus at its highest concentration. The second possibility also arises because in the first downstream reach the effluent was not yet fully mixed in the river. Under this scenario, communities on one bank may be in the effluent plume while those on the opposite bank receive little if any effluent.

Sampling below the Weldwood mill has generally involved taking collections from both the left and right banks at a point approximately 0.6 km downstream of the pulp mill outfall. Water quality data taken from both banks at this location indicates that the effluent plume "hugs", or is confined to, the south bank of the river, exposing invertebrates on that side of the river to relatively high concentrations of effluent while leaving the benthic community on the north bank to live under conditions that more closely resemble that experienced by communities at reference sites upstream of the mill (C. Podemski, personal communication). In other words, information on water quality suggests that the second explanation offered above may be the more likely reason for the increased variation in community structure observed immediately downstream of the Weldwood mill.

More importantly, these observations serve to demonstrate the importance of collecting "high quality" environmental data at the same site from which benthic invertebrate collections are taken. Benthic community structure contains a wealth of useful information but, as can be seen in this example, it is information that can only be properly and fully interpreted in the light of adequate environmental data. Analyses of benthic macroinvertebrate community structure in the absence of environmental data may illustrate major shifts in community structure but there is a danger that equally important but subtler shifts will be missed, that changes caused by anthropogenic activity will go undetected, or that changes will be attributed to anthropogenic stress when such is not the case.

3.4.3 Conclusions

The PCA results described here demonstrate significant year to year and between season (spring and autumn) variation in benthic macroinvertebrate community structure in the Hinton area of the Athabasca river. However these same analyses do not serve to separate consistently upstream reference sites from downstream impact sites. Communities both above and below the Weldwood mill tend to be numerically dominated by chironomids and oligochates and observed differences between sites were most often a function of changes in total density or in the relative numbers of a small number of rare taxa. These analyses provide no evidence to argue that changes in benthic community structure downstream of the mill result from the loss of taxa. Indeed, as will be discussed below, total number of taxa below the mill is often greater than that observed upstream of the mill.

This lack of a demonstrable shift in community structure is consistent with the findings of Scrimgeour *et al.* (1995) who also analyzed benthic community structure data from the Hinton area but employed different (i.e., clustering) techniques. Other workers have found higher macroinvertebrates densities (Sentar Consultants Ltd. 1993) and larger individuals (Podemski and Culp 1995) in the area immediately below the mill. These findings suggest that nutrients contained in the pulp mill effluent serve to increase primary productivity downstream of the mill and in turn, have pronounced affects on the macroinvertebrate taxa found there. Thus, while effluent from the Weldwood mill certainly has an effect on benthic macroinvertebrates, these effects act primarily at the level of the individual (i.e., body size) and with respect to overall macroinvertebrate densities and do not produces significant and consistent changes in overall community structure.

The preceding discussion should not be interpreted as an argument against the use of benthic community structure measures in these basins. The fact that the multivariate analyses used in this report fail to separate consistently impact from reference sites does not imply that these techniques are incapable of detecting shifts but rather, given the available data, that there were no consistent shifts to detect. Indeed, while the ability of these multivariate techniques to detect major shifts in community structure and/or changes in overall abundance is adequate their ability to detect more subtle changes is constrained by the numbers of sites available for analysis. Alternative multivariate techniques (e.g., canonical correspondence analysis) are capable of directly and quantitatively relating benthic community structure to environmental data and provide much more insight than do measures of community structure alone.

Future studies that choose to collect detailed and quantified information on environmental variables from the same location at which benthic collections are made will possess a biomonitoring tool that is both more powerful and more cost-effective (i.e., provide a greater return of information for time and money invested). It is also important to note that while overall community structure may not respond in a consistent manner to effluent from the Weldwood mill certain components within that community may be very sensitive and would constitute an excellent indicator of pulp mill effects. Thus measuring relative abundance of selected taxa (another community-level measure) may ultimately provide more insight into changes in these communities than would an analysis of overall community structure alone.

The general arguments given in this section apply to all areas within these basins. The reader is therefore asked to be mindful of these arguments when interpreting results described elsewhere in this report.

3.5 ALBERTA NEWSPRINT CORPORATION (ANC) AND MILLAR WESTERN (MW)

3.5.1 Introduction

The Alberta Newsprint Corporation (ANC) and Millar Western (MW) mills both employ a chemi-thermomechanical process (CTMP) and are located on the Athabasca River near Whitecourt. Millar Western began to discharge to the Athabasca in August of 1988, while startup for the ANC mill was August 1990. The master database contains data collected in the area surrounding these mills following the startup of MW and prior to and following the startup of ANC. This data set covers a period from 1987 to 1993 and 12 separate year/season combinations were deemed appropriate for analyses for this report (see Appendix E-2). For the purposes of this report, benthic macroinvertebrate community samples collected from the Athabasca River in the area surrounding the ANC and MW pulp mills were placed into one of five categories: (1) the area upstream of the ANC pulp mill outfall, (2) the area between the ANC outfall and the MW outfall, (3) the area between 0 and 5 km downstream of the MW outfall, (4) the area between 5 and 20 km downstream of the MW outfall, and (4) the area between 20 and 50 km downstream of the MW outfall.

3.5.2 Results and Discussion

The results of multivariate analyses on the benthic invertebrate community structure above and below the ANC and MW mills are provided in Appendix E-2. In general, communities above, between, and below the mills were numerically dominated by chironomids (Orthocladiinae and Chironominae), mayflies (Baetidae, Heptageniidae and Ephemerellidae) and oligochaetes (Naididae and Tubificidae). Interestingly, certain groups of stonefilies (Capniidae and Taeniopterygidae) were also numerically abundant in autumn samples but not in spring or summer samples. These stonefly taxa emerge early in the spring (soon after ice-off and probably prior to spring collections) and were thus absent from samples taken during those seasons. As was the case with samples from the Hinton area, observed differences among sites were generally a function of changes in relative numbers of taxa rather than a result of the disappearance or addition of specific taxa (see master database).

The analyses presented in Appendix E-2 can be divided into two periods, (1) the period prior to the startup of ANC (1987-1990), and (2) the period following the startup (1990-1993). These periods will be considered separately below.

Six separate year/season data sets were available from the period prior to the startup of ANC. However, in the PCA for the autumn of 1989 the first two axes explained only one third of the total variation in community structure. Because of this low explanatory power, results of the PCA for this period will not be considered further.

Among the remaining analyses, several important trends are apparent. (1) First, reference sites were plotted close to one another in ordination space, suggesting little variation among communities sampled in this reach. (2) Second, reference sites were not consistently separated from impact sites in ordination space, indicating that overall community structure does not differ significantly between reference and impact sites. (3) Third, the variance among sites immediately downstream (0 - 5 km downstream) of the mill was greater than that observed in other reaches.

The observed increase in variance among sites immediately downstream of the mill was similar to the pattern observed below the Weldwood mill however, in that case there was evidence to suggest that the increase in variation was a consequence of incomplete mixing of effluent across the river. Incomplete mixing of effluent may also be responsible for the increased variance in community structure seen immediately below MW and this mixing pattern could be further complicated by the confluence of the Athabasca and McLeod rivers which is located immediately upstream of MW. Increased variance in community structure within this reach resulting from increased exposure to effluent is also possible, but in the absence of a determination of effluent concentrations at the point at which benthic collections were made it is difficult to distinguish among these alternatives.

Following ANC becoming operational in August of 1990, there was little evidence to suggest that benthic community structure at reference sites above ANC were significantly and consistently different from those below the mill. Indeed, in most cases samples from above ANC were closely associated with samples taken between ANC and MW. The only year/season combination in which reference sites were clearly separated from impact sites was in autumn 1993. In that case the separation along the first PCA axis did not appear to be driven by any particular taxa (as determined by eginvector values), rather it was reflective a general increase in macroinvertebrate abundance along the axis. In other words, reference and impact sites were separated as a consequence of a tendency for overall densities to rise from upstream reference sites to downstream impact sites. As was observed in the period prior to the startup of ANC, the reach immediately downstream of MW continued to display the greatest variability in overall community structure. However, as stated above it is difficult to distinguish among competing explanations for this observation.

3.5.3 Conclusions

As was observed in the area surrounding the Weldwood mill at Hinton, the multivariate analyses described here demonstrate significant year to year and between season variation in benthic macroinvertebrate community structure in the reaches upstream of ANC, between ANC and MW, and downstream of MW. However, these same analyses do not serve to separate consistently upstream reference sites from downstream impact sites. Macroinvertebrate communities both above, between and below the mills all tend to be numerically dominated by chironomids, mayflies and oligochaetes (as well as stoneflies in the autumn) and observed differences between sites were most often a function of changes in total density or in the relative numbers of a small number of rare taxa.

The analyses presented here provide no direct evidence to argue that significant and consistent changes in overall benthic community structure occur as a consequence of exposure to pulp mill effluent, nor do they indicate any loss of taxa as a consequence of this exposure. However, as was the case at Hinton, benthic communities are impacted by pulp mill effluent in so far as there appears to be an increase in overall invertebrate density (including rare taxa) below the mill. Changes in individual size as a result of effluent exposure is also a distinct possibility but has not been investigated in this reach.

3.6 SLAVE LAKE PULP CORPORATION (SLPC)

3.6.1 Introduction

The Slave Lake Pulp Corporation (SLPC) mill employs a CTMP process, is located at Slave Lake and discharges to the Lesser Slave River. This mill first began to discharge to the Lesser Slave River in late 1990 and the master database contains data collected in the area surrounding SLPC from the spring of 1989 until the autumn of 1992. Ten separate year/season combinations were deemed appropriate for analyses for this report (see Appendix E-3). For the purposes of this report, benthic macroinvertebrate community samples collected from the Lesser Slave River around SLPC were placed into one of four categories: (1) the area upstream of the SLPC pulp mill outfall, (2) the area between 0 and 5 km downstream of the pulp mill outfall, (3) the area between 5 and 20 km downstream of the pulp mill outfall, and (4) the area between 20 and 50 km downstream of the pulp mill outfall.

3.6.2 Results and Discussion

Results of multivariate analyses measuring changes in benthic invertebrate community structure above and below the SLPC mill are provided in Appendix E-3. The habitat within the Lesser Slave River differs from that of the mainstem of the Athabasca River in so far as it contains more depositional habitat. This habitat difference is reflected in the techniques used to sample the system (primarily Ponar and Hess samplers rather than Neill or Surber samplers) and in the general structure of the benthic macroinvertebrate community. In general, communities above SLPC and those sampled from 0 - 5km downstream of the mill were numerically dominated by chironomids (Orthocladiinae and Chironominae), oligochaetes (Naididae and Tubificidae) and caddisflies (Hydropshchidae and Polycentropodidae). Communities further (i.e. > 6 km) downstream are also comprised of large numbers of individuals of these taxa but in addition, contain significant numbers of mayflies (Baetidae, Heptageniidae and Ephemerellidae), stoneflies

(Perlodidae) and in some cases blackflies (Simuliidae) and generally show higher overall densities of invertebrates (see master database).

The analyses presented in Appendix E-3 show a strong tendency for reference sites to be plotted close to one another in ordination space and for reference sites to be plotted close to sites immediately downstream of the SLPC. There was also a strong tendency for the distance (in ordination space) between reference and impact sites to increase with increasing distance (in river kilometres) between those sites. In other words, benthic macroinvertebrate community structure did not differ greatly among reference sites or between reference sites and sites immediately downstream of the mill. However, the benthic community structure measured at reference sites does differ dramatically from that measured at sites 5 - 50 km downstream of the mill.

This difference between reference/near-field sites and far-field sites is apparent both prior to (1989 - 1990) and following (1991 - 1993) the startup of the mill. More specifically, in the spring of 1989 reference and "near-field" (i.e. between 0 and 5 km downstream of what would be the pulp mill outfall) tended to be separated along the first PCA axis. This axis reflected an increase in overall density along its length and in particular, an increase in relative numbers of several mayfly and caddisfly taxa. In the autumn of 1989 a similar trend is apparent along the first PCA axis and is reflective of increases of total abundance in general and of certain mayfly, caddisfly and stonefly taxa in particular. In both the spring and autumn of 1990, reference sites were plotted close to one another and to near-field sites. However, reference sites could not be as clearly distinguished from far-field sites as in the previous year. In the years 1990 - 1993, and regardless of season, reference sites could be clearly distinguished from far-field impact sites along the first PCA axis. As was the case in 1989, this separation largely reflected changes in overall abundance but only in the spring of 1991 did eigenvectors indicate that increases in specific taxa (stoneflies and mayflies) were particularly important in the observed shift in benthic community structure.

3.6.3 Conclusions

As has been noted for mills along the Athabasca, PCA of benthic community structure based on collections from above and below SLPC demonstrate significant year to year and between season variation. However, these analyses also suggest that while the benthic community sampled at upstream reference sites did not differ significantly from one another or from those sampled immediately below the mill, both reference and near-field sites differ dramatically from those sampled further downstream. This difference was primarily a result of increases in overall density and was, in some year/season combinations, also reflective of particularly strong increases in the relative abundance of selected taxa (e.g., Baetidae, Heptageniidae, Ephemerellidae, Perlodidae, and/or Simuliidae.

The data presented here provide no direct, quantitative, evidence to argue that significant and consistent changes in overall macroinvertebrate community structure occur at near-field sites as a consequence of exposure to pulp mill effluent. Nor do these results indicate any loss of taxa as a consequence of this exposure. Although differences in community structure between reference and impact sites increased as distance between those sites increased it is not clear if these differences are attributable to pulp mill activities. First, differences in benthic community structure of this type were apparent even before the startup of the SLPC mill. Second, differences between reference and impact site community structure increased as effluent concentration decreased (i.e., the further downstream, the more dilute the effluent would be) suggesting that the observed shifts in benthic macroinvertebrate community structure may be more a function of natural variability in habitat than a consequence of pulp mill effluent exposure. Any future studies that choose to collect environmental data at the same time and from the same location at which benthic community structure will be measured would be in a much stronger position to determine the underlying cause(s) of the observed shifts in benthic macroinvertebrate community structure. The database constructed for this project may suggest that the observed differences result from habitat changes but unfortunately, the database cannot, by itself, be used to address directly this question.

3.7 ALBERTA PACIFIC CORPORATION (ALPAC)

3.7.1 Introduction

The Alberta Pacific Corporation (ALPAC) mill employs a Kraft-type process and began full operation in September of 1993. The master database contains data collected in the area surrounding the ALPAC mill but only from the period prior to startup (i.e. 1991 -1992). While this data cannot be used to assess directly the impact of pulp mill effluent from ALPAC on downstream benthic community structure it provides important background data and a basis for pre- and post-startup comparisons. For the purposes of this report, benthic macroinvertebrate community samples collected from the Athabasca River around APLAC were placed into one of five categories: (1) the area upstream of the ALPAC pulp mill outfall, (2) the area between 0 and 5 km downstream of the pulp mill outfall, (3) the area between 5 and 20 km downstream of the pulp mill outfall, (4) the area between 20 and 50 km downstream of the pulp mill outfall and (5) the area more than 50 km downstream of the pulp mill outfall.

3.7.2 Results and Discussion

Results of multivariate analyses on benthic macroinvertebrate community structure above and below the ALPAC mill site are provided in Appendix E-4. All communities above and below the ALPAC site were numerically dominated by chironomids (Orthocladiinae and Chironominae), mayflies (Baetidae, Heptageniidae) and caddisflies (Hydropsychidae). In addition, oligochaetes (Naididae and Tubificidae) were numerically abundant in the spring of 1991 and in both the 1992 samples. As was observed in the Whitecourt area, stoneflies (Perlodidae, Nemouridae) were abundant in autumn samples but early spring emergence explains their reduced numbers in spring samples (see master data base).

The analyses presented in Appendix E-4 show considerable variation in overall community structure among different sites. However, in contrast to other areas sampled within these basins, there is no obvious tendancy for samples within a reach to be plotted near one another in ordination space. In the area of the SLPC mill for example, there was an obvious downstream change in the plotted location of sampling locations, however, no such pattern is apparent in the Athabasca River near ANC. Nor, as was observed at other mills, was there any strong tendency for sampling location sites downstream of the mill to show consistently higher overall abundances relative to reference sites. At other locations, downstream increase in total abundance are thought to result from exposure to effluent but, as illustrated by the pre-startup data from SLPC, such a pattern can also occur naturally.

3.7.3 Conclusions

The fact that benthic community structure measured at reference sites does not consistently and predictably differ from that observed at what were to become impact sites suggests an absence of major habitat differences between the two site categories and indicates that the chosen reference sites are adequate for monitoring the effect of pulp mill effluent on the downstream benthic community, particulary at near-field sites.

The significant variability in community structure observed among the ALPAC sites, even prior to startup, illustrates the extent and importance of natural variation in these systems. Following startup, observed differences among sites may well be a consequence of effluent exposure but could also result from natural or stochastic variation. To return to a now tiresome theme, collection of adequate environmental data will better allow researchers and managers to distinguish among these sources of variation.

It is also important to note that while it is extremely useful to possess data from the period prior to the mill startup it is also necessary to recognize the potential limitations of any such data. In the current scenario, two years worth of data prior to the mill startup serve to provide valuable insight into what post-startup patterns should resemble. However, it would be dangerous in the extreme to assume that these two years worth of data adequately captured the extent of natural variation at what were to become the downstream impact sites. In other words, any future deviation (relative to what was observed in 1991 and 1992) in benthic macroinvertebrate community structure at these impact sites cannot *a priori* be construed as proof of pulp mill effluent impact.

3.8 PROCTER GAMBLE/WEYERHAEUSER (PG)

3.8.1 Introduction

The Proctor Gamble/Weyerhaeuser (hereafter, Weyerhaeuser) mill employs a Kraft-type process and began discharging to the Wapiti River in 1973. The master database contains data collected above and below the Weyerhaeuser mill, and covers the period from the summer of 1974 until the autumn of 1992. A total of twelve year/season combinations of data were deemed appropriate for PCA and the results of these analyses are presented in Appendix E-5.

Any analysis of the effects of the Weyerhaeuser mill on the downstream benthic community will be complicated by the presence of the town of Grande Prairie, which is located upstream of the Weyerhaeuser mill. In 1987, the Grand Prairie Sewage Treatment Plant began to discharge treated city sewage effluent to the Wapiti River. The outfall from the city sewage plant is located 6 km upstream of the Weyerhaeuser mill and has the potential to impact downstream benthic communities. For these reasons, benthic macroinvertebrate community samples collected from the Wapiti River around the vicinity of the Weyerhaeuser mill were placed into one of five categories: (1) the area upstream of the Grande Prairie Sewage Treatment Plant, (2) the area between the Grande Prairie Sewage Treatment Plant and the Weyerhaeuser pulp mill outfall, (3) the area between 0 and 5 km downstream of the Weyerhaeuser pulp mill outfall, (4) the area between 5 and 20 km downstream of the Weyerhaeuser pulp mill outfall and, (5) the area between 20 and 50 km downstream of the Weyerhaeuser pulp mill outfall.

3.8.2 Results and Discussion

Results of multivariate analyses on benthic invertebrate community structure above and below the Weyerhaeuser mill are provided in Appendix E-5. One striking difference in benthic community structure exists between samples collected near the Weyerhaeuser mill and those collected from the Athabasca River and this difference relates to the dominance of chironomids. Although chironomids tend to dominate numerically the benthic community in both rivers, the extent of that numerical domination is much greater in the Wapiti River both upstream and downstream of the Weyerhaeuser mill. Regardless of season or year, there was a strong tendency for chironomids (Tanypodinae, Orthocladinae and Chironominae) to dominate the benthic community at sites covering an area from above Grande Prairie to points more than 50 km downstream of the Weyerhaeuser mill. In some samples and in some year/season combinations as much as 50-80% of all animals collected were chironomids.

Other taxa that were at times numerically abundant in the Wapiti River included stoneflies (Taeniopterygidae and Perlodidae), mayflies (Baetidae, Heptageniidae and Ephemerellidae) and caddisflies (Hydropsychidae). Oligochaetes (Naididae) were never common at reference sites or near-field sites but were numerically abundant at sites > 10 km downstream of the Weyerhaeuser mill (see master database).

An examination of the data collected in the Weyerhaeuser area also reveals a considerable change in overall macroinvertebrate abundance/density over time, even at reference sites. Total densities in *reference* samples in the period from 1974 to 1980 averages only 114 individuals per m^2 whereas average densities at *reference* sites following 1980 was 3662 individuals per m^2. Unfortunately, the reasons for this thirty-fold difference between reference sites are not clear. Samples from the earlier period did sometimes involve the use of artificial substrate samplers, which, as discussed above may not accurately measure community structure. Samples from the earlier period were also taken during the summer period. In these basins, and independent of location, measured invertebrate densities tend to be highest in spring and autumn and this is the most likely explanation for differences in density observed here. For these reasons, and because multivariate analyses on total densities as low as 17 individuals/m^2 are untrustworthy, only analyses following 1980 will be discussed here. PCA results from 1974 - 1980 are, however, presented in Appendix E-5.

Results of multivariate analyses on the remaining eight year/season combinations indicate that measures of benthic community structure taken at various points in the Wapiti River differ primarily in terms of total abundance and that both the first and second PCA axes reflect increases in total density in general and in chironomids and oligochaetes in particular. There is a marked tendency for reference sites to be plotted close to one another in ordination space and near the origin of the figure, suggesting that overall densities tend to be lowest at these sites. In general, reference sites also tend to be plotted close to those between the Grande Prairie Sewage Treatment Plant and the Weyerhaeuser mills, indicating a minimal effect of the sewage plant.

Interestingly, sites immediately (0 - 5 km) downstream of the Weyerhaeuser mill were seldom plotted near sites above the mill (autumn 1992 provides an exception) and typically show higher total abundance and greater variability in community structure than all other sites sampled. This pattern suggests an effect of pulp mill effluent on benthic community structure in the near-field sites and that this effect is primarily reflected by an increase in total abundance of macroinvertebrates. Sites from 5 - 20 km below Weyerhaeuser tended to be plotted closer to reference sites than did near-field sites, suggesting that any effect of effluent is most strongly felt at the near-field sites and begins to diminish at sites further downstream.

3.8.3 Conclusions

Analyses of benthic community structure in the Wapiti River, from above Grande Prairie to a point approximately 50 km downstream of the Weyerhaeuser mill, reveal chironomid dominated communities that display significant temporal and spatial variation. In this sense the results agree with what was observed in the Athabasca and Lesser Slave rivers, however, benthic communities in the Wapiti River are dominated by chironomids to a much greater extent than was observed in the other rivers.

Results also suggest the community structure at sites between the Grande Prairie Sewage Treatment Plant and the Weyerhaeuser mill did not differ significantly from that observed at reference sites. In contrast, sites immediately below the Weyerhaeuser differ from reference sites in that they display higher total abundance in general, and higher abundances of chironomids and oligochaetes in particular. The observed shift in community structure did not result in the loss of any taxa. Sites at intermediate (5 - 20 km) distances below the mill tend to more closely resemble sites above the mill, suggesting the effect at near-field sites may diminish at sites further downstream. It is also important to note that the Wapiti River may well experience a natural increase in invertebrate numbers from upstream to downstream sites. The effect of any such natural trend would have to be understood better before the precise effects of the Weyerhaeuser mill could be identified.

3.9 PEACE RIVER PULP COMPANY (DAISHOWA)

3.9.1 Introduction

The Peace River Pulp Company (Daishowa) employs a Kraft-type process and began discharging to the Peace River in July 1990. The master database contains data collected in the Peace River above and below the Daishowa mill and covers a period both prior to (summer 1988 - spring 1990) and following (autumn 1991 - autumn 1992) the mill startup. A total of nine year/season combinations of data were deemed appropriate for PCA and the results of these analyses are presented in Appendix E-6. For the purposes of this report benthic macroinvertebrate community samples collected from the Peace River in the vicinity of the Daishowa mill were placed into one of five categories: (1) the area upstream of the Daishowa pulp mill effluent, (2) the area between 0 and 5 km downstream of the Daishowa pulp mill outfall, (3) the area between 5 and 20 km downstream of the Daishowa pulp mill outfall, (4) the area between 20 and 50 km downstream of the Daishowa pulp mill outfall, and (5) the area more than 50 km downstream of the Daishowa pulp mill outfall.

3.9.2 Results and Discussions

Results of multivariate analyses on benthic macroinvertebrate community structure above and below the Daishowa mill are provided in Appendix E-6. These analyses can be divided into two temporal groups: (1) samples from the summer and autumn of 1988, and (2) samples taken between the summer of 1989 and the autumn of 1992. The first set of samples employed a Neill sampler, included samples obtained in the area immediately downstream (0 - 5 km) of what was to become the outfall for the pulp mill and measured average macroinvertebrates densities typical of these rivers (i.e. 2200 individuals per m^2 for summer samples and 12000 individuals per m^2 for autumn samples). In contrast, later collections employed a Hess sampler, with the exception of the 1989 summer sample did not include data from the near-field area below the mill, and measured extremely low densities at both reference and impact sites.

Indeed, the one set of summer samples averaged a density of 12.5 individuals per m^2 while other year/season combinations from autumn and spring gave average densities of between 67 and 136 individuals per m^2. These densities are based (as are all densities) on a conversion from the numbers of invertebrates collected in the sampler to a measure of the number of individuals in a square meter. In the case of the Hess sampler the conversion factor is ten; in other words the post-1988 samples averaged only 2 to 14 animals per sample. Clearly it would be unwise to comment on community structure when community measures are so low (and hence so imprecise). For these reasons the results of PCA for these sites are given in Appendix E-6 but they are not, and should not, be considered representative of conditions in this area.

Of particular concern is the fact that the 100 to 1000 fold decrease in measured densities in the Daishowa area occurred prior to the start up of the mill, coincided with a change in technique and sampling agency, and involved an elimination of near-field sites, an essential component in any effective monitoring program. As a consequence, the data available from the Peace River in the area of the Daishowa mill is not adequate to assess the impact of effluent from that mill on the downstream benthic community.

4.0 BIOMONITORING USING BENTHIC MACROINVERTEBRATE COMMUNITY STRUCTURE DATA

4.1 INTRODUCTION

As the extent and complexity of anthropogenic impact on the environment increases so does the need to develop effective management criteria that can be used to maintain current levels of ecosystem structure and function and, where necessary and possible, take remedial action in those systems deemed to have been unacceptably impacted. Essential to the establishment of effective management criteria is the need to develop biomonitoring tools that provide environmental managers with information in a timely and cost-effective manner. On a global scale, benthic macroinvertebrates have been used more than any other single group of organisms in the assessment of general water quality and particular anthropogenic impacts (Resh *et al.* 1995). Benthic macroinvertebrates are also known to be among the most sensitive and cost-effective biomonitoring tools available. This approach clearly holds great promise for environmental monitoring within the northern river basins.

In addition to the many inherent advantages of using benthic macroinvertebrates in environmental assessment (described in Section 3.1 of this report), there is an added advantage in that experience gained in other systems, and in attempts to solve other problems, can be employed within the northern river basins. However, while techniques developed for other ecosystems will almost certainly have relevance for the northern river basins they will also almost certainly require modification or refinement before they will be useful in assessing the condition of these unique systems. While it is tempting simply to apply procedures developed in other areas to issues within these ecosystems, there are three vital considerations that must be addressed prior to any such application.

First, the northern river basins constitute a unique system with a unique ecology and unique issues. The general ecology (structure and function) of the ecosystem, independent of any anthropogenic activities acting upon it, will largely serve to determine the types of biomonitoring techniques that should be employed. For example, in the case of the northern river basins, the objective is to assess and maintain ecological condition in large, oligotrophic (nutrient poor), northern rivers that may be ice-covered for significant portions of the year. This information suggests, *a priori*, that issues such as extreme eutrophication (surplus of nutrients) is unlikely to be the problem in these basins that it is in other lakes and river systems. Conversely, low dissolved oxygen levels may be common under full ice cover, may be exacerbated by anthropogenic activity, or may act synergistically with other stresses to impact the ecosystem. Similarly, there may be key components of the ecosystem or benthic community of particular importance to overall system function, or which are particularly sensitive to anthropogenic stress. Knowledge of any such components would provide insight into the development of appropriate bioindicators. Unfortunately, as discussed above and by Cash (1995), there are several major gaps in our understanding of large, norther river ecosystems in general, and of these systems in particular.

The second consideration relates to the evaluation of potential biomonitoring tools in relation to the scale of the ecosystem being managed. For example, the use of fish community indices have been vigorously promoted as an ideal biomonitoring tool (Karr 1991, 1992; Dionne and Karr 1992; Fore *et al.* 1994; Kerans and Karr 1994). Whatever the strengths or shortcomings of this approach it is one clearly developed for small streams and rivers (and potentially, lakes) and unlikely to be of utility in these basins. Indeed, as discussed above (Section 2.2), accurately defining, measuring and sampling fish communities within these basins presents considerable logistic and financial difficulties. To include such procedures as a part of a routine monitoring program, would be far beyond the scope of any realistic monitoring program for these basins. Similarly, approaches such as the UK, **R**iver **InV**ertebrate **P**rediction **A**nd **C**lassification **S**ystem (RIVPACS) program (Wright *et al.* 1984, 1988; Wright 1995) provide considerable detail on both environmental parameters and biological structure; however, the frequency and intensity of sampling employed by RIVPACS (see below) cannot be reasonably duplicated in an area as large and as sparsely populated as the northern river basins.

The final consideration relates to the concerns of the public in general, and those living in the basins, in particular. More specifically, the public must be involved in the establishment of ecosystem goals and in the identification of tools that can address those goals (Wrona and Cash in press). The development of specific ecosystem goals and objectives is essential to the development of an effective biomonitoring program because it provides a framework within which the monitoring program itself would develop. It also represents a process by which the public (informed by the best available scientific knowledge) determines the nature of the world in which they want to live.

Clearly, this is a societal decision and not a scientific issue. Science plays a role in refining general goals and in developing specific monitoring objectives that will help satisfy those goals, but the goals themselves must first be determined by society. Any biomonitoring program developed solely on scientific priorities could prove unpopular with the public at large and would be very unlikely to receive legislative approval and support. It is also clear that societal priorities will vary from place to place (and possibly over time) and must be accounted for in the selection and implementation of specific biomonitoring tools.

The preceding discussion will hopefully illustrate that differences in general and specific ecologies, spatial scales of relevance, and public priorities necessitate an ecosystem-specific approach to the selection of biomonitoring tools. Given that this is the case, it is unlikely that any generic or "off the shelf" biomonitoring tools will adequately address the unique ecology and concerns found within the northern river basins. This should not be interpreted as an argument in favour of developing new biomonitoring techniques for each ecosystem, rather we argue that available techniques should be closely examined and, where necessary and appropriate, be modified prior to their application within these basins. A corollary to this argument is the need for any effective monitoring program to include a research component to develop and refine biomonitoring tools and to test, using rigorously designed experiments, hypotheses generated from biomonitoring observations. Biomonitoring tools may indicate environmental changes but only properly designed experiments can test hypotheses as to the underlying causal mechanisms responsible for those observations.

In the following sections currently popular biomonitoring techniques that employ measures of benthic macroinvertebrate community structure will be briefly outlined and their applicability to the northern river basins examined. This section will be followed by recommendations as to how measures of benthic macroinvertebrate community structure might be best incorporated into a monitoring program within the northern river basins.

4.2 GENERAL APPROACHES

Historically, a variety of biomonitoring techniques employing benthic macroinvertebrate community structure have been employed in Europe and North America. Several of these approaches, including the use of saprobic indices (Cairns and Pratt 1993; Metcalfe-Smith 1994; Cash 1995), and a reliance on diversity indices (Green 1979; Norris and Georges 1993), have been increasingly criticized in recent years and are no longer commonly employed in monitoring programs. Other approaches, such as the use of community comparison indices (Resh and

Jackson 1993) hold promise but are of little immediate and practical utility (Reynoldson and Metcalfe-Smith 1992).

Currently, biomonitoring approaches that make use of benthic macroinvertebrate community structure can be roughly divided into two groups (Resh *et al.* 1995). The first of these takes a more qualitative approach to biomonitoring, was largely developed in the USA, and is exemplified by the US EPA's Rapid Bioassessment Protocols (Plafkin *et al.* 1989). The second general approach is far more quantitative, relies on the use of multivariate statistical techniques, was largely developed in Britain, and is exemplified by the UK's RIVPACS program (Wright *et al.* 1984, 1988; Wright 1995) and by the BEAST approach as employed in the Great Lakes region (Reynoldson *et al.* 1995).

4.3 RAPID BIOASSESSMENT

The rapid bioassessment approach to biomonitoring is characterized by a more qualitative approach to the assessment of environmental condition and relies on a series of individual measures or metrics that are eventually summarized in a single score or index. This score serves to categorize sites as to pollution level (usually into one of three or four levels) and provide easily understood monitoring results to nonspecialists, including managers and members of the general public (Norris and Norris 1995).

As the name suggests, a major objective of the rapid bioassessment approach is to provide useful information in a timely and cost effective manner (Resh *et al.* 1995). This is accomplished by: (1) reducing the number of habitats sampled and by reducing (or pooling) the number of replicates taken within each habitat; (2) eliminating measures of absolute density, thus allowing for the use of easier to use, more rapid sampling techniques such as kick nets; (3) enumerating some subset of the animals collected rather than the entire sample; (4) employing the coarsest taxonomic resolution (i.e. family level or higher) that satisfies the program objectives (Resh and Jackson 1993).

The rapid bioassessment approach has been most fully developed by the US EPA (Plafkin *et al.* 1989) and is now the primary biomonitoring tool used in many American states for environmental assessment in streams and rivers. This approach relies on the identification of potential impact and reference sites followed by detailed habitat characterization of both sites. This characterization recognizes the importance of habitat characteristics in determining benthic community structure and helps to "tease" apart natural and anthropogenically induced variation in benthic community structure. Once habitat characterization is complete a variety of measures or metrics (usually eight) are taken on the benthic macroinvertebrate community at both reference and study (impact sites). Scores are then determined based on the ratio values of the metrics from study and reference sites and these scores are categorized into one of three or four levels of "biological condition". These categories of "biological condition" include (1) unimpaired, (2) slightly impaired, (3) moderately impaired, and (4) severely impaired, and serve as the basis for a management decision to intervene in the system.

This approach has the advantage of being relatively rapid (i.e. usually capable of providing information on the order of weeks), inexpensive (i.e. requires little time or training to sample or sort invertebrates) and provides managers with simple, readily understood measures of the environment (i.e. "biological condition"). However, the use of ratios and indices are integral to this approach and have been severely criticized by a number of researchers. Of particular concern is the fact that the use of some ratios and indices may provide little biological insight and are often not amenable to statistical investigation (Green 1979; Norris and Georges 1993). Despite these limitations, use of rapid bioassessment techniques has been shown to be a valuable monitoring tool in a variety of locations and is particularly valuable in initial screening of habitat and in the identification of potential "trouble spots" that warrant further, more detailed, consideration (Resh *et al.* 1995).

Obviously the efficacy of any rapid biomonitoring approach will depend largely on the specific metrics chosen. In a review of the subject Resh *et al.* (1995) provide a partial list of metrics employed in rapid bioassessment protocols. The list contains 65 separate entries which were classified into six different categories: (1) *Richness measures* include measures such as the total number of taxa, the number of Ephemeroptera, Plecoptera and Trichoptera (EPT), or counts of other taxa such as Chironomidae or Mollusca. (2) *Enumerations* refers to the total number of individuals present in the sample or to the percentage of individuals belonging to specific taxa or groups of taxa (e.g., EPT, Chironomidae, non-dipterans etc.). (3) *Community diversity and similarity* measures include Shannon's Index, Coefficient of Community Loss and Jaccard Coefficient (see Resh *et al.* 1995 for specific references). (4) *Biotic indices* such as the Belgian Biotic Index and the BMWP Score (see Cash 1995 for a discussion). (5) *Functional measures* including, %shredders, %scrapers, ratio of scrapers/collector-filterers (see Cummins 1988). (6) *combination indices* such as the Benthic Index of Biotic Integrity, or the B-IBI (Karr 1992; Kerans and Karr 1994).

In order to test the potential utility of the rapid assessment approach for the northern rivers basin we applied different metrics to benthic community structure data collected in the Hinton area of the Athabasca River. More specifically, we chose to apply three of the four metrics identified by Resh *et al.* (1995) as being the most useful and the logical candidates to employ in any new monitoring program. These metrics include: (1) taxa richness, (2) EPT index, and (3) ratio of scraper/grazers and filter/collector functional feeding groups. These metrics are discussed in detail below.

4.3.1 Taxa Richness

Taxa richness is simply the ratio of the number of taxa present at the impact site and reference site multiplied by 100. In this and subsequent examples, numbers of taxa within a given reach are based on the mean number of taxa calculated from the different samples collected within that reach. For example, the number of taxa present in the area 0 - 5 km downstream of the Weldwood mill in a particular is considered to be the average number of taxa present in all samples collected within that reach in that year and season.

According to the EPA protocol (Plafkin *et al.* 1989) a site can be considered unimpaired if the calculated Taxa Richness for that site is greater than 80%. As can be seen from the results presented in Table 1. Taxa Richness exceeded 80% in every year, season and downstream reach sampled. In fact, in 29 of the 36 cases displayed (80.5%) calculated Taxa Richness exceeded 100% indicating greater taxa richness downstream of the Weldwood mill relative to reference sites. Unfortunately, the EPA protocol does not account for Taxa Richness values that exceed 100%, largely because this metric was designed to be sensitive to losses rather than increases in taxa. The implications of this assumption for the northern rivers basins will be discussed in more detail below.

Table 1. Calculation of Taxa Richness Metric (Plafkin *et al.* 1989) for Reaches Below the Weldwood Mill at Hinton Alberta. Samples collected by Neill Cylinder only.

Year	Season	Collector	<5 km d/s	5-20 km d/s	>20 km d/s
1983	spring	AEP	122%	---	---
1983	autumn	AEP	93%	---	---
1984	spring	AEP	113%	---	107%
1984	spring	IES	105%	113%	100%
1985	spring	AEP	107%		100%
1985	autumn	AEP	102%	91%	106%
1986	spring	AEP	107%	---	---
1986	spring	IES	107%	114%	101%
1986	autumn	AEP	118%	---	---
1987	spring	AEP	113%	---	---
1987	autumn	AEP	96%	---	---
1989	spring	TAEM	120%	93%	93%
1990	autumn	TAEM	101%	95%	110%
1991	spring	TAEM	107%	119%	110%
1992	spring	RL&L	146%	---	150%
1992	spring	TAEM	117%	127%	117%
1992	autumn	TAEM	94%	107%	131%

AEP - Alberta Environmental Protection
IES - Integrated Environmental Services
TAEM - Terrestrial & Aquatic Environmental Managers
RL&L - R.L. & L. Environmental Services

4.3.2 EPT Index

The EPT index is similar to Total Richness in that it is based on the ratio of these taxa observed at impact sites and reference sites multiplied by 100. Taxa belonging to the EPT groups are considered "pollution intolerant", thus any reduction in their numbers at presumed impact sites could be considered as evidence of impairment. According to the EPA protocol (Plafkin *et al.* 1989) a potential impact site can be considered unimpaired if the calculated EPT index for that site is greater than 90%. The metric values for EPT indices based on benthic collections made in the area surrounding the Weldwood mill are given in Table 2. As can be seen from the results, calculated EPT indices exceeded 90% in every year season and downstream reach sampled. In fact, in 26 of the 37 cases displayed (72.2%) calculated EPT indices exceeded 100%, and in two cases exceeded 200%. These results suggest an increase in EPT taxa at downstream impact sites relative to upstream reference sites and are consistent with the results for measures of Total Richness.

Table 2. Calculation of EPT Index Metric (Plafkin *et.al.* 1989) for Reaches Below the Weldwood Mill at Hinton Alberta. Samples collected by Neill Cylinder only.

Year	Season	Collector	<5 km d/s	5-20 km d/s	>20 km d/s
1983	spring	AEP	233%	---	---
1983	autumn	AEP	113%	---	---
1984	spring	AEP	113%	---	77%
1984	spring	IES	113%	94%	113%
1985	spring	AEP	120%	---	113%
1985	autumn	AEP	102%	86%	81%
1986	spring	AEP	129%	---	---
1986	spring	IES	114%	132%	84%
1986	autumn	AEP	169%	---	---
1987	spring	AEP	173%	---	---
1987	autumn	AEP	125%	---	---
1989	spring	TAEM	113%	109%	82%
1990	autumn	TAEM	109%	105%	99%
1991	spring	TAEM	107%	132%	104%
1992	spring	RL&L	222%	---	194%
1992	spring	TAEM	123%	117%	99%
1992	autumn	TAEM	96%	96%	98%

AEP - Alberta Environmental Protection
IES - Integrated Environmental Services
TAEM - Terrestrial & Aquatic Environmental Managers
RL&L - R.L. & L. Environmental Services

4.3.3 Ratio of Scraper/Grazers and Filter/Collector Functional Feeding Groups

The use of this metric is based on the functional feeding group (Merritt and Cummins 1984) approach to aquatic biomonitoring and combines the River Continuum Concept with a knowledge of food acquisition techniques and/or mouthpart morphology of benthic macroinvertebrates. It then makes use of this information to generate predictions as to the presence/absence and distribution of different functional feeding groups within a site. This approach is based on the assumption that as pollution levels change within a site so does the distribution of functional feeding groups. For example, an undisturbed site typified by autotrophically-driven processes might have relatively large numbers of individuals or taxa belonging to the scraper feeding group and relatively few that belong to collector-filterer or gatherer functional groups. As organic pollution levels increase this trend is reversed and the community would be increasingly dominated by collector-filters and gatherers.

In this case, the relative numbers of scrapers is thought to provide information on the periphyton community (scrapers increase with increasing diatoms and decrease with increasing filamentous algae). Alternatively, filterers will increase with increasing filamentous algae and aquatic moss and are sensitive to toxicants bound to small particles. According to the EPA protocol (Plafkin *et al.* 1989) a site can be considered unimpaired if the calculated ratio of scraper/grazers and filter/collector functional feeding groups at impact and reference sites is greater than 50%, slightly impaired at values between 35% and 50%, moderately impaired at values between 20% and 35%, and severely impaired at values less than 20%. The metric values for the ratios of these functional groups, based on benthic collections made in the area surrounding the Weldwood mill are given in Table 3. Of the 34 separate analyses presented in Table 3, 29 (85.3%) suggest downstream sites are completely unimpaired, 3 (8.9%) suggest downstream sites are slightly impaired, 1 (2.9%) suggests moderate impairment and 1 (2.9%) suggests severe impairment. Values downstream of the Weldwood mill varied from 18% to 2454% and within a site (i.e. < 5 km d/s) range from 18% to 690%.

In other words, these results indicate that at the same location, over a period of five years, the system varied in metric values from a value fifty times greater than required to be judged unimpaired (spring 1986), to one that indicated severe impairment (spring 1989), and then rebounded to a value double that required to be judged unimpaired (spring 1991, Table 3). The extreme variation and inconsistency in metric values for this ratio indicate that knowledge of scraper/filterer ratios at reference and impact sites is unlikely to provide utility in assessing environmental conditions in this region of the Athabasca River.

Table 3. Calculation of Ratio of Scraper/Grazers and Filterer/Collector Functional Feeding Groups Metric (Plafkin *et.al.* 1989) for Reaches Below the Weldwood Mill at Hinton Alberta. Samples collected by Neill Cylinder only.

Year	Season	Collector	<5 km d/s	5-20 km d/s	>20 km d/s
1983	spring	AEP	47%	---	---
1983	autumn	AEP	35%	---	---
1984	spring	AEP	385%	---	404%
1984	spring	IES	42%	86%	61%
1985	spring	AEP	31%	684%	---
1985	autumn	AEP	109%	121%	220%
1986	spring	AEP	61%	---	---
1986	spring	IES	690%	2290%	2454%
1986	autumn	AEP	52%	---	---
1987	spring	AEP	130%	---	---
1987	autumn	AEP	64%	---	---
1989	spring	TAEM	18%	70%	101%
1990	autumn	TAEM	80%	101%	171%
1991	spring	TAEM	96%	61%	212%
1992	spring	TAEM/RL&L	83%	67%	171%
1992	autumn	TAEM	105%	119%	241%

AEP - Alberta Environmental Protection
IES - Integrated Environmental Services
TAEM - Terrestrial & Aquatic Environmental Managers
RL&L - R.L. & L. Environmental Services

4.3.4 Conclusions

The foregoing discussion and analysis will hopefully demonstrate that the most popular and favoured metrics currently used in rapid bioassessment (Plafkin *et al.* 1989; Resh *et al.* 1995) provide little utility in the assessment of pulp mill effluent effects on downstream benthic communities within these basins. It is true that metric calculations were presented only on data collected from the Hinton area, but other analyses demonstrate similar trends above and below other pulp mills in the basin.

The reason these metrics fail is that they were essentially designed to be sensitive to the loss of taxa at impact sites, particularly those taxa thought to be "pollution intolerant". In the case of the northern river basins one of the primary effects of pulp mill effluent on communities downstream of mills is to provide nutrients to an oligotrophic system. The resulting increase in primary productivity results in increases in invertebrate density. We do not argue that exposure to pulp mill effluent results in the introduction of new taxa. Rather, the most likely explanation is that taxa that were previously rare, and thus unlikely to be found in samples, were able to take advantage of the changes in primary productivity and become sufficiently abundant to be captured in routine sampling programs. The metrics tested here were not designed to measure or address increases in taxa number and thus give the absurd scores illustrated in Tables 1-3. However, these same metrics are known to provide biological insight in other systems that suffer loss of taxa due to organic pollution.

At another level, this bias in the type of metric employed raises an important issue regarding the nature of anthropogenic impacts on ecological systems. An impact can be thought of as any shift in ecological structure (or function) away from the natural state. Ignoring for the moment, the difficulties in defining a "normal state", it is clear that the definition of impact does not contain any element of direction. Thus, to speak of a positive impact is complete nonsense. Ecological shifts that involve additions to, or deletions from, the ecosystem are both impacts. To judge one type of ecological shift as positive and another as negative may conform to societal values or objectives but it must be remembered that, even if adopted by environmental managers, such a view has no basis in science or ecology. It is also important to remember that impacts judged by society as being "positive" (e.g., increases in total invertebrate density) may eventually have negative consequences (e.g., undesired shifts at other trophic levels) and as such, it is probably best to avoid these types of value judgments all together.

Finally, although the specific metrics tested are of little utility we argue that a rapid approach to bioassessment may still be of value within these basins. Before the approach can be of practical value however, a concerted effort must be directed toward identifying key components and processes that should be monitored within these basins as well as the metrics that provide insight into those components and processes. It will also be necessary to develop an improved understanding of the basic ecology and function of these ecosystems and to modify existing rapid bioassessment approaches for use in large northern rivers and at the scale (both spatial and temporal) presented by this ecosystem.

4.4 MULTIVARIATE STATISTICAL APPROACHES

RIVPACS and other similar multivariate techniques are based on the combination of a detailed knowledge of aquatic macroinvertebrate community structure (often expressed as a biotic indices scores) at a given site, with physical and chemical data (i.e., environmental variables) collected from the same location (Furse *et al.* 1984; Wright *et al.* 1984, 1988; Moss *et al.* 1987). Multivariate techniques are then used to determine the relationship between community and environmental data and to make predictions as to the expected structure of the aquatic community at a given site. The resulting model is a robust and powerful indicator of expected community structure and shows very high success (> 70%) in correctly classifying sites among as many as 25 different groupings. This approach is also useful in determining the nature of an expected or "target" community for a given site. Target communities can then serve as goals and indicators of progress in any remediation program.

As with the more qualitative rapid bioassessment approach, multivariate approaches to the study of community composition are sensitive to a wide variety of pollution types and to the combined effects of multiple pollutants. Unlike rapid bioassessment approaches, multivariate approaches can also supply managers with indications of the possible mechanisms responsible for shifts in community structure because they include quantitative measures of biological, environmental, and physicochemical variables. In other words, these models have predictive value. They cannot, by themselves, determine underlying causal mechanisms but they can provide direction as to the most important factors to investigate using experimental techniques.

The strength of these models rests on access to a large database of environmental and community data. RIVPACS for example, currently derives predictions based on a data set comprised of 700 sites from over 80 different rivers with measurements of up to 28 predictor variables from each site (Wright 1995).

Obviously such a database is not currently available for the Slave, Peace, and Athabasca river basins. Nor has there been any consistent attempt to simultaneously collect the required macroinvertebrate and environmental data to run such a model within these basins. Indeed, the creation of such a database would represent a considerable (and, in all likelihood, prohibitive) investment of time, effort and expense. In addition, the accuracy of the model will decrease when it encounters environmental values outside the range present in its database. This suggests that the information base dealing with expected community structure is not directly transferable from one site to another. In other words, data collected as part of similar programs conducted in other regions may be of little direct value within the northern river basins.

There are however, several advantages associated with taking the trouble to develop such a database: (1) The resulting model of community composition is a robust and powerful indicator of expected community structure. The model is sensitive to all types of perturbation and contains explicit information on the effects of changing environmental variables on aquatic community structure. (2) Because different biomonitoring techniques typically require similar types of data, a database established for multivariate analysis of community structure could also be interpreted in light of other biomonitoring applications. This would allow managers to pick and choose from among available biomonitoring techniques to select the one that best fills their immediate objectives. (3) An information-rich database of this type would also better accommodate advances in biomonitoring research and technique refinement as the required data would most likely already be collected and available. (4) The establishment of such a database would make a significant contribution to the understanding of the basic ecology of the system (section 2). (5) Although initially developed to measure aquatic macroinvertebrate community structure there is no reason the same techniques could not be successfully applied to other communities such as the algal community or to riparian vegetation.

The establishment of such a database would also fulfil one of the major objectives of the NRBS, namely to "provide baseline information with regard to the Peace, Athabasca and Slave river basins, both to establish current contaminant levels within the aquatic environment and to develop a baseline for future comparisons" (NRBS 1994) and thus directly address concerns identified by stakeholders.

The BEAST approach (Zarull and Reynoldson 1992; Reynoldson and Zarull 1993; Reynoldson *et al.* 1994) has been developed for use in the Great Lakes region and makes use of an approach essentially similar to that employed by RIVPACS but with several minor modifications in the collection and analysis of data and in the use of important additional procedures involving sediment toxicological testing. Within BEAST, patterns in macroinvertebrate community structure are investigated using ordination and cluster analysis. Results of ordination analysis are then correlated with environmental variables to determine which of the measured environmental variables are most strongly associated with variability in macroinvertebrate community structure. Multiple discriminant analysis is then used to relate site groupings from pattern analysis to the environmental variables and to generate a model which can be used to predict community structure at other sites with unknown but potential contamination but for which environmental data are available.

In addition to collecting information on the structure of biological communities and on a variety of environmental variables, BEAST also includes laboratory-based bioassays which measure the life-history responses (survival, growth, reproduction) of four benthic invertebrates exposed to sediment collected from the same site. Thus this approach provides information both on general community structure and on the life-history traits of selected taxa exposed to sediment collected from the environment.

BEAST possess all the advantages (and disadvantages) of RIVPACS discussed above but goes further in so far as it provides information on community function (bioassays) as well as community structure (multivariate analyses) at each site. In a study of nearshore areas of the Great Lakes, BEAST correctly predicted benthic macroinvertebrate community structure > 86% of the time (Reynoldson *et al.* 1994).

Multivariate approaches such as RIVPACS and BEAST clearly provide the maximum amount of useful information pertaining to ecosystem structure and function. They measure both environmental and biological variables, are sensitive to a wide variety of stressors and have direct predictive value. However, the cost of establishing an initial data base for these approaches would be considerable. As stated above, in the latest version of RIVPACS approximately 700 sites are sampled and are used in the assessment of almost 9000 sites throughout the United Kingdom (Wright 1995). Granted, the program is now almost twenty years old and began at a more modest scale, but even the initial phase of RIVPACS involved the sampling of 268 separate sites in each of three seasons (spring, summer, autumn) and required an investment beyond the scope of existing monitoring programs in the northern river basins. As will be discussed below, a more modest approach to the use of multivariate statistical measures may be applicable for the northern river basins.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 INTRODUCTION

Although the specific objectives of this report are described in detail in Appendix A, the general objectives of this study were three in number: (1) We first collected and assessed the nature and quality of long-term data sets measuring benthic macroinvertebrate and fish community structure within the Peace, Athabasca and Slave river systems. Within the logistic and financial limitations of the project, we then compiled these existing data bases into a single standardized and accessible master database. The master database now exists in electronic format as a relational database (in Microsoft Access) and is accompanied by a manual (Ouellette and Cash 1995) explaining its use. (2) We next analyzed the available data on fish and benthic macroinvertebrate community structure collected in these basins to address the following questions: (i) What have been the long-term, basin-wide and local effects of anthropogenic activity, particularly pulp mill activity, on aquatic community structure? (ii) Is the data currently being collected within the northern river basins of sufficient quality and quantity to address the above question? (3) Finally, we reviewed and assessed currently popular biomonitoring techniques that rely on measures of benthic community structure, we assessed the applicability of these approaches to the northern river basins situation and we provide recommendations for the development of biomonitoring tools employing benthic community structure measures within these basins. Each of these general objectives will be dealt with separately in the following sections.

5.2 MASTER DATABASE

Although, the master database did not figure directly throughout much of this report it is arguably the most important product provided by this study. One of the primary objectives of the NRBS has been to construct a baseline data set describing ecological structure and function within these systems. By combining and standardizing the hundreds of different studies measuring benthic community structure within these basins this study has made considerable progress toward this goal.

More importantly, and in addition to standardizing the dozens of different formats that have been employed in data collection within these basins, all of the data have been placed in an accessible electronic format. By creating a relational database (using Microsoft ACCESS) containing all available data, and by providing a separate users guide explaining how to make use of that database (Ouellette and Cash 1995) we have made it possible to quickly and efficiently produce overviews of basin-wide changes in benthic macroinvertebrate community structure, or to sort through the data and extract relevant subsets of data for more detailed examination. These data extractions could occur at the level of a particular mill, during particular seasons, for a particular taxa or group of taxa, or could focus on particular sampling techniques. In other words, researchers and environmental managers will be able to use this database to quickly and easily investigate a large number of questions and issues that were outside the mandate of this report. Indeed, the database will hopefully be used to identify and investigate issues within these basins that have yet to be even recognized.

The database has also been constructed so as to maintain maximum flexibility. By including all aquatic macroinvertebrate taxa known to occur in the basins and by directly linking taxonomic levels so that groups can be easily "lumped or split" we have facilitated the addition of new data sets to this master database. In other words, depending on the objectives of the relevant agencies, the database, could serve not only as an historical record of monitoring activities within these basins, but could be easily updated on a regular basis allowing it to serve as a single and current repository for all such data collected within the basins. Indeed, the database could be expanded to accommodate information collected over a much broader spatial scale and even in its current form can accept aquatic macroinvertebrate community data collected from most habitats in western and northern Canada.

Finally, Microsoft Access can be readily linked to other electronic data sets even if those data sets exist in different formats. The ability to form direct links between separate data sets containing information on for example, benthic macroinvertebrate community structure, water quality, hydrologic records and climatic data would be of great value to researchers and environmental managers within these regions.

5.3 PATTERNS IN COMMUNITY STRUCTURE WITHIN THE NORTHERN RIVER BASINS

Although considerable time and effort has been invested in the collection and analysis of data relating to population and community structure within these basins there still exist major information gaps. In the case of fish, there is actually very little information available on community structure. This lack of data is understandable in light of historical bias and because of the tremendous logistical difficulty associated with trying to measure accurately and precisely the entire fish community. For these reasons, and because of difficulties associated with defining and delineating a fish community as well as in identifying reference and impact communities within these basins it was decided that fish community structure data could not be effectively used as an biomonitoring tool in the northern river basins. This does not suggest that particular components or populations within that community could not prove to serve as valuable biomonitoring tools in these basins.

As with fish community structure, there are significant gaps in available data measuring benthic macroinvertebrate community structure. In particular, there is insufficient data available to assess benthic macroinvertebrate community structure at a basin-wide scale. This data gap is a consequence of an understandable focus on those sections of the river immediately downstream of anthropogenic inputs, primarily pulp mill effluent, and may also stem from the logistical difficulties associated with sampling other sections of the river. However, this lack of information seriously constrains our ability to assess properly the general state and function of these ecosystems.

Measures of benthic macroinvertebrate community structure in the areas immediately above and below pulp mills are available and provide the greatest insight into natural benthic community structure and to the effect of pulp mill effluent on those communities. In general, communities both above and below the pulp mills were numerically dominated by chironomids (Orthocladiinae and Chironominae), oligochaete worms (Naididae and Tubificidae) and mayflies (Baetidae, Ephemerellidae and Heptageniidae). Stoneflies (Perlodidae, Capniidae, Taeniopterygidae) and caddisflies (Hydropsychidae and Polycentropodidae) were also abundant at certain sites and at certain times. Observed differences among sites upstream and downstream of any particular pulp mill were generally a function of changes in relative numbers of taxa rather than a result of the disappearance or addition of specific taxa.

Results from over 100 separate multivariate analyses are presented in Appendix E. Scores of other analyses were performed and while these are referred to in the text the specific results are not provided. Multivariate results described in this report demonstrate significant year to year and between season (spring and autumn) variation in benthic macroinvertebrate community structure upstream and downstream of all mills. The analyses also show a tendency for reference site above a given mill to be plotted close to one another in ordination space (suggesting little variation among these sites) but do not serve to consistently separate upstream reference sites from downstream impact sites. Communities both above and below the pulp mills tend to be numerically dominated by chironomids and oligochaetes and observed differences between sites were most often a function of changes in total density or in the relative abundance of a small number of rare taxa. These analyses provide no evidence to argue that changes in benthic community structure downstream of the pulp mills result from the loss of taxa. Indeed, in most cases total number of taxa observed below pulp mills was greater than that observed upstream of the mills.

This lack of a demonstrable shift in community structure is consistent with the findings of Scrimgeour *et al.* (1995) who also analyzed benthic community structure data from the Athabasca River in the Hinton area but employed different (i.e., multivariate clustering) techniques. Other workers have found higher macroinvertebrates densities (Sentar Consultants Ltd. 1993) and larger individuals (Podemski and Culp 1995) in the area immediately below these pulp mills suggesting that nutrients contained in the pulp mill effluent serve to increase primary productivity downstream of the mill and in turn, have pronounced affects on the macroinvertebrate taxa found there. Thus, while effluent from the pulp mills appears toaffect benthic macroinvertebrates, these affects act primarily at the level of the individual (i.e., body size) and with respect to overall macroinvertebrate densities and do not produce significant and consistent changes in overall community structure.

The fact that the multivariate analyses described in this report fail to consistently and predictably separate impact from reference sites does not imply that these techniques are incapable of detecting shifts but rather, given the available data, that there were no consistent shifts to detect. Indeed, while the ability of these multivariate techhniques to detect major shifts in community structure and/or changes in overall abundance is adequate their ability to detect more subtle changes is constrained by the numbers of sites available for analysis.

At a more important level, these observations serve to demonstrate the importance of collecting "high quality" environmental data at the same site from which benthic invertebrate collections are taken. Benthic community structure contains a wealth of useful information but it is information that can only be properly and fully interpreted in the light of adequate environmental data. Analyses of benthic macroinvertebrate community structure in the absence of environmental data may illustrate major shifts in community structure but there is a danger that equally important but subtler shifts will be missed, that changes caused by anthropogenic activity will go undetected, or that changes will be attributed to anthropogenic stress when such is not the case. Alternative multivariate techniques (e.g., cannocial correspondence analysis) are capable of directly and quantitatively relating benthic community structure to environmental data and provide much more insight than do measures of community structure alone.

Future studies that choose to collect detailed and quantified information on environmental variables from the same location at which benthic collections are made will possess a biomonitoring tool that is both more powerful and more cost-effective (i.e., provide a greater return of information for time and money invested). It is also important to note that while overall community structure may not respond in a consistent manner to effluent from pulp mills certain components within that community may be very sensitive and would constitute an excellent indicator of pulp mill effects. Thus, measuring relative numbers of selected taxa (another community-level measure) may ultimately provide more insight into changes in these communities than would an analysis of overall community structure alone.

5.4 FUTURE BIOMONITORING USING MEASURES OF COMMUNITY STRUCTURE

Biomonitoring programs, particularly those operating on the scale required by the NRBS are both expensive and labour intensive. Benthic macroinvertebrates are more commonly used in the assessment and monitoring of aquatic ecosystems than are any other group of organisms and have been shown to be one of the most cost-effective biomonitoring tools available (Resh and Jackson 1993; Resh *et al.* 1995).

As discussed earlier in this report, it is not sufficient to collect data on benthic macroinvertebrate community structure alone. Rather, there is a great and urgent need to construct a "quality" data set for the northern river basins that contains information not only on the structure and function of the benthic community at a given site but also characterizes the site in terms of physical and chemical variables. Both the qualitative (rapid bioassessment) and quantitative (multivariate statistics) approaches discussed above stress the need to collect habitat or environmental data of this type and while it remains to be determined how many sites would require sampling and how often each site should be sampled it is clear that any basin-wide effort would represent a considerable investment in both time and effort. In the case of the NRBS, the collection of this type of baseline data is also an explicit objective of the program (NRBS 1994) and is necessary to the development of any effective biomonitoring program.

It is also important that data not be collected merely for its own sake (as has occurred in some areas), rather there is a need for a carefully designed sampling program that will provide the maximum return of information for invested energy. It is worth noting that the two general biomonitoring approaches to make use of benthic macroinvertebrate community measures have similar data requirements suggesting that costs associated with the different techniques, at least with regard to data collection, may not differ greatly. Costs associated with analyzing the data once collected will vary according to the level of taxonomic resolution required and by the types of statistical techniques applied to the data.

Multivariate approaches such as RIVPACS and BEAST clearly provide a greater amount of detailed information than does the rapid assessment approach or the multivariate analyses performed in this report. Multivariate techniques measure both environmental and biological variables, are sensitive to a wide variety of stressors and have direct predictive value. Unfortunately, the cost of establishing an initial data base for these approaches would be considerable though initial costs would also be offset by a reduction in monitoring costs once the data base is established.

Rather than recommend one approach over the other we feel that the two general approaches can be combined in a complimentary fashion that minimizes costs and maximizes the return in information. Rapid bioassessments are a relatively inexpensive and simple way to rapidly characterize sites within the basins and to identify those areas in need of more detailed investigations. This approach is particularly useful in a situation such as the northern river basins in which there is a lack of baseline data at a basin-wide scale. However, the efficacy of any rapid bioassment employed in these basins would be dependent on the particular metrics chosen.

As has been demonstrated, several of the most widely-used rapid bioassment metrics are not appropriate for these systems, indicating a need for alternative metrics to be developed for the northern river basins. The development of these metrics will involve additional research but will contribute directly to our knowledge of the basic ecology of these ecosystems and will ultimately provide a return in terms of reduced monitoring costs.

Multivariate techniques could be employed to gain more detailed information in reference sites and in those areas identified as "hot spots" by the rapid assessment approach and over time could contribute to the sort of database required to implement a RIVPACS type approach. Use of multivariate statistics in this fashion would spread out the costs of the approach and yet still provide detailed and timely information in areas of concern. The success of any multivariate statistical approach will be largely determined by the ability to adequately measure the range of variation (in benthic community structure and environmental variables) within these systems. Clearly, a data base of this type would have to be developed over a period of several years, but proper attention to study design and the careful and considered selection of sampling sites would reduce costs and provide the maximum amount of useful information.

This report would thus recommend a multivariate approach that combines rapid assessment protocols and multivariate statistical approaches to biomonitoring. These techniques are capable of assessing current ecosystem condition and of providing information on long-term trends within the ecosystem. They also evaluate community structure in the light of environmental data. We would further suggest that this approach be extended to other aquatic and riparian communities, but that fish communities not be included in this approach.

Combining qualitative and quantitative approaches to bioassessment is one way to reduce overall biomonitoring costs but these costs could be further reduced by better coordinating current sampling efforts within the basins. Pulp mills currently conduct their own monitoring studies and will be increasingly responsible for monitoring under the EEM legislation (Environment Canada and Department of Fisheries and Oceans 1991). At present these monitoring efforts are not standardized with respect to timing (season), sampling technique, or data analysis. By coordinating and standardizing these independent efforts a much more complete and useful data set would be available. Of equal importance is the need to establish a protocol to analyze and interpret this data once collected. Such provisions will exist under EEM legislation but will relate only to individual mills; there is a need for a similar exercise at a basin-wide level to synthesize data collected by pulp mills, consultants and government agencies.

As industry begins to assume the responsibility of monitoring in the areas upstream and downstream of the pulp mills, government agencies (e.g., AEP, DOE) could begin to redirect their efforts to monitoring those reaches of the river between the mills. As discussed above, sampling between point sources presents logistical and financial challenges, but these can be minimized through a careful consideration of sampling design and a redistribution of available resources. For example, sampling between pulp mills every third year would significantly reduce costs and yet still provide information on a basin-wide scale. Such an approach would provide the data required to assess the ecosystem as a whole and would represent a dramatic advance in biomonitoring within these basins.

Finally, as research in aquatic biomonitoring continues to advance there will no doubt be significant improvements in available techniques and theoretical approaches. Unfortunately, it is difficult to predict the nature of these advancements and the direction from which they will come. For these reasons it is important to maintain a flexible aquatic biomonitoring program that will be capable of adapting and incorporating new or improved techniques as they become available.

Equally important is the need to establish a decision making framework in which the results of biomonitoring can be incorporated into appropriate management acitivties. The chief role of biomonitoring is to provide data to those tasked with managing the ecosystem; the ultimate value of any biomonitoring program will thus depend on the manner in which it is employed by the decision making process.

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APPENDIX A

Questions identified by the NRBS Study Board which are to serve as guidelines to help the study meet its objectives (NRBS 1992).

Scientific Questions

1) a) How has the aquatic ecosystem, including fish and/or other aquatic organisms, been affected by exposure to organochlorines or other toxic compounds?
   b) How can the ecosystem be protected from the effects of these compounds?

2) What is the current state of water quality in the Peace, Athabasca and Slave river basins, including the Peace-Athabasca delta?

3) Who are the stakeholders and what are the consumptive and non-consumptive uses of water resources in the river basin?

4) a) What are the contents and nature of the contaminants entering the system and what is their distribution and toxicity in the aquatic ecosystem with particular reference to water, sediments and biota?
   b) Are toxins such as dioxins, furans, mercury, etc. increasing or decreasing and what is their rate of change?

5) Are the substances added to the rivers by natural and man made discharge likely to cause deterioration of the water quality?

6) What is the distribution and movement of fish species in the watersheds of the Peace, Athabasca and Slave rivers? Where and when are they most likely to be exposed to changes in water quality and where are their most important habitats?

7) What concentrations of dissolved oxygen are required seasonally to protect the various life stages of fish, and what factors control dissolved oxygen in the rivers?

8) Recognizing that people drink water and eat fish from these systems, what is the current concentration of contaminants in water and edible fish tissue and how are these levels changing through time and by location?

9) Are fish tainted in these waters and, if so, what is the source of the tainting compounds (i.e. compounds affecting how fish taste and smell to humans)?

10) How does and how could river flow regulation impact the aquatic ecosystem?

11) Have the riparian vegetation, riparian wildlife and domestic livestock in the river basins been affected by exposure to organochlorines or other toxic compounds?

12) What native traditional knowledge exists to enhance the physical science studies in all areas of the enquiry?

13) a) What predictive tools are required to determine the cumulative effects of man made discharges on the water and aquatic environment?
b) What are the cumulative effects of man made discharge on the water and aquatic environment?

14) What long term monitoring programs and predictive models are required to provide an ongoing assessment of the state of the aquatic ecosystems? These programs must ensure all stakeholders have the opportunity for input.

Non-Scientific Questions

15) How can the Study results be communicated most effectively?

16) What form of interjurisdictional body can be established, ensuring stakeholder participation for the ongoing protection and use of the river basins?

APPENDIX B

NORTHERN RIVER BASINS STUDY

TERMS OF REFERENCE

Project 5211-D1: Quantitative Analysis of Benthic Macroinvertebrate and Fish Community Structure: A Critique and Comparison of Biomonitoring Techniques

I. Background and Objectives

One of the primary objectives of the Northern River Basins Study (NRBS) is to identify long-term monitoring programs and predictive models for providing an ongoing assessment of the state of the aquatic ecosystem (Question 14). Data on benthic invertebrate and/or fish community structure is widely recognized as providing valuable insight into ecosystem health (see Cash 1994) and has been collected periodically within the Peace (including Alberta and B.C.), Athabasca (including Lake Athabasca in Alberta and Saskatchewan) and Slave river systems for much of the past 40 years and more intensively over the last 15 years. Unfortunately, these data sets have not yet been analyzed with the specific objective of assessing the appropriateness of the monitoring data collected, or for the purpose of assessing the general state of the aquatic ecosystem.

The purpose of this project is to apply a variety of biomonitoring (data analysis) techniques (see Cash 1994) to existing macroinvertebrate and fisheries data sets to address the following questions:

(1) Are the data currently being collected within the Peace, Athabasca and Slave river systems of sufficient quality and quantity to permit application of widely used biomonitoring (data analysis) techniques?;

(2) What (if any) additional information is required before these techniques can be successfully applied?

(3) Do current techniques adequately identify and capture changes in benthic invertebrate and/or fish community structure caused by changes in effluent loadings within this system?

(4) What are the strengths and weaknesses of each technique when applied to this data set and are results obtained from the application of different techniques comparable?

(5) Which technique or group of techniques will best fulfil the Northern River Basins Study objective of identifying those monitoring programs necessary for ongoing assessment of cumulative effects and aquatic ecosystem integrity?

This study will complement work being carried out by the Nutrients Component which is employing univariate and multivariate statistics to test specific hypotheses relating to effluent loadings and subsequent shifts in benthic invertebrate community structure (report being prepared under NRBS Project 2616-C1; draft project report should be available in August 1994). This study will also provide background information for more direct comparisons of the monitoring program developed for the Peace, Athabasca and Slave River systems with monitoring programs developed for other large river systems.

II. General Requirements

1) Assess the nature and quality of long-term data sets measuring benthic macroinvertebrate community structure (being prepared under NRBS Project 2616-C1) in relation to effluent loadings (see NRBS Projects 2111-A1 [McCubbin & Folke 1993, McCubbin 1993] & C1, and 2112-B1/C1 [Sentar Consultants Ltd. 1993]) within the Peace, Athabasca and Slave river systems. Data from NRBS projects 2616-C1, 2111-A1, 2111-C1 and 2112-B1/C1 will be supplied to the contractor by the NRBS.

2) Compile into databases existing information on benthic macroinvertebrate and fish community structure on the Peace (including Wapiti-Smoky rivers), Athabasca and Slave River systems. Sources of information are to include government, academic and industry studies carried out in the Peace, Athabasca and Slave river basins (see Wallace and McCart 1984, Paetz 1984, Hildebrand 1990, Swanson 1992), including recent data from Alberta-Pacific Forest Industries Inc. and studies carried out by the Northern River Basins Study (particularly Boag (1993) and R. L. & L. Environmental Services Ltd 1994a; but see also Balagus *et al.* (1993), Barton and Courtney (1993), R. L. & L. Environmental Services Ltd. (1994b), D. A. Westworth & Associates (1993), Golder Associates Ltd. (1994), Patalas (1993), Dunnigan and Millar (1993)).

3) Assess the feasibility of applying biomonitoring (data analysis) techniques (that make use of benthic macroinvertebrates and/or fish distribution and abundance data) to the data sets described above. The assessment should include the use of multivariate analyses (cluster and ordination analysis) and biotic integrity analysis (e.g., Karr 1991; biotic index approach).

4) Based on the biomonitoring techniques outlined in Cash (1994) identify biomonitoring (data analysis) techniques that could be applied to long-term macroinvertebrate and fisheries data sets from the northern river basins. Where

possible, apply currently used biomonitoring (data analysis) techniques to the long-term data sets.

5) Compare and contrast the results obtained when different biomonitoring techniques are applied to the same data sets and provide recommendations as to the most appropriate techniques to be incorporated into a long-term cumulative effects monitoring plan for the Peace, Athabasca and Slave river systems. Clearly outline criteria for the selection and dismissal of various biomonitoring techniques for assessing long-term cumulative effects and ecosystem health in the northern river basins. Where appropriate, relate the selection of appropriate biomonitoring techniques for the northern river basins to biomonitoring techniques employed on other large river systems.

6) Consult extensively with staff from Alberta Environmental Protection during the review of existing macroinvertebrate databases, the assessment of the feasibility of applying biomonitoring techniques to the macroinvertebrate databases, and the development of a long-term cumulative effects monitoring program. The list of AEP staff to contact includes:

   Dr. Anne-Marie Anderson, Technical Services and Monitoring Division (427-5893)
   Mr. Leigh Noton, Technical Services and Monitoring Division (427-5893)
   Mr. Ian MacKenzie, Standards and Approvals Division (427-5888)

7) Consult extensively with staff from Alberta Environmental Protection (contact Maurice Drouin, Fish and Wildlife Services - (403) 427-6730) to identify existing fisheries databases and during the review of existing fisheries databases, the assessment of the feasibility of applying biomonitoring techniques to fisheries databases and the development of a long-term cumulative effects monitoring program.

III. Deliverables

1. Two interim progress reports, one to be delivered on November 1, 1994 and the other to be delivered by March 31, 1995.

2. Elctronic copies of the databases used for all analyses, as well as a manual that specifies the data structure and format.

3. A comprehensive draft report to be delivered to the Study Office on or before July 1, 1995, and a final report three weeks following the reciept of reviewers comments.

4. Six to ten 35 mm slides that can be used at public meetings to summarize the project, methods and key findings.

IV. Reporting Requirements

1. Prepare a comprehensive report that identifies existing fish and macroinvertebrate community structure data within the Peace (including Wapiti-Smoky rivers), Athabasca and Slave river systems and outlines the feasibility of applying the various biomonitoring techniques to existing fish and macroinvertebrate community structure information. Where applicable, the report should discuss the results of applying biomonitoring techniques to fish and macroinvertebrate data sets and make recommendations regarding appropriate biomonitoring techniques that could be incorporated into a long-term cumulative effects monitoring plan for the Peace, Slave and Athabasca river systems.

2. Interim progress reports are to be submitted to the Component Coordinator on **November 1, 1994** and **March 31, 1995.**

3. Electronic copies of the macroinvertebrate and fish databases used for all analyses are to be provided to the Study Office by **March 31, 1995**. An accompanying manual should also be provided that specifies data structure and format. These data must be in Quattro Pro and FoxPro/dBase IV compatible formats.

4. Ten copies of the draft report are to be submitted to the Component Coordinator by **July 1, 1995.**

5. Three weeks after the receipt of review comments on the draft report, the Contractor is to provide the Component Coordinator with two unbound, camera ready originals and ten cerlox bound copies of the final report along with an electronic version.

6. The Contractor is to provide draft and final reports in the style and format outlined in the NRBS document, "A Guide for the Preparation of Reports," which will be supplied upon execution of the contract.

   The final report is to include the following: an acknowledgement section that indicates any local involvement in the project, Report Summary, Table of Contents, List of Tables, List of Figures and an Appendix with the Terms of Reference for this project.
   Text for the report should be set up in the following format:

   a) Times Roman 12 point (Pro) or Times New Roman (WPWIN60) font.
   b) Margins; are 1" at top and bottom, 7/8" on left and right.
   c) Headings; in the report body are labelled with hierarchical decimal Arabic numbers.

d) Text; is presented with full justification; that is, the text aligns on both left and right margins.

e) Page numbers; are Arabic numerals for the body of the report, centred at the bottom of each page and bold.

- If photographs are to be included in the report text they should be high contrast black and white.
- All tables and figures in the report should be clearly reproducible by a black and white photocopier.
- Along with copies of the final report, the Contractor is to supply an electronic version of the report in Word Perfect 5.1 or Word Perfect for Windows Version 6.0 format.
- Electronic copies of tables, figures and data appendices in the report are also to be submitted to the Component Coordinator along with the final report. These should be submitted in a spreadsheet (Quattro Pro preferred, but also Excel or Lotus) or database (dBase IV) format. Where appropriate, data in tables, figures and appendices should be geo-referenced.

7. All figures and maps are to be delivered in both hard copy (paper) and digital formats. Acceptable formats include: DXF, uncompressed E⌀⌀, VEC/VEH, Atlas and ISIF. All digital maps must be properly geo-referenced.

8. All sampling locations presented in report and electronic format should be geo-referenced. This is to include decimal latitudes and longitudes (to six decimal places) and UTM coordinates. The first field for decimal latitudes / longitudes should be latitudes (10 spaces wide). The second field should be longitude (11 spaces wide).

9. The presentation package of 35 mm slides is to comprise of one original and four duplicates of each slide.

V. Contract Administration

This project is being conducted by the Synthesis and Modelling Component of the Northern River Basins Study (Component Leader - Dr. Fred Wrona)

The Scientific Authority for this project is:

Dr. Fred Wrona
Chief, Ecosystem Evaluation Division
National Hydrology Research Institute
11 Innovation Blvd.
Saskatoon, Saskatchewan S7N 3H5
phone: (306) 975-6099 fax: (306) 975-6414

Questions of a technical nature should be directed to him.

The Component Coordinator for this project is:

Richard Chabaylo
Northern River Basins Study
690 Standard Life Centre
10405 Jasper Avenue
Edmonton, Alberta T5J 3N4
phone: (403) 427-1742 fax: (403) 422-3055

Questions of an administrative nature should be directed to him.

VI. Literature Cited

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APPENDIX C

Key to data file descriptions

I. Location abbreviations

u/s upstream
d/s downstream
PMO pulp mill outfall, diffuser
STP sewage treatment plant outfall diffuser

II. Location explanation

Location descriptions are as given in the source documents. Site codes used in source documents are included to facilitate site identification. In some instances, the site code is the only description availble in the source document.

Locations described as upstream or downstream of another river are relative to the confluence of the two rivers. The determination of the location of the confluence is not specified in any of the source documents, but is presumed to be the upstream edge of the confluence.

Locations relative to impact sources are relative to the diffuser or outfall from that source. Locations relative to landmarks (*e.g.* bridges, pipelines, islands, *etc.*) are usually the first suitable sampling site *downstream* of that landmark unless otherwise specified.

Since many sites are in shallow water, and the rivers of concern to this study vary greatly in flows both inter- and intra-annually, sites with the same description may actually be several hundred metres apart. Where it is specified in the source information, these differences are included in the site descriptions.

III. Description of data structure

All files are in Borland QuattroPro version 5.00 format. Each file contains one notebook page, and no formulas. Figure 1 shows a portion of a typical spreadsheet file.

All supporting information is contained in the first 8 rows of the spreadsheet using the conventions specified in Table 1. The first column contains the 4 digit taxonmic codes (see Appendix C) used in this study, the second the scientific name of that taxon. Taxa names are as specified in the source document, unless several taxa have been grouped together, in which case the new taxon name is provided. Taxonomic name changes may result in currently invalid names in the source files. However, the since the taxonomic code rather than the name is imported to the master database, this will not result in inaccuracies in the database.

Abundance data are expressed as counts, unless otherwise specified, and begin in cell C9. There may be as many as ten replicates, or only a single value when an average or total number is presented. Mean and standard error are located in the columns following the data.

	Peace River	Sampler: Neill cylinder sanpler (0.1 m^2)							
	0.25 km upstream of Clear River	Finest mesh size: 0.210 mm							
	left bank	Collection by: B. Jackson and D. Allen							
	May 26, 1987	Sorting by: M. Mychaijluk							
	00AL07FD1050	Counts and identifications by: W.J. Anderson							
	a0474.wb1								
		Replicates					**Mean**	**Std.Err.**	
003	Acari	0	0	1	0	0	0.2	0.20	
0311	Daphnia	3	2	3	1	5	2.8	0.66	
0401	Calanoida	10	14	20	18	17	15.8	1.74	
0402	Cyclopoida	28	46	29	18	37	31.6	4.70	
0800	Ostracoda	0	0	1	3	0	0.8	0.58	

Figure 1. **Partial QuattroPro spreadsheet.**

Table 1. **Specification for location of information in spreadsheet file.**

Cell location	Information	Cell location	Information
B1	River sampled	**C1**	Type of sampling device (area sampled*)
B2	Site description	**C2**	Finest mesh size used inthe collection of the sample
B3	Site description continued	**C3**	Agency or individuals collecting sample
B4	Sampling date	**C4**	Individual(s) sorting sample
B5	NAQUADAT code for site (if available)	**C5**	Taxonomist overseeing identification of animals in sample
B6	Name of file		

* when data represents total animals collected in multiple samples, this value is the total area sampled.

A rigid structure is used in the spreadsheet design to permit creation of macros to extract and manipulate the data, increasing efficiency and accuracy of data handling. Use of this format, or any consistent format for storage of data, facilitates incorporation of the data into larger datasets, increasing the utility of the information.

Electronic copy of all 1,027 data files is included on nine high density diskettes with this report (Interim Report, March, 1995). NRBS project 2616-C1 has collected the source literature for the majority of these data, and will present the original data in its report. Hardcopy of the data would be redundant with project 2616-C1, and would exceed 1,300 printed pages and is not included with this report.

File Name	River	Date	Collector	Location	Disk
a0001.wb1	Athabasca	06/03/87	Alberta Environment	2.1 km u/s McCleod River right bank (A1R)	5211-D1-01
a0002.wb1	Athabasca	06/03/87	Alberta Environment	0.5 km u/s McLeod River right bank (A2R)	5211-D1-01
a0003.wb1	Athabasca	06/03/87	Alberta Environment	0.8 km d/s McLeod River left bank (A3L)	5211-D1-01
a0004.wb1	Athabasca	06/03/87	Alberta Environment	0.8 km d/s McLeod River centre (A3C)	5211-D1-01
a0005.wb1	Athabasca	06/03/87	Alberta Environment	0.8 km d/s McLeod River right bank (A3R)	5211-D1-01
a0006.wb1	Athabasca	06/03/87	Alberta Environment	2.5 km d/s McLeod River at pipeline crossing left bank (A4L)	5211-D1-01
a0007.wb1	Athabasca	06/03/87	Alberta Environment	2.5 km d/s McLeod River at pipeline crossing centre (A4C)	5211-D1-01
a0008.wb1	Athabasca	06/03/87	Alberta Environment	2.5 km d/s McLeod River at pipeline crossing right bank (A4R)	5211-D1-01
a0009.wb1	Athabasca	06/03/87	Alberta Environment	4.5 km d/s McLeod River, north of STP centre (A5C)	5211-D1-01
a0010.wb1	Athabasca	06/03/87	Alberta Environment	6 km d/s McLeod River left bank (A6L)	5211-D1-01
a0011.wb1	Athabasca	06/03/87	Alberta Environment	6 km d/s McLeod River right bank (A6R)	5211-D1-01
a0012.wb1	McLeod	06/03/87	Alberta Environment	2.7 km above Athabasca River left bank (MCL1L)	5211-D1-01
a0013.wb1	McLeod	06/03/87	Alberta Environment	1 km above Athabasca River right bank (MCL2R)	5211-D1-01
a0014.wb1	Athabasca	09/07/87	Alberta Environment	2.1 km u/s McCleod River right bank (A1R)	5211-D1-01
a0015.wb1	Athabasca	09/07/87	Alberta Environment	0.5 km u/s McLeod River right bank (A2R)	5211-D1-01
a0016.wb1	Athabasca	09/07/87	Alberta Environment	0.8 km d/s McLeod River left bank (A3L)	5211-D1-01
a0017.wb1	Athabasca	09/07/87	Alberta Environment	0.8 km d/s McLeod River centre (A3C)	5211-D1-01
a0018.wb1	Athabasca	09/07/87	Alberta Environment	0.8 km d/s McLeod River right bank (A3R)	5211-D1-01
a0019.wb1	Athabasca	09/07/87	Alberta Environment	2.5 km d/s McLeod River at pipeline crossing left bank (A4L)	5211-D1-01
a0020.wb1	Athabasca	09/07/87	Alberta Environment	2.5 km d/s McLeod River at pipeline crossing centre (A4C)	5211-D1-01
a0021.wb1	Athabasca	09/07/87	Alberta Environment	2.5 km d/s McLeod River at pipeline crossing right bank (A4R)	5211-D1-01
a0022.wb1	Athabasca	09/07/87	Alberta Environment	4.5 km d/s McLeod River, north of STP centre (A5C)	5211-D1-01
a0023.wb1	Athabasca	09/07/87	Alberta Environment	6 km d/s McLeod River left bank (A6L)	5211-D1-01
a0024.wb1	Athabasca	09/07/87	Alberta Environment	6 km d/s McLeod River right bank (A6R)	5211-D1-01
a0025.wb1	McLeod	09/07/87	Alberta Environment	2.7 km above Athabasca River left bank (MCL1L)	5211-D1-01
a0026.wb1	McLeod	09/07/87	Alberta Environment	1 km above Athabasca River right bank (MCL2R)	5211-D1-01
a0027.wb1	Athabasca	10/19/88	Alberta Environment	0.5 km u/s McLeod River right bank (A2R)	5211-D1-01
a0028.wb1	Athabasca	10/19/88	Alberta Environment	0.8 km d/s McLeod River centre (A3C)	5211-D1-01
a0029.wb1	Athabasca	10/19/88	Alberta Environment	0.8 km d/s McLeod River right bank (A3R)	5211-D1-01

File Name	River	Date	Collector	Location	Disk
a0030.wb1	Athabasca	10/19/88	Alberta Environment	2.5 km d/s McLeod River at pipeline crossing centre (A4C)	5211-D1-01
a0031.wb1	Athabasca	10/19/88	Alberta Environment	2.5 km d/s McLeod River at pipeline crossing right bank (A4R)	5211-D1-01
a0032.wb1	Athabasca	10/19/88	Alberta Environment	4.5 km d/s McLeod River, north of STP right bank (A5R)	5211-D1-01
a0033.wb1	McLeod	10/19/88	Alberta Environment	2.7 km above Athabasca River left bank (MCL1L)	5211-D1-01
a0034.wb1	Athabasca	10/19/88	Alberta Environment	3.5km u/s ANC	5211-D1-01
a0035.wb1	Athabasca	10/19/88	Alberta Environment	0.5km d/s ANC	5211-D1-01
a0036.wb1	Athabasca	10/19/88	Alberta Environment	3km d/s ANC, north bank (ANC 4)	5211-D1-01
a0037.wb1	Athabasca	06/14/89	Alberta Environment	Millar Western s5 & 13 k d/s ANC outfall, south bank (ANC 6)	5211-D1-01
a0038.wb1	Athabasca	06/14/89	Alberta Environment	0.8 km d/s McLeod River centre (A3C)	5211-D1-01
a0039.wb1	Athabasca	06/14/89	Alberta Environment	0.8 km d/s McLeod River right bank (A3R)	5211-D1-01
a0040.wb1	Athabasca	06/14/89	Alberta Environment	2.5 km d/s McLeod River at pipeline crossing centre (A4C)	5211-D1-01
a0041.wb1	Athabasca	06/14/89	Alberta Environment	2.5 km d/s McLeod River at pipeline crossing right bank (A4R)	5211-D1-01
a0042.wb1	Athabasca	06/14/89	Alberta Environment	4.5 km d/s McLeod River, north of STP centre (A5C)	5211-D1-01
a0043.wb1	McLeod	06/14/89	Alberta Environment	2.7 km above Athabasca River left bank (MCL1L)	5211-D1-01
a0044.wb1	Athabasca	06/14/89	Alberta Environment	5 km u/s ANC	5211-D1-01
a0045.wb1	Athabasca	06/14/89	Alberta Environment	3.5km u/s ANC	5211-D1-01
a0046.wb1	Athabasca	06/14/89	Alberta Environment	0.5km d/s ANC	5211-D1-01
a0047.wb1	Athabasca	06/14/89	Alberta Environment	3km d/s ANC, north bank (ANC 4)	5211-D1-01
a0048.wb1	Athabasca	10/18/89	Alberta Environment	0.5 km u/s McLeod River right bank (A2R)	5211-D1-01
a0049.wb1	Athabasca	10/18/89	Alberta Environment	0.5 km u/s McLeod River left bank (A2L)	5211-D1-01
a0050.wb1	Athabasca	10/18/89	Alberta Environment	0.8 km d/s McLeod River centre (A3C)	5211-D1-01
a0051.wb1	Athabasca	10/18/89	Alberta Environment	0.8 km d/s McLeod River right bank (A3R)	5211-D1-01
a0052.wb1	Athabasca	10/18/89	Alberta Environment	2.5 km d/s McLeod River at pipeline crossing centre (A4C)	5211-D1-01
a0053.wb1	Athabasca	10/18/89	Alberta Environment	2.5 km d/s McLeod River at pipeline crossing right bank (A4R)	5211-D1-01
a0054.wb1	Athabasca	10/18/89	Alberta Environment	4.5 km d/s McLeod River, north of STP centre (A5C)	5211-D1-01
a0055.wb1	Athabasca	10/18/89	Alberta Environment	4.5 km d/s McLeod River, north of STP right bank (A5R)	5211-D1-01
a0056.wb1	McLeod	10/18/89	Alberta Environment	2.7 km above Athabasca River left bank (MCL1L)	5211-D1-01
a0057.wb1	McLeod	06/05/87	Sentar	Millar Western s1	5211-D1-01
a0058.wb1	Athabasca	06/05/87	Sentar	Millar Western s2 & 8.5 k d/s ANC outfall, south bank (ANC 5)	5211-D1-01

File Name	River	Date	Collector	Location	Disk
a0059.wb1	Athabasca	06/05/87	Sentar	Millar Western s3 (~1.2 km d/s McLeod River)	5211-D1-01
a0060.wb1	Athabasca	06/05/87	Sentar	Millar Western s4 (~2.7 km d/s McLeod River)	5211-D1-01
a0061.wb1	Athabasca	06/05/87	Sentar	Millar Western s5 & 13 k d/s ANC outfall, south bank (ANC 6)	5211-D1-01
a0062.wb1	McLeod	11/05/87	Sentar	Millar Western s1	5211-D1-01
a0063.wb1	Athabasca	11/05/87	Sentar	Millar Western s2 & 8.5 k d/s ANC outfall, south bank (ANC 5)	5211-D1-01
a0064.wb1	Athabasca	11/05/87	Sentar	Millar Western s3 (~1.2 km d/s McLeod River)	5211-D1-01
a0065.wb1	Athabasca	11/05/87	Sentar	Millar Western s4 (~2.7 km d/s McLeod River)	5211-D1-01
a0066.wb1	Athabasca	11/05/87	Sentar	Millar Western s5 & 13 k d/s ANC outfall, south bank (ANC 6)	5211-D1-01
a0067.wb1	McLeod	06/05/88	Sentar	Millar Western s1	5211-D1-01
a0068.wb1	Athabasca	06/05/88	Sentar	Millar Western s2 & 8.5 k d/s ANC outfall, south bank (ANC 5)	5211-D1-01
a0069.wb1	Athabasca	06/05/88	Sentar	Millar Western s3 (~1.2 km d/s McLeod River)	5211-D1-01
a0070.wb1	Athabasca	06/05/88	Sentar	Millar Western s4 (~2.7 km d/s McLeod River)	5211-D1-01
a0071.wb1	Athabasca	06/05/88	Sentar	Millar Western s5 & 13 k d/s ANC outfall, south bank (ANC 6)	5211-D1-01
a0072.wb1	McLeod	10/05/88	Sentar	Millar Western s1	5211-D1-01
a0073.wb1	Athabasca	10/05/88	Sentar	Millar Western s2 & 8.5 k d/s ANC outfall, south bank (ANC 5)	5211-D1-01
a0074.wb1	Athabasca	10/05/88	Sentar	Millar Western s3 (~1.2 km d/s McLeod River)	5211-D1-01
a0075.wb1	Athabasca	10/05/88	Sentar	Millar Western s4 (~2.7 km d/s McLeod River)	5211-D1-01
a0076.wb1	Athabasca	10/05/88	Sentar	Millar Western s5 & 13 k d/s ANC outfall, south bank (ANC 6)	5211-D1-01
a0077.wb1	McLeod	06/08/89	Sentar	Millar Western s1	5211-D1-01
a0078.wb1	Athabasca	06/08/89	Sentar	Millar Western s2 & 8.5 k d/s ANC outfall, south bank (ANC 5)	5211-D1-01
a0079.wb1	Athabasca	06/08/89	Sentar	Millar Western s3 (~1.2 km d/s McLeod River)	5211-D1-01
a0080.wb1	Athabasca	06/08/89	Sentar	Millar Western s4 (~2.7 km d/s McLeod River)	5211-D1-01
a0081.wb1	Athabasca	06/08/89	Sentar	Millar Western s4a (~2.2 km d/s McLeod River)	5211-D1-01
a0082.wb1	Athabasca	06/08/89	Sentar	Millar Western s5 & 13 k d/s ANC outfall, south bank (ANC 6)	5211-D1-01
a0083.wb1	Athabasca	06/08/89	Sentar	Millar Western s6 (~8 KM d/s McLeod River)	5211-D1-01
a0084.wb1	Athabasca	06/08/89	Sentar	Millar Western s7 & 33 k d/s ANC outfall, south bank (ANC 7)	5211-D1-01
a0085.wb1	McLeod	10/08/89	Sentar	Millar Western s1	5211-D1-01
a0086.wb1	Athabasca	10/08/89	Sentar	Millar Western s2 & 8.5 k d/s ANC outfall, south bank (ANC 5)	5211-D1-01
a0087.wb1	Athabasca	10/08/89	Sentar	Millar Western s3 (~1.2 km d/s McLeod River)	5211-D1-01

File Name	River	Date	Collector	Location	Disk
a0088.wb1	Athabasca	10/08/89	Sentar	Millar Western s4 (~2.7 km d/s McLeod River)	5211-D1-01
a0089.wb1	Athabasca	10/08/89	Sentar	Millar Western s4a (~2.2 km d/s McLeod River)	5211-D1-01
a0090.wb1	Athabasca	10/08/89	Sentar	Millar Western s5 & 13 k d/s ANC outfall, south bank (ANC 6)	5211-D1-01
a0091.wb1	Athabasca	10/08/89	Sentar	Millar Western s6 (~8 KM d/s McLeod River)	5211-D1-01
a0092.wb1	Athabasca	10/08/89	Sentar	Millar Western s7 & 33 k d/s ANC outfall, south bank (ANC 7)	5211-D1-01
a0093.wb1	McLeod	05/08/90	Sentar	Millar Western s1	5211-D1-01
a0094.wb1	Athabasca	05/08/90	Sentar	Millar Western s2 & 8.5 k d/s ANC outfall, south bank (ANC 5)	5211-D1-01
a0095.wb1	Athabasca	05/08/90	Sentar	Millar Western s3 (~1.2 km d/s McLeod River)	5211-D1-01
a0096.wb1	Athabasca	05/08/90	Sentar	Millar Western s4 (~2.7 km d/s McLeod River)	5211-D1-01
a0097.wb1	Athabasca	05/08/90	Sentar	Millar Western s4a (~2.2 km d/s McLeod River)	5211-D1-01
a0098.wb1	Athabasca	05/08/90	Sentar	Millar Western s5 & 13 k d/s ANC outfall, south bank (ANC 6)	5211-D1-01
a0099.wb1	Athabasca	05/08/90	Sentar	Millar Western s6 (~8 KM d/s McLeod River)	5211-D1-01
a0100.wb1	Athabasca	05/08/90	Sentar	Millar Western s7 & 33 k d/s ANC outfall, south bank (ANC 7)	5211-D1-01
a0101.wb1	McLeod	10/08/90	Sentar	Millar Western s1	5211-D1-01
a0102.wb1	Athabasca	10/08/90	Sentar	Millar Western s2 & 8.5 k d/s ANC outfall, south bank (ANC 5)	5211-D1-01
a0103.wb1	Athabasca	10/08/90	Sentar	Millar Western s3 (~1.2 km d/s McLeod River)	5211-D1-01
a0104.wb1	Athabasca	10/08/90	Sentar	Millar Western s4 (~2.7 km d/s McLeod River)	5211-D1-01
a0105.wb1	Athabasca	10/08/90	Sentar	Millar Western s4a (~2.2 km d/s McLeod River)	5211-D1-01
a0106.wb1	Athabasca	10/08/90	Sentar	Millar Western s5 & 13 k d/s ANC outfall, south bank (ANC 6)	5211-D1-01
a0107.wb1	Athabasca	10/08/90	Sentar	Millar Western s6 (~8 KM d/s McLeod River)	5211-D1-01
a0108.wb1	Athabasca	10/08/90	Sentar	Millar Western s7 & 33 k d/s ANC outfall, south bank (ANC 7)	5211-D1-01
a0109.wb1	McLeod	05/08/91	Sentar	Millar Western s1	5211-D1-01
a0110.wb1	Athabasca	05/08/91	Sentar	Millar Western s2 & 8.5 k d/s ANC outfall, south bank (ANC 5)	5211-D1-01
a0111.wb1	Athabasca	05/08/91	Sentar	Millar Western s3 (~1.2 km d/s McLeod River)	5211-D1-01
a0112.wb1	Athabasca	05/08/91	Sentar	Millar Western s4 (~2.7 km d/s McLeod River)	5211-D1-01
a0113.wb1	Athabasca	05/08/91	Sentar	Millar Western s4a (~2.2 km d/s McLeod River)	5211-D1-01
a0114.wb1	Athabasca	05/08/91	Sentar	Millar Western s5 & 13 k d/s ANC outfall, south bank (ANC 6)	5211-D1-01
a0115.wb1	Athabasca	05/08/91	Sentar	Millar Western s6 (~8 KM d/s McLeod River)	5211-D1-01
a0116.wb1	Athabasca	05/08/91	Sentar	Millar Western s7 & 33 k d/s ANC outfall, south bank (ANC 7)	5211-D1-01

File Name	River	Date	Collector	Location	Disk
a0117.wb1	McLeod	10/08/91	Sentar	Millar Western s1	5211-D1-01
a0118.wb1	Athabasca	10/08/91	Sentar	Millar Western s2 & 8.5 k d/s ANC outfall, south bank (ANC 5)	5211-D1-01
a0119.wb1	Athabasca	10/08/91	Sentar	Millar Western s3 (~1.2 km d/s McLeod River)	5211-D1-01
a0120.wb1	Athabasca	10/08/91	Sentar	Millar Western s4 (~2.7 km d/s McLeod River)	5211-D1-01
a0121.wb1	Athabasca	10/08/91	Sentar	Millar Western s4a (~2.2 km d/s McLeod River)	5211-D1-01
a0122.wb1	Athabasca	10/08/91	Sentar	Millar Western s5 & 13 k d/s ANC outfall, south bank (ANC 6)	5211-D1-01
a0123.wb1	Athabasca	10/08/91	Sentar	Millar Western s6 (~8 KM d/s McLeod River)	5211-D1-01
a0124.wb1	Athabasca	10/08/91	Sentar	Millar Western s7 & 33 k d/s ANC outfall, south bank (ANC 7)	5211-D1-01
a0125.wb1	McLeod	04/08/92	Sentar	Millar Western s1	5211-D1-01
a0126.wb1	Athabasca	04/08/92	Sentar	Millar Western s2 & 8.5 k d/s ANC outfall, south bank (ANC 5)	5211-D1-01
a0127.wb1	Athabasca	04/08/92	Sentar	Millar Western s3 (~1.2 km d/s McLeod River)	5211-D1-01
a0128.wb1	Athabasca	04/08/92	Sentar	Millar Western s4 (~2.7 km d/s McLeod River)	5211-D1-01
a0129.wb1	Athabasca	04/08/92	Sentar	Millar Western s4a (~2.2 km d/s McLeod River)	5211-D1-01
a0130.wb1	Athabasca	04/08/92	Sentar	Millar Western s5 & 13 k d/s ANC outfall, south bank (ANC 6)	5211-D1-01
a0131.wb1	Athabasca	04/08/92	Sentar	Millar Western s6 (~8 KM d/s McLeod River)	5211-D1-01
a0132.wb1	Athabasca	04/08/92	Sentar	Millar Western s7 & 33 k d/s ANC outfall, south bank (ANC 7)	5211-D1-01
a0133.wb1	McLeod	10/08/92	Sentar	Millar Western s1	5211-D1-01
a0134.wb1	Athabasca	10/08/92	Sentar	Millar Western s2 & 8.5 k d/s ANC outfall, south bank (ANC 5)	5211-D1-01
a0135.wb1	Athabasca	10/08/92	Sentar	Millar Western s3 (~1.2 km d/s McLeod River)	5211-D1-01
a0136.wb1	Athabasca	10/08/92	Sentar	Millar Western s4 (~2.7 km d/s McLeod River)	5211-D1-01
a0137.wb1	Athabasca	10/08/92	Sentar	Millar Western s4a (~2.2 km d/s McLeod River)	5211-D1-01
a0138.wb1	Athabasca	10/08/92	Sentar	Millar Western s5 & 13 k d/s ANC outfall, south bank (ANC 6)	5211-D1-01
a0139.wb1	Athabasca	10/08/92	Sentar	Millar Western s6 (~8 KM d/s McLeod River)	5211-D1-01
a0140.wb1	Athabasca	10/08/92	Sentar	Millar Western s7 & 33 k d/s ANC outfall, south bank (ANC 7)	5211-D1-01
a0141.wb1	Athabasca	06/07/89	Sentar	2.5 k u/s ANC (ANC 1)	5211-D1-01
a0142.wb1	Athabasca	06/07/89	Sentar	1 k u/s ANC (ANC 2)	5211-D1-01
a0143.wb1	Athabasca	06/07/89	Sentar	1k d/s ANC outfall, north bank (ANC 3)	5211-D1-02
a0144.wb1	Athabasca	06/07/89	Sentar	3km d/s ANC, north bank (ANC 4)	5211-D1-02
a0148.wb1	Athabasca	10/07/89	Sentar	2.5 k u/s ANC (ANC 1)	5211-D1-02

File Name	River	Date	Collector	Location	Disk
a0149.wb1	Athabasca	10/07/89	Sentar	1 k u/s ANC (ANC 2)	5211-D1-02
a0150.wb1	Athabasca	10/07/89	Sentar	1k d/s ANC outfall, north bank (ANC 3)	5211-D1-02
a0151.wb1	Athabasca	10/07/89	Sentar	3km d/s ANC, north bank (ANC 4)	5211-D1-02
a0155.wb1	Athabasca	05/07/90	Sentar	2.5 k u/s ANC (ANC 1)	5211-D1-02
a0156.wb1	Athabasca	05/07/90	Sentar	1 k u/s ANC (ANC 2)	5211-D1-02
a0157.wb1	Athabasca	05/07/90	Sentar	1k d/s ANC outfall, north bank (ANC 3)	5211-D1-02
a0158.wb1	Athabasca	05/07/90	Sentar	3km d/s ANC, north bank (ANC 4)	5211-D1-02
a0162.wb1	Athabasca	10/07/90	Sentar	2.5 k u/s ANC (ANC 1)	5211-D1-02
a0163.wb1	Athabasca	10/07/90	Sentar	1 k u/s ANC (ANC 2)	5211-D1-02
a0164.wb1	Athabasca	10/07/90	Sentar	1k d/s ANC outfall, north bank (ANC 3)	5211-D1-02
a0165.wb1	Athabasca	10/07/90	Sentar	3km d/s ANC, north bank (ANC 4)	5211-D1-02
a0169.wb1	Athabasca	05/07/91	Sentar	2.5 k u/s ANC (ANC 1)	5211-D1-02
a0170.wb1	Athabasca	05/07/91	Sentar	1 k u/s ANC (ANC 2)	5211-D1-02
a0171.wb1	Athabasca	05/07/91	Sentar	1k d/s ANC outfall, north bank (ANC 3)	5211-D1-02
a0172.wb1	Athabasca	05/07/91	Sentar	3km d/s ANC, north bank (ANC 4)	5211-D1-02
a0176.wb1	Athabasca	10/07/91	Sentar	2.5 k u/s ANC (ANC 1)	5211-D1-02
a0177.wb1	Athabasca	10/07/91	Sentar	1 k u/s ANC (ANC 2)	5211-D1-02
a0178.wb1	Athabasca	10/07/91	Sentar	1k d/s ANC outfall, north bank (ANC 3)	5211-D1-02
a0179.wb1	Athabasca	10/07/91	Sentar	3km d/s ANC, north bank (ANC 4)	5211-D1-02
a0183.wb1	Athabasca	04/07/92	Sentar	2.5 k u/s ANC (ANC 1)	5211-D1-02
a0184.wb1	Athabasca	04/07/92	Sentar	1 k u/s ANC (ANC 2)	5211-D1-02
a0185.wb1	Athabasca	04/07/92	Sentar	1k d/s ANC outfall, north bank (ANC 3)	5211-D1-02
a0186.wb1	Athabasca	04/07/92	Sentar	3km d/s ANC, north bank (ANC 4)	5211-D1-02
a0190.wb1	Athabasca	10/07/92	Sentar	2.5 k u/s ANC (ANC 1)	5211-D1-02
a0191.wb1	Athabasca	10/07/92	Sentar	1 k u/s ANC (ANC 2)	5211-D1-02
a0192.wb1	Athabasca	10/07/92	Sentar	1k d/s ANC outfall, north bank (ANC 3)	5211-D1-02
a0193.wb1	Athabasca	10/07/92	Sentar	3km d/s ANC, north bank (ANC 4)	5211-D1-02
a0197.wb1	Athabasca	10/09/91	Alberta Environment	# 1 (5 km d/s of Deep Creek)	5211-D1-02
a0198.wb1	Athabasca	10/09/91	Alberta Environment	# 2 (3 km u/s of ALPAC diffuser)	5211-D1-02

File Name	River	Date	Collector	Location	Disk
a0199.wb1	Athabasca	10/09/91	Alberta Environment	# 3 (1 km d/s of ALPAC diffuser)	5211-D1-02
a0200.wb1	Athabasca	10/10/91	Alberta Environment	# 4 (11 km d/s of ALPAC diffuser)	5211-D1-02
a0201.wb1	Athabasca	10/10/91	Alberta Environment	# 5 (4 km d/s of LaBiche River)	5211-D1-02
a0202.wb1	Athabasca	10/10/91	Alberta Environment	# 6 (3 km d/s of Calling River)	5211-D1-02
a0203.wb1	Lesser Slave	05/16/90	Alberta Environment	# 1 (Mitsue bridge) (0 km) Station 1	5211-D1-05
a0204.wb1	Lesser Slave	05/17/90	Alberta Environment	# 2 (u/s pulpmill)	5211-D1-05
a0205.wb1	Lesser Slave	05/17/90	Alberta Environment	# 3 (d/s of pulpmill)	5211-D1-05
a0206.wb1	Lesser Slave	05/17/90	Alberta Environment	# 4 (150m u/s of Saulteaux River); (17.7 km) Station 37	5211-D1-05
a0207.wb1	Lesser Slave	05/17/90	Alberta Environment	# 5 (u/s of Driftwood River); 24.2 km Station 52	5211-D1-05
a0208.wb1	Lesser Slave	09/12/90	Alberta Environment	# 1 (Mitsue bridge) (0 km) Station 1	5211-D1-05
a0209.wb1	Lesser Slave	09/12/90	Alberta Environment	# 2 (u/s pulpmill)	5211-D1-05
a0210.wb1	Lesser Slave	09/12/90	Alberta Environment	# 3 (d/s of pulpmill)	5211-D1-05
a0211.wb1	Lesser Slave	09/12/90	Alberta Environment	# 4 (150m u/s of Saulteaux River); (17.7 km) Station 37	5211-D1-05
a0212.wb1	Lesser Slave	09/12/90	Alberta Environment	# 5 (u/s of Driftwood River); 24.2 km Station 52	5211-D1-05
a0213.wb1	Wapiti	02/25/91	Alberta Environment	# 1 near HWY 40/O'Brien Park	5211-D1-07
a0214.wb1	Wapiti	02/27/91	Alberta Environment	# 2 just u/s of Grande Prairie STP effluent	5211-D1-07
a0215.wb1	Wapiti	02/26/91	Alberta Environment	# 3 5 km d/s of Grande Prairie STP	5211-D1-07
a0216.wb1	Wapiti	02/27/91	Alberta Environment	# 4 d/s of P&G haul road	5211-D1-07
a0217.wb1	Wapiti	02/25/91	Alberta Environment	# 3 5 km d/s of Grande Prairie STP	5211-D1-07
a0218.wb1	Wapiti	02/26/91	Alberta Environment	# 6 near RR bridge -LB or C	5211-D1-07
a0219.wb1	Wapiti	02/26/91	Alberta Environment	# 7 (5-10 km d/s P&G Effluent)	5211-D1-07
a0220.wb1	Wapiti	02/26/91	Alberta Environment	# 8 - 0.1 km u/s of Bear R	5211-D1-07
a0221.wb1	Wapiti	02/26/91	Alberta Environment	# 9 10 km u/s of mouth	5211-D1-07
a0222.wb1	Wapiti	02/26/91	Alberta Environment	Above Smoky River left bank (W2L)	5211-D1-07
a0223.wb1	Athabasca	05/09/60	Beak	BEAK 1A - About 3 miles (4.8 km) u/s of Hinton	5211-D1-02
a0224.wb1	Athabasca	05/09/60	Beak	Hinton log boom - North side	5211-D1-02
a0225.wb1	Athabasca	05/09/60	Beak	Hinton log boom - South side	5211-D1-02
a0226.wb1	Athabasca	05/09/60	Beak	BEAK 4N - On North Side of River, 1.5 Miles (2.4 km) d/s from outfall	5211-D1-02
a0227.wb1	Athabasca	05/09/60	Beak	BEAK 4S - 1.5 Miles (2.4 km) d/s from outfall on South Side	5211-D1-02

File Name	River	Date	Collector	Location	Disk
a0228.wb1	Athabasca	05/09/60	Beak	BEAK 6S - On South Side of River, 5.0 miles (8.0 km) d/s from outfall	5211-D1-02
a0229.wb1	Athabasca	05/09/60	Beak	South side of Island	5211-D1-02
a0230.wb1	Athabasca	05/09/60	Beak	~14 miles (22.6 km) d/s mill	5211-D1-02
a0231.wb1	Athabasca	05/09/60	Beak	Obed Ferry north side	5211-D1-02
a0232.wb1	Athabasca	05/09/60	Beak	Obed Ferry south side	5211-D1-02
a0233.wb1	Athabasca	05/09/60	Beak	Marlboro	5211-D1-02
a0234.wb1	Athabasca	05/09/60	Beak	North of Edson	5211-D1-02
a0235.wb1	Athabasca	05/09/60	Beak	Windfall Creek	5211-D1-02
a0236.wb1	Athabasca	05/09/60	Beak	Whitecourt Road Bridge	5211-D1-02
a0237.wb1	Athabasca	05/09/60	Beak	Fort Assiniboine	5211-D1-02
a0238.wb1	Athabasca	09/06/72	Beak	9 miles u/s of Hinton, North Bank	5211-D1-02
a0239.wb1	Athabasca	09/06/72	Beak	BEAK 2S - 0.2 Miles (0.3 km) d/s from outfall on South Side	5211-D1-02
a0240.wb1	Athabasca	09/06/72	Beak	BEAK 3N - 0.75 Miles (1.2 km) d/s from outfall on North Side	5211-D1-02
a0241.wb1	Athabasca	09/06/72	Beak	BEAK 4S - 1.5 Miles (2.4 km) d/s from outfall on South Side	5211-D1-02
a0242.wb1	Athabasca	09/06/72	Beak	3.2 miles (5.2 km) d/s of Hinton mill outfall, north side	5211-D1-02
a0243.wb1	Athabasca	09/06/72	Beak	BEAK 6S - On South Side of River, 5.0 miles (8.0 km) d/s from outfall	5211-D1-02
a0244.wb1	Athabasca	09/06/72	Beak	BEAK 8 - 27.5 miles (44.3 km) d/s from outfall	5211-D1-02
a0245.wb1	Athabasca	09/06/72	Beak	BEAK 9 - 57.5 miles (92.5 km) d/s from outfall	5211-D1-02
a0246.wb1	Athabasca	09/06/74	Beak	BEAK 1N - 1.5 Miles (2.4 km) u/s from outfall on North Side	5211-D1-02
a0247.wb1	Athabasca	09/06/74	Beak	BEAK 1S - 1.5 Miles (2.4 km) u/s from outfall on South Side	5211-D1-02
a0248.wb1	Athabasca	09/06/74	Beak	BEAK 2N - 0.2 Miles (0.3 km) d/s from outfall on North Side	5211-D1-02
a0249.wb1	Athabasca	09/06/74	Beak	BEAK 3S - 0.75 Miles (1.2 km) d/s from outfall on South Side	5211-D1-02
a0250.wb1	Athabasca	09/06/74	Beak	BEAK 5N - On north side of River, 3.0 miles (4.8 km) d/s from outfall	5211-D1-02
a0251.wb1	Athabasca	09/06/74	Beak	BEAK 5S - On South Side of River, 3.0 miles (4.8 km) d/s from outfall	5211-D1-02
a0252.wb1	Athabasca	09/06/74	Beak	BEAK 6N - On north side of River, 5.0 miles (8.0 km) d/s from outfall	5211-D1-02
a0253.wb1	Athabasca	09/06/74	Beak	BEAK 2S - 0.2 Miles (0.3 km) d/s from outfall on South Side	5211-D1-02
a0254.wb1	Athabasca	09/06/74	Beak	BEAK 3N - 0.75 Miles (1.2 km) d/s from outfall on North Side	5211-D1-02
a0255.wb1	Athabasca	09/06/74	Beak	BEAK 4N - On North Side of River, 1.5 Miles (2.4 km) d/s from outfall	5211-D1-02
a0256.wb1	Athabasca	09/06/74	Beak	BEAK 4S - 1.5 Miles (2.4 km) d/s from outfall on South Side	5211-D1-02

File Name	River	Date	Collector	Location	Disk
a0257.wb1	Athabasca	09/06/74	Beak	BEAK 6S - On South Side of River, 5.0 miles (8.0 km) d/s from outfall	5211-D1-02
a0258.wb1	Athabasca	09/06/74	Beak	BEAK 7 - 12.5 miles (20.1 km) d/s from outfall	5211-D1-02
a0259.wb1	Athabasca	09/06/74	Beak	BEAK 8 - 27.5 miles (44.3 km) d/s from outfall	5211-D1-02
a0260.wb1	Athabasca	09/06/74	Beak	BEAK 9 - 57.5 miles (92.5 km) d/s from outfall	5211-D1-02
a0261.wb1	Athabasca	10/14/76	Beak	BEAK 1A - About 3 miles (4.8 km) u/s of Hinton	5211-D1-02
a0262.wb1	Athabasca	10/14/76	Beak	BEAK 1B (3.2 km (2 mi) u/s of Hinton mill outfall	5211-D1-02
a0263.wb1	Athabasca	10/14/76	Beak	BEAK 2N - 0.2 Miles (0.3 km) d/s from outfall on North Side	5211-D1-02
a0264.wb1	Athabasca	10/14/76	Beak	BEAK 3N - 0.75 Miles (1.2 km) d/s from outfall on North Side	5211-D1-02
a0265.wb1	Athabasca	10/14/76	Beak	Fish Creek (~1 .5 km d/s of mill outfall)	5211-D1-02
a0266.wb1	Athabasca	10/14/76	Beak	BEAK 4N - On North Side of River, 1.5 Miles (2.4 km) d/s from outfall	5211-D1-02
a0267.wb1	Athabasca	10/14/76	Beak	BEAK 5N - On north side of River, 3.0 miles (4.8 km) d/s from outfall	5211-D1-02
a0268.wb1	Athabasca	10/14/76	Beak	BEAK 6N - On north side of River, 5.0 miles (8.0 km) d/s from outfall	5211-D1-02
a0269.wb1	Athabasca	10/14/76	Beak	BEAK 7 - 12.5 miles (20.1 km) d/s from outfall	5211-D1-02
a0270.wb1	Athabasca	10/14/76	Beak	BEAK 8 - 27.5 miles (44.3 km) d/s from outfall	5211-D1-02
a0271.wb1	Athabasca	10/14/76	Beak	BEAK 9 - 57.5 miles (92.5 km) d/s from outfall	5211-D1-02
a0272.wb1	Athabasca	05/19/77	Beak	BEAK 1A - About 3 miles (4.8 km) u/s of Hinton	5211-D1-02
a0273.wb1	Athabasca	05/19/77	Beak	BEAK 1B (3.2 km (2 mi) u/s of Hinton mill outfall	5211-D1-02
a0274.wb1	Athabasca	05/19/77	Beak	BEAK 2N - 0.2 Miles (0.3 km) d/s from outfall on North Side	5211-D1-02
a0275.wb1	Athabasca	05/19/77	Beak	BEAK 3N - 0.75 Miles (1.2 km) d/s from outfall on North Side	5211-D1-02
a0276.wb1	Athabasca	05/19/77	Beak	BEAK 5N - On north side of River, 3.0 miles (4.8 km) d/s from outfall	5211-D1-02
a0277.wb1	Athabasca	05/19/77	Beak	BEAK 6N - On north side of River, 5.0 miles (8.0 km) d/s from outfall	5211-D1-02
a0278.wb1	Athabasca	05/19/77	Beak	BEAK 7 - 12.5 miles (20.1 km) d/s from outfall	5211-D1-02
a0279.wb1	Athabasca	05/19/77	Beak	BEAK 8 - 27.5 miles (44.3 km) d/s from outfall	5211-D1-02
a0280.wb1	Athabasca	10/23/79	Beak	BEAK 1A - About 3 miles (4.8 km) u/s of Hinton	5211-D1-02
a0281.wb1	Athabasca	10/23/79	Beak	BEAK 1B (3.2 km (2 mi) u/s of Hinton mill outfall	5211-D1-02
a0282.wb1	Athabasca	10/23/79	Beak	BEAK 2N - 0.2 Miles (0.3 km) d/s from outfall on North Side	5211-D1-02
a0283.wb1	Athabasca	10/23/79	Beak	BEAK 3N - 0.75 Miles (1.2 km) d/s from outfall on North Side	5211-D1-02
a0284.wb1	Athabasca	10/23/79	Beak	BEAK 4N - On North Side of River, 1.5 Miles (2.4 km) d/s from outfall	5211-D1-02
a0285.wb1	Athabasca	10/23/79	Beak	BEAK 5N - On north side of River, 3.0 miles (4.8 km) d/s from outfall	5211-D1-02

File Name	River	Date	Collector	Location	Disk
a0286.wb1	Athabasca	10/23/79	Beak	BEAK 6N - On north side of River, 5.0 miles (8.0 km) d/s from outfall	5211-D1-02
a0287.wb1	Athabasca	10/23/79	Beak	BEAK 7 - 12.5 miles (20.1 km) d/s from outfall	5211-D1-02
a0288.wb1	Athabasca	10/23/79	Beak	BEAK 8 - 27.5 miles (44.3 km) d/s from outfall	5211-D1-02
a0289.wb1	Athabasca	04/26/84	Integrated Env. Sci.	IES 1A - 4.7 km u/s outfall	5211-D1-02
a0290.wb1	Athabasca	04/26/84	Integrated Env. Sci.	IES 1B d/s Happy Cr. (0.5 km u/s outfall)	5211-D1-02
a0291.wb1	Athabasca	04/26/84	Integrated Env. Sci.	IES 2 Hardisty Cr. (0.6 km d/s outfall)	5211-D1-02
a0292.wb1	Athabasca	04/26/84	Integrated Env. Sci.	IES 3 upstream of Fish Creek (1.5 km d/s outfall)	5211-D1-02
a0293.wb1	Athabasca	04/26/84	Integrated Env. Sci.	IES 4 u/s Centre Cr. (2.7 km d/s outfall)	5211-D1-02
a0294.wb1	Athabasca	04/26/84	Integrated Env. Sci.	IES/TAEM 5 d/s Tiecamp Cr. (6.3 km d/s outfall)	5211-D1-02
a0295.wb1	Athabasca	04/26/84	Integrated Env. Sci.	IES/TAEM 6 d/s Trail Cr. (9 km d/s outfall)	5211-D1-02
a0296.wb1	Athabasca	04/26/84	Integrated Env. Sci.	Beak 8; IES 7 between Baseline Cr. and Panaka Cr. (21 km d/s outfall)	5211-D1-02
a0297.wb1	Athabasca	04/26/84	Integrated Env. Sci.	IES 8 - 43 km d/s outfall	5211-D1-02
a0298.wb1	Athabasca	04/08/86	Integrated Env. Sci.	IES 1A - 4.7 km u/s outfall	5211-D1-02
a0299.wb1	Athabasca	04/08/86	Integrated Env. Sci.	IES 1B d/s Happy Cr. (0.5 km u/s outfall)	5211-D1-02
a0300.wb1	Athabasca	04/08/86	Integrated Env. Sci.	IES 2 Hardisty Cr. (0.6 km d/s outfall)	5211-D1-02
a0301.wb1	Athabasca	04/08/86	Integrated Env. Sci.	IES 3 upstream of Fish Creek (1.5 km d/s outfall)	5211-D1-02
a0302.wb1	Athabasca	04/08/86	Integrated Env. Sci.	IES 4 u/s Centre Cr. (2.7 km d/s outfall)	5211-D1-02
a0303.wb1	Athabasca	04/08/86	Integrated Env. Sci.	IES/TAEM 5 d/s Tiecamp Cr. (6.3 km d/s outfall)	5211-D1-02
a0304.wb1	Athabasca	04/08/86	Integrated Env. Sci.	IES/TAEM 6 d/s Trail Cr. (9 km d/s outfall)	5211-D1-02
a0305.wb1	Athabasca	04/08/86	Integrated Env. Sci.	Beak 8; IES 7 between Baseline Cr. and Panaka Cr. (21 km d/s outfall)	5211-D1-02
a0306.wb1	Athabasca	04/08/86	Integrated Env. Sci.	IES 8 - 43 km d/s outfall	5211-D1-02
a0307.wb1	Athabasca	04/25/89	TAEM	IES 1A - 4.7 km u/s outfall	5211-D1-02
a0308.wb1	Athabasca	04/25/89	TAEM	IES 1B d/s Happy Cr. (0.5 km u/s outfall)	5211-D1-02
a0309.wb1	Athabasca	04/25/89	TAEM	TAEM 1C - 0.8 km u/s outfall	5211-D1-02
a0310.wb1	Athabasca	04/25/89	TAEM	IES 2 Hardisty Cr. (0.6 km d/s outfall)	5211-D1-02
a0311.wb1	Athabasca	04/25/89	TAEM	IES/TAEM 5 d/s Tiecamp Cr. (6.3 km d/s outfall)	5211-D1-02
a0312.wb1	Athabasca	04/25/89	TAEM	IES/TAEM 6 d/s Trail Cr. (9 km d/s outfall)	5211-D1-02
a0313.wb1	Athabasca	04/25/89	TAEM	Beak 8; IES 7 between Baseline Cr. and Panaka Cr. (21 km d/s outfall)	5211-D1-02
a0314.wb1	Athabasca	04/25/89	TAEM	IES 8 - 43 km d/s outfall	5211-D1-02

File Name	River	Date	Collector	Location	Disk
a0315.wb1	Athabasca	10/11/90	TAEM	TAEM 1A - 2.1 km u/s outfall	5211-D1-02
a0316.wb1	Athabasca	10/11/90	TAEM	TAEM 1B - 5.8 km u/s outfall	5211-D1-02
a0317.wb1	Athabasca	10/11/90	TAEM	TAEM 1C - 0.8 km u/s outfall	5211-D1-02
a0318.wb1	Athabasca	10/11/90	TAEM	TAEM 2 - 0.8 km d/s outfall, mid-channel	5211-D1-02
a0319.wb1	Athabasca	10/11/90	TAEM	TAEM 4 - 3.6 km u/s outfall	5211-D1-02
a0320.wb1	Athabasca	10/11/90	TAEM	IES/TAEM 5 d/s Tiecamp Cr. (6.3 km d/s outfall)	5211-D1-02
a0321.wb1	Athabasca	10/11/90	TAEM	IES/TAEM 6 d/s Trail Cr. (9 km d/s outfall)	5211-D1-02
a0322.wb1	Athabasca	10/11/90	TAEM	TAEM 7 - 22 km d/s outfall	5211-D1-02
a0323.wb1	Athabasca	10/11/90	TAEM	TAEM 8 - 44 km km u/s outfall, left side	5211-D1-02
a0324.wb1	Athabasca	04/18/91	TAEM	TAEM 1A - 2.1 km u/s outfall	5211-D1-02
a0325.wb1	Athabasca	04/18/91	TAEM	TAEM 1B - 5.8 km u/s outfall	5211-D1-02
a0326.wb1	Athabasca	04/18/91	TAEM	TAEM 1C - 0.8 km u/s outfall	5211-D1-02
a0327.wb1	Athabasca	04/18/91	TAEM	TAEM 2 - 0.8 km d/s outfall, mid-channel	5211-D1-02
a0328.wb1	Athabasca	04/18/91	TAEM	TAEM 4 - 3.6 km u/s outfall	5211-D1-02
a0329.wb1	Athabasca	04/18/91	TAEM	IES/TAEM 5 d/s Tiecamp Cr. (6.3 km d/s outfall)	5211-D1-02
a0330.wb1	Athabasca	04/18/91	TAEM	IES/TAEM 6 d/s Trail Cr. (9 km d/s outfall)	5211-D1-02
a0331.wb1	Athabasca	04/18/91	TAEM	TAEM 7 - 22 km d/s outfall	5211-D1-02
a0332.wb1	Athabasca	04/18/91	TAEM	TAEM 8 - 44 km km u/s outfall, left side	5211-D1-02
a0333.wb1	Athabasca	04/15/92	TAEM	TAEM 1A - 2.1 km u/s outfall	5211-D1-02
a0334.wb1	Athabasca	04/15/92	TAEM	TAEM 1B - 5.8 km u/s outfall	5211-D1-02
a0335.wb1	Athabasca	04/15/92	TAEM	TAEM 1C - 0.8 km u/s outfall	5211-D1-02
a0336.wb1	Athabasca	04/15/92	TAEM	TAEM 2 - 0.8 km d/s outfall, mid-channel	5211-D1-02
a0337.wb1	Athabasca	04/15/92	TAEM	TAEM 4 - 3.6 km u/s outfall	5211-D1-02
a0338.wb1	Athabasca	04/15/92	TAEM	IES/TAEM 5 d/s Tiecamp Cr. (6.3 km d/s outfall)	5211-D1-02
a0339.wb1	Athabasca	04/15/92	TAEM	IES/TAEM 6 d/s Trail Cr. (9 km d/s outfall)	5211-D1-02
a0340.wb1	Athabasca	04/15/92	TAEM	TAEM 7 - 22 km d/s outfall	5211-D1-02
a0341.wb1	Athabasca	04/15/92	TAEM	TAEM 8 - 44 km km u/s outfall, left side	5211-D1-02
a0342.wb1	Athabasca	10/22/92	TAEM	TAEM 1A - 2.1 km u/s outfall	5211-D1-02
a0343.wb1	Athabasca	10/22/92	TAEM	TAEM 1B - 5.8 km u/s outfall	5211-D1-02

File Name	River	Date	Collector	Location	Disk
a0344.wb1	Athabasca	10/22/92	TAEM	TAEM 1C - 0.8 km u/s outfall	5211-D1-02
a0345.wb1	Athabasca	10/22/92	TAEM	TAEM 2 - 0.8 km d/s outfall, mid-channel	5211-D1-02
a0346.wb1	Athabasca	10/22/92	TAEM	TAEM 4 - 3.6 km u/s outfall	5211-D1-02
a0347.wb1	Athabasca	10/22/92	TAEM	IES/TAEM 5 d/s Tiecamp Cr. (6.3 km d/s outfall)	5211-D1-02
a0348.wb1	Athabasca	10/22/92	TAEM	IES/TAEM 6 d/s Trail Cr. (9 km d/s outfall)	5211-D1-02
a0349.wb1	Athabasca	10/22/92	TAEM	TAEM 7 - 22 km d/s outfall	5211-D1-03
a0350.wb1	Athabasca	10/22/92	TAEM	TAEM 8 - 44 km km u/s outfall, left side	5211-D1-03
a0351.wb1	Athabasca	05/19/83	Alberta Environment	Upstream of Hinton (above Old Entrance) right bank	5211-D1-03
a0352.wb1	Athabasca	09/12/83	Alberta Environment	Upstream of Hinton (above Old Entrance) right bank	5211-D1-03
a0353.wb1	Athabasca	05/16/84	Alberta Environment	Upstream of Hinton (above Old Entrance) left bank	5211-D1-03
a0354.wb1	Athabasca	05/16/84	Alberta Environment	Upstream of Hinton (above Old Entrance) right bank	5211-D1-03
a0355.wb1	Athabasca	06/12/85	Alberta Environment	Upstream of Hinton (above Old Entrance) right bank	5211-D1-03
a0356.wb1	Athabasca	10/09/85	Alberta Environment	Upstream of Hinton (above Old Entrance) left bank	5211-D1-03
a0357.wb1	Athabasca	10/09/85	Alberta Environment	Upstream of Hinton (above Old Entrance) right bank	5211-D1-03
a0358.wb1	Athabasca	05/21/86	Alberta Environment	Upstream of Hinton (above Old Entrance) right bank	5211-D1-03
a0359.wb1	Athabasca	09/02/86	Alberta Environment	Upstream of Hinton (above Old Entrance) right bank	5211-D1-03
a0360.wb1	Athabasca	05/27/87	Alberta Environment	Upstream of Hinton (above Old Entrance) right bank	5211-D1-03
a0361.wb1	Athabasca	09/09/87	Alberta Environment	Upstream of Hinton (above Old Entrance) right bank	5211-D1-03
a0362.wb1	Athabasca	05/19/83	Alberta Environment	d/s Hinton 1 km bridge right bank	5211-D1-03
a0363.wb1	Athabasca	09/12/83	Alberta Environment	d/s Hinton 1 km bridge right bank	5211-D1-03
a0364.wb1	Athabasca	05/16/84	Alberta Environment	d/s Hinton 1 km bridge left bank	5211-D1-03
a0365.wb1	Athabasca	05/16/84	Alberta Environment	d/s Hinton 1 km bridge right bank	5211-D1-03
a0366.wb1	Athabasca	06/12/85	Alberta Environment	d/s Hinton 1 km bridge right bank	5211-D1-03
a0367.wb1	Athabasca	10/08/85	Alberta Environment	d/s Hinton 1 km bridge right bank	5211-D1-03
a0368.wb1	Athabasca	10/08/85	Alberta Environment	d/s Hinton 1 km bridge left bank	5211-D1-03
a0369.wb1	Athabasca	05/21/86	Alberta Environment	d/s Hinton 1 km bridge right bank	5211-D1-03
a0370.wb1	Athabasca	09/02/86	Alberta Environment	d/s Hinton 1 km bridge right bank	5211-D1-03
a0371.wb1	Athabasca	05/27/87	Alberta Environment	d/s Hinton 1 km bridge right bank	5211-D1-03
a0372.wb1	Athabasca	09/09/87	Alberta Environment	d/s Hinton 1 km bridge right bank	5211-D1-03

File Name	River	Date	Collector	Location	Disk
a0373.wb1	Athabasca	10/09/85	Alberta Environment	6 km d/s of Hinton right bank	5211-D1-03
a0374.wb1	Athabasca	10/09/85	Alberta Environment	6 km d/s of Hinton right bank	5211-D1-03
a0375.wb1	Athabasca	05/16/84	Alberta Environment	d/s Hinton 20 km Bridge right bank	5211-D1-03
a0376.wb1	Athabasca	05/16/84	Alberta Environment	d/s Hinton 20 km Bridge left bank	5211-D1-03
a0377.wb1	Athabasca	06/12/85	Alberta Environment	d/s Hinton 20 km Bridge right bank	5211-D1-03
a0378.wb1	Athabasca	10/08/85	Alberta Environment	d/s Hinton 20 km Bridge right bank	5211-D1-03
a0379.wb1	Athabasca	10/08/85	Alberta Environment	d/s Hinton 20 km Bridge left bank	5211-D1-03
a0380.wb1	Athabasca	10/08/85	Alberta Environment	30 km d/s of Hinton left bank	5211-D1-03
a0381.wb1	Athabasca	05/15/84	Alberta Environment	50 km d/s of Hinton right bank	5211-D1-03
a0382.wb1	Athabasca	05/15/84	Alberta Environment	50 km d/s of Hinton left bank	5211-D1-03
a0383.wb1	Athabasca	10/07/85	Alberta Environment	50 km d/s of Hinton right bank	5211-D1-03
a0384.wb1	Athabasca	10/07/85	Alberta Environment	50 km d/s of Hinton left bank	5211-D1-03
a0385.wb1	Athabasca	03/02/93	R.L.&L Environmental	Station 1A - 0.2 km u/s Maskuta Creek (Entrance)	5211-D1-03
a0386.wb1	Athabasca	02/24/93	R.L.&L Environmental	IES 4 u/s Centre Cr. (2.7 km d/s outfall)	5211-D1-03
a0387.wb1	Athabasca	02/28/93	R.L.&L Environmental	Obed Mtn. Coal Bridge - OB	5211-D1-03
a0388.wb1	Athabasca	03/07/93	R.L.&L Environmental	2 km d/s Emerson Lakes Road Bridge - AREL ~50 km d/s Weldwood outfall	5211-D1-03
a0389.wb1	Athabasca	03/13/93	R.L.&L Environmental	Blue Ridge left bank	5211-D1-03
a0390.wb1	Athabasca	03/13/93	R.L.&L Environmental	Blue Ridge right bank	5211-D1-03
a0391.wb1	Athabasca	03/18/93	R.L.&L Environmental	d/s Athabasca Town right bank	5211-D1-03
a0392.wb1	Athabasca	03/21/93	R.L.&L Environmental	d/s Athabasca Town left bank	5211-D1-03
a0393.wb1	Athabasca	03/20/93	R.L.&L Environmental	u/s Athabasca Town	5211-D1-03
a0394.wb1	Athabasca	03/23/93	R.L.&L Environmental	Poacher's Landing	5211-D1-03
a0395.wb1	Athabasca	03/26/93	R.L.&L Environmental	u/s Ft. McMurray	5211-D1-03
a0396.wb1	Athabasca	08/27/85	Alberta Environment	Upstream of Athabasca left bank	5211-D1-03
a0397.wb1	Athabasca	08/27/85	Alberta Environment	Upstream of Athabasca right bank	5211-D1-03
a0398.wb1	Athabasca	08/27/85	Alberta Environment	0.5 km d/s of Athabasca left bank	5211-D1-03
a0399.wb1	Athabasca	08/27/85	Alberta Environment	0.5 km d/s of Athabasca right bank	5211-D1-03
a0400.wb1	Athabasca	08/27/85	Alberta Environment	1.5 km d/s of Athabasca left bank	5211-D1-03
a0401.wb1	Athabasca	08/27/85	Alberta Environment	1.5 km d/s of Athabasca right bank	5211-D1-03

File Name	River	Date	Collector	Location	Disk
a0402.wb1	Athabasca	08/27/85	Alberta Environment	2.5 km d/s of Athabasca left bank	5211-D1-03
a0403.wb1	Athabasca	08/27/85	Alberta Environment	2.5 km d/s of Athabasca right bank	5211-D1-03
a0404.wb1	Athabasca	08/27/85	Alberta Environment	3.5 km d/s of Athabasca left bank	5211-D1-03
a0405.wb1	Athabasca	08/27/85	Alberta Environment	3.5 km d/s of Athabasca right bank	5211-D1-03
a0406.wb1	Athabasca	05/26/83	Alberta Environment	(100 m) Upstream of Horse River (Fort McMurray)	5211-D1-03
a0407.wb1	Athabasca	09/22/83	Alberta Environment	(100 m) Upstream of Horse River (Fort McMurray)	5211-D1-03
a0408.wb1	Athabasca	05/15/84	Alberta Environment	(100 m) Upstream of Horse River (Fort McMurray)	5211-D1-03
a0409.wb1	Athabasca	09/11/84	Alberta Environment	(100 m) Upstream of Horse River (Fort McMurray)	5211-D1-03
a0410.wb1	Athabasca	05/27/85	Alberta Environment	(100 m) Upstream of Horse River (Fort McMurray)	5211-D1-03
a0411.wb1	Athabasca	09/09/85	Alberta Environment	(100 m) Upstream of Horse River (Fort McMurray)	5211-D1-03
a0412.wb1	Athabasca	05/29/86	Alberta Environment	(100 m) Upstream of Horse River (Fort McMurray)	5211-D1-03
a0413.wb1	Athabasca	09/04/86	Alberta Environment	(100 m) Upstream of Horse River (Fort McMurray)	5211-D1-03
a0414.wb1	Athabasca	06/04/87	Alberta Environment	(100 m) Upstream of Horse River (Fort McMurray)	5211-D1-03
a0415.wb1	Athabasca	08/31/87	Alberta Environment	(100 m) Upstream of Horse River (Fort McMurray)	5211-D1-03
a0416.wb1	Athabasca	08/31/87	Alberta Environment	0.5 km u/s of Ft. McMurray STP left bank	5211-D1-03
a0417.wb1	Athabasca	08/31/87	Alberta Environment	0.1 km d/s of Ft. McMurray STP left bank	5211-D1-03
a0418.wb1	Athabasca	08/31/87	Alberta Environment	1.0 km d/s of Ft. McMurray STP left bank	5211-D1-03
a0419.wb1	Athabasca	08/31/87	Alberta Environment	10.0 km d/s of Ft. McMurray STP left bank	5211-D1-03
a0420.wb1	Athabasca	05/24/83	Alberta Environment	At Embarras WSC gauge	5211-D1-03
a0421.wb1	Athabasca	09/19/83	Alberta Environment	At Embarras WSC gauge	5211-D1-03
a0422.wb1	Athabasca	05/16/84	Alberta Environment	At Embarras WSC gauge	5211-D1-03
a0423.wb1	Athabasca	09/11/84	Alberta Environment	At Embarras WSC gauge	5211-D1-03
a0424.wb1	Athabasca	05/27/85	Alberta Environment	At Embarras WSC gauge	5211-D1-03
a0425.wb1	Athabasca	09/09/85	Alberta Environment	At Embarras WSC gauge	5211-D1-03
a0426.wb1	Athabasca	05/29/86	Alberta Environment	At Embarras WSC gauge	5211-D1-03
a0427.wb1	Athabasca	09/04/86	Alberta Environment	At Embarras WSC gauge	5211-D1-03
a0428.wb1	Athabasca	06/04/87	Alberta Environment	At Embarras WSC gauge	5211-D1-03
a0429.wb1	Athabasca	09/29/87	Alberta Environment	At Embarras WSC gauge	5211-D1-03
a0430.wb1	Smoky	05/10/83	Alberta Environment	Upstream Wapiti River left bank (S1)	5211-D1-04

File Name	River	Date	Collector	Location	Disk
a0431.wb1	Smoky	05/10/83	Alberta Environment	0.1 km u/s Wapiti River right bank (S1)	5211-D1-04
a0432.wb1	Smoky	09/27/83	Alberta Environment	Upstream Wapiti River left bank (S1)	5211-D1-04
a0433.wb1	Smoky	09/27/83	Alberta Environment	0.1 km u/s Wapiti River right bank (S1)	5211-D1-04
a0434.wb1	Smoky	05/10/83	Alberta Environment	Above Simonette River left bank (S2)	5211-D1-04
a0435.wb1	Smoky	05/10/83	Alberta Environment	Above Simonette River right bank (S2)	5211-D1-04
a0436.wb1	Smoky	09/27/83	Alberta Environment	Above Simonette River left bank (S2)	5211-D1-04
a0437.wb1	Smoky	09/27/83	Alberta Environment	Above Simonette River right bank (S2)	5211-D1-04
a0438.wb1	Smoky	05/09/83	Alberta Environment	At Bezanson Bridge (Highway 34) left bank (S3L)	5211-D1-04
a0439.wb1	Smoky	05/09/83	Alberta Environment	At Bezanson Bridge (Highway 34) right bank (S3R)	5211-D1-04
a0440.wb1	Smoky	09/27/83	Alberta Environment	At Bezanson Bridge (Highway 34) left bank (S3L)	5211-D1-04
a0441.wb1	Smoky	09/27/83	Alberta Environment	At Bezanson Bridge (Highway 34) right bank (S3R)	5211-D1-04
a0442.wb1	Smoky	05/11/83	Alberta Environment	d/s Bad Heart River left bank (S4)	5211-D1-04
a0443.wb1	Smoky	05/11/83	Alberta Environment	d/s Bad Heart River right bank (S4)	5211-D1-04
a0444.wb1	Smoky	09/28/83	Alberta Environment	d/s Bad Heart River left bank (S4)	5211-D1-04
a0445.wb1	Smoky	09/28/83	Alberta Environment	d/s Bad Heart River right bank (S4)	5211-D1-04
a0446.wb1	Smoky	05/11/83	Alberta Environment	At Watino left bank (S5)	5211-D1-04
a0447.wb1	Smoky	05/11/83	Alberta Environment	At Watino right bank (S5)	5211-D1-04
a0448.wb1	Smoky	09/28/83	Alberta Environment	At Watino left bank (S5)	5211-D1-04
a0449.wb1	Smoky	09/28/83	Alberta Environment	At Watino right bank (S5)	5211-D1-04
a0450.wb1	Smoky	05/11/83	Alberta Environment	Halfway from Watino to mouth left bank (S6)	5211-D1-04
a0451.wb1	Smoky	05/11/83	Alberta Environment	Halfway from Watino to mouth right bank (S6)	5211-D1-04
a0452.wb1	Smoky	09/28/83	Alberta Environment	Halfway from Watino to mouth left bank (S6)	5211-D1-04
a0453.wb1	Smoky	09/28/83	Alberta Environment	Halfway from Watino to mouth right bank (S6)	5211-D1-04
a0454.wb1	Smoky	05/11/83	Alberta Environment	At mouth left bank (S7)	5211-D1-04
a0455.wb1	Smoky	05/11/83	Alberta Environment	At mouth right bank (S7)	5211-D1-04
a0456.wb1	Smoky	09/28/83	Alberta Environment	At mouth left bank (S7)	5211-D1-04
a0457.wb1	Smoky	09/28/83	Alberta Environment	At mouth right bank (S7)	5211-D1-04
a0458.wb1	Wapiti	05/10/83	Alberta Environment	Upstream of O'Brien Park (HW440) left bank (W1)	5211-D1-07
a0459.wb1	Wapiti	05/10/83	Alberta Environment	Upstream of O'Brien Park (HW440) right bank (W1)	5211-D1-07

File Name	River	Date	Collector	Location	Disk
a0460.wb1	Wapiti	09/27/83	Alberta Environment	Upstream of O'Brien Park (HW440) right bank (W1)	5211-D1-07
a0461.wb1	Wapiti	09/27/83	Alberta Environment	Upstream of O'Brien Park (HW440) right bank (W1)	5211-D1-07
a0462.wb1	Wapiti	05/10/83	Alberta Environment	Above Smoky River left bank (W2L)	5211-D1-07
a0463.wb1	Wapiti	05/10/83	Alberta Environment	Above Smoky River right bank (W2R)	5211-D1-07
a0464.wb1	Wapiti	09/27/83	Alberta Environment	Above Smoky River left bank (W2L)	5211-D1-07
a0465.wb1	Wapiti	09/27/83	Alberta Environment	Above Smoky River right bank (W2R)	5211-D1-07
a0466.wb1	Peace	05/26/87	Alberta Environment	Border left bank	5211-D1-06
a0467.wb1	Peace	05/26/87	Alberta Environment	Border right bank	5211-D1-06
a0468.wb1	Peace	09/27/83	Alberta Environment	Border left bank	5211-D1-06
a0469.wb1	Peace	09/27/83	Alberta Environment	Border right bank	5211-D1-06
a0470.wb1	Peace	07/21/88	Alberta Environment	Border left bank	5211-D1-06
a0471.wb1	Peace	07/21/88	Alberta Environment	Border right bank	5211-D1-06
a0472.wb1	Peace	10/03/88	Alberta Environment	Border left bank	5211-D1-06
a0473.wb1	Peace	10/03/88	Alberta Environment	Border right bank	5211-D1-06
a0474.wb1	Peace	05/26/87	Alberta Environment	0.25 km u/s of Clear River left bank	5211-D1-06
a0475.wb1	Peace	05/27/87	Alberta Environment	0.25 km u/s of Clear River right bank	5211-D1-06
a0476.wb1	Peace	09/28/87	Alberta Environment	0.25 km u/s of Clear River left bank	5211-D1-06
a0477.wb1	Peace	09/28/87	Alberta Environment	0.25 km u/s of Clear River right bank	5211-D1-06
a0478.wb1	Peace	09/28/87	Alberta Environment	4.2 km u/s of Clear River centre	5211-D1-06
a0479.wb1	Peace	07/21/88	Alberta Environment	0.25 km u/s of Clear River left bank	5211-D1-06
a0480.wb1	Peace	07/21/88	Alberta Environment	0.25 km u/s of Clear River right bank	5211-D1-06
a0481.wb1	Peace	09/27/88	Alberta Environment	0.25 km u/s of Clear River left bank	5211-D1-06
a0482.wb1	Peace	09/27/88	Alberta Environment	0.25 km u/s of Clear River right bank	5211-D1-06
a0483.wb1	Peace	09/27/88	Alberta Environment	4.2 km u/s of Clear River centre	5211-D1-06
a0484.wb1	Peace	05/12/83	Alberta Environment	At Dunvegan	5211-D1-06
a0485.wb1	Peace	09/29/83	Alberta Environment	At Dunvegan	5211-D1-06
a0486.wb1	Peace	05/12/83	Alberta Environment	Above Smoky River left bank (P1)	5211-D1-06
a0487.wb1	Peace	05/12/83	Alberta Environment	Above Smoky River right bank (P1)	5211-D1-06
a0488.wb1	Peace	09/29/83	Alberta Environment	Above Smoky River left bank (P1)	5211-D1-06

File Name	River	Date	Collector	Location	Disk
a0489.wb1	Peace	09/29/83	Alberta Environment	Above Smoky River right bank (P1)	5211-D1-06
a0490.wb1	Peace	05/12/83	Alberta Environment	At Peace River above Heart River left bank (P2)	5211-D1-06
a0491.wb1	Peace	05/12/83	Alberta Environment	At Peace River above Heart River right bank (P2)	5211-D1-06
a0492.wb1	Peace	09/29/83	Alberta Environment	At Peace River above Heart River left bank (P2)	5211-D1-06
a0493.wb1	Peace	09/29/83	Alberta Environment	At Peace River above Heart River right bank (P2)	5211-D1-06
a0494.wb1	Peace	07/27/88	Alberta Environment	(B1R) 4 km u/s Daishowa pulpmill	5211-D1-06
a0495.wb1	Peace	10/04/88	Alberta Environment	(B1R) 4 km u/s Daishowa pulpmill	5211-D1-06
a0496.wb1	Peace	07/27/88	Alberta Environment	(B1L) 3 km u/s Daishowa pulpmill	5211-D1-06
a0497.wb1	Peace	10/04/88	Alberta Environment	(B1L) 3 km u/s Daishowa pulpmill	5211-D1-06
a0498.wb1	Peace	07/26/88	Alberta Environment	(B2R) 2 km d/s Daishowa pulpmill	5211-D1-06
a0499.wb1	Peace	10/04/88	Alberta Environment	(B2R) 2 km d/s Daishowa pulpmill	5211-D1-06
a0500.wb1	Peace	07/27/88	Alberta Environment	(B2L) 5 km d/s Daishowa pulpmill	5211-D1-06
a0501.wb1	Peace	10/04/88	Alberta Environment	(B2L) 5 km d/s Daishowa pulpmill	5211-D1-06
a0502.wb1	Peace	07/27/88	Alberta Environment	(B2C) 7 km d/s Daishowa pulpmill	5211-D1-06
a0503.wb1	Peace	10/04/88	Alberta Environment	(B2C) 7 km d/s Daishowa pulpmill	5211-D1-06
a0504.wb1	Peace	07/26/88	Alberta Environment	(B3L) 17 km d/s Daishowa pulpmill	5211-D1-06
a0505.wb1	Peace	10/04/88	Alberta Environment	(B3L) 17 km d/s Daishowa pulpmill	5211-D1-06
a0506.wb1	Peace	07/26/88	Alberta Environment	(B3R) 20 km d/s Daishowa pulpmill	5211-D1-06
a0507.wb1	Peace	10/04/88	Alberta Environment	(B3R) 20 km d/s Daishowa pulpmill	5211-D1-06
a0508.wb1	Peace	07/26/88	Alberta Environment	(B4R) 32 km d/s Daishowa pulpmill	5211-D1-06
a0509.wb1	Peace	10/04/88	Alberta Environment	(B4R) 32 km d/s Daishowa pulpmill	5211-D1-06
a0510.wb1	Peace	07/26/88	Alberta Environment	(B4C) 33 km d/s Daishowa Pulpmill	5211-D1-06
a0511.wb1	Peace	10/04/88	Alberta Environment	(B4C) 33 km d/s Daishowa Pulpmill	5211-D1-06
a0512.wb1	Peace	07/26/88	Alberta Environment	(B4L) 35 km d/s Daishowa Pulpmill	5211-D1-06
a0513.wb1	Peace	10/04/88	Alberta Environment	(B4L) 35 km d/s Daishowa Pulpmill	5211-D1-06
a0514.wb1	Peace	09/27/88	Alberta Environment	Dunvegan left bank	5211-D1-06
a0515.wb1	Peace	10/05/88	Alberta Environment	Above Smoky River	5211-D1-06
a0516.wb1	Peace	09/28/88	Alberta Environment	Above Notikewin River	5211-D1-06
a0517.wb1	Peace	09/28/88	Alberta Environment	Near Carcajou centre	5211-D1-06

File Name	River	Date	Collector	Location	Disk
a0518.wb1	Peace	09/28/88	Alberta Environment	Near LaCrete	5211-D1-06
a0519.wb1	Peace	09/29/88	Alberta Environment	At Fort Vermillion	5211-D1-06
a0520.wb1	Peace	09/29/88	Alberta Environment	Above Wood Buffalo Park	5211-D1-06
a0521.wb1	Peace	09/29/88	Alberta Environment	Near Peace Point centre	5211-D1-06
a0522.wb1	Any River	10/13/70	Beak	Blank Site for unspecified locations	5211-D1-08
a0523.wb1	Any River	10/13/70	Beak	Blank Site for unspecified locations	5211-D1-08
a0524.wb1	Any River	10/13/70	Beak	Blank Site for unspecified locations	5211-D1-08
a0525.wb1	Any River	10/13/70	Beak	Blank Site for unspecified locations	5211-D1-08
a0526.wb1	Any River	10/13/70	Beak	Blank Site for unspecified locations	5211-D1-08
a0527.wb1	Any River	10/13/70	Beak	Blank Site for unspecified locations	5211-D1-08
a0528.wb1	Wapiti	06/15/72	Beak	Station 1(N) - 2.3 mi (3.7 km) u/s Grande Prairie STP	5211-D1-08
a0529.wb1	Wapiti	06/15/72	Beak	Station 2(N) / Wapiti 2 - 0.2 mi (0.3 km) d/s PMO	5211-D1-08
a0530.wb1	Wapiti	06/15/72	Beak	Station 3 (1972-1985) 4.3 km d/s PMO	5211-D1-08
a0531.wb1	Wapiti	06/15/72	Beak	Station O3 (=4) 13.5 km d/s PMO - right/north side	5211-D1-08
a0532.wb1	Wapiti	06/15/72	Beak	Station O4 (=5) 24 km d/s PMO - center	5211-D1-08
a0533.wb1	Wapiti	06/15/72	Beak	Station O5 (=6) 29 km d/s PMO - center	5211-D1-08
a0534.wb1	Wapiti	06/15/72	Beak	Station 2(N) / Wapiti 2 - 0.2 mi (0.3 km) d/s PMO	5211-D1-08
a0535.wb1	Wapiti	06/15/72	Beak	Station O4 (=5) 24 km d/s PMO - center	5211-D1-08
a0536.wb1	Wapiti	06/15/72	Beak	Station 1(N) - 2.3 mi (3.7 km) u/s Grande Prairie STP	5211-D1-08
a0537.wb1	Wapiti	06/15/72	Beak	Station 2(N) / Wapiti 2 - 0.2 mi (0.3 km) d/s PMO	5211-D1-08
a0538.wb1	Wapiti	06/15/72	Beak	Station 3 (1972-1985) 4.3 km d/s PMO	5211-D1-08
a0539.wb1	Wapiti	06/15/72	Beak	Station O3 (=4) 13.5 km d/s PMO - right/north side	5211-D1-08
a0540.wb1	Wapiti	06/15/72	Beak	Station O4 (=5) 24 km d/s PMO - center	5211-D1-08
a0541.wb1	Wapiti	06/15/72	Beak	Station O5 (=6) 29 km d/s PMO - center	5211-D1-08
a0542.wb1	Wapiti	09/26/72	Beak	Station 1(N) - 2.3 mi (3.7 km) u/s Grande Prairie STP	5211-D1-08
a0543.wb1	Wapiti	09/26/72	Beak	Station 2(N) / Wapiti 2 - 0.2 mi (0.3 km) d/s PMO	5211-D1-08
a0544.wb1	Wapiti	09/26/72	Beak	Station 3 (1972-1985) 4.3 km d/s PMO	5211-D1-08
a0545.wb1	Wapiti	09/26/72	Beak	Station O3 (=4) 13.5 km d/s PMO - right/north side	5211-D1-08
a0546.wb1	Wapiti	09/26/72	Beak	Station O4 (=5) 24 km d/s PMO - center	5211-D1-08

File Name	River	Date	Collector	Location	Disk
a0547.wb1	Wapiti	09/26/72	Beak	Station O5 (=6) 29 km d/s PMO - center	5211-D1-08
a0548.wb1	Wapiti	09/26/72	Beak	Station 1(N) - 2.3 mi (3.7 km) u/s Grande Prairie STP	5211-D1-08
a0549.wb1	Wapiti	09/26/72	Beak	Station 2(N) / Wapiti 2 - 0.2 mi (0.3 km) d/s PMO	5211-D1-08
a0550.wb1	Wapiti	09/26/72	Beak	Station 3 (1972-1985) 4.3 km d/s PMO	5211-D1-08
a0551.wb1	Wapiti	09/26/72	Beak	Station O3 (=4) 13.5 km d/s PMO - right/north side	5211-D1-08
a0552.wb1	Wapiti	09/26/72	Beak	Station O4 (=5) 24 km d/s PMO - center	5211-D1-08
a0553.wb1	Wapiti	09/26/72	Beak	Station O5 (=6) 29 km d/s PMO - center	5211-D1-08
a0554.wb1	Wapiti	09/26/72	Beak	Station 1(N) - 2.3 mi (3.7 km) u/s Grande Prairie STP	5211-D1-08
a0555.wb1	Wapiti	09/26/72	Beak	Station 2(N) / Wapiti 2 - 0.2 mi (0.3 km) d/s PMO	5211-D1-08
a0556.wb1	Wapiti	09/26/72	Beak	Station 3 (1972-1985) 4.3 km d/s PMO	5211-D1-08
a0557.wb1	Wapiti	09/26/72	Beak	Station O3 (=4) 13.5 km d/s PMO - right/north side	5211-D1-08
a0558.wb1	Wapiti	09/26/72	Beak	Station O4 (=5) 24 km d/s PMO - center	5211-D1-08
a0559.wb1	Wapiti	09/26/72	Beak	Station O5 (=6) 29 km d/s PMO - center	5211-D1-08
a0560.wb1	Wapiti	06/07/74	Beak	Station 1(N) - 2.3 mi (3.7 km) u/s Grande Prairie STP	5211-D1-08
a0561.wb1	Wapiti	06/07/74	Beak	Station 2(N) / Wapiti 2 - 0.2 mi (0.3 km) d/s PMO	5211-D1-08
a0562.wb1	Wapiti	06/07/74	Beak	Station 3 (1972-1985) 4.3 km d/s PMO	5211-D1-08
a0563.wb1	Wapiti	06/07/74	Beak	Station O3 (=4) 13.5 km d/s PMO - right/north side	5211-D1-08
a0564.wb1	Wapiti	06/07/74	Beak	Station O4 (=5) 24 km d/s PMO - center	5211-D1-08
a0565.wb1	Wapiti	06/07/74	Beak	Station O5 (=6) 29 km d/s PMO - center	5211-D1-08
a0566.wb1	Wapiti	06/07/74	Beak	Station 1(N) - 2.3 mi (3.7 km) u/s Grande Prairie STP	5211-D1-08
a0567.wb1	Wapiti	06/07/74	Beak	Station 2(N) / Wapiti 2 - 0.2 mi (0.3 km) d/s PMO	5211-D1-08
a0568.wb1	Wapiti	06/07/74	Beak	Station 3 (1972-1985) 4.3 km d/s PMO	5211-D1-08
a0569.wb1	Wapiti	06/07/74	Beak	Station O3 (=4) 13.5 km d/s PMO - right/north side	5211-D1-08
a0570.wb1	Wapiti	06/07/74	Beak	Station O4 (=5) 24 km d/s PMO - center	5211-D1-08
a0571.wb1	Wapiti	06/07/74	Beak	Station O5 (=6) 29 km d/s PMO - center	5211-D1-08
a0572.wb1	Wapiti	06/07/74	Beak	Station 1(N) - 2.3 mi (3.7 km) u/s Grande Prairie STP	5211-D1-08
a0573.wb1	Wapiti	06/07/74	Beak	Station 2(N) / Wapiti 2 - 0.2 mi (0.3 km) d/s PMO	5211-D1-08
a0574.wb1	Wapiti	06/07/74	Beak	Station 3 (1972-1985) 4.3 km d/s PMO	5211-D1-08
a0575.wb1	Wapiti	06/07/74	Beak	Station O3 (=4) 13.5 km d/s PMO - right/north side	5211-D1-08

File Name	River	Date	Collector	Location	Disk
a0576.wb1	Wapiti	06/07/74	Beak	Station O4 (=5) 24 km d/s PMO - center	5211-D1-08
a0577.wb1	Wapiti	06/07/74	Beak	Station O5 (=6) 29 km d/s PMO - center	5211-D1-08
a0578.wb1	Wapiti	06/07/74	Beak	Station 1(N) - 2.3 mi (3.7 km) u/s Grande Prairie STP	5211-D1-08
a0579.wb1	Wapiti	06/07/74	Beak	Station 2(N) / Wapiti 2 - 0.2 mi (0.3 km) d/s PMO	5211-D1-08
a0580.wb1	Wapiti	06/07/74	Beak	Station 3 (1972-1985) 4.3 km d/s PMO	5211-D1-08
a0581.wb1	Wapiti	06/07/74	Beak	Station O3 (=4) 13.5 km d/s PMO - right/north side	5211-D1-08
a0582.wb1	Wapiti	06/07/74	Beak	Station O4 (=5) 24 km d/s PMO - center	5211-D1-08
a0583.wb1	Wapiti	06/07/74	Beak	Station O5 (=6) 29 km d/s PMO - center	5211-D1-08
a0584.wb1	Wapiti	11/01/74	Beak	Station 1(N) - 2.3 mi (3.7 km) u/s Grande Prairie STP	5211-D1-08
a0585.wb1	Wapiti	11/01/74	Beak	Station 2(N) / Wapiti 2 - 0.2 mi (0.3 km) d/s PMO	5211-D1-08
a0586.wb1	Wapiti	11/01/74	Beak	Station 3 (1972-1985) 4.3 km d/s PMO	5211-D1-08
a0587.wb1	Wapiti	11/01/74	Beak	Station O3 (=4) 13.5 km d/s PMO - right/north side	5211-D1-08
a0588.wb1	Wapiti	11/01/74	Beak	Station O4 (=5) 24 km d/s PMO - center	5211-D1-08
a0589.wb1	Wapiti	11/01/74	Beak	Station O5 (=6) 29 km d/s PMO - center	5211-D1-08
a0590.wb1	Wapiti	11/01/74	Beak	Station 1(N) - 2.3 mi (3.7 km) u/s Grande Prairie STP	5211-D1-08
a0591.wb1	Wapiti	11/01/74	Beak	Station 2(N) / Wapiti 2 - 0.2 mi (0.3 km) d/s PMO	5211-D1-08
a0592.wb1	Wapiti	11/01/74	Beak	Station 3 (1972-1985) 4.3 km d/s PMO	5211-D1-08
a0593.wb1	Wapiti	11/01/74	Beak	Station O3 (=4) 13.5 km d/s PMO - right/north side	5211-D1-08
a0594.wb1	Wapiti	11/01/74	Beak	Station O4 (=5) 24 km d/s PMO - center	5211-D1-08
a0595.wb1	Wapiti	11/01/74	Beak	Station O5 (=6) 29 km d/s PMO - center	5211-D1-08
a0596.wb1	Wapiti	11/01/74	Beak	Station 1(N) - 2.3 mi (3.7 km) u/s Grande Prairie STP	5211-D1-08
a0597.wb1	Wapiti	11/01/74	Beak	Station 2(N) / Wapiti 2 - 0.2 mi (0.3 km) d/s PMO	5211-D1-08
a0598.wb1	Wapiti	11/01/74	Beak	Station 3 (1972-1985) 4.3 km d/s PMO	5211-D1-08
a0599.wb1	Wapiti	11/01/74	Beak	Station O3 (=4) 13.5 km d/s PMO - right/north side	5211-D1-08
a0600.wb1	Wapiti	11/01/74	Beak	Station O4 (=5) 24 km d/s PMO - center	5211-D1-08
a0601.wb1	Wapiti	11/01/74	Beak	Station O5 (=6) 29 km d/s PMO - center	5211-D1-08
a0602.wb1	Wapiti	11/01/74	Beak	Station 1(N) - 2.3 mi (3.7 km) u/s Grande Prairie STP	5211-D1-08
a0603.wb1	Wapiti	11/01/74	Beak	Station 2(N) / Wapiti 2 - 0.2 mi (0.3 km) d/s PMO	5211-D1-08
a0604.wb1	Wapiti	11/01/74	Beak	Station 3 (1972-1985) 4.3 km d/s PMO	5211-D1-08

File Name	River	Date	Collector	Location	Disk
a0605.wb1	Wapiti	11/01/74	Beak	Station O3 (=4) 13.5 km d/s PMO - right/north side	5211-D1-08
a0606.wb1	Wapiti	11/01/74	Beak	Station O4 (=5) 24 km d/s PMO - center	5211-D1-08
a0607.wb1	Wapiti	11/01/74	Beak	Station O5 (=6) 29 km d/s PMO - center	5211-D1-08
a0608.wb1	Wapiti	10/25/75	Beak	Station 1(N) - 2.3 mi (3.7 km) u/s Grande Prairie STP	5211-D1-08
a0609.wb1	Wapiti	10/25/75	Beak	Station 2(N) / Wapiti 2 - 0.2 mi (0.3 km) d/s PMO	5211-D1-08
a0610.wb1	Wapiti	10/25/75	Beak	Station 1S - 1.5 mi (2.4 km) u/s PMO	5211-D1-08
a0611.wb1	Wapiti	10/25/75	Beak	Station 2S - 0.2 mi d/s PMO	5211-D1-08
a0612.wb1	Wapiti	10/25/75	Beak	Station 3 (1972-1985) 4.3 km d/s PMO	5211-D1-08
a0613.wb1	Wapiti	10/25/75	Beak	Station O3 (=4) 13.5 km d/s PMO - right/north side	5211-D1-08
a0614.wb1	Wapiti	10/25/75	Beak	Station O4 (=5) 24 km d/s PMO - center	5211-D1-08
a0615.wb1	Wapiti	11/07/75	Beak	Station O5 (=6) 29 km d/s PMO - center	5211-D1-08
a0617.wb1	Wapiti	10/24/75	Beak	Station 1(N) - 2.3 mi (3.7 km) u/s Grande Prairie STP	5211-D1-08
a0618.wb1	Wapiti	10/24/75	Beak	Station 2(N) / Wapiti 2 - 0.2 mi (0.3 km) d/s PMO	5211-D1-08
a0619.wb1	Wapiti	10/24/75	Beak	Station 1S - 1.5 mi (2.4 km) u/s PMO	5211-D1-08
a0620.wb1	Wapiti	10/24/75	Beak	Station 2S - 0.2 mi d/s PMO	5211-D1-08
a0621.wb1	Wapiti	10/24/75	Beak	Station 3 (1972-1985) 4.3 km d/s PMO	5211-D1-08
a0622.wb1	Wapiti	10/24/75	Beak	Station O3 (=4) 13.5 km d/s PMO - right/north side	5211-D1-08
a0623.wb1	Wapiti	10/24/75	Beak	Station O4 (=5) 24 km d/s PMO - center	5211-D1-08
a0624.wb1	Wapiti	10/24/75	Beak	Station O5 (=6) 29 km d/s PMO - center	5211-D1-08
a0625.wb1	Wapiti	10/25/78	Beak	Station 1(N) - 2.3 mi (3.7 km) u/s Grande Prairie STP	5211-D1-08
a0626.wb1	Wapiti	10/25/78	Beak	Station 1S - 1.5 mi (2.4 km) u/s PMO	5211-D1-08
a0627.wb1	Wapiti	10/25/78	Beak	Station 2(N) / Wapiti 2 - 0.2 mi (0.3 km) d/s PMO	5211-D1-08
a0628.wb1	Wapiti	10/25/78	Beak	Station 2(N) / Wapiti 2 - 0.2 mi (0.3 km) d/s PMO	5211-D1-08
a0629.wb1	Wapiti	10/25/78	Beak	Station O3 (=4) 13.5 km d/s PMO - right/north side	5211-D1-08
a0630.wb1	Wapiti	10/25/78	Beak	Station O4 (=5) 24 km d/s PMO - center	5211-D1-08
a0631.wb1	Wapiti	10/25/78	Beak	Station O5 (=6) 29 km d/s PMO - center	5211-D1-08
a0632.wb1	Wapiti	10/09/80	Beak	WTC - first gravel bar upstream of Grande Prairie STP	5211-D1-08
a0633.wb1	Wapiti	10/09/80	Beak	Station 1(N) - 2.3 mi (3.7 km) u/s Grande Prairie STP	5211-D1-08
a0634.wb1	Wapiti	10/09/80	Beak	Station 1S - 1.5 mi (2.4 km) u/s PMO	5211-D1-08

File Name	River	Date	Collector	Location	Disk
a0635.wb1	Wapiti	10/09/80	Beak	Station 2(N) / Wapiti 2 - 0.2 mi (0.3 km) d/s PMO	5211-D1-08
a0636.wb1	Wapiti	10/09/80	Beak	Station 3 (1972-1985) 4.3 km d/s PMO	5211-D1-08
a0637.wb1	Wapiti	10/09/80	Beak	Station O3 (=4) 13.5 km d/s PMO - right/north side	5211-D1-08
a0638.wb1	Wapiti	10/09/80	Beak	Station O4 (=5) 24 km d/s PMO - center	5211-D1-08
a0639.wb1	Wapiti	10/09/80	Beak	Station O5 (=6) 29 km d/s PMO - center	5211-D1-08
a0640.wb1	Wapiti	10/09/80	Beak	WTC - first gravel bar upstream of Grande Prairie STP	5211-D1-08
a0641.wb1	Wapiti	10/09/80	Beak	Station 1S - 1.5 mi (2.4 km) u/s PMO	5211-D1-08
a0642.wb1	Wapiti	10/09/80	Beak	Station 1(N) - 2.3 mi (3.7 km) u/s Grande Prairie STP	5211-D1-08
a0643.wb1	Wapiti	10/09/80	Beak	Station 2(N) / Wapiti 2 - 0.2 mi (0.3 km) d/s PMO	5211-D1-08
a0644.wb1	Wapiti	10/09/80	Beak	Station 3 (1972-1985) 4.3 km d/s PMO	5211-D1-08
a0645.wb1	Wapiti	10/09/80	Beak	Station O3 (=4) 13.5 km d/s PMO - right/north side	5211-D1-08
a0646.wb1	Wapiti	10/09/80	Beak	Station O5 (=6) 29 km d/s PMO - center	5211-D1-08
a0647.wb1	Wapiti	10/24/81	Integrated Env. Sci.	WTC - first gravel bar upstream of Grande Prairie STP	5211-D1-08
a0648.wb1	Wapiti	10/24/81	Integrated Env. Sci.	Station 1(N) - 2.3 mi (3.7 km) u/s Grande Prairie STP	5211-D1-08
a0649.wb1	Wapiti	10/24/81	Integrated Env. Sci.	Station 1S - 1.5 mi (2.4 km) u/s PMO	5211-D1-08
a0650.wb1	Wapiti	10/24/81	Integrated Env. Sci.	Station 2(N) / Wapiti 2 - 0.2 mi (0.3 km) d/s PMO	5211-D1-08
a0651.wb1	Wapiti	10/24/81	Integrated Env. Sci.	Station 3 (1972-1985) 4.3 km d/s PMO	5211-D1-08
a0652.wb1	Wapiti	10/24/81	Integrated Env. Sci.	Station O3 (=4) 13.5 km d/s PMO - right/north side	5211-D1-08
a0653.wb1	Wapiti	10/24/81	Integrated Env. Sci.	Station O4 (=5) 24 km d/s PMO - center	5211-D1-08
a0654.wb1	Wapiti	10/24/81	Integrated Env. Sci.	Station O5 (=6) 29 km d/s PMO - center	5211-D1-08
a0655.wb1	Wapiti	10/24/81	Integrated Env. Sci.	WTC - first gravel bar upstream of Grande Prairie STP	5211-D1-08
a0656.wb1	Wapiti	10/24/81	Integrated Env. Sci.	Station 1(N) - 2.3 mi (3.7 km) u/s Grande Prairie STP	5211-D1-08
a0657.wb1	Wapiti	10/24/81	Integrated Env. Sci.	Station 1S - 1.5 mi (2.4 km) u/s PMO	5211-D1-09
a0658.wb1	Wapiti	10/24/81	Integrated Env. Sci.	Station 2(N) / Wapiti 2 - 0.2 mi (0.3 km) d/s PMO	5211-D1-09
a0659.wb1	Wapiti	10/24/81	Integrated Env. Sci.	Station 3 (1972-1985) 4.3 km d/s PMO	5211-D1-09
a0660.wb1	Wapiti	10/24/81	Integrated Env. Sci.	Station O3 (=4) 13.5 km d/s PMO - right/north side	5211-D1-09
a0661.wb1	Wapiti	10/24/81	Integrated Env. Sci.	Station O4 (=5) 24 km d/s PMO - center	5211-D1-09
a0662.wb1	Wapiti	10/24/81	Integrated Env. Sci.	Station O5 (=6) 29 km d/s PMO - center	5211-D1-09
a0663.wb1	Wapiti	10/28/82	Integrated Env. Sci.	Station CC 5.0 km u/s PMO (1.8 km d/s Grande Prairie STP) center	5211-D1-09

File Name	River	Date	Collector	Location	Disk
a0664.wb1	Wapiti	10/28/82	Integrated Env. Sci.	Station 1(N) - 2.3 mi (3.7 km) u/s Grande Prairie STP	5211-D1-09
a0665.wb1	Wapiti	10/28/82	Integrated Env. Sci.	Station 1S - 1.5 mi (2.4 km) u/s PMO	5211-D1-09
a0666.wb1	Wapiti	10/28/82	Integrated Env. Sci.	Station 2(N) / Wapiti 2 - 0.2 mi (0.3 km) d/s PMO	5211-D1-09
a0667.wb1	Wapiti	10/28/82	Integrated Env. Sci.	Station 3 (1972-1985) 4.3 km d/s PMO	5211-D1-09
a0668.wb1	Wapiti	10/28/82	Integrated Env. Sci.	Station O3 (=4) 13.5 km d/s PMO - right/north side	5211-D1-09
a0669.wb1	Wapiti	10/28/82	Integrated Env. Sci.	Station O4 (=5) 24 km d/s PMO - center	5211-D1-09
a0670.wb1	Wapiti	10/28/82	Integrated Env. Sci.	Station O5 (=6) 29 km d/s PMO - center	5211-D1-09
a0671.wb1	Wapiti	10/28/82	Integrated Env. Sci.	Station CC 5.0 km u/s PMO (1.8 km d/s Grande Prairie STP) center	5211-D1-09
a0672.wb1	Wapiti	10/28/82	Integrated Env. Sci.	Station 1(N) - 2.3 mi (3.7 km) u/s Grande Prairie STP	5211-D1-09
a0673.wb1	Wapiti	10/28/82	Integrated Env. Sci.	Station 1S - 1.5 mi (2.4 km) u/s PMO	5211-D1-09
a0674.wb1	Wapiti	10/28/82	Integrated Env. Sci.	Station 2(N) / Wapiti 2 - 0.2 mi (0.3 km) d/s PMO	5211-D1-09
a0675.wb1	Wapiti	10/28/82	Integrated Env. Sci.	Station 3 (1972-1985) 4.3 km d/s PMO	5211-D1-09
a0676.wb1	Wapiti	10/28/82	Integrated Env. Sci.	Station O3 (=4) 13.5 km d/s PMO - right/north side	5211-D1-09
a0677.wb1	Wapiti	10/28/82	Integrated Env. Sci.	Station O4 (=5) 24 km d/s PMO - center	5211-D1-09
a0678.wb1	Wapiti	10/28/82	Integrated Env. Sci.	Station O5 (=6) 29 km d/s PMO - center	5211-D1-09
a0679.wb1	Wapiti	10/15/83	Integrated Env. Sci.	Station CC 5.0 km u/s PMO (1.8 km d/s Grande Prairie STP) center	5211-D1-09
a0680.wb1	Wapiti	10/15/83	Integrated Env. Sci.	Station 1(N) - 2.3 mi (3.7 km) u/s Grande Prairie STP	5211-D1-09
a0681.wb1	Wapiti	10/15/83	Integrated Env. Sci.	Station 1S - 1.5 mi (2.4 km) u/s PMO	5211-D1-09
a0682.wb1	Wapiti	10/15/83	Integrated Env. Sci.	Station 2(N) / Wapiti 2 - 0.2 mi (0.3 km) d/s PMO	5211-D1-09
a0683.wb1	Wapiti	10/15/83	Integrated Env. Sci.	Station 3 (1972-1985) 4.3 km d/s PMO	5211-D1-09
a0684.wb1	Wapiti	10/15/83	Integrated Env. Sci.	Station O3 (=4) 13.5 km d/s PMO - right/north side	5211-D1-09
a0685.wb1	Wapiti	10/15/83	Integrated Env. Sci.	Station O4 (=5) 24 km d/s PMO - center	5211-D1-09
a0686.wb1	Wapiti	10/15/83	Integrated Env. Sci.	Station O5 (=6) 29 km d/s PMO - center	5211-D1-09
a0687.wb1	Wapiti	10/12/85	Integrated Env. Sci.	Station CC 5.0 km u/s PMO (1.8 km d/s Grande Prairie STP) center	5211-D1-09
a0688.wb1	Wapiti	10/12/85	Integrated Env. Sci.	Station 1(N) - 2.3 mi (3.7 km) u/s Grande Prairie STP	5211-D1-09
a0689.wb1	Wapiti	10/12/85	Integrated Env. Sci.	Station 1S - 1.5 mi (2.4 km) u/s PMO	5211-D1-09
a0690.wb1	Wapiti	10/12/85	Integrated Env. Sci.	Station 2(N) / Wapiti 2 - 0.2 mi (0.3 km) d/s PMO	5211-D1-09
a0691.wb1	Wapiti	10/12/85	Integrated Env. Sci.	Station 3 (1972-1985) 4.3 km d/s PMO	5211-D1-09
a0692.wb1	Wapiti	10/12/85	Integrated Env. Sci.	Station O3 (=4) 13.5 km d/s PMO - right/north side	5211-D1-09

File Name	River	Date	Collector	Location	Disk
a0693.wb1	Wapiti	10/12/85	Integrated Env. Sci.	Station O4 (=5) 24 km d/s PMO - center	5211-D1-09
a0694.wb1	Wapiti	10/12/85	Integrated Env. Sci.	Station O5 (=6) 29 km d/s PMO - center	5211-D1-09
a0695.wb1	Wapiti	06/07/74	Beak	Station 1(N) - 2.3 mi (3.7 km) u/s Grande Prairie STP	5211-D1-09
a0696.wb1	Wapiti	06/07/74	Beak	Station 2(N) / Wapiti 2 - 0.2 mi (0.3 km) d/s PMO	5211-D1-09
a0697.wb1	Wapiti	06/07/74	Beak	Station 3 (1972-1985) 4.3 km d/s PMO	5211-D1-09
a0698.wb1	Wapiti	06/07/74	Beak	Station O3 (=4) 13.5 km d/s PMO - right/north side	5211-D1-09
a0699.wb1	Wapiti	06/07/74	Beak	Station O4 (=5) 24 km d/s PMO - center	5211-D1-09
a0700.wb1	Wapiti	06/07/74	Beak	Station O5 (=6) 29 km d/s PMO - center	5211-D1-09
a0706.wb1	Wapiti	10/16/87	TAEM	Station C5S 6.5 km u/s PMO (2.3 km d/s Grande Prairie STP) center	5211-D1-09
a0707.wb1	Wapiti	10/16/87	TAEM	Station 1(N) - 2.3 mi (3.7 km) u/s Grande Prairie STP	5211-D1-09
a0708.wb1	Wapiti	10/16/87	TAEM	Station 1S - 1.5 mi (2.4 km) u/s PMO	5211-D1-09
a0709.wb1	Wapiti	10/16/87	TAEM	Station 2(N) / Wapiti 2 - 0.2 mi (0.3 km) d/s PMO	5211-D1-09
a0710.wb1	Wapiti	10/16/87	TAEM	Station 3 (1987-1988) 3.8 km d/s PMO	5211-D1-09
a0711.wb1	Wapiti	10/16/87	TAEM	Station O3 (=4) 13.5 km d/s PMO - right/north side	5211-D1-09
a0712.wb1	Wapiti	10/16/87	TAEM	Station O4 (=5) 24 km d/s PMO - center	5211-D1-09
a0713.wb1	Wapiti	10/16/87	TAEM	Station O5 (=6) 29 km d/s PMO - center	5211-D1-09
a0714.wb1	Wapiti	10/08/88	TAEM	Station WT1 10.5 km u/s PMO (1.2 km u/s Grande Prairie STP) center	5211-D1-09
a0715.wb1	Wapiti	10/08/88	TAEM	Station C3 (= WT2) 9.6 km u/s PMO (0.5 km u/s Grande Prairie STP) north side	5211-D1-09
a0716.wb1	Wapiti	10/08/88	TAEM	Station WT3 6.3 km u/s PMO (0.5 km d/s Grande Prairie STP) south side	5211-D1-09
a0717.wb1	Wapiti	10/08/88	TAEM	Station CC 5.0 km u/s PMO (1.8 km d/s Grande Prairie STP) center	5211-D1-09
a0718.wb1	Wapiti	10/08/88	TAEM	Station 1(N) - 2.3 mi (3.7 km) u/s Grande Prairie STP	5211-D1-09
a0719.wb1	Wapiti	10/08/88	TAEM	Station 1S - 1.5 mi (2.4 km) u/s PMO	5211-D1-09
a0720.wb1	Wapiti	10/08/88	TAEM	Station 2(N) / Wapiti 2 - 0.2 mi (0.3 km) d/s PMO	5211-D1-09
a0721.wb1	Wapiti	10/08/88	TAEM	Station 3 (1987-1988) 3.8 km d/s PMO	5211-D1-09
a0722.wb1	Wapiti	10/08/88	TAEM	Station O3 (=4) 13.5 km d/s PMO - right/north side	5211-D1-09
a0723.wb1	Wapiti	10/08/88	TAEM	Station O4 (=5) 24 km d/s PMO - center	5211-D1-09
a0724.wb1	Wapiti	10/08/88	TAEM	Station O5 (=6) 29 km d/s PMO - center	5211-D1-09
a0725.wb1	Wapiti	10/06/90	TAEM	Station C1 12.8 km u/s PMO (3.5 km u/s Grande Prairie STP) center	5211-D1-09
a0726.wb1	Wapiti	10/06/90	TAEM	Station C2 11.3 km u/s PMO (2.0 km u/s Grande Prairie STP) center	5211-D1-09

File Name	River	Date	Collector	Location	Disk
a0727.wb1	Wapiti	10/06/90	TAEM	Station C3 (= WT2) 9.6 km u/s PMO (0.5 km u/s Grande Prairie STP) north side	5211-D1-09
a0728.wb1	Wapiti	10/06/90	TAEM	Station C4S 8.6 km u/s PMO (0.4 km d/s Grande Prairie STP) south side	5211-D1-09
a0729.wb1	Wapiti	10/06/90	TAEM	Station C5S 6.5 km u/s PMO (2.3 km d/s Grande Prairie STP) center	5211-D1-09
a0730.wb1	Wapiti	10/06/90	TAEM	Station C6S 2.5 km u/s PMO (6.0 km d/s Grande Prairie STP) south side	5211-D1-09
a0731.wb1	Wapiti	10/06/90	TAEM	Station C6SR	5211-D1-09
a0732.wb1	Wapiti	10/06/90	TAEM	Station O1 0.7 km d/s PMO center	5211-D1-09
a0733.wb1	Wapiti	10/06/90	TAEM	Station O2 5.5 km d/s PMO - right/north side	5211-D1-09
a0734.wb1	Wapiti	10/06/90	TAEM	Station O3 (=4) 13.5 km d/s PMO - right/north side	5211-D1-09
a0735.wb1	Wapiti	10/06/90	TAEM	Station O3L	5211-D1-09
a0736.wb1	Wapiti	10/06/90	TAEM	Station O4 (=5) 24 km d/s PMO - center	5211-D1-09
a0737.wb1	Wapiti	10/06/90	TAEM	Station O5 (=6) 29 km d/s PMO - center	5211-D1-09
a0738.wb1	Wapiti	04/15/91	TAEM	Station C1 12.8 km u/s PMO (3.5 km u/s Grande Prairie STP) center	5211-D1-09
a0739.wb1	Wapiti	04/15/91	TAEM	Station C2 11.3 km u/s PMO (2.0 km u/s Grande Prairie STP) center	5211-D1-09
a0740.wb1	Wapiti	04/15/91	TAEM	Station C3 (= WT2) 9.6 km u/s PMO (0.5 km u/s Grande Prairie STP) north side	5211-D1-09
a0741.wb1	Wapiti	04/15/91	TAEM	Station C4S 8.6 km u/s PMO (0.4 km d/s Grande Prairie STP) south side	5211-D1-09
a0742.wb1	Wapiti	04/15/91	TAEM	Station C5S 6.5 km u/s PMO (2.3 km d/s Grande Prairie STP) center	5211-D1-09
a0743.wb1	Wapiti	04/15/91	TAEM	Station C6S 2.5 km u/s PMO (6.0 km d/s Grande Prairie STP) south side	5211-D1-09
a0744.wb1	Wapiti	04/15/91	TAEM	Station O1 0.7 km d/s PMO center	5211-D1-09
a0745.wb1	Wapiti	04/15/91	TAEM	Station O2 5.5 km d/s PMO - right/north side	5211-D1-09
a0746.wb1	Wapiti	04/15/91	TAEM	Station O3 (=4) 13.5 km d/s PMO - right/north side	5211-D1-09
a0747.wb1	Wapiti	04/15/91	TAEM	Station O4 (=5) 24 km d/s PMO - center	5211-D1-09
a0748.wb1	Wapiti	04/15/91	TAEM	Station O5 (=6) 29 km d/s PMO - center	5211-D1-09
a0749.wb1	Wapiti	01/11/92	TAEM	Station C1 12.8 km u/s PMO (3.5 km u/s Grande Prairie STP) center	5211-D1-09
a0750.wb1	Wapiti	01/11/92	TAEM	Station C2 11.3 km u/s PMO (2.0 km u/s Grande Prairie STP) center	5211-D1-09
a0751.wb1	Wapiti	01/11/92	TAEM	Station C3 (= WT2) 9.6 km u/s PMO (0.5 km u/s Grande Prairie STP) north side	5211-D1-09
a0752.wb1	Wapiti	01/11/92	TAEM	Station C4S 8.6 km u/s PMO (0.4 km d/s Grande Prairie STP) south side	5211-D1-09
a0753.wb1	Wapiti	01/11/92	TAEM	Station C5S 6.5 km u/s PMO (2.3 km d/s Grande Prairie STP) center	5211-D1-09
a0754.wb1	Wapiti	01/11/92	TAEM	Station C6S 2.5 km u/s PMO (6.0 km d/s Grande Prairie STP) south side	5211-D1-09
a0755.wb1	Wapiti	01/11/92	TAEM	Station O1 0.7 km d/s PMO center	5211-D1-09

File Name	River	Date	Collector	Location	Disk
a0756.wb1	Wapiti	01/11/92	TAEM	Station O2 5.5 km d/s PMO - right/north side	5211-D1-09
a0757.wb1	Wapiti	01/11/92	TAEM	Station O3 (=4) 13.5 km d/s PMO - right/north side	5211-D1-09
a0758.wb1	Wapiti	01/11/92	TAEM	Station O4 (=5) 24 km d/s PMO - center	5211-D1-09
a0759.wb1	Wapiti	01/11/92	TAEM	Station O5 (=6) 29 km d/s PMO - center	5211-D1-09
a0760.wb1	Wapiti	10/25/92	TAEM	Station C1 12.8 km u/s PMO (3.5 km u/s Grande Prairie STP) center	5211-D1-09
a0761.wb1	Wapiti	10/25/92	TAEM	Station C2 11.3 km u/s PMO (2.0 km u/s Grande Prairie STP) center	5211-D1-09
a0762.wb1	Wapiti	10/25/92	TAEM	Station C3 (= WT2) 9.6 km u/s PMO (0.5 km u/s Grande Prairie STP) north side	5211-D1-09
a0763.wb1	Wapiti	10/25/92	TAEM	Station C4S 8.6 km u/s PMO (0.4 km d/s Grande Prairie STP) south side	5211-D1-09
a0764.wb1	Wapiti	10/25/92	TAEM	Station C5S 6.5 km u/s PMO (2.3 km d/s Grande Prairie STP) center	5211-D1-09
a0765.wb1	Wapiti	10/25/92	TAEM	Station C6S 2.5 km u/s PMO (6.0 km d/s Grande Prairie STP) south side	5211-D1-09
a0766.wb1	Wapiti	10/25/92	TAEM	Station O1 0.7 km d/s PMO center	5211-D1-09
a0767.wb1	Wapiti	10/25/92	TAEM	Station O2 5.5 km d/s PMO - right/north side	5211-D1-09
a0768.wb1	Wapiti	10/25/92	TAEM	Station O3 (=4) 13.5 km d/s PMO - right/north side	5211-D1-09
a0769.wb1	Wapiti	10/25/92	TAEM	Station O4 (=5) 24 km d/s PMO - center	5211-D1-09
a0770.wb1	Wapiti	10/25/92	TAEM	Station O5 (=6) 29 km d/s PMO - center	5211-D1-09
a0771.wb1	Wapiti	10/25/78	Beak	Station 1(N) - 2.3 mi (3.7 km) u/s Grande Prairie STP	5211-D1-09
a0772.wb1	Wapiti	10/25/78	Beak	Station 1S - 1.5 mi (2.4 km) u/s PMO	5211-D1-09
a0773.wb1	Wapiti	10/25/78	Beak	Station 2(N) / Wapiti 2 - 0.2 mi (0.3 km) d/s PMO	5211-D1-09
a0774.wb1	Wapiti	10/25/78	Beak	Station 3 (1972-1985) 4.3 km d/s PMO	5211-D1-09
a0775.wb1	Wapiti	10/25/78	Beak	Station O3 (=4) 13.5 km d/s PMO - right/north side	5211-D1-09
a0776.wb1	Wapiti	10/25/78	Beak	Station O4 (=5) 24 km d/s PMO - center	5211-D1-09
a0777.wb1	Wapiti	10/25/78	Beak	Station O5 (=6) 29 km d/s PMO - center	5211-D1-09
a0790.wb1	Wapiti	10/02/89	Alberta Environment	# 1 near HWY 40/O'Brien Park	5211-D1-09
a0791.wb1	Wapiti	10/02/89	Alberta Environment	Highway 40 Bridge, centre channel	5211-D1-09
a0792.wb1	Wapiti	10/02/89	Alberta Environment	# 2 just u/s of Grande Prairie STP effluent	5211-D1-09
a0793.wb1	Wapiti	10/03/89	Alberta Environment	# 3 5 km d/s of Grande Prairie STP	5211-D1-09
a0794.wb1	Wapiti	10/03/89	Alberta Environment	# 4 d/s of P&G haul road	5211-D1-09
a0795.wb1	Wapiti	10/03/89	Alberta Environment	1 km upstream PG Effluent outfall	5211-D1-09
a0796.wb1	Wapiti	10/03/89	Alberta Environment	Railway bridge	5211-D1-09

File Name	River	Date	Collector	Location	Disk
a0797.wb1	Wapiti	10/03/89	Alberta Environment	10 km d/s PG effluent outfall	5211-D1-09
a0798.wb1	Wapiti	10/04/89	Alberta Environment	# 8 - 0.1 km u/s of Bear R	5211-D1-09
a0799.wb1	Wapiti	10/04/89	Alberta Environment	# 9 10 km u/s of mouth	5211-D1-09
a0800.wb1	Wapiti	10/04/89	Alberta Environment	# 10 0.5 km u/s of mouth (W2C)	5211-D1-09
a0801.wb1	Smoky	10/04/89	Alberta Environment	Upstream Wapiti River right bank	5211-D1-04
a0802.wb1	Smoky	10/04/89	Alberta Environment	Upstream Wapiti River left bank	5211-D1-04
a0803.wb1	Smoky	10/05/89	Alberta Environment	At Bezanson Bridge (Highway 34) centre channel (S3C)	5211-D1-04
a0804.wb1	Smoky	10/05/89	Alberta Environment	0.1 km u/s Puskwaskau River, centre channel	5211-D1-04
a0805.wb1	Smoky	10/05/89	Alberta Environment	At Watino, centre channel	5211-D1-04
a0806.wb1	Athabasca	06/03/87	Alberta Environment	0.5 km u/s McLeod River left bank (A2L)	5211-D1-03
a0807.wb1	McLeod	06/03/87	Alberta Environment	2.7 km above Athabasca River left bank (MCL1L)	5211-D1-03
a0808.wb1	McLeod	06/03/87	Alberta Environment	1 km above Athabasca River right bank (MCL2R)	5211-D1-03
a0809.wb1	Athabasca	06/03/87	Alberta Environment	0.8 km d/s McLeod River left bank (A3L)	5211-D1-03
a0810.wb1	Athabasca	06/03/87	Alberta Environment	0.8 km d/s McLeod River centre (A3C)	5211-D1-03
a0811.wb1	Athabasca	06/03/87	Alberta Environment	0.8 km d/s McLeod River right bank (A3R)	5211-D1-03
a0812.wb1	Athabasca	06/03/87	Alberta Environment	2.5 km d/s McLeod River at pipeline crossing left bank (A4L)	5211-D1-03
a0813.wb1	Athabasca	06/03/87	Alberta Environment	2.5 km d/s McLeod River at pipeline crossing centre (A4C)	5211-D1-03
a0814.wb1	Athabasca	06/03/87	Alberta Environment	2.5 km d/s McLeod River at pipeline crossing right bank (A4R)	5211-D1-03
a0815.wb1	Athabasca	06/03/87	Alberta Environment	4.5 km d/s McLeod River, north of STP centre (A5C)	5211-D1-03
a0816.wb1	Athabasca	06/03/87	Alberta Environment	6 km d/s McLeod River left bank (A6L)	5211-D1-03
a0817.wb1	Athabasca	06/03/87	Alberta Environment	6 km d/s McLeod River right bank (A6R)	5211-D1-03
a0818.wb1	Athabasca	09/01/87	Alberta Environment	0.5 km u/s Suncor south mine drainage, left bank	5211-D1-03
a0819.wb1	Athabasca	09/01/87	Alberta Environment	0.05 km u/s Suncor	5211-D1-03
a0820.wb1	Athabasca	09/01/87	Alberta Environment	0.1 km d/s Suncor north mine drainage, left bank	5211-D1-03
a0821.wb1	Athabasca	09/01/87	Alberta Environment	1.0 km d/s Suncor north mine drainage, left bank	5211-D1-03
a0822.wb1	Athabasca	09/01/87	Alberta Environment	10 km d/s Suncor north mine drainage, left bank	5211-D1-03
a0823.wb1	Athabasca	09/30/87	Alberta Environment	2.1 km u/s McCleod River right bank (A1R)	5211-D1-03
a0824.wb1	McLeod	09/30/87	Alberta Environment	1 km above Athabasca River right bank (MCL2R)	5211-D1-03
a0825.wb1	McLeod	09/30/87	Alberta Environment	2.7 km above Athabasca River left bank (MCL1L)	5211-D1-03

File Name	River	Date	Collector	Location	Disk
a0826.wb1	Athabasca	09/30/87	Alberta Environment	0.5 km u/s McLeod River left bank (A2L)	5211-D1-03
a0827.wb1	Athabasca	09/30/87	Alberta Environment	0.8 km d/s McLeod River right bank (A3R)	5211-D1-03
a0828.wb1	Athabasca	09/30/87	Alberta Environment	0.8 km d/s McLeod River left bank (A3L)	5211-D1-04
a0829.wb1	Athabasca	09/30/87	Alberta Environment	0.8 km d/s McLeod River centre (A3C)	5211-D1-04
a0830.wb1	Athabasca	09/30/87	Alberta Environment	2.5 km d/s McLeod River at pipeline crossing right bank (A4R)	5211-D1-04
a0831.wb1	Athabasca	09/30/87	Alberta Environment	2.5 km d/s McLeod River at pipeline crossing left bank (A4L)	5211-D1-04
a0832.wb1	Athabasca	09/30/87	Alberta Environment	2.5 km d/s McLeod River at pipeline crossing centre (A4C)	5211-D1-04
a0833.wb1	Athabasca	09/30/87	Alberta Environment	4.5 km d/s McLeod River, north of STP centre (A5C)	5211-D1-04
a0834.wb1	Athabasca	09/30/87	Alberta Environment	6 km d/s McLeod River left bank (A6L)	5211-D1-04
a0835.wb1	Athabasca	09/30/87	Alberta Environment	6 km d/s McLeod River right bank (A6R)	5211-D1-04
a0836.wb1	McLeod	10/19/88	Alberta Environment	2.7 km above Athabasca River left bank (MCL1L)	5211-D1-04
a0837.wb1	Athabasca	10/19/88	Alberta Environment	0.5 km u/s McLeod River right bank (A2R)	5211-D1-04
a0838.wb1	Athabasca	10/19/88	Alberta Environment	0.8 km d/s McLeod River right bank (A3R)	5211-D1-04
a0839.wb1	Athabasca	10/19/88	Alberta Environment	0.8 km d/s McLeod River centre (A3C)	5211-D1-04
a0840.wb1	Athabasca	10/19/88	Alberta Environment	2.5 km d/s McLeod River at pipeline crossing right bank (A4R)	5211-D1-04
a0841.wb1	Athabasca	10/20/88	Alberta Environment	2.5 km d/s McLeod River at pipeline crossing centre (A4C)	5211-D1-04
a0842.wb1	Athabasca	10/20/88	Alberta Environment	4.5 km d/s McLeod River, north of STP right bank (A5R)	5211-D1-04
a0843.wb1	Athabasca	10/13/93	Sentar	2.5 k u/s ANC (ANC 1)	5211-D1-04
a0844.wb1	Athabasca	10/13/93	Sentar	1 k u/s ANC (ANC 2)	5211-D1-04
a0845.wb1	Athabasca	10/13/93	Sentar	1k d/s ANC outfall, north bank (ANC 3)	5211-D1-04
a0846.wb1	Athabasca	10/13/93	Sentar	3km d/s ANC, north bank (ANC 4)	5211-D1-04
a0847.wb1	Athabasca	10/13/93	Sentar	Millar Western s2 & 8.5 k d/s ANC outfall, south bank (ANC 5)	5211-D1-04
a0848.wb1	Athabasca	10/13/93	Sentar	Millar Western s5 & 13 k d/s ANC outfall, south bank (ANC 6)	5211-D1-04
a0849.wb1	Athabasca	10/13/93	Sentar	Millar Western s7 & 33 k d/s ANC outfall, south bank (ANC 7)	5211-D1-04
a0850.wb1	Athabasca	04/07/92	R.L.&L Environmental	0.1 km u/s Maskuta Creek (Entrance) (ARC)	5211-D1-04
a0851.wb1	Athabasca	04/09/92	R.L.&L Environmental	Weldwood Haul Bridge (km 1226.7) - WHB, HB	5211-D1-04
a0852.wb1	Athabasca	04/10/92	R.L.&L Environmental	Obed Mtn. Coal Bridge - OB	5211-D1-04
a0853.wb1	Athabasca	04/11/92	R.L.&L Environmental	2.3 km d/s Emerson Lakes Road Bridge - EL	5211-D1-04
a0854.wb1	Athabasca	04/13/92	R.L.&L Environmental	Knight Bidge ~120 km d/s Weldwood outfall	5211-D1-04

File Name	River	Date	Collector	Location	Disk
a0855.wb1	Athabasca	04/14/92	R.L.&L Environmental	4 km u/s Windfall bridge	5211-D1-04
a0856.wb1	Athabasca	04/07/92	R.L.&L Environmental	0.1 km u/s Maskuta Creek (Entrance) (ARC)	5211-D1-04
a0857.wb1	Athabasca	04/09/92	R.L.&L Environmental	Weldwood Haul Bridge (km 1226.7) - WHB, HB	5211-D1-04
a0858.wb1	Athabasca	04/10/92	R.L.&L Environmental	Obed Mtn. Coal Bridge - OB	5211-D1-04
a0859.wb1	Athabasca	04/11/92	R.L.&L Environmental	2.3 km d/s Emerson Lakes Road Bridge - EL	5211-D1-04
a0860.wb1	Athabasca	04/13/92	R.L.&L Environmental	Knight Bidge ~120 km d/s Weldwood outfall	5211-D1-04
a0861.wb1	Athabasca	04/14/92	R.L.&L Environmental	1 km d/s Windfall bridge - ARW, WB ~160 km d/s Weldwood outfall	5211-D1-04
a0862.wb1	Athabasca	05/05/93	R.L.&L Environmental	2.3 km d/s Emerson Lakes Road Bridge - EL	5211-D1-04
a0863.wb1	Athabasca	05/05/93	R.L.&L Environmental	Weldwood Haul Bridge (km 1226.7) - WHB, HB	5211-D1-04
a0864.wb1	Athabasca	05/07/93	R.L.&L Environmental	1.5 km d/s of Athabasca left bank	5211-D1-04
a0865.wb1	Athabasca	05/05/93	R.L.&L Environmental	0.1 km u/s Maskuta Creek (Entrance) (ARC)	5211-D1-04
a0866.wb1	Athabasca	05/05/93	R.L.&L Environmental	Obed Mtn. Coal Bridge - OB	5211-D1-04
a0867.wb1	Athabasca	05/06/93	R.L.&L Environmental	0.5 km d/s Blue Ridge bridge - ARBR	5211-D1-04
a0868.wb1	Athabasca	05/06/93	R.L.&L Environmental	1 km u/s Berland River - ARBER	5211-D1-04
a0869.wb1	Athabasca	05/06/93	R.L.&L Environmental	4 km u/s Windfall bridge	5211-D1-04
a0870.wb1	Athabasca	09/17/93	R.L.&L Environmental	1 km u/s Berland River - ARBER	5211-D1-04
a0871.wb1	Athabasca	09/17/93	R.L.&L Environmental	4 km u/s Windfall bridge	5211-D1-04
a0872.wb1	Athabasca	09/17/93	R.L.&L Environmental	Obed Mtn. Coal Bridge - OB	5211-D1-04
a0873.wb1	Athabasca	09/15/93	R.L.&L Environmental	Station 1A - 0.2 km u/s Maskuta Creek (Entrance)	5211-D1-04
a0874.wb1	Athabasca	09/15/93	R.L.&L Environmental	0.1 km u/s Maskuta Creek (Entrance) (ARC)	5211-D1-04
a0875.wb1	Athabasca	09/15/93	R.L.&L Environmental	Weldwood Haul Bridge (km 1226.7) - WHB, HB	5211-D1-04
a0876.wb1	Athabasca	09/15/93	R.L.&L Environmental	2.3 km d/s Emerson Lakes Road Bridge - EL	5211-D1-04
a0877.wb1	Peace	07/07/89	Monenco Consultants	~5.5 km u/s Smoky River, gravel bar on south side	5211-D1-06
a0878.wb1	Smoky	07/07/89	Monenco Consultants	~5 km u/s Peace River, gravel bar on west side	5211-D1-04
a0879.wb1	Peace	07/07/89	Monenco Consultants	Just u/s boat launch at Peace River, south side	5211-D1-06
a0880.wb1	Peace	07/07/89	Monenco Consultants	Southern tip of Bewley Island (~1.5 km d/s bridge at Peace River)	5211-D1-06
a0881.wb1	Peace	07/07/89	Monenco Consultants	10 km u/s Daishowa, north bank (Site 4, Jun 1989)	5211-D1-06
a0882.wb1	Peace	07/07/89	Monenco Consultants	1.5 km d/s Daishowa, south side=	5211-D1-06
a0883.wb1	Peace	07/07/89	Monenco Consultants	4.5 km d/s Daishowa, north side (Site 6, Jun 1989)	5211-D1-06

File Name	River	Date	Collector	Location	Disk
a0884.wb1	Peace	07/07/89	Monenco Consultants	8 km d/s Daishowa, south side	5211-D1-06
a0885.wb1	Peace	07/07/89	Monenco Consultants	12 km d/s Daishowa, north side (Site 8, Jun 1989)	5211-D1-06
a0886.wb1	Peace	07/07/89	Monenco Consultants	(B3R) 20 km d/s Daishowa pulpmill	5211-D1-06
a0887.wb1	Peace	07/07/89	Monenco Consultants	(B4L) 35 km d/s Daishowa Pulpmill	5211-D1-06
a0888.wb1	Peace	09/29/89	Monenco Consultants	14 km u/s Daishowa	5211-D1-06
a0889.wb1	Peace	09/29/89	Monenco Consultants	14 km u/s Daishowa	5211-D1-06
a0890.wb1	Peace	09/29/89	Monenco Consultants	5 km u/s Daishowa (Site 2R, Sep 1989, May 92, Oct 92)	5211-D1-06
a0891.wb1	Peace	09/29/89	Monenco Consultants	7.5 km u/s Daishowa	5211-D1-06
a0892.wb1	Peace	09/29/89	Monenco Consultants	3.5 km u/s Daishowa	5211-D1-06
a0893.wb1	Peace	09/29/89	Monenco Consultants	3.5 km u/s Daishowa	5211-D1-06
a0894.wb1	Peace	09/29/89	Monenco Consultants	9 km d/s Daishowa	5211-D1-06
a0895.wb1	Peace	09/29/89	Monenco Consultants	9 km d/s Daishowa	5211-D1-06
a0896.wb1	Peace	09/29/89	Monenco Consultants	12.5 km d/s Daishowa	5211-D1-06
a0897.wb1	Peace	09/29/89	Monenco Consultants	12.5 km d/s Daishowa	5211-D1-06
a0898.wb1	Peace	09/29/89	Monenco Consultants	21 km d/s Daishowa	5211-D1-06
a0899.wb1	Peace	09/29/89	Monenco Consultants	21 km d/s Daishowa	5211-D1-06
a0900.wb1	Peace	09/29/89	Monenco Consultants	30 km d/s Daishowa	5211-D1-06
a0901.wb1	Peace	09/29/89	Monenco Consultants	55 km d/s Daishowa; ~5 km d/s Cadotte River	5211-D1-06
a0902.wb1	Peace	04/21/90	Monenco Consultants	14 km u/s Daishowa	5211-D1-06
a0903.wb1	Peace	04/21/90	Monenco Consultants	14 km u/s Daishowa	5211-D1-06
a0904.wb1	Peace	04/21/90	Monenco Consultants	Southern tip of Bewley Island (~1.5 km d/s bridge at Peace River)	5211-D1-06
a0905.wb1	Peace	04/21/90	Monenco Consultants	3.5 km u/s Daishowa	5211-D1-06
a0906.wb1	Peace	04/21/90	Monenco Consultants	3.5 km u/s Daishowa	5211-D1-06
a0907.wb1	Peace	04/21/90	Monenco Consultants	9 km d/s Daishowa	5211-D1-06
a0908.wb1	Peace	04/21/90	Monenco Consultants	9 km d/s Daishowa	5211-D1-06
a0909.wb1	Peace	04/21/90	Monenco Consultants	21 km d/s Daishowa	5211-D1-06
a0910.wb1	Peace	04/21/90	Monenco Consultants	30 km d/s Daishowa	5211-D1-06
a0911.wb1	Peace	04/21/90	Monenco Consultants	30 km d/s Daishowa	5211-D1-06
a0912.wb1	Peace	04/21/90	Monenco Consultants	55 km d/s Daishowa; ~5 km d/s Cadotte River	5211-D1-06

File Name	River	Date	Collector	Location	Disk
a0913.wb1	Peace	04/27/91	Monenco Consultants	14 km u/s Daishowa	5211-D1-06
a0914.wb1	Peace	04/27/91	Monenco Consultants	14 km u/s Daishowa	5211-D1-06
a0915.wb1	Peace	04/27/91	Monenco Consultants	7.5 km u/s Daishowa	5211-D1-06
a0916.wb1	Peace	04/27/91	Monenco Consultants	9 km d/s Daishowa	5211-D1-06
a0917.wb1	Peace	04/27/91	Monenco Consultants	12.5 km d/s Daishowa	5211-D1-06
a0918.wb1	Peace	04/27/91	Monenco Consultants	12.5 km d/s Daishowa	5211-D1-06
a0919.wb1	Peace	04/27/91	Monenco Consultants	21 km d/s Daishowa	5211-D1-06
a0920.wb1	Peace	04/27/91	Monenco Consultants	21 km d/s Daishowa	5211-D1-06
a0921.wb1	Peace	04/27/91	Monenco Consultants	30 km d/s Daishowa	5211-D1-06
a0922.wb1	Peace	04/27/91	Monenco Consultants	30 km d/s Daishowa	5211-D1-06
a0923.wb1	Peace	10/05/91	Monenco Consultants	14 km u/s Daishowa	5211-D1-06
a0924.wb1	Peace	10/05/91	Monenco Consultants	Southern tip of Bewley Island (~1.5 km d/s bridge at Peace River)	5211-D1-06
a0925.wb1	Peace	10/05/91	Monenco Consultants	14 km u/s Daishowa	5211-D1-06
a0926.wb1	Peace	10/05/91	Monenco Consultants	7.5 km u/s Daishowa	5211-D1-06
a0927.wb1	Peace	10/05/91	Monenco Consultants	3.5 km u/s Daishowa	5211-D1-06
a0928.wb1	Peace	10/05/91	Monenco Consultants	3.5 km u/s Daishowa	5211-D1-06
a0929.wb1	Peace	10/05/91	Monenco Consultants	9 km d/s Daishowa, South side	5211-D1-06
a0930.wb1	Peace	10/05/91	Monenco Consultants	9 km d/s Daishowa	5211-D1-06
a0931.wb1	Peace	10/05/91	Monenco Consultants	12.5 km d/s Daishowa	5211-D1-06
a0932.wb1	Peace	10/05/91	Monenco Consultants	21 km d/s Daishowa	5211-D1-06
a0933.wb1	Peace	10/05/91	Monenco Consultants	21 km d/s Daishowa	5211-D1-06
a0934.wb1	Peace	10/05/91	Monenco Consultants	30 km d/s Daishowa	5211-D1-06
a0935.wb1	Peace	10/05/91	Monenco Consultants	55 km d/s Daishowa; ~5 km d/s Cadotte River	5211-D1-06
a0936.wb1	Peace	05/22/92	Monenco Consultants	14 km u/s Daishowa	5211-D1-06
a0937.wb1	Peace	05/22/92	Monenco Consultants	Gravel shoal north of Bewley Island (~3.5 km d/s bridge at Peace River)	5211-D1-06
a0938.wb1	Peace	05/22/92	Monenco Consultants	14 km u/s Daishowa	5211-D1-06
a0939.wb1	Peace	05/22/92	Monenco Consultants	7.5 km u/s Daishowa	5211-D1-06
a0940.wb1	Peace	05/22/92	Monenco Consultants	5 km u/s Daishowa (Site 2R, Sep 1989, May 92, Oct 92)	5211-D1-06
a0941.wb1	Peace	05/22/92	Monenco Consultants	3.5 km u/s Daishowa	5211-D1-06

File Name	River	Date	Collector	Location	Disk
a0942.wb1	Peace	05/22/92	Monenco Consultants	9 km d/s Daishowa	5211-D1-06
a0943.wb1	Peace	05/22/92	Monenco Consultants	9 km d/s Daishowa, South side	5211-D1-06
a0944.wb1	Peace	05/22/92	Monenco Consultants	12.5 km d/s Daishowa	5211-D1-06
a0945.wb1	Peace	05/22/92	Monenco Consultants	21 km d/s Daishowa	5211-D1-06
a0946.wb1	Peace	05/22/92	Monenco Consultants	21 km d/s Daishowa	5211-D1-06
a0947.wb1	Peace	05/22/92	Monenco Consultants	21 km d/s Daishowa	5211-D1-06
a0948.wb1	Peace	05/22/92	Monenco Consultants	30 km d/s Daishowa	5211-D1-06
a0949.wb1	Peace	05/22/92	Monenco Consultants	30 km d/s Daishowa	5211-D1-06
a0950.wb1	Peace	05/22/92	Monenco Consultants	55 km d/s Daishowa; ~5 km d/s Cadotte River	5211-D1-06
a0951.wb1	Peace	10/15/92	Monenco Consultants	14 km u/s Daishowa	5211-D1-06
a0952.wb1	Peace	10/15/92	Monenco Consultants	Southern tip of Bewley Island (~1.5 km d/s bridge at Peace River)	5211-D1-06
a0953.wb1	Peace	10/15/92	Monenco Consultants	14 km u/s Daishowa	5211-D1-06
a0954.wb1	Peace	10/15/92	Monenco Consultants	5 km u/s Daishowa (Site 2R, Sep 1989, May 92, Oct 92)	5211-D1-06
a0955.wb1	Peace	10/15/92	Monenco Consultants	7.5 km u/s Daishowa	5211-D1-06
a0956.wb1	Peace	10/15/92	Monenco Consultants	3.5 km u/s Daishowa	5211-D1-06
a0957.wb1	Peace	10/15/92	Monenco Consultants	3.5 km u/s Daishowa	5211-D1-06
a0958.wb1	Peace	10/15/92	Monenco Consultants	9 km d/s Daishowa, South side	5211-D1-06
a0959.wb1	Peace	10/15/92	Monenco Consultants	9 km d/s Daishowa	5211-D1-06
a0960.wb1	Peace	10/15/92	Monenco Consultants	9 km d/s Daishowa	5211-D1-06
a0961.wb1	Peace	10/15/92	Monenco Consultants	12.5 km d/s Daishowa	5211-D1-06
a0962.wb1	Peace	10/15/92	Monenco Consultants	21 km d/s Daishowa	5211-D1-06
a0963.wb1	Peace	10/15/92	Monenco Consultants	21 km d/s Daishowa	5211-D1-06
a0964.wb1	Peace	10/15/92	Monenco Consultants	30 km d/s Daishowa	5211-D1-06
a0965.wb1	Peace	10/15/92	Monenco Consultants	30 km d/s Daishowa	5211-D1-06
a0966.wb1	Peace	10/15/92	Monenco Consultants	55 km d/s Daishowa; ~5 km d/s Cadotte River	5211-D1-06
a0967.wb1	Wapiti	07/15/74	Alberta Environment	Wembly ferry	5211-D1-09
a0968.wb1	Wapiti	07/15/74	Alberta Environment	Highway 40 Bridge, centre channel	5211-D1-09
a0969.wb1	Wapiti	07/15/74	Alberta Environment	At Big Mountain Creek	5211-D1-09
a0970.wb1	Wapiti	07/15/74	Alberta Environment	# 6 near RR bridge -LB or C	5211-D1-09

File Name	River	Date	Collector	Location	Disk
a0971.wb1	Wapiti	07/15/74	Alberta Environment	# 8 - 0.1 km u/s of Bear R	5211-D1-09
a0972.wb1	Wapiti	07/15/74	Alberta Environment	d/s Bear River	5211-D1-09
a0973.wb1	Wapiti	07/15/74	Alberta Environment	~2.4 km u/s Smoky River	5211-D1-09
a0974.wb1	Wapiti	07/15/75	Alberta Environment	Wembly ferry	5211-D1-09
a0975.wb1	Wapiti	07/15/75	Alberta Environment	Highway 40 Bridge, centre channel	5211-D1-09
a0976.wb1	Wapiti	07/15/75	Alberta Environment	At Big Mountain Creek	5211-D1-07
a0977.wb1	Wapiti	07/15/75	Alberta Environment	# 6 near RR bridge -LB or C	5211-D1-07
a0978.wb1	Wapiti	07/15/75	Alberta Environment	# 8 - 0.1 km u/s of Bear R	5211-D1-07
a0979.wb1	Wapiti	07/15/75	Alberta Environment	d/s Bear River	5211-D1-07
a0980.wb1	Lesser Slave	05/06/89	EVS Consultants	# 1 (Mitsue bridge) (0 km) Station 1	5211-D1-05
a0981.wb1	Lesser Slave	05/06/89	EVS Consultants	Hydroelectric line crosses hwy 2A (3km) Station 7	5211-D1-05
a0982.wb1	Lesser Slave	05/06/89	EVS Consultants	6.5 km Station 16	5211-D1-05
a0983.wb1	Lesser Slave	05/06/89	EVS Consultants	1 km d/s mill discharge (7.2 km) Station 18	5211-D1-05
a0984.wb1	Lesser Slave	05/06/89	EVS Consultants	12.6 km Station 25	5211-D1-05
a0985.wb1	Lesser Slave	05/06/89	EVS Consultants	just above Outauwau (13 km) Station 26	5211-D1-05
a0986.wb1	Lesser Slave	05/06/89	EVS Consultants	# 4 (150m u/s of Saulteaux River); (17.7 km) Station 37	5211-D1-05
a0987.wb1	Lesser Slave	05/06/89	EVS Consultants	23.8 km Station 51	5211-D1-05
a0988.wb1	Lesser Slave	10/15/89	EVS Consultants	# 1 (Mitsue bridge) (0 km) Station 1	5211-D1-05
a0989.wb1	Lesser Slave	10/15/89	EVS Consultants	Hydroelectric line crosses hwy 2A (3km) Station 7	5211-D1-05
a0990.wb1	Lesser Slave	10/15/89	EVS Consultants	200 m ds mill pumphouse Station 15	5211-D1-05
a0991.wb1	Lesser Slave	10/15/89	EVS Consultants	1 km d/s mill discharge (7.2 km) Station 18	5211-D1-05
a0992.wb1	Lesser Slave	10/15/89	EVS Consultants	1 km above Outauwau (12.2 km) Station 24	5211-D1-05
a0993.wb1	Lesser Slave	10/15/89	EVS Consultants	12.6 km Station 25	5211-D1-05
a0994.wb1	Lesser Slave	10/15/89	EVS Consultants	5 km d/s Outauwau, at stream (17.7 km) Station 36	5211-D1-05
a0995.wb1	Lesser Slave	10/15/89	EVS Consultants	# 4 (150m u/s of Saulteaux River); (17.7 km) Station 37	5211-D1-05
a0996.wb1	Lesser Slave	10/15/89	EVS Consultants	Rapids (21.0 km) Station 45	5211-D1-05
a0997.wb1	Lesser Slave	10/15/89	EVS Consultants	14 km d/s Driftwood (38 km) Station 87	5211-D1-05
a0998.wb1	Lesser Slave	10/15/89	EVS Consultants	Hydroelectric line crosses hwy 2A (3km) Station 7	5211-D1-05
a0999.wb1	Lesser Slave	10/15/89	EVS Consultants	200 m ds mill pumphouse Station 15	5211-D1-05

File Name	River	Date	Collector	Location	Disk
a1000.wb1	Lesser Slave	10/15/89	EVS Consultants	# 4 (150m u/s of Saulteaux River); (17.7 km) Station 37	5211-D1-05
a1001.wb1	Lesser Slave	04/18/90	EVS Consultants	# 1 (Mitsue bridge) (0 km) Station 1	5211-D1-05
a1002.wb1	Lesser Slave	04/18/90	EVS Consultants	Hydroelectric line crosses hwy 2A (3km) Station 7	5211-D1-05
a1003.wb1	Lesser Slave	04/18/90	EVS Consultants	300 m ds mill discharge (6.2 km) Station 13	5211-D1-05
a1004.wb1	Lesser Slave	04/18/90	EVS Consultants	1 km d/s mill discharge (7.2 km) Station 18	5211-D1-05
a1005.wb1	Lesser Slave	04/18/90	EVS Consultants	1 km above Outauwau (12.2 km) Station 24	5211-D1-05
a1006.wb1	Lesser Slave	04/18/90	EVS Consultants	just above Outauwau (13 km) Station 26	5211-D1-05
a1007.wb1	Lesser Slave	04/18/90	EVS Consultants	5 km d/s Outauwau, at stream (17.7 km) Station 36	5211-D1-05
a1008.wb1	Lesser Slave	04/18/90	EVS Consultants	# 4 (150m u/s of Saulteaux River); (17.7 km) Station 37	5211-D1-05
a1009.wb1	Lesser Slave	04/18/90	EVS Consultants	1 km d/s Salteaux (19 km) Station 42	5211-D1-05
a1010.wb1	Lesser Slave	04/18/90	EVS Consultants	14 km d/s Driftwood (38 km) Station 87	5211-D1-05
a1011.wb1	Lesser Slave	09/18/90	EVS Consultants	# 1 (Mitsue bridge) (0 km) Station 1	5211-D1-05
a1012.wb1	Lesser Slave	09/18/90	EVS Consultants	Hydroelectric line crosses hwy 2A (3km) Station 7	5211-D1-05
a1013.wb1	Lesser Slave	09/18/90	EVS Consultants	1 km d/s mill discharge (7.2 km) Station 18	5211-D1-05
a1014.wb1	Lesser Slave	09/18/90	EVS Consultants	1 km above Outauwau (12.2 km) Station 24	5211-D1-05
a1015.wb1	Lesser Slave	09/18/90	EVS Consultants	just above Outauwau (13 km) Station 26	5211-D1-05
a1016.wb1	Lesser Slave	09/18/90	EVS Consultants	5 km d/s Outauwau, at stream (17.7 km) Station 36	5211-D1-05
a1017.wb1	Lesser Slave	09/18/90	EVS Consultants	# 4 (150m u/s of Saulteaux River); (17.7 km) Station 37	5211-D1-05
a1018.wb1	Lesser Slave	09/18/90	EVS Consultants	# 5 (u/s of Driftwood River); 24.2 km Station 52	5211-D1-05
a1019.wb1	Lesser Slave	09/18/90	EVS Consultants	14 km d/s Driftwood (38 km) Station 87	5211-D1-05
a1020.wb1	Lesser Slave	05/12/91	EVS Consultants	# 1 (Mitsue bridge) (0 km) Station 1	5211-D1-05
a1021.wb1	Lesser Slave	05/12/91	EVS Consultants	Hydroelectric line crosses hwy 2A (3km) Station 7	5211-D1-05
a1022.wb1	Lesser Slave	05/12/91	EVS Consultants	300 m ds mill discharge (6.2 km) Station 13	5211-D1-05
a1023.wb1	Lesser Slave	05/12/91	EVS Consultants	1 km d/s mill discharge (7.2 km) Station 18	5211-D1-05
a1024.wb1	Lesser Slave	05/12/91	EVS Consultants	1 km above Outauwau (12.2 km) Station 24	5211-D1-05
a1025.wb1	Lesser Slave	05/12/91	EVS Consultants	just above Outauwau (13 km) Station 26	5211-D1-05
a1026.wb1	Lesser Slave	05/12/91	EVS Consultants	5 km d/s Outauwau, at stream (17.7 km) Station 36	5211-D1-05
a1027.wb1	Lesser Slave	05/12/91	EVS Consultants	# 4 (150m u/s of Saulteaux River); (17.7 km) Station 37	5211-D1-05
a1028.wb1	Lesser Slave	05/12/91	EVS Consultants	1 km d/s Salteaux (19 km) Station 42	5211-D1-05

File Name	River	Date	Collector	Location	Disk
a1029.wb1	Lesser Slave	05/12/91	EVS Consultants	14 km d/s Driftwood (38 km) Station 87	5211-D1-05
a1030.wb1	Lesser Slave	09/17/91	EVS Consultants	# 1 (Mitsue bridge) (0 km) Station 1	5211-D1-05
a1031.wb1	Lesser Slave	09/17/91	EVS Consultants	Hydroelectric line crosses hwy 2A (3km) Station 7	5211-D1-05
a1032.wb1	Lesser Slave	09/17/91	EVS Consultants	300 m ds mill discharge (6.2 km) Station 13	5211-D1-05
a1033.wb1	Lesser Slave	09/17/91	EVS Consultants	1 km d/s mill discharge (7.2 km) Station 18	5211-D1-05
a1034.wb1	Lesser Slave	09/17/91	EVS Consultants	1 km above Outauwau (12.2 km) Station 24	5211-D1-05
a1035.wb1	Lesser Slave	09/17/91	EVS Consultants	just above Outauwau (13 km) Station 26	5211-D1-05
a1036.wb1	Lesser Slave	09/17/91	EVS Consultants	5 km d/s Outauwau, at stream (17.7 km) Station 36	5211-D1-05
a1037.wb1	Lesser Slave	09/17/91	EVS Consultants	# 4 (150m u/s of Saulteaux River); (17.7 km) Station 37	5211-D1-05
a1038.wb1	Lesser Slave	09/17/91	EVS Consultants	1 km d/s Salteaux (19 km) Station 42	5211-D1-05
a1039.wb1	Lesser Slave	09/17/91	EVS Consultants	14 km d/s Driftwood (38 km) Station 87	5211-D1-05
a1040.wb1	Lesser Slave	05/06/92	EVS Consultants	# 1 (Mitsue bridge) (0 km) Station 1	5211-D1-05
a1041.wb1	Lesser Slave	05/06/92	EVS Consultants	Hydroelectric line crosses hwy 2A (3km) Station 7	5211-D1-05
a1042.wb1	Lesser Slave	05/06/92	EVS Consultants	300 m ds mill discharge (6.2 km) Station 13	5211-D1-05
a1043.wb1	Lesser Slave	05/06/92	EVS Consultants	1 km d/s mill discharge (7.2 km) Station 18	5211-D1-05
a1044.wb1	Lesser Slave	05/06/92	EVS Consultants	1 km above Outauwau (12.2 km) Station 24	5211-D1-05
a1045.wb1	Lesser Slave	05/06/92	EVS Consultants	just above Outauwau ('13 km) Station 26	5211-D1-05
a1046.wb1	Lesser Slave	05/06/92	EVS Consultants	5 km d/s Outauwau, at stream (17.7 km) Station 36	5211-D1-05
a1047.wb1	Lesser Slave	05/06/92	EVS Consultants	# 4 (150m u/s of Saulteaux River); (17.7 km) Station 37	5211-D1-05
a1048.wb1	Lesser Slave	05/06/92	EVS Consultants	1 km d/s Salteaux (19 km) Station 42	5211-D1-05
a1049.wb1	Lesser Slave	05/06/92	EVS Consultants	14 km d/s Driftwood (38 km) Station 87	5211-D1-05
a1050.wb1	Lesser Slave	09/11/92	EVS Consultants	# 1 (Mitsue bridge) (0 km) Station 1	5211-D1-05
a1051.wb1	Lesser Slave	09/11/92	EVS Consultants	Hydroelectric line crosses hwy 2A (3km) Station 7	5211-D1-05
a1052.wb1	Lesser Slave	09/11/92	EVS Consultants	300 m ds mill discharge (6.2 km) Station 13	5211-D1-05
a1053.wb1	Lesser Slave	09/11/92	EVS Consultants	1 km d/s mill discharge (7.2 km) Station 18	5211-D1-05
a1054.wb1	Lesser Slave	09/11/92	EVS Consultants	1 km above Outauwau (12.2 km) Station 24	5211-D1-05
a1055.wb1	Lesser Slave	09/11/92	EVS Consultants	just above Outauwau (13 km) Station 26	5211-D1-05
a1056.wb1	Lesser Slave	09/11/92	EVS Consultants	5 km d/s Outauwau, at stream (17.7 km) Station 36	5211-D1-05
a1057.wb1	Lesser Slave	09/11/92	EVS Consultants	# 4 (150m u/s of Saulteaux River); (17.7 km) Station 37	5211-D1-05

File Name	River	Date	Collector	Location	Disk
a1058.wb1	Lesser Slave	09/11/92	EVS Consultants	1 km d/s Salteaux (19 km) Station 42	5211-D1-05
a1059.wb1	Lesser Slave	09/11/92	EVS Consultants	14 km d/s Driftwood (38 km) Station 87	5211-D1-05
a1060.wb1	Lesser Slave	05/15/93	EVS Consultants	# 1 (Mitsue bridge) (0 km) Station 1	5211-D1-05
a1061.wb1	Lesser Slave	05/15/93	EVS Consultants	Hydroelectric line crosses hwy 2A (3km) Station 7	5211-D1-05
a1062.wb1	Lesser Slave	05/15/93	EVS Consultants	300 m ds mill discharge (6.2 km) Station 13	5211-D1-05
a1063.wb1	Lesser Slave	05/15/93	EVS Consultants	1 km d/s mill discharge (7.2 km) Station 18	5211-D1-05
a1064.wb1	Lesser Slave	05/15/93	EVS Consultants	1 km above Outauwau (12.2 km) Station 24	5211-D1-05
a1065.wb1	Lesser Slave	05/15/93	EVS Consultants	just above Outauwau (13 km) Station 26	5211-D1-05
a1066.wb1	Lesser Slave	05/15/93	EVS Consultants	5 km d/s Outauwau, at stream (17.7 km) Station 36	5211-D1-05
a1067.wb1	Lesser Slave	05/15/93	EVS Consultants	# 4 (150m u/s of Saulteaux River); (17.7 km) Station 37	5211-D1-05
a1068.wb1	Lesser Slave	05/15/93	EVS Consultants	1 km d/s Salteaux (19 km) Station 42	5211-D1-05
a1069.wb1	Lesser Slave	05/15/93	EVS Consultants	14 km d/s Driftwood (38 km) Station 87	5211-D1-05
a1070.wb1	Lesser Slave	09/15/93	EVS Consultants	# 1 (Mitsue bridge) (0 km) Station 1	5211-D1-05
a1071.wb1	Lesser Slave	09/15/93	EVS Consultants	Hydroelectric line crosses hwy 2A (3km) Station 7	5211-D1-05
a1072.wb1	Lesser Slave	09/15/93	EVS Consultants	300 m ds mill discharge (6.2 km) Station 13	5211-D1-05
a1073.wb1	Lesser Slave	09/15/93	EVS Consultants	1 km d/s mill discharge (7.2 km) Station 18	5211-D1-05
a1074.wb1	Lesser Slave	09/15/93	EVS Consultants	1 km above Outauwau (12.2 km) Station 24	5211-D1-05
a1075.wb1	Lesser Slave	09/15/93	EVS Consultants	just above Outauwau (13 km) Station 26	5211-D1-05
a1076.wb1	Lesser Slave	09/15/93	EVS Consultants	5 km d/s Outauwau, at stream (17.7 km) Station 36	5211-D1-05
a1077.wb1	Lesser Slave	09/15/93	EVS Consultants	# 4 (150m u/s of Saulteaux River); (17.7 km) Station 37	5211-D1-05
a1078.wb1	Lesser Slave	09/15/93	EVS Consultants	1 km d/s Salteaux (19 km) Station 42	5211-D1-05
a1079.wb1	Lesser Slave	09/15/93	EVS Consultants	14 km d/s Driftwood (38 km) Station 87	5211-D1-05

APPENDIX D

Standardized taxonomic list for master database.

Phylum
Class
Order
Sub-Order
Family
Sub-Family
Tribe
Genus/species

1	**Arthropoda**
2	**Arachnida**
3	**Acari**
4	Hydracarina
5	Oribatei
200	**Aranea**
300	**Crustacea**
301	**Branchiopoda**
302	Anostraca
303	Cladocera
304	Bosminidae
305	*Bosmina*
306	Chydoridae
307	*Alona*
308	*Alonella*
309	*Leydigia*
310	Daphniidae
311	*Daphnia*
312	Leptodoridae
313	*Leptodora*
314	Macrothricidae
315	*Acantholebris*
316	*Ilyocryptus*
317	Conchostraca
318	Notostraca
319	*Macrothrix*
320	*Chydorus*
321	*Ceriodaphnia*
350	**Branchiura**
400	**Copepoda**
401	Calanoida
402	Cyclopoida
403	Harpacticoida
500	**Malacostraca**
501	Amphipoda
502	Gammaridae
503	*Gammarus lacustris*
504	*Gammarus*
505	Talitridae
506	*Hyalella azteca*
507	*Hyalella*
510	Haustoriidae
511	*Pontoporeia*

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512	*Pontoporeia hoyi*
800	**Ostracoda**
801	**Podocopa**
1000	**Insecta**
1001	**Terrestrial insects**
1002	**Collembola**
1100	**Plecoptera**
1101	Capniidae
1102	*Bolshecapnia*
1103	*Capnia*
1104	*Eucapnopsis*
1105	*Isocapnia*
1106	*Mesocapnia*
1107	*Paracapnia*
1108	*Utacapnia*
1109	Chloroperlidae
1110	Chloroperlinae
1111	*Alloperla*
1112	*Haploperla (=Hastaperla)*
1113	*Neaviperla*
1114	*Suwallia*
1115	*Sweltsa*
1116	*Triznaka*
1117	Paraperlinae
1118	*Kathroperla*
1119	*Paraperla*
1120	*Utaperla*
1121	Leuctridae
1122	*Despaxia*
1123	*Leuctra*
1124	*Megaleuctra*
1125	*Paraleuctra*
1126	*Perlomyia*
1127	Nemouridae
1128	*Amphinemura*
1129	*Brachyptera*
1130	*Lednia*
1131	*Malenka*
1132	*Nemoura*
1133	*Podmosta*
1134	*Prostoia*
1135	*Shipsa*
1136	*Soyedina*

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1137	*Visoka*
1138	*Zapada*
1139	Peltoperlidae
1140	*Yoraperla*
1141	Perlidae
1142	*Acroneuria*
1143	*Calineuria*
1144	*Claassenia*
1145	*Doroneuria*
1146	*Hesperoperla*
1147	*Neoperla*
1148	*Paragnetina*
1149	*Perlesta*
1150	*Perlinella (=Atoperla)*
1151	Perlodidae
1152	*Arcynopteryx*
1153	*Cultus*
1154	*Diura*
1155	*Isogenoides*
1156	*Isoperla*
1157	*Kogotus*
1158	*Megarcys*
1159	*Perlinodes*
1160	*Pictetiella*
1161	*Setvena*
1162	*Skwala*
1163	Pteronarcyidae
1164	*Pteronarcella*
1165	*Pteronarcys*
1166	Taeniopterygidae
1167	*Doddsia*
1168	*Oemopteryx*
1169	*Taenionema*
1170	*Taeniopteryx*
1500	**Ephemeroptera**
1502	Siphlonuridae
1503	*Ameletus*
1504	*Analetris*
1505	*Parameletus*
1506	*Siphlonurus*
1507	*Metretopus*
1508	*Siphloplecton*
1509	Baetidae
1510	*Acentrella*

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1511	*Acerpenna*
1512	*Baetis*
1513	*Callibaetis*
1514	*Centroptilum*
1515	*Cloeon*
1516	*Dactylobaetis*
1517	*Pseudocloeon*
1518	Ametropodidae
1519	*Ametropus*
1520	Oligoneuridae
1521	*Isonychia*
1522	*Lachlania*
1523	Heptageniidae
1524	*Acanthomola*
1525	*Cinygma*
1526	*Cinygmula*
1527	*Epeorus (=Iron, Ironopsis)*
1528	*Heptagenia*
1529	*Macdunnoa*
1530	*Pseudiron*
1531	*Raptoheptagenia*
1532	*Rhithrogena*
1533	*Stenacron*
1534	*Stenonema*
1535	Heptageniidae (early instars)
1536	Ephemerellidae
1537	*Atenella (=Atenuatella)*
1538	*Caudatella*
1539	*Ephemerella (Danella)*
1540	*Ephemerella (Attenuatella)*
1541	*Ephemerella (Caudetella)*
1542	*Ephemerella (Drunella) colaradensis*
1543	*Ephemerella (Drunella) doddsi*
1544	*Ephemerella (Drunella) grandis*
1545	*Ephemerella (Drunella) grandis ingens*
1546	*Ephemerella (Drunella) inermis*
1547	*Ephemerella (Drunella) spinifera*
1548	*Ephemerella (Drunella)*

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1549	*Ephemerella (Ephemerella) inermis*
1550	*Ephemerella (Ephemerella)*
1551	*Ephemerella (Eurylophella)*
1552	*Ephemerella infrequens*
1553	*Ephemerella invaria*
1554	*Ephemerella mollitia*
1555	*Ephemerella needhami*
1556	*Ephemerella simples*
1557	*Ephemerella*
1558	*Serratella*
1559	*Timpanoga*
1560	Tricorythidae
1561	*Tricorythodes*
1562	Caenidae
1563	*Brachycercus*
1564	*Caenis*
1565	Baetiscidae
1566	*Baetisca*
1567	Leptophlebiidae
1568	*Choroterpes*
1569	*Leptophlebia*
1570	*Paraleptophlebia*
1571	*Traverella*
1572	Ephemeridae
1573	*Ephemera*
1574	*Hexagenia*
1575	Polymitarcyidae
1576	*Ephoron*
1577	Metretopidae
2000	**Trichoptera**
2001	Brachycentridae
2002	*Amiocentrus*
2003	*Brachycentrus*
2004	*Micrasema*
2005	Glossosomatidae
2006	*Agapetus*
2007	*Anagapetus*
2008	*Glossosoma*
2009	*Protoptila*
2010	Helicopsychidae
2011	*Helicopsyche*
2012	Hydropsychidae
2013	*Arctopsyche*

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2014	*Cheumatopsyche*
2015	*Hydropsyche*
2016	*Parapsyche*
2017	*Symphitopsyche*
2018	Hydroptilidae
2019	*Agraylea*
2020	*Hydroptila*
2021	*Mayatrichia*
2022	*Neotrichia*
2023	*Ochrotrichia*
2024	*Orthotrichia*
2025	*Oxyethira*
2026	*Stactobiella (=Tascobia)*
2027	Lepidostomatidae
2028	*Lepidostoma*
2029	Leptoceridae
2030	*Ceraclea*
2031	*Mystacides*
2032	*Nectopsyche (=Leptocella)*
2033	*Oecetis*
2034	*Triaenodes (=Ylodes)*
2035	Limnephilidae
2036	Apataniinae
2037	*Apatania*
2038	Dicosmoecinae
2039	*Amphicosmoecus*
2040	*Dicosmoecus*
2041	*Ecclisomyia*
2042	*Imania (=Allomyia)*
2043	*Onocosmoecus*
2044	Limnephilinae
2045	*Anabolia*
2046	*Arctopora*
2047	*Asynarchus*
2048	*Chilostigmodes*
2049	*Chyranda*
2050	*Clistoronia*
2051	*Clostoeca*
2052	*Glyphopsyche*
2053	*Grammotaulius*
2054	*Hesperophylax (=Platyphylax)*
2055	*Homophylax*
2056	*Lenarchus*

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2057	*Limnephilus*
2058	*Nemotaulius (=Glyphotaelius)*
2059	*Pedomoecus*
2060	*Phanocelia*
2061	*Philarctus*
2062	*Philocasca*
2063	*Platycentropus*
2064	*Psychoglypha*
2065	*Pycnopsyche*
2066	Molannidae
2067	*Molanna*
2068	*Molannodes*
2069	Philopotamidae
2070	*Chimarra*
2071	*Dolophilodes*
2072	*Wormaldia*
2073	Phryganeidae
2074	*Agrypnia*
2075	*Banksiola*
2076	*Fabria*
2077	*Phryganea*
2078	*Ptilostomis*
2079	Polycentropodidae
2080	*Neureclipsis*
2081	*Nyctiophylax*
2082	*Polycentropus*
2083	Psychomyiidae
2084	*Psychomyia*
2085	Rhyacophilidae
2086	*Rhyacophila*
2087	Uenoidae
2088	*Neophylax*
2089	*Neothremma*
2090	*Oligophlebodes*
2500	**Coleoptera**
2501	Amphizoidae
2502	*Amphizoa*
2503	Carabidae
2504	Chrysomelidae
2505	*Donacia*
2506	*Plateumaris*
2507	*Macroplea (=Neohaemonia)*
2508	*Pyrrhalta (=Galerucella)*

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2509 Curculionidae

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2510 *Bagous*
2511 *Euhrichopsis*
2512 *Lissorhoptrus*
2513 *Litodactylus*
2514 *Lixellus*
2515 *Notiodes (=Endalus)*
2516 *Phytobius*
2517 *Tanysphyrus*
2518 Dryopidae
2519 *Helichus*
2520 Dytiscidae
2521 Colymbetinae
2522 *Agabus*
2523 *Carryhydrus*
2524 *Colymbetes*
2525 *Coptomus*
2526 *Ilybius*
2527 *Neoscutopterus*
2528 *Rhanatus*
2529 Dytiscinae
2530 *Acilius*
2531 *Dytiscus*
2532 *Graphoderus*
2533 *Hydaticus*
2534 Hydroporinae
2535 *Desmopachria*
2536 *Hydroporous*
2537 *Hygrotus*
2538 *Laccornis*
2539 *Liodessus*
2540 *Oreodytes*
2541 *Potamonectes*
2542 Laccophilinae
2543 *Laccophilus*
2544 Elmidae
2545 *Cleptelmis*
2546 *Dubiraphia*
2547 *Heterlimnius*
2548 *Narpus*
2549 *Optioservus*
2550 *Zaitzevia*
2551 Gyrinidae
2552 *Dineutus*

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2553 *Gyrinus*
2554 Haliplidae
2555 *Brychius*
2556 *Haliplus*
2557 *Peltodytes*
2558 Hydraenidae
2559 *Hydraena*
2560 *Ochthebius*
(=Gymnochthebius)
2561 *Limnebius*
2562 Hydrophilidae
2563 *Ametor*
2564 *Anacaena*
2565 *Berosus*
2566 *Cercyon*
2567 *Crenitis*
2568 *Cymbiodyta*
2569 *Enochrus*
2570 *Helophorus*
2571 *Hydrobius*
2572 *Hydrochara*
2573 *Hydrochus*
2574 *Hydrophilus*
2575 *Laccobius*
2576 *Paracymus*
2577 *Tropisternus*
2578 Lampyridae
2579 Limnichidae
2580 Ptilodactylidae
2581 Scirtidae (=Helodidae)
2582 *Cyphon*
2583 *Scirtes*
3000 **Diptera**
3001 Chironomidae (Tendipedidae)
3010 Diamesinae
3011 Diamesini
3012 *Diamesa*
3013 *Pagastia*
3014 *Potthastia*
3015 *Pseudodiamesa*
3016 *Pseudokiefferiella*
3017 *Sympotthastia*
3018 Protanypini

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3019 *Protanypus*
3030 Prodiamesinae
3031 *Monodiamesa*
3032 *Odontomesa*
3033 *Prodiamesa*
3040 Podonominae
3041 *Boreochlus*
3042 *Lasiodiamesa*
3043 *Trichotanypus*
3050 Tanypodinae
3051 Tanypodini
3052 *Tanypus*
3060 Macropelopiini
3061 *Anatopynia*
3062 *Derotanypus*
3063 *Procladius*
3064 *Psectrotanypus*
3070 Pentaneurini
3071 *Ablabesmyia*
3072 *Arctopelopia*
3073 *Conchapelopia*
3074 *Labrundinia*
3075 *Larsia*
3076 *Monopelopia*
3077 *Nilotanypus*
3078 *Paramerina*
3079 *Pentaneura*
3080 *Rheopelopia*
3081 *Thienemannimyia*
3082 *Trissopelopia*
3083 *Zavrelimyia*
3100 Orthocladiinae (=Hydrobaenae)
3101 Orthocladiini & Metriocnemini
3102 *Acricotopus (=Trichocladius)*
3103 *Brillia*
3104 *Camptocladius*
3105 *Cardiocladius*
3106 *Cricotopus*
3107 *Diplocladius*
3108 *Eukiefferiella (=Adactylocladius)*
3109 *Eurycnemus*
3110 *Euryhapsis*
3111 *Gymnometriocnemus*

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3112 *Heleniella*

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3113 *Heterotrissocladius*
3114 *Hydrobaenus*
3115 *Krenosmittia*
3116 *Limnophyes*
3117 *Mesocricotopus*
3118 *Metriocnemus*
3119 *Nanocladius (=Microcricotopus)*
3120 *Orthocladius*
3121 *Paracladius*
3122 *Parakiefferiella*
3123 *Parametriocnemus*
3124 *Paraphaenocladius*
3125 *Paratrichocladius*
3126 *Psectrocladius*
3127 *Pseudorthocladius*
3128 *Pseudosmittia (=Prosmittia)*
3129 *Rheocricotopus*
3130 *Rheosmittia*
3131 *Smittia*
3132 *Symbiocladius*
3133 *Synorthocladius*
3134 *Trissocladius*
3135 *Tvetenia*
3136 *Zalutschia*
3137 *Paracricotopus*
3180 Corynoneurini
3181 *Corynoneura*
3182 *Thienemanniella*
3200 Chironominae
3201 Chironomini
3202 *Beckiella*
3203 *Chernovskiia*
3204 *Chironomus (=Tendipes)*
3205 *Cryptochironomus nais*
3206 *Cryptochironomus*
3207 *Cryptotendipes*
3208 *Cyphomella*
3209 *Demicryptochironomus*
3210 *Dicrotendipes*
3211 *Einfeldia*
3212 *Endochironomus*
3213 *Glyptotendipes*
3214 *Harnischia*

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3215	*Lauterborniella*
3216	*Microtendipes*
3217	*Pagastiella*
3218	*Parachironomus*
3219	*Paracladopelma*
3220	*Paralauterborniella*
3221	*Paratendipes*
3222	*Phaenopsectra*
3223	*Polypedilum*
3224	*Pseudochironomus*
3225	*Robackia*
3226	*Saetheria*
3227	*Stenochironomus*
3228	*Stictochironomus*
3229	*Xenochironomus*
3230	*Tribelos*
3270	Tanytarsini
3271	*Cladotanytarsus*
3272	*Constempellina*
3273	*Corynocera*
3274	*Micropsectra*
3275	*Paratanytarsus*
3276	*Rheotanytarsus*
3277	*Stempellina*
3278	*Stempellinella*
3279	*Sublettea*
3280	*Tanytarsus (=Calopsectra)*
3281	*Zavrelia*
3300	Tipulidae
3301	Limnoiinae
3302	Eriopterini
3303	*Arctoconopa*
3304	*Erioptera*
3305	*Gonomyia*
3306	*Gonomyodes*
3307	*Hesperoconopa*
3308	*Molophilus*
3309	*Ormosia*
3310	*Rhabdomastix*
3320	Hexatomini
3321	*Dactylolabis*
3322	*Hexatoma*
3323	*Limnophila*
3324	*Pilaria*
3325	*Pseudolimnophila*
3340	Limnoiini
3341	*Antocha*
3342	*Elliptera*
3343	*Helius*
3344	*Limonia*
3350	Pedicini
3351	*Dicranota*
3352	*Pedicia*
3360	Tipulinae
3361	*Prinocera*
3362	*Tipula*
3390	Cylindrotominae
3391	*Phalacrocera*
3400	Ceratopogonidae (Heleidae)
3401	*Atrichopogon*
3402	*Dasyhelea*
3403	*Forcipomyia*
3404	*Leptoconops*
3420	Ceratopogoninae
3421	*Alluaudomyia*
3422	*Bezzia*
3423	*Culicoides*
3424	*Mallochohelea*
3425	*Palpomyia*
3426	*Probezzia*
3427	*Serromyia*
3428	*Sphaeromias*
3429	*Stilobezzia*
3450	Simulidae
3451	*Cnephia*
3452	*Ectemnia*
3453	*Greniera*
3454	*Gymnopais*
3455	*Mayacnephia*
3456	*Metacnephia*
3457	*Prosimulium*
3458	*Simulium*
3459	*Stegopterna*
3460	*Twinnia*
3500	Ephydridae
3501	Ephydrinae

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3502 *Ephydra*

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3503 *Lamproscatella*
3504 *Paracoenia*
3505 *Scatella*
3506 *Scatophila*
3507 *Setacera*
3520 Notiphilinae
3521 *Dichaeta*
3522 *Hydrellia*
3523 *Ilythea*
3524 *Nostima*
3525 *Notiphila*
3526 *Philygria*
3528 *Typopsilopa*
3550 Parydrinae
3551 *Axysta*
3552 *Brachydeutera*
3553 *Hyadina*
3554 *Lytogaster*
3555 *Ochthera*
3556 *Parydra*
3557 *Pelina*
3570 Psilopinae
3571 *Alloctyrichoma*
3572 *Athyroglossa*
3573 *Atissa*
3574 *Clanoneurum*
3575 *Diclasiopa*
3576 *Ditrichophora*
3577 *Hecamedoides*
3578 *Hydrochasma*
3579 *Leptopsilopa*
3580 *Mosillus*
3581 *Polytrichophora*
3582 *Psilopa*
3583 *Trimerina*
3600 Tabanidae
3601 *Atylotus*
3602 *Chrysops*
3603 *Haematopota*
3604 *Hybomitra*
3605 *Silvius*
3606 *Tabanus*
3650 Dolichopodidae

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3651 *Aphroxylus*
3652 *Argyra*
3653 *Campsicnemus*
3654 *Dolichopus*
3655 *Hercostomus*
3656 *Hydrophorus*
3657 *Liancalus*
3658 *Rhaphium*
3659 *Sympycnus*
3660 *Tachytrechus*
3661 *Thinophilus*
3700 Empididae
3701 *Chelifera*
3702 *Chelipoda*
3703 *Clinocera*
3704 *Hemerodromia*
3705 *Metachela*
3706 *Neoplasta*
3707 *Rhamphomyia*
3708 *Wiedemannia*
3709 *Oreogeton*
3800 Athericidae (=Rhagionidae)
3801 *Atherix*
3810 Stratiomyidae
3811 *Beris*
3812 *Caloparyphus*
3813 *Euparyphus*

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3814 *Hedriodiscus*
3815 *Nemotelus*
3816 *Odontomyia*
3817 *Oxycera*
3818 *Sargus*
3819 *Stratiomys*
3830 Syrphidae
3831 *Chrysogaster*
3832 *Eristalis*
3833 *Helophilus*
3834 *Neoascia*
3840 Sciomyzidae
3841 *Antichaeta*
3842 *Atrichomolina*
3843 *Dictya*
3844 *Dictacium*
3845 *Elgiva*
3846 *Hedria*
3847 *Limnia*
3848 *Pherbellia*
3849 *Pteromicra*
3850 *Renocera*
3851 *Sepedon*
3852 *Tetanocera*
3870 Muscidae
3880 Anthomyiidae
3881 *Lispoides*
3882 *Spilogona*
3883 *Limnophora*
3884 *Lispocephala*
3885 *Lispe*
3886 *Phaonia*
3890 Deuterophlebiidae
3891 *Deuterophlebia*
3900 Culicidae
3901 *Aedes*
3902 *Anopheles*
3903 *Culex*
3904 *Culiseta*
3905 *Mansonia*
3930 Chaoboridae
3931 *Chaoborus*
3932 *Eucorethra*

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3933	*Mochlonyx*
3940	Blephariceridae
3941	*Agathon*
3942	*Bibiocephala*
3943	*Philorus*
3944	*Blepharicera*
3950	Psychodidae
3951	*Pericoma*
3952	*Psychoda*
3953	*Telmatoscopus*
3960	Tanyderidae
3961	*Protanyderus*
3962	*Protoplasa*
3970	Ptychopteridae (=Liriopeidae)
3980	Thaumaleidae
3981	*Ptychoptera*
3982	*Thaumalea*
3990	Dixidae
3991	*Dixa*
3992	*Dixella*
4000	**Odonata**
4001	Anisoptera
4002	Aeshnidae
4003	*Aeshna*
4004	*Anax*
4005	Cordullidae
4006	*Cordulia*
4007	*Epitheca*
4008	*Somatochlora*
4009	Gomphidae
4010	*Gomphus*
4011	*Ophiogomphus*
4012	Libellulidae
4013	*Leucorrhinia*
4014	*Libellula*
4015	*Sympetrum*
4016	Zygoptera
4017	Calopterygidae
4018	*Calopteryx*
4019	Coenagrionidae
4020	*Argia*
4021	*Amphiagrion*
4022	*Nehalennia*
4023	*Coenagrion*
4024	*Enallagma*
4025	*Ischnura*
4026	Lestidae
4027	*Lestes*
4300	**Hemiptera**
4301	Belostomatidae
4302	*Lethocerus*
4303	Corixidae
4304	*Arctocorixa*
4305	*Callicorixa*
4306	*Cenocorixa*
4307	*Corisella*
4308	*Cymatia*
4309	*Dasycorixa*
4310	*Hesperocorixa*
4311	*Morphocorixa*
4312	*Palmacorixa*
4313	*Sigara*
4314	*Trichocorixa*
4315	Gerridae
4316	*Gerris*
4317	*Limnoporus*
4318	Hebridae
4319	*Merragata*
4320	Mesoveliidae
4321	*Mesovelia*
4322	Notonectidae
4323	*Buenoa*
4324	*Notonecta*
4325	Saldidae
4326	*Lampracanthia*
4327	*Micranthia*
4328	*Salda*
4329	*Saldula*
4330	*Teloleuca*
4331	Veliidae
4332	*Microvelia*
4500	**Neuroptera**
4530	**Megaloptera**
4560	**Lepidoptera**
4561	Pyralidae
4680	**Hymenoptera**

Code	Phylum / Class / Order / Sub-Order / Family / Sub-Family / Tribe / Genus/species
5000	**Annelida**
5001	**Aphanoneura**
5002	Aeolosomatidae
5003	*Aeolosoma*
5100	**Oligochaeta**
5101	**Haplotaxida**
5102	Enchytraeidae
5103	Naididae
5104	Tubificidae
5105	**Lumbriculida**
5106	Lumbricidae
5107	Lumbriculidae
5500	**Hirudinea**
5501	**Pharyngobdellida**
5502	Erpobdellidae
5503	*Dina*
5504	*Dina dubia*
5505	*Dina parva*
5506	*Erpobdella*
5507	*Erpobdella punctata*
5508	*Mooreobdella*
5509	*Mooreobdella fervida*
5510	*Nephelopsis*
5511	*Nephelopsis obscura*
5600	**Rhynchobdellida**
5601	Glossiphoniidae
5602	*Alboglossiphonia*
5603	*Alboglossiphonia heteroclita*
5604	*Batrachobdella*
5605	*Batrachobdella picta*
5606	*Glossiphonia*
5607	*Glossiphonia complanata*
5608	*Helobdella*
5609	*Helobdella elongata*
5610	*Helobdella fusca*
5611	*Helobdella stagnalis*
5612	*Helobdella triserialis*
5613	*Marvinmeyeria*
5614	*Marvinmeyeria lucida*
5615	*Placobdella*
5616	*Placobdella montifera*
5617	*Placobdella ornata*
5618	*Placobdella papillifera*
5619	*Placobdella parasitica*
5620	*Theromyzon*
5621	*Theromyzon maculosum*
5622	*Theromyzon rude*
5623	Pisciolidae
5624	*Cystobranchus*
5625	*Cystobranchus verrilli*
5626	*Myzobdella*
5627	*Myzobdella lugubris*
5628	*Piscicola*
5629	*Piscicola milneri*
5630	*Piscicola punctata*
5800	**Gnathobdellida**
5801	Hirudinidae
5802	*Macrobdella*
5803	*Macrobdella decora*
5804	*Haemopsis*
5805	*Haemopsis grandis*
5806	*Haemopsis marmorata*
6000	**Mollusca**
6001	**Gastropoda**
6002	**Prosobranchia (Mesogastropoda)**
6003	Hydrobiidae
6004	*Amnicola*
6005	Valvatidae
6006	*Valvata*
6200	**Pulmonata (Basommatophora)**
6201	Acroloxidae
6202	Anyclidae
6203	*Ferrissia*
6204	Lymnaeidae
6205	*Lymnaea*
6206	*Stagnicola*
6207	Physidae
6208	*Physa*
6209	*Physella*
6210	Planorbidae
6211	*Planorbula*
6212	*Gyralus*
6213	*Armiger*
6214	*Promenetus*
6215	*Menetus*
6216	*Helisoma*

Phylum
  Class
    Order
      Sub-Order
        Family
          Sub-Family
            Tribe
              Genus/species

6500	**Pelecypoda**
6501	**Bivalvia (Heterodonta)**
6502	Sphaeridae (Pisidiidae)
6503	*Pisidium*
6504	*Sphaerium*
6505	Unionidae
6506	*Anodonta*
6507	*Elliptio*
6508	*Lampsilis*
6509	*Strophitus*
7000	**Nematoda**
7001	**Aphasmidia**
7002	**Enoplida**
7003	*Mermithoidea*
7500	**Coelenterata**
7501	**Hydrozoa**

Phylum
  Class
    Order
      Sub-Order
        Family
          Sub-Family
            Tribe
              Genus/species

7502	**Hydroidea**
7503	Hydridae
7504	*Hydra*
7600	**Tardigrada**
8000	**Platyhelminthes**
8001	**Turbellaria**
8002	**Tricladida**
8003	Planariidae
8004	*Polycelis*
8005	**Microturbellaria**
8500	**Porifera**
8501	**Desmospongiae**
8502	Spongillidae
8503	**Nematomorpha**
8504	*Gordus*
8505	*Paragordius*

Appendix E

Principal Component Analysis of Benthic Invertebrate Community Structure

Appendix E1 Weldwood (Hinton, Alberta)
Appendix E2 Alberta Newsprint Corporation (ANC) and Millar Western (MW), Whitecourt
Appendix E3 Slave Lake Pulp Corporation (SLPC)
Appendix E4 Alberta Pacific Coroporation (ALPAC)
Appendix E5 Proctor Gamble / Weyerhauser, Grande Prairie (PG)
Appendix E6 Peace River Pulp Company (Daishowa)

Appendix E1

Principal Component Analysis of Benthic Invertebrate Community Structure Weldwood (Hinton, Alberta)

Axis labels represent the principal component axis shown (eg PRIN 1) followed by the proportion of the total variation explained by that principal component axis. The first two principal component axes are shown for all analyses. The third axis is shown only when it explains more than 15% of the total variation.

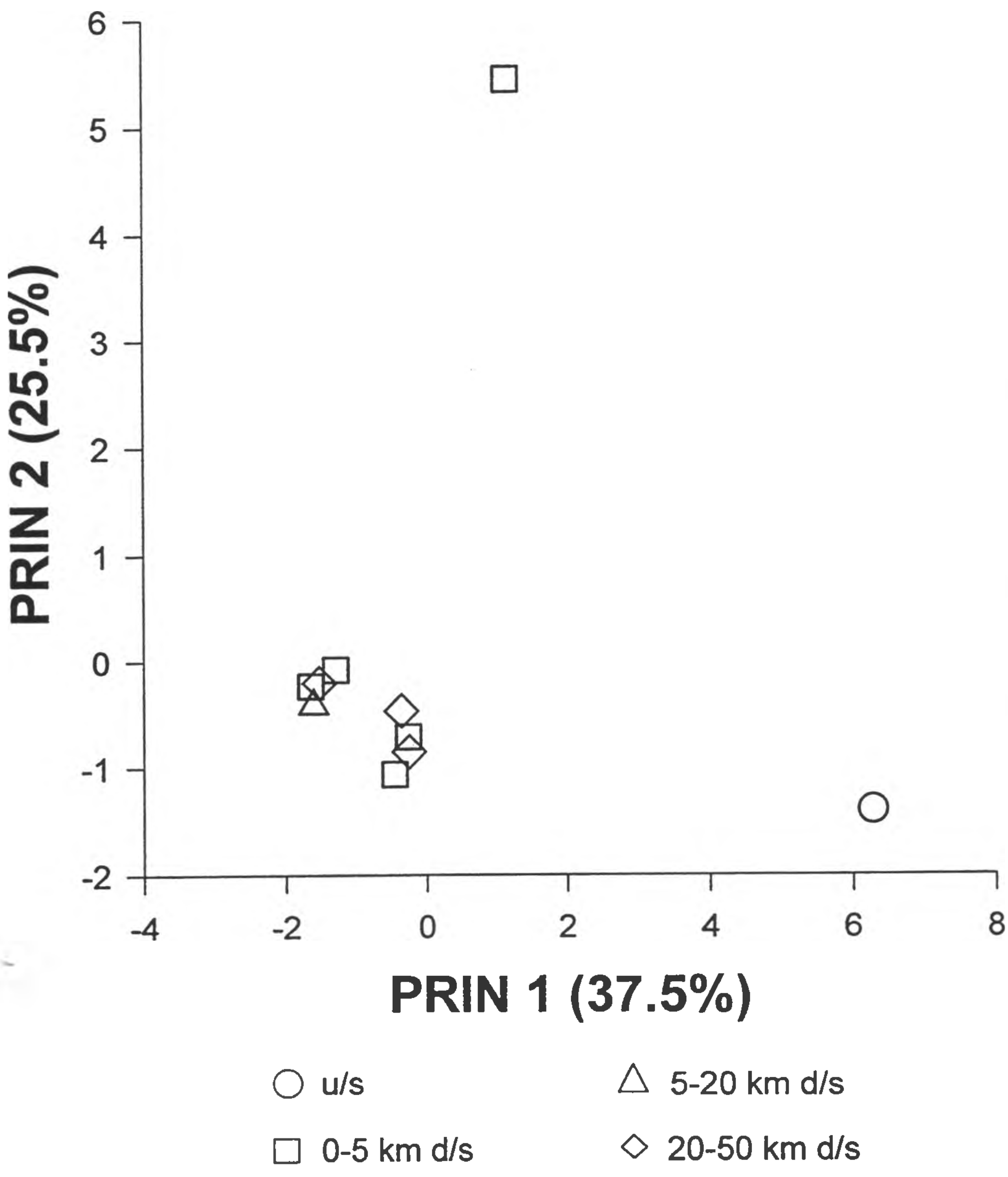
There are four distinct reaches of the Athabasca River around Weldwood considered:

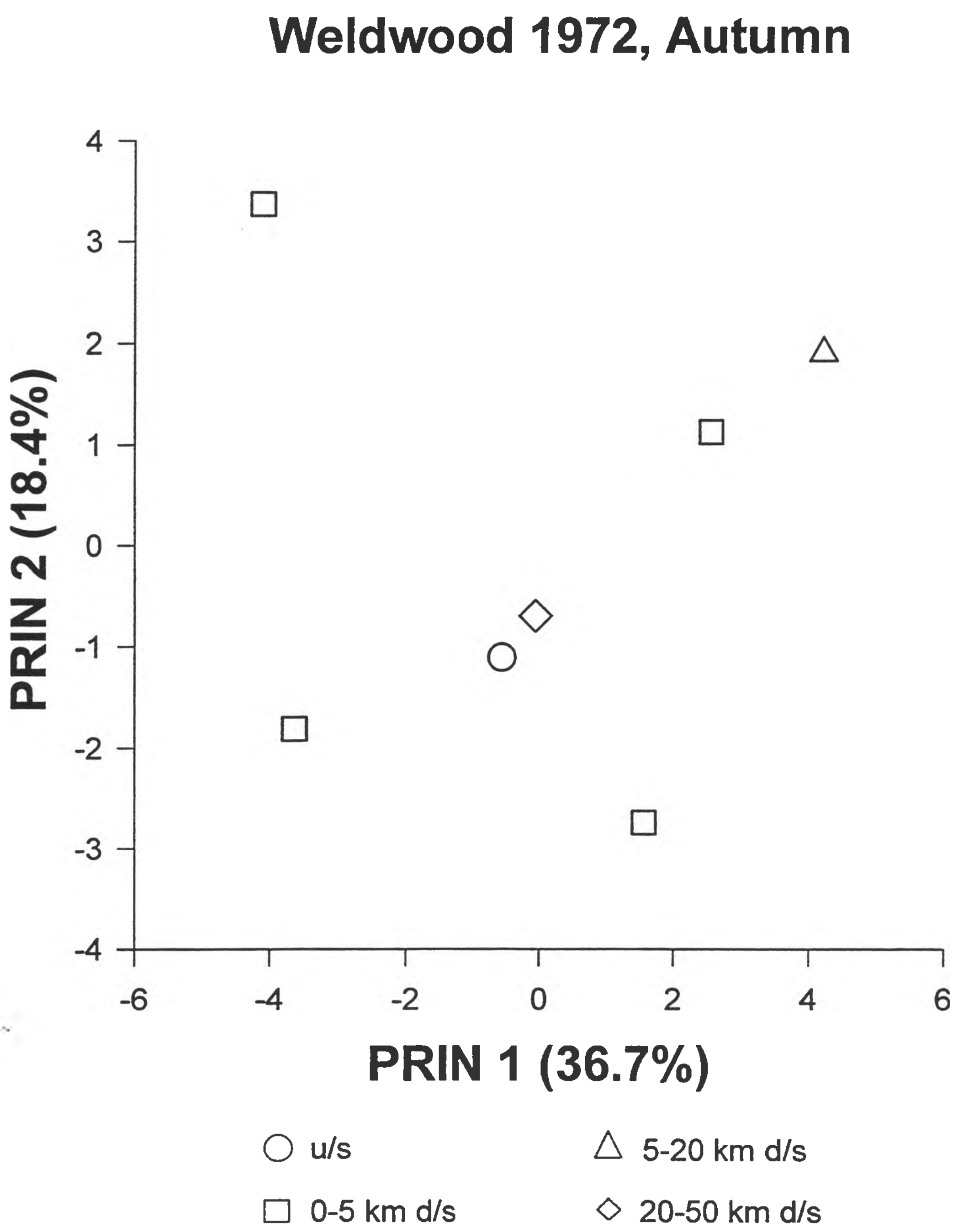
upstream of the pulp mill outfall	u/s
between 0 and 5 km downstream of the pulp mill outfall	0-5 km d/s
between 5 and 20 km downstream of the pulp mill outfall	5-20 km d/s
between 20 and 50 km downstream of the pulp mill outfall	20-50 km d/s

Analysis is appended for the following years:

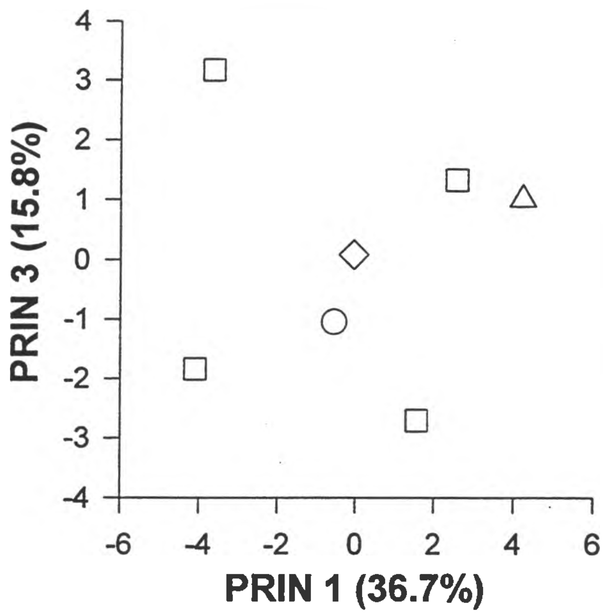
1960	spring
1972	autumn
1974	autumn
1976	autumn
1977	spring
1979	autumn
1984	spring
1985	autumn
1986	spring
1989	spring
1990	autumn
1991	spring
1992	spring
1992	autumn

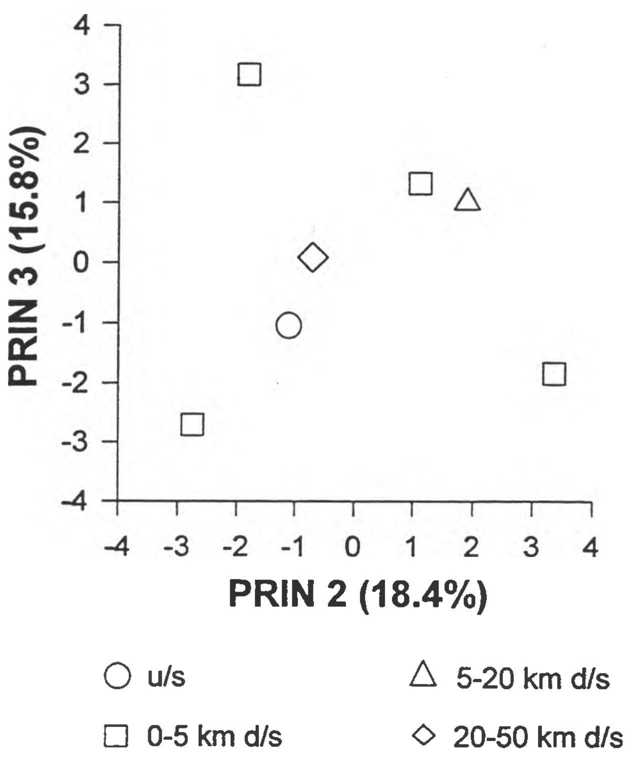
Weldwood 1960, Spring

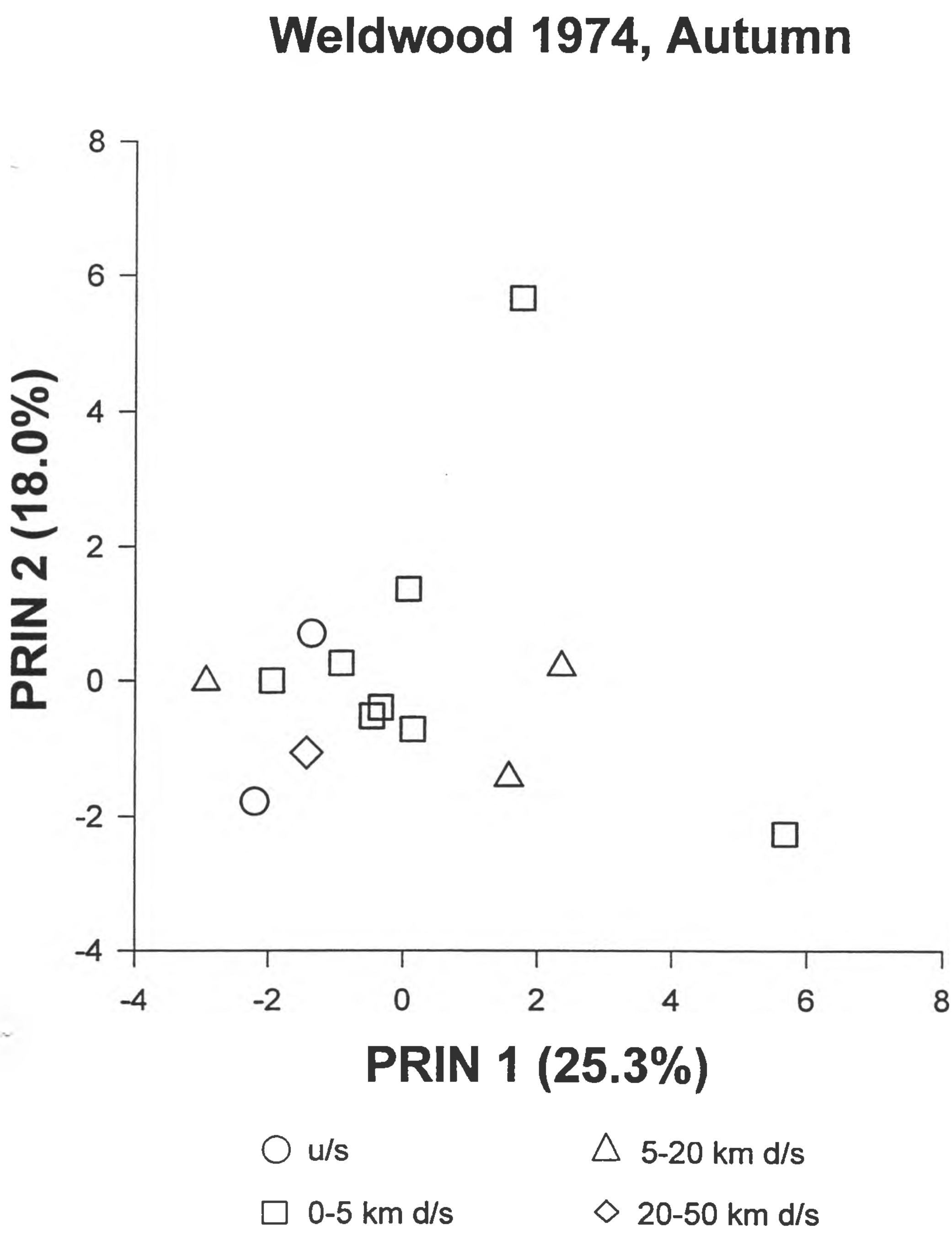


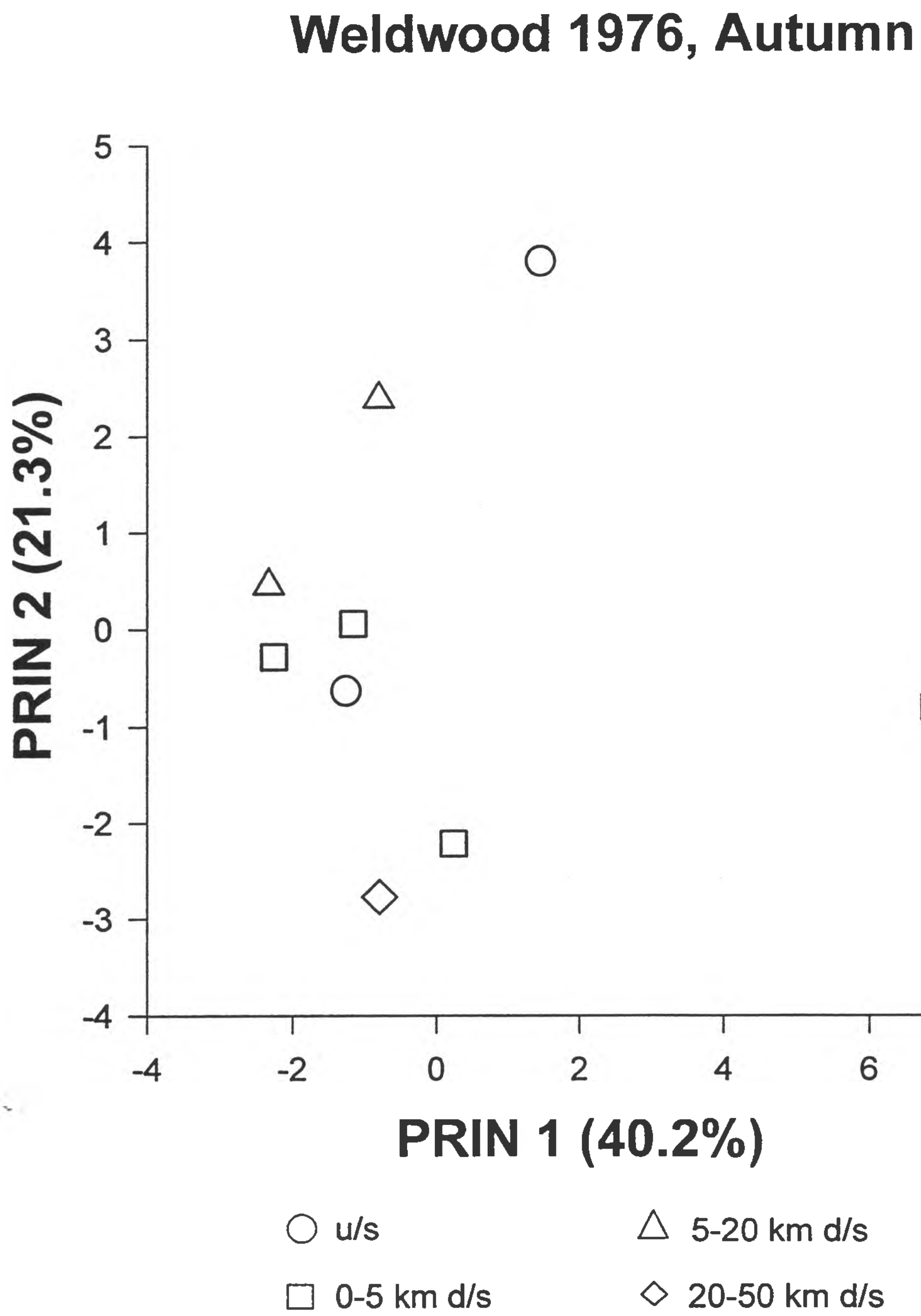

Weldwood 1972, Autumn
4
3
2
1
0
-1
-2
-3
-4
-6
-4
-2
0
2
4
6
PRIN 2 (18.4%)
PRIN 1 (36.7%)
u/s
0-5 km d/s
5-20 km d/s
20-50 km d/s

Weldwood 1972, Autumn

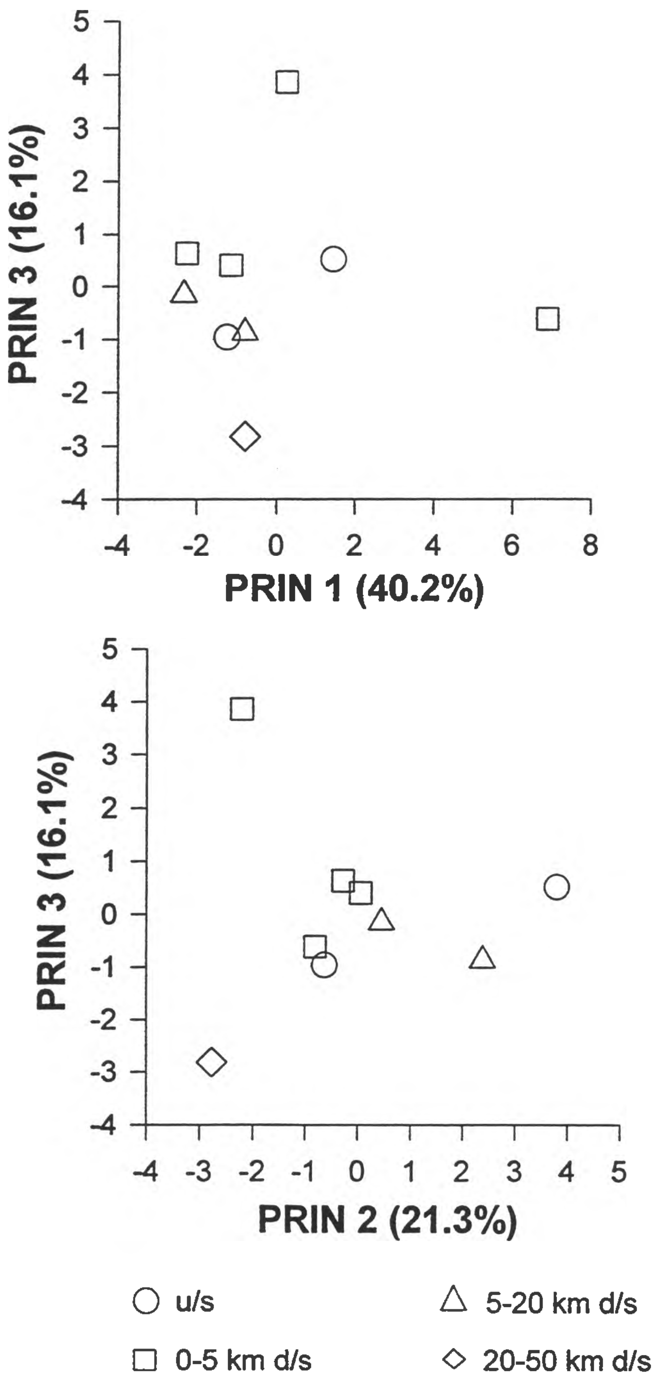




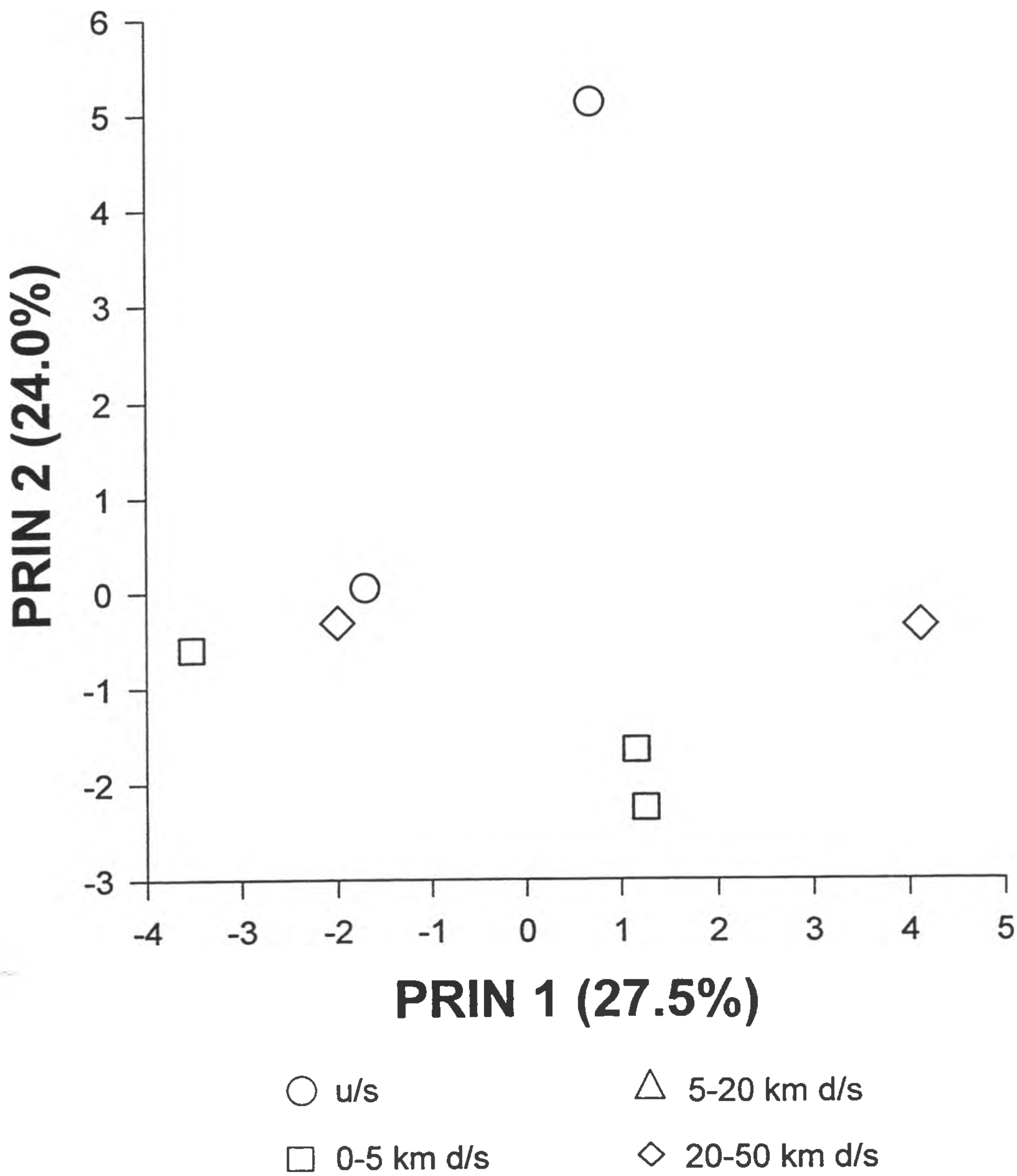

Weldwood 1974, Autumn
PRIN 2 (18.0%)
PRIN 1 (25.3%)
8
6
4
2
0
-2
-4
-4
-2
0
2
4
6
8
u/s
0-5 km d/s
5-20 km d/s
20-50 km d/s


Weldwood 1976, Autumn
PRIN 2 (21.3%)
5
4
3
2
1
0
-1
-2
-3
-4
-4
-2
0
2
4
6
8
PRIN 1 (40.2%)
u/s
5-20 km d/s
0-5 km d/s
20-50 km d/s

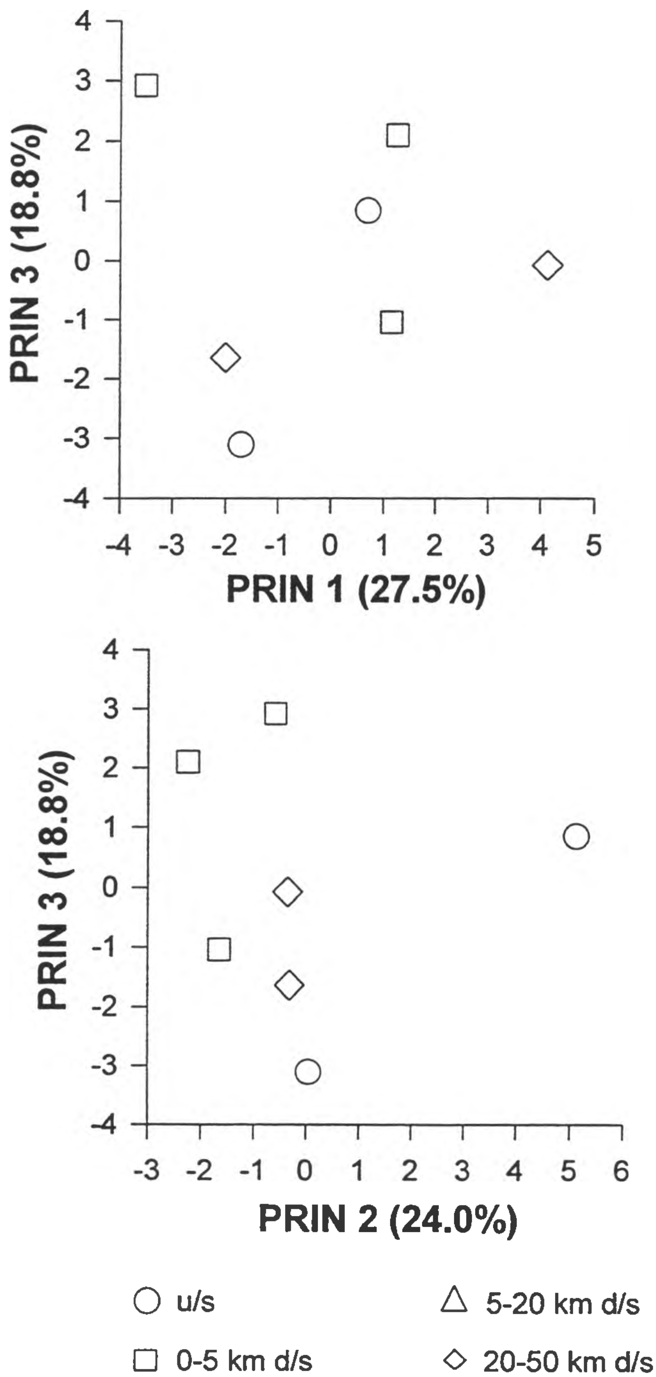
Weldwood 1976, Autumn

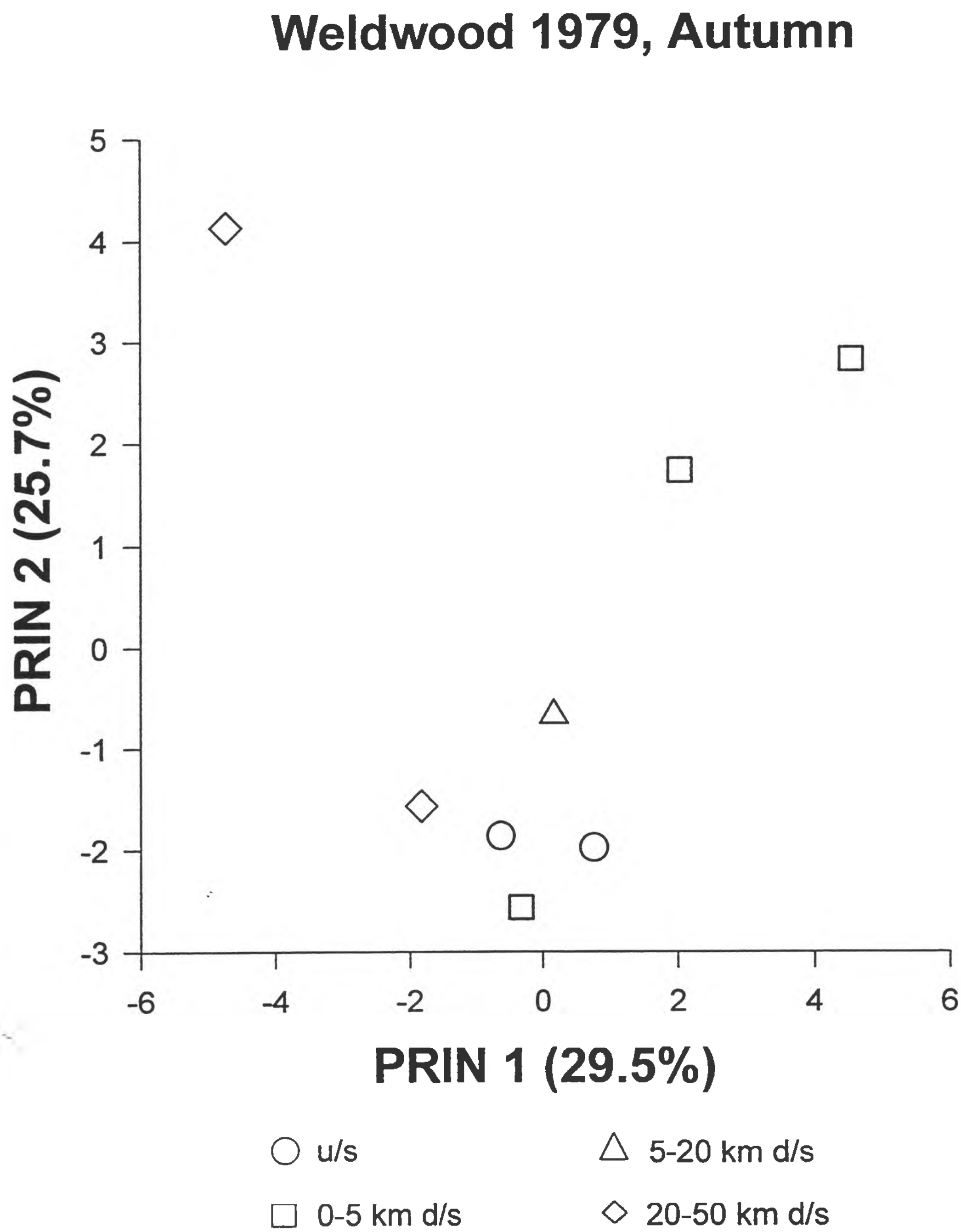


Weldwood 1977, Spring



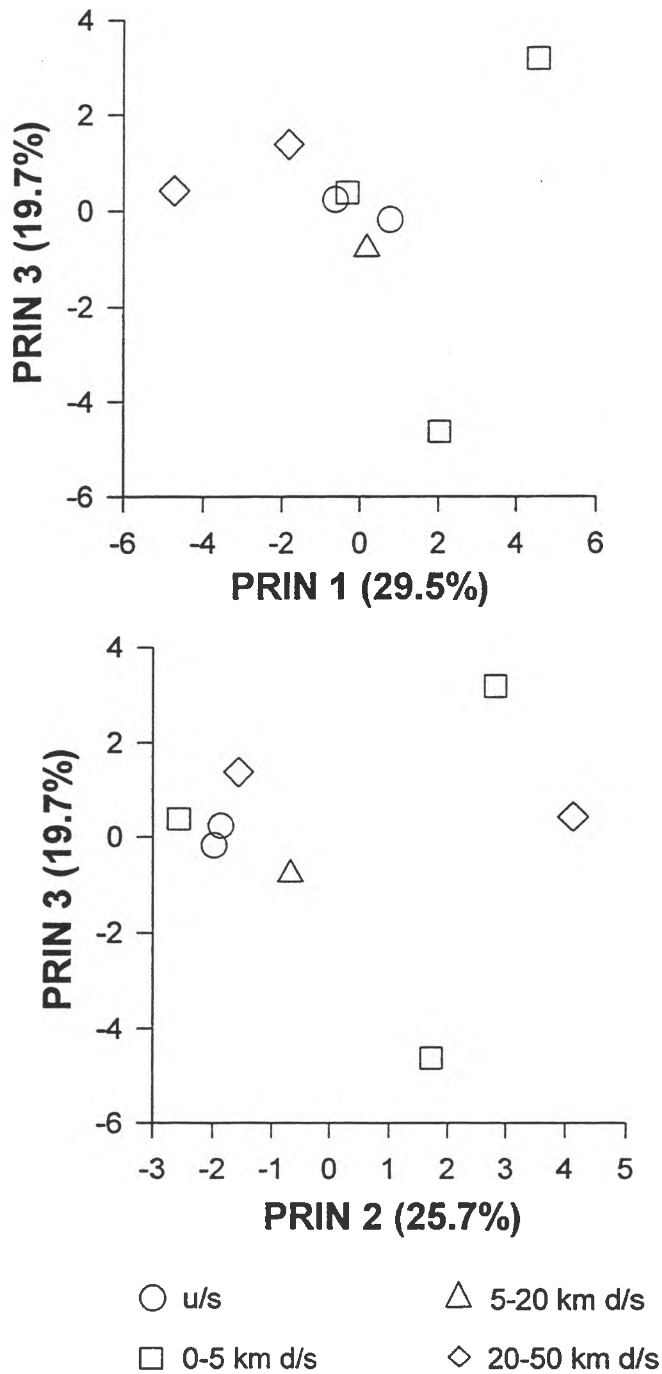
Weldwood 1977, Spring

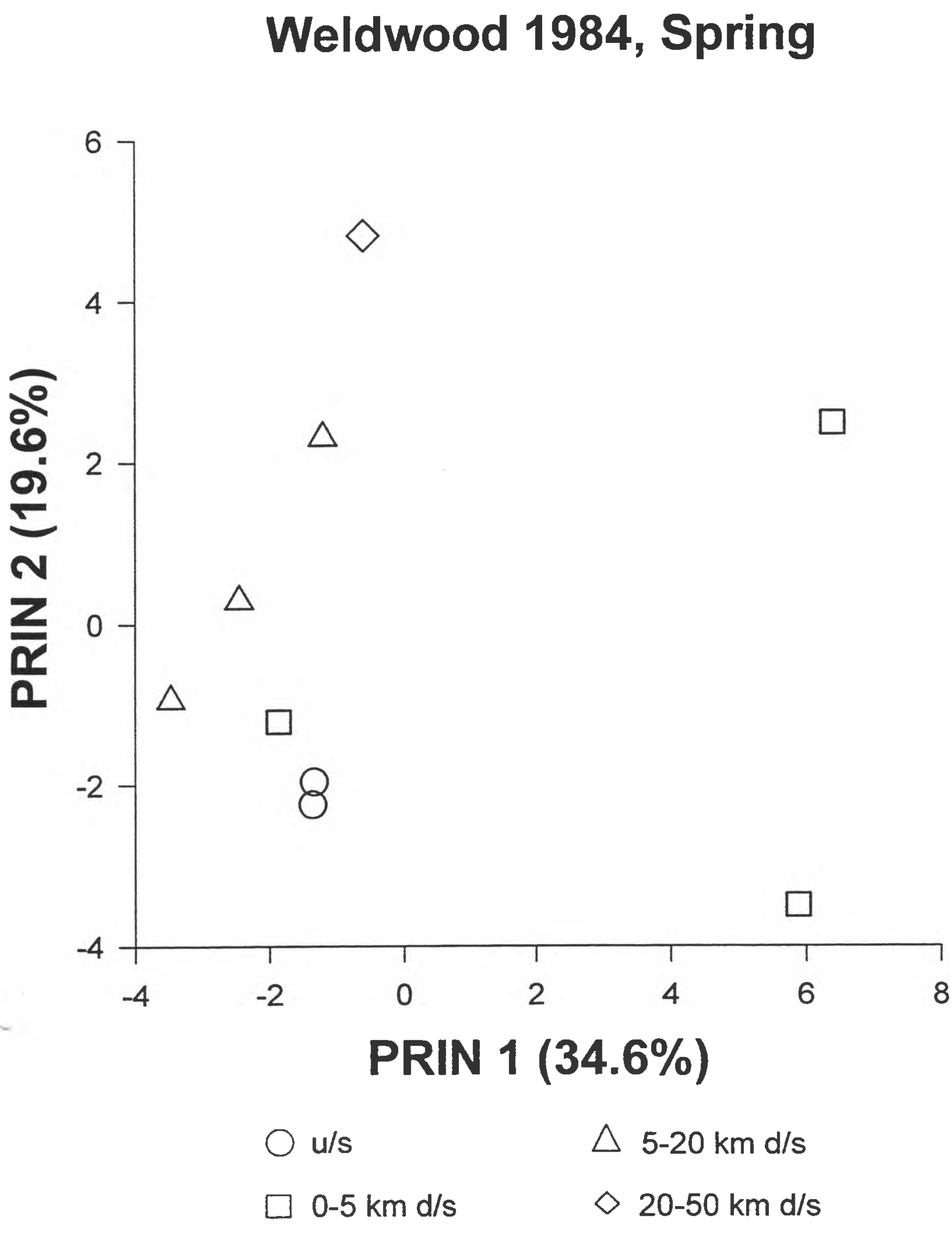




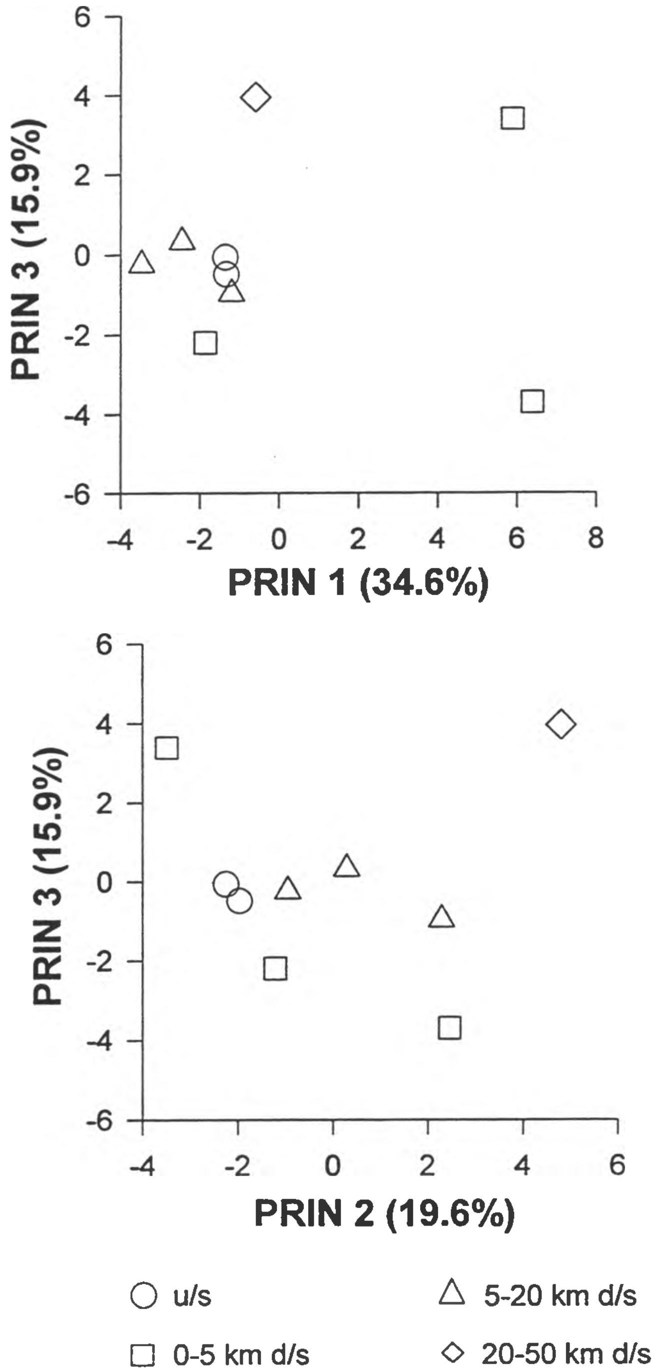
Weldwood 1979, Autumn
PRIN 2 (25.7%)
PRIN 1 (29.5%)
5
4
3
2
1
0
-1
-2
-3
-6
-4
-2
0
2
4
6
u/s
5-20 km d/s
0-5 km d/s
20-50 km d/s

Weldwood 1979, Autumn

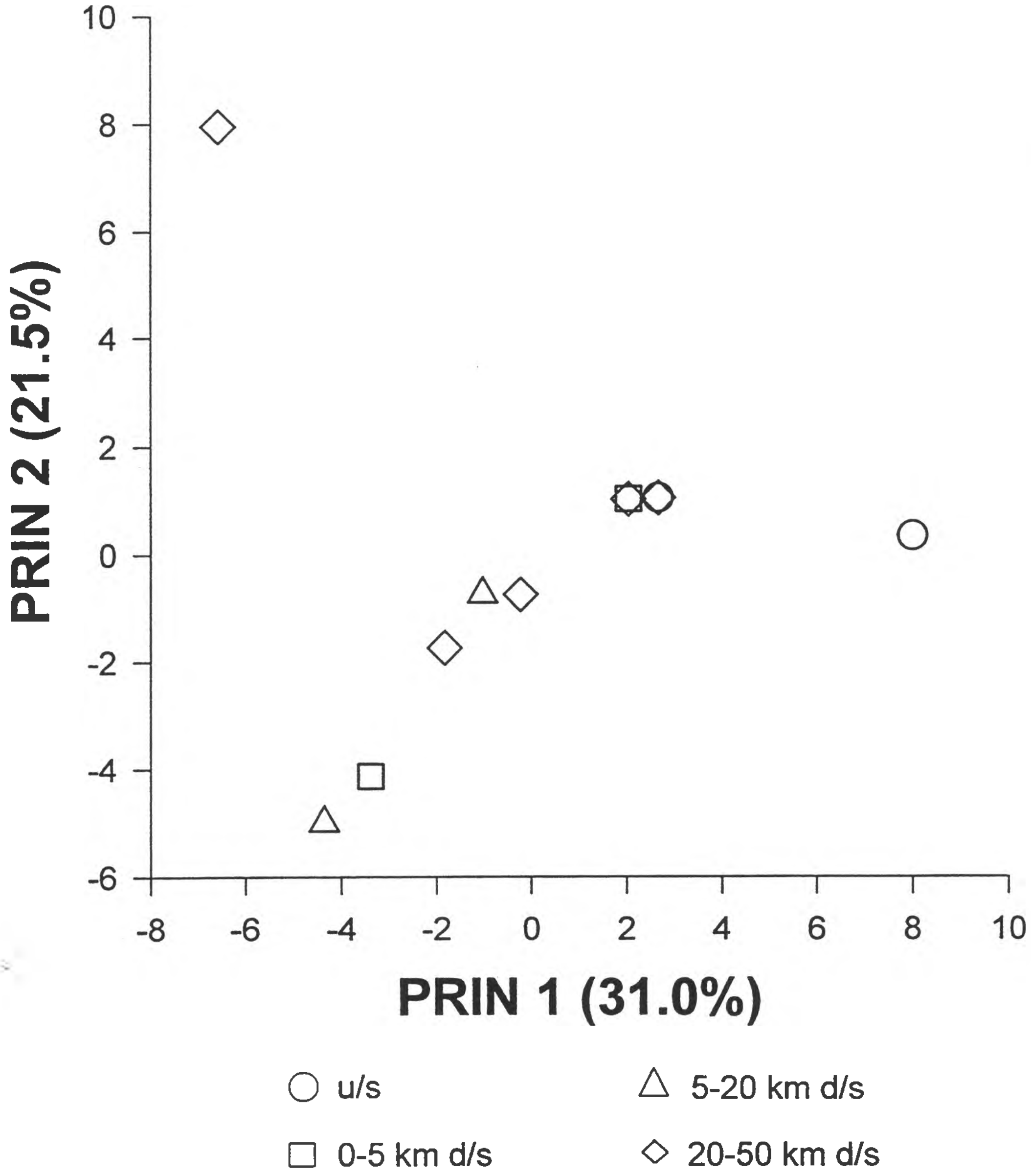



Weldwood 1984, Spring
PRIN 2 (19.6%)
6
4
2
0
-2
-4
-4
-2
0
2
4
6
8
PRIN 1 (34.6%)
u/s
5-20 km d/s
0-5 km d/s
20-50 km d/s

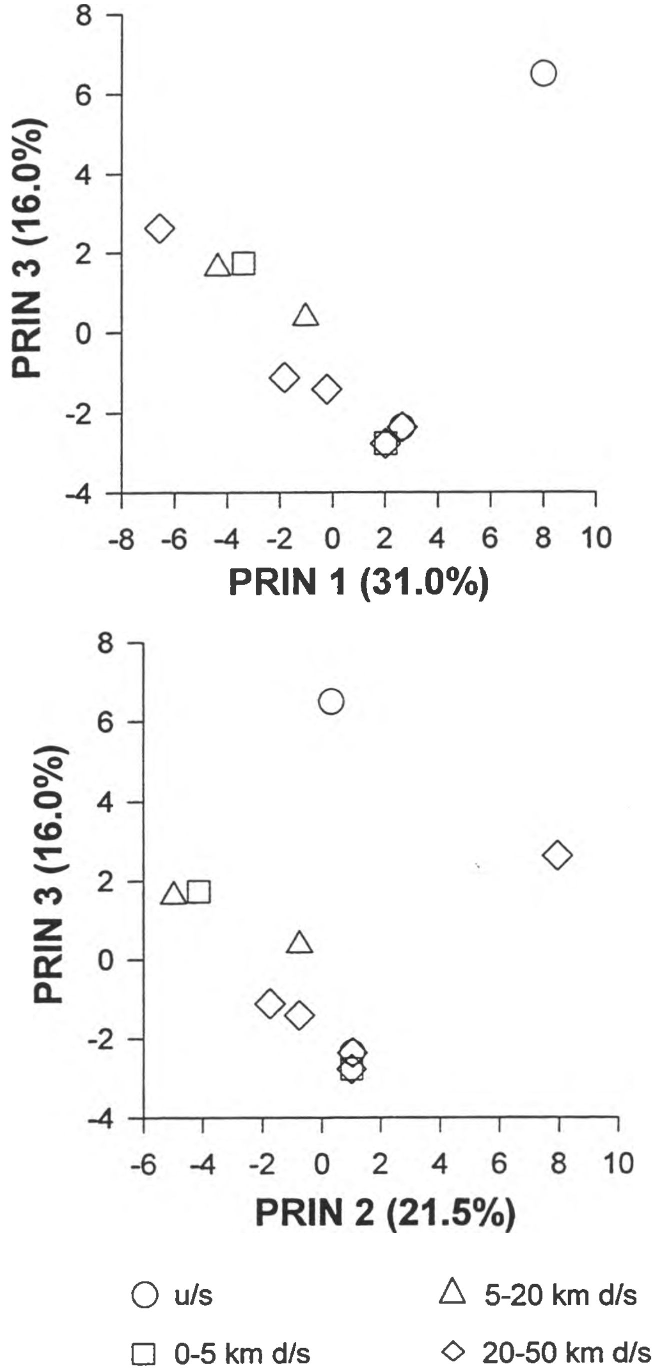
Weldwood 1984, Spring

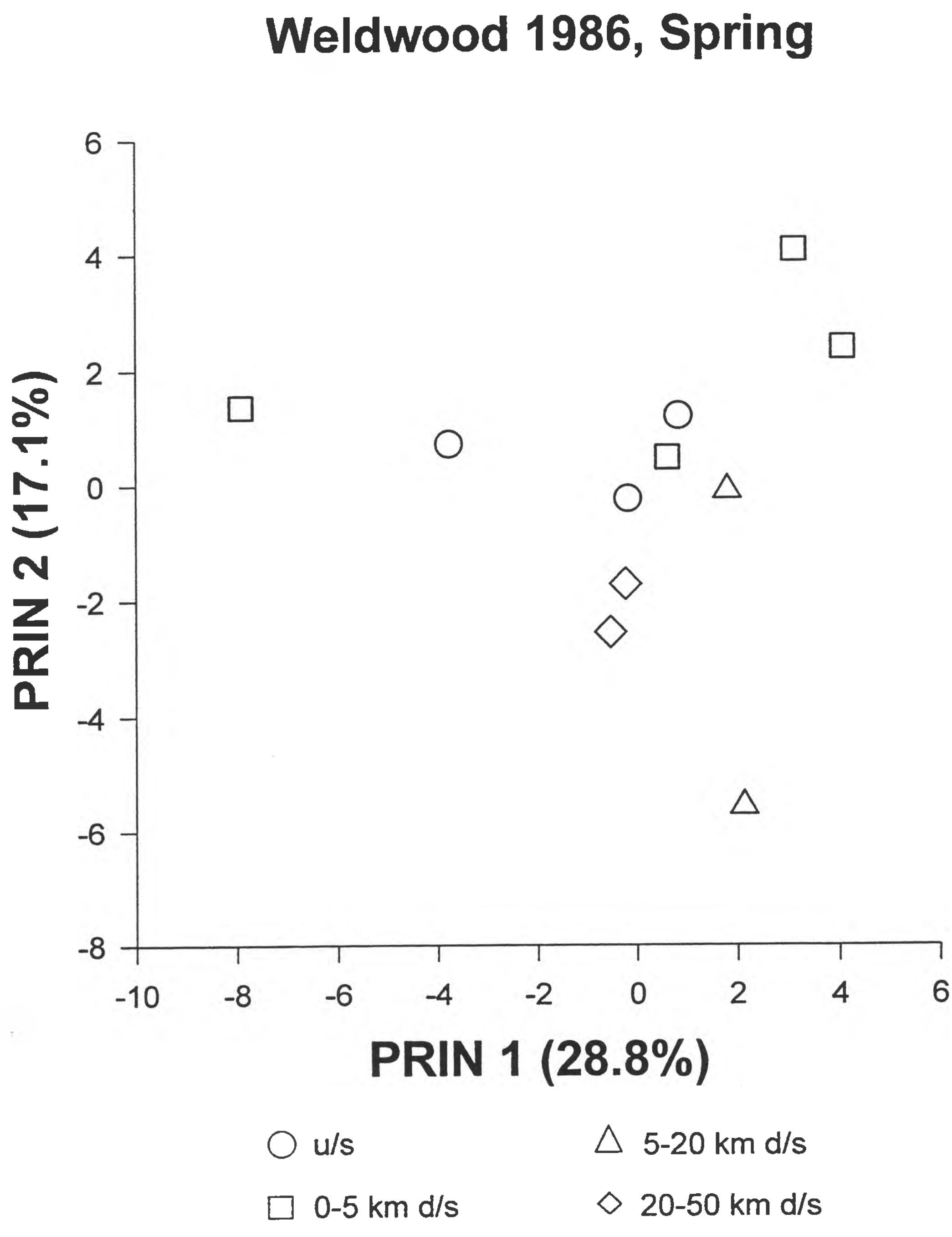


Weldwood 1985, Autumn

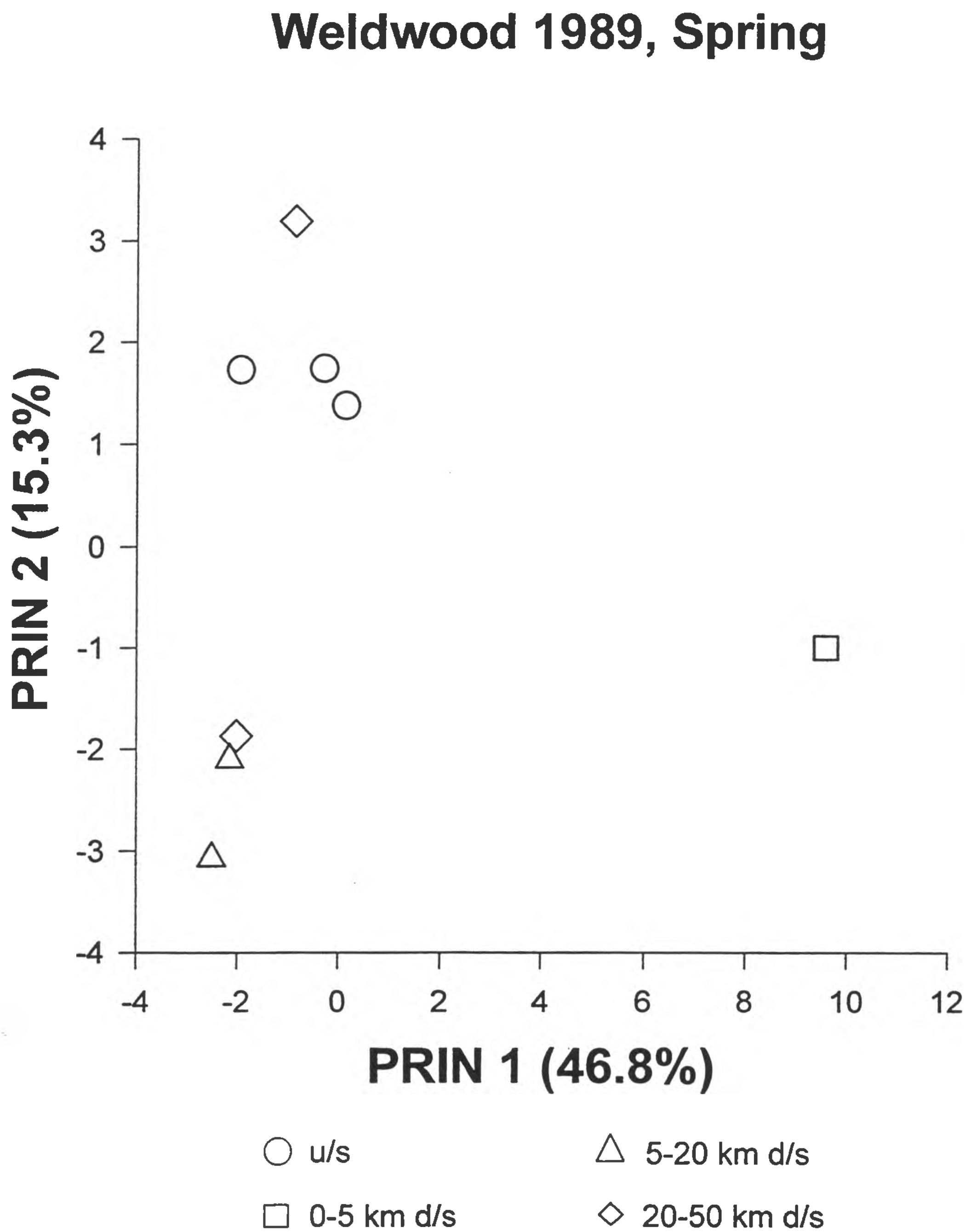


Weldwood 1985, Autumn

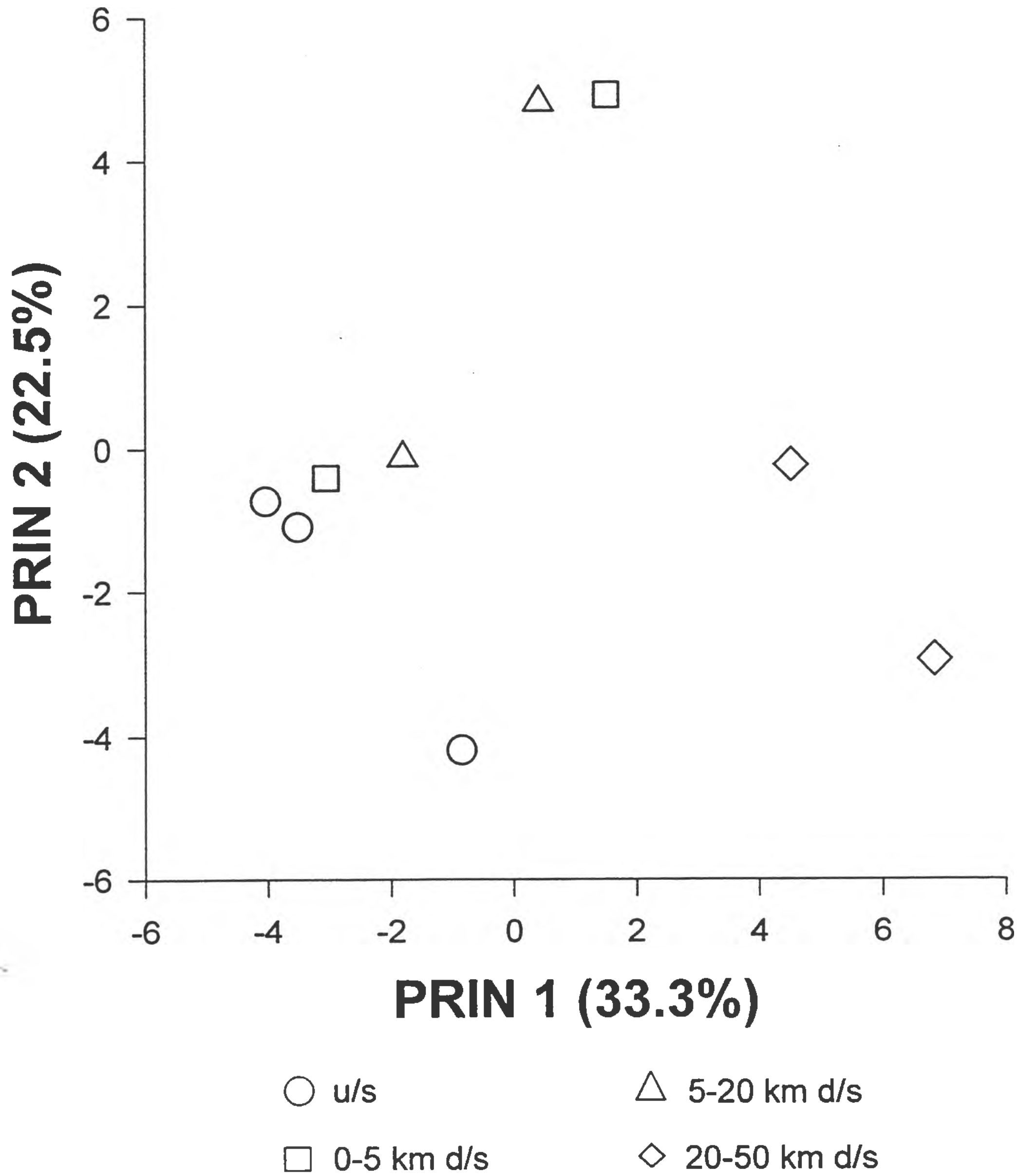


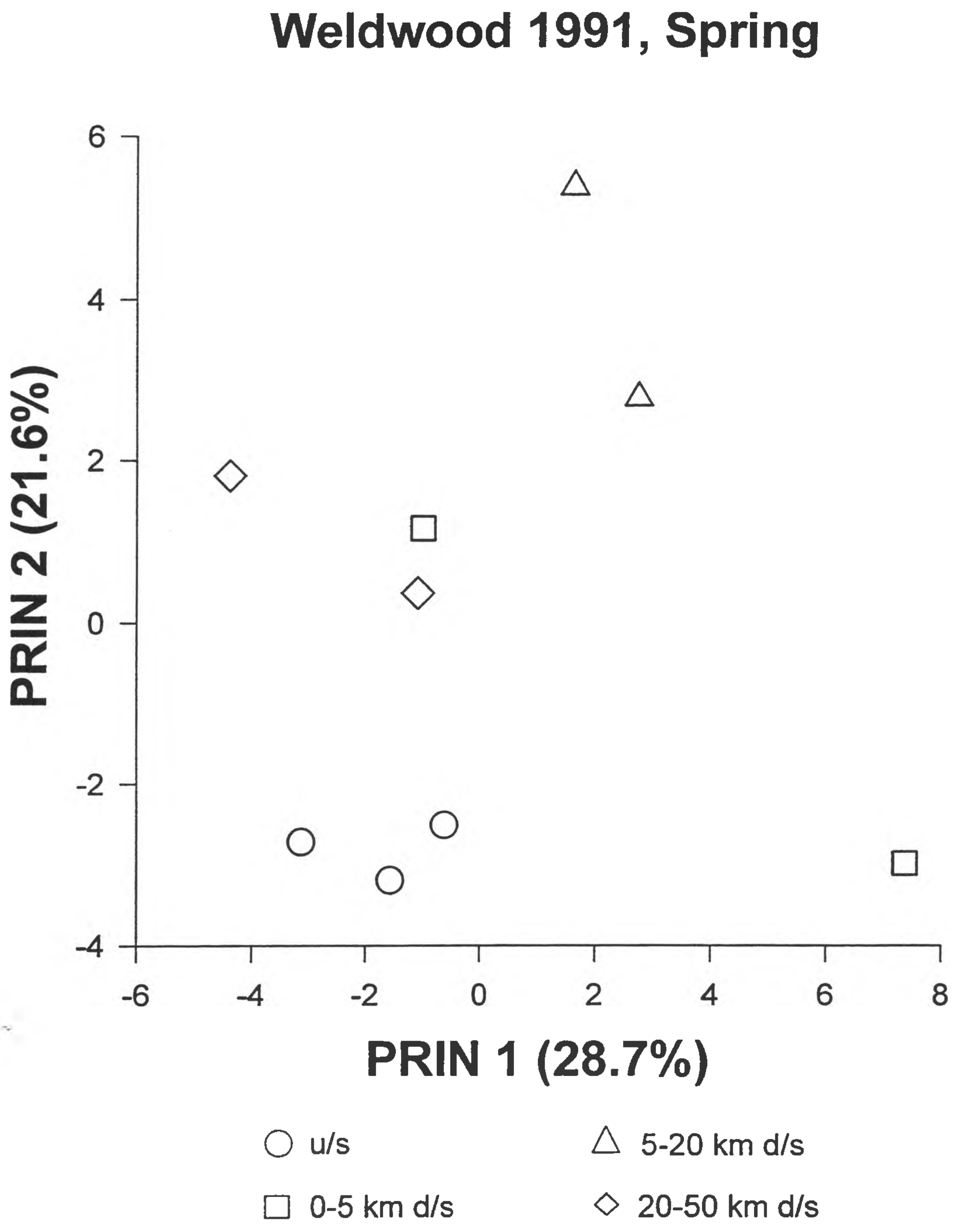


Weldwood 1986, Spring
PRIN 2 (17.1%)
PRIN 1 (28.8%)
6
4
2
0
-2
-4
-6
-8
-10
-8
-6
-4
-2
0
2
4
6
u/s
0-5 km d/s
5-20 km d/s
20-50 km d/s

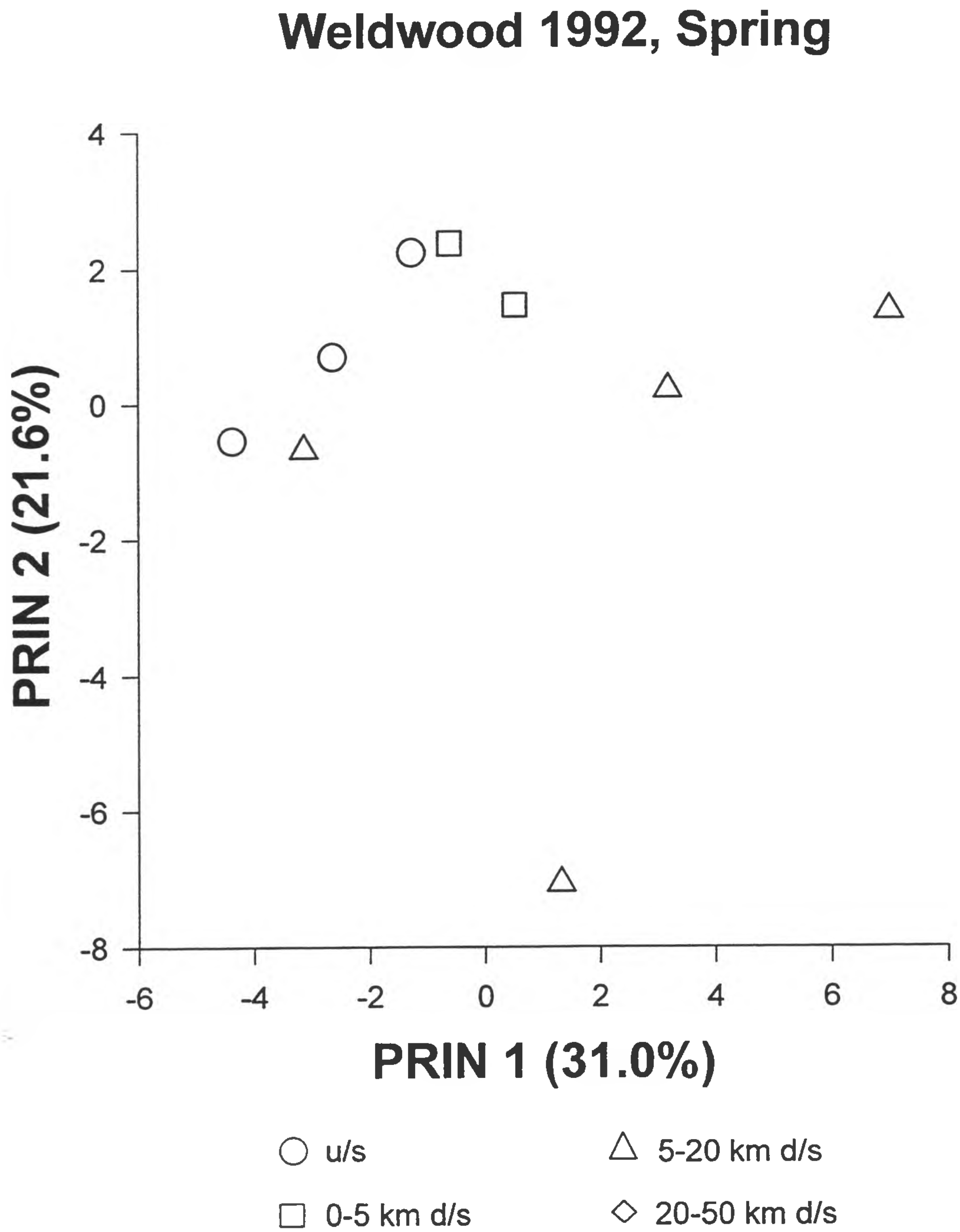

Weldwood 1989, Spring
PRIN 2 (15.3%)
PRIN 1 (46.8%)
4
3
2
1
0
-1
-2
-3
-4
-4
-2
0
2
4
6
8
10
12
u/s
5-20 km d/s
0-5 km d/s
20-50 km d/s

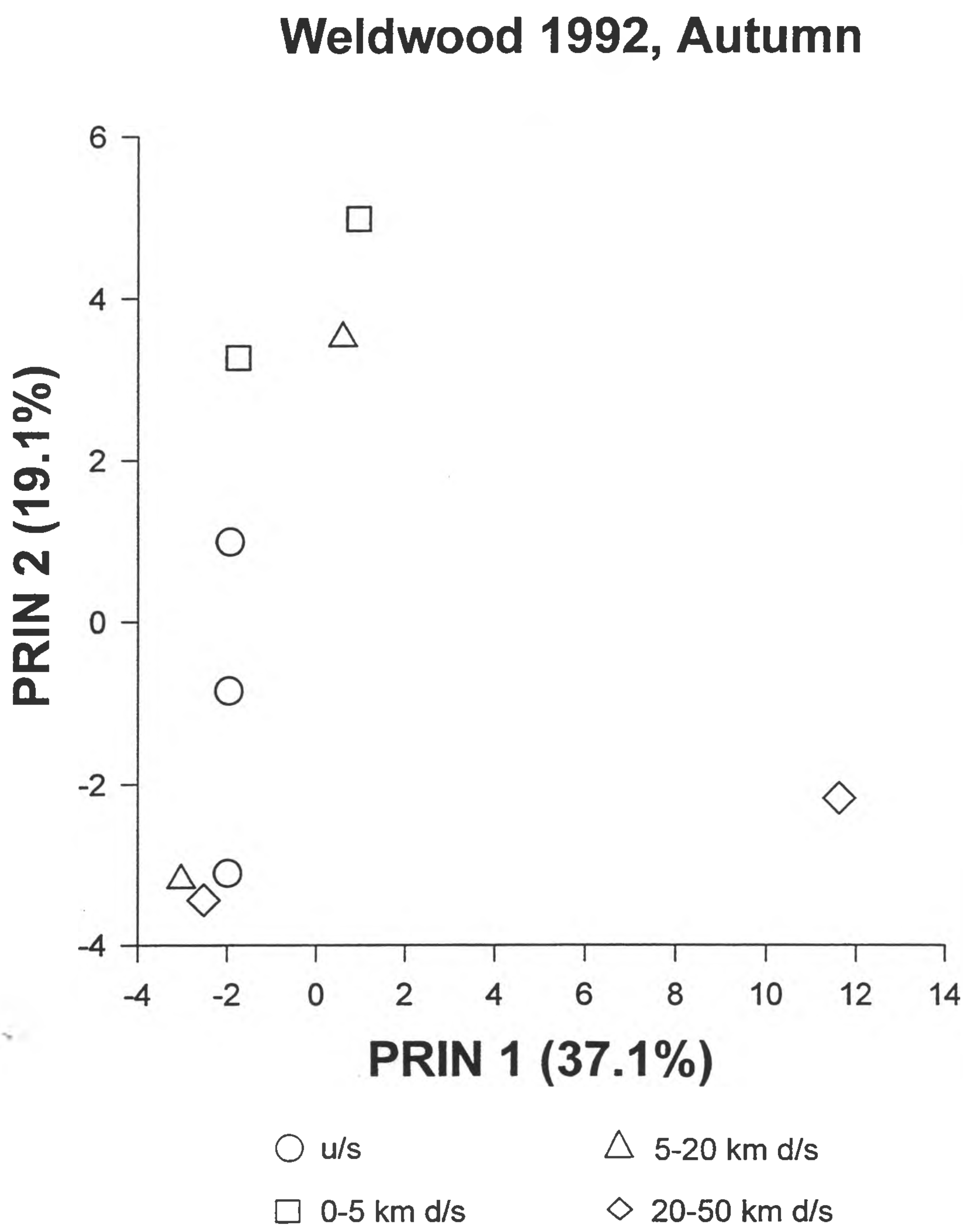
Weldwood 1990, Autumn





Weldwood 1991, Spring
6
4
2
0
-2
-4
-6
-4
-2
0
2
4
6
8
PRIN 2 (21.6%)
PRIN 1 (28.7%)
u/s
5-20 km d/s
0-5 km d/s
20-50 km d/s


Weldwood 1992, Spring
4
2
0
-2
-4
-6
-8
PRIN 2 (21.6%)
-6
-4
-2
0
2
4
6
8
PRIN 1 (31.0%)
u/s
5-20 km d/s
0-5 km d/s
20-50 km d/s


Weldwood 1992, Autumn
PRIN 2 (19.1%)
PRIN 1 (37.1%)
6
4
2
0
-2
-4
-4
-2
0
2
4
6
8
10
12
14
u/s
5-20 km d/s
0-5 km d/s
20-50 km d/s

Appendix E2

Principal Component Analysis of Benthic Invertebrate Community Structure Alberta Newsprint Corporation (ANC) and Millar Western (MW), Whitecourt

Axis labels represent the principal component axis shown (eg PRIN 1) followed by the proportion of the total variation explained by that principal component axis. The first two principal component axes are shown for all analyses. The third axis is shown only when it explains more than 15% of the total variation.

There are five distinct reaches of the Athabasca River around Whitecourt considered:

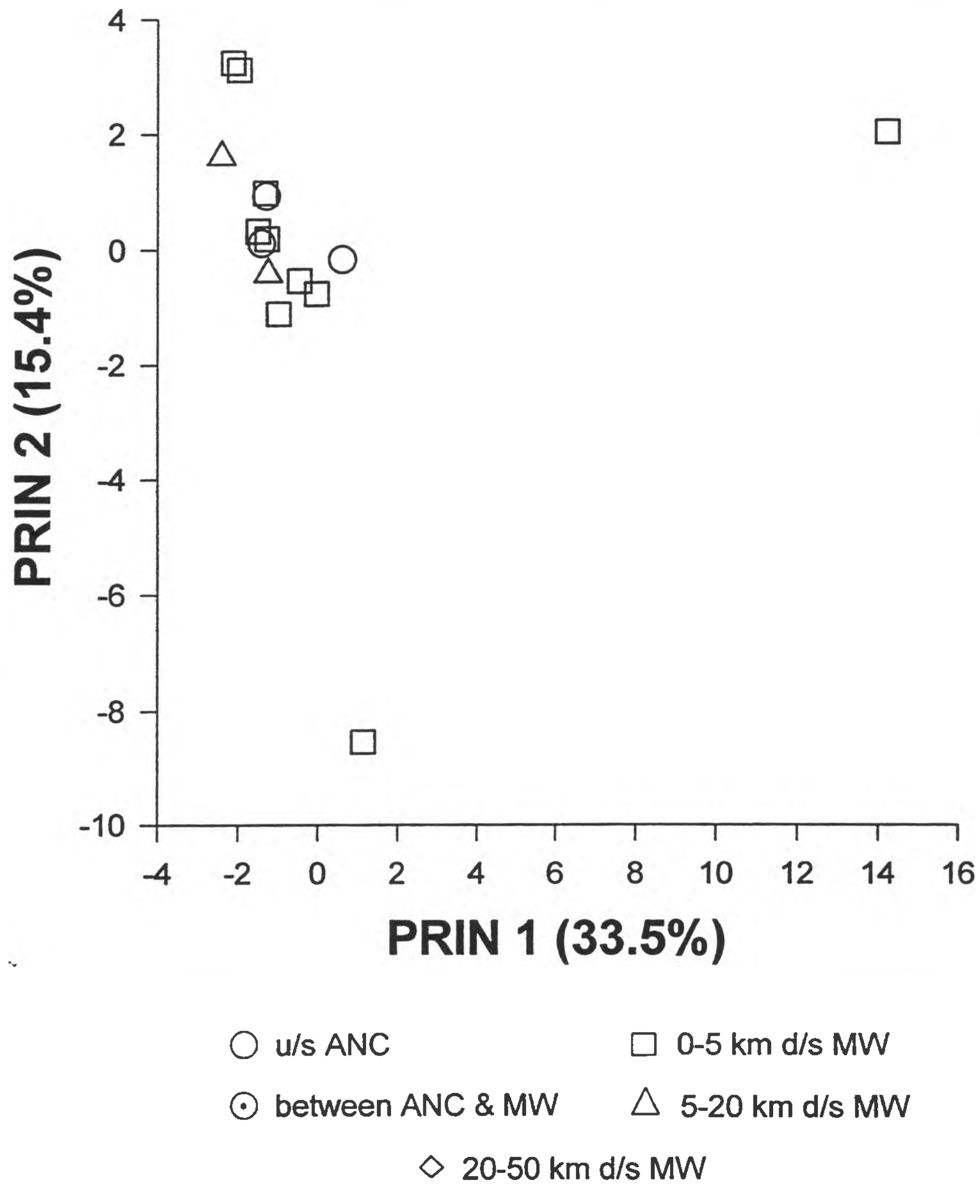
upstream of the ANC pulp mill outfall	u/s ANC
between the ANC outfall and the MW outfall	between ANC & MW
between 0 and 5 km downstream of the MW outfall	0-5 km d/s MW
between 5 and 20 km downstream of the MW outfall	5-20 km d/s MW
between 20 and 50 km downstream of the MW outfall	20-50 km d/s MW

NOTE: Alberta Newsprint Corporation did not begin to discharge effluent until August 1990.

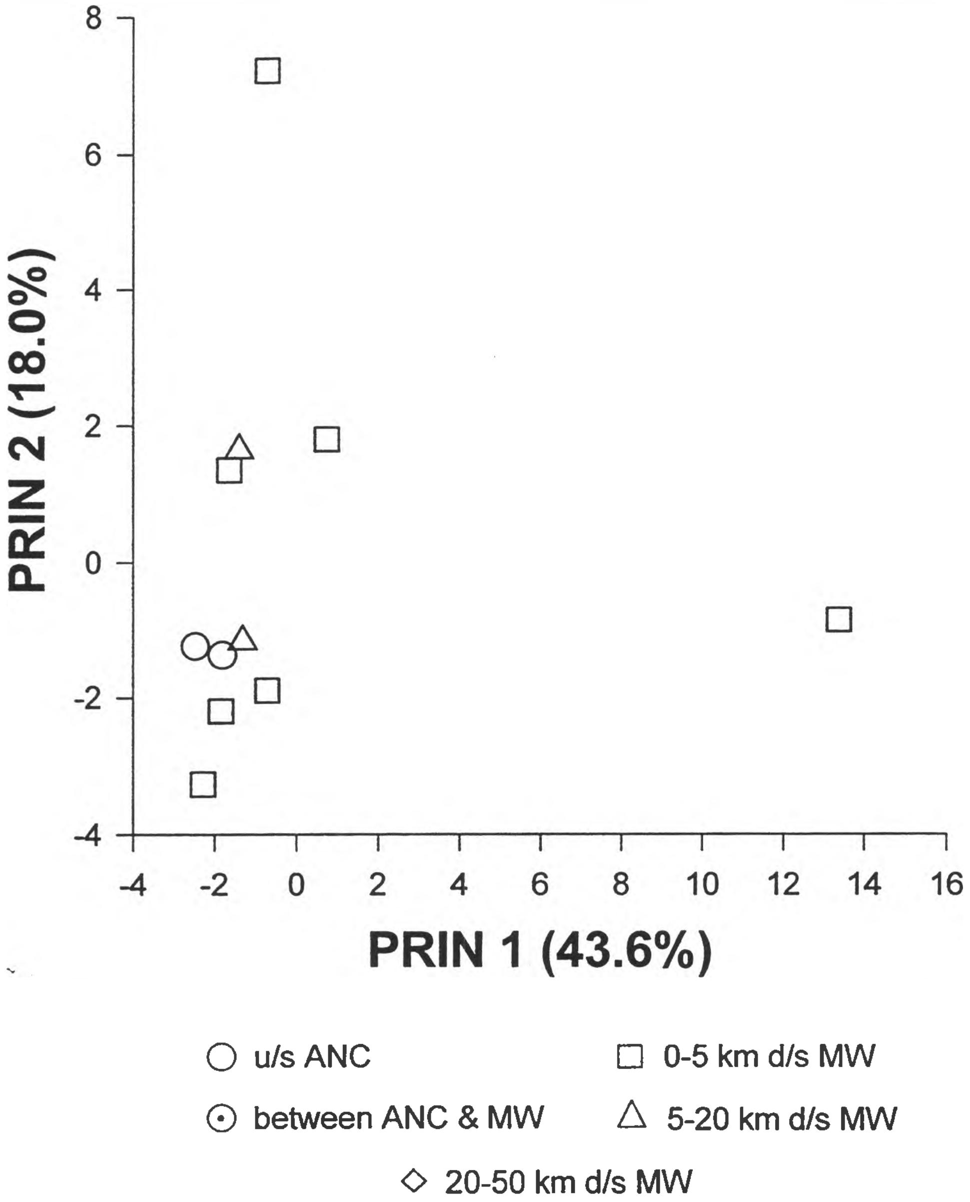
Analysis is appended for the following years:

1987 summer
1987 autumn
1988 autumn
1989 summer
1989 autumn
1990 spring
1990 autumn
1991 spring
1991 autumn
1992 spring
1992 autumn
1993 autumn

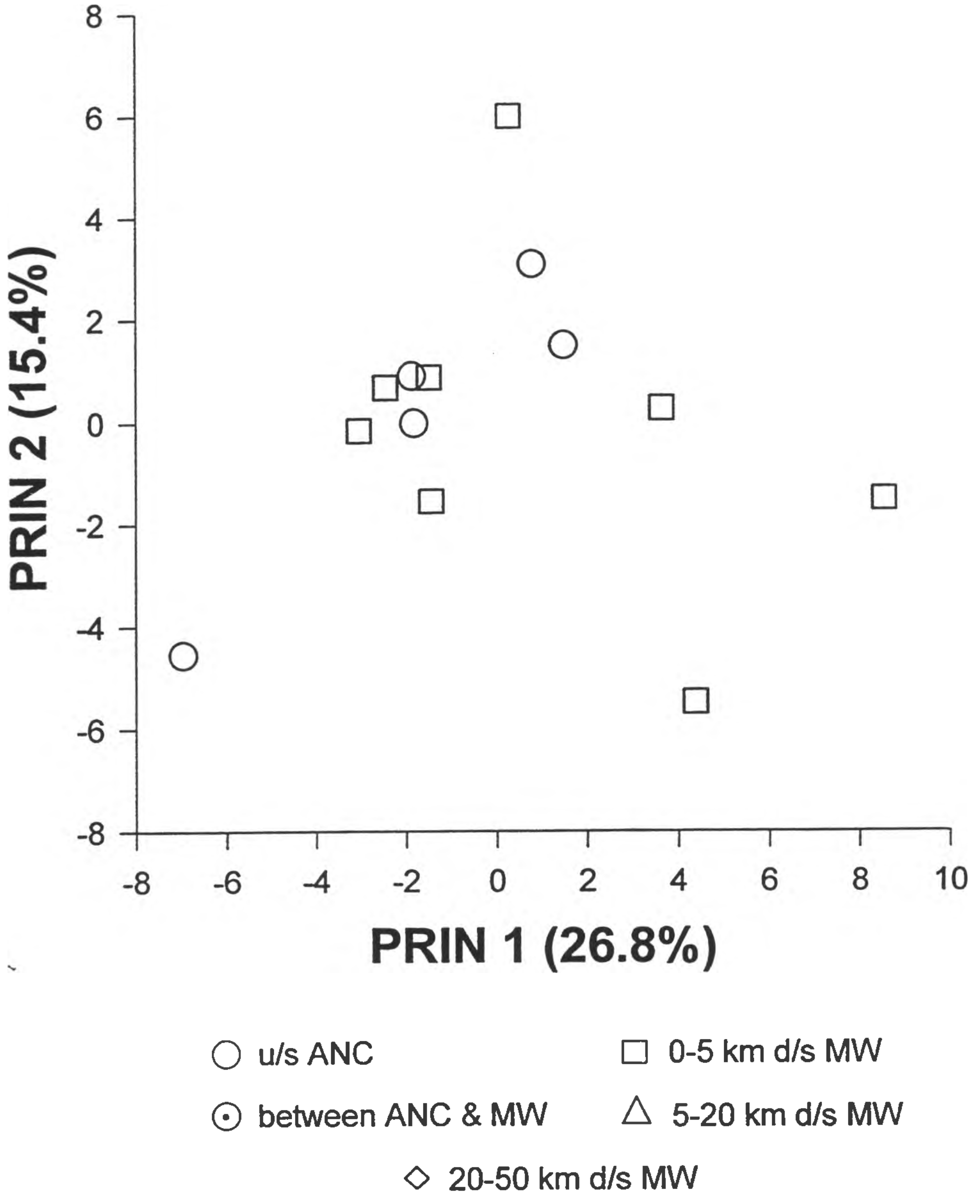
Millar Western/Alberta Newsprint Corporation
1987, Summer



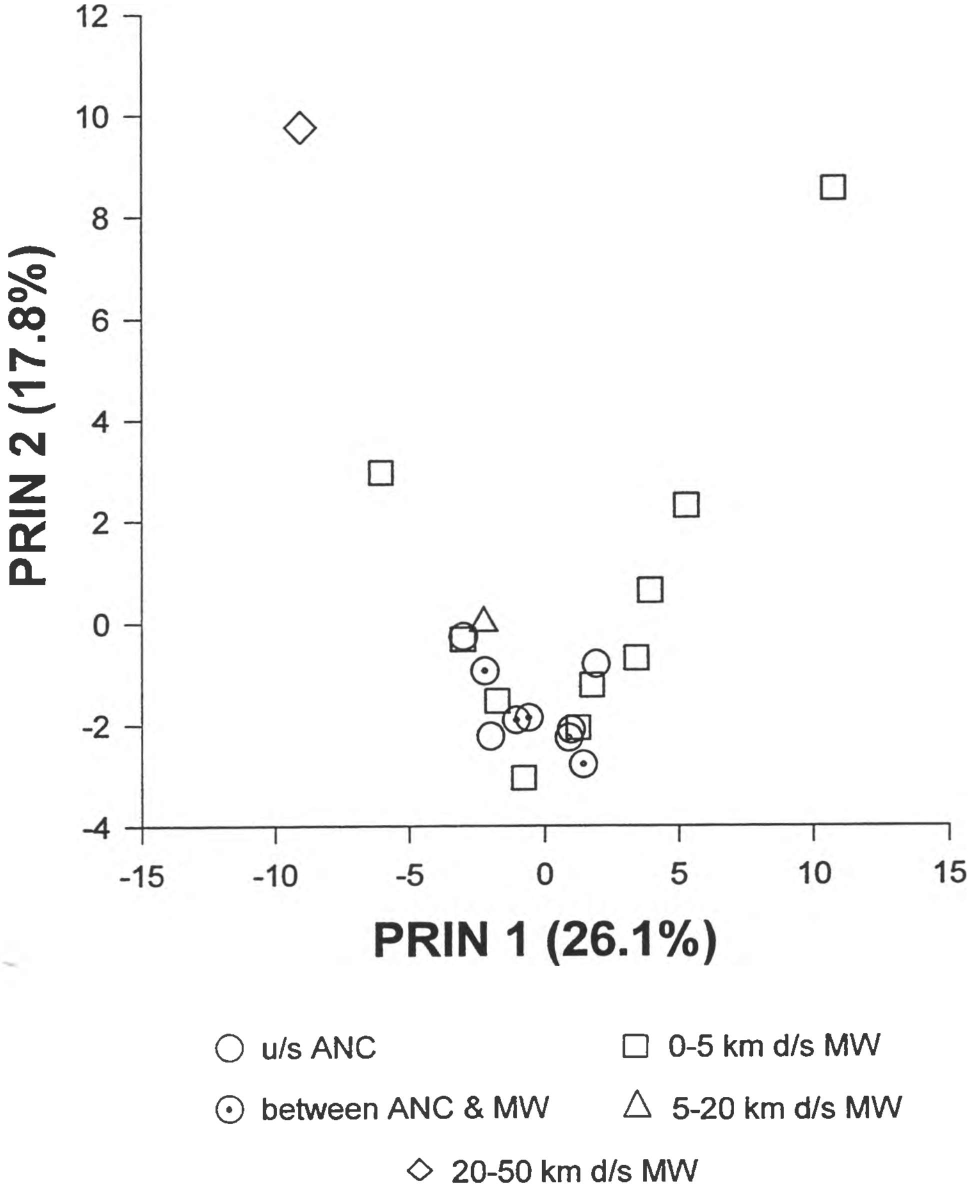
Millar Western/Alberta Newsprint Corporation
1987, Autumn



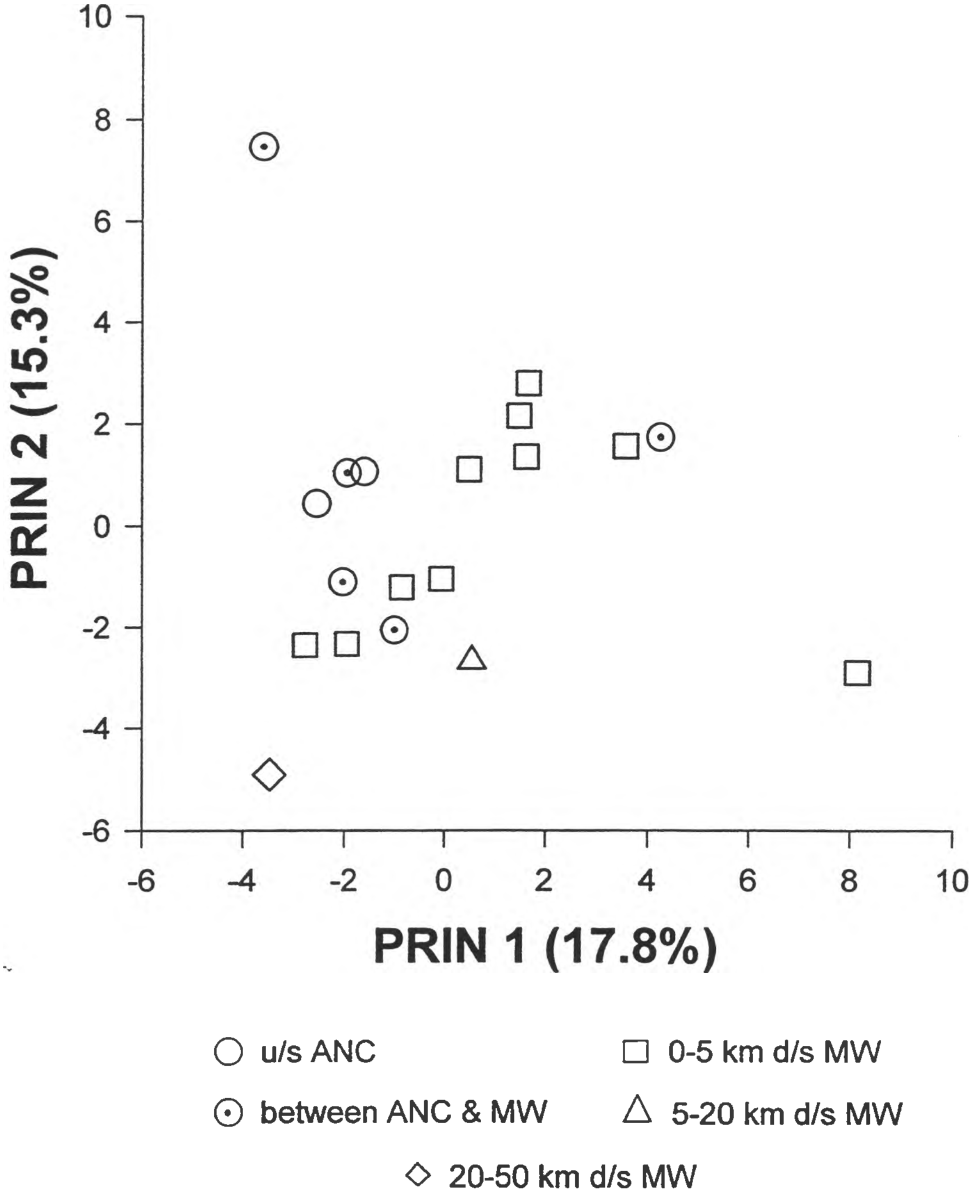
Millar Western/Alberta Newsprint Corporation
1988, Autumn



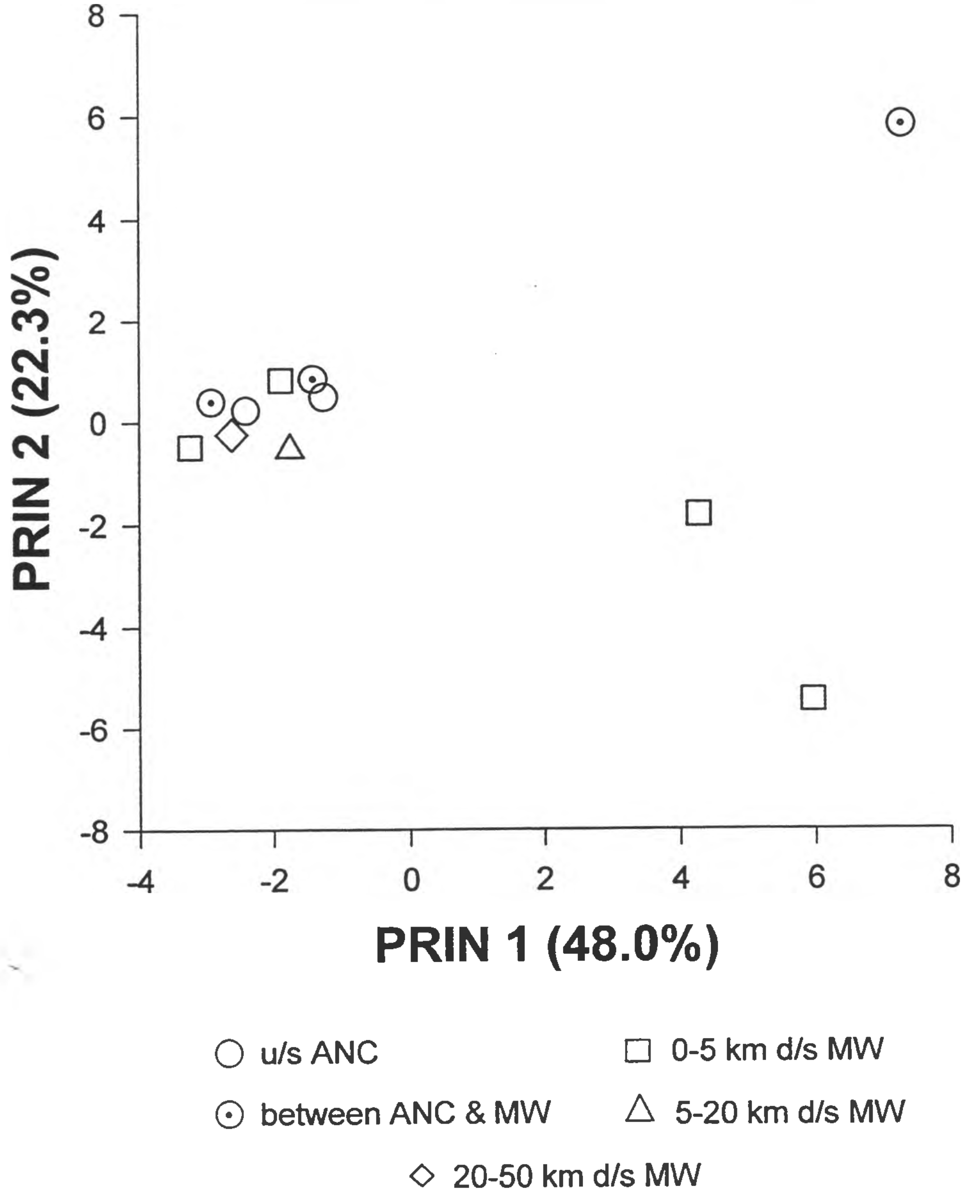
Millar Western/Alberta Newsprint Corporation
1989, Summer



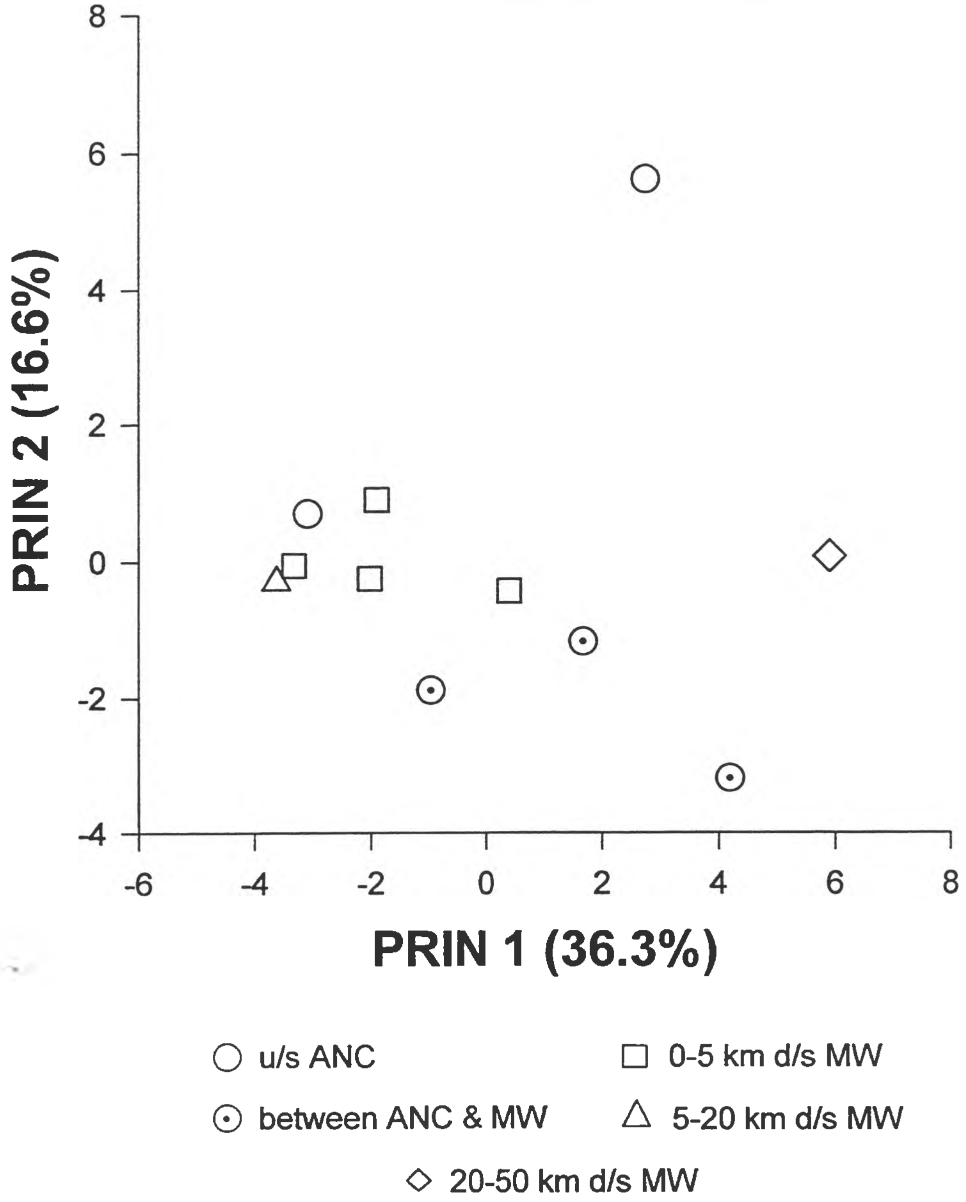
Millar Western/Alberta Newsprint Corporation
1989, Autumn



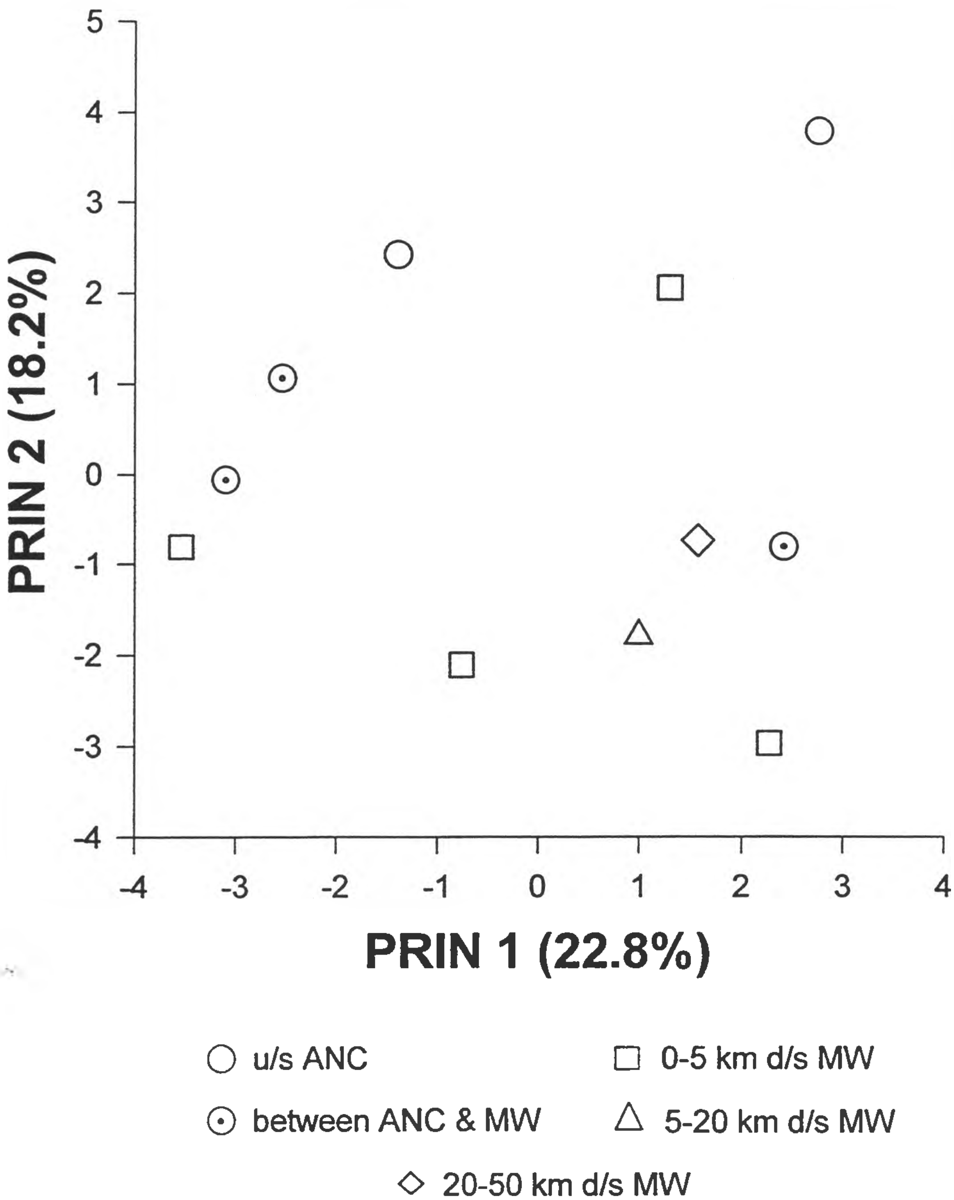
Millar Western/Alberta Newsprint Corporation
1990, Spring



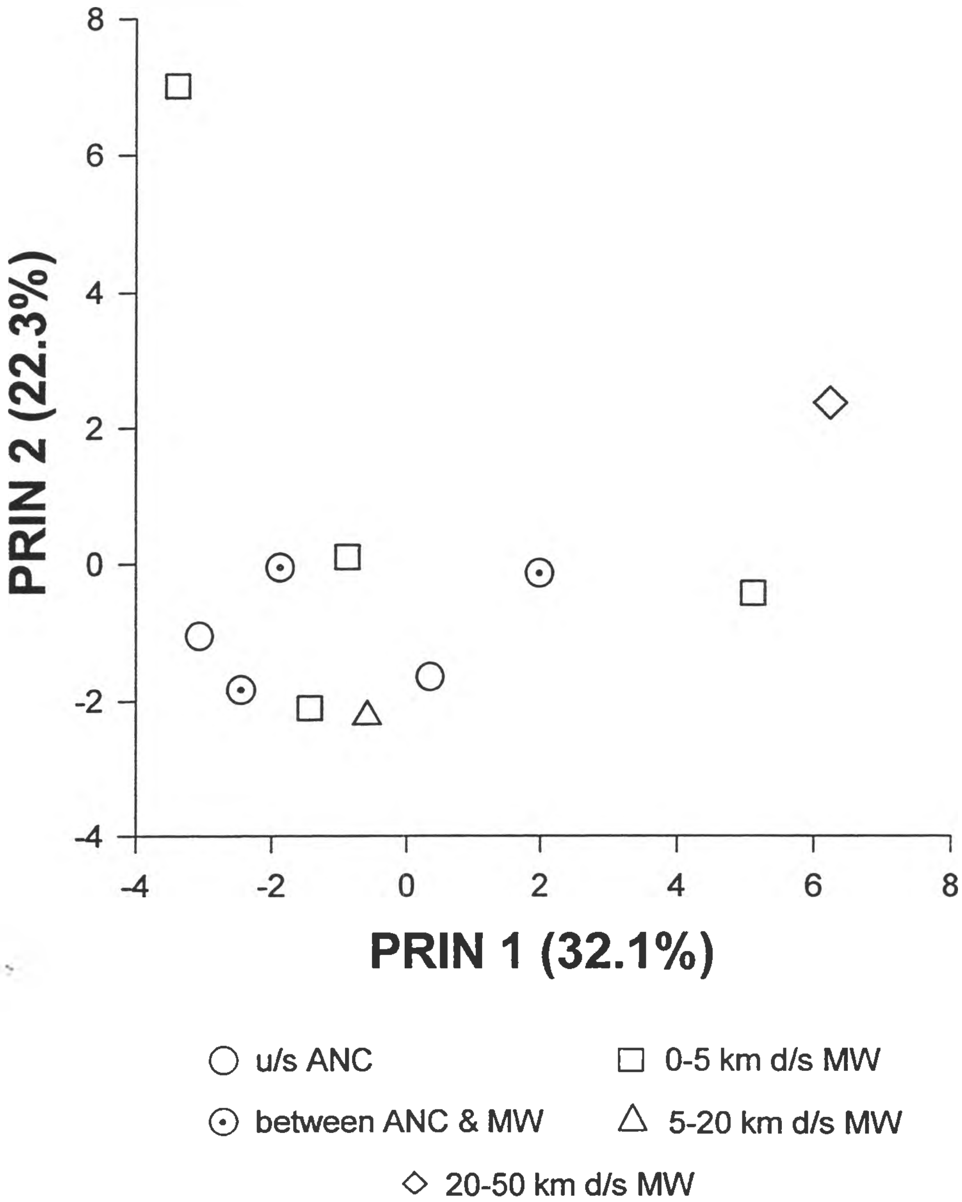
Millar Western/Alberta Newsprint Corporation
1990, Autumn



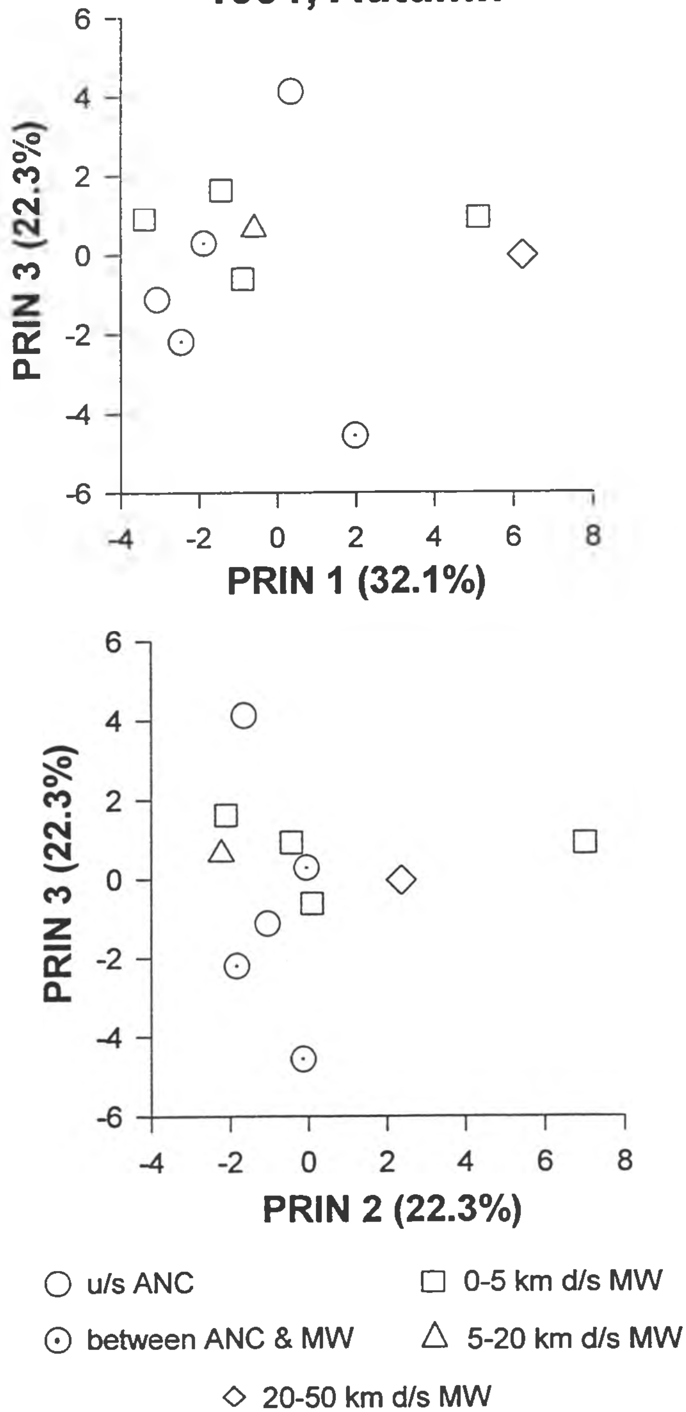
Millar Western/Alberta Newsprint Corporation
1991, Spring

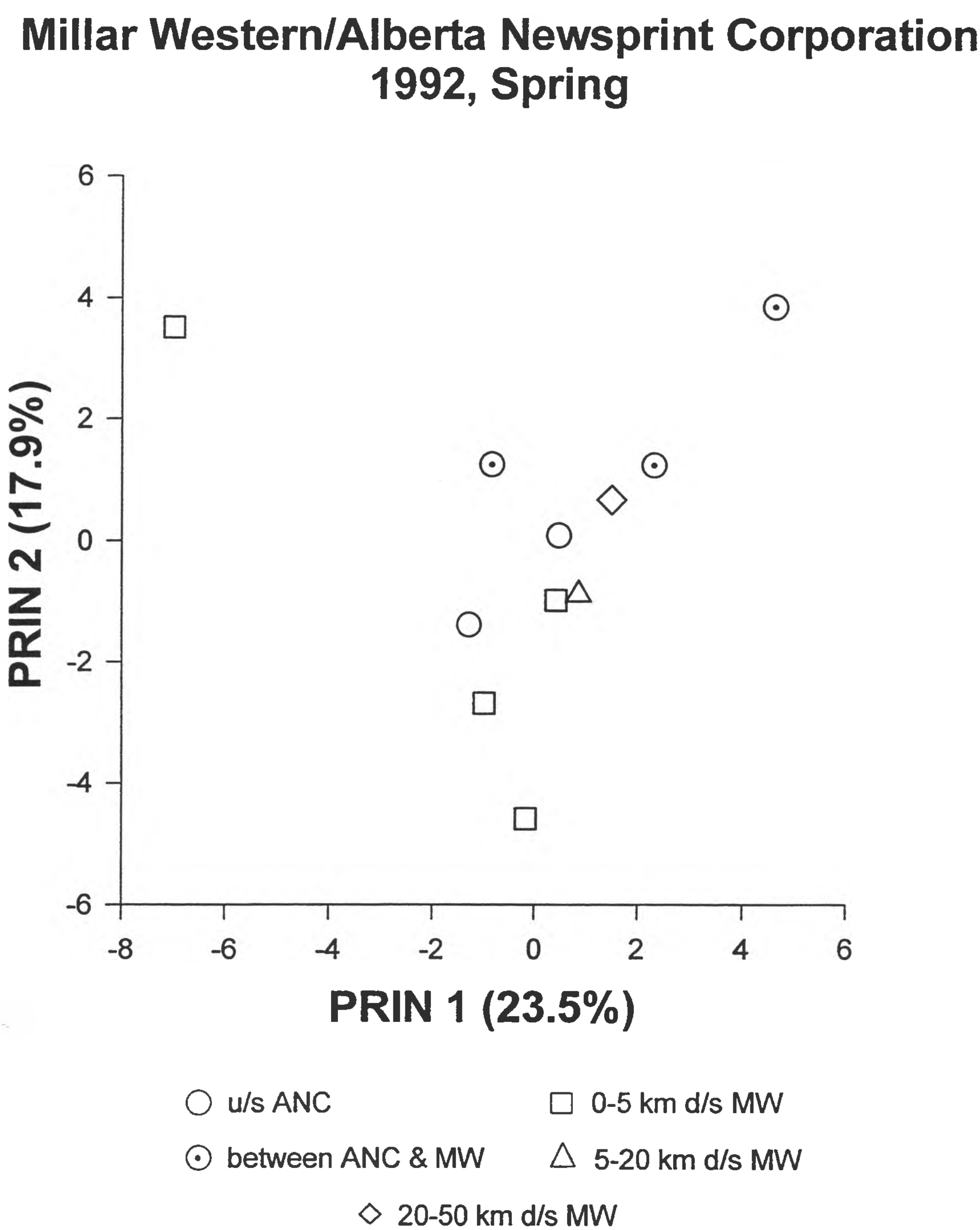


Millar Western/Alberta Newsprint Corporation
1991, Autumn

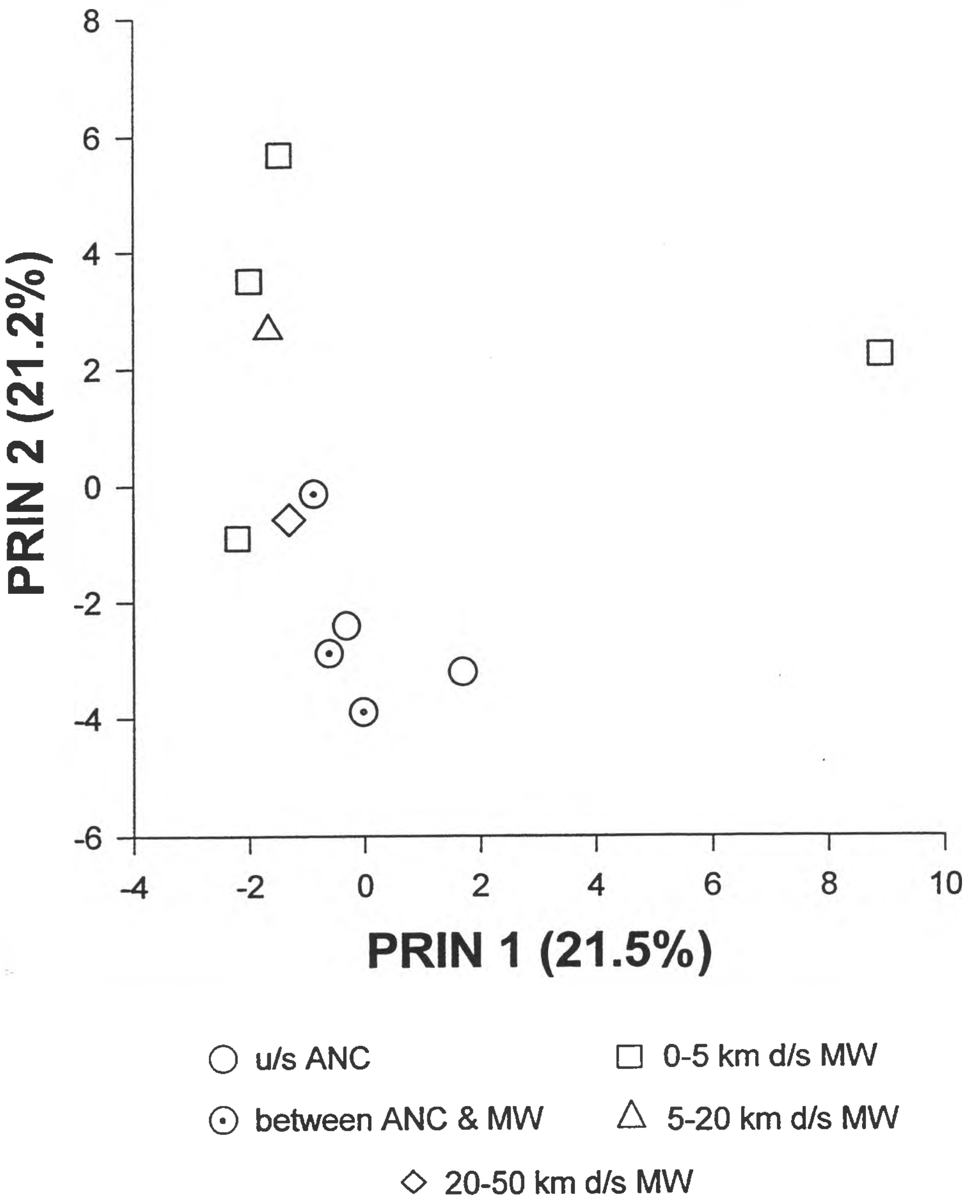


Millar Western/Alberta Newsprint Corporation
1991, Autumn

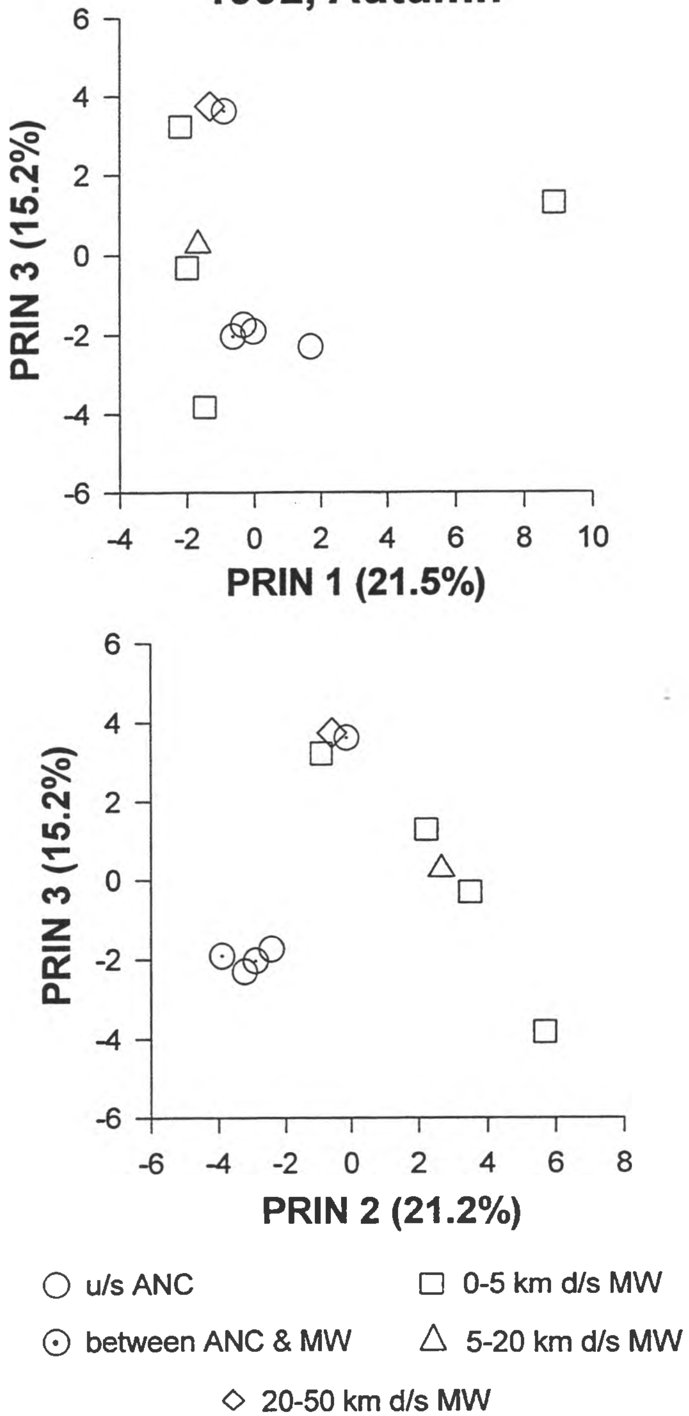



Millar Western/Alberta Newsprint Corporation
1992, Spring
PRIN 2 (17.9%)
PRIN 1 (23.5%)
6
4
2
0
-2
-4
-6
-8
-6
-4
-2
0
2
4
6
u/s ANC
between ANC & MW
0-5 km d/s MW
5-20 km d/s MW
20-50 km d/s MW

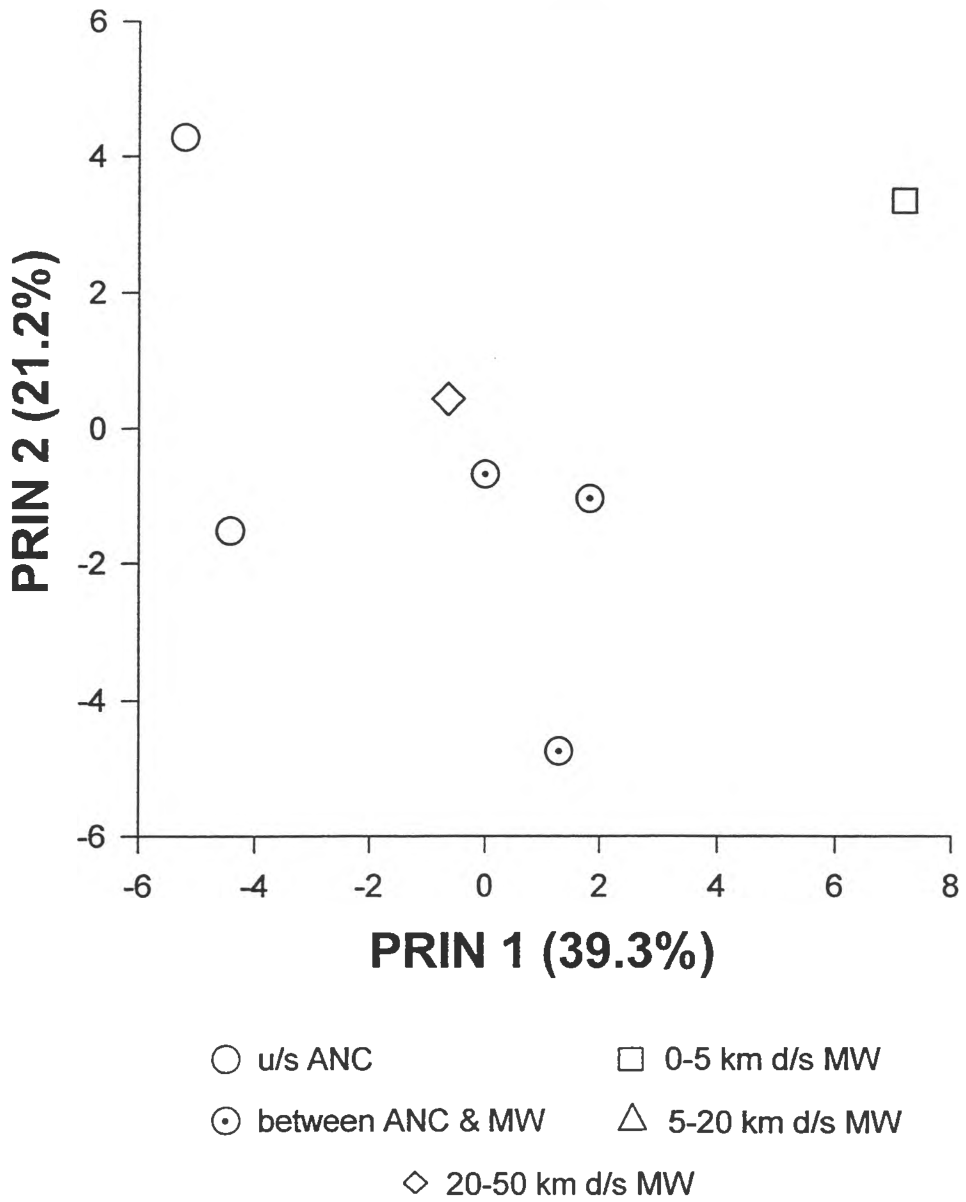
Millar Western/Alberta Newsprint Corporation
1992, Autumn



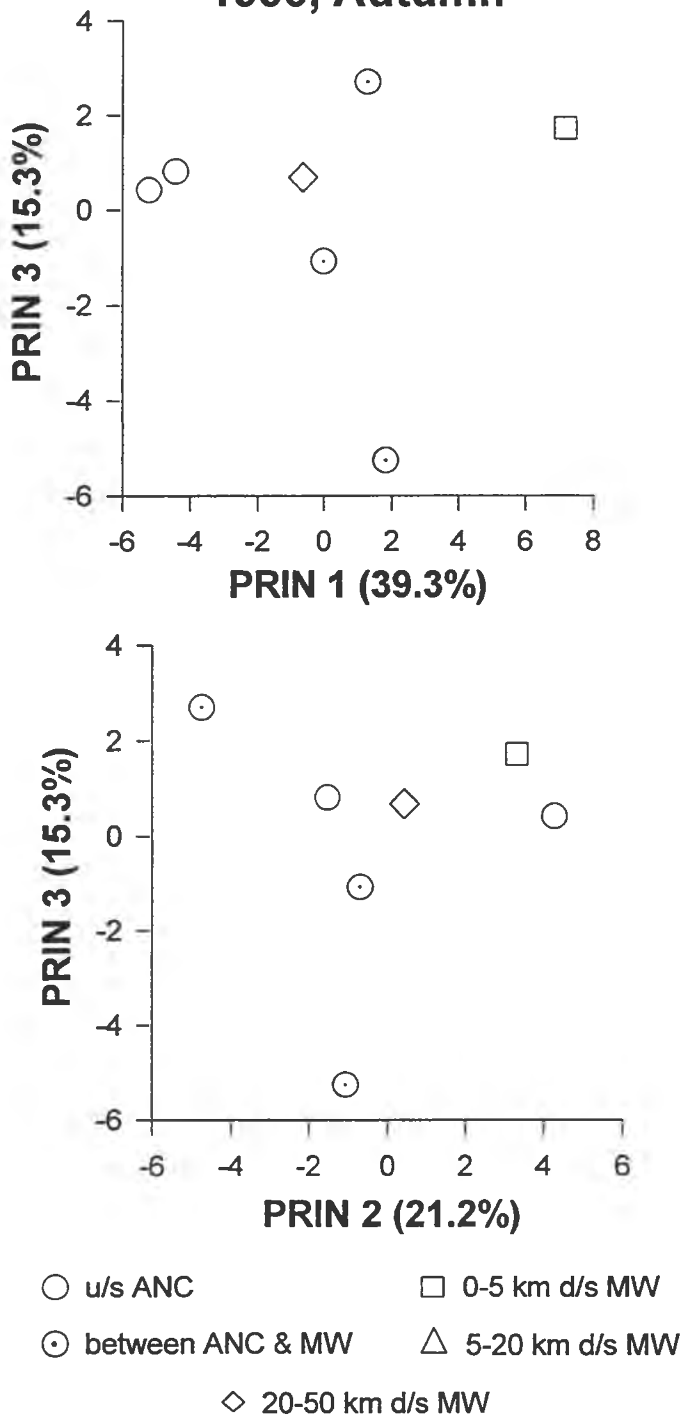
Millar Western/Alberta Newsprint Corporation
1992, Autumn



Millar Western/Alberta Newsprint Corporation
1993, Autumn



Millar Western/Alberta Newsprint Corporation
1993, Autumn



Appendix E3

Principal Component Analysis of Benthic Invertebrate Community Structure
Slave Lake Pulp Corporation (SLPC)

Axis labels represent the principal component axis shown (eg PRIN 1) followed by the proportion of the total variation explained by that principal component axis. The first two principal component axes are shown for all analyses. The third axis is shown only when it explains more than 15% of the total variation.

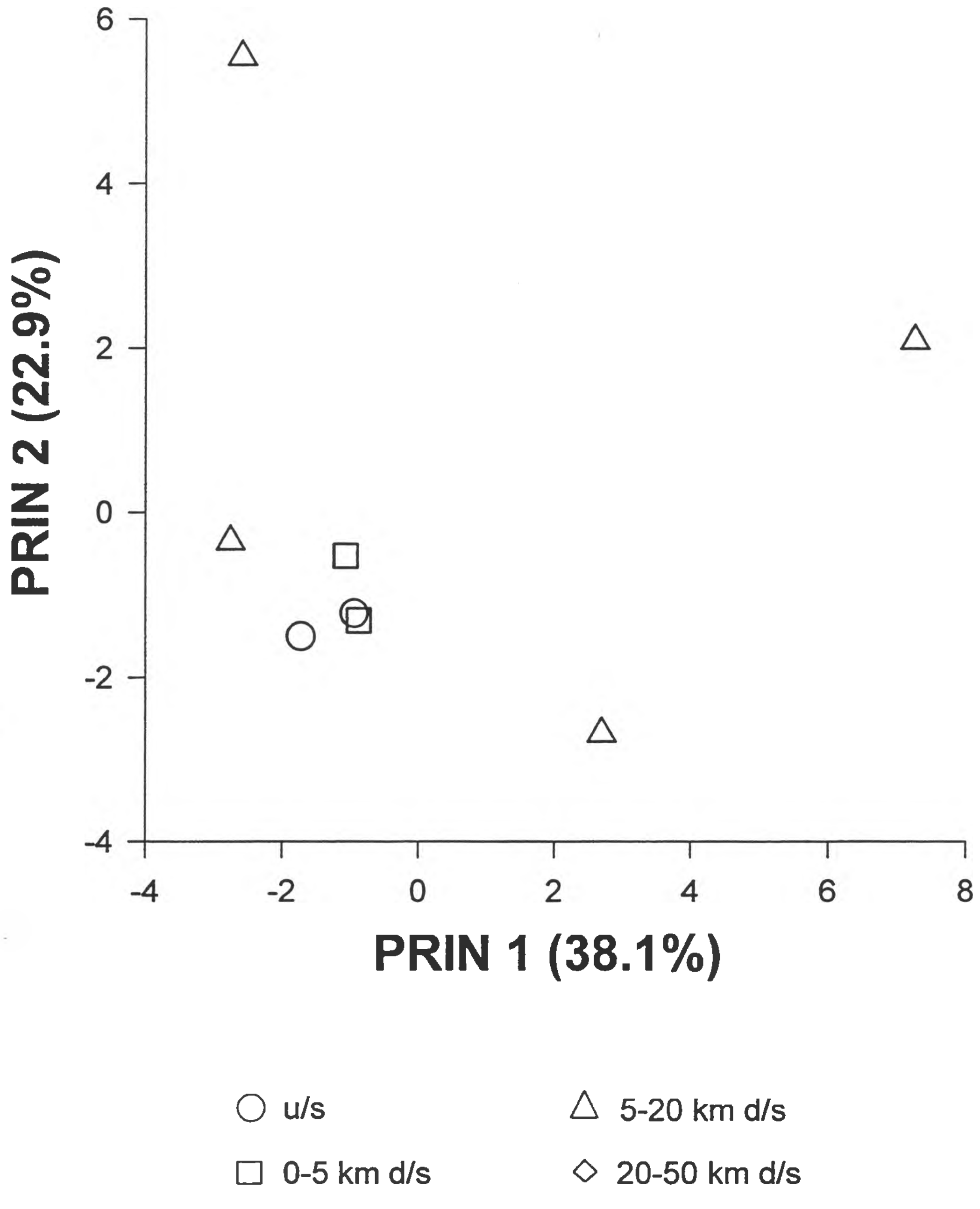
There are four distinct reaches of the Lesser Slave River around SLPC considered:

upstream of the pulp mill outfall	u/s
between 0 and 5 km downstream of the pulp mill outfall	0-5 km d/s
between 5 and 20 km downstream of the pulp mill outfall	5-20 km d/s
between 20 and 50 km downstream of the pulp mill outfall	20-50 km d/s

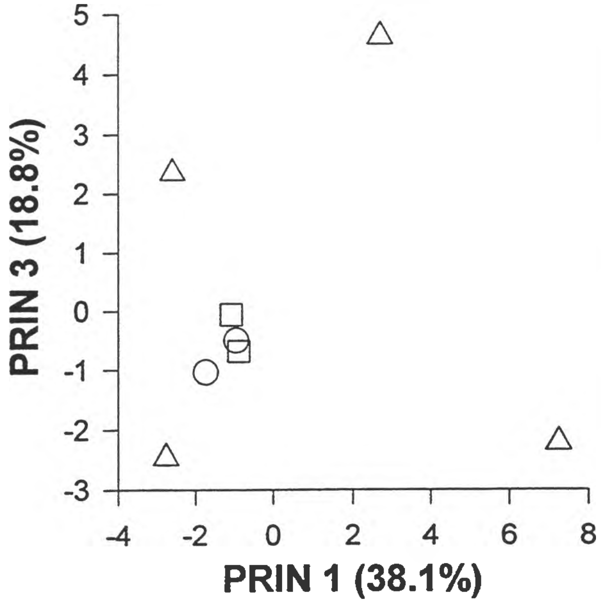
Analysis is appended for the following years:

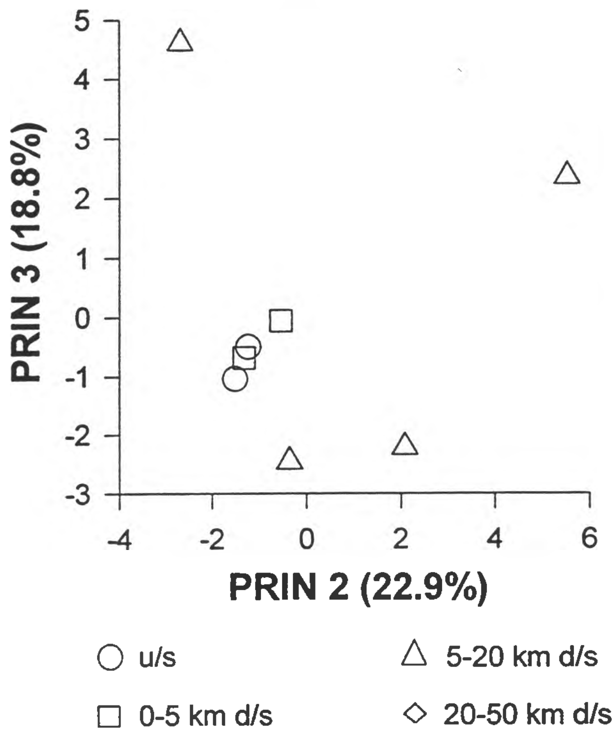
1989 spring
1989 autumn
1990 spring
1990 autumn
1991 spring
1991 autumn
1992 spring
1992 autumn
1993 spring
1993 autumn

Slave Lake Pulp Corporation
1989, Spring

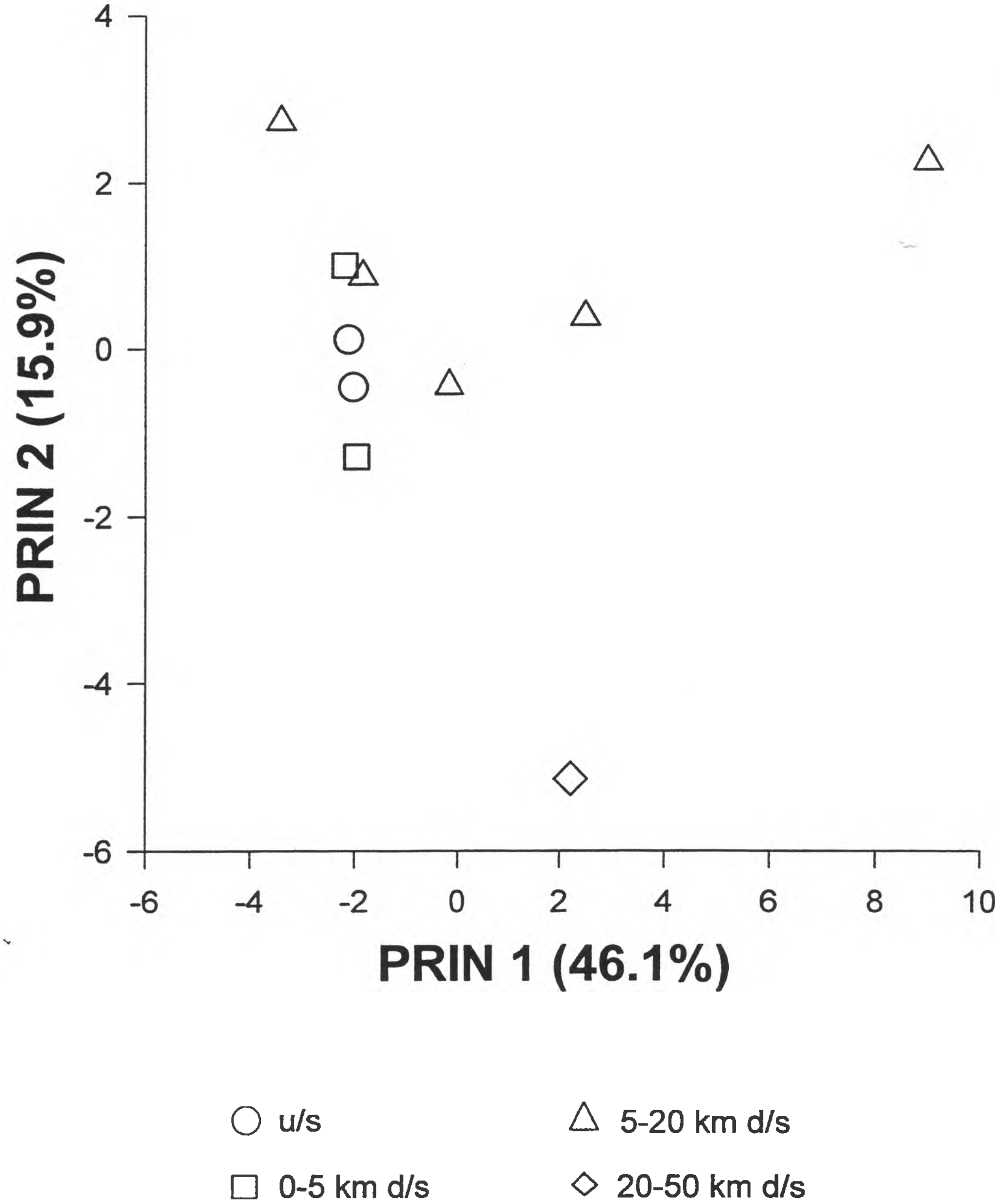


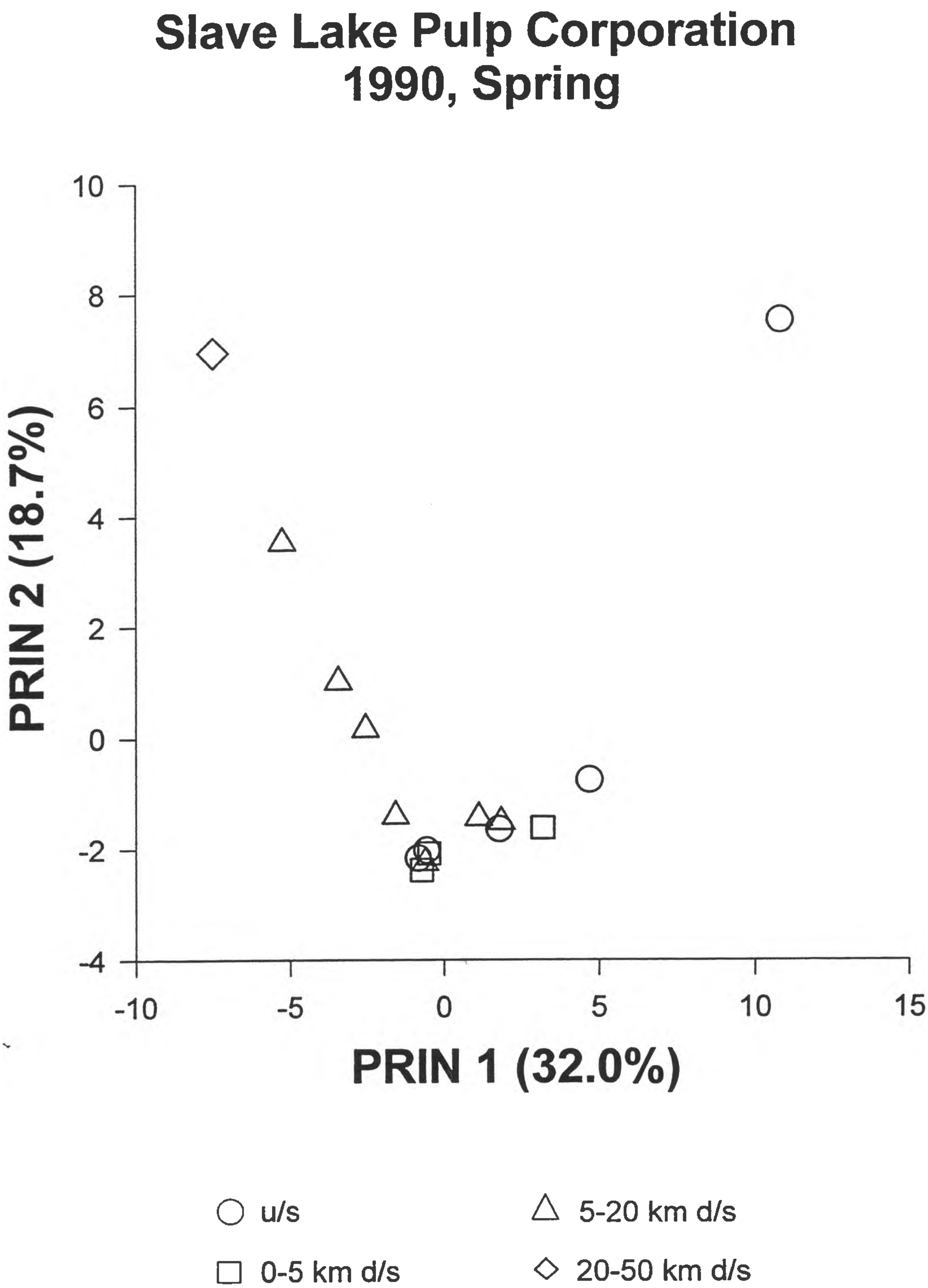
Slave Lake Pulp Corporation
1989, Spring

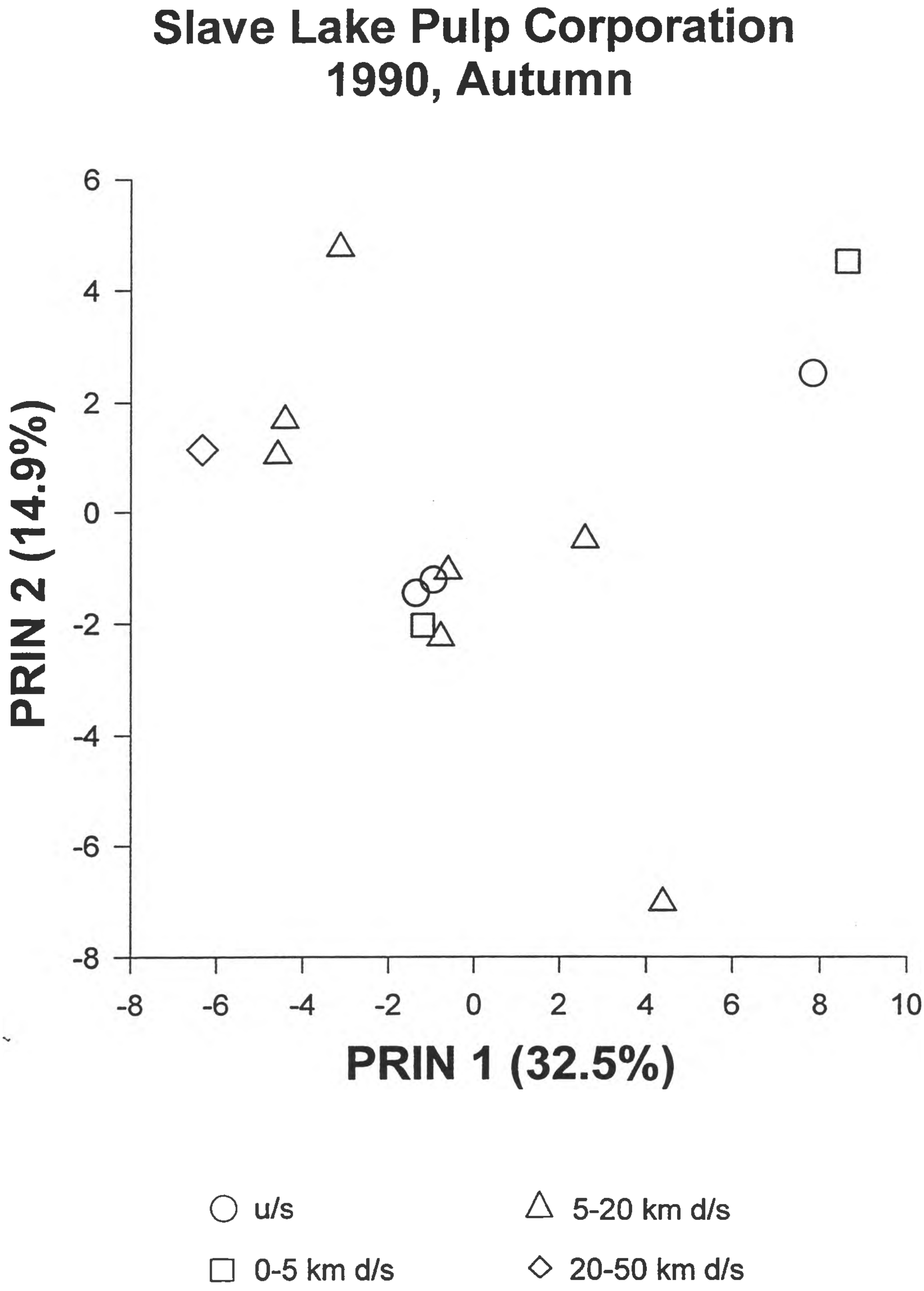




Slave Lake Pulp Corporation
1989, Autumn

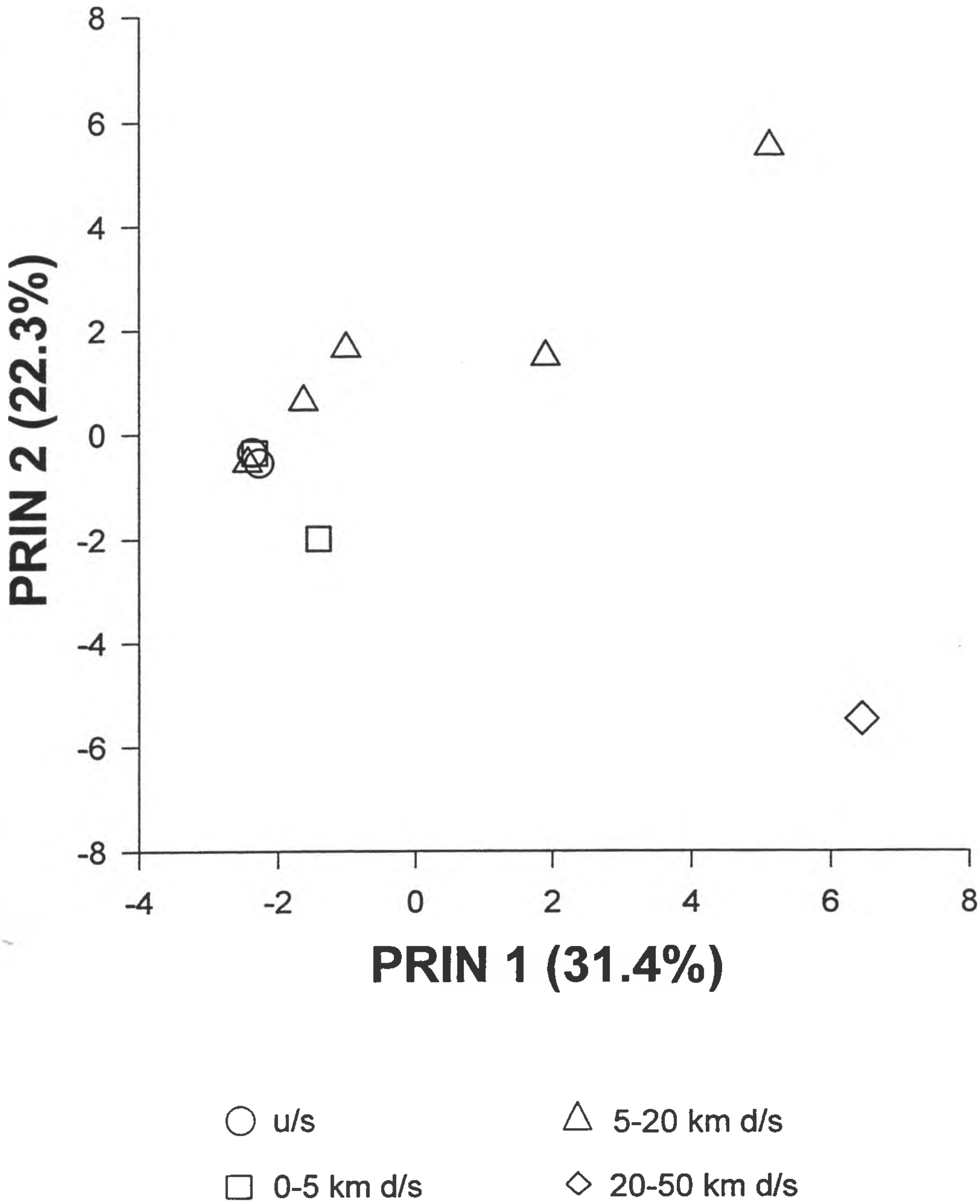



Slave Lake Pulp Corporation
1990, Spring
PRIN 2 (18.7%)
PRIN 1 (32.0%)
10
8
6
4
2
0
-2
-4
-10
-5
0
5
10
15
u/s
5-20 km d/s
0-5 km d/s
20-50 km d/s

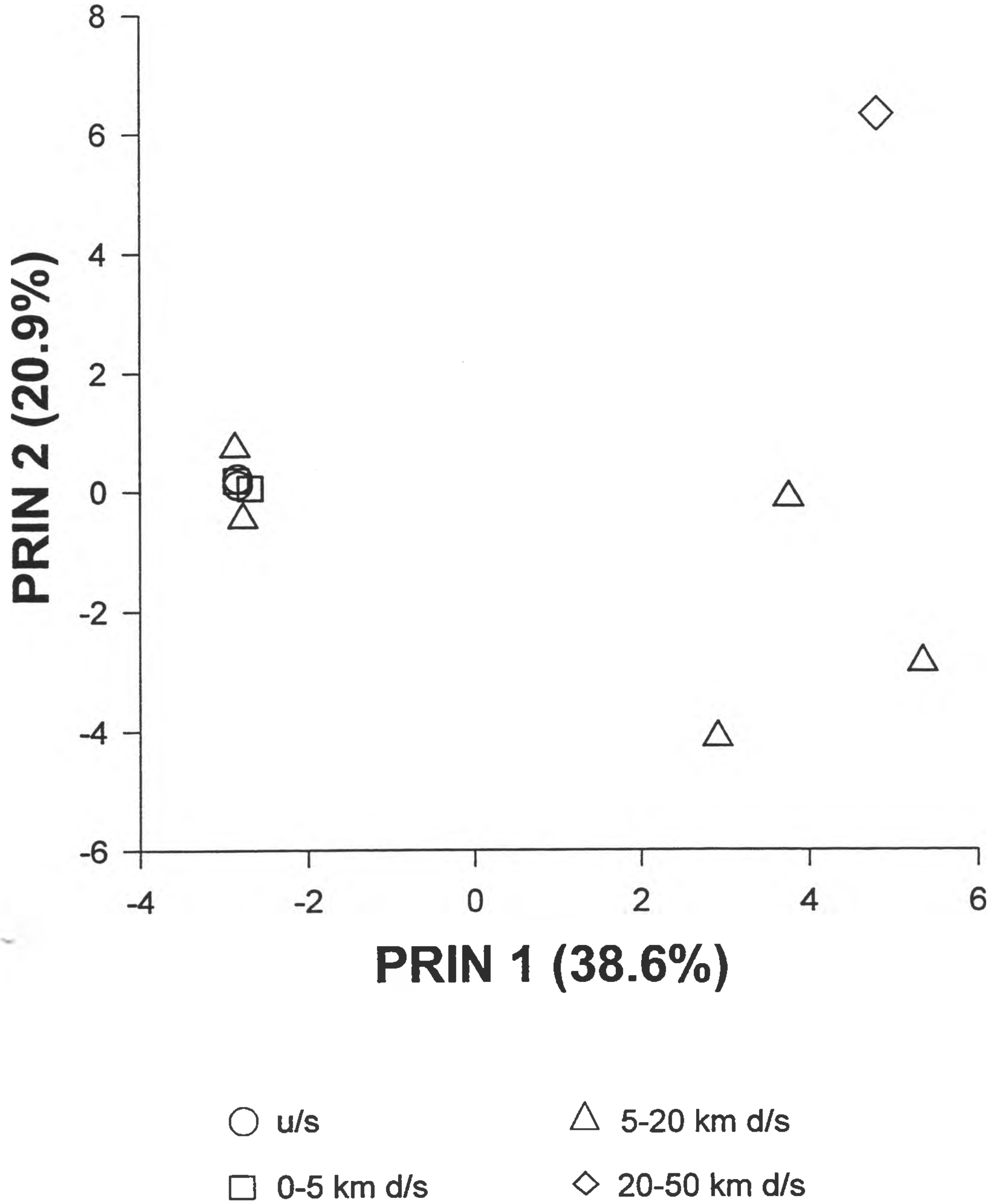


Slave Lake Pulp Corporation
1990, Autumn
6
4
2
0
-2
-4
-6
-8
PRIN 2 (14.9%)
-8
-6
-4
-2
0
2
4
6
8
10
PRIN 1 (32.5%)
u/s
5-20 km d/s
0-5 km d/s
20-50 km d/s

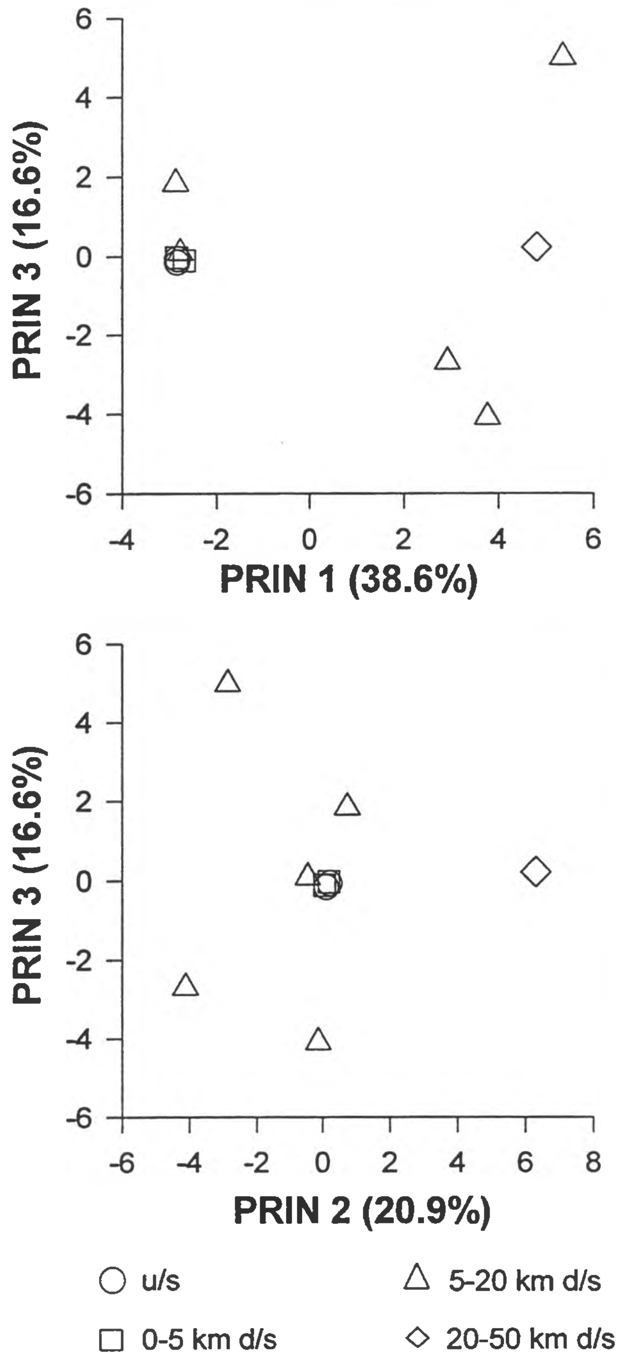
Slave Lake Pulp Corporation
1991, Spring



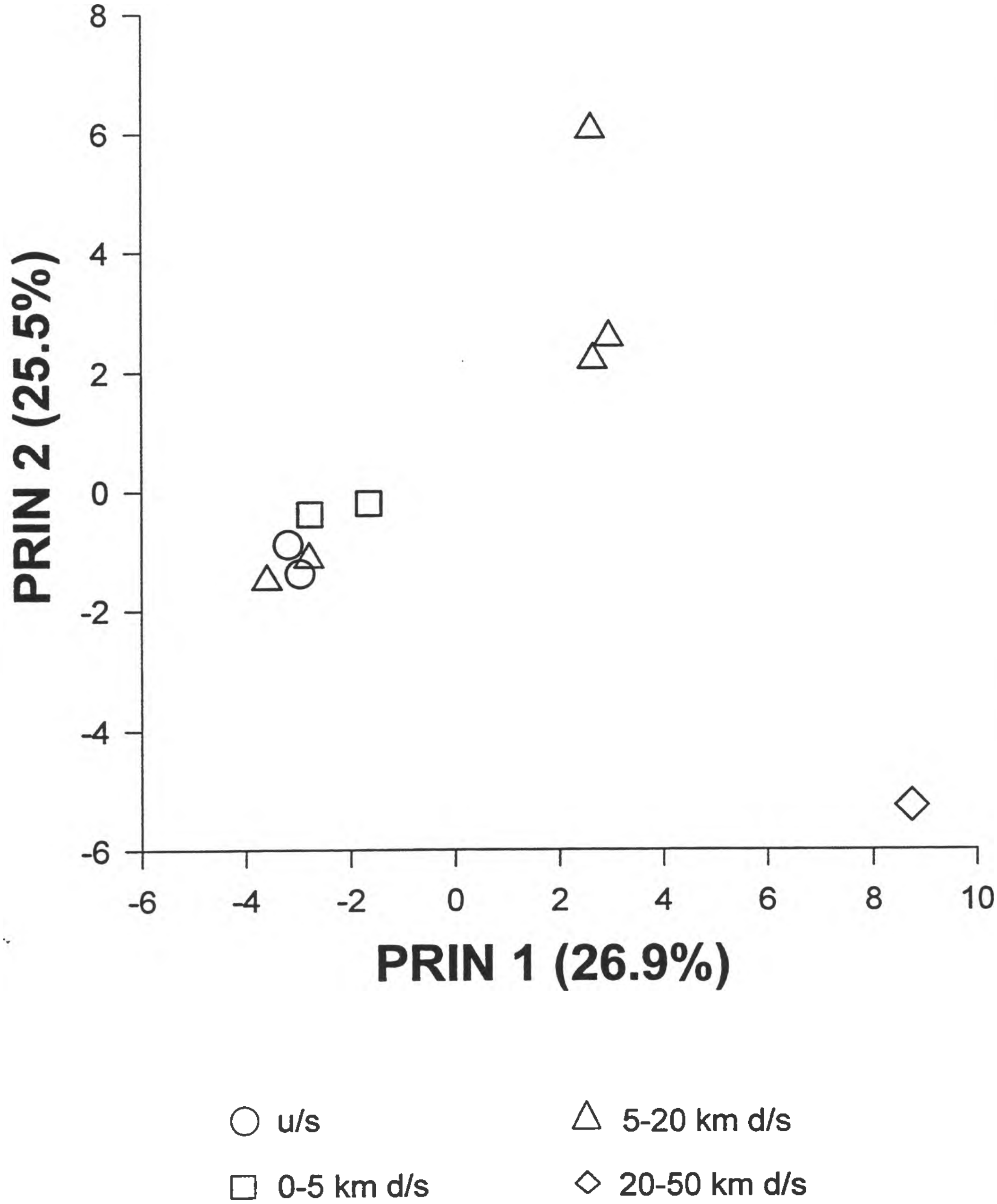
Slave Lake Pulp Corporation
1991, Autumn

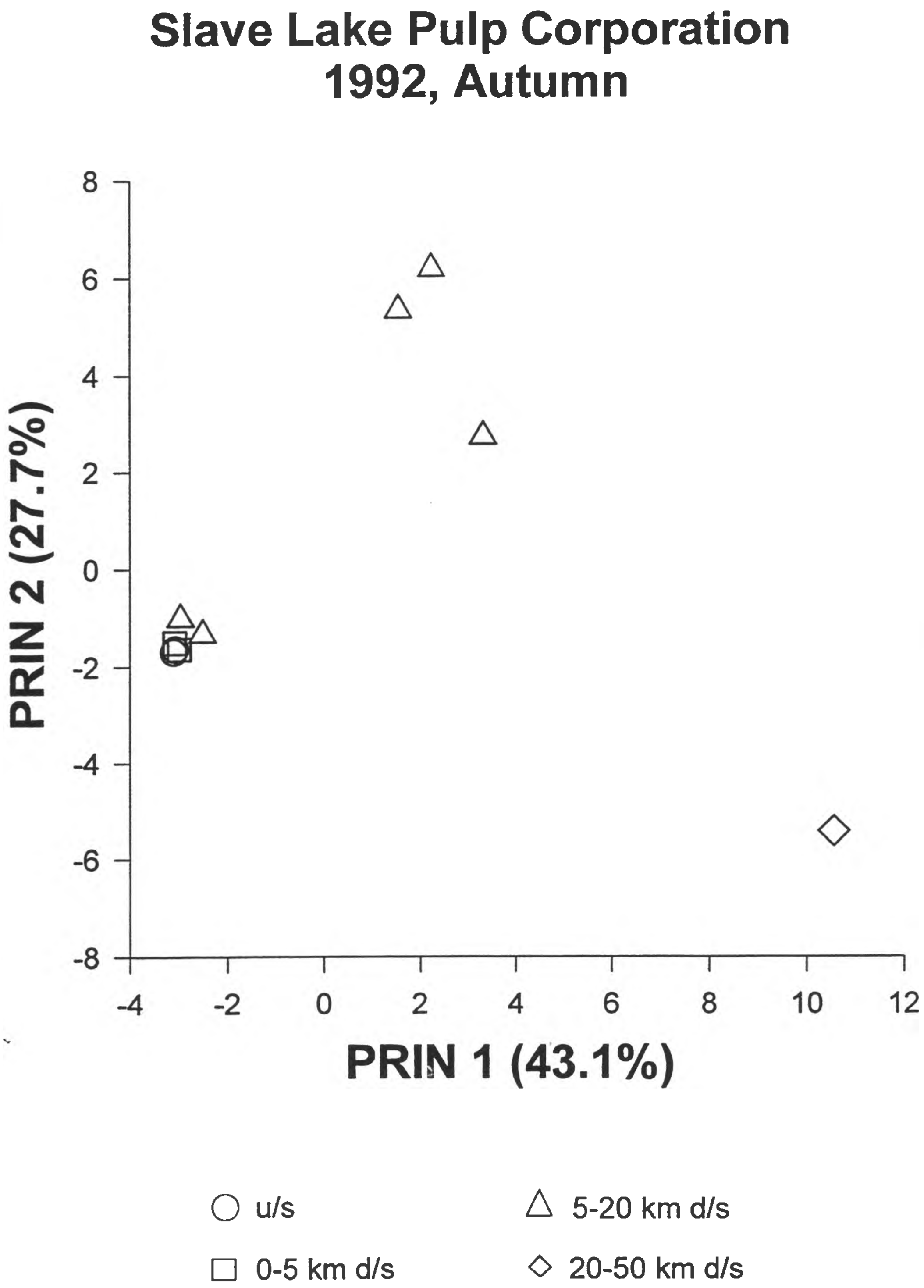


Slave Lake Pulp Corporation
1991, Autumn

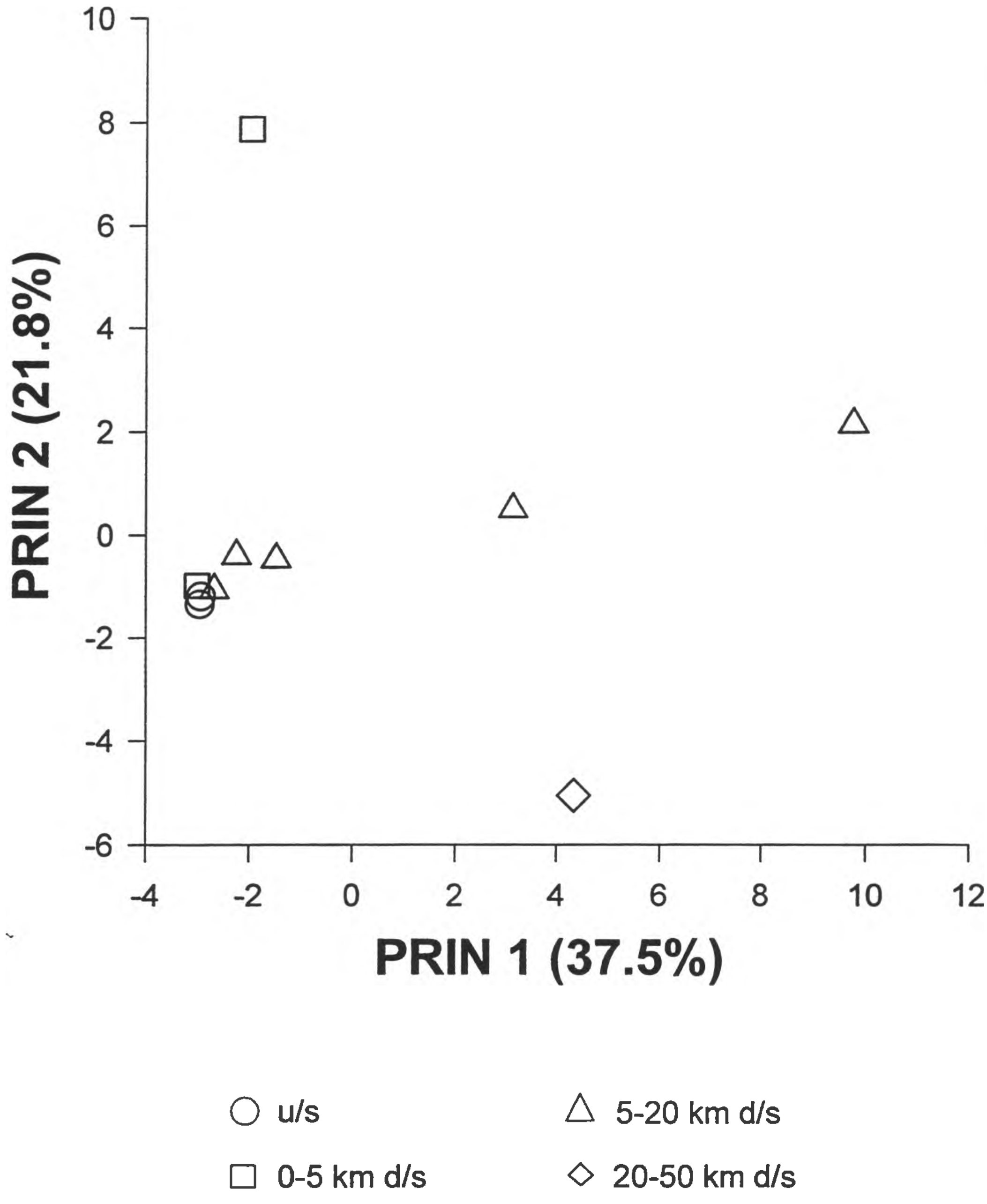


Slave Lake Pulp Corporation
1992, Spring

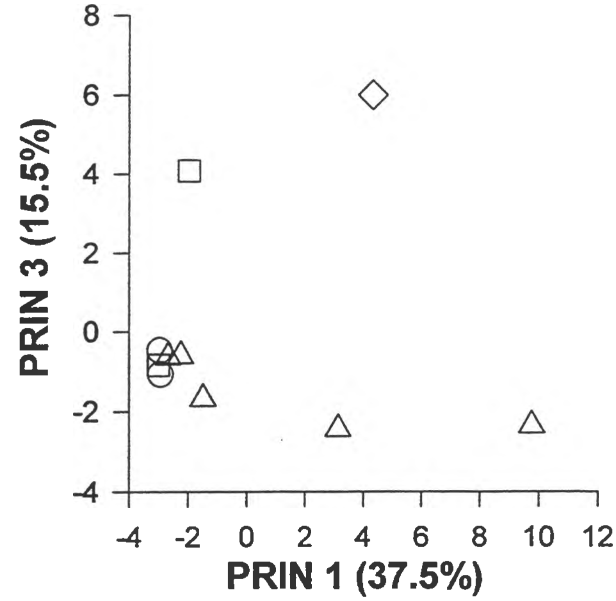


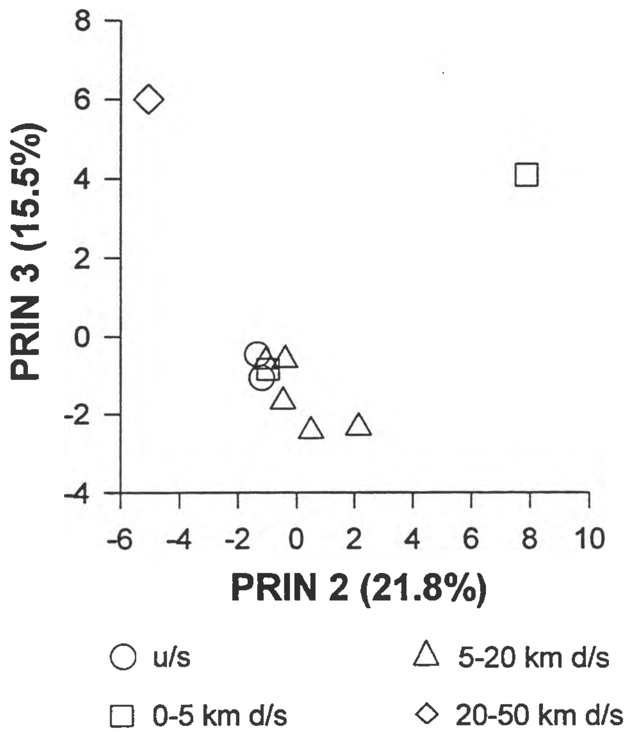

Slave Lake Pulp Corporation
1992, Autumn
PRIN 2 (27.7%)
PRIN 1 (43.1%)
8
6
4
2
0
-2
-4
-6
-8
-4
-2
0
2
4
6
8
10
12
u/s
0-5 km d/s
5-20 km d/s
20-50 km d/s

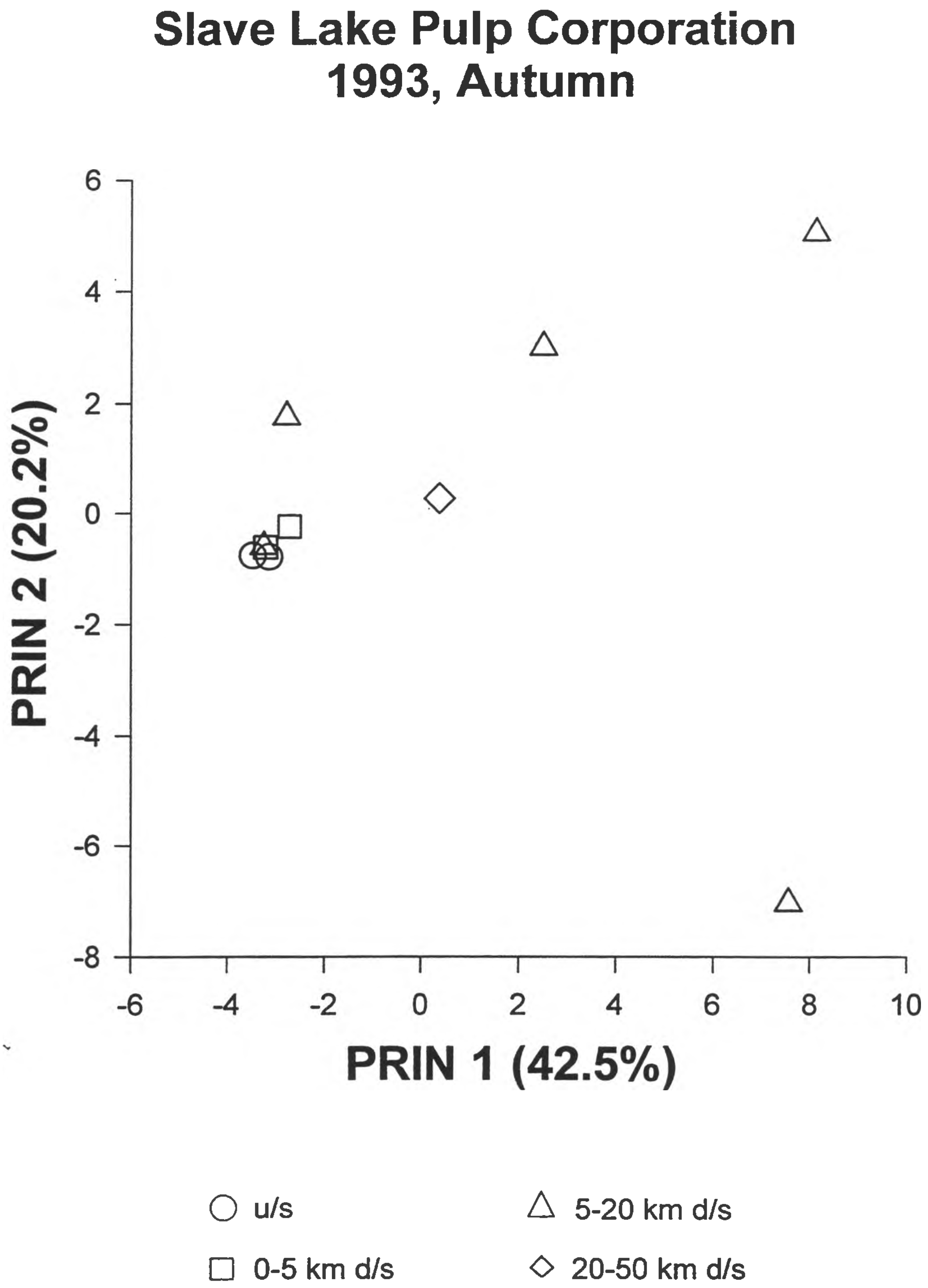
Slave Lake Pulp Corporation
1993, Spring



Slave Lake Pulp Corporation
1993, Spring






Slave Lake Pulp Corporation
1993, Autumn
6
4
2
0
-2
-4
-6
-8
PRIN 2 (20.2%)
-6
-4
-2
0
2
4
6
8
10
PRIN 1 (42.5%)
u/s
5-20 km d/s
0-5 km d/s
20-50 km d/s

Appendix E4

Principal Component Analysis of Benthic Invertebrate Community Structure
Alberta Pacific Coroporation (ALPAC)

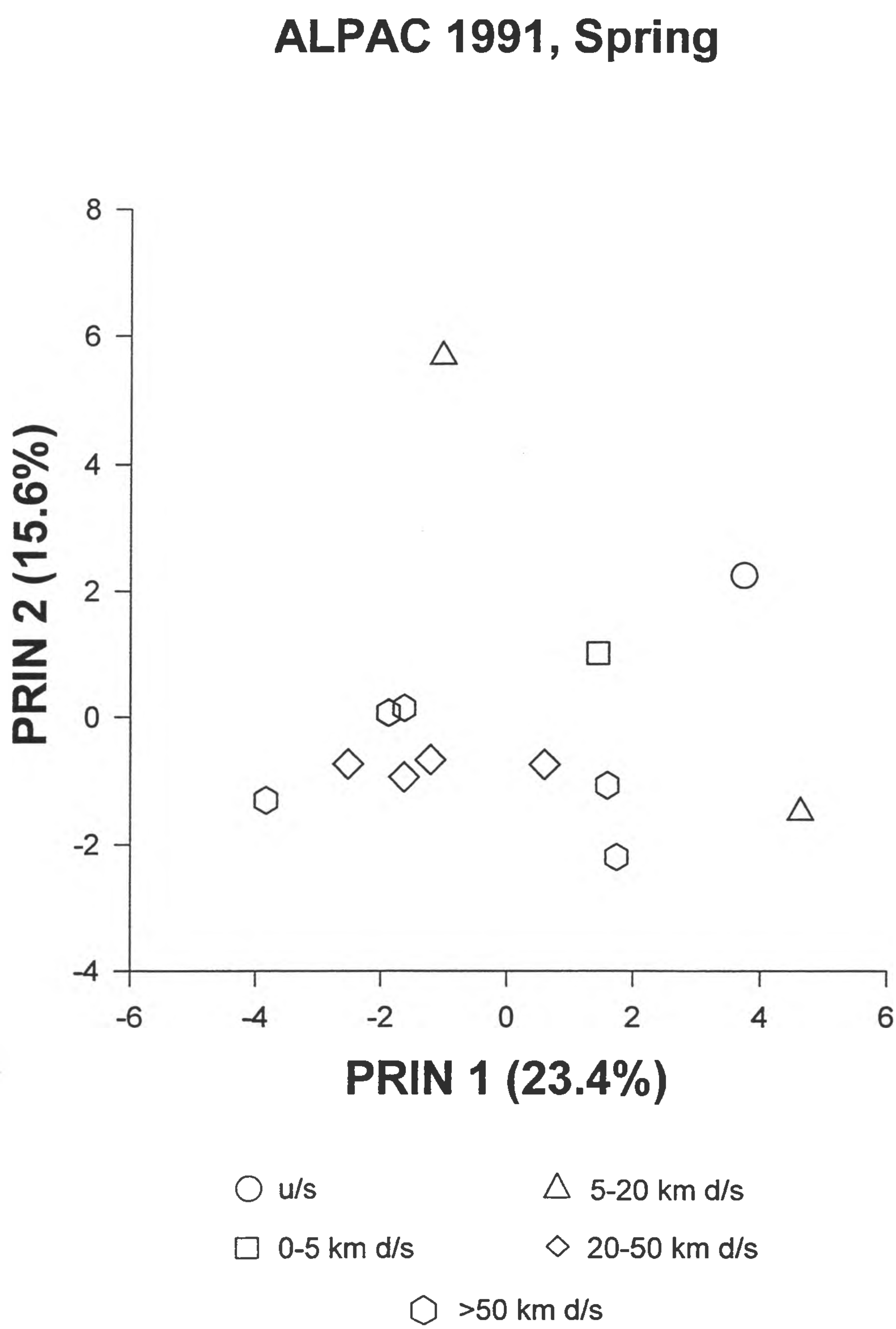
Axis labels represent the principal component axis shown (eg PRIN 1) followed by the proportion of the total variation explained by that principal component axis. The first two principal component axes are shown for all analyses. The third axis is shown only when it explains more than 15% of the total variation.

There are five distinct reaches of the Athabasca River around ALPAC considered:

upstream of the pulp mill outfall	u/s
between 0 and 5 km downstream of the pulp mill outfall	0-5 km d/s
between 5 and 20 km downstream of the pulp mill outfall	5-20 km d/s
between 20 and 50 km downstream of the pulp mill outfall	20-50 km d/s
greater than 50 km downstream of the pulp mill outfall	>50 km d/s

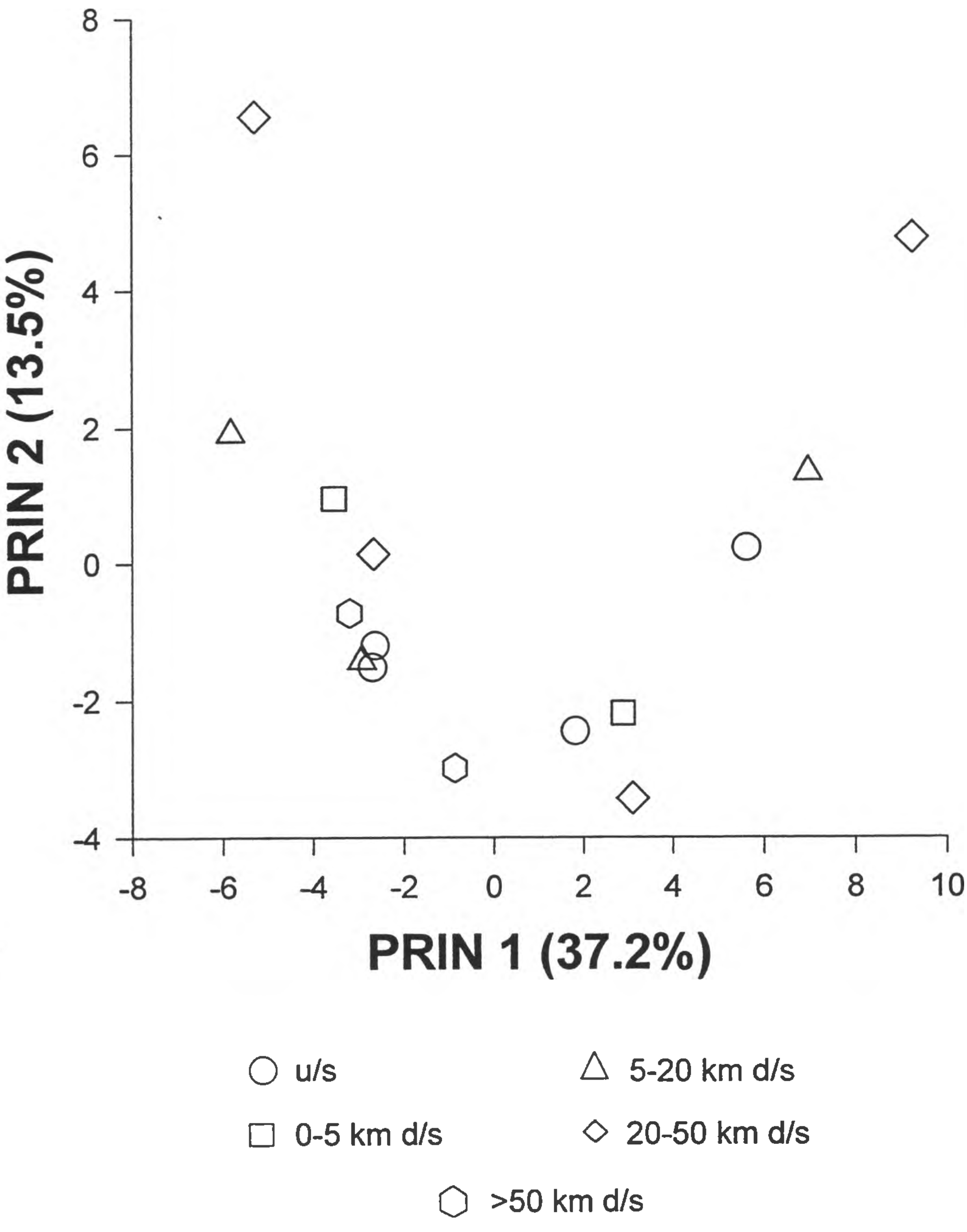
Analysis is appended for the following years:

1991 spring
1991 autumn
1992 spring
1992 autumn

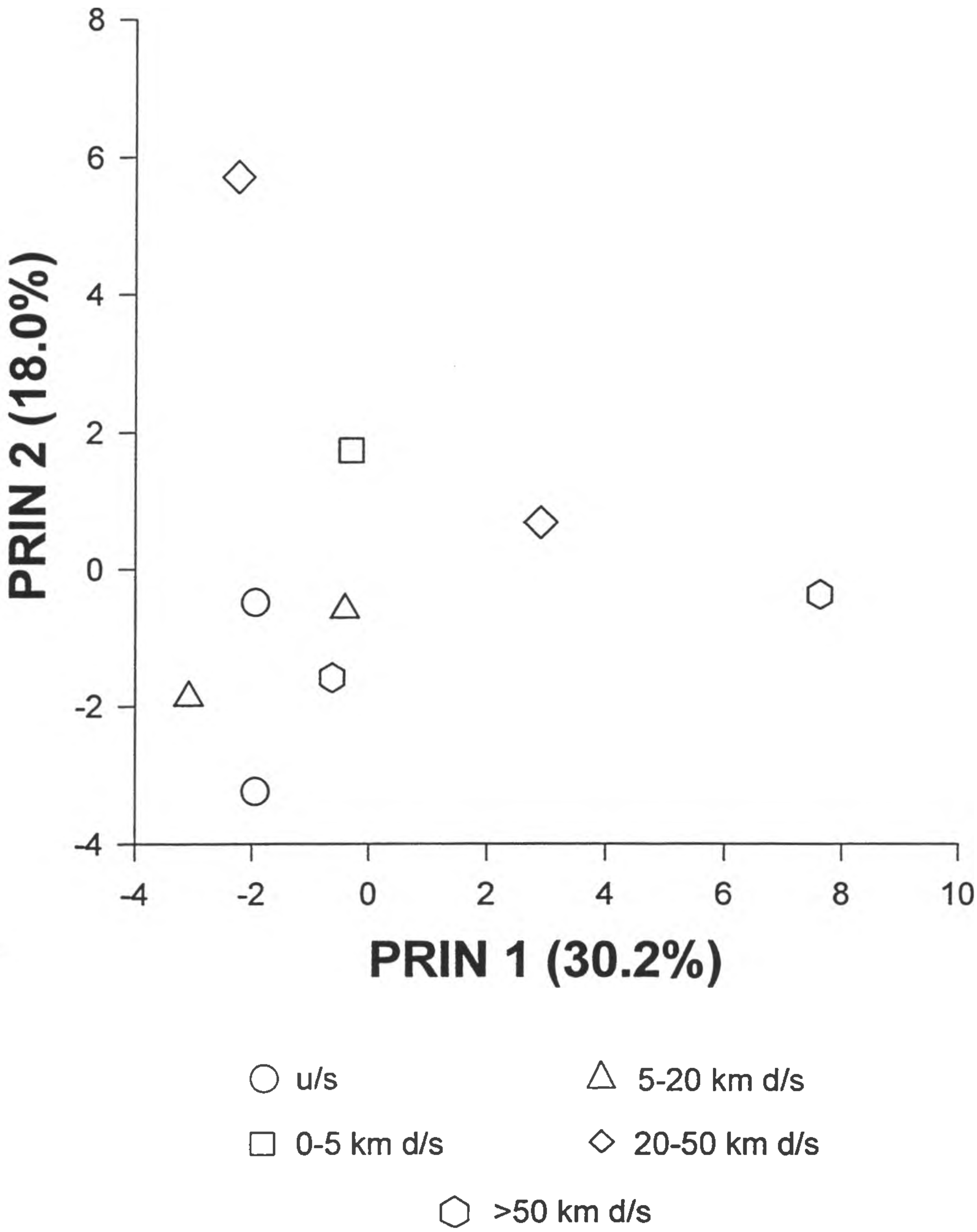


ALPAC 1991, Spring
8
6
4
2
0
-2
-4
-6
-4
-2
0
2
4
6
PRIN 2 (15.6%)
PRIN 1 (23.4%)
u/s
5-20 km d/s
0-5 km d/s
20-50 km d/s
>50 km d/s

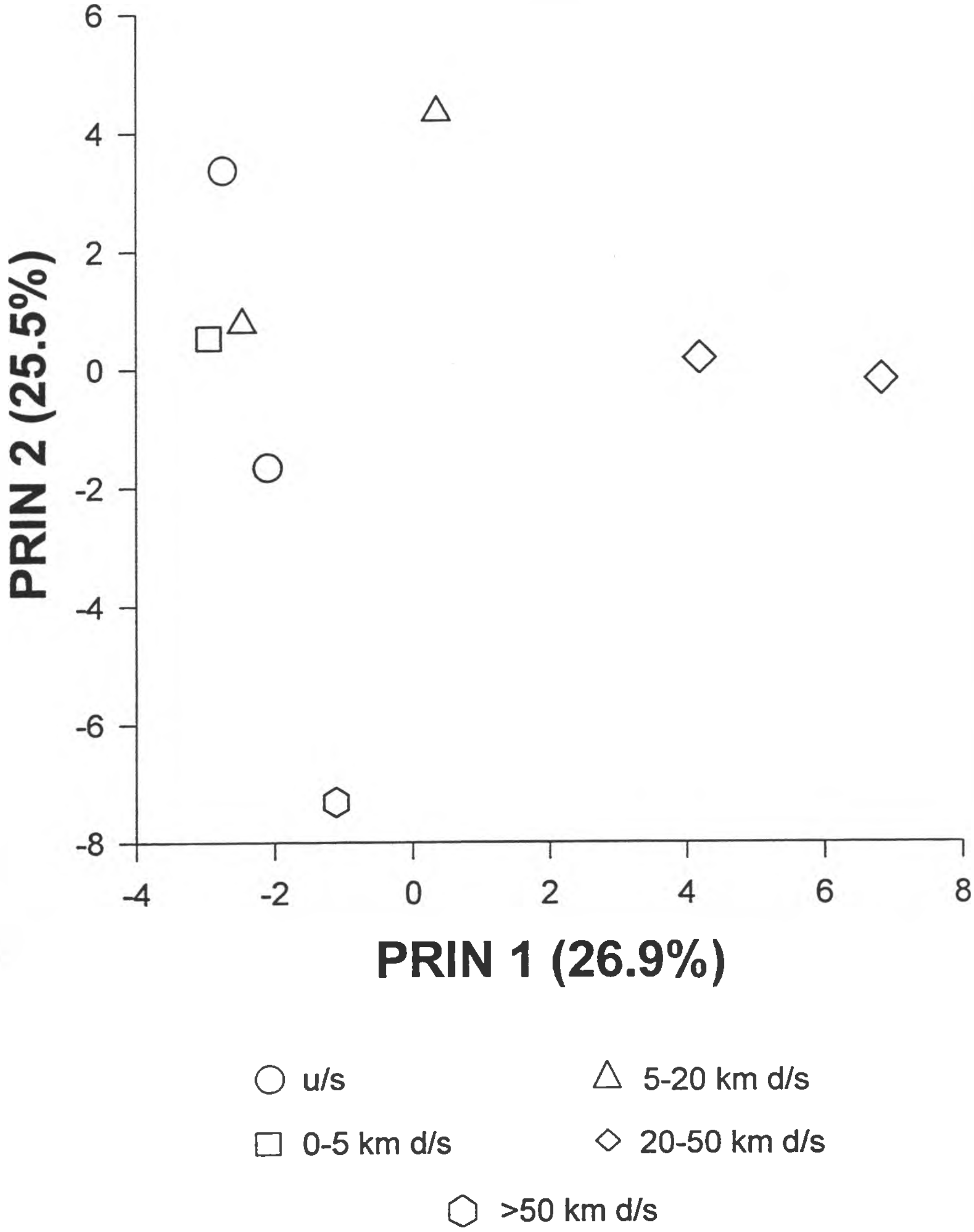
ALPAC 1991, Autumn



ALPAC 1992, Spring



ALPAC 1992, Autumn



Appendix E5

Principal Component Analysis of Benthic Invertebrate Community Structure
Proctor Gamble / Weyerhauser, Grande Prairie (PG)

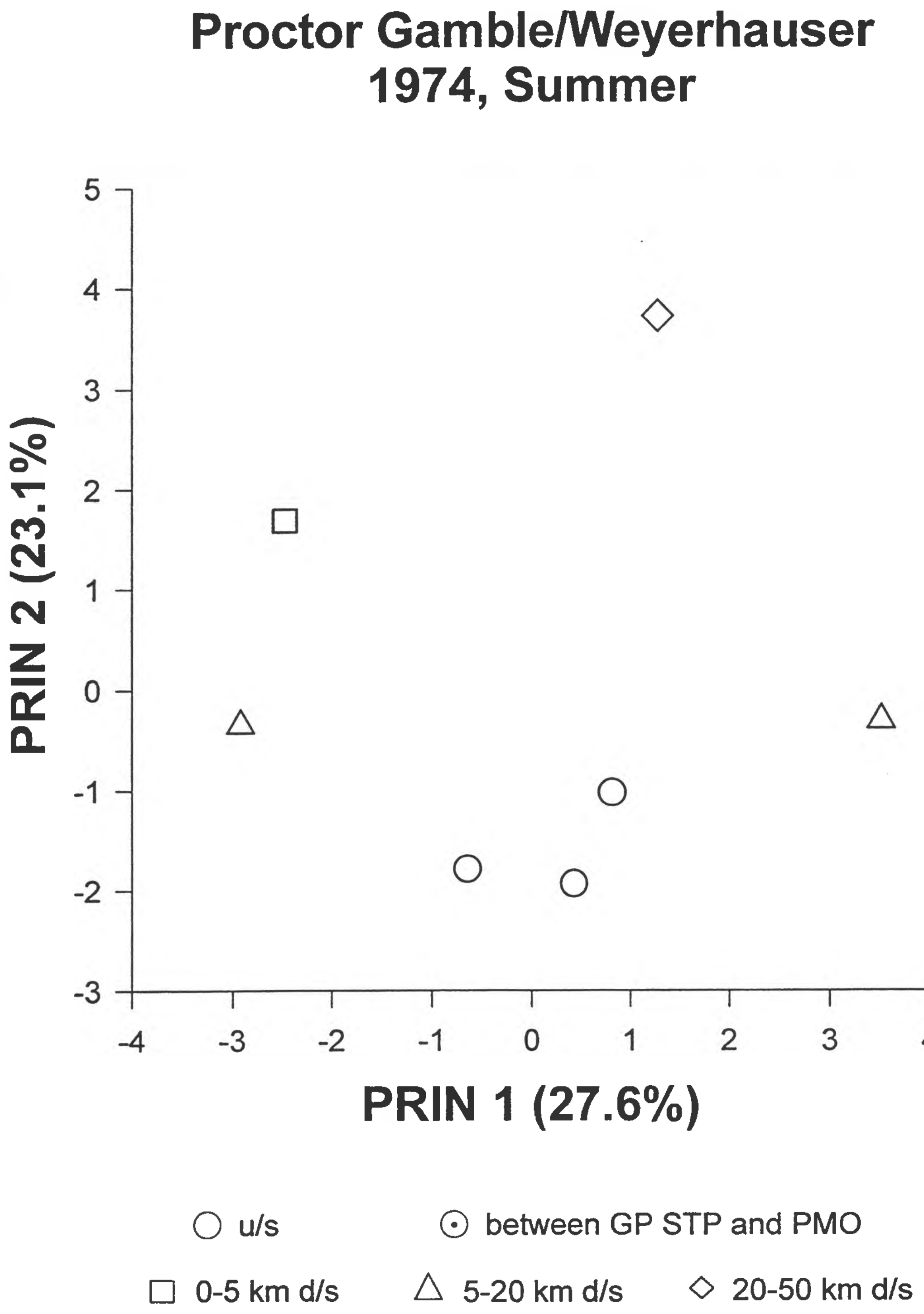
Axis labels represent the principal component axis shown (eg PRIN 1) followed by the proportion of the total variation explained by that principal component axis. The first two principal component axes are shown for all analyses. The third axis is shown only when it explains more than 15% of the total variation.

There are five distinct reaches of the Wapiti River around Weyerhauser considered:

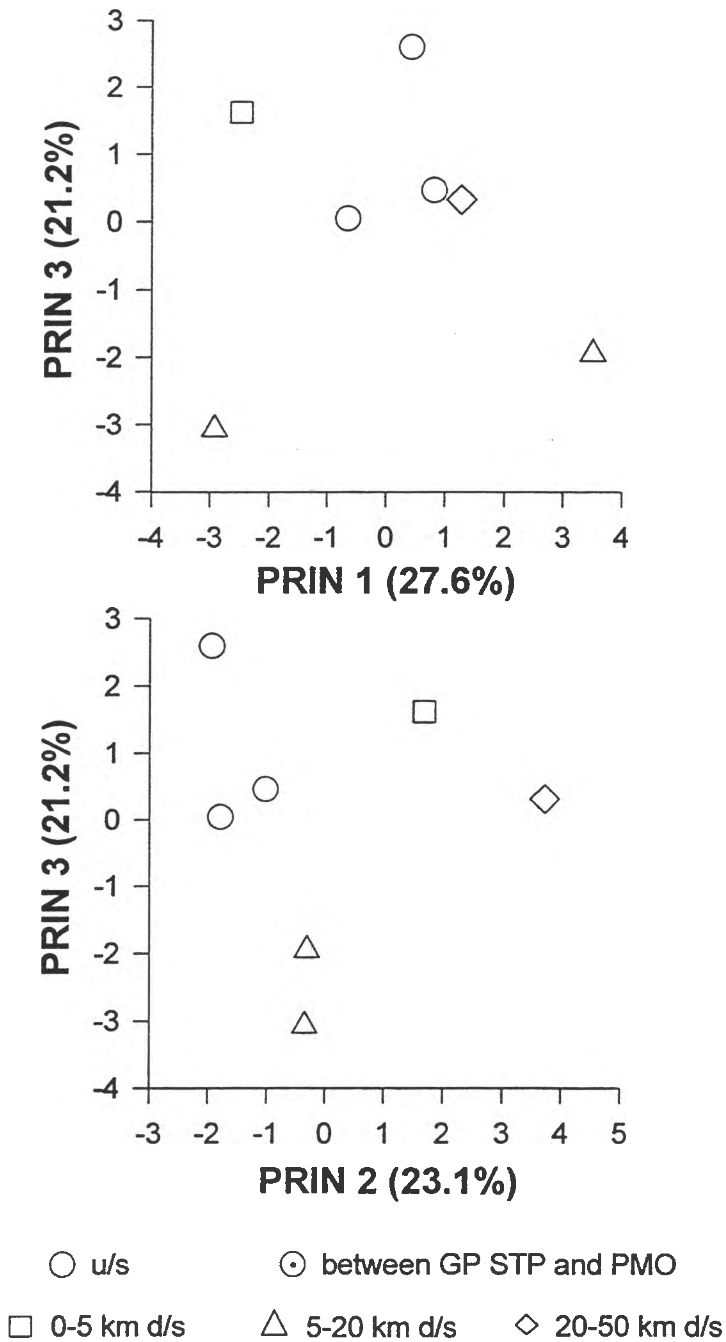
upstream of the Grande Prairie Sewage Treatment Plant	u/s
between Sewage Treament Plant and the pulp mill outfall	
between 0 and 5 km downstream of the pulp mill outfall	0-5 km d/s
between 5 and 20 km downstream of the pulp mill outfall	5-20 km d/s
between 20 and 50 km downstream of the pulp mill outfall	20-50 km d/s

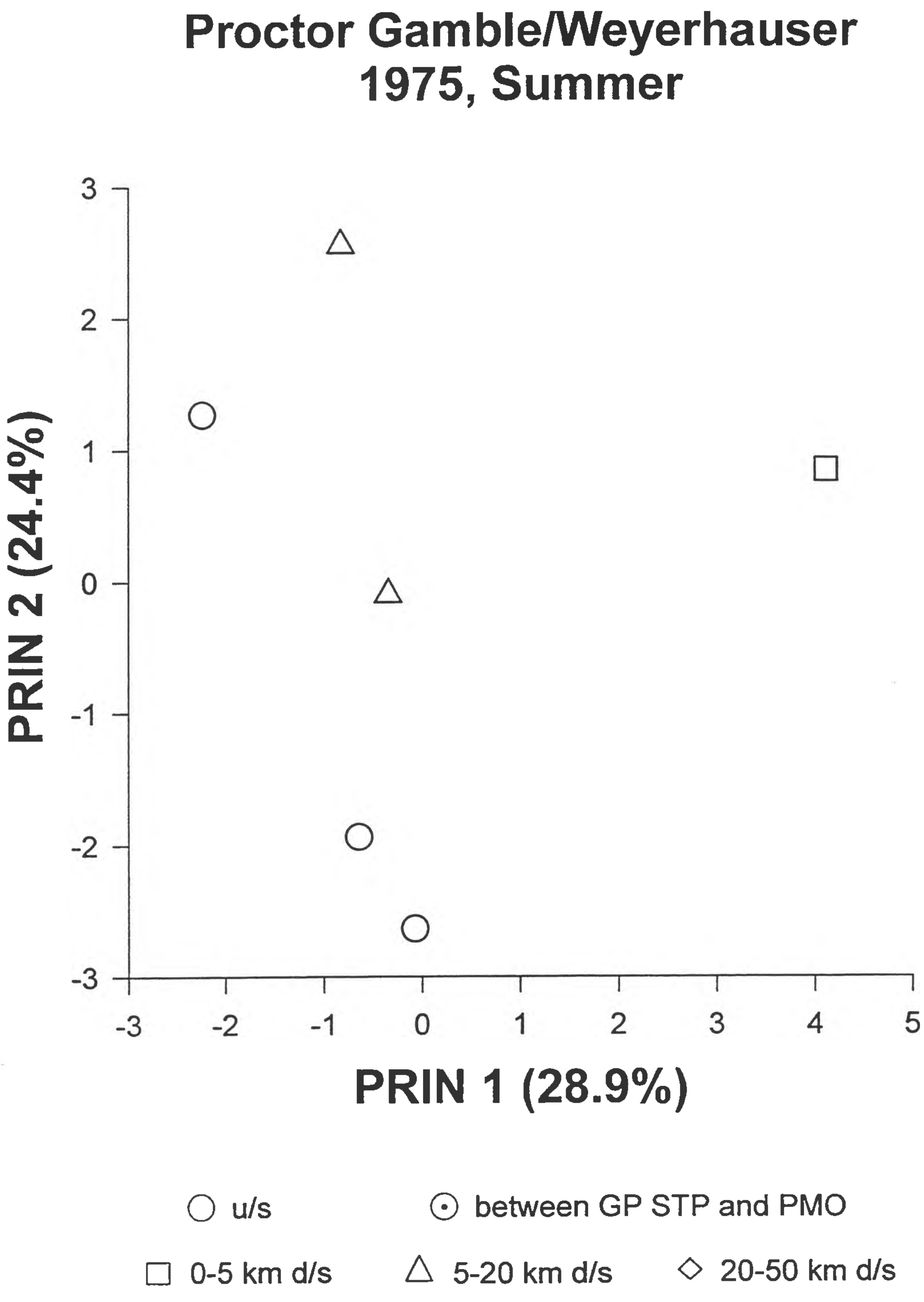
Analysis is appended for the following years:

1974	summer
1975	summer
1980	autumn
1981	autumn
1988	autumn
1989	autumn
1990	autumn
1991	winter
1991	spring
1992	winter
1992	autumn

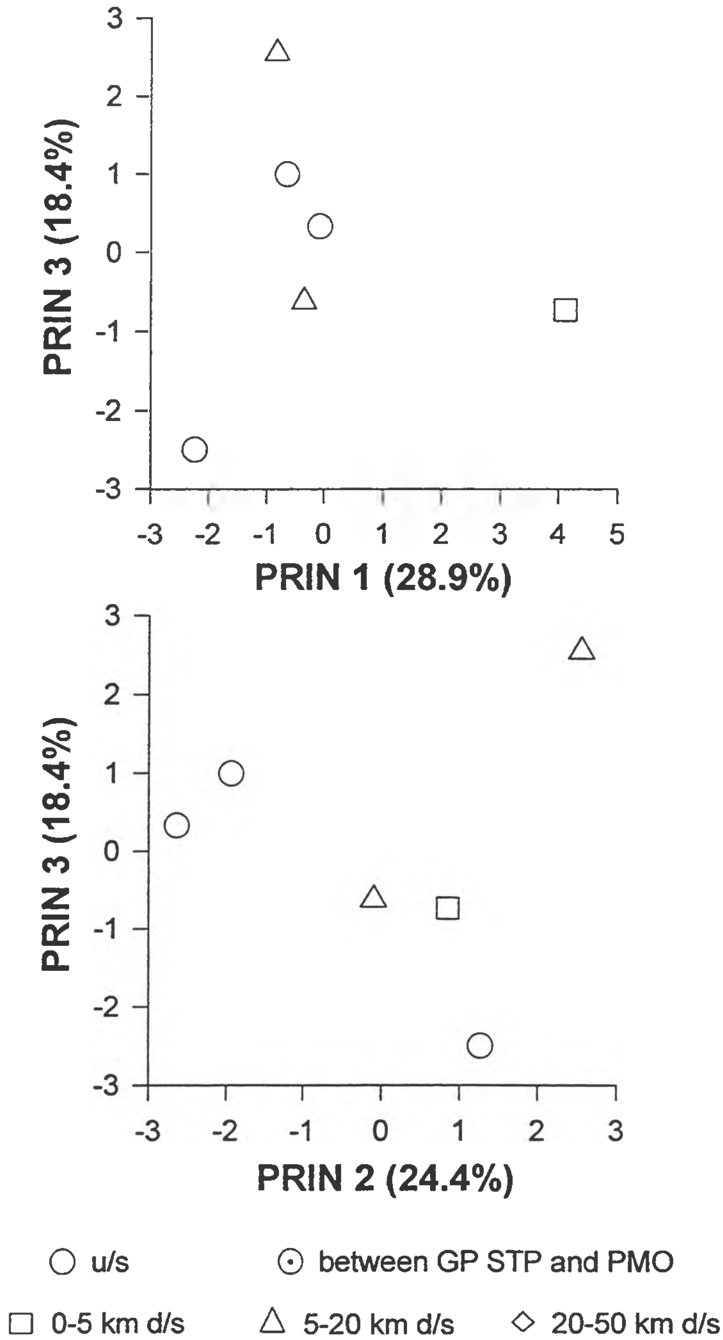

Proctor Gamble/Weyerhauser
1974, Summer
PRIN 2 (23.1%)
PRIN 1 (27.6%)
5
4
3
2
1
0
-1
-2
-3
-4
-3
-2
-1
0
1
2
3
4
u/s
between GP STP and PMO
0-5 km d/s
5-20 km d/s
20-50 km d/s

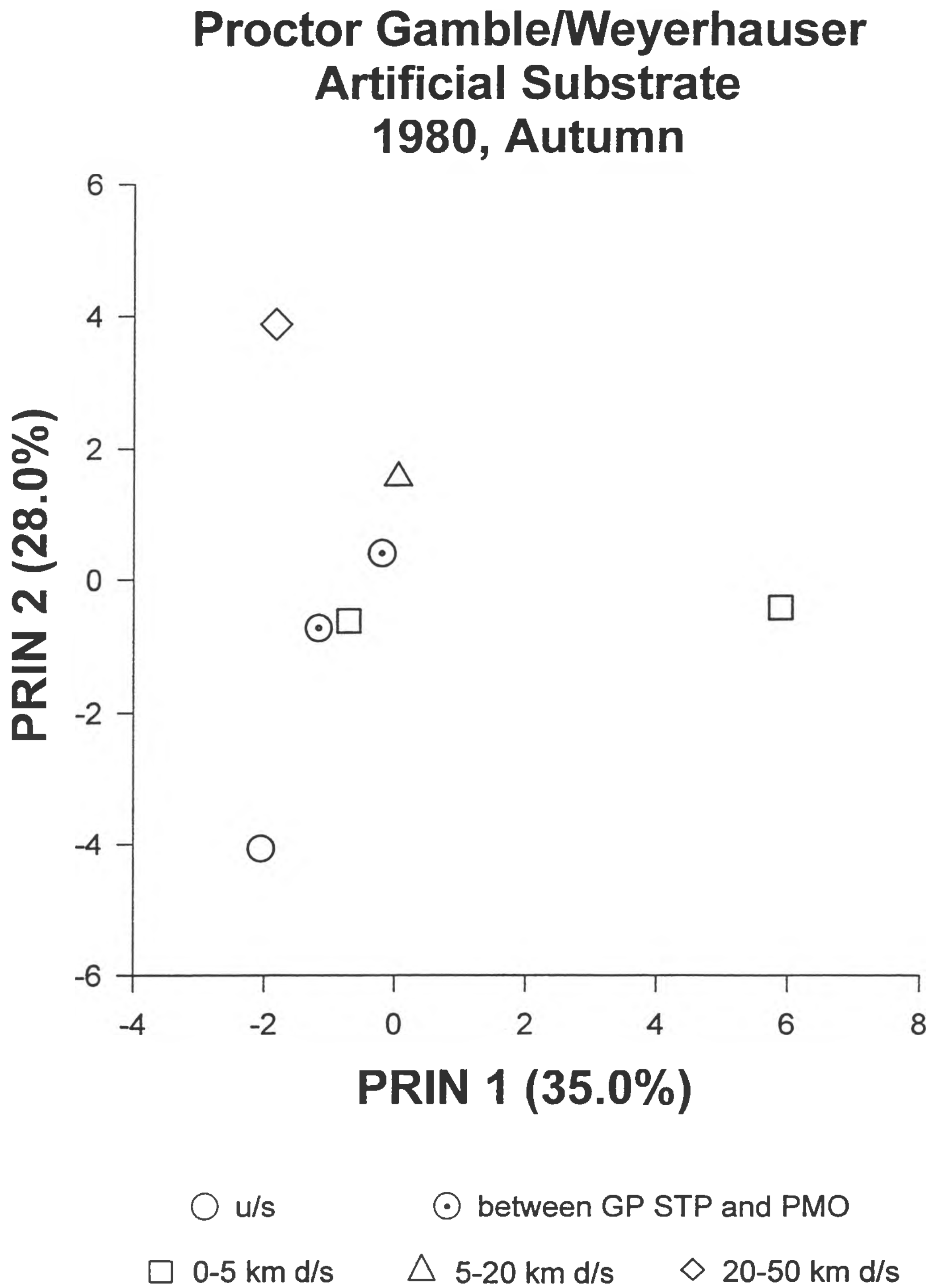
Proctor Gamble/Weyerhauser
1974, Summer

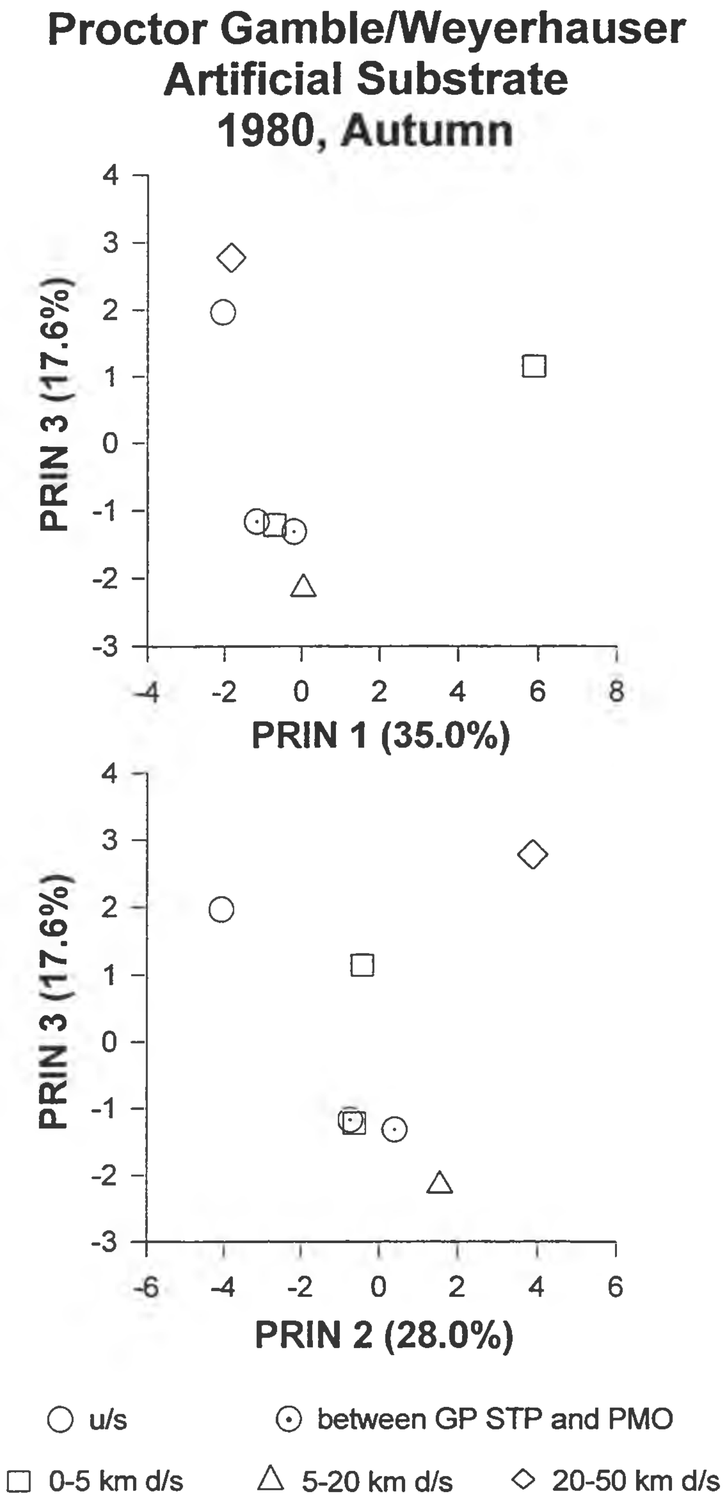


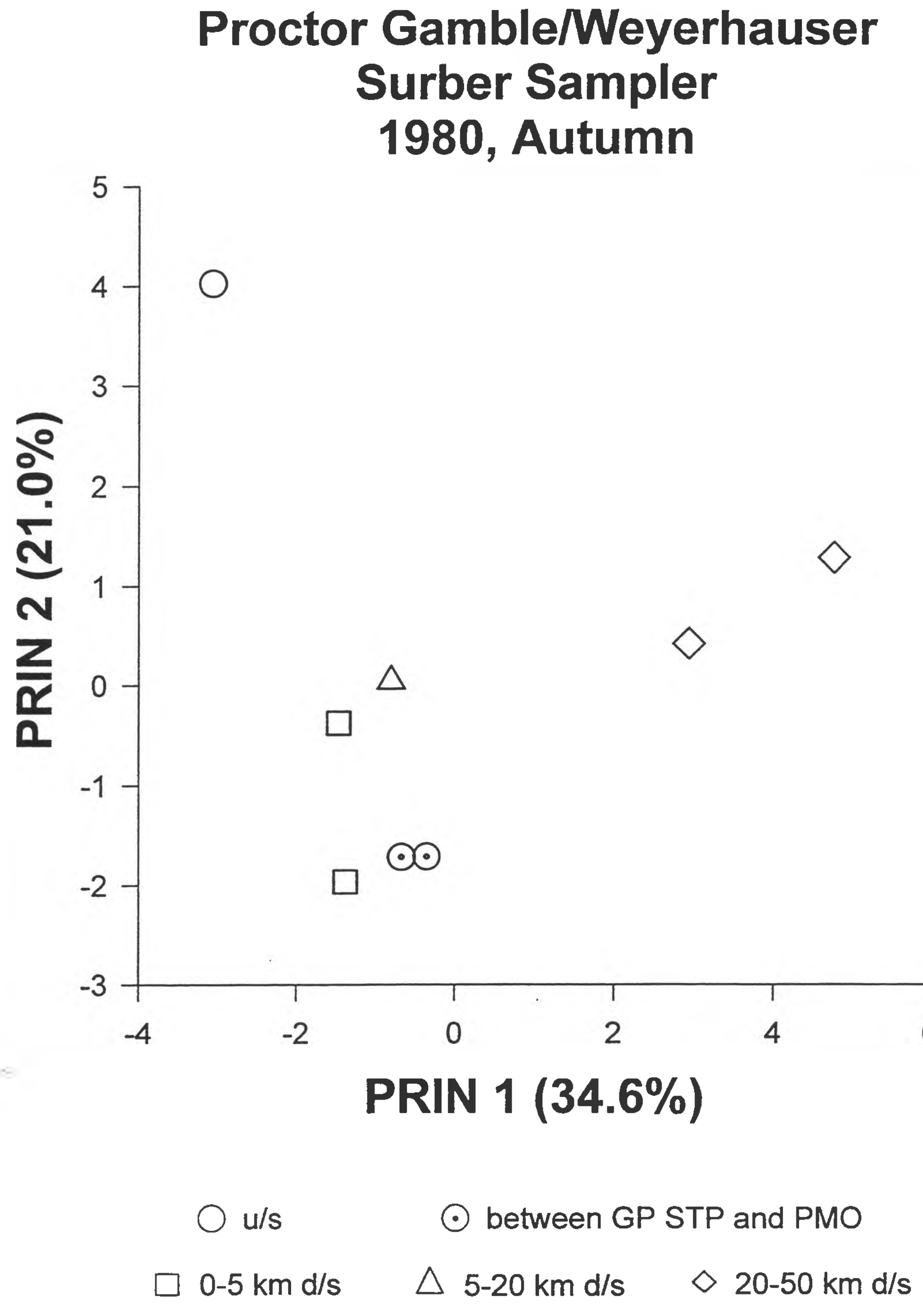

Proctor Gamble/Weyerhauser
1975, Summer
3
2
1
0
-1
-2
-3
-3
-2
-1
0
1
2
3
4
5
PRIN 2 (24.4%)
PRIN 1 (28.9%)
u/s
between GP STP and PMO
0-5 km d/s
5-20 km d/s
20-50 km d/s

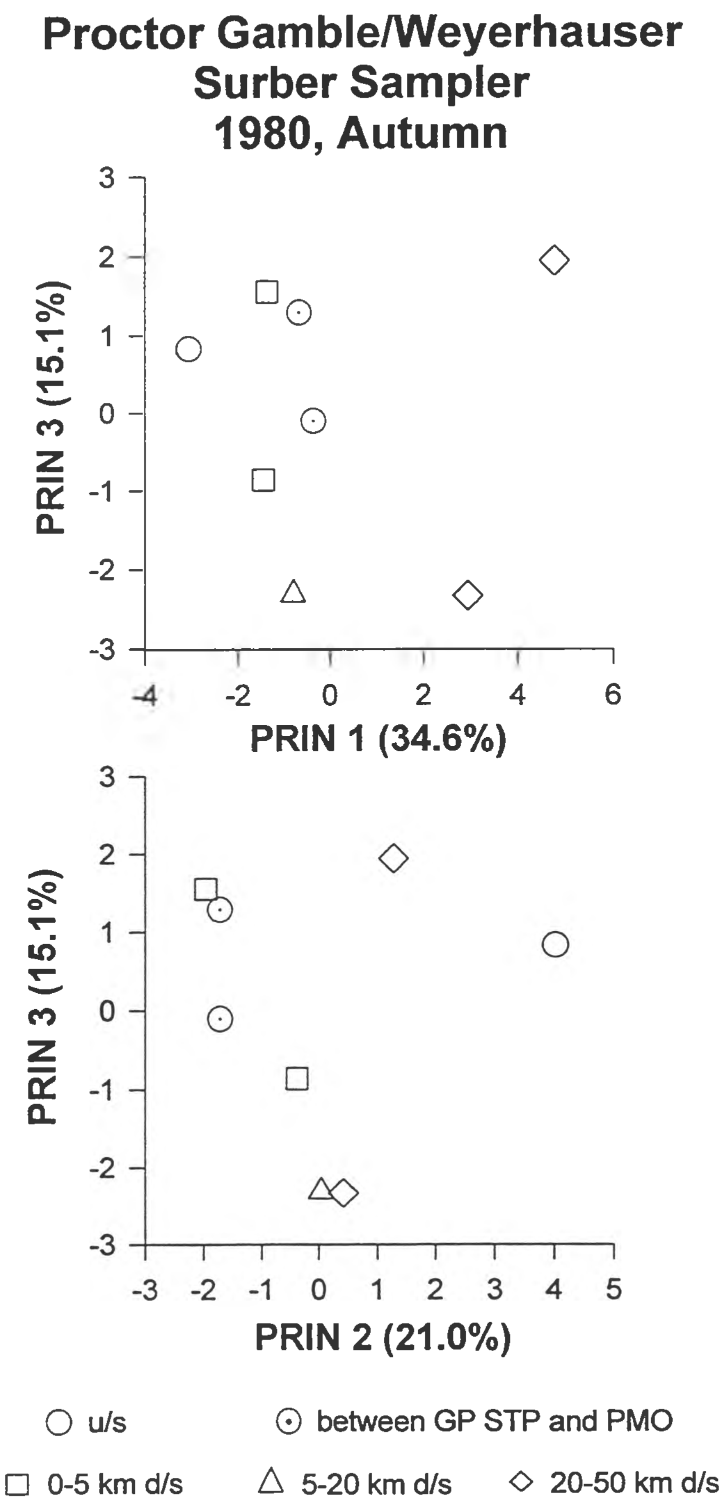
Proctor Gamble/Weyerhauser
1975, Summer

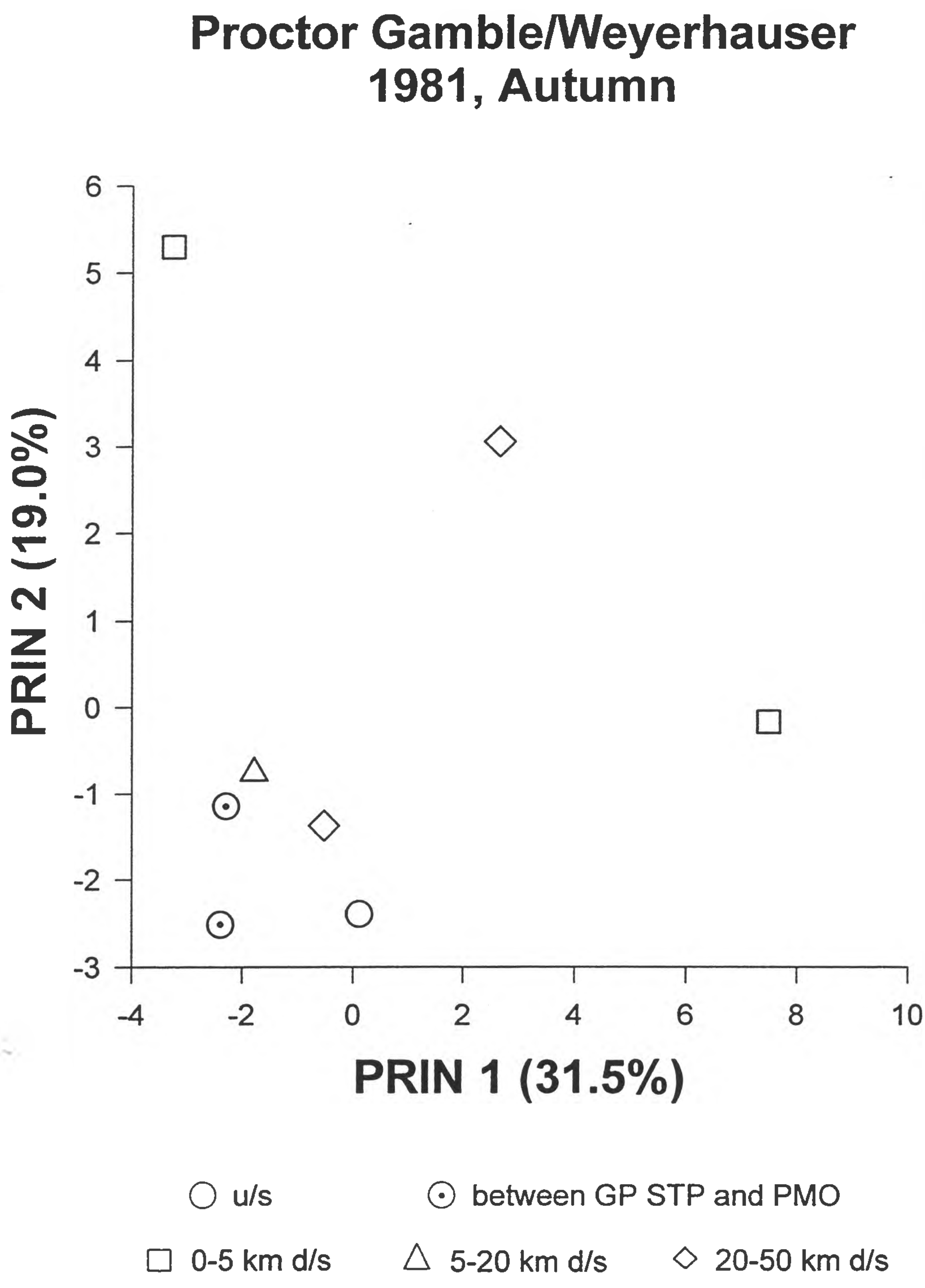



Proctor Gamble/Weyerhauser
Artificial Substrate
1980, Autumn
6
4
2
0
-2
-4
-6
PRIN 2 (28.0%)
-4
-2
0
2
4
6
8
PRIN 1 (35.0%)
u/s
between GP STP and PMO
0-5 km d/s
5-20 km d/s
20-50 km d/s

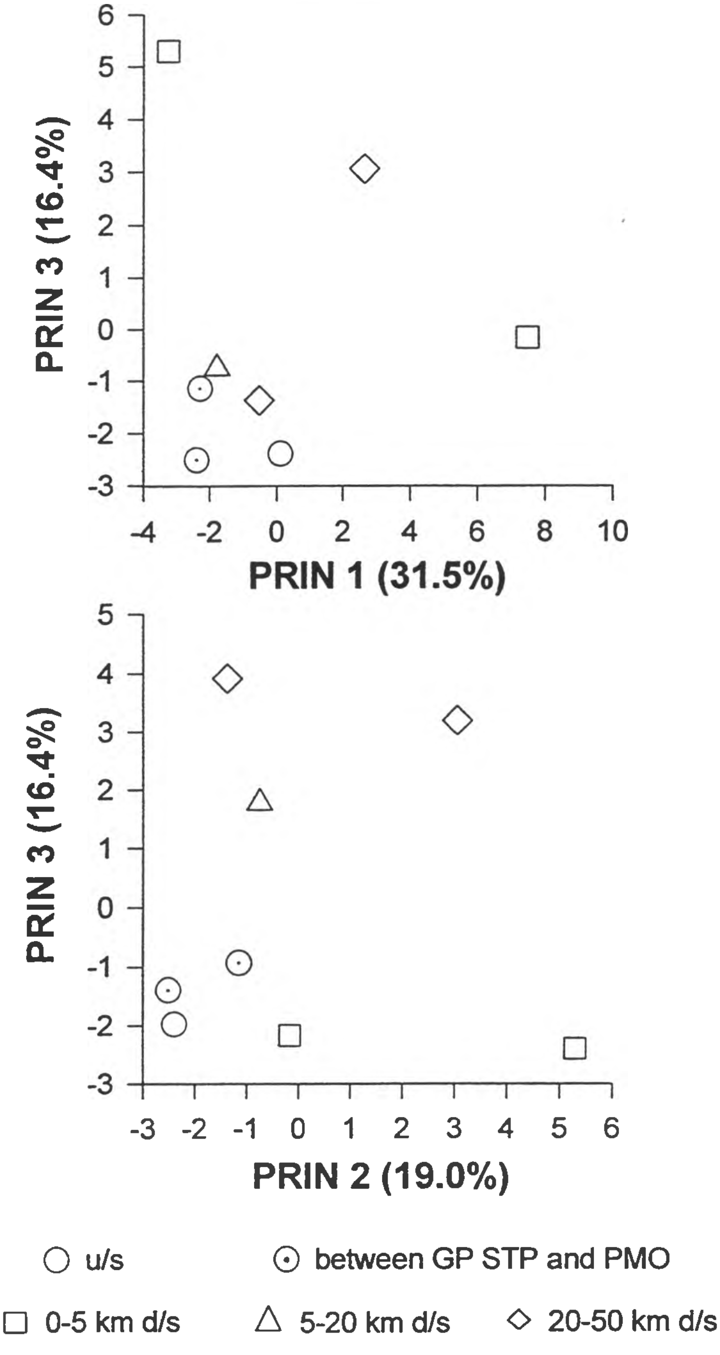

Proctor Gamble/Weyerhauser
Artificial Substrate
1980, Autumn
PRIN 3 (17.6%)
PRIN 1 (35.0%)
PRIN 3 (17.6%)
PRIN 2 (28.0%)
u/s
between GP STP and PMO
0-5 km d/s
5-20 km d/s
20-50 km d/s

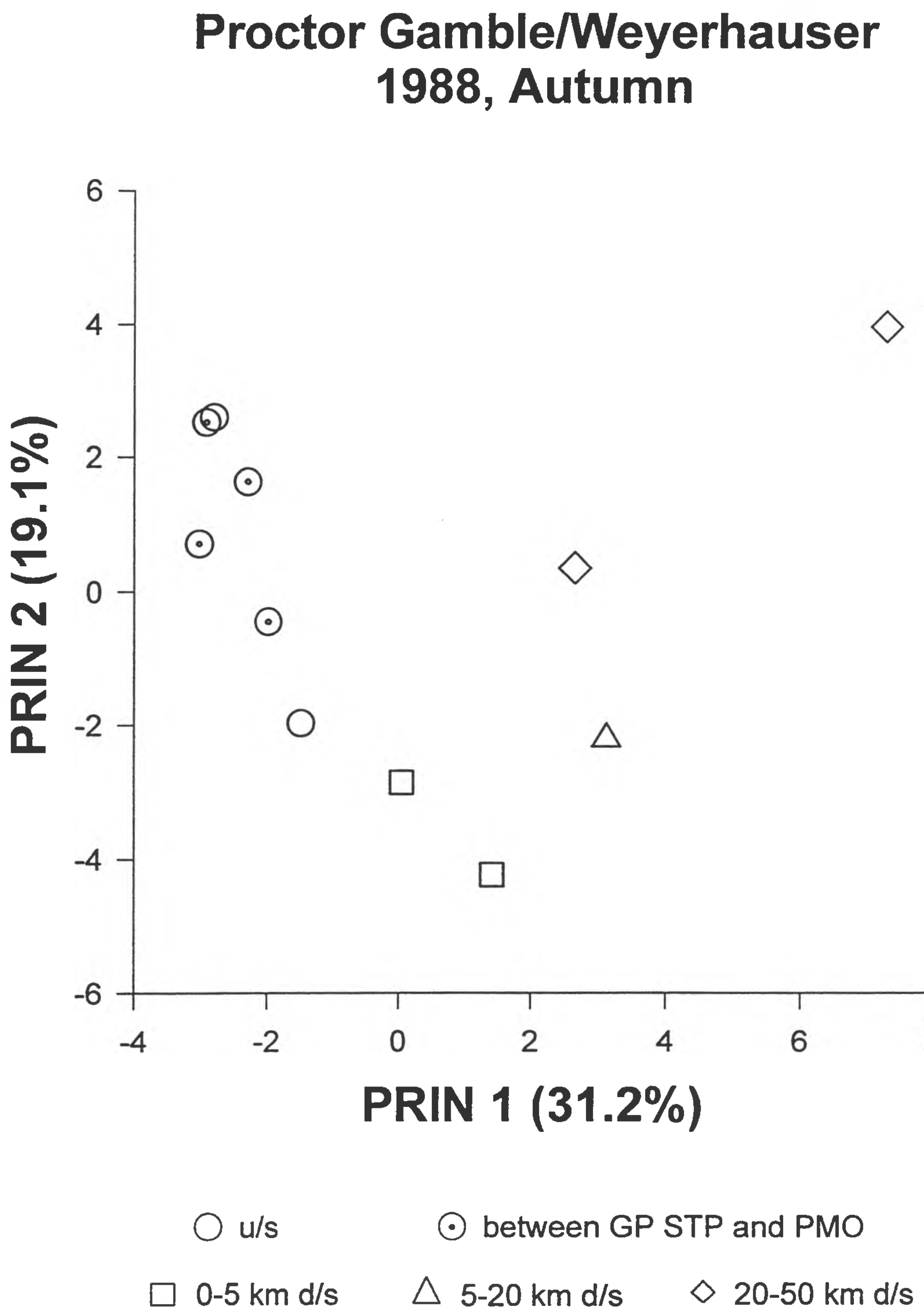

Proctor Gamble/Weyerhauser
Surber Sampler
1980, Autumn
PRIN 2 (21.0%)
5
4
3
2
1
0
-1
-2
-3
-4
-2
0
2
4
6
PRIN 1 (34.6%)
u/s
between GP STP and PMO
0-5 km d/s
5-20 km d/s
20-50 km d/s

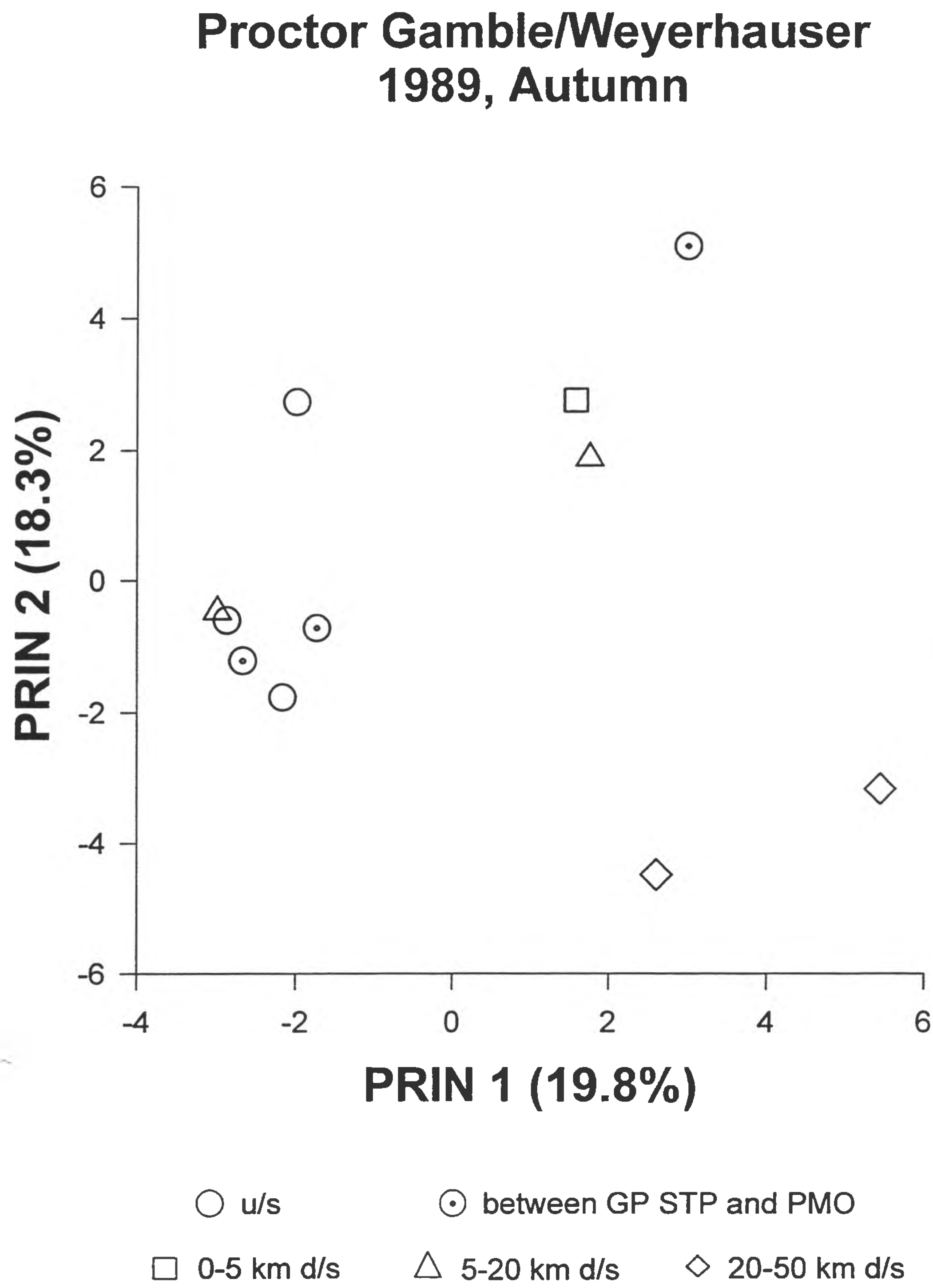

Proctor Gamble/Weyerhauser
Surber Sampler
1980, Autumn
PRIN 3 (15.1%)
PRIN 1 (34.6%)
PRIN 3 (15.1%)
PRIN 2 (21.0%)
u/s
between GP STP and PMO
0-5 km d/s
5-20 km d/s
20-50 km d/s


Proctor Gamble/Weyerhauser
1981, Autumn
6
5
4
3
2
1
0
-1
-2
-3
PRIN 2 (19.0%)
-4
-2
0
2
4
6
8
10
PRIN 1 (31.5%)
u/s
between GP STP and PMO
0-5 km d/s
5-20 km d/s
20-50 km d/s

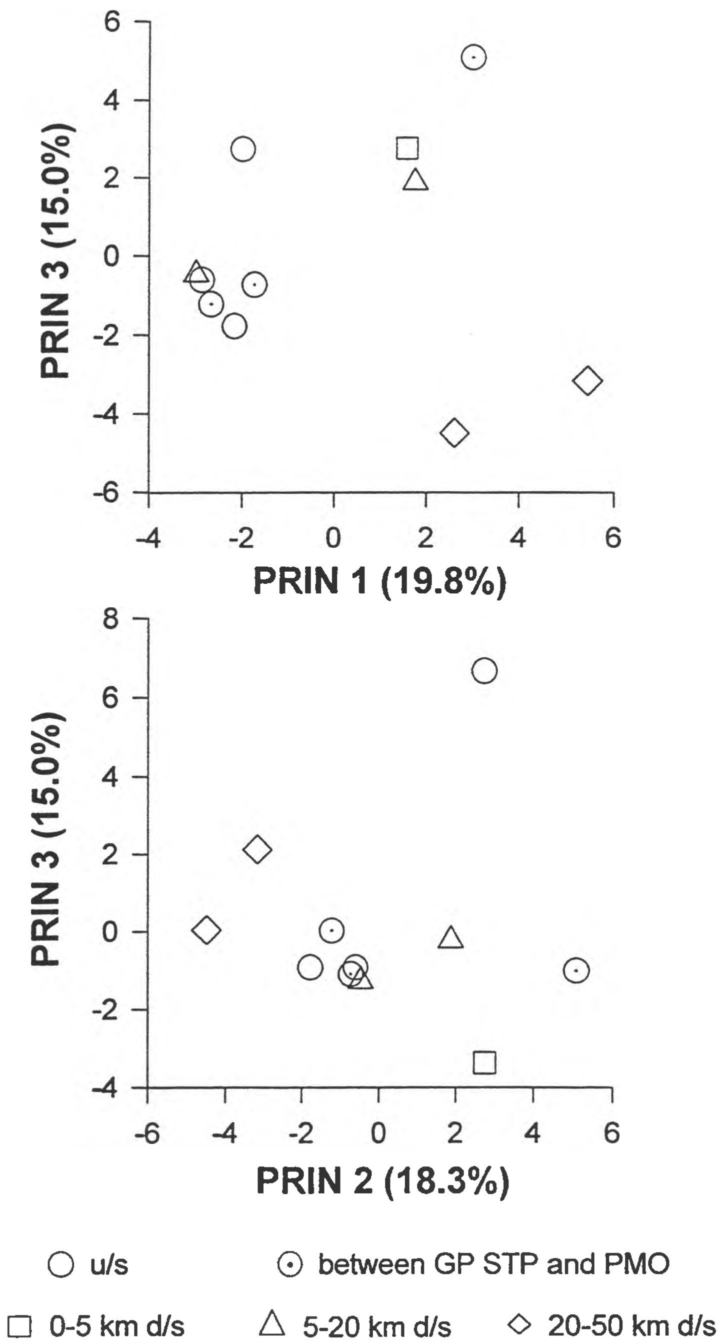
Proctor Gamble/Weyerhauser
Artificial Substrate
1981, Autumn

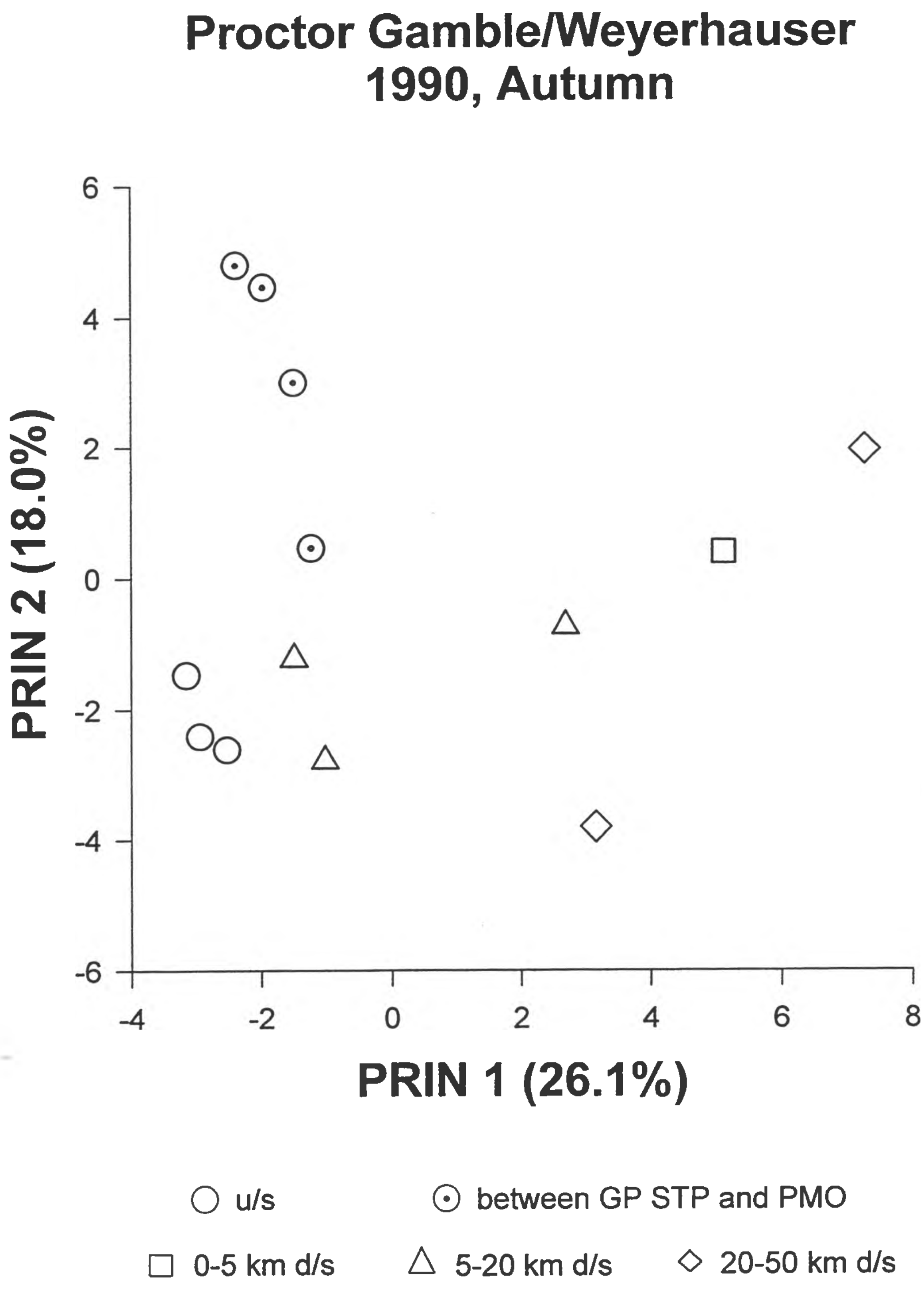



Proctor Gamble/Weyerhauser
1988, Autumn
PRIN 2 (19.1%)
PRIN 1 (31.2%)
6
4
2
0
-2
-4
-6
-4
-2
0
2
4
6
8
u/s
between GP STP and PMO
0-5 km d/s
5-20 km d/s
20-50 km d/s


Proctor Gamble/Weyerhauser
1989, Autumn
6
4
2
0
-2
-4
-6
-4
-2
0
2
4
6
PRIN 2 (18.3%)
PRIN 1 (19.8%)
u/s
between GP STP and PMO
0-5 km d/s
5-20 km d/s
20-50 km d/s

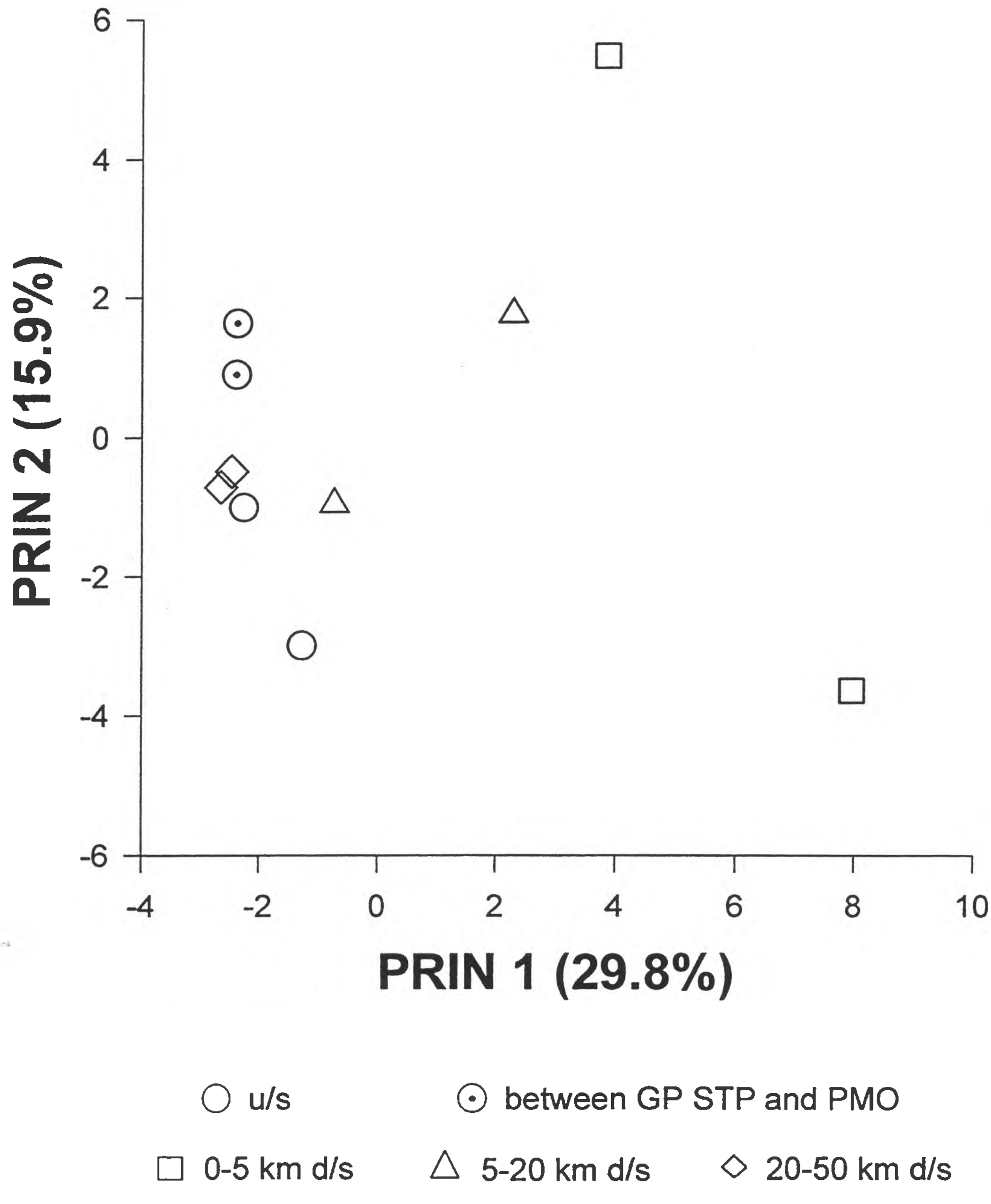
Proctor Gamble/Weyerhauser
1989, Autumn

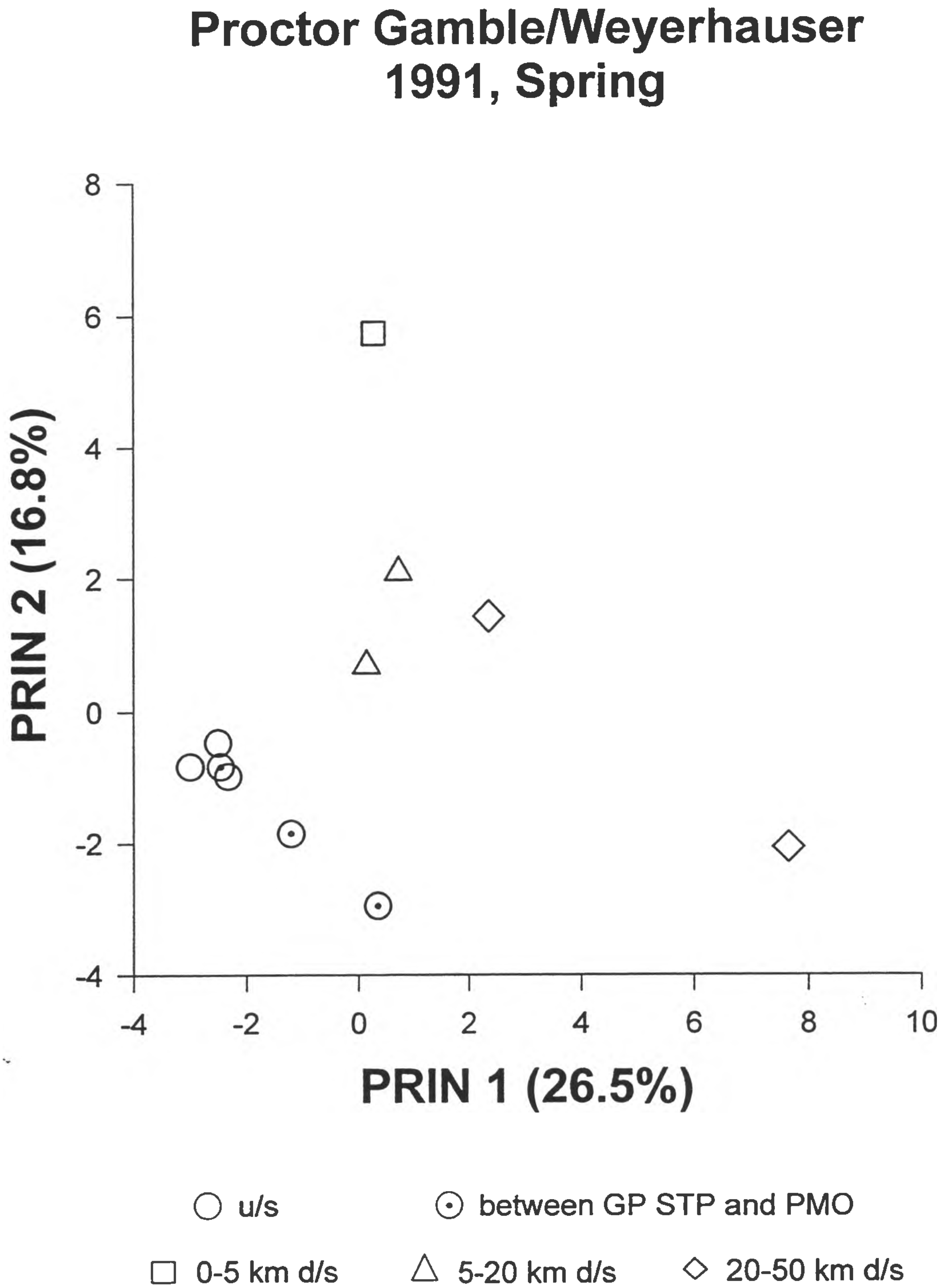




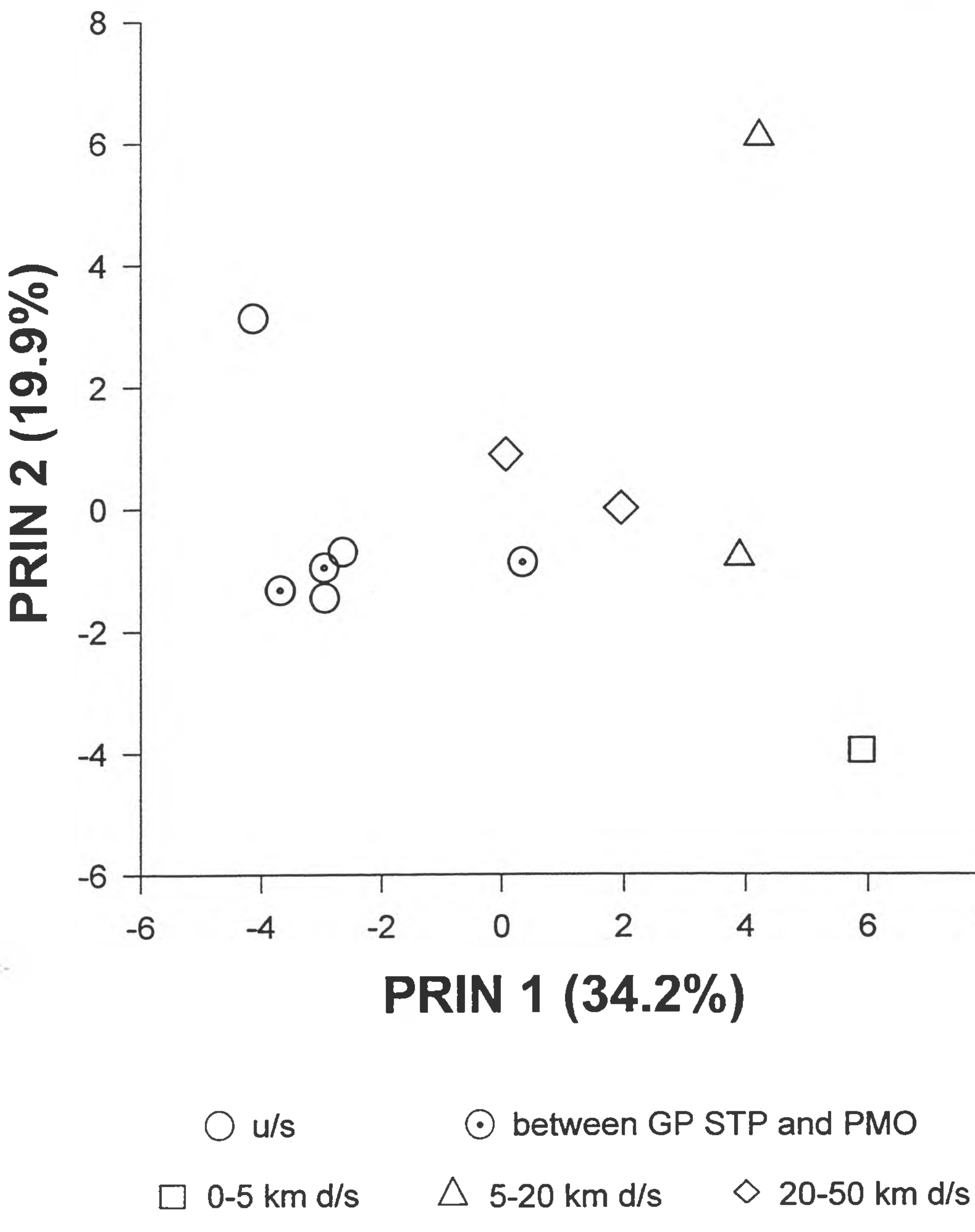
Proctor Gamble/Weyerhauser
1990, Autumn
6
4
2
0
-2
-4
-6
PRIN 2 (18.0%)
-4
-2
0
2
4
6
8
PRIN 1 (26.1%)
u/s
between GP STP and PMO
0-5 km d/s
5-20 km d/s
20-50 km d/s

Proctor Gamble/Weyerhauser 1991, Winter

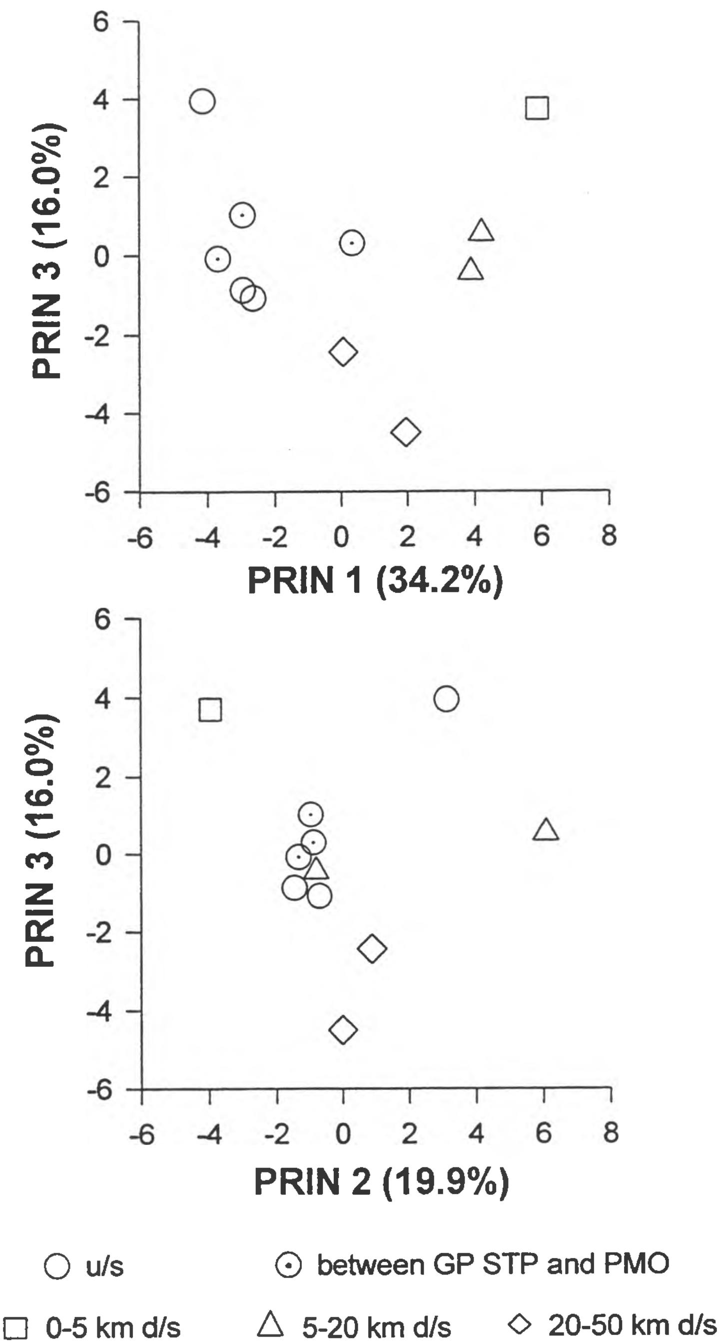


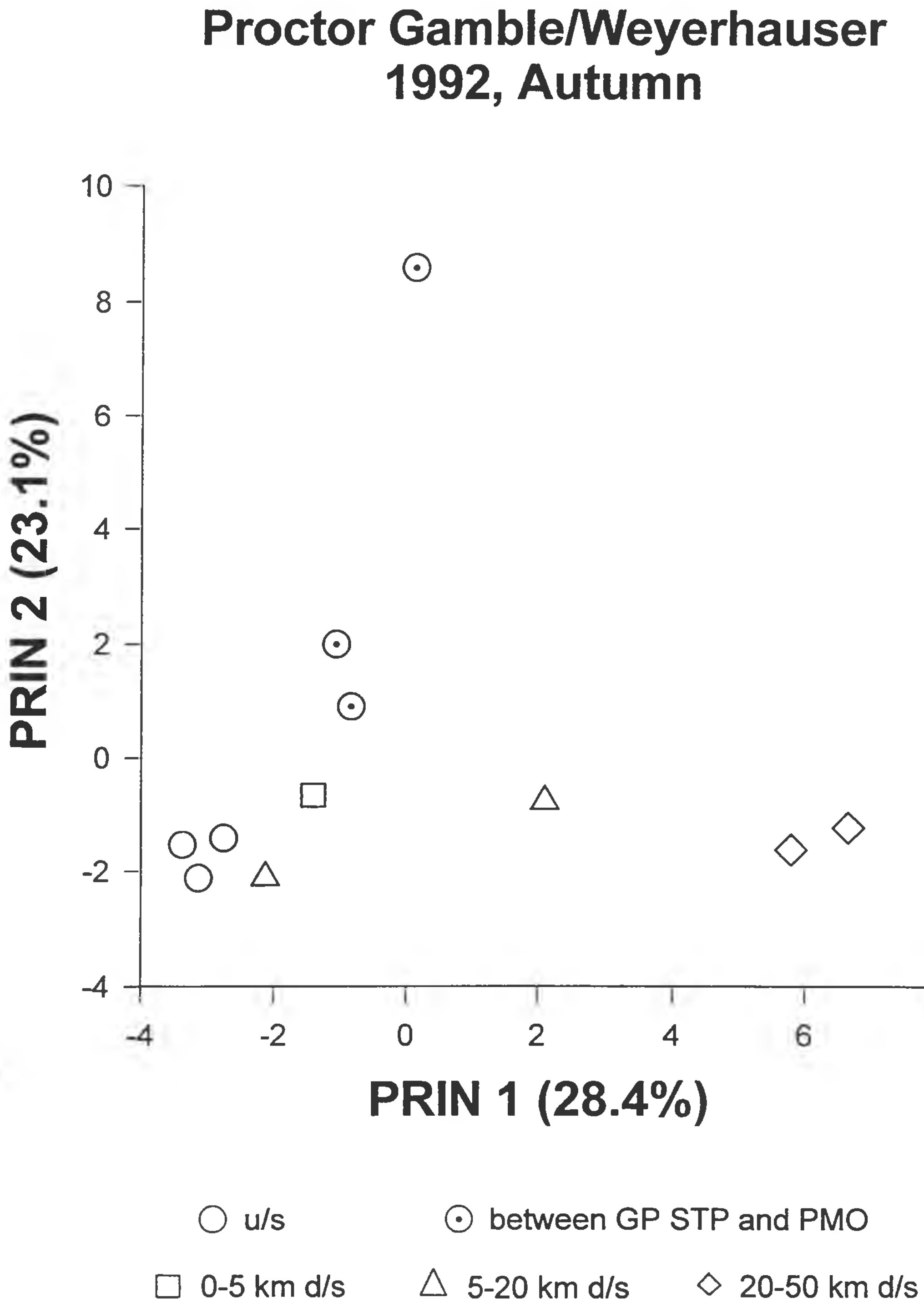

Proctor Gamble/Weyerhauser
1991, Spring
PRIN 2 (16.8%)
8
6
4
2
0
-2
-4
-4
-2
0
2
4
6
8
10
PRIN 1 (26.5%)
u/s
between GP STP and PMO
0-5 km d/s
5-20 km d/s
20-50 km d/s

Proctor Gamble/Weyerhauser
1992, Winter



Proctor Gamble/Weyerhauser
1992, Winter




Proctor Gamble/Weyerhauser
1992, Autumn
PRIN 2 (23.1%)
PRIN 1 (28.4%)
10
8
6
4
2
0
-2
-4
-4
-2
0
2
4
6
8
u/s
between GP STP and PMO
0-5 km d/s
5-20 km d/s
20-50 km d/s

Appendix E6

Principal Component Analysis of Benthic Invertebrate Community Structure
Peace River Pulp Company (Daishowa)

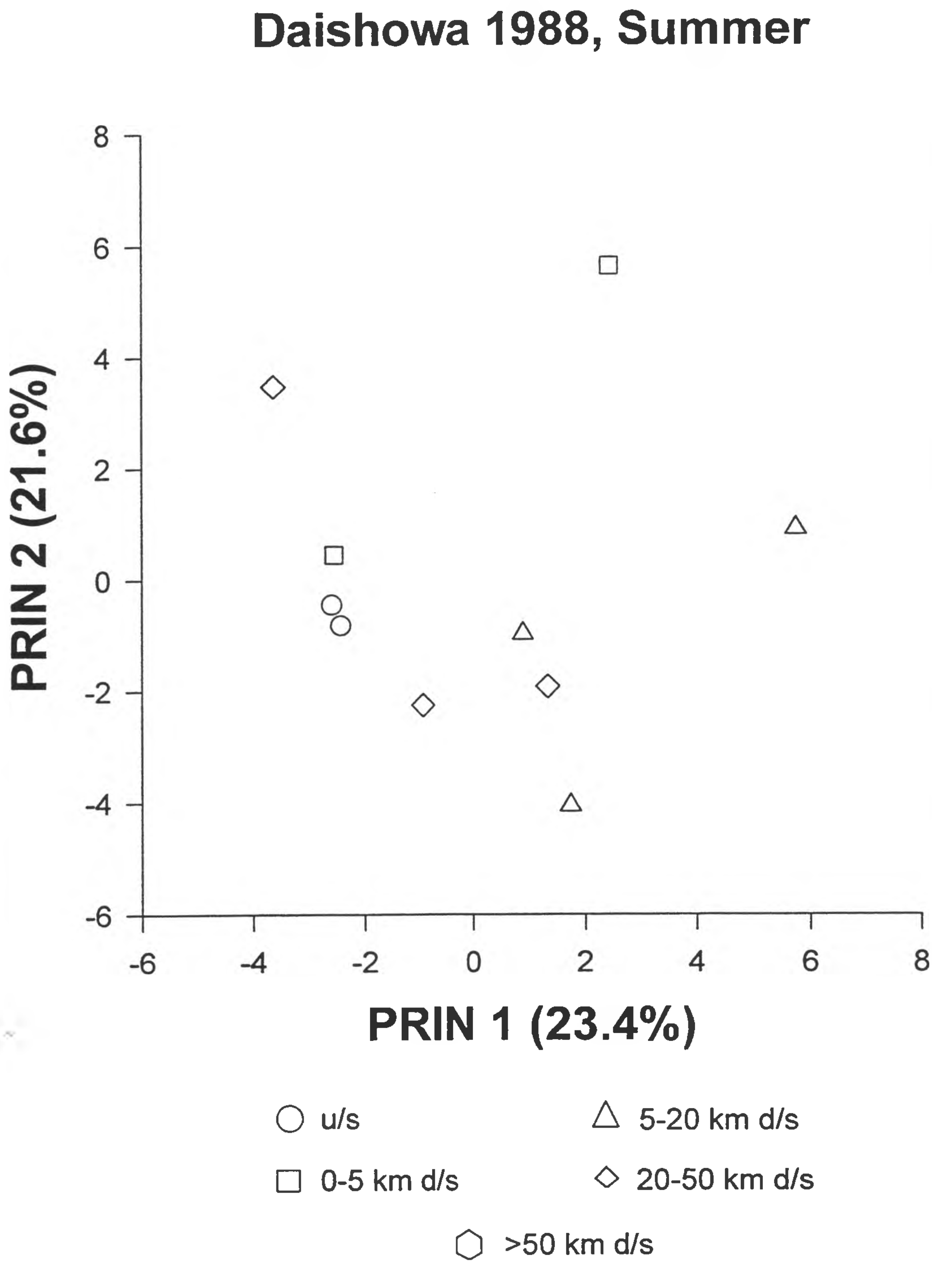
Axis labels represent the principal component axis shown (eg PRIN 1) followed by the proportion of the total variation explained by that principal component axis. The first two principal component axes are shown for all analyses. The third axis is shown only when it explains more than 15% of the total variation.

There are five distinct reaches of the Peace River around Daishowa considered:

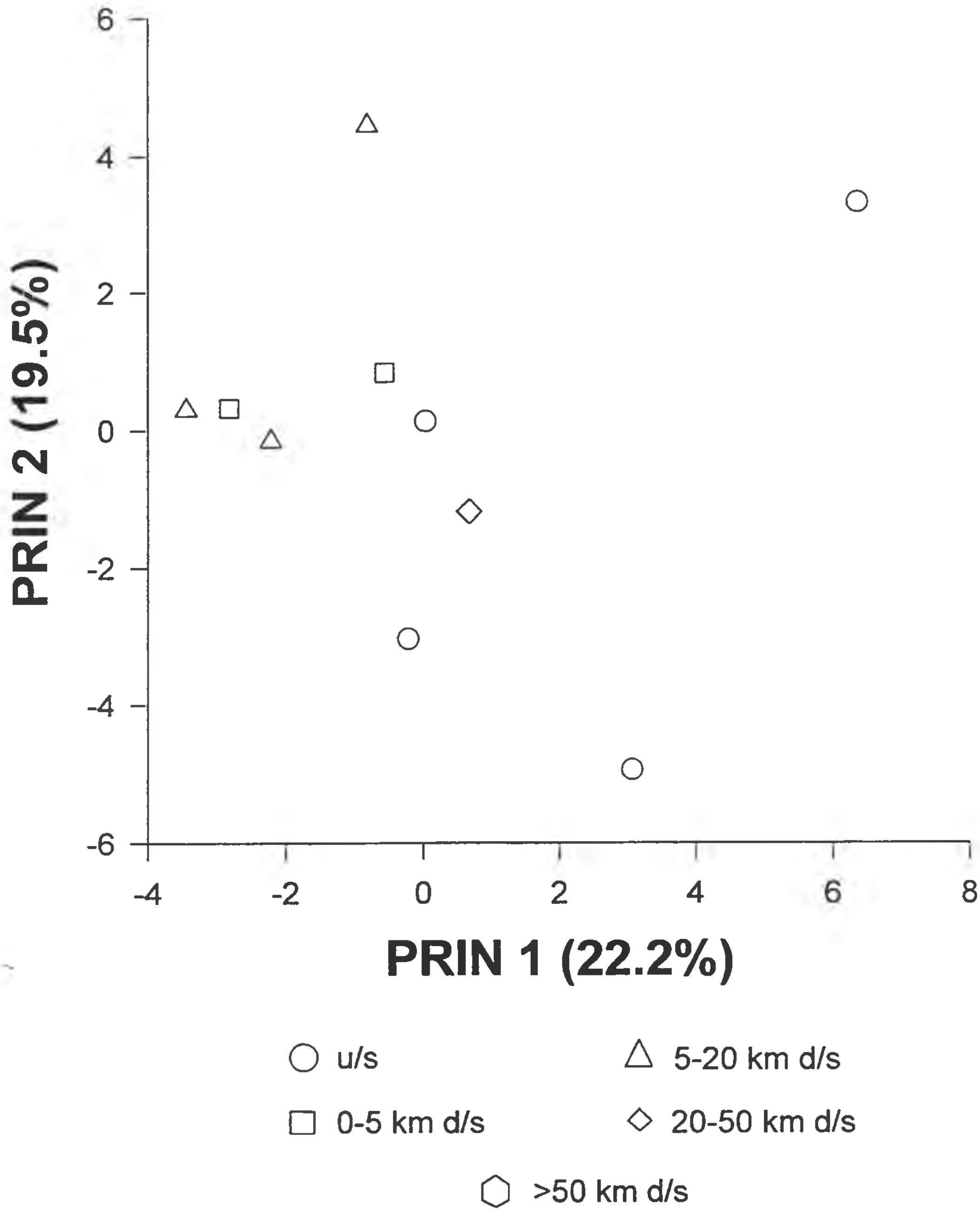
upstream of the pulp mill outfall	u/s
between 0 and 5 km downstream of the pulp mill outfall	0-5 km d/s
between 5 and 20 km downstream of the pulp mill outfall	5-20 km d/s
between 20 and 50 km downstream of the pulp mill outfall	20-50 km d/s
greater than 50 km downstream of the pulp mill outfall	>50 km d/s

Analysis is appended for the following years:

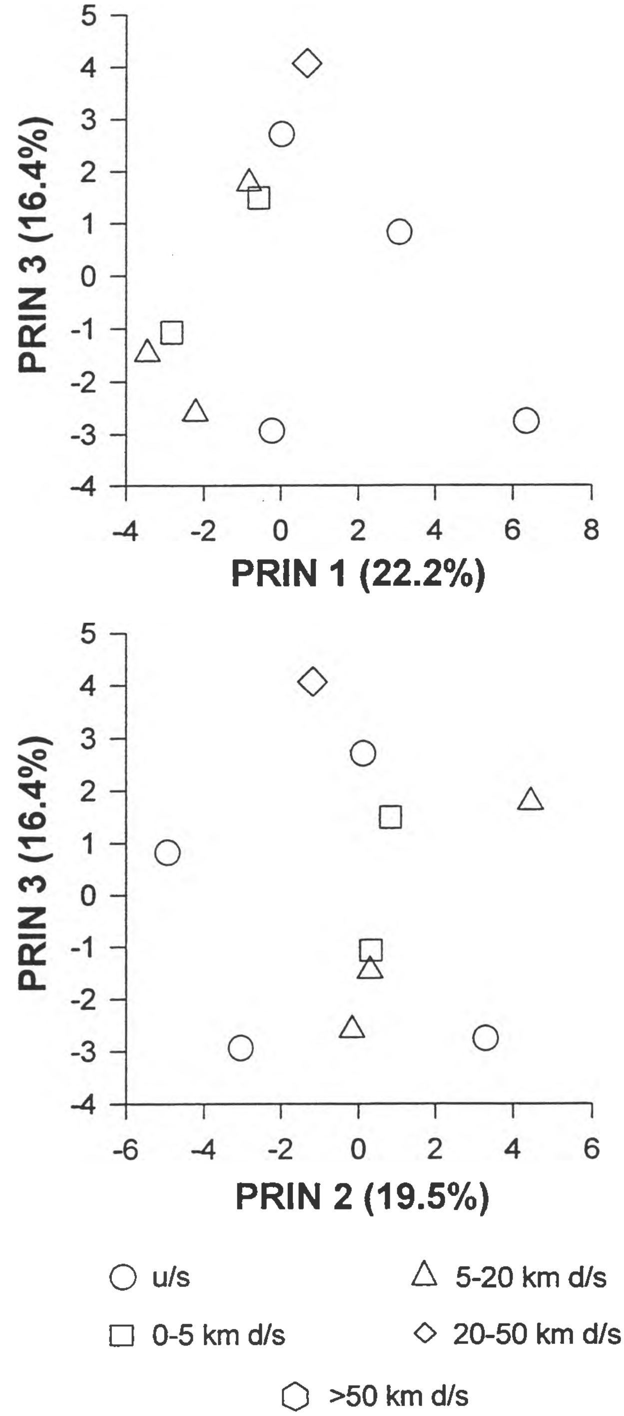
1988	summer
1988	autumn
1989	summer
1989	autumn
1990	spring
1991	spring
1991	autumn
1992	spring
1992	autumn

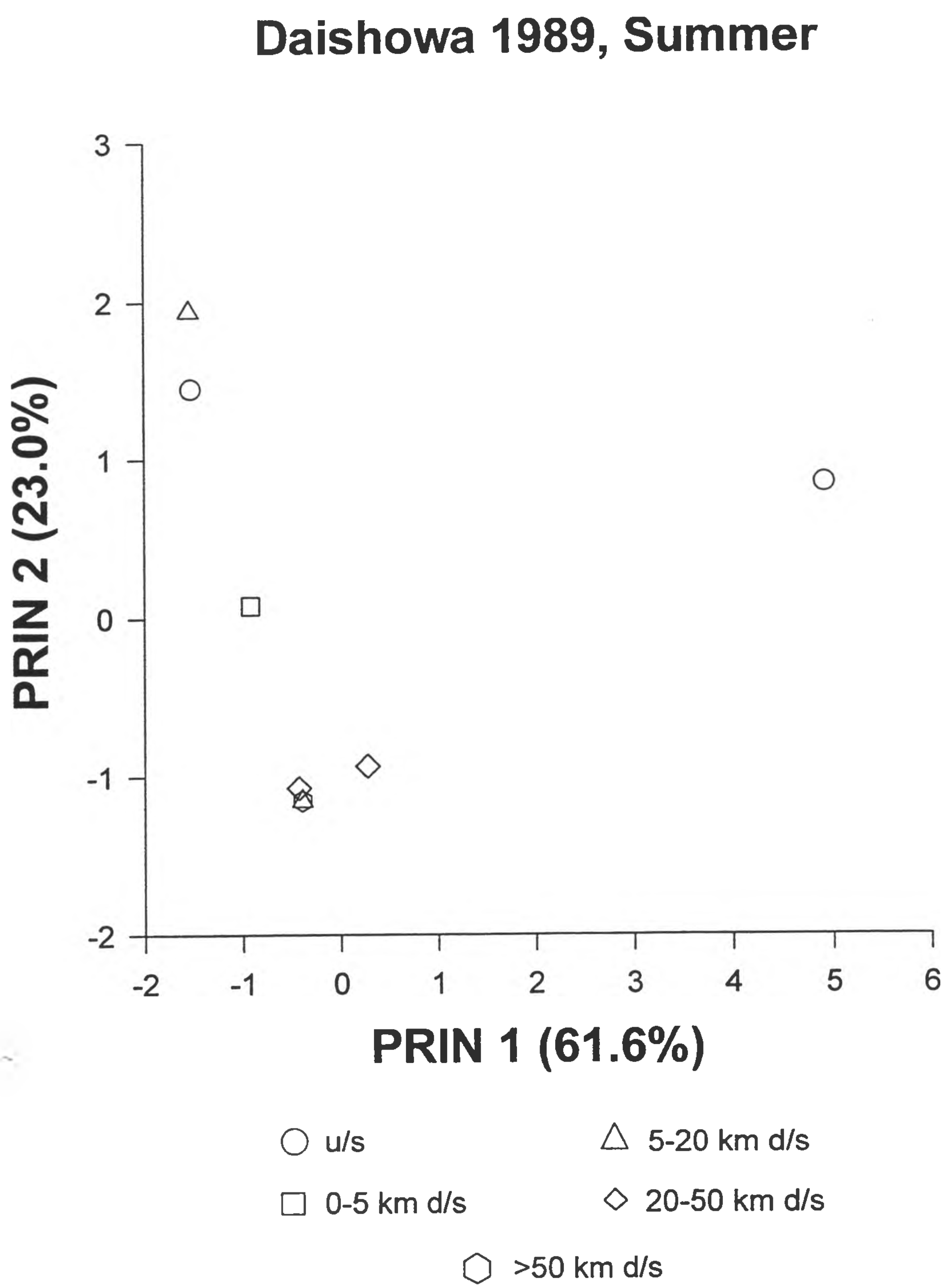

Daishowa 1988, Summer
8
6
4
2
0
-2
-4
-6
PRIN 2 (21.6%)
-6
-4
-2
0
2
4
6
8
PRIN 1 (23.4%)
u/s
5-20 km d/s
0-5 km d/s
20-50 km d/s
>50 km d/s

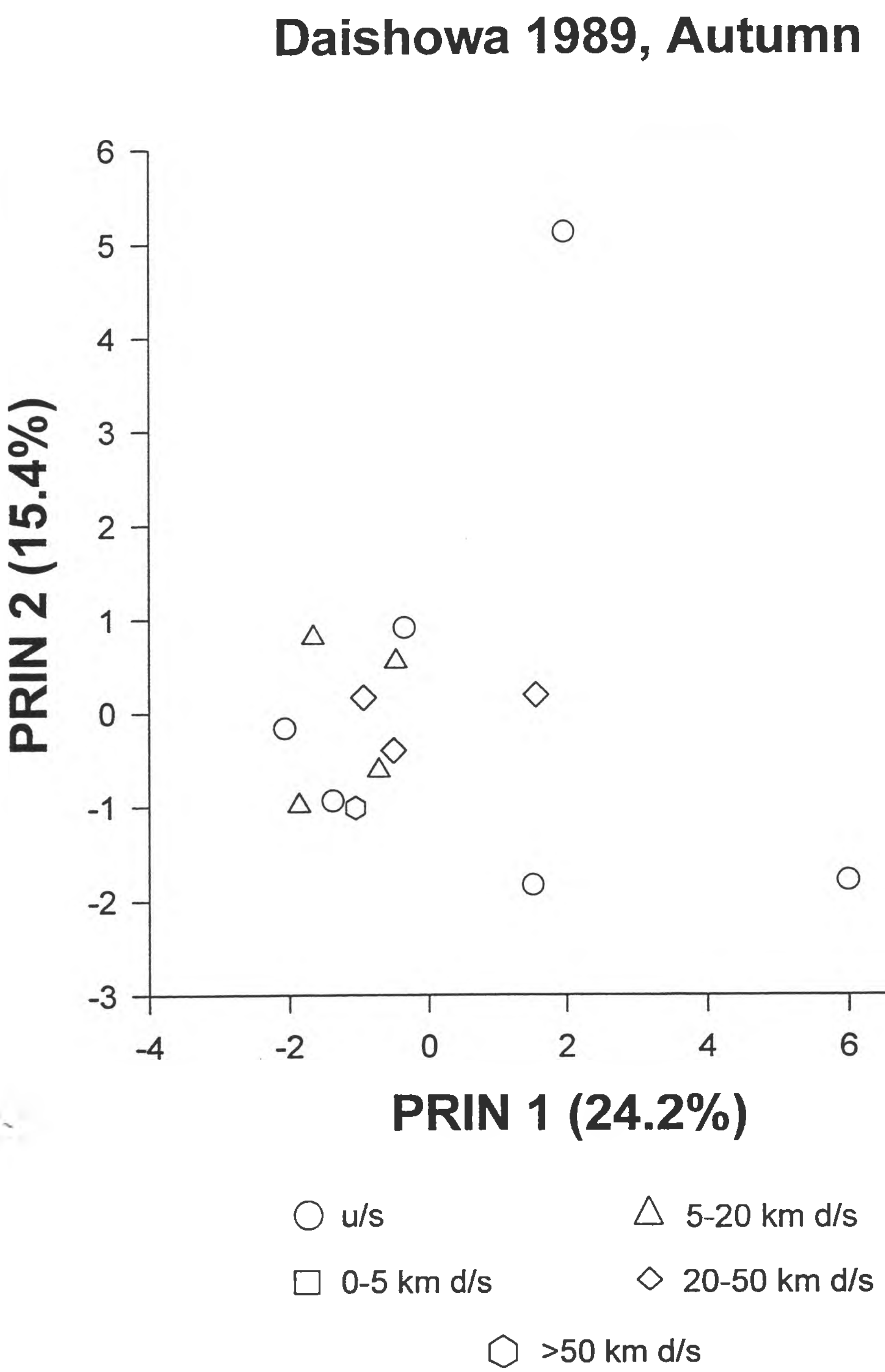
Daishowa 1988, Autumn

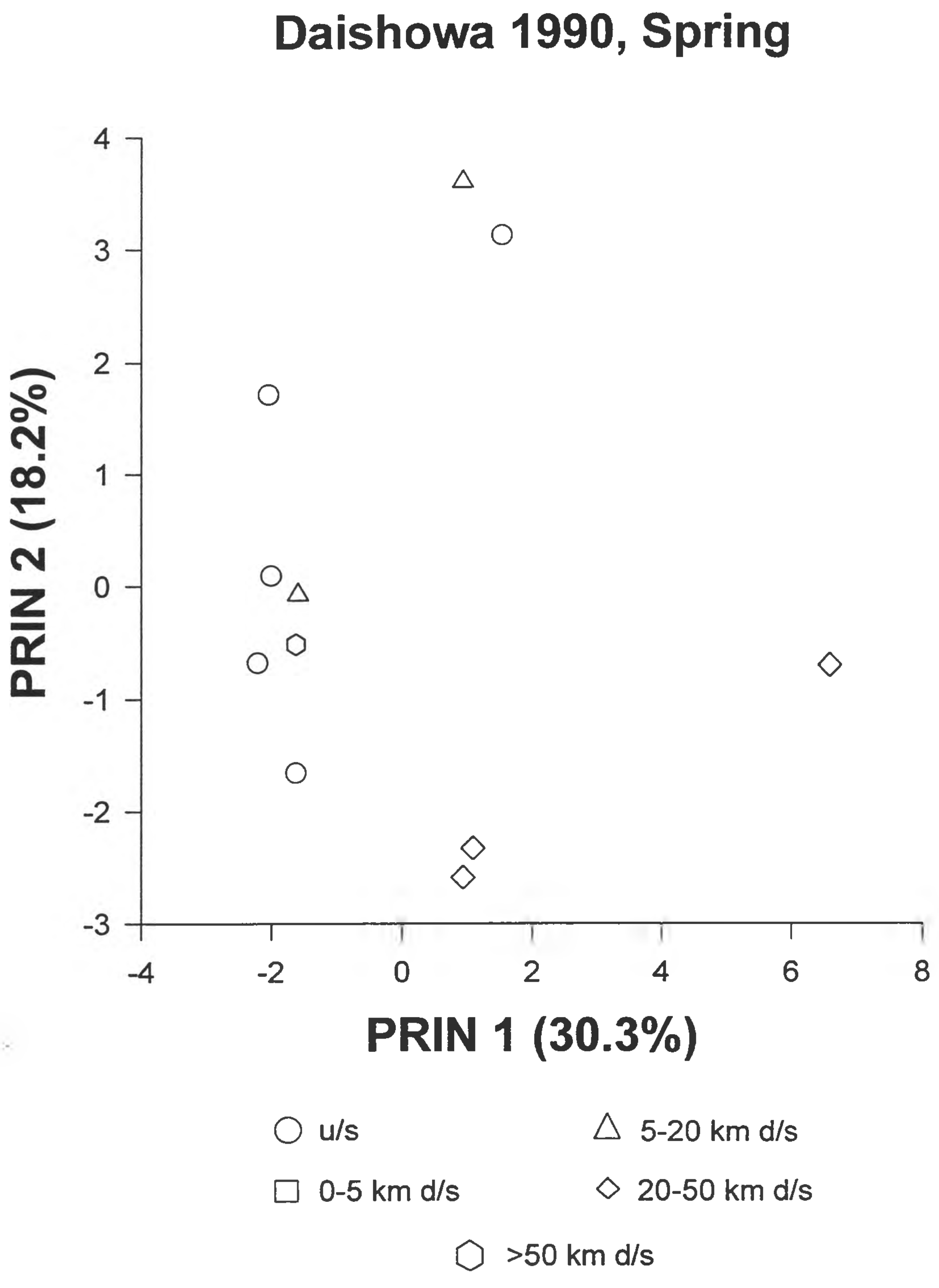


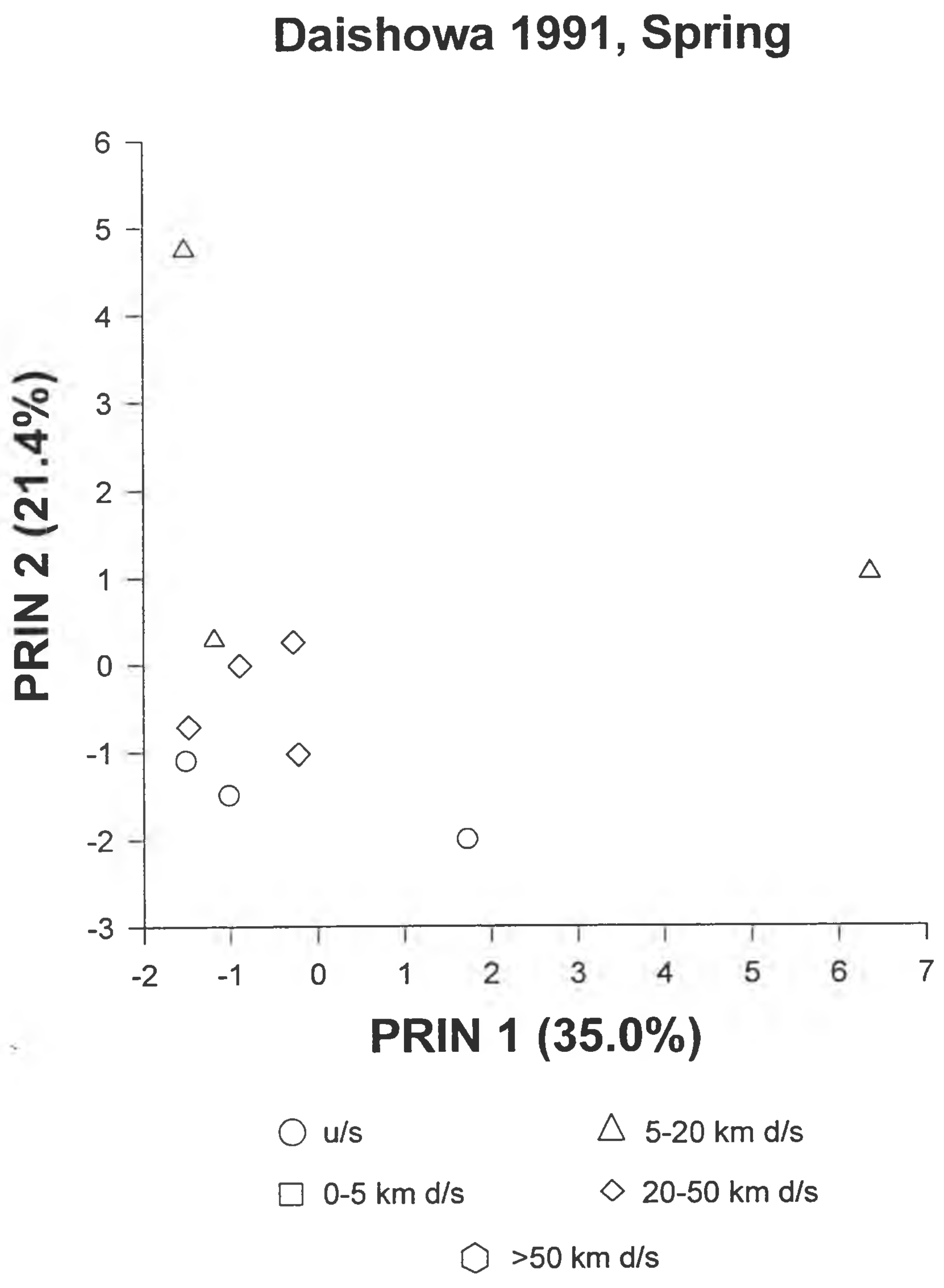
Daishowa 1988, Autumn



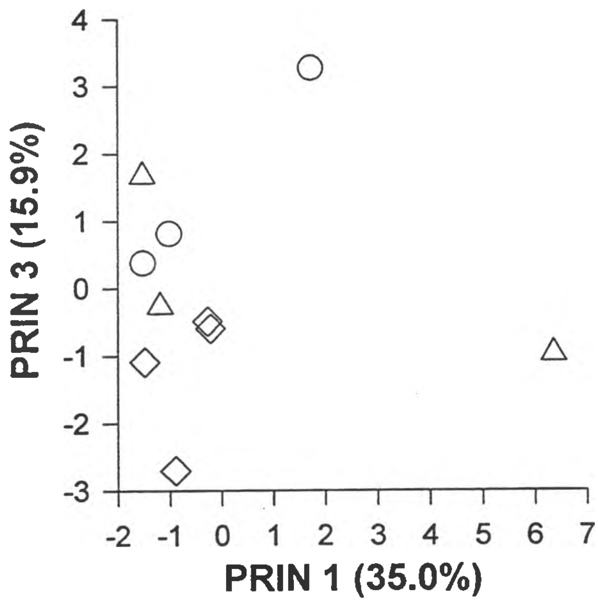

Daishowa 1989, Summer
PRIN 2 (23.0%)
PRIN 1 (61.6%)
3
2
1
0
-1
-2
-2
-1
0
1
2
3
4
5
6
u/s
5-20 km d/s
0-5 km d/s
20-50 km d/s
>50 km d/s

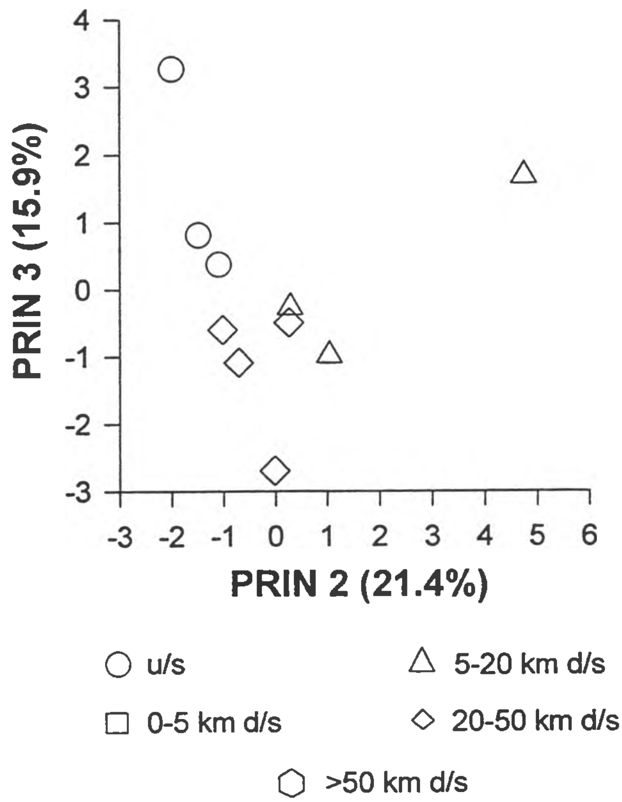

Daishowa 1989, Autumn
PRIN 2 (15.4%)
PRIN 1 (24.2%)
6
5
4
3
2
1
0
-1
-2
-3
-4
-2
0
2
4
6
8
u/s
5-20 km d/s
0-5 km d/s
20-50 km d/s
>50 km d/s


Daishowa 1990, Spring
PRIN 2 (18.2%)
PRIN 1 (30.3%)
4
3
2
1
0
-1
-2
-3
-4
-2
0
2
4
6
8
u/s
5-20 km d/s
0-5 km d/s
20-50 km d/s
>50 km d/s

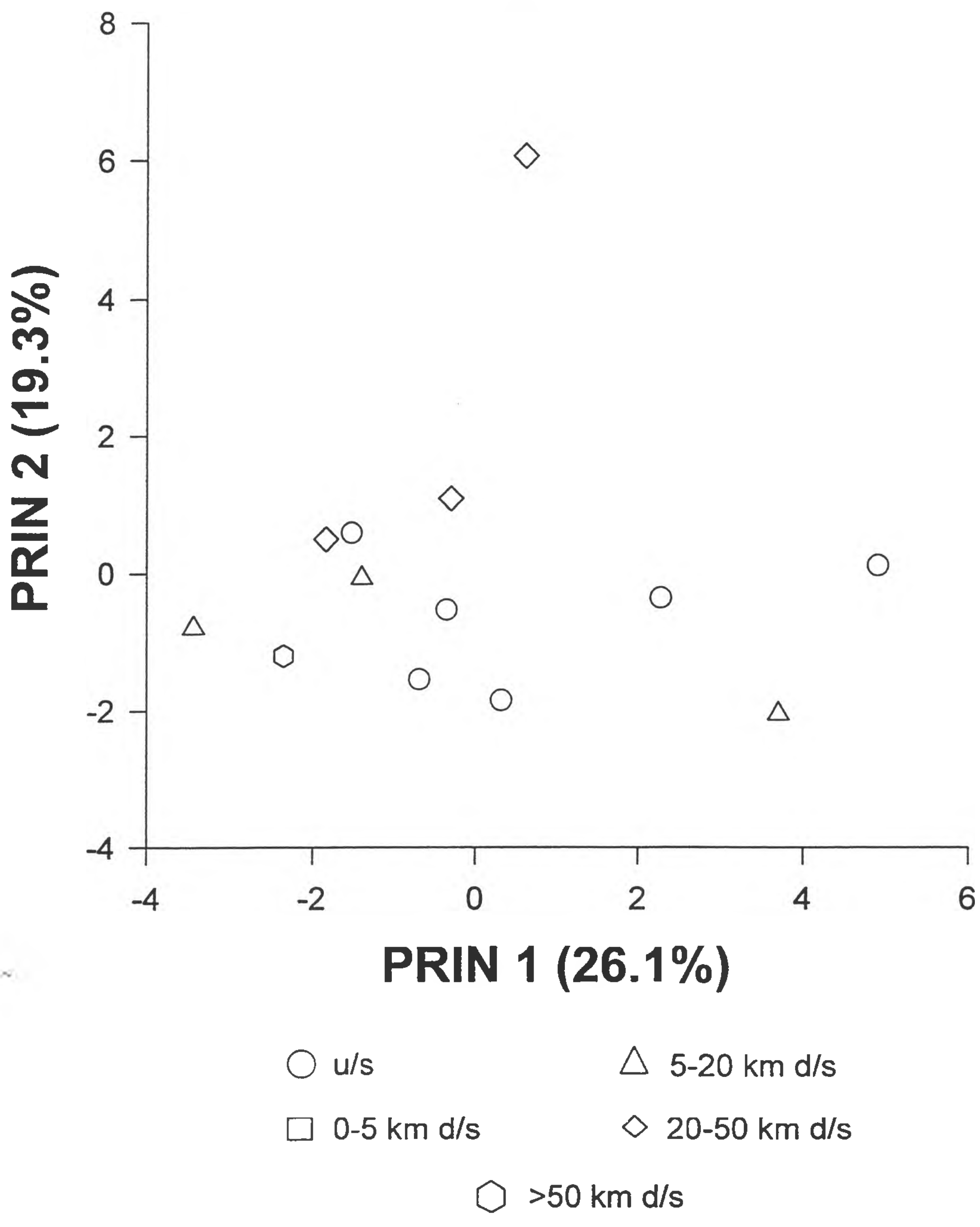

Daishowa 1991, Spring
PRIN 2 (21.4%)
6
5
4
3
2
1
0
-1
-2
-3
-2
-1
0
1
2
3
4
5
6
7
PRIN 1 (35.0%)
u/s
5-20 km d/s
0-5 km d/s
20-50 km d/s
>50 km d/s

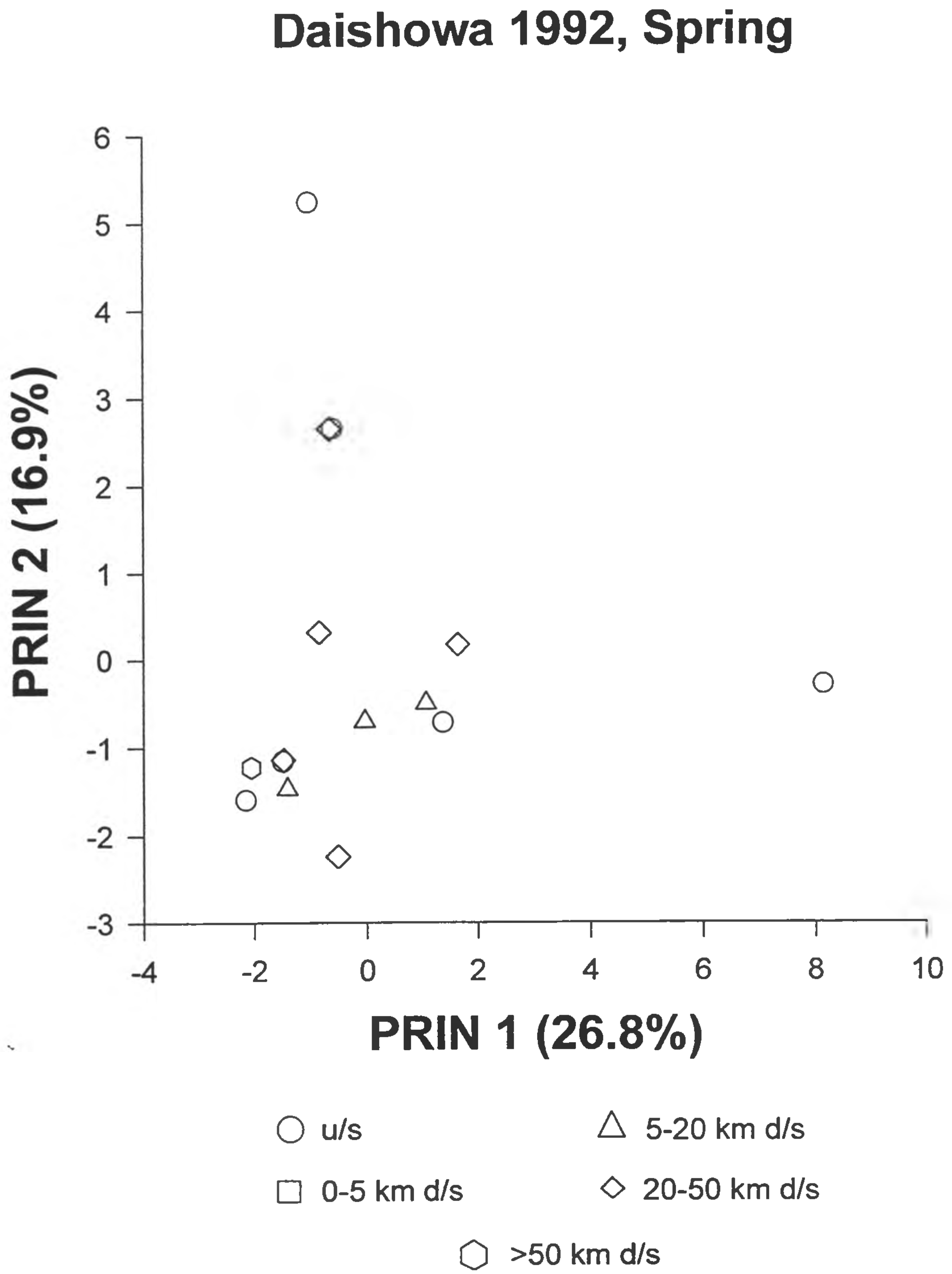
Daishowa 1991, Spring

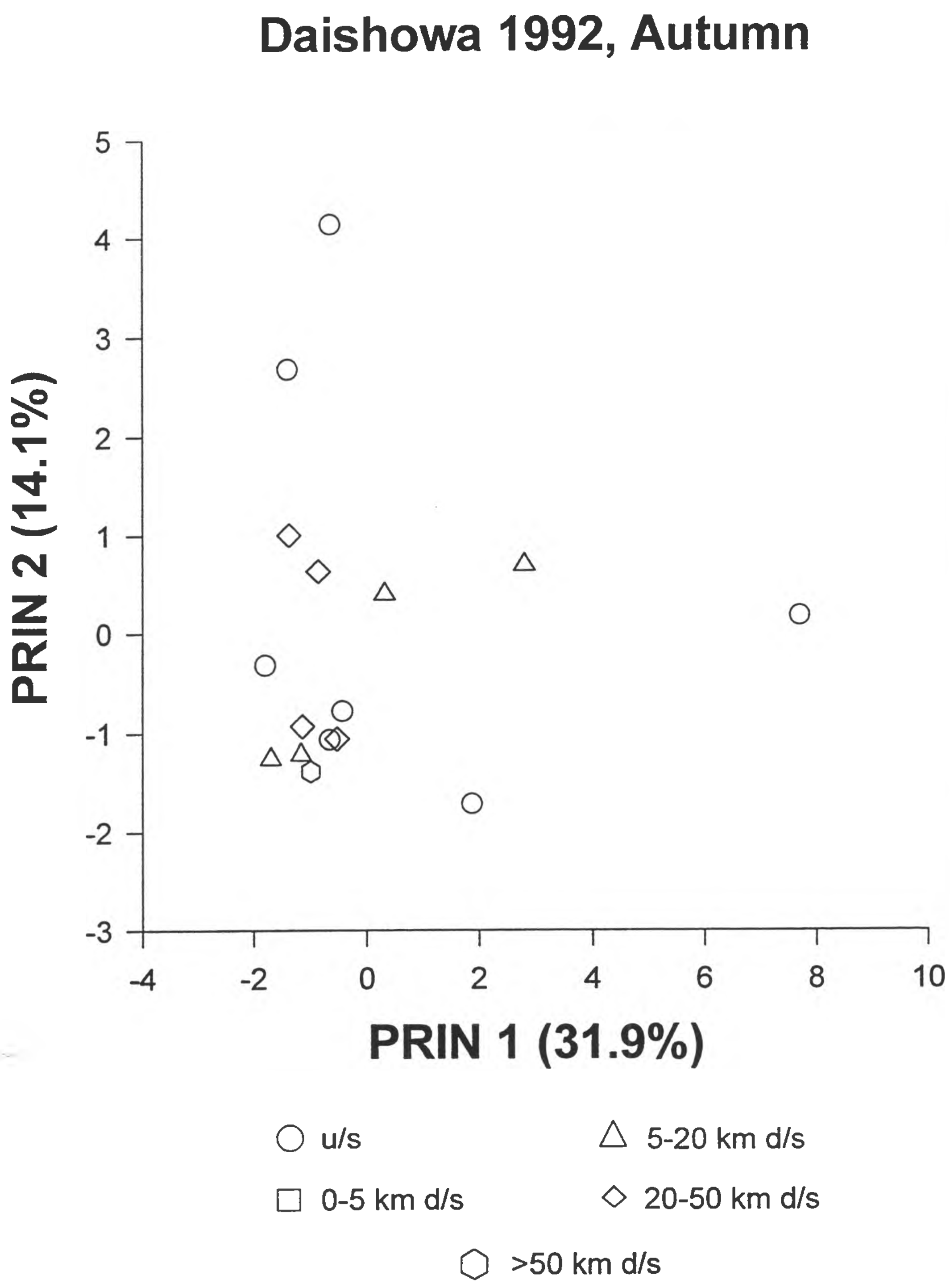




Daishowa 1991, Autumn




Daishowa 1992, Spring
PRIN 2 (16.9%)
PRIN 1 (26.8%)
6
5
4
3
2
1
0
-1
-2
-3
-4
-2
0
2
4
6
8
10
u/s
5-20 km d/s
0-5 km d/s
20-50 km d/s
>50 km d/s


Daishowa 1992, Autumn
PRIN 2 (14.1%)
PRIN 1 (31.9%)
5
4
3
2
1
0
-1
-2
-3
-4
-2
0
2
4
6
8
10
u/s
0-5 km d/s
5-20 km d/s
20-50 km d/s
>50 km d/s