ALBERTA OIL SANDS
ENVIRONMENTAL
RESEARCH PROGRAM

WATER QUALITY OF THE ATHABASCA OIL SANDS AREA:
A REGIONAL STUDY

AOSERP Report L-85

1985

Alberta
ENVIRONMENT
Research Management Division
14th Floor, Standard Life Centre
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ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM
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Water Quality of the Athabasca Oil Sands Area:
A Regional Study

AOSERP Report L-85

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The Hon. F. Bradley
Minister of the Environment
222 Legislative Building
Edmonton, Alberta

Sir:

Enclosed is the report "Water Quality of the Athabasca Oil Sands Area: A Regional Study."

This report was prepared for the Research Management Division, through the Alberta Oil Sands Environmental Research Program.

Respectfully,

Walter Solodzuk, P.Eng.
Deputy Minister, Alberta Environment

WATER QUALITY OF THE ATHABASCA OIL SANDS AREA:
A REGIONAL STUDY

by

LYNDA D. CORKUM

Water Quality Control Branch
Alberta Environment

for

RESEARCH MANAGEMENT DIVISION
Alberta Environment

1985

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ABSTRACT

The objective of this report is to summarize water quality constituents in the AOSERP study area and to examine relationships between these constituents and changes in land formation, hydrology, and development.

Summaries of routine parameters, nutrients, and metals are presented for sampling sites along the Athabasca River to detect longitudinal and seasonal changes in water quality and to determine the effects of point source effluents on the river. Changes in ion concentrations on the Athabasca River were attributed to inputs from the Clearwater River rather than industrial saline discharge via Poplar Creek. The downstream effect of the Fort McMurray sewage treatment plant was limited to the mainstem upstream of the confluence with the Muskeg River. Elevated concentrations of nickel and vanadium occurred during high flow periods, indicating that concentrations of these metals in surface waters were associated with weathering of natural bitumen rather than with industrial effluents. A principal component analysis (PCA) was used for the simultaneous examination of selected water quality parameters on the Athabasca River. Sites exhibiting similar water quality characteristics were delineated on schematic maps of the river.

Baseline data and relationships among parameters also are presented for east, west, and south drainages entering the Athabasca River between Fort McMurray and Embarras Airport, as well as the Athabasca Delta drainage. An overall analysis of the four regions was conducted using PCA to delineate those sites with similar water quality characteristics. Site groupings often reflected the geological type of the region.

ACKNOWLEDGEMENTS

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1. INTRODUCTION

1.1 ATHABASCA OIL SANDS AREA

The Alberta Oil Sands Environmental Research Program (AOSERP) study area encompasses about 28 400 km^2 in northeast Alberta (Figure 1). The area occurs between 56° and 59° north latitude and 111° and 113° west longitude, excluding Wood Buffalo National Park.

The AOSERP study area includes most of the mineable area of the Athabasca Wabiskaw-McMurray deposit of oil sands. Suncor Inc. and Syncrude Canada Ltd. are the two oil sands mining and processing plants in the study area. Fort McMurray, located in the southern part of the study area, is a major population centre. Anzac, Fort Chipewyan, and Fort MacKay are small settlements. Increased demands on surface waters associated with mining development include recreational, domestic, and commercial uses. Despite these demands there is a concern to minimize impacts of development on water quality within the Athabasca Basin.

This report summarizes regional water quality data and, when applicable, impacts of development on surface water quality.

1.1.1 Regional Surface Water Quality Monitoring Program

Several specific water quality studies related to industrial development were initiated in 1976 throughout the AOSERP area. In 1977, a three-year co-ordinated regional sampling program was conducted by the Water Quality Control Branch, Pollution Control Division, Alberta Environment. Sampling sites were selected in four major regions of the study area including:

1. Mainstem Athabasca River
2. Tributaries
3. Lakes
4. Athabasca Delta

All recorded data were stored in the National Water Quality Data Bank (NAQUADAT). Water quality monitoring activities have continued from 1981 to the present, focussing on the Athabasca mainstem and the Athabasca Delta.

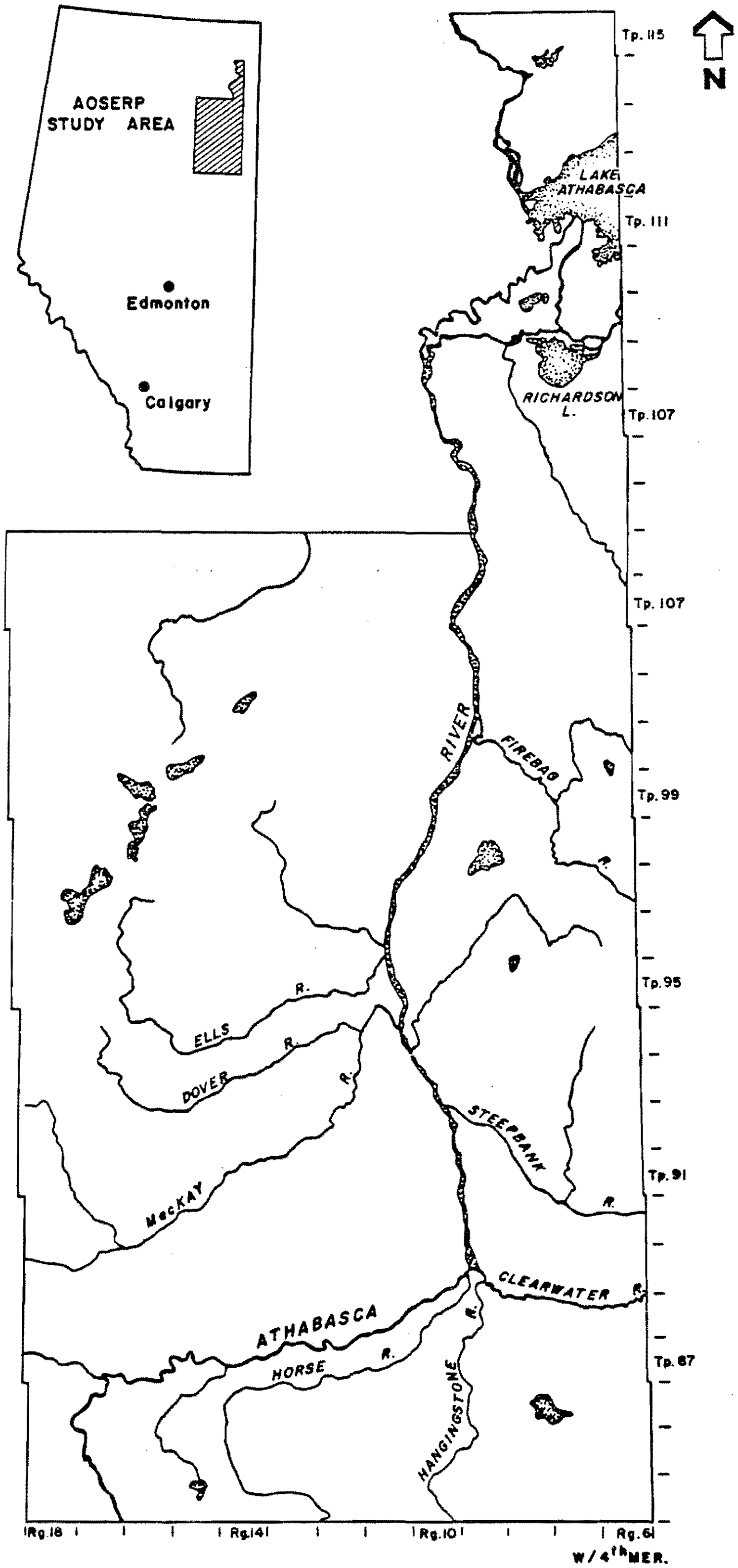


Figure 1. AOSERP study area.

1.1.2 Reports

Several water quality AOSERP reports have been published which dwell on specific water quality aspects within the study area (Akena 1979; Costerton and Gessy 1979; Nix et al. 1979). Seidner (1980) summarized regional water quality in the AOSERP study area based on 1976 and 1977 data sets. Description of sampling sites and analytical procedures used in the regional sampling program have been prepared by Akena (1980). Non-AOSERP surface water quality data for the region have been compiled by Akena and Christian (1981). Recently, a compilation of non-NAQUADAT and NAQUADAT water quality data (historical to 1982) has been prepared for the Athabasca River Basin (Alberta Environment, Planning Division 1983a, 1983b). In these reports, the AOSERP study area data are presented for Reach 7 of the Athabasca Basin. A detailed water quality summary for the mainstem Athabasca within the AOSERP study area is being prepared (Akena in prep.). The present report will emphasize regional characteristics of the study area.

1.1.3 Report Objectives

The objective of the co-ordinated regional water quality program was to establish baseline data for aquatic resources in the AOSERP study area, thus providing a standard against which any impact could be measured. Oil sands development, however, had already occurred: Suncor Ltd. (originally, Great Canadian Oil Sands Ltd.) began operations in 1967; Syncrude Canada Ltd. began operations in 1977. Because additional oil sands development was planned for several watersheds in the area, a broad regional data base was required. This regional report is a summary of water quality constituents characteristic of watersheds associated with the Athabasca River in the north, east, west, and south.

Specific objectives of the report include:

1. descriptions of regional baseline states;
2. identification of physical, chemical, and biological processes affecting surface water quality;

3. identification of significant correlations between water quality constituents and hydrology;
4. evaluation of the significance of natural levels of physical and chemical parameters to biological communities; and
5. when possible, an assessment of impacts of development on surface water quality.

1.2 DESCRIPTION OF THE ATHABASCA OIL SANDS AREA

1.2.1 Ecoregions

Ecoregions are land areas "characterized by a distinctive regional climate as expressed by vegetation" (Subcommittee on Biophysical Land Classification 1969). Strong and Leggat (1981) delineated ecoregions for Alberta using map units identified by vegetation, climate and, to a lesser extent, soils. The approach used was similar to that of the Canadian Committee on Ecological Land Classification (Hills 1976).

Turchenek and Lindsay (1982) used the ecoregions defined by Strong and Leggat (1981) as a framework for studying soils in the AOSERP area. Vegetation (a reflection of climate) is often used to describe ecoregions when climatological data are insufficient. Turchenek and Lindsay (1982) subdivided ecoregions into ecodistricts and physiographic units (adapted from Pettapiece 1981). Ecodistricts are land areas with distinct patterns of "relief, geology, geomorphology and associated regional vegetation" (Turchenek and Lindsay 1982). The Boreal Mixedwood and the Northern Boreal are the two ecoregions represented in the AOSERP study area.

Boreal Mixedwood, which constitutes the largest land area (43%) of Alberta, is characterized by deciduous forests underlain by gray luvisolic soils. Jack pine communities are found on sandy material; aspen poplar/white spruce occur on moderately drained soils. More than 70% of the annual precipitation in this region occurs in summer. July is the wettest month.

The Northern Boreal Ecoregion is characterized by deciduous (aspen) and coniferous (white spruce) forests underlain by gray luvisolic soils. The Northern Boreal region is distinguished from the Mixedwood by an increase in abundance of white spruce and a colder, drier climate.

1.2.2 Climate

Longley and Janz (1978) present summary climatological data for the AOSERP study area. A climatic summary for the Northern Boreal Forest and the Boreal Mixedwood Forest is presented in Table 1.

Climatologists rely on a continuous record of 30 years to develop sets of normal values for weather stations. Such long-term climatic information is available for Fort McMurray (1944 to present). Other data are available for Embarras Airport (February 1943 to September 1962) and Fort Chipewyan (October 1962 to present), plus several forestry lookout stations (summer data only). The climate of the AOSERP study area is continental, characterized by cold winters with relatively little snow, and cool, wet summers. Most precipitation occurs in summer as major rainfalls.

Mean daily temperatures for both Fort McMurray and Fort Chipewyan are 16.3°C in July and -21.5° and -26.2°C for the two locales in January. Fort McMurray and Fort Chipewyan receive 223 and 226 days of frost each year, respectively. At Fort McMurray, the average annual precipitation is 435 mean (305 mm rainfall and 140 cm snowfall). The amount of precipitation decreases northward from Fort McMurray to Fort Chipewyan.

1.2.3 Vegetation

Thompson et al. (1978) present a classification scheme for the AOSERP study area, based on major vegetation types described by Stringer (1976). Turchenek and Lindsay (1982) identified the vegetation and soil types associated with each drainage system and presented descriptions of ecological units.

Table 1. Summary of climatic data for Alberta ecoregions (adapted from Strong and Leggat 1981). Values expressed as (minimum to maximum) mean.

	Ecoregion	
May to September	Boreal Mixedwood	Boreal Northlands
Mean T (°C)	(10.5 to 14.0) 12.0	(10.0 to 12.0)11.0 $_3$
Growing degree days	(970 to 1310) 1190	(1010 to 1080)$_3$1050^3
Freeze free period (Days)	(50 to 120) 85	(65 to 105) 85
Number days (_0°C)	(10 to 30) 20	(25 to 30) 25
Total precipitation (mm)	(200 to 440) 300	(180 to 340) 250
% of annual precipitation	72	55
October to April		
Total precipitation (mm)	(120 to 250) 170	(140 to 170) 160^3
Annual		
Temperature (°C)	(-3.0 to 3.0) 0.5	(-4 to -3.5)-3.5$_3$
Total precipitation (mm)	(350 to 520) 440	(300 to 450) 340$_2$
No. of days precipitation (0.2 mm)	(60 to 135) 105	(115 to 130) 120^2
Hours of bright sunshine	(1840 to 2340) 2060	2040

^{1,2,3,4} Superscipts indicate the number of stations when less than 5.

Northern Alberta is located within the Boreal Forest region (Rowe 1972). The four subdivisions of the Boreal Forest which occur within the AOSERP study area are Boreal Mixedwood, Athabasca South, Northwest Transition Zone, and Upper Mackenzie.

The Boreal Mixedwood Forest region occupies most of the study area. Here, aspen poplar (*Populus tremuloides* Michx) and white spruce (*Picea glauca* Voss) are the main tree species. Aspen poplar, a species capable of rapid regeneration in disturbed regions, covers the largest areal extent of the study area (Thompson et al. 1978). White spruce is the climax species in well drained areas. Jack pine (*Pinus banksiana* Lamb.) occupies the eastern sand hills. Larch (*Larix laricina* Koch) and black spruce (*Picea mariana* BSP) grow in open muskeg.

The Athabasca South Forest region occurs in the northeast part of the study area (Richardson and Firebag uplands). Jack pine inhabits dry, sandy areas and black spruce, wetlands.

The Northwest Transitional Forest region is found north of Lake Athabasca within the Precambrian Shield. Black spruce is the dominant tree species.

The Upper Mackenzie Forest region occurs in the north of the study area. Alder (*Alnus tenuifolia* Nutt.), balsam poplar (*Populus balsamifera* L.), and white spruce are found in lowlands bordering rivers. Jack pine and aspen poplar with black spruce and larch occur in the uplands.

1.2.4 Physiography

The two major physiographic provinces within the AOSERP study area are the Interior Plains and the Precambrian Shield (Atlas of Alberta 1969). Pettapiece (1981) has subdivided the provinces into regions, sections, and districts. Detailed descriptions of these units are presented by Thompson et al. (1978) and Turchenek and Lindsay (1982).

The physical geography of a region is based on surficial deposits, geology, and vegetation. Chemical characteristics of surface water differ significantly between physiographic regions (Dillon and Kirchner 1975; Kirchner 1975) and geological type (Naumann 1929). Accordingly, water quality constituents of surface waters within the same physiographic region should be similar.

1.2.5 Geology

1.2.5.1 Bedrock geology. A bedrock geology map of the AOSERP area, presented in Figure 2, was derived by Turchenek and Lindsay (1982).

The geology of the AOSERP study area is characterized by material from the Pleistocene and Recent eras (Carrigy 1959; McPherson and Kathol 1977). Since surface mining for oil sands does not extend beneath the McMurray formation, most regional studies have focussed on rocks of the Cretaceous age or younger (Mellon and Wall 1956). Saline water may occur in the basal McMurray formation, presenting ecological and engineering concerns in oil sands development.

Cretaceous rocks (sandstone and shale) dominate most of the study area. Sandstones including the oil sands are exposed in the Athabasca River valley. Shales, with some sandstone, occupy the uplands. Devonian rocks (limestone, dolomite and gypsum) occur in the north and Precambrian granite, the extreme northeast.

1.2.5.2 Surficial geology. Thompson et al. (1978) developed surficial geological maps (1:50 000) for the AOSERP study area that provided detailed information on deposits and land forms. Surficial geological maps also have been prepared for specific mining areas (McPherson and Kathol 1977). Bayrock (1971, 1972a, 1972b) and Bayrock and Riemchen (1974) mapped (1:250 000) surficial geology on several National Topographic Sheets (74C, 74L, 74M, 74P, 84I). Turchenek and Lindsay (1982) prepared a soil parent materials map (1:500 000) and detailed soil maps (1:126 720) for the AOSERP area.

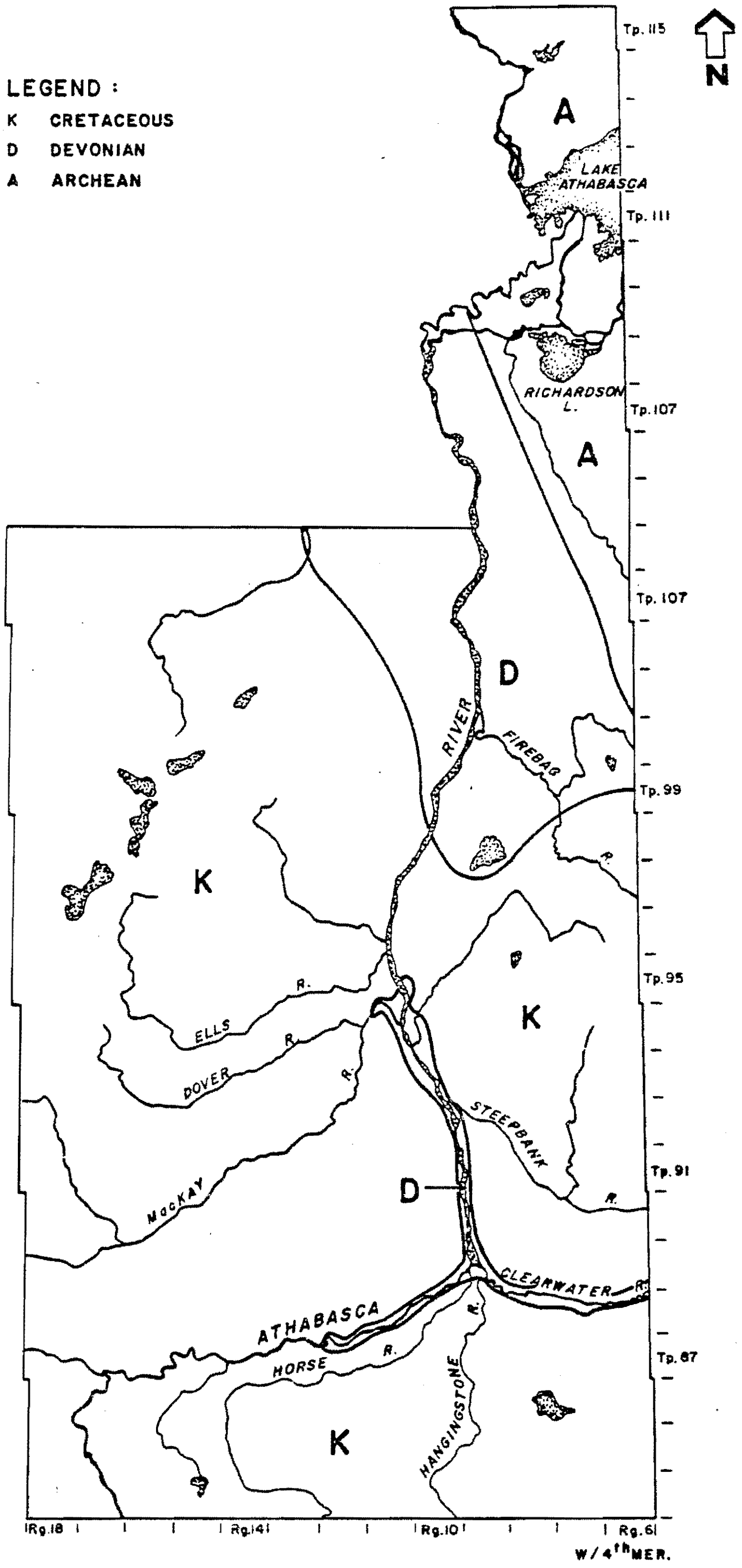


Figure 2. Bedrock geology of the AOSERP study area. (Adopted from Turchenek and Lindsay, 1982)

Surficial geology is determined by glacial and post glacial deposition and erosion. Soil classification is based on genetic types of material on which soil develops (Turchenek and Lindsay 1982). Three main types of surficial geology in the AOSERP study area include (Thompson et al. 1978):

1. Ground and hummocky morain (till) - Birch Mountains and Methy Portage Plain;
2. Silt and clay lake deposits - Birch Mountains; and
3. Silt and gravel deposits from fluvial, lacustrine, and aeolian sources - lower valley areas, eastern study area, and delta.

Surficial geology affects the rate of water percolation, groundwater storage, surface runoff, land erosion, and vegetation cover. All these factors affect water quality.

1.2.6 Drainage Systems

A map of watersheds associated with the AOSERP study area presented by Neill and Evans (1979) is reproduced in Figure 3. Neill and Evans (1979) consider the following drainages to be major components of the surface water drainage within the area:

1. The Athabasca River enters the study area from the southwest and extends to the Athabasca Delta.
2. The Clearwater River, which originates in Saskatchewan, enters the study area from the southeast and joins the Athabasca River at Fort McMurray.
3. Major tributary streams south of Fort McMurray include the Horse, Hangingstone, and Christina rivers. The Horse River enters the Athabasca River. The Hangingstone and Christina rivers are tributaries of the Clearwater.
4. Major tributaries flowing from the east to the Athabasca River north of Fort McMurray include the Steepbank, Muskeg, and Firebag rivers. For the purpose of this

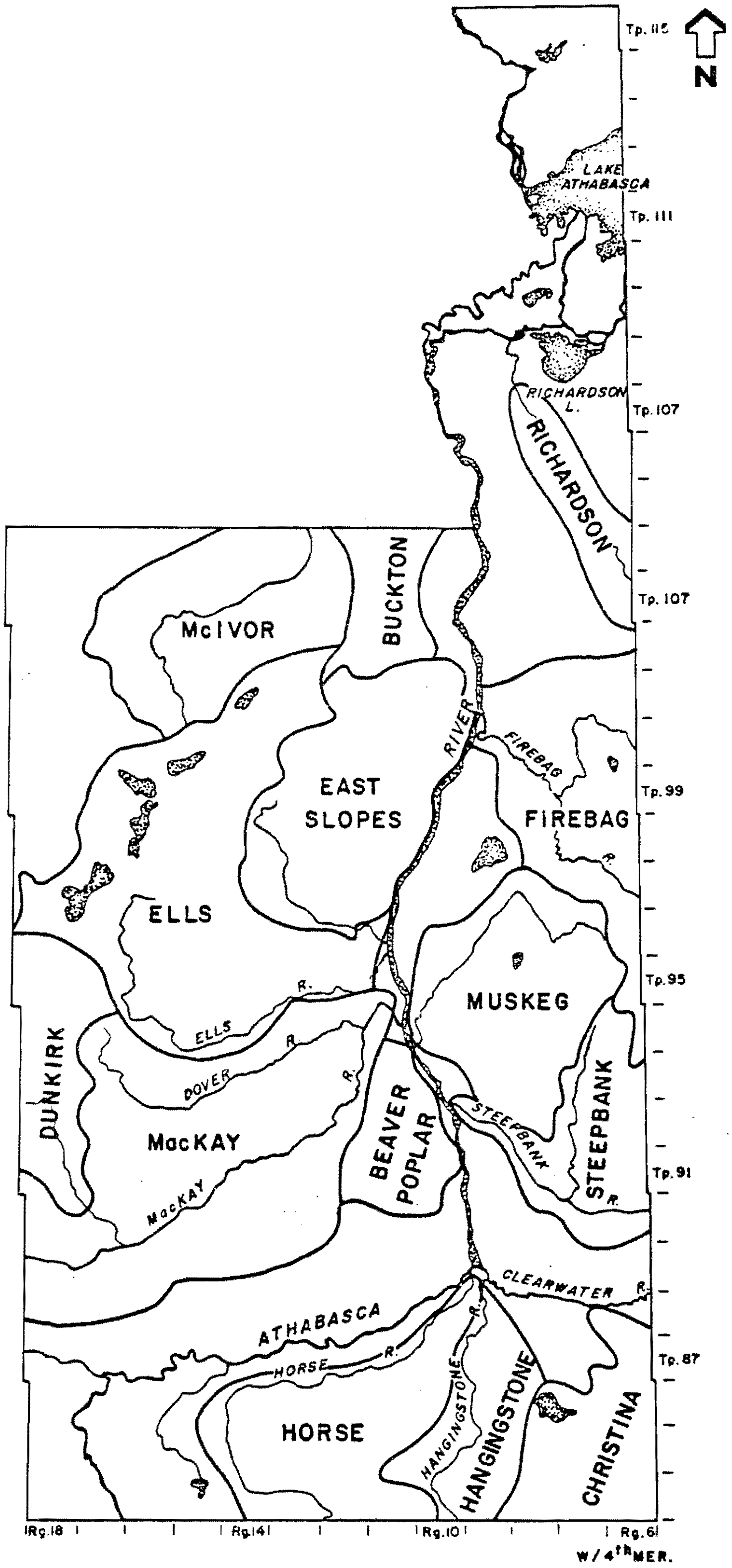


Figure 3. Surface water drainage of the AOSERP study area.
(Adapted from Neill and Evans , 1979)

report, the Richardson River will be included in the eastern region. The Richardson River originates in Saskatchewan and enters the Athabasca mainstem in the delta area.

5. Major tributaries flowing from the west to the Athabasca River north of Fort McMurray include the Beaver/Poplar, MacKay, and Ells. Several smaller tributaries drain the east slopes of the Birch Mountains.
6. Water bodies associated with the Athabasca Delta, including lake distributary channels, will be discussed in the section of this report concerning the northern region.

1.2.7 Surface Water Hydrology

Stream gauging data for tributaries in the AOSERP study area were complied by Loeppky and Spitzer (1977), Warner and Spitzer (1979), and Warner (1979). Neill and Evans (1979) provided an overview of surface water hydrology of the study area. Sekerak and Walder (1980) included some hydrological data in their biophysical inventory of major tributaries in the AOSERP area. Schwartz (1979) summarized the hydrology of the Muskeg River. Locations of stream gauging stations within the study area are indicated in Figure 4.

Gauging stations on the Athabasca River above Fort McMurray and the Clearwater above Fort McMurray have been in operation since 1957. The downstream gauge at Embarras was installed in 1971. Short-term records (since 1975) are available for most of the tributaries entering the mainstem.

1.2.7.1 Water balance: precipitation, runoff, and evapotranspiration. Water is supplied by precipitation and lost through runoff and evapotranspiration. Water also may remain as surface or subsurface storage, but over the long term this component is assumed to be negligible (Neill and Evans 1979). Thus, a water balance equation may be expressed as follows:

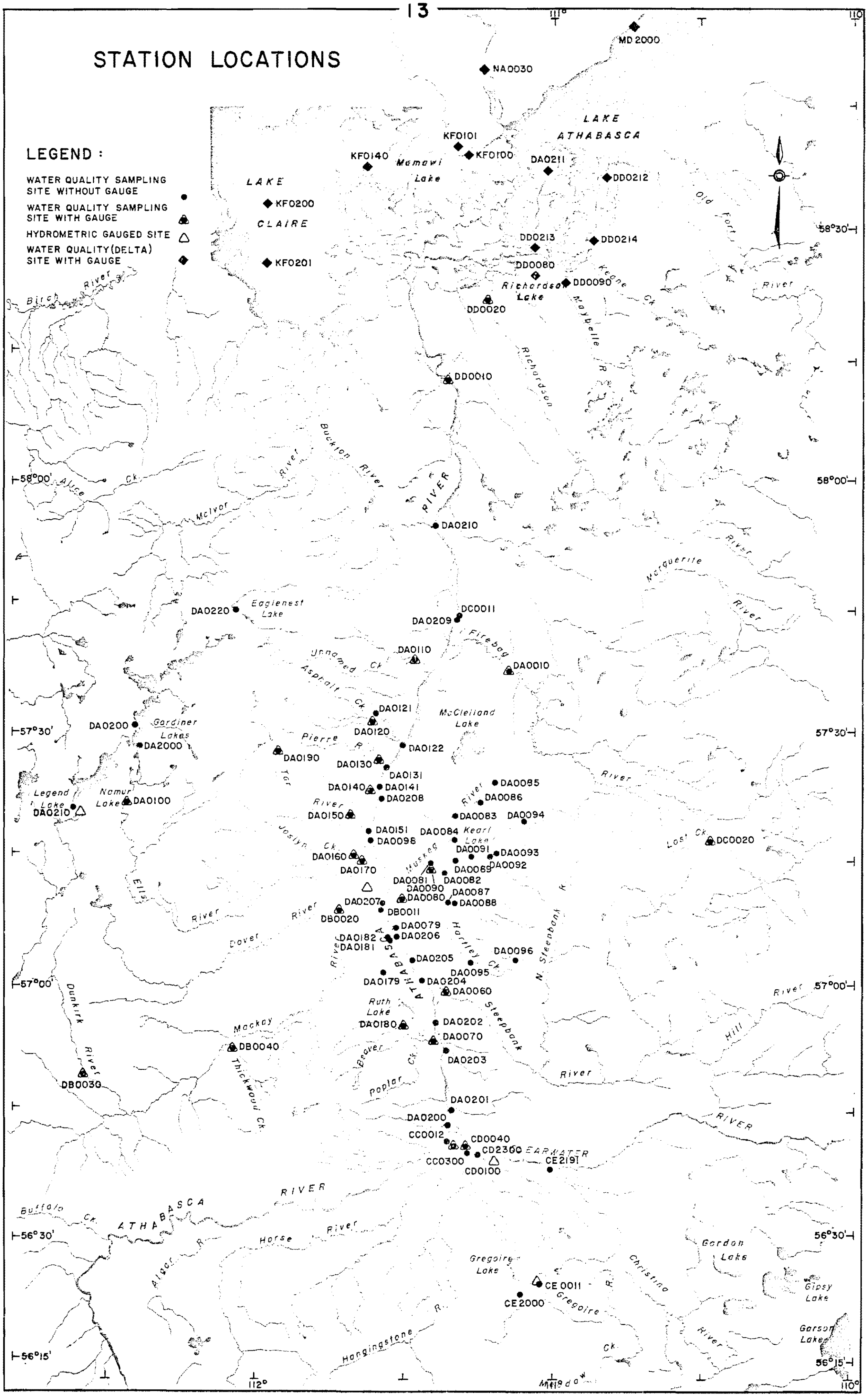


Figure 4. Water quality sampling and gauging station locations.

$$P = R + ET$$

where: P = total precipitation;
R = runoff; and
ET = evapotranspiration.

When values for all three components are known, there are often inconsistencies in the water balance because of inadequate estimates of precipitation and evaporation (Neill and Evans 1979; Hydrological Atlas of Canada 1978). Errors in runoff estimates (stream discharge data) are minor.

Neill and Evans (1979) presented the mean annual water balance for Fort McMurray and the Athabasca Delta based on data provided in the Hydrological Atlas of Canada (1978). In the AOSERP study area, evaporation accounted for 78 to 80% of precipitation; accordingly, runoff accounts for 20 to 25% of precipitation. This high evapotranspiration:runoff ratio results from high summer temperatures, long hours of sunshine, low humidity, abundant vegetation, open water, and muskeg (Neill and Evans 1979).

The annual water balance determined for the region using the limited local data set (1976-77) generally supported the findings presented in the Hydrological Atlas of Canada (1978). Runoff and derived evapotranspiration (precipitation-runoff) estimates from the limited data set were lower than the long-term means (Neill and Evans 1979).

1.2.7.2 Interaction of surface flows with groundwater. The Alberta Research Council conducted a regional hydrogeological evaluation of the Athabasca Oil Sands area (Hackbarth and Nastasa 1979). A total of 75 observation wells were installed at 15 locations within the study area during 1974-75 and 1975-76. Hackbarth and Nastasa (1979) estimate that groundwater contributions entering the Athabasca River between Fort McMurray and Embarras are negligible.

1.2.7.3. Streamflow balance. The Athabasca (17.2 km^3/a) and Clearwater (4.3 km^3/a) rivers provide the major discharge inputs into the AOSERP study area (Neill and Evans 1979). The contribution of flows from tributary streams are relatively minor (Figure 5). Flow from the southern tributaries (Horse and Hangingstone rivers) contribute about 0.4 km^3/a. Flow contribution from the west bank (0.8 km^3/a) is less than the east bank (1.2 km^3/a) tributaries. The mean annual inflow from the Athabasca River system to Lake Athabasca is 23.9 km^3/a.

Several northern rivers drain directly into Lake Athabasca, the largest of which is the Fond du Lac River (9.4 km^3/a). The average outflow from Lake Athabasca and the delta to the Slave River is about 45.3 km^3/a.

1.2.7.4 Response of streamflow to snowmelt and rainfall. Neill and Evans (1979) developed runoff snowmelt and rainfall coefficients for various basins within the AOSERP study area.

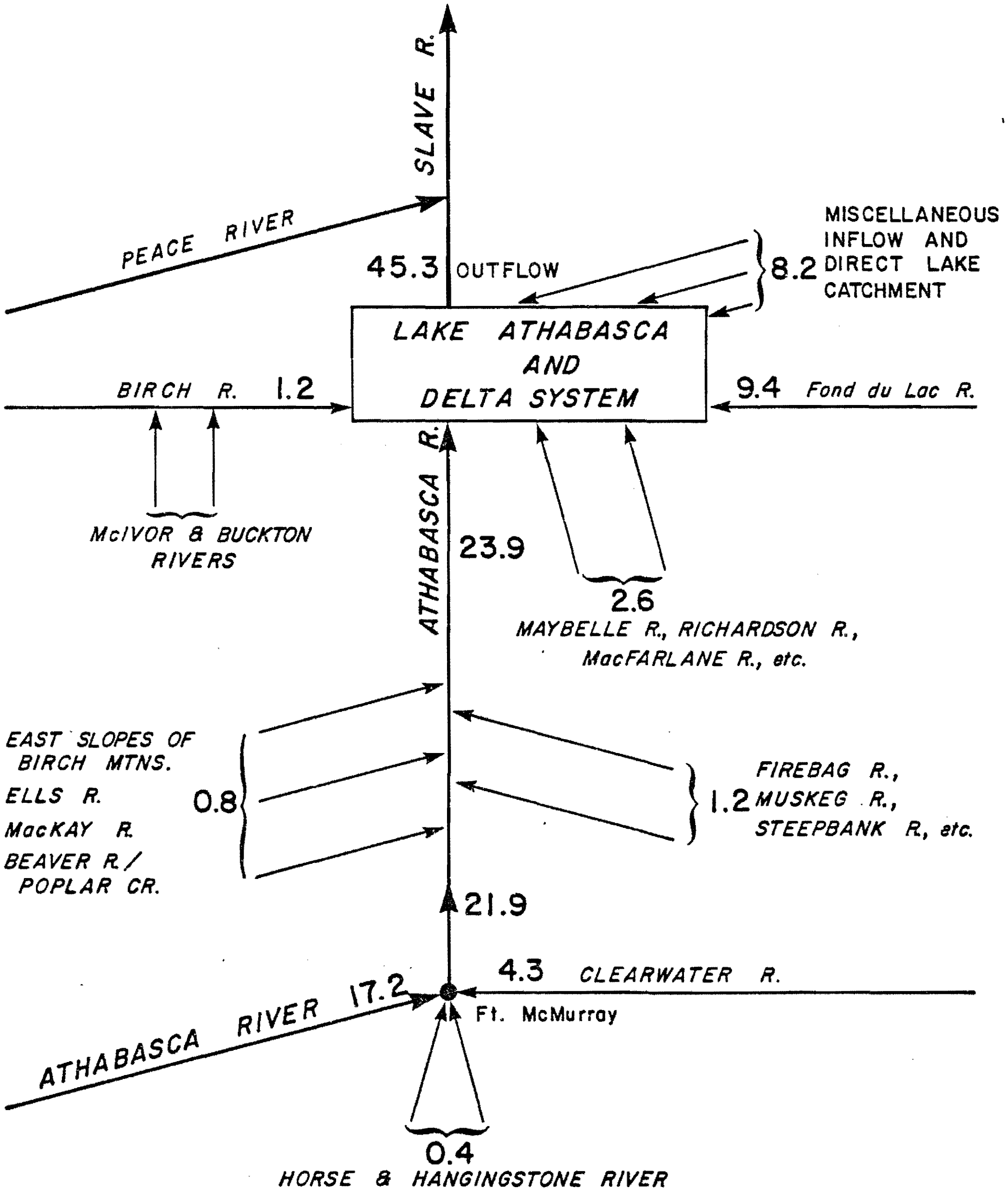
Hydrographs for streams in the area depict a snowmelt response beginning at the end of March and peaking in mid-April. Estimated snowmelt runoff coefficients (volume of runoff divided by volume of snowwater equivalent on the ground) ranged from 18% (Muskeg River) to 56% (Joslyn and MacKay rivers). These values are underestimates because some snowmelt is stored in the soil and subsequently used by vegetation or is lost to evaporation (Neill and Evans 1979).

Estimated rainfall runoff coefficients were calculated using the following formula (Neill and Evans 1979):

$$RR = SF - SR$$

where:
RR = rainfall runoff coefficient;
SF = stream flow (01 April to 31 December 1976); and
SR = snowmelt runoff.

Values for rainfall runoff coefficients were low (4 to 19%) for most basins except for those in the southern region (Horse River, 28%; Hangingstone, 32%). Rainfall runoff coefficients were lower than snowfall runoff coefficients for basins on the west bank of the Athabasca River.



Athabasca River inflow to lake system : 17.2 + 0.4 + 4.3 + 0.8 + 1.2 = 23.9
Lake outflow to Slave River : 23.9 + 1.2 + 2.6 + 9.4 + 8.2 = 45.3
Units of km^3 (= 10^9 m^3)

Figure 5. Mean annual streamflow balance .
(Adapted from Neill and Evans , 1979)

1.2.7.5 Erosion and sedimentation. Suspended materials follow a seasonally cyclical pattern, with high levels occurring during high flow periods. Suspended sediment data have been recorded at WSC gauging stations along the Athabasca River within the AOSERP study area at sites below Fort McMurray and at Embarras. Other sediment samples have been obtained at infrequent intervals throughout the study area.

Doyle (1977) described the suspended sediment regime of the Athabasca River using suspended sediment rating curves. During high flow conditions, the upstream section of the Athabasca River within the study area has a higher capacity to transport sediments; whereas during lower flows, the carrying capacity of the downstream section becomes more important.

The average annual sediment load upstream of Fort McMurray is 13.6×10^6 tonnes/a (Thurber et al. 1975), of which 5% is bedload. The average annual sediment load from the Clearwater River is 0.9×10^6 tonnes/a. Griffiths and Walton (1978) estimated that the average annual sediment load entering the Athabasca River between Fort McMurray and Embarras from tributary streams represents 5% of the load at the downstream site.

Most tributaries entering the Athabasca maintream have characteristically stable channels. Little erosion of the bank materials occurs within the basin because of dense vegetation cover and low runoff. Also, downstream reaches are entrenched in bedrock. Erosion, however, is prevalent in streams draining the east slopes of the Birch Mountains. Here, there is extensive slumping in the headwater reaches, resulting in eroded material being transported into alluvial fans at the confluence with the Athabasca mainstem (Griffiths and Walton 1978; Corkum et al. 1982).

1.2.7.6 Impacts of oil sands development on hydrology. Hackbarth and Nastasa (1979) outline hydrogeological difficulties associated with oil sands development, including groundwater depressurization, natural gas occurrence, saline water, and induced infiltration.

Oil sands development places increasing demands on water supply. Surface waters and groundwaters are used in processing and are later discharged into waterways. Groundwater associated with oil sands must be disposed of before the sands can be mined. This water is highly saline and frequently toxic to aquatic organisms (Tsui et al. 1980).

Depressurization (reduction of pore pressure) and dewatering (removal of pore water) are required to ensure pit slope stability and dry pit conditions. Chemical characteristics of mine depressurization water (high saline levels, range of heavy metals, and organic constituents) have been described by McMahon et al. (1977), Lake and Rogers (1979), and Giles et al. (1979). Natural gas has been produced from the basal McMurray aquifer and may present problems for depressurization (Hackbarth and Nastasa 1979). High saline levels will be most severe during low flow (winter) conditions and where groundwater constitutes base flows.

Infiltration may occur from the Athabasca River to oil sands mines which are located close to the mainstem (Hackbarth and Nastasa 1979). Infiltation may reduce saline concentrations of groundwater during mining operations, but may be detrimental once operations cease and water moves from the basal McMurray aquifer to the Athabasca River.

2. APPROACH

This report is a study of water quality parameters within and among four sub-basins of the AOSERP study area and the Athabasca mainstem. The sub-basins include south, west, and east drainages entering the Athabasca River between Fort McMurray and Embarras Airport, and the Athabasca Delta drainage.

The objective of this report is to establish relationships among water quality parameters which can be used to reflect changes in water quality owing to developmental impact or hydrological regime. Within each region or sub-basin such relationships will be established between water quality and surface water discharge. Other relationships will be established (depending on available data) among habitat characteristics of rivers, land formations (ecodistrict, geology) through which rivers flow, and benthic invertebrates (environmental indicators) inhabiting the rivers.

This report is organized by region, concluding with an overall summary analysis. The aim is to establish relationships among parameters in regions without perturbations and then to determine the effect of point source effluents on the Athabasca mainstem.

When analysing data by regions, there is a difficulty in that the study area may be so homogenous that no significant relationships exist. Also, the various data sets have not always been retrieved from the same location, with the same frequency, or within the same time frame.

2.1 METHODS

The following information will be presented for each region:

1. baseline data;
2. analysis; and
3. impact of development.

2.1.1 Baseline Data

2.1.1.1 Land formations. Maps of watersheds, ecoregions, ecodistrict, physiology, and bedrock geology that were prepared for the AOSERP study area by other workers are presented and enlarged for the regions. The delineation of watersheds were obtained from Neill and Evans (1979). Ecoregion and ecodistrict maps as well as physiographic regions were obtained from Turchenek and Lindsay (1982) based on work by Pettapiece (1981). The bedrock geology maps were derived by Turchenek and Lindsay (1982).

2.1.1.2 Discharge. Discharge data (m^3/s) have been obtained from the Water Survey of Canada (Environment Canada 1974) for the network of stations within the AOSERP study area (Figure 4). The gauging stations, period of record, and plots of discharge with time are presented for each region to correspond with the water quality sampling record.

2.1.1.3 Water quality. The water quality records used in this study were restricted to those monitoring programs conducted by Alberta Environment throughout the AOSERP region. Procedures for the collection, preservation, and transport of water samples are outlined in Akena (1980). Most samples were analysed by Chemex Labs (Alberta) Ltd. under contracts with AOSERP and Alberta Environment. The analytical methods are registered with the National Water Quality Data Bank (NAQUADAT) (Appendix 10.1). Bacteriological samples (fecal and total coliforms) were analysed by the Public Health Laboratory, Edmonton.

Field data sheets for each sampling event included on-site water quality measurements and details on location and depth at which samples were retrieved. This information as well as tabulated data may be obtained from the Water Quality Control Branch, Alberta Environment.

2.1.1.4 Benthic invertebrates. Aquatic invertebrates are frequently used as environmental indicators of water quality (McCart and Mayhood

1980). Site-specific studies frequently were instituted to determine the effects of effluents on the abundance and species composition of invertebrates by analysing samples above and below point sources as well as before and during development. Other invertebrate studies were conducted to provide baseline data in watersheds where government or industry anticipated development.

Most studies were conducted by private consulting firms or government agencies under contract to Alberta Environment and industrial proponents. With permission, data for analysis have been retrieved from AOSERP reports.

2.1.2 Data Presentation and Analysis

2.1.2.1 Within regions. The relationships examined within each region depended on which parameters were measured at the same location and time. For example, there were more water quality sampling locations than gauging stations in the study area and, for site-specific investigations, there were more biological sampling sites than water quality sites.

Tabular summaries were prepared representing number of samples, and median and maximum values for water quality parameters. Values representing the Alberta Surface Water Objectives (ASWO) and Canadian Drinking Water Guidelines (CDWG) also are provided.

A correlation analysis (Sokal and Rohlf 1969) was performed using median values for water quality parameters (routine, nutrients, and metals) for each site with more than 10 samples. Results of the correlation analysis of water quality parameters were used to select those parameters to be used in subsequent regression analysis (Draper and Smith 1966) relating water quality and discharge.

For those WSC sites with continuous discharge data, a data set was prepared using all available water quality data obtained at or near that locale and corresponding mean daily discharge values for the period of record during which water quality values were obtained.

Water quality parameters vary directly (e.g., suspended solids) or indirectly (e.g., specific conductance) with discharge. Since values for specific conductance and total dissolved solids were frequently determined by calculation of ions, it seemed inappropriate to present relationships for ions which are autocorrelated with conductivity.

When benthic invertebrate data were available, an analysis of variance (Sokal and Rohlf 1969) was used to test if significant differences occurred in mean abundance of invertebrates among sampling sites. If differences occurred in mean abundance, the a posteriori test, Student Newman's Kuels procedure (Sokal and Rohlf 1969), was used to determine which sites were similar to one another. Multiple regression analysis was used to determine which few (if any) of the physical and land formation parameters would be useful in predicting the abundance or percentage of clean water organisms. Codes were assigned to the various land formation parameters.

A monitoring program of water quality and biological parameters was conducted on the Athabasca mainstem in 1981 and 1983. Results from these studies are being prepared as separate reports for Alberta Environment.

Differences in study objectives, habitat type, and sampling bias resulted in the use of a variety of invertebrate sampling techniques in the AOSERP region. Sampling differences which hinder data comparisons could be alleviated if guidelines were established for monitoring studies in erosional and depositional habitats.

2.1.2.2 Among regions. Cluster analysis (Wishart 1975) was used to determine grouping of similar sites for three sets of water quality parameters (routine, nutrients, and metals) at sites throughout the AOSERP study area. Dendrograms were used to display groupings among sites.

A principal component analysis (PCA) was used to reduce the number of water quality parameters for use in subsequent analysis. The details of PCA are outlined by several authors including Davis (1973), Orloci (1975), and Morrison (1967). Green (1979) discusses the application of the analyses to environmental problems.

A PCA summarizes the information from a correlation or covariance (abundance data) matrix in terms of new components. The first principal component accounts for the greatest proportion of total variation among sites, with successive components contributing progressively smaller portions of the total variation. The first two or three principal components generally account for most of the variability in the original data. The principal component scores for each river site can be used in subsequent analysis (in place of the original data) with little loss of information.

2.1.2.3 Statistical analysis. In this study, data were entered into files on the Michigan Terminal System (MTS) at the University of Alberta. Cluster analysis was performed using Ward's method of the Clustan C-1 computer package (Wishart 1975). Analyses of variance and covariance were performed using the APL (A Programing Language) library of statistical packages. Correlation and multiple regression analyses were performed using the BMDP (Biomedical Computer Programs-P Series) package of computer programs (Dixon and Brown 1979).

2.1.3 Impact of Development

Increased demands on surface waters associated with oil sands development include recreational, domestic, and commercial demands on water quality. This study will consider diffuse and point source effluents into the Athabasca mainstem. Diffuse inputs occur as a result of runoff from various land use activities or weathering of surficial material. The effluent from the Fort McMurray sewage treatment plant, saline discharge by Syncrude Canada Ltd. via Poplar Creek, and waste discharge (industrial and lagoons) from the Suncor oil sands facility, all of which enter the Athabasca River from the west bank, are the major cultural point source effluents within the AOSERP study area. The effects of the Clearwater River (the major tributary of the Athabasca River) on the mainstem also will be examined.

3. ATHABASCA MAINSTEM

The Athabasca River originates in the Columbia Glacier of Jasper National Park and flows unregulated 1450 km to Lake Athabasca via the delta distributaries.

This section of the report will focus on the lower Athabasca River from the Fort McMurray area (upstream of the confluence with the Horse River) to the Embarras Airport, a distance of about 190 km.

3.1 BASIN FEATURES

3.1.1 Land Formation

The Athabasca River flows easterly to Fort McMurray where the bedrock geology changes from Cretaceous rocks (shale and sandstone) to Devonian limestone and the river is directed northward. With the exception of a 35 km stretch of Cretaceous rocks between the Ells and Eymundson rivers, the Athabasca River flows over Devonian rocks to the delta. The Clearwater River, a major tributary of the Athabasca River, enters the mainstem at Fort McMurray.

The Athabasca River flows through the Methy Portage and Great Slave (Muskeg-Embarras-Athabasca Delta ecodistricts) plains of the Boreal Mixedwood Forest. The transition between the southern Methy Portage and northern Great Slave plains occurs between the confluences of the Steepbank and Muskeg rivers with the mainstem.

3.1.2 Watershed

The Athabasca River below Fort McMurray (WSC gauging station 07DA001) drains 1.33×10^5 km^2. At Embarras (WSC station 07DD001), the river drains 1.52×10^5 km^2. The river distance between the two locations is 180 km. The southern lowlands and northern plains of the river valley are moderately forested.

3.1.3 Physical Description

The river reach upstream of Fort McMurray is gorge-like with many meanders confined within steep banks and rapids (Grand, Brule, Bortes, Cascade, and Mountain) (Bond and Berry 1980). The Mountain Rapids are located 2 km upstream of Fort McMurray. The river bed is composed of coarse gravel, cobble, and boulders.

There are high clay bluffs with exposed bitumen at Fort McMurray where the river turns northward. The river gradient is gradual between Fort McMurray and Fort MacKay (0.144 m/km) and further reduced between Fort MacKay and the Embarras Airport (0.117 m/km) (Kellerhals et al. 1972).

The Athabasca River below Fort McMurray has a mean channel width of 448 m and mean depth of 1.37 m. The channel is straight with occasional islands and mid-channel bars. The riverbed is sand with some local gravel over limestone. Bank materials consist of silt and clay.

At the Embarras Airport, the river channel has a mean width of 384 m and mean depth of 2.65 m. The channel has irregular meanders with occasional islands, point bars, and mid-channel bars. The riverbed consists of deep sand; the bank is of sand, silt, and clay.

3.2 BASELINE DATA

3.2.1 Discharge

The two Water Survey of Canada gauging stations located on the Athabasca River within the study area are below Fort McMurray (07DA001) and the Embarras Airport (07DD001). Stage records only are available at Fort McMurray and at Shott Island upstream of the Firebag River.

Mean monthly discharge is presented for the McMurray (1976 to 1983) and Embarras (1977 to 1983) gauging stations in Figure 6. This period of record corresponds to the water quality sampling regime.

During the eight years of record, the mean annual discharge for the Athabasca River below Fort McMurray ranged from 481 m^3/s (1981) to 773 m^3/s (1978). With one exception (August 1976), maximum mean monthly flows occurred in June and July and ranged from 1010 to 1990 m^3/s. Minimum mean monthly "winter" flows ranged from 107 m^3/s (1982) to 208 m^3/s (1980).

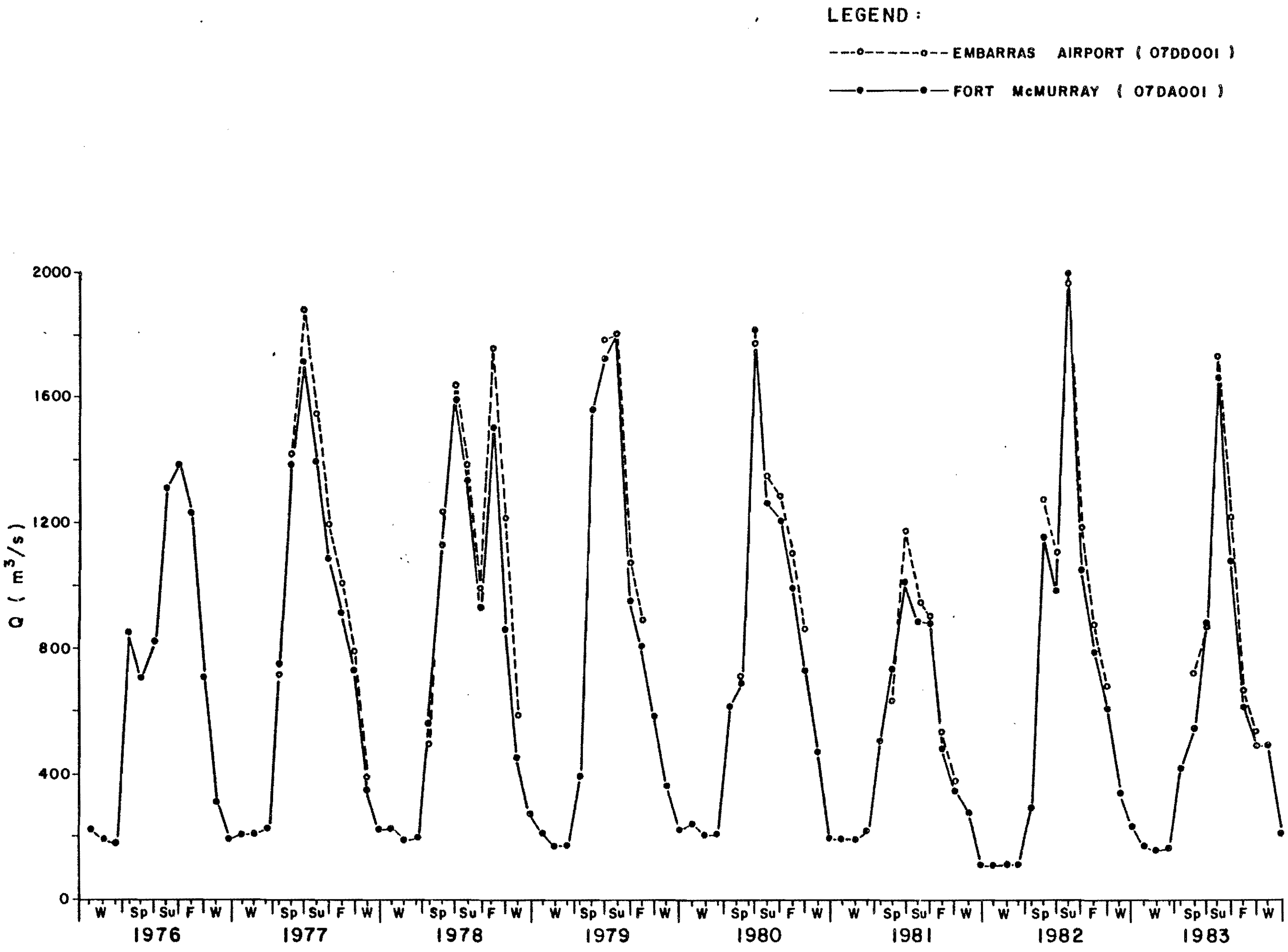


Figure 6. Mean monthly discharge at Fort McMurray and Embarras Airport on the Athabasca River .

Mean annual long-term discharge for the Athabasca River at Embarras Airport is estimated to be 766 m^3/s (Kellerhals et al. 1972). Actual values are unavailable because of interrupted flow measurements between November and May. Maximum mean monthly flow typically occurred in June and July, with flows ranging from 1170 to 1960 m^3/s. In 1978, maximum flow occurred in September when mean monthly discharge was 1755 m^3/s.

The Hydrology Branch, Technical Services Division of Alberta Environment (Alberta Environment 1984) conducted a low flow analysis of the Athabasca River Basin based on 21 years of data using a water year from July 1 to June 30. The 1:10 year, 7-year draught for the Athabasca River below Fort McMurray (WSC Station 07DA001) is 119 cms. The 7-day low flows (119 cms) were recorded in 1961-62, 1967-68, 1970-71 and 1981-82. The 1981-82 low flow event of 95.1 cms for December 16 to 22 represented the lowest sequence for the Athabasca River below Fort McMurray. This draught represented a 1 in 100 year low flow event.

3.2.2 Water Quality

Seven water quality locations were regularly monitored along the Athabasca River from 1976 to 1983. Generally, samples were taken from the centre of the river at the site upstream of Fort McMurray (CC0012) and at Embarras (DD0010), the furthest downstream site. At the other five stations (DA0203, DA0205, DA0206, DA0207, and DA0208), samples were taken from the left and right banks of the river. A total of 12 sites was examined.

A brief description of the historical water quality sampling stations is presented in Table 2. A seasonal summary of water quality constituents for the 12 sites is presented in Appendix 10.2. Seasons were designated on the basis of discharge regimes: winter (Nov. 1 to April 15), spring (April 16 to June 30), summer (July 1 to August 31) and Fall (Sept. 1 to Oct. 31).

Since such a large data set is available for the Athabasca mainstem, the discussion of routine, nutrient, and metal parameters will be as follows:

Table 2. Description, period of record, and number of samples obtained for water quality sampling stations along the Athabasca River.

Code (00AT07-)	Latitude N Longitude W (D M S)			Description	Period of Record	Number of Samples
CC0012	56	43	06	Above Fort McMurray	1976-83	74
	111	24	11	100 m above Horse River		
DA0200	56	44	33	Off McDonald Island	1976	15
	111	23	25			
DA0201	56	46	48	Km 10.5	1976	7
	111	24	18			
DA0202	56	58	01	Above Suncor plant	1976	8
	111	27	14			
DA0203	56	56	21	Above Poplar Creek	1976-77	69
	111	26	34	km 30.6	1981-83	
DA0204	57	01	15	At old AOSERP dock	1976-77	11
	111	29	49	km 42.3		
DA0205	57	04	33	Below Suncor	1976-77	51
	111	31	59	km 47.9	1982-83	
DA0206	57	07	49	Above Muskeg River	1976-77	107
	111	36	18	km 55.5	1980-83	
DA0207	57	11	16	At Fort MacKay	1976-83	111
	111	37	26			
DA0208	57	21	56	Above Tar River	1976-77	49
	111	39	43	km 84.3	1980-83	

continued . . .

Table 2. Concluded.

Code	Latitude N Longitude W (D	M	S)	Description	Period of Record	Number of Samples
DA0209	57 111	44 21	23 58	Above Firebag River	1976-77, 1980	12
DA0210	57 111	55 26	31 41	Below Firebag River	1976-78	8
DD0010	58 111	12 23	18 24	At Embarras Airport, WSC gauge	1977-83	47

1. Those not found above the detection limit;
2. Those found not to vary longitudinally or seasonally (i.e., in space or time);
3. Those exhibiting seasonal but not longitudinal changes;
4. Those exhibiting longitudinal but not seasonal changes; and
5. Those that change longitudinally and seasonally.

3.2.2.1 Routine parameters. Routine parameters include the major inorganic ions, parameters related to suspended particulates, organic constituents such as total organic carbon, phenolic substances, and oil and grease. The major ions reflect the influence of seasonal discharge changes on the river. The ions and suspended substances occur in water as a result of natural erosion of bedrock and surficial materials. Ions are considered to be conservative parameters (i.e., they may be used as tracers in the river system because they are not affected by chemical or biological processes). Chloride, however, may vary in surface waters because of the use of chlorine in domestic or industrial processes.

The surface waters of the Athabasca River are characterized as well buffered (elevated pH and alkalinity levels) and hard to very hard, with median hardness concentrations ranging from 84 to 177 mg/L (Appendix 10.2, Tables 27 to 38).

The maximum and minimum values (expressed as me/L) of major ions are displayed in Figure 7. Specific conductance or conductivity, which is a measure of the total ion composition, expresses the degree to which water conducts an electrical current. Changes in conductivity are a function of mineral concentration in the river water. Thus, increases in conductivity in the downstream direction reflect increases in the mineral content and sediment load.

The dissolved salts, sodium chloride and calcium bicarbonate, vary indirectly with discharge (i.e., seasonally) and among sites. Accordingly, conductivity, filterable residue (dissolved solids), hardness (a measure of calcium and magnesium), and alkalinity (a measure of carbonate, bicarbonate, and hydroxides) change in the same manner.

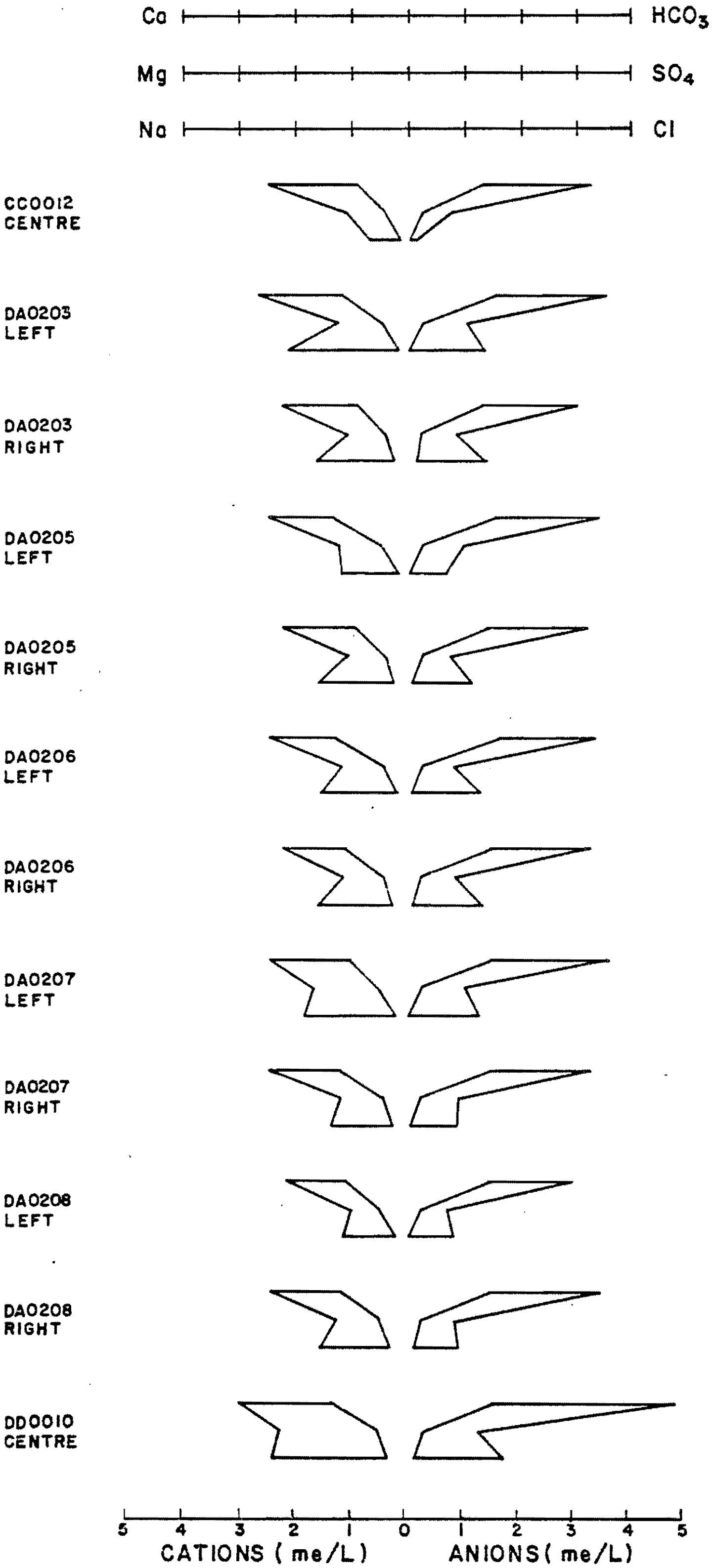


Figure 7. Maximum and minimum values (me/L) of major ions at sites along the Athabasca River.

Although calcium bicarbonate is the dominant dissolved salt, sodium chloride is prevalent at several sites. Sources of sodium chloride include the inputs from the Clearwater watershed, saline groundwater discharge from Syncrude Canada Ltd.'s mining operation via Poplar Creek (upstream of site DA0205), and saline seepage into the mainstem (e.g., Embarras site DD0010). Elevated chloride levels present at site DA0203 (right bank) reflect the chlorine used in treatment of domestic sewage.

Since ion constituents vary inversely with flow, the highest concentrations are present during low winter flows. Magnesium and sulphate ions did vary inversely with discharge but did not vary among sites. Potassium did ot vary with discharge or among sites.

Total organic (TOC) consists of dissolved and particulate organic fractions. Most of the TOC in water samples is composed of humic substances resulting from the degradation of plant and animal matter. Decomposition of carbon reduces oxygen concentrations in surface waters. No surface water guidelines have been established for TOC.

Although median and maximum values of TOC were generally lower in winter than in the other seasons, no real differences in TOC could be discerned at different sampling times within the open water season. Differences in TOC, however, occurred among sites. Maximum winter TOC values were encountered in the Fort MacKay area (site 8, 35 mg/L; site 9, 63 mg/L). These differences among sites were not pronounced in other seasons.

Phenolic compounds at very high concentrations may be toxic to fish. At lower levels, phenols may cause fish tainting and taste problems. The Alberta Surface Water Objective (ASWO) for phenols is 0.005 mg/L and the Canadian Drinking Water Guideline (CDWG) is 0.002 mg/L.

With few exceptions, median values of phenolics were below the surface water objectives. Median values of phenolic compounds exceeded the ASWO at the Ells River (DA0208, left bank) in winter (0.012 mg/L) and at the Embarras Airport (DD0012) in spring (0.008 mg/L).

Maximum values of phenols exceeded the objectives on several occasions. In winter, non-compliance occurred at all sites except CC0012 (upstream of Fort McMurray). Maximum values were reduced to 0.006 mg/L at the Embarras Airport. In spring the maximum value of phenols was recorded at the upstream control site CC0012 (0.041 mg/L). Somewhat elevated levels also were noted in spring at site DA0207 near Fort MacKay (left bank, 0.016 mg/L; right bank, 0.012) and at the Embarras Airport (0.011 mg/L). In summer, maximum phenolic values exceeding the objectives were noted at site DA0203 below the sewage treatment plant on the left bank (0.009 mg/L) and at the barge tie-up on the right bank (0.015 mg/L). Levels were exceeded below Suncor (DA0205 left bank; 0.009 mg/L) and at other locations downstream, but not at the Embarras site. During the fall, non-compliant values occurred at several locations along the mainstem, including the site upstream of Fort McMurray.

No guidelines have been established for oil and grease. Because these products occur on the surface film, the concentrations do not vary with flow. No distinctive pattern was noted among sites.

3.2.2.2 Nutrients. Phosphorus and nitrogen are essential nutrients which may limit plant growth.

Data representing two forms of phosphorus (total and orthophosphate) are presented in Appendix 10.2 (Tables 39 to 44). Because total phosphorus includes both dissolved and particulate forms, concentrations vary directly with flow. The particulate or apatite phosphorus leached from rocks is generally not biologically available in rivers. Orthophosphate phosphorus (PO_4-P) which is present in fertilizers, storm runoff, and sewage treatment wastes, is biologically available.

The ASWO for total phosphorus is 50 ug/L. Median values of total phosphorus were below this level in water and fall (low flow periods), but exceeded the objectives during spring and summer. Orthophosphates did not vary appreciably with season. In the spring, maximum values were higher at both banks of sites DA0203, DA0205, DA0206, and DA0207 than at other locations (Appendix 10.2, Tables 39 to 44).

Results representing three forms of nitrogen (nitrate/nitrite, ammonia, and total kjeldahl nitrogen) are presented in Appendix 10.2 (Tables 39 to 44). Inorganic forms of nitrogen include ammonia, nitrite, and nitrate. Total kjeldahl nitrogen (TKN) measures both ammonia and organic forms. Total nitrogen is calculated by the addition of TKN and nitrate/nitrite nitrogen. The ASWO for total nitrogen is 1.0 mg/L (1000 ug/L).

Nitrite nitrogen is readily converted to nitrate nitrogen in the presence of oxygen. Of the inorganic forms, ammonia is the major form discharged from sewage treatment plants and industrial effluents. Sources of organic nitrogen include watershed runoff and sewage effluents.

Nitrate/nitrites vary seasonally, with the highest levels occurring in winter particularly below the Fort McMurray sewage treatment plant (max. 560 ug/L) and in the Fort MacKay area (max. 500 ug/L).

Although ammonia levels are reduced in the fall (median values, 6 to 43 ug/L; maximum values, 9 to 130 ug/L), there are no substantial differences in concentrations during other seasons (Appendix 10.2, Tables 39 to 44). Differences in ammonia levels do occur among sites. In winter, elevated levels occur below Fort McMurray (max. level 440 ug/L). In spring, concentrations are lower at the Ells River (DA0208) and Embarras Airport (DD0010) sites than at other locales. A similar pattern occurs in summer along with reduced ammonia concentrations downstream of Suncor (DA0205). There was insufficient information on TKN to determine if differences occurred among seasons or sites.

Bacteriological indicators (total and fecal coliforms) reflect biological activity. Bacteria are ubiquitous and may always be observed at low levels. Sources of bacterial activity include sewage and industrial effluents as well as agricultural runoff contaminated with animal wastes. Coliform bacteria is an indicator of the possible presence of disease-producing organisms. Fecal coliforms are less likely to grow outside the intestinal tract of warm-blooded animals. Objectives for outdoor recreation that excludes direct contact with water are 90% of the samples with a total coliform density less than 5 000 per 100 mL and fecal coliform density less than 1 000 per 100 mL. More stringent objectives are set for direct contact with a limited number of samples allowed to exceed 1 000 per 100 mL total coliforms and 200 per 100 mL for fecal coliforms.

Data for total coliforms and fecal coliforms are presented in Appendix 10.2 (Tables 45 and 46). Lower levels of fecal coliforms were recorded in the fall than in other seasons. Relatively higher levels of fecal coliforms occur near settlements (Fort McMurray and Fort MacKay) in winter, spring, and summer. Maximum recorded levels of total coliforms were elevated at all sites during the winter (540 t.c./100 mL), summer (540 to 2400 t.c./100 mL) and fall (690 t.c./100 mL). In spring elevated values (2400 t.c./100 mL) were noted at several sites including the site upstream of Fort McMurray.

3.2.2.3 Metals. Of the suite of metals which are typically analysed, nine exhibited values above the detection limit (aluminum, arsenic, boron, copper, iron, manganese, nickel, vanadium, and zinc) Appendix 10.2 (Tables 47 to 58).

Aluminum concentrations varied directly with discharge, with elevated levels being present in spring and summer. Differences in concentrations occurred among sites, with the highest values being recorded at sites CC0012, DA0206, and DA0207. Aluminum is not considered to be a public hazard and guidelines have not been established for the metal.

Median values of arsenic concentrations did not differ among sites or seasons. Maximum values were higher (exceeding the surface water objective of 10 mg/L) at sites CC0012, DA0206, and DA0207 in the spring than elsewhere.

Boron did not change seasonally and, although concentrations were elevated at sites DA0206 and DA0207, all values were below the surface water objectives of 500 ug/L.

Copper varied directly with discharge, with maximum concentrations exceeding the surface water objectives of 20 ug/L in spring and summer. Median values of copper were below the objective in all cases.

Iron levels increased with increasing flows. With the exception of a few median values in winter, both maximum and median values of iron exceeded the surface water objectives of 300 ug/L. The guidelines, however, were established for aesthetic rather than health reasons as iron discolors clothing and stains plumbing fixtures.

Manganese levels varied directly with discharge, exhibiting median and maximum values which exceeded the surface water objective (50 ug/L) in the spring and summer. Maximum values were non-compliant in fall and winter. Guidelines for manganese were established because of unfavourable taste and staining properties at high concentrations.

Nickel values were higher during spring and summer than in fall or winter. Although there was no consistent longitudinal trend in nickel concentrations, maximum values were consistently high at site CC0012, upstream of Fort McMurray. Nickel occurs in substantial amounts in oil sands and its presence in surface waters may be attributed to the weathering and leaching of oil sands. In spring and summer, bitumen frequently can be observed oozing out of the valley walls along the mainstem, particularly in the high cliffs upstream of Fort McMurray.

Maximum levels of vanadium recorded at each site were higher in spring and summer than in fall or winter. Median values were consistently low (1 to 2 ug/L) in all seasons. Although vanadium occurs in oil sands, concentrations in surface waters below the Suncor plant were within the range of values recorded at other sites.

Median levels of zinc exhibited higher values during spring and summer than in other seasons. Although median values were below the surface water objective of 50 ug/L, maximum values at some sites exceeded the objective in all four seasons.

In summary, the metals (with the exception of arsenic and boron) varied directly with discharge, indicating that concentrations are associated with weathering and transport of bedrock and surficial material rather than with point source inputs. No consistent longitudinal trend was noted in metal concentrations. High values, however, typically occurred upstream of Fort McMurray (DD0012) as well as upstream of the Muskeg (DA0206) and MacKay (DA0207) rivers.

3.3 DELINEATION OF IMPACTS

The numbers and locations of all samples collected from the Athabasca River are presented in Table 3. Principal component analysis (PCA), however, was used for the simultaneous examination of water quality parameters at those 12 specified sites having sufficient data (Table 4). The analysis was performed on median and maximum values of selected water quality parameters for the winter, spring, summer, and fall data sets (1976 to 1983). Median values were selected to represent typical conditions; maximum values were selected to represent the worst situation.

The following parameters were selected for use in the PCA because of their association with diffuse and point source effluents:

1. Specific conductivity;
2. Bicarbonate ion;
3. Chloride ion;
4. Total organic carbon (TOC);
5. Phenolic compounds;
6. Oils and grease;
7. Orthophosphate phosphorus (PO_4-P);
8. Ammonia;
9. Fecal coliforms;
10. Nickel; and
11. Vanadium.

Table 3. Number and location of samples collected at sites along the Athabasca River.

Code (00AT07-)	Location[a]				Total
	Left	Centre	Right	Not Specified	
CC0012	3	34	15	22	74
DA0203	30	1	31	7	69
DA0205	23	0	21	7	51
DA0206	46	13	41	7	107
DA0207	50	8	35	18	111
DA0208	20	0	21	8	49
DD0010	4	20	6	17	47

[a] Looking downstream.

Table 4. Sample sites used in data analysis.

Site	Code (00AT07-)	Location[a]
1	CC0012	Centre
2	DA0203	Left
3	DA0203	Right
4	DA0205	Left
5	DA0205	Right
6	DA0206	Left
7	DA0206	Right
8	DA0207	Left
9	DA0207	Right
10	DA0208	Left
11	DA0208	Right
12	DD0010	Centre

[a] Looking downstream.

The ionic parameters (numbers 1, 2, and 3) which vary inversely with discharge reflect changes in ion concentration between tributaries and the mainstem as well as industrial saline discharge from Poplar Creek during the open water season. Parameter 4 (TOC) is a measure of biological degradation. Parameters 5 (phenols) and 6 (oils and grease) can occur naturally within the system, but elevated levels are often associated with domestic and industrial wastes. Parameters 7 to 9, the nutrients and fecal coliforms, are associated with sewage effluents. Although total kjeldahl nitrogen would typically be used as a measure of sewage effluents, there was not sufficient information available to use this parameter in the analysis. Instead, ammonia, the major inorganic form of nitrogen discharged from sewage plants, was selected. The metals (no. 10, nickel and no. 11, vanadium) are associated with oil sands.

The factor scores for all sites are presented on bivariate plots of the first and second principal components. Designated site clusters (i.e., those sites exhibiting similar water quality parameters) are delineated on schematic maps of the river.

3.3.1 Winter (Median Values)

The first two principal components (PC) of median values of selected water quality parameters in the winter accounted for 51.5% of the total variance. The first component alone accounted for 30.6% of the variance. To interpret the results, the coefficients (loadings) of the 11 parameters were examined. The first PC is interpreted as a comparison of bicarbonate ions and fecal coliforms (with high positive coefficients) to PO_4-P (lowest coefficient). For PC2, chlorides and ammonia represent the highest positive loadings, whereas TOC represents the lowest negative loadings.

The cluster of sites are represented as five groups on the bivariate plot and corresponding river map (Figures 8 and 9). Sites 2 (DA0203 left) and 9 (DA0207 right), which are grouped together,

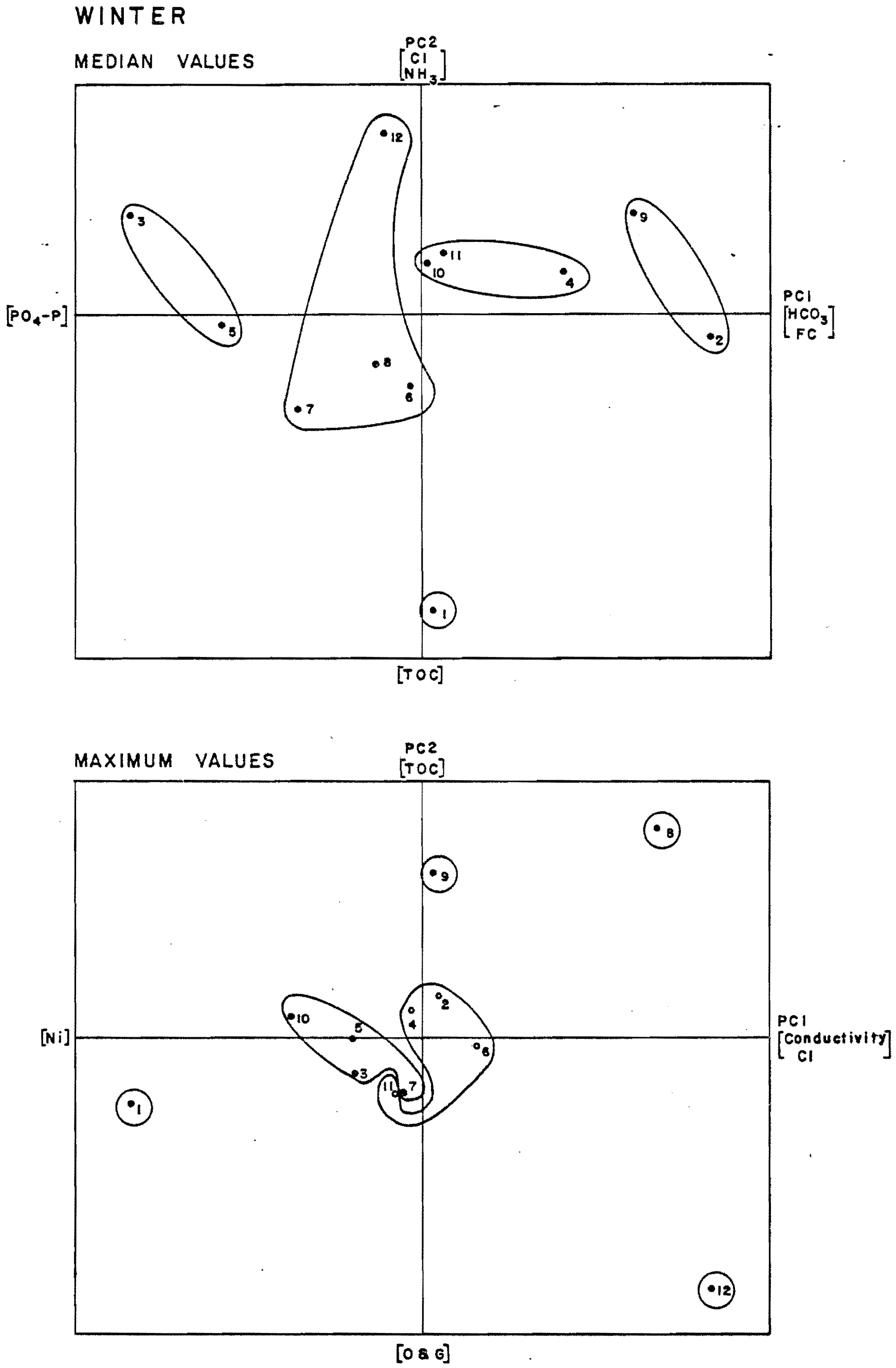


Figure 8. Principal component analysis of sample sites on the Athabasca River.

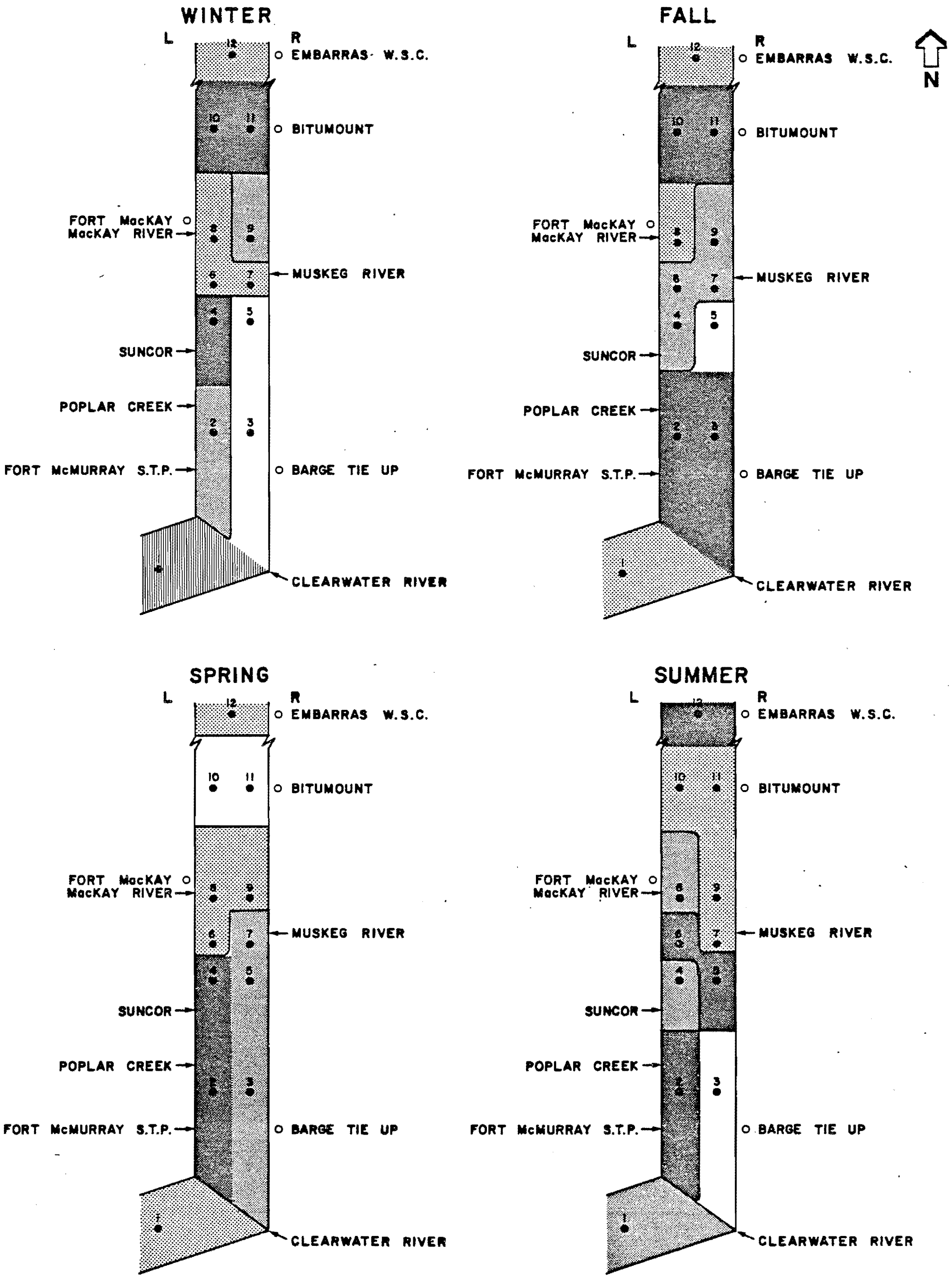


FIGURE 9. ATHABASCA RIVER , 1976-1983
REACH DEFINITION FROM CLUSTER ANALYSIS OF WATER QUALITY PARAMETERS USING MEDIAN VALUES .

exhibited highest values of bicarbonate ions and fecal coliforms. The sites are associated with the Fort McMurray sewage effluent and the Fort MacKay settlement.

Cluster 2 (sites 4, 10, and 11) represents an intermediate recovery zone downstream from the areas of enrichment. Cluster 3 (sites 6, 7, 8, and 12) is interpreted to represent recovered, well-mixed areas of the river.

Sites 3 and 5, along the true right bank of the Athabasca River downstream from the Clearwater River, form a distinct group characterized by elevated levels of PO_4-P and low levels of bicarbonate ions and fecal coliforms.

Site 1 (upstream of Fort McMurray) with elevated levels of TOC is distinct from the other 11 sites.

3.3.2 Winter (Maximum Values)

The first two principal components resulting from the analysis of maximum values in winter accounted for 58.7% of the total variance. PC1 contributed 35.9% of the total variability. For PC1, conductivity (along with chloride) and nickel exhibited the highest and lowest coefficients, respectively. For PC2, TOC and oil/grease displayed the highest and lowest coefficients, respectively.

The two major clusters, numbers 1 (sites 2, 4, 6, and 11) and 2 (sites 3, 5, 7, and 10), were grouped at the intersection of PC1 and PC2 (Figure 10). The other four sites exhibited distinct features. Interestingly, nickel concentrations were highest at site 1 (upstream of Fort McMurray) (Figure 10).

3.3.3 Spring (Median Values)

Together, PC1 (35.7%) and PC2 (21.7%) explained 57.4% of the total variability of the PCA using median water quality parameters. Nickel and chloride exhibited the highest and lowest coefficients for PC1. Conductivity (along with PO_4-P) and chloride had the highest and lowest loading coefficients for PC2.

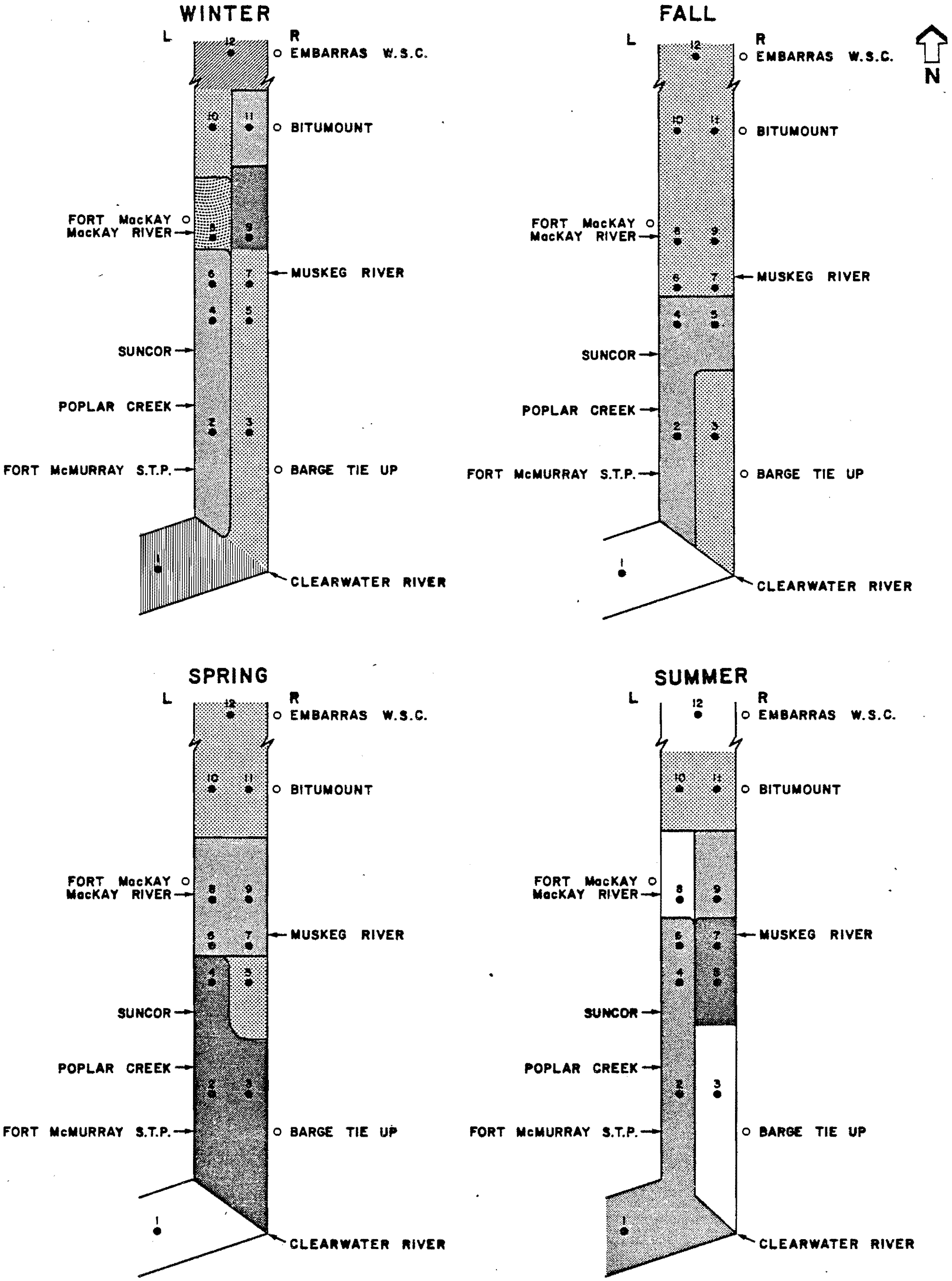


FIGURE 10. ATHABASCA RIVER, 1976-1983
REACH DEFINITION FROM CLUSTER ANALYSIS OF WATER QUALITY PARAMETERS USING MAXIMUM VALUES.

The sampling sites differentiated into three major clusters (Figure 11). Cluster 1 sites (1, 6, 8, 9, and 12) were characterized by elevated concentrations of nickel and low levels of chloride.

Cluster 2 consisted of two subgroups. One subgroup (sites 3, 5, and 7), located along the true right bank downstream of the Clearwater River, exhibited high chloride values. The other subgroup (sites 10 and 11) had lower levels of chloride.

Cluster 3 included site 2 (below the Fort McMurray sewage treatment plant) and site 4 (downstream from Suncor). Water samples from these locales were high in conductivity and PO_4-P.

3.3.4 Spring (Maximum Values)

PC1 (43.7%) and PC2 (24.82%) accounted for 68.5% of the total variability in the data set, representing maximum parameter values in spring.

Three major clusters of sample sites were evident (Figure 11). Cluster 1 (sites 2, 3, and 4) exhibited maximum levels of conductivity and PO_4-P, reflecting the inputs from the Clearwater River and Fort McMurray sewage plant. The highest PO_4-P levels throughout the year were recorded in the spring. Cluster 2 represents sites with high concentrations of chloride and phenolic material (sites 5, 10, 11, and 12). Cluster 3 sites (6, 7, 8 and 9) exhibited high levels of TOC and nickel. Nickel concentrations were higher in the spring than in any other season. Site 1 was characterized by the high concentrations of phenols, TOC, and nickel.

3.3.5 Summer (Median Values)

PC1 (32.8%) and PC2 (16.4%) accounted for about one half of the total variability in the data set.

Site 3 was distinct from other site groupings because of the high concentrations of chloride ions (Figure 12). The remaining 11

SPRING

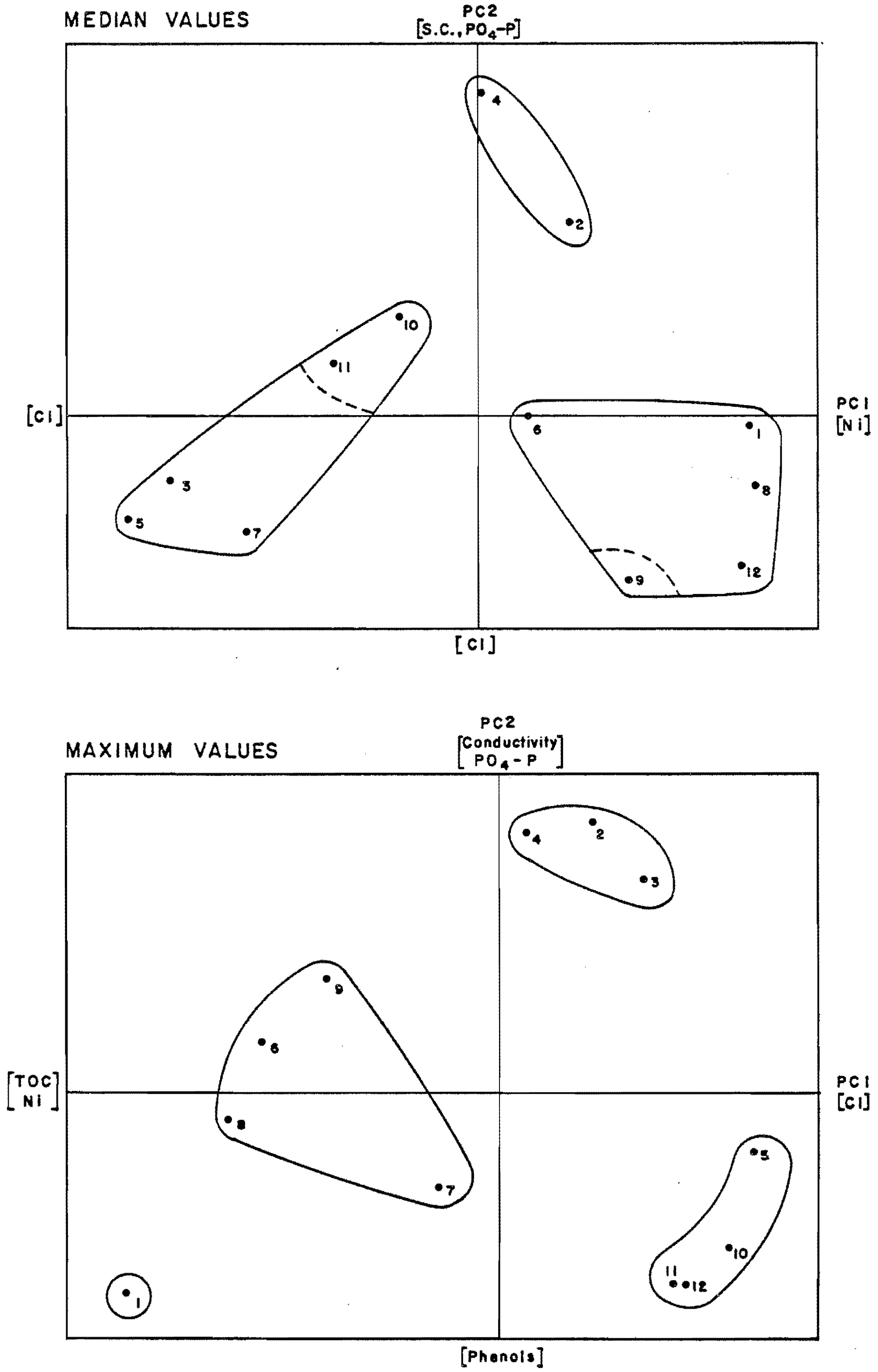
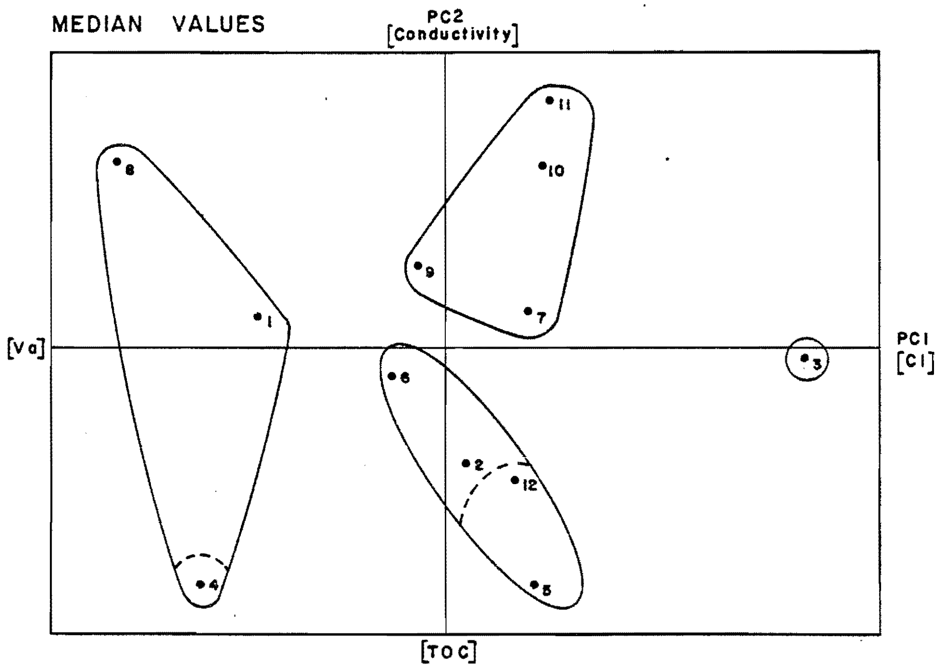


Figure 11. Principal component analysis of sample sites on the Athabasca River.

SUMMER

MEDIAN VALUES



MAXIMUM VALUES

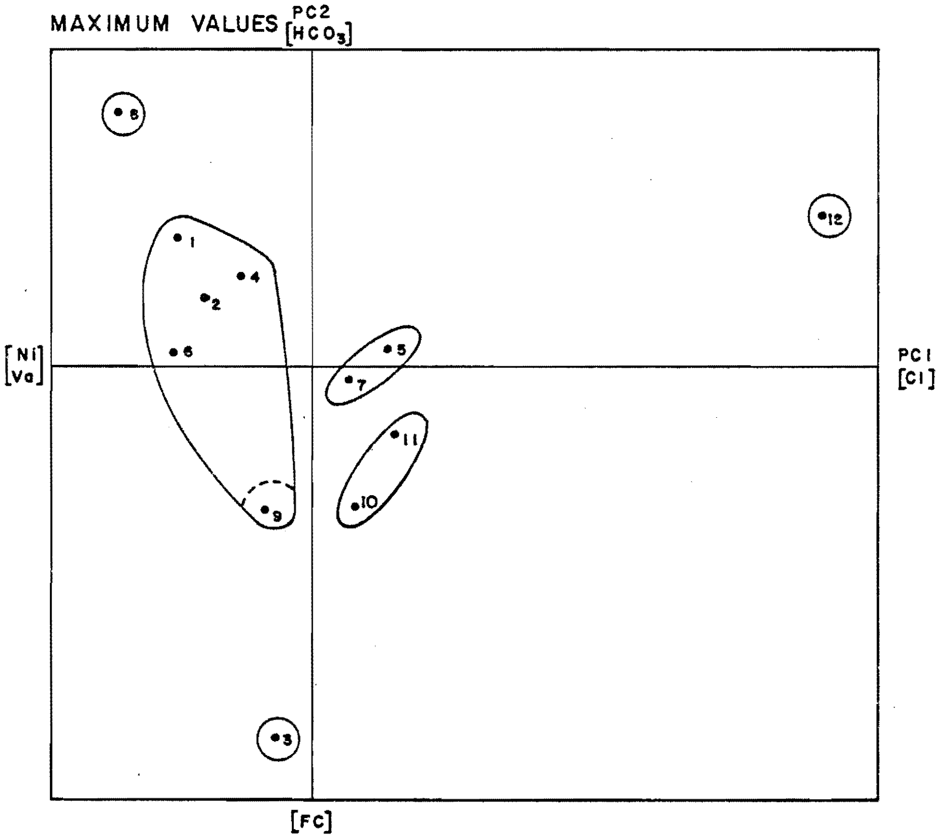


Figure 12. Principal component analysis of sample sites on the Athabasca River.

sites formed three clusters. Cluster 1 (sites 1, 4, and 8) exhibited elevated concentrations of vanadium. Within the cluster, site 8 had characteristically high conductivity levels and site 4 had high TOC concentrations. Cluster 2 (sites 2, 5, 6, and 12) was characterized by elevated levels of TOC. Cluster 3 sites (7, 9, 10, and 11) had relatively high levels of conductivity.

3.3.6 Summer (Maximum Values)

PC1 (27.6%) and PC2 (23.1%) accounted for about 51% of the total variability in the data set. Chloride and metals (nickel and vanadium) values differentiated site groupings along PC1 in a similar manner to the spring (median value) data set. In contrast, site 12 (the Embarras Airport locale) rather than site 3 exhibited the highest chloride values. Site 3 (elevated fecal coliforms) and site 8 (high bicarbonate and metal concentrations) also were distinct from other groups (Figure 12).

The largest cluster of five sites (1, 2, 4, 6, and 9) had characteristically high concentrations of nickel and vanadium. Metal concentrations, however, were lower in the summer than spring as discharge levels begin to decline.

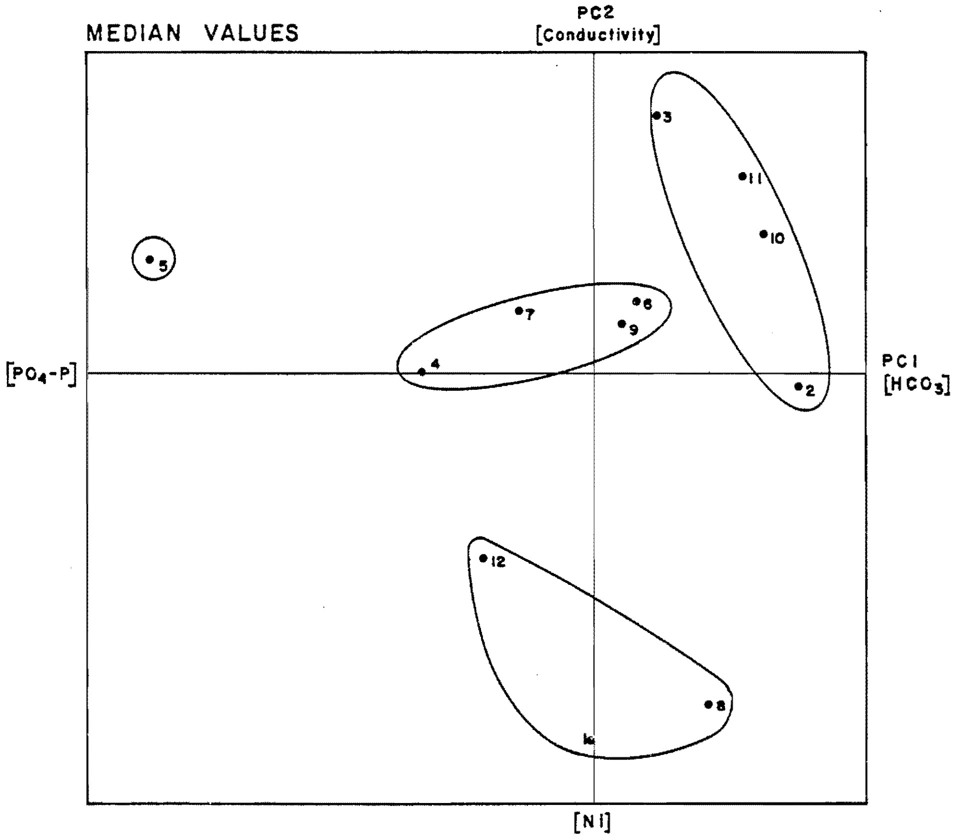
3.3.7 Fall (Median Values)

Because all sites exhibited the same low value of vanadium (1 ug/L), the parameter was deleted from the data set for the analysis.

The first two PCs accounted for 62.6% of the variability in the data. Bicarbonate ions and PO_4-P differentiated site clusters along the first principal component (accounting for 32.4% of the variability). Conductivity and nickel concentrations distinguished sites along the second component.

Site 5 was distinguished from all other sites because of relatively high levels of PO_4-P (Figure 13). The three clusters of the remaining sites formed a patchwork of interlocking sites along the

FALL



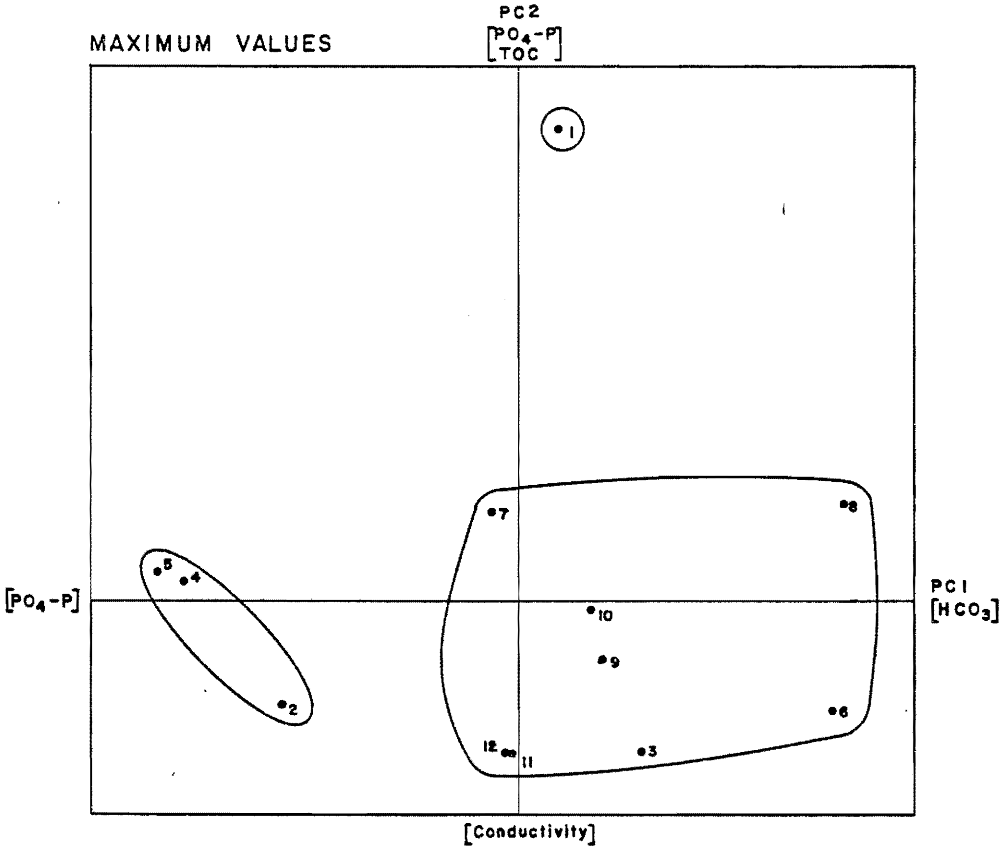


Figure 13. Principal component analysis of sample sites on the Athabasca River.

length of the mainstem (Figure 9). For example, sites 1, 8, and 12 were grouped together because concentrations of nickel at these sites were greater than 1 mg/L. Left and right bank pairs (sites 2/3 and 10/11) were grouped because of similarities in conductivity levels.

3.3.8 Fall (Maximum Values)

All 11 parameters were used in the PCA of the fall (maximum values) data set. PC1 (33.2%) and PC2 (27.6%) accounted for about 61% of the variability in the data set.

Conductivity, bicarbonate ions, and PO_4-P were useful to a limited extent in isolating clusters of sample sets (Figure 13). Eight sites were incorporated into one loose cluster on the basis of conductivity. Sites 2, 4, and 5 (located downstream from the Fort McMurray sewage treatment plant) formed one group characterized by elevated levels of PO_4-P. Site 1, exhibiting high concentrations of TOC and PO_4-P, was isolated from other river sites.

3.3.9 Summary

The following items summarize the results of the principal component analyses of impact related water quality parameters at 12 sites along the Athabasca River.

1. There was a consistent seasonal pattern in the parameters which distinguished sites along the first component. During low flow periods (winter and fall) bicarbonate ions and PO_4-P were the parameters that differentiated sample sites. In addition, concentrations of nickel were useful in distinguishing sites in winter (maximum values). During high flow periods (spring and summer), TOC, chloride ions, nickel, and vanadium differentiated groups of sample sites.
2. Change in ion concentration was attributed to inputs from either the Clearwater River or natural saline seepage rather than the industrial saline discharge via Poplar Creek.

3. Parameters which serve as markers for sewage effluents are PO_4-P, TOC and fecal coliforms. Municipal wastes at Fort McMurray were continuously discharged. The downstream effects of treated sewage were limited to the mainstem upstream of the confluence with the Muskeg River.
4. The metals nickel and vanadium are associated with oil sands in the AOSERP region. The concentrations of nickel and vanadium were higher at periods of increased flow (spring and summer), indicating the significant effect of weathering of rocks. Sites exhibiting elevated concentrations of nickel and vanadium in surface waters were associated with the natural occurrence of bitumen in the river bank and valley wall (e.g., CC0012) rather than with industrial effluents (site DA0205 left bank). Some metals, however, which exhibit very low concentrations in water may be associated with sediments.

4. THE NORTH

The northern region includes the drainage basins within the Athabasca Delta. The delta includes the following three subregions: (1) the distributaries (Embarras River, Fletcher Channel, Goose Island Channel, and Big Point Channel) which enter Lake Athabasca from the Athabasca River; (2) outflow from Lakes Claire and Mamawi which originate from the Birch River system; and (3) Lake Athabasca outflows of Chenal des Quatre Fourches and Riviere des Rochers which join the Peace River to form the Slave River.

4.1 BASIN FEATURES

4.1.1 Land Formations

Land formations of the Athabasca Delta region have been discussed by Bayrock (1971) and Turchenek and Lindsay (1982).

The delta was formed about 10 000 years ago during the recession of the Pleistocene ice age. Although the delta now separates Lakes Claire and Athabasca, the two lakes were formerly one basin.

All Athabasca River sediments are deposited in the delta. Sedimentation from streams entering Lake Claire constitutes less than 15% of the delta sediments. Coarse sands representing the bottom load are deposited first. The sands are subsequently covered by fine sediments which settle out of the water column.

Most of the region, with the exception of the Athabasca distributaries, occurs within the Northern Boreal Forest. The distributaries lie within the Boreal Mixedwood Forest. Riparian forests, deciduous shrubs, and fen communities are prevalent throughout the delta.

The bedrock geology of the north is characterized by granite rocks of the Archean in the east and Devonian rocks (limestone and shale) in the west (Figure 14). The Archean constitutes the earlier or older rocks of the Precambrian era. The line separating the two geological types passes through Mamawi Lake.

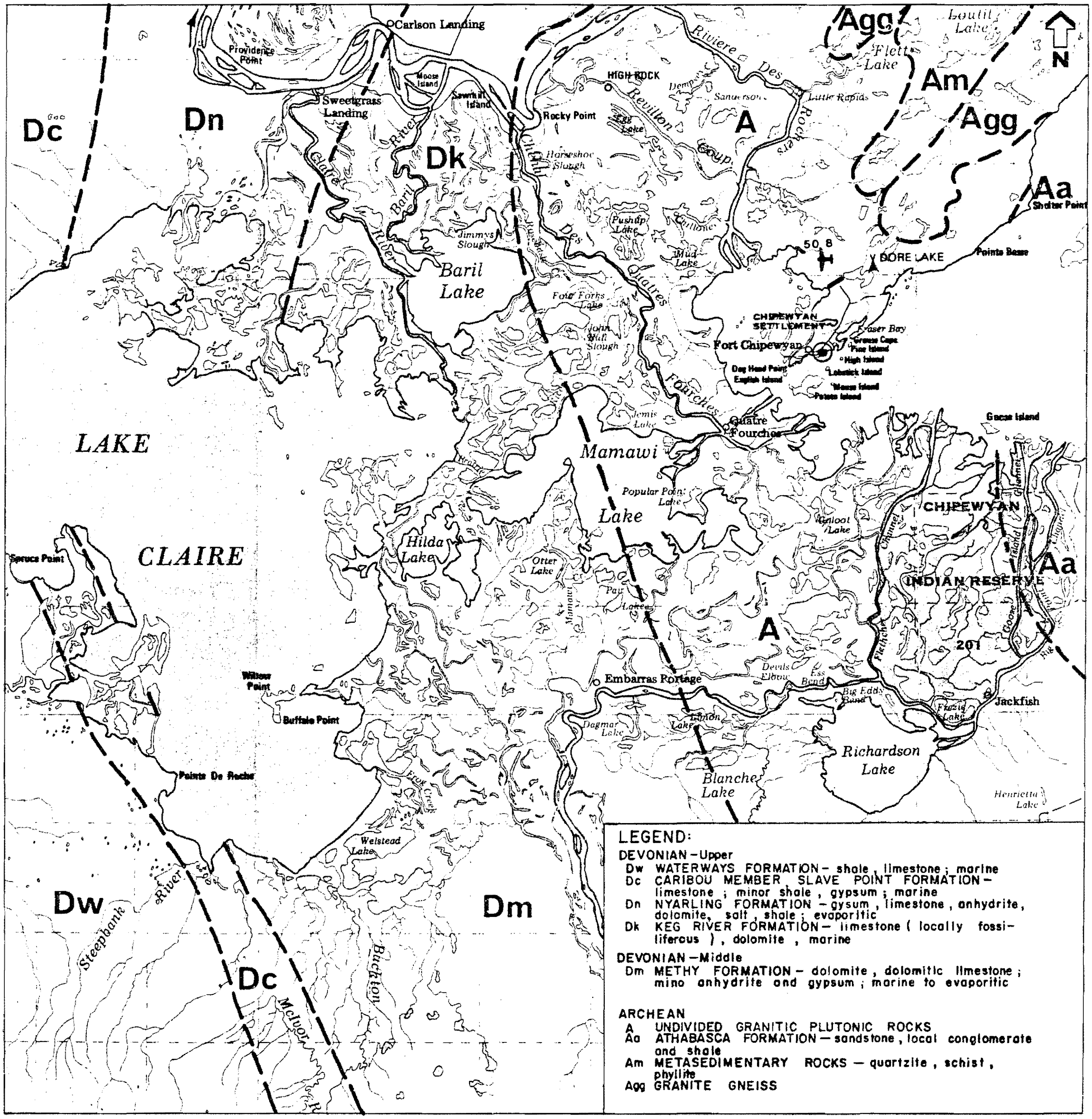


Figure 14. Bedrock geology of the delta area .
(Based on Bayrock , 1971)

4.1.2 Watershed

The Athabasca River enters Lake Athabasca through a system of channels including the Embarras River, Fletcher Channel, Goose Island Channel, and Big Point Channel (Figure 15). Flow and sediment deposition increase in channels from west to east, resulting in a migration of river outflow to the east.

Bayrock (1971) forecasted the breakthrough of the Athabasca River into the Embarras River with flow ultimately being redirected into Lakes Mamawi and Claire. To prevent this flow transfer, a cutoff was constructed near Embarras Portage in 1972.

Flow from the Birch River system through Lakes Claire (area, 1160 km^2; volume, 1.2 km^3) and Mamawi (area, 160 km^2; volume, 0.16 km^3) enters the Peace River (via Chenal des Quatre Fourches) and Lake Athabasca (area, 7850 km^2; estimated volume, 200 km^3). Reverse flows can occur in the Chenal des Quatre Fourches bringing Peace River water into Lake Mamawi.

Most of the Lake Athabasca outflow occurs through Riviere des Rochers and Chenal des Quatre Fourches (Neill et al. 1981). Revillon Coupe is a sub-distributary of the Riviere des Rochers.

4.1.3 Physical Description of Water Bodies

Neill et al. (1981) summarized hydraulic conditions of the channels and lakes of the delta using satellite imagery and colour aerial photography.

Operation of the Bennett Dam, located on the Peace River in British Columbia, has altered the physical features of the Peace Athabasca Delta by controlling water levels and flow regimes. The Bennett Dam was constructed in 1967 and the filling of the reservoir, Williston Lake, was completed in 1972, witholding a volume of 60 km^3 from the Peace River in Alberta. Prior to dam closure, water levels in the Peace River at the confluence of the Athabasca outflow were high enough to restrict or reverse flow, thereby flooding low lying areas, and thus enhancing nutrients and organic levels. The control structure

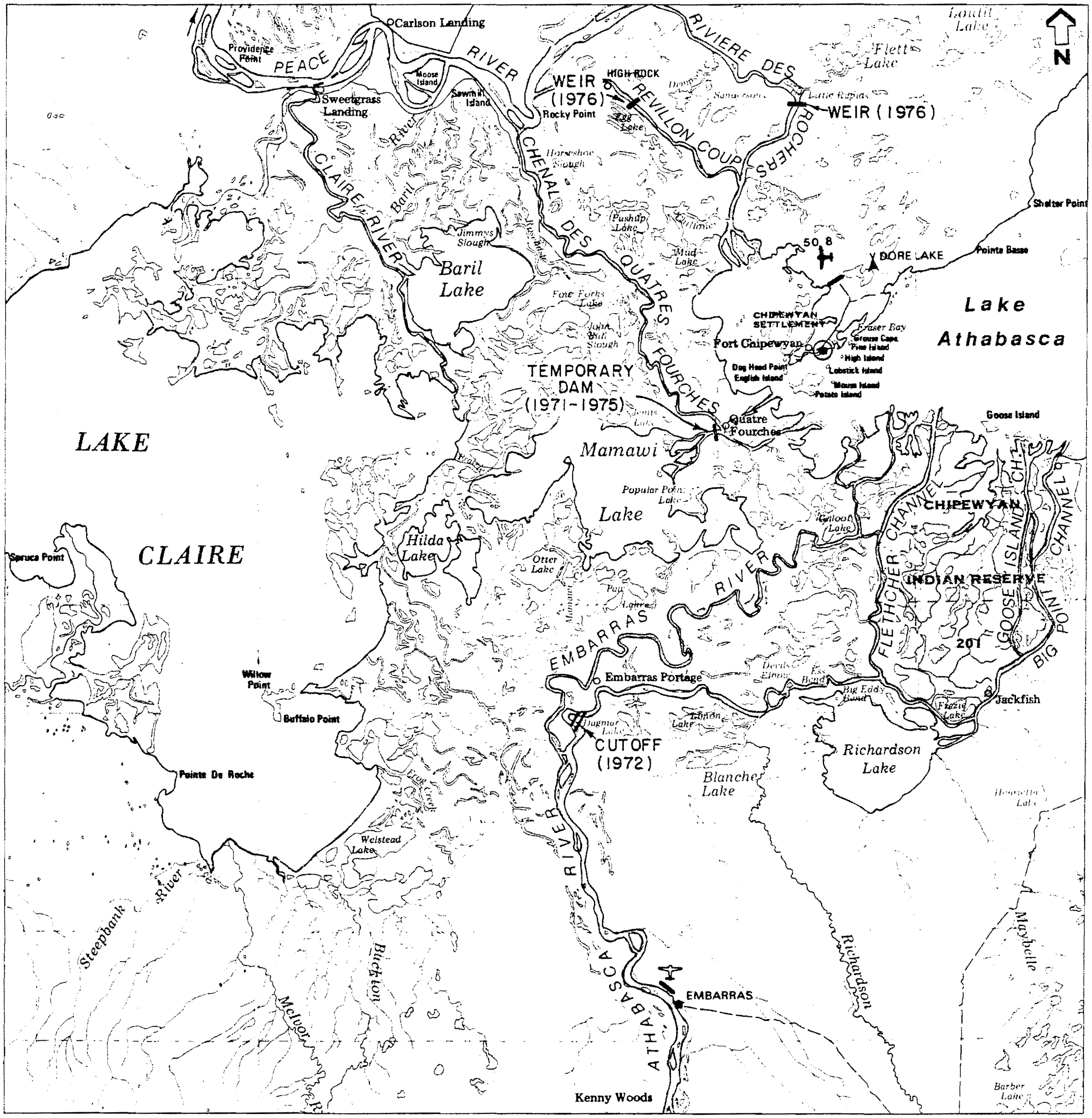


Figure 15. Delta area surface water drainage.
(Adapted from Neill et al., 1981)

reduced water levels about 3 metres at the confluence of the Peace River and Riviere des Rochers. Annual maximum water levels in Lake Athabasca were reduced about 1.2 metres.

Mitigation measures to maintain water levels included construction of weirs on delta channels. A temporary dam was constructed in 1971 on the soutwest arm of Chenal des Quatre Fourches, the control outlet of Lake Mamawi. The weir, which was designed to maintain water levels in Lakes Claire and Mamawi, was frequently washed out and rebuilt until the project was abandoned in December 1975. Water levels, however, have remained the same in Lakes Claire, Mamawi, and Athabasca because slopes of the connecting channels are flat. In June 1975 and March 1976, permanent weirs were established on Riviere des Rochers and Revillon Coupe to control the outflow from Lake Athabasca when water levels on the Peace River are low.

4.2 BASELINE DATA

4.2.1 Discharge

There are no continuous gauging stations on the Athabasca River distributaries, although infrequent flow measurements have been taken by the Water Survey of Canada. Most (75%) of the flow from the Athabasca mainstem enters the delta via the Goose Island and Big Point channels (Figure 16) (Neill et al. 1981).

The average annual outflow from Lake Athabasca is about 45 km^3. The river systems contributing to this outflow are the Athabasca (52%), Fond du Lac (21%), and small tributaries (21%) (Figure 5) (Neill and Evans 1979). Outflows from Lakes Claire and Mamawi, which for the most part bypass Lake Athabasca, contribute less than 3% of the average annual Lake Athabasca outflow (Neill et al. 1981).

4.2.2 Water Quality

Water quality of lakes and channels in the northern region is likely influenced by the control structure on the Peace River and by

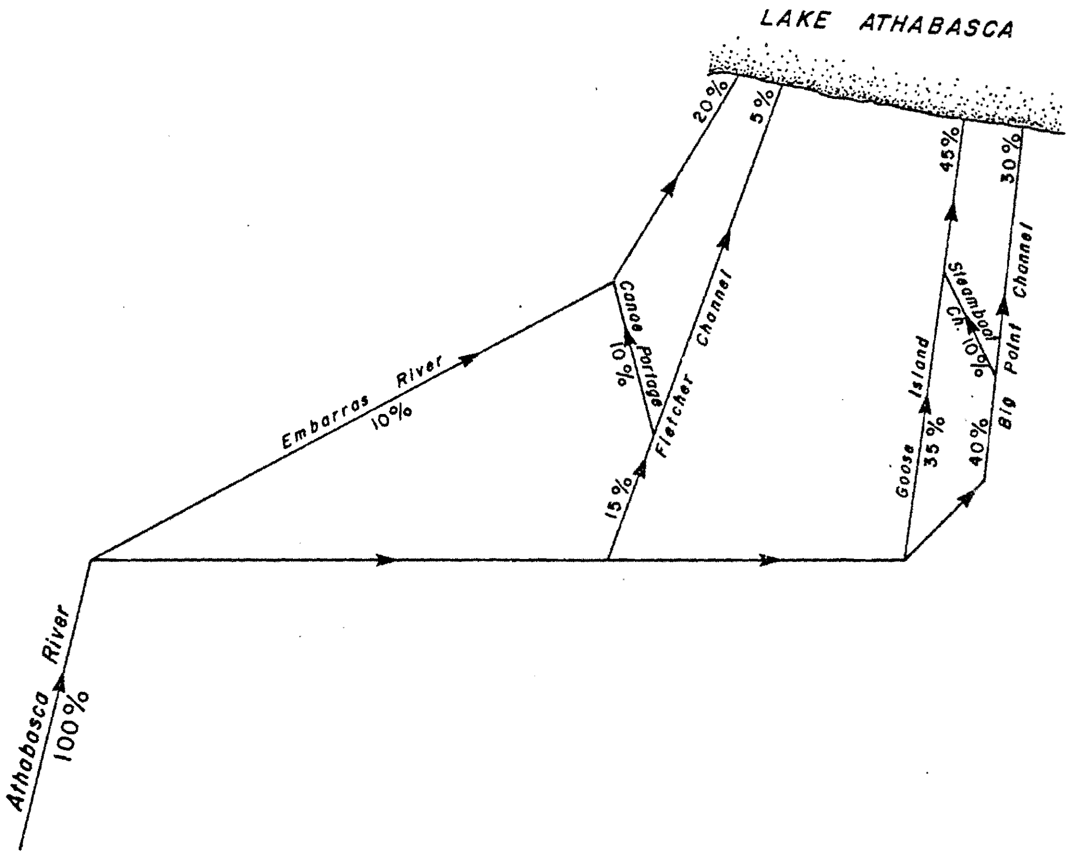


Figure 16. Approximate average distribution of Athabasca River flow among four main delta distributaries. (Adapted from Neill et al., 1981)

differing geology. Water quality values also may differ between lake-draining and river-draining channels. A description of the water quality sampling sites is presented in Table 5.

4.2.2.1 Routine parameters. A summary of routine parameters for the region is presented in Appendix 10.3 (Table 59).

Surface waters of the northern region are neutral or alkaline. Lowest pH values were recorded in waters overlying granite rocks, including Lake Athabasca (6.7), Riviere des Rochers (6.8), and Jackfish Creek (7.0). These water bodies also exhibited the lowest buffering capacity in the region with median values ranging from 33 to 70 mg/L. Median values of total alkalinity for other waterbodies ranged from 99 to 118 mg/L. Water samples from the devonian (limestone) area exhibited higher median values of hardness (147 to 162 mg/L) than waters overlying granite (35 to 113 mg/L). Similar trends in the relationship between water quality constituents and geology (i.e., lower values in waters overlying granite than limestone) were noted for turbidity, colour, filterable residue, and conductivity (Appendix 10.3, Table 59).

The relative contribution of major ions is presented in Figure 17. The total ion concentration exhibited by sites located on granite is lower than sites located in limestone areas. The relative contribution of ions also differs between geological types. In granite areas, calcium bicarbonate is the dominant dissolved salt in drainage systems. In limestone areas, both sodium chloride and calcium bicarbonate salts are prevalent. Lake Claire also exhibits elevated levels of sulphate ions.

Because soil layers overlying limestone are thicker than layers overlying granite, values of total organic content are correspondingly higher at sample sites on the devonian than the Archean geological type (Appendix 10.3, Table 59).

Median values of phenolic materials were below the Alberta Surface Water Objective (ASWO) of 0.005 mg/L. Maximum values exceeded the objectives at Big Point Channel (0.032), Chenal des Quatre Fourches (0.019 mg/L), and Riviere des Rochers (0.022 mg/L).

Table 5. Description, period of record, and number of samples obtained for water quality sampling stations within the northern region. See Figure 4 for location of sites.

Input/Output Drainage for Lake Athabasca	Code Rivers: 00AT07- Lakes: 01AT07-	Latitude N Longitude W (D M S)	Description	Period of Record	Number of samples[a]
Southern Inputs	DA0211	58 38 24 111 02 35	Embarras River	1976-77	2
	DD0080	58 24 00 111 04 00	Richardson Lake	1976-78	10
	DD0090	58 24 47 110 55 12	Jackfish Creek	1977-79	12
	DD0212	58 38 25 110 46 26	Big Point Channel	1976-83	48
	DD0213	58 39 06 110 58 33	Fletcher Channel	1976, 1980	2
	DD0214	58 38 16 110 50 03	Goose Island Channel	1979	1
Western Inputs	KF0100	58 39 00 111 18 24	Mamawi Lake Channel	1977-79	13
	KF0140	58 37 25 111 40 50	Prairie River	1977-79	12
	KF0200	58 34 33 112 04 31	Lake Claire west of Birch River	1977-79	12
	KF0201	58 26 00 112 04 12	Lake Claire at Willow Point	1977-79	11

continued . . .

Table 5. Concluded.

Input/Output Drainage for Lake Athabasca	Code Rivers: 00AT07- Lakes: 01AT07-	Latitude N Longitude W (D M S)	Description	Period of Record	Number of Samples
Northern Outputs	KF0101	58 39 55 111 21 24	Chenal des Quatre Fourches	1977-83	33
	NA0030	58 50 42 111 15 32	Riviere des Rochers	1976-83	50
	NA0031	58 49 13 111 16 30	Riviere des Rochers, km 350	1977	1
Lake Athabasca	MD2000	58 56 11 110 42 44	Lake Athabasca at Sandy Point	1977-79	8

[a] Sites with 8 or more samples were used in subsequent analysis.

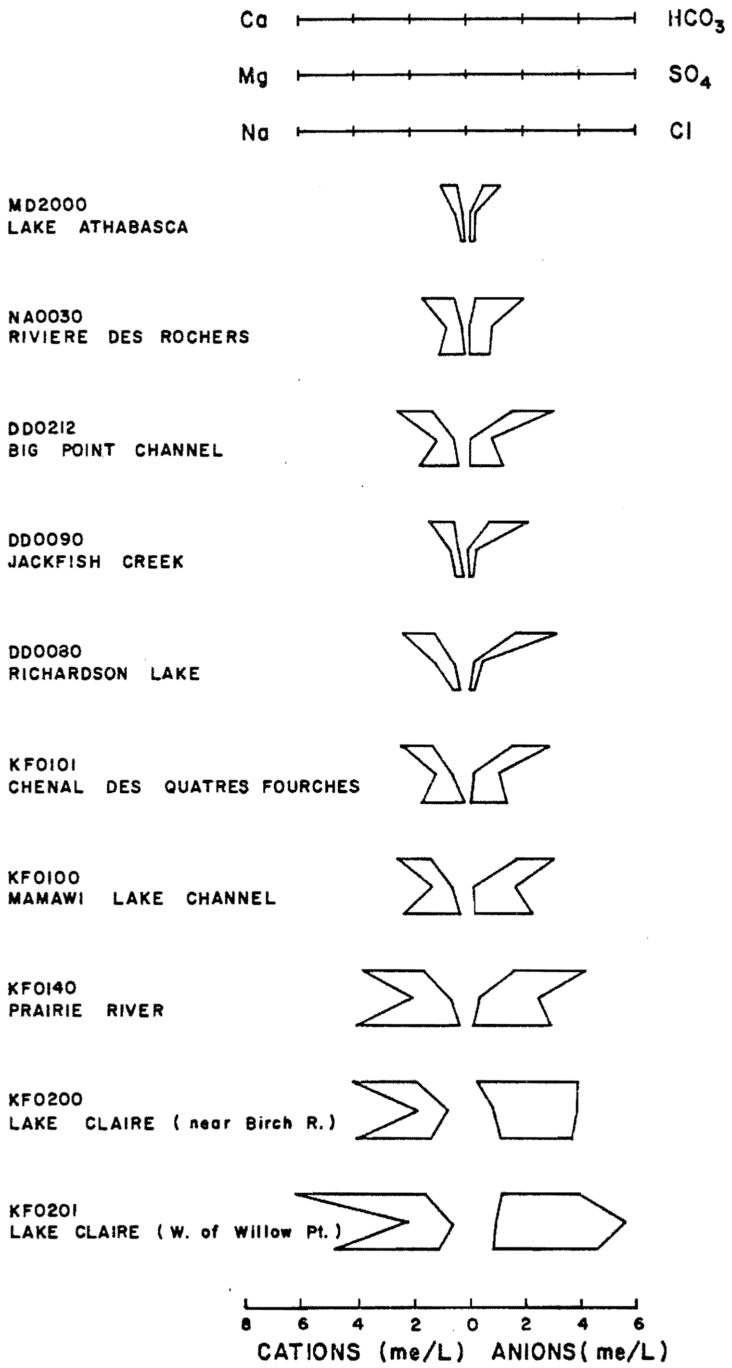


Figure 17. Maximum and minimum values (me/L) of major ions in the northern region.

No guidelines have been established for oil and grease. Median values ranged from 0.5 to 1.2 mg/L; maximum values ranged from 1.3 to 3.8 mg/L.

4.2.2.2 Nutrients. Phosphorus and nitrogen are the major nutrients controlling plant growth.

Total phosphorus (particulate and dissolved fractions) and orthophosphate phosphorus (PO_4-P) are the two forms which are presented in Appendix 10.3 (Table 60). Since total phosphorus varies directly with discharge, values are elevated in spring and summer during high runoff periods. Median values of total phosphorus were below the ASWO of 50 ug/L in Lake Athabasca, Jackfish Creek, and Riviere des Rochers. Median values at the other sites ranged from 51 to 80 ug/L. Maximum values ranged from 40 to 930 ug/L.

Orthophosphates are a measure of natural or cultural enrichment. Median values ranged from 4 to 14 ug/L. Maximum levels of PO_4-P in Lake Athabasca (9 ug/L) and Richardson Lake (19 ug/L) in granite areas were substantially lower than in Mamawi Lake Channel (280 ug/L) and Lake Claire (180 ug/L) in limestone areas. Maximum PO_4-P levels in Big Point Channel (235 ug/L) and Chenal des Quatre Fourches (360 ug/L) were higher than maximum levels in other channels (18 to 70 ug/L).

The ASWO for total nitrogen (total kjeldahl nitrogen and nitrate/nitrite) is 1.0 mg/L (1000 ug/L). Values for total kjeldahl nitrogen (TKN is a measure of organic nitrogen and ammonia), ammonia, and nitrate/nitrite nitrogen are presented in Appendix 10.3 (Table 60).

Maximum values of TKN for all water bodies in the region ranged from 1.20 to 9.15 mg/L, exceeding the ASWO for total nitrogen. Elevated median values were recorded in water bodies of the limestone region (1.06 to 1.62 mg/L) as well as in Richardson Lake (1.40 mg/L).

Ammonia and nitrate/nitrite nitrogen are the two inorganic forms of nitrogen. Median values of ammonia ranged from 0.03 to 0.06 mg/L. The highest ammonia value was recorded in Big Point Channel

(1.10 mg/L). Median values of nitrate/nitrite nitrogen ranged from less than 0.01 to 0.07 mg/L. Maximum values ranged from 0.08 to 0.80 mg/L, with the highest value recorded in Riviere des Rochers.

4.2.2.3 Metals. Summary data for 16 metals obtained from the monitoring program in the northern region are presented in Appendix 10.3 (Table 61). Surface water objectives have been established for 12 of the 16 metals. Objectives have not been established for aluminum, cobalt, nickel, or vanadium because they are usually of no public health significance (McNeely et al. 1979).

Median and maximum values were below the ASWO in all waterbodies for arsenic (10 ug/L), boron (500 ug/L), cadmium (10 ug/L), chromium (50 ug/L), lead (50 ug/L), selenium (10 ug/L), and silver (50 ug/L).

Median values of aluminum at all sites ranged from 120 to 645 ug/L and so were within the typical surface water levels of less than 1.0 mg/L (1000 ug/L) (McNeely et al. 1979). The highest value of aluminum (30.4 mg/L) was recorded at Prairie Creek. Other maximum values ranged from 440 to 6900 ug/L).

The presence of cobalt in surface waters results from weathering of surficial material. Median values of cobalt for all sample sites were less than the detection limit of 2 ug/L. Maximum values ranged from less than 2 to 4 ug/L.

Although copper is an essential element for plants and animals, elevated levels of copper in water are distasteful. The threshold levels for taste perception range from 1 to 5 mg/L (McNeely et al. 1979). The highest value of copper was recorded in samples from Big Point Channel (150 ug/L) and Rivere des Rochers (260 ug/L).

The ASWOs for iron (300 ug/L) and manganese (50 ug/L) were established for aesthetic reasons since elevated levels of these constituents can alter the taste of water as well as stain clothes and plumbing fixtures. Median and maximum values of iron exceeded the objective at all sample sites. Although median values of manganese for all sites were within the ASWO, maximum values exceeded the objective at all sites.

Non-compliance with surface water objectives was also noted for mercury. All sites (except Richardson Lake) exceeded the objective of 0.1 ug/L.

Nickel and vanadium may occur in surface waters as a result of weathering of surficial material or as wastes from industrial processing such as fossil fuels. Median values of nickel ranged from less than 2 to 4 ug/L. A sample from Big Point Channel exhibited the highest nickel levels (30 ug/L). Median values of vanadium were less than or equal to 1 ug/L at all sites. The highest value of vanadium was recorded at Big Point Channel (20 ug/L) and Chenal des Quatres Fourches (32 ug/L).

The median values of zinc at all sites were below the ASWO of 50 ug/L. With the exception of Prairie River, maximum values of sample sites exceeded the objectives. Although zinc is not toxic to man, elevated levels (5 mg/L) will alter the taste of water (McNeely et al. 1979).

4.2.3 Benthic Invertebrates

Gallup et al. (1971) conducted a survey of planktonic and benthic invertebrates of the Peace Athabasca Delta during the summer of 1971. Earlier, Rawson (1947) studied the invertebrates of Lake Athabasca.

Gallup et al. (1971) collected benthic invertebrates with an Ekman grab, the contents of which were washed through a 600 micron sieve. Highest standing crops (more than 500 mg wet weight/sample) of invertebrates were recorded in the lower reaches of rivers entering lakes (Birch River and Mamawi Creek) and channels between Lakes Claire and Mamawi. A mean standing crop of 100 mg wet weight/sample was recorded for the other sites. Production was greater near shorelines than in open water areas of lakes.

Pontoporeia hoyi, an amphipod, dominated the bottom fauna of the western end of Lake Athabasca in numbers (61%) and wet weight (70%)

(Gallup et al. 1971). Clams (Sphaeridae), snails (Lymnaeidae) and midges dominated the fauna in other water bodies.

4.3 RELATIONSHIPS AMONG PARAMETERS

Because only stage (water level) data are available at sites in the delta, relationships among parameters focussed on water quality constituents alone. A correlation analysis was performed between conductivity (a known correlate of discharge) and other water quality constituents using median values from each sampling site (Appendix 10.3, Tables 59 to 61). Results showed that six constituents (total organic carbon, total phosphorus, total kjeldahl nitrogen, aluminum, copper, and iron) were significantly correlated with conductivity at the 0.01 level.

Relationships between each of the six constituents and conductivity were estimated using all available data from sample sites representing water bodies entering Lake Athabasca from southern distributaries (Jackfish Creek, Big Point Channel), channel inputs from lentic areas in the west (Prairie Creek, Mamawi Lake Channel), and channels leaving the northwest end of Lake Athabasca (Chenal des Quatre Fourches, Riviere des Rochers). Of the six sample sites, one (Big Point Channel) receives river water and the other five receive drainage from lakes.

Regression analyses were performed using linear, log/linear, and log/log transformations of the data. Equations from those transformations yielding the best fit (i.e., least variability and highest R^2) were selected and presented in Table 6.

There were significant relationships between TOC and conductivity for Jackfish Creek, Prairie Creek, and Big Point Channel (Table 6). The TOC varies inversely with conductivity in channels which drain lakes (Jackfish and Prairie creeks), but directly with Big Point Channel, a distributary of the Athabasca River. These relationships suggest that there are seasonal differences in biological activity (indicated by TOC) between rivers and lakes.

There was a significant log/log positive relationship between total phosphorus and conductivity in Big Point Channel. No significant

Table 6. Summary of regression equations of total organic carbon (TOC), total phosphorus (TP), total kjeldahl nitrogen (TKN), aluminum (Al), copper (Cu), and iron (Fe) with conductivity for water bodies of the northern region. Equations with the best fit of the data were of the following format:

linear $Y = A + Bx$ (1)

log/linear $Y = Ae^{Bx}$ (2)

log/log $Y = Ax^{B}$ (3)

where: A = intercept, B = slope, Y = dependent water quality variable; and
X = independent variable (conductivity).

Water Body	Equation Format (1, 2, 3)	df (n-2)	Y	A	B	R²	p ($Ho:B_1=0$)
Jackfish Creek (DD0090)	1	10	TOC	-0.43	0.046	.69	L0.001
	3	10	TP	2.16	0.583	.17	ns
	1	10	TKN	362.60	2.861	.11	ns
	3	8	Al	1.00×10^{-3}	2.480	.54	L0.025
	1	10	Cu	4.15	-0.009	.06	ns
	3	10	Fe	450.79	0.168	.01	ns
Big Point Channel (DD0212)	3	41	TOC	527.95	-0.709	.23	L0.01
	3	44	TP	1.12×10^{6}	-1.742	.35	L0.001
	1	30	TKN	589.48	0.163	.00	ns
	2	41	Al	1.97×10^{3}	-0.008	.25	L0.001
	1	44	Cu	-2.442	0.034	.02	ns
	3	44	Fe	6.50×10^{7}	-1.999	.23	L0.001
Input from W: Mamawi Lake Channel (KF0100)	1	10	TOC	7.60	0.012	.03	ns
	3	11	TP	11.88	0.268	.01	ns
	1	11	TKN	838.22	0.644	.01	ns
	1	8	Al	2433.72	-3.363	.10	ns
	3	11	Cu	2.73	0.197	.00	ns
	2	11	Fe	383.37	0.002	.08	ns
Input from W: Prairie Creek (KF0140)	3	10	TOC	8.66×10^{-3}	1.268	.56	L0.01
	1	10	TP	181.08	-0.164	.15	ns
	3	10	TKN	1.45×10^{4}	-0.368	.02	ns
	3	8	Al	2.75×10^{12}	-3.485	.29	ns
	2	10	Cu	5.49	0.007	.09	ns
	2	10	Fe	1.03×10^{4}	-0.003	.27	ns

continued . . .

Table 6. Concluded.

Water Body	Equation Format (1, 2, 3)	df (n-2)	Y	A	B	R^2	p ($Ho:B_1=0$)
Output:							
Riv des	3	43	TOC	1.20	0.339	.06	ns
Rochers	1	46	TP	-3.01	0.395	.08	ns
(NA0030)	3	45	TKN	136.05	0.280	.01	ns
	2	45	Al	524.79	-0.005	.02	ns
	2	48	Cu	2.28	0.004	.04	ns
	2	48	Fe	511.83	0.002	.00	ns
Output:							
Chenel des	2	25	TOC	8.25	0.0006	.01	ns
Quatres	1	31	TP	207.05	-0.294	.04	ns
Fourches	1	29	TKN	-1118.26	6.650	.14	L0.05
(KF0101)	1	29	Al	1357.63	-2.034	.03	ns
	3	31	Cu	250.14	-0.681	.06	ns
	1	31	Fe	3841.05	-6.761	.06	ns

L = less than

relationships, however, were established for the other five channels which drain lakes. The association between total phosphorus and conductivity in rivers reflects the direct relationship between apatite phosphorus and discharge.

There was a significant positive relationship between TKN and conductivity in Chenal des Quatres Fourches, the output channel draining the northwest end of Lake Athabasca. There were no significant relationships between the two parameters in the other five channels.

Significant relationships between aluminum and conductivity were noted in the channels which enter Lake Athabasca from the southern Athabasca River drainage, but not from the lentic inputs from the west or the two outlet channels. There was an inverse relationship between aluminum and conductivity in Big Point Channel, but a direct relationship between parameters in Jackfish Creek, the channel which drains Richardson Lake.

No significant relationships were established between copper and conductivity in any of the drainages.

There was a significant negative relationship between iron concentrations and conductivity in Big Point Channel but not for any of the lake-draining channels. The negative relationship between iron and conductivity implies a direct association between iron and discharge. Thus, the increased iron concentrations in surface waters during high flows resulted from weathering of surficial materials.

5. THE EAST

This region includes watersheds east of the Athabasca mainstem between the Clearwater River in the south and the delta in the north, a range in latitude of about 1°45'. The four major watersheds of the eastern region are the Firebag, Muskeg, Steepbank, and Richardson. The Richardson drains north into the delta; the others drain west into the Athabasca River.

5.1 BASIN FEATURES

5.1.1 Land Formations

Land formations of the eastern region, which have been delineated by Turchenek and Lindsay (1982), are presented in Figure 18.

The eastern region lies entirely within the Boreal Mixedwood Forest. This forest type is characterized by aspen and white spruce, with jack pine present on well-drained sandy soils and black spruce on wetland communities.

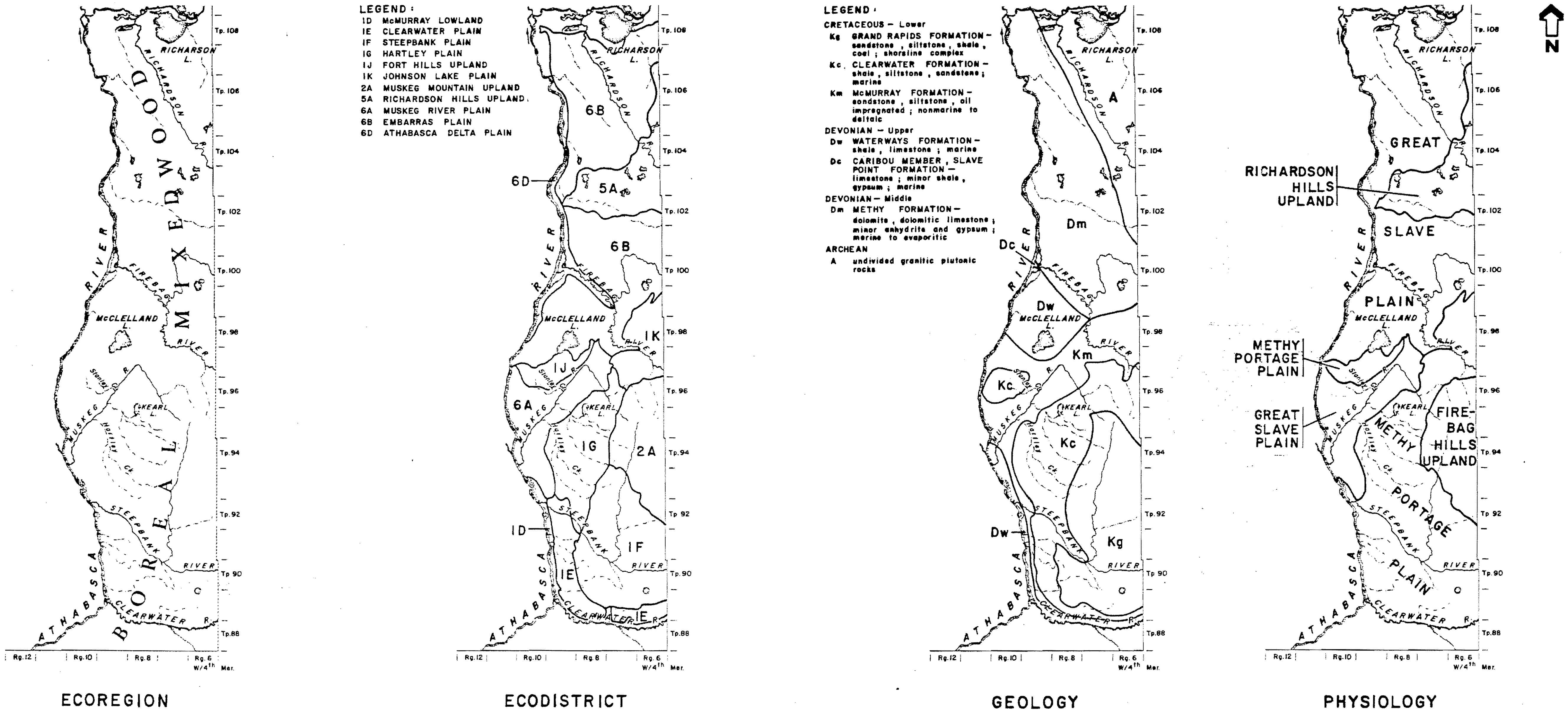
The bedrock geology of the northern portion of the region is characterized by Devonian rocks (limestone and shale) of the Paleozoic era and in the extreme northeast by granite rocks of the Archean. Younger Cretaceous rocks of sandstone and shale occur in the southern half of the region.

The Steepbank River originates in the Muskeg River uplands and flows through level and undulating plains before entering the Athabasca River in the McMurray lowland. Although the Muskeg and Richardson rivers originate in upland areas, the major portion of each watershed flows through undulating plains. The Firebag watershed lies within the Great Slave Plain.

5.1.2 Watershed

The following is a brief description of the four major drainages within the eastern region (Figure 19).

The Steepbank River watershed (1425 km^2) encompasses the land drained by the mainstem and the North Steepbank River. The Steepbank



ECOREGION   ECODISTRICT   GEOLOGY   PHYSIOLOGY

Scale – 1 : 1500000

Figure 18. Land formations of the eastern region.
(Adapted from Turchenek and Lindsay, 1982)

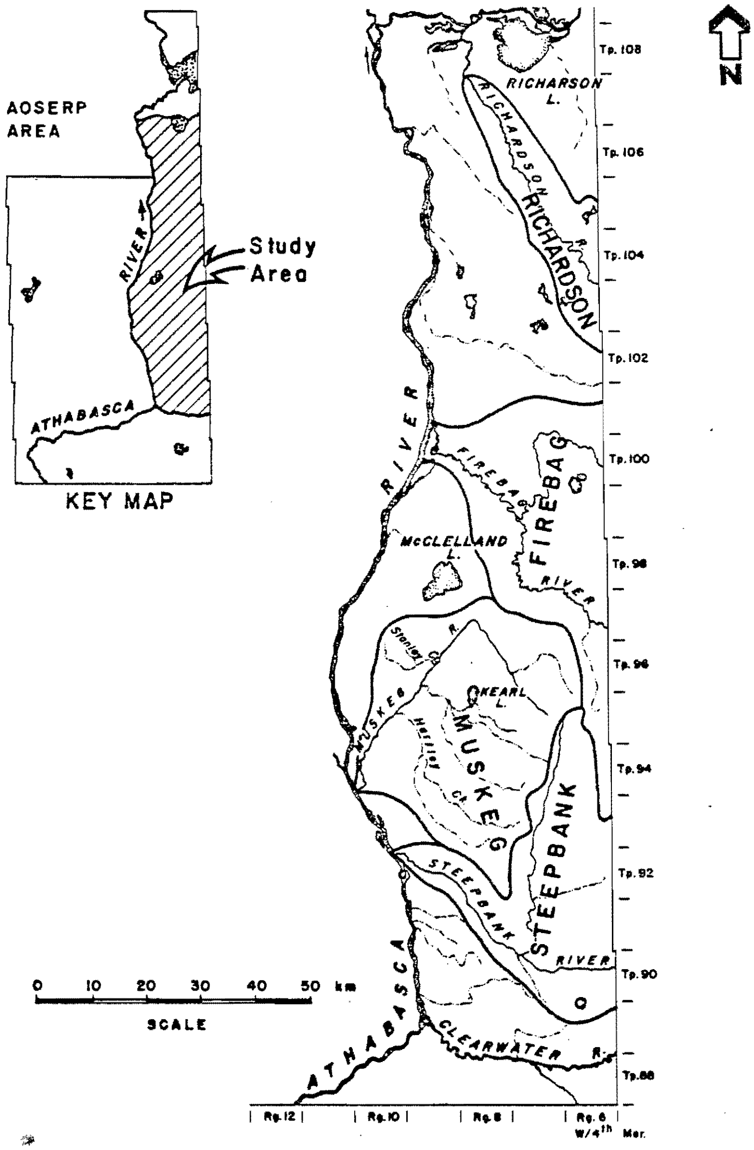


Figure 19. East surface water drainage.

(Adapted from Neill and Evans, 1979)

River flows 120 km northwest to its confluence with the Athabasca River. The North Steepbank River drains an area of 525 km^2 before joining the Steepbank River about 32 km upstream from the Athabasca mainstem.

The upper reaches of the watershed are meandering, with extensive beaver activity impounding 90 to 95% of the channel (Griffiths 1973). River gradient increases downstream from the junction of the North Steepbank river and mainstem, forming alternating sections of riffles and pools. Outcroppings of the bitumen-impregnated McMurray Formation and the Devonian Waterways Formation occur in the downstream 15-km stretch of the Steepbank River.

<u>The Muskeg River</u> watershed (1480 km^2) drains an area of forest and muskeg. The Muskeg River originates in the Muskeg Mountains uplands and flows 110 km to its confluence with the Athabasca River. Hartley Creek (drainage area, 325 km^2) joins the Muskeg River 33 km upstream of its confluence. Stanley Creek (66 km^2), a minor tributary, flows southeasterly to the Muskeg River. Kearl Lake (surface area, 5.4 km^2; maximum depth, 2 m) occurs within the watershed. The Kearl Lake tributary enters the Muskeg River from the southeast between Stanley and Hartley Creeks.

The upper reaches of the Muskeg River are well drained as the river flows over steep channel slopes. As the river flows to the southwest, gradient is reduced and muskeg is a characteristic feature of the watershed. The river gradient increases in the downstream 16 km section where oil sands of the McMurray Formation and limestone of the Devonian Waterways Formation are exposed (Northwest Hydraulics Consulting Ltd. 1975). Bitumen-impregnated sands also are exposed in the lower reaches of Hartley Creek.

<u>The Firebag River</u> watershed (6138 km^2) drains into the Athabasca River, 113 km north of Fort McMurray. The Marguerite River (1746 km^2) and the Firebag River above the confluence of the Marguerite are the two major sub-basins of the watershed. The confluence of the sub-basins is about 45 km upstream from the mouth of the Firebag.

Headwater regions for the sub-basins occur outside of the AOSERP study area. Upstream, watercourses meander through the Firebag

Plain; beaver dams are frequent. Stream gradient is moderate and bitumen deposits are exposed along the Firebag and Marguerite Rivers. Downstream of the confluence of the Marguerite, river gradient is low as the meandering river enters the Athabasca Plain.

Groundwater contribution to the Firebag watershed is substantial, maintaining base flows and moderating water temperatures in summer (Northwest Hydraulics Consulting Ltd. 1975).

The Richardson River watershed is located on granite rocks of the Precambrian Shield. The river drains a watershed area of 2925 km^2 of which 56% is located in the province of Saskatchewan (Northwest Hydraulics Consulting Ltd. 1975). The Richardson River forms a sand/silt delta where it enters the Athabasca River, about 35 km upstream of Lake Athabasca. Sand riverbed and bank material in the downstream Richardson River reach enhances percolation of precipitation to groundwater sources. Numerous lakes within the watershed also reduce surface runoff and maintain high base flows.

5.1.3 Physical Description of Study Streams

Erosional and depositional habitats can be discerned from elevation profiles of rivers (Figure 20). Sekerak and Walder (1980) present elevation profiles and associated channel characteristics for the Firebag, Muskeg, and Steepbank rivers. Although no information is available on channel characteristics for the Richardson River, general features may be inferred from the elevation profile of the river (NTS maps 74E, F, and L).

The Richardson River was arbitrarily subdivided into reaches based on the elevation profile presented in Figure 20. The major portion of the river has characteristically steep gradients (Reach 4, 5 m/km; Reach 3, 9.1 m/km; Reach 2, 4.6 m/km). Steep gradients are typical of erosional habitats which are characterized by fast flowing waters and coarse substrates. The downstream reach with a gradient of 0.5 m/km is likely characterized by placid flows and fine substrates.

The Firebag River is subdivided into four upstream, steep gradient reaches and two downstream, low gradient reaches. Riffle areas

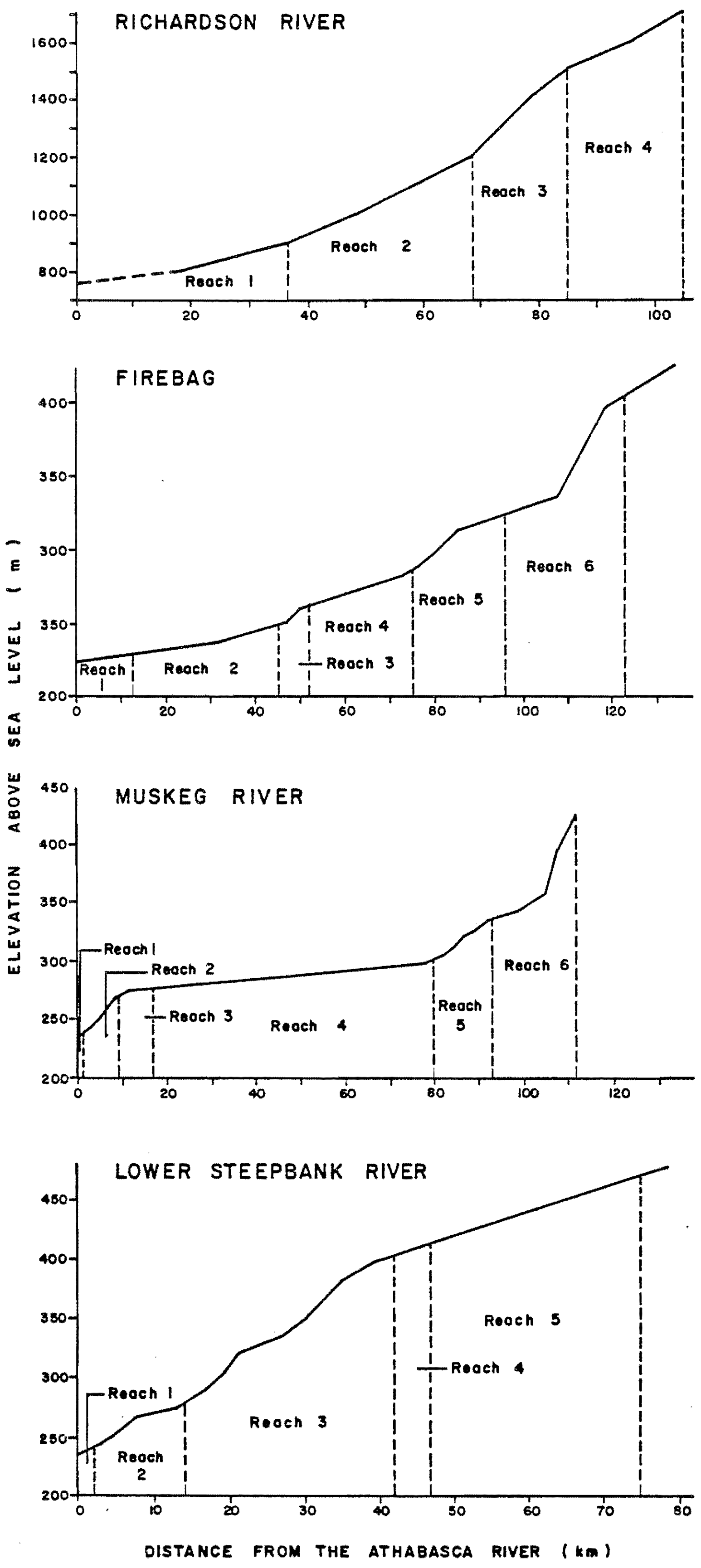


Figure 20. Elevation profiles of rivers in the eastern region.
(Adapted Sekerak and Walder, 1980)

and coarse substrates predominate in the upstream reaches; pools and fine substrates predominate in the downstream reaches. High banks are prevalent along the entire length of the river, particularly in Reaches 1 and 6.

The Muskeg River channel is characterized by steep gradients in the upstream and downstream reaches. The river, however, is low in gradient for most of its length (Reach 4). Beaver dams and associated pools are prevalent within Reach 4. Mud and silt characterize the greater portion of the Muskeg River, shifting to coarse gravel and boulders in the downstream 15 km.

Sekerak and Walder (1980) restricted their investigation of the Steepbank River to the downstream reaches. Here, erosional habitats prevail. Although Reach 5 is depositional in nature, there is a shift from fine to coarse substrates and from pools to riffles in the downstream 45 km of the river. Reach 2 is characterized by canyon walls 60 km high.

5.2 BASELINE DATA

5.2.1 Discharge

Five Water Survey of Canada gauging stations within the eastern region were selected for study (Table 7; Figure 4). The stations were located near the mouth of the major rivers (Steepbank, Muskeg, Hartley, Firebag, and Richardson) and the recorded flow represented surface water drainage from each of the watersheds.

Mean daily discharge (1 in 5 days) is presented for the Steepbank (1976 to 1980), Muskeg (1976 to 1981), Hartley Creek (1976 to 1981), Firebag (1976 to 1979) and Richardson (1977 to 1979) rivers in Figures 21 to 25. The discharge years were selected for illustration because they corresponded to the water quality sampling regime.

Of the five rivers, the Firebag, with the largest drainage area (6138 km^2), contributed the greatest flow to the Athabasca mainstem. The mean annual discharge for the Firebag River was 22.0 m^3/s, 30.0 m^3/s, and 27.4 m^3/s in 1977, 1978, and 1979,

Table 7. Water Survey of Canada gauging stations in the east.

Station	Description	Drainage Area (km)	Gauge Location (Lat N/Long W)	Period of Record	Gauge Type[a]
07DA006	Steepbank R.	1379	57 00 17	1972-73	RS
			111 24 63	1974-pres.	RC
07DA008	Muskeg R.	1460	57 11 30	1974-pres.	RC
			111 34 05		
07DA008	Hartley Ck.	357	57 15 34	1975	RS
			111 27 53	1976-pres.	RC
07DC001	Firebag R.	6030	57 38 30	1971	RS
			111 10 30	1972-pres.	RC
07DD002	Richardson R.	2950	58 21 48	1970-pres.	RC
			111 14 14		

[a] R = recording gauge; S = seasonal operation; C = continuous operation.

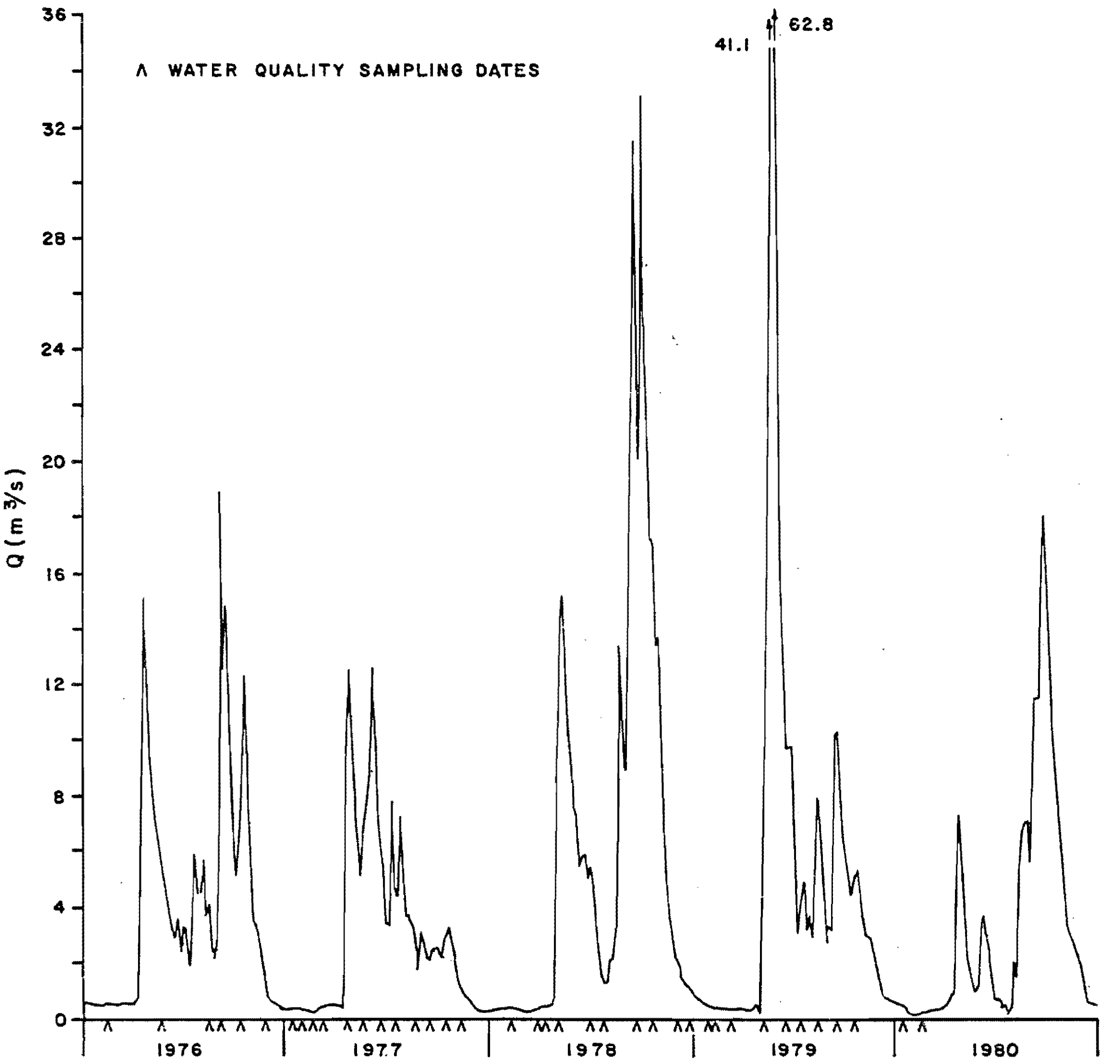


Figure 21. Daily discharge (1 in 5) in the Steepbank River, 1976-1980.

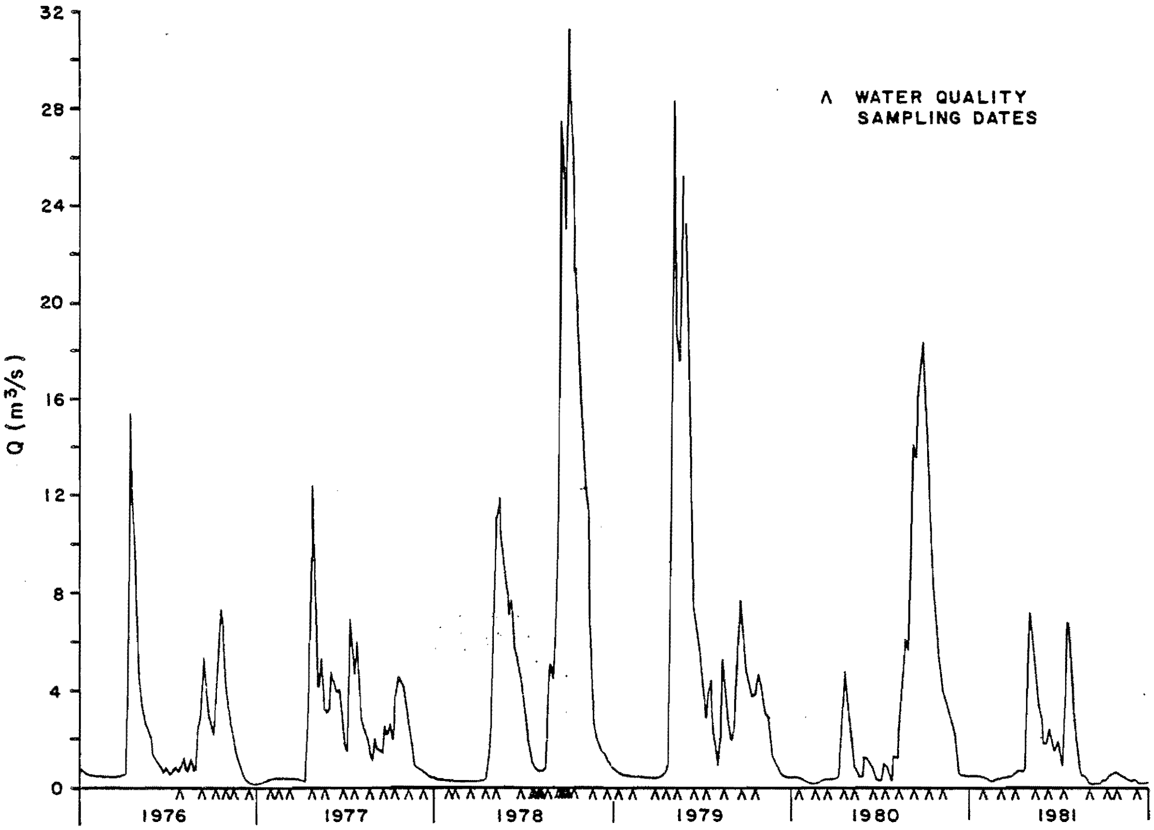


Figure 22. Daily discharge (1 in 5) in the Muskeg River, 1976-1981.

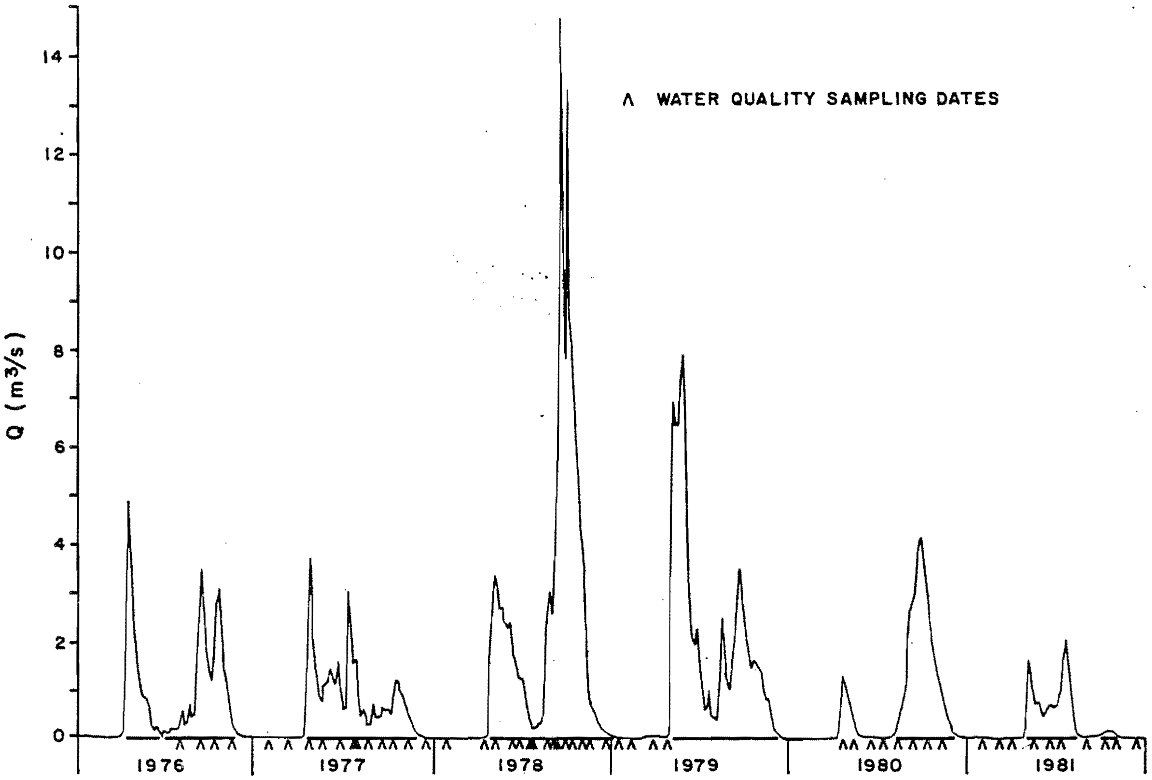


Figure 23. Daily discharge (1 in 5) in Hartley Creek, 1976-1981.

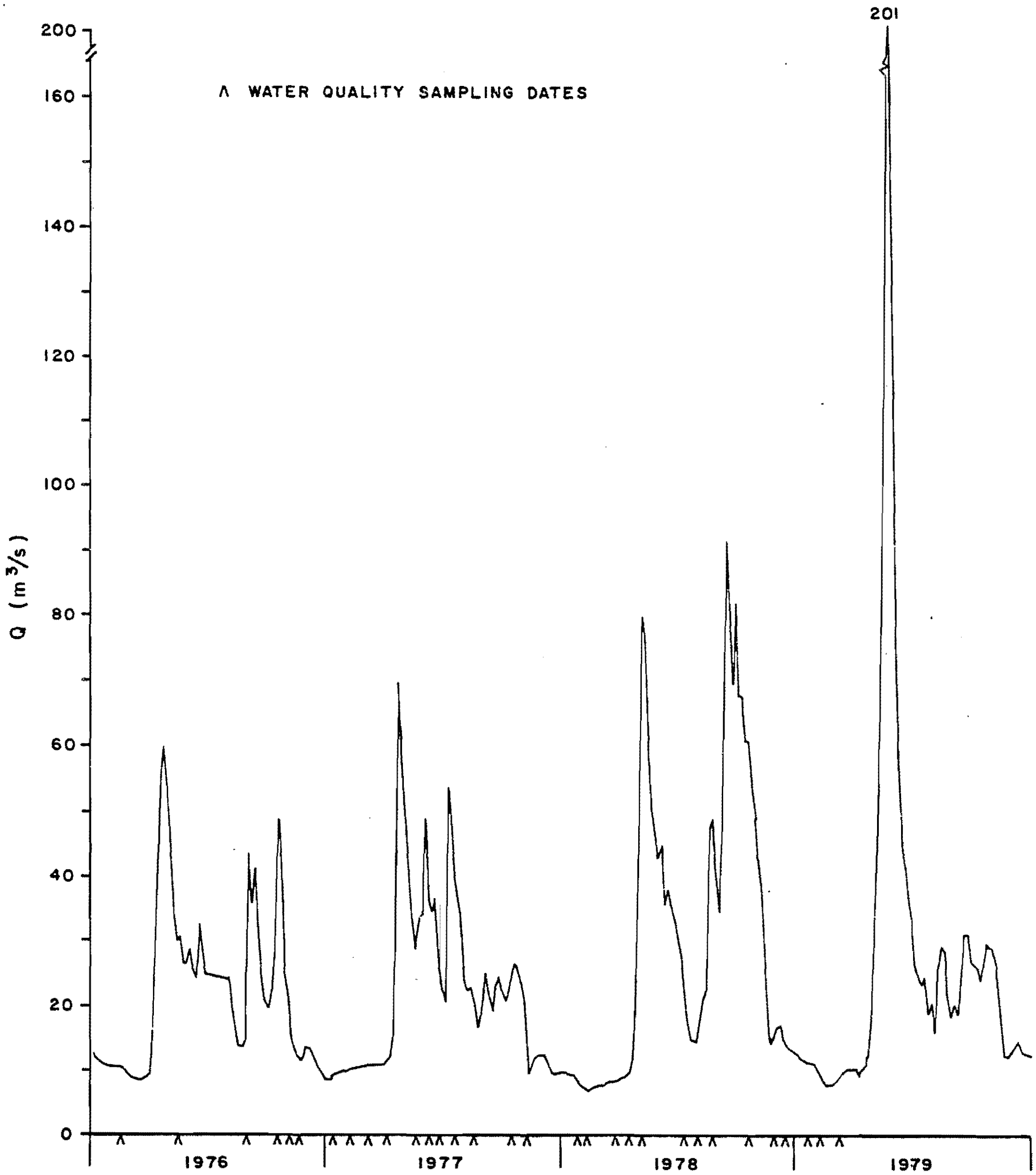


Figure 24. Daily discharge (1 in 5) in the Firebag River, 1976 - 1979.

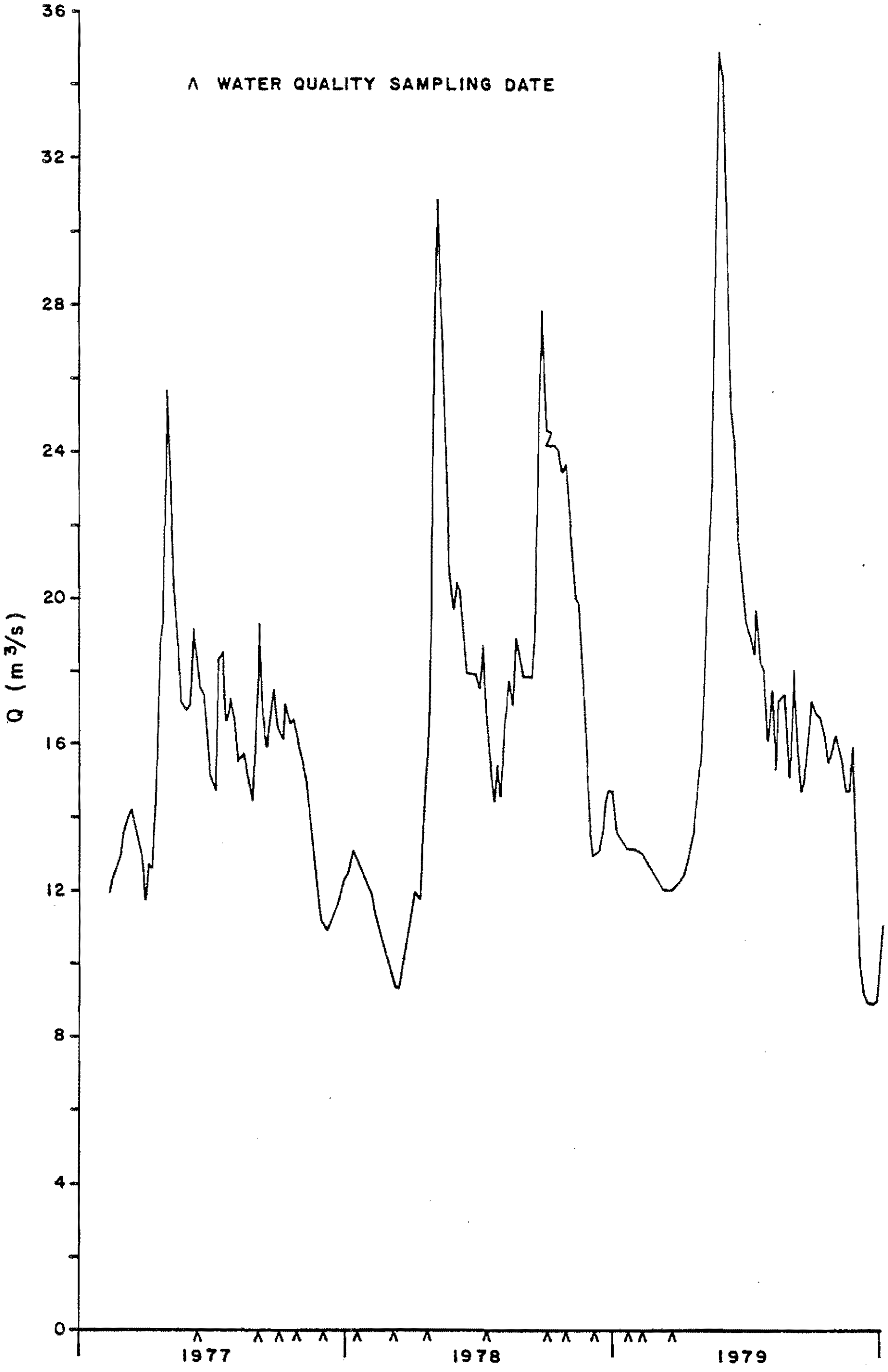


Figure 25. Daily discharge (1 in 5) in the Richardson River, 1977-1979.

respectively. Mean flow data were unavailable in 1976 because of interrupted records. Maximum flows occurred in April and May, with maximum mean monthly flows ranging from 37.7 to 113.5 m^3/s between 1976 and 1979. Elevated flows occurred occasionally in summer or fall as a result of storms. Winter base flows ranged from 7.5 to 11.0 m^3/s

The mean annual discharge for the Richardson River was 15.2 m^3/s, 17.0 m^3/s, and 16.1 m^3/s in 1977, 1978, and 1979, respectively. Maximum mean monthly discharge occurred in May, with flows ranging from 18.4 to 28.9 m^3/s during the three years. Elevated flows may occur in the fall as a result of flood conditions (e.g., 1976, 1978). Winter base flows ranged from 9 to 15 m^3/s.

The mean annual discharge for the Muskeg River varied considerably, ranging from 1.3 to 5.9 m^3/s during a six-year period (1976 to 1981). Maximum mean monthly flows occurred during September in 1978 (21.9 m^3/s) and 1980 (15.5 m^3/s). Maximum mean monthly flows during spring runoff (April/May) ranged from 2.7 to 21.4 m^3/s during the six years. Winter base flows ranged from 0.2 to 0.5 m^3/s (Figure 22).

The discharge pattern for Hartley Creek, a major tributary of the Muskeg River, followed that of the larger river. Discharge differences occurred only in amplitude (Figure 23).

Mean annual flow in the Steepbank River ranged from 3.0 to 6.4 m^3/s during the five-year period (1976 to 1980). Maximum mean monthly flow occurred in September (1978 and 1980) as a result of rainstorms. Maximum mean monthly flows during spring runoff ranged from 3.6 to 30.1 m^3/s during the five years. Winter base flows ranged from 0.2 to 0.5 m^3/s.

5.2.2 Water Quality

Water quality sampling sites within the eastern region are presented in Table 8. Only sites with sufficient data (more than 10 samples) were selected for analysis. Data used in the analysis are summarized in Appendix 10.4 (Tables 62 to 64). Water quality data were available for each of the major rivers within the region including Steepbank, Muskeg, Hartley, Firebag, and Richardson rivers.

Table 8. Description, period of record and number of samples obtained for water quality sampling stations within the eastern region. See Figure 4 for location of sites.

Watershed	Code (00AT07-)	Latitude N Longitude W (D M S)	Description	Period of Record	Number of Samples
Muskeg	DA0079	57 08 05 111 36 08	Muskeg River near mouth	1976-78	10
	DA0080	57 11 30 111 34 05	Muskeg River at at WSC gauge	1976-81	77[a]
	DA0081	57 08 03 111 35 53	Muskeg River above Shell pumping above Hartley Creek	1976-81	17[a]
	DA0082	57 14 18 111 24 55	Hartley Creek 3.2 kmupstream from mouth	1976-81	10
	DA0083	57 21 08 111 22 44	Stanley Creek	1976-77	11[a]
	DA0084	57 18 14 111 22 30	Kearl Lake tributary 1.6 km upstream from Muskeg River	1976-78	16[a]
	DA0085	57 25 00 111 13 16	Muskeg River 11.2 km upstream from Stanley Creek	1976-81	26[a]
	DA0086	57 22 48 111 16 44	Muskeg tributary 5.6 km upstream from Stanley Creek and 0.8 km upstream from Muskeg River.	1976-77	10
	DA0087	57 11 21 111 23 44	Hartley Creek SW fork 0.4 km from junction with SE fork	1976-77	9
	DA0088	57 09 23 111 23 27	Hartley Creek, SE fork 0.4 km from junction with SW fork	1976-77	9
	DA0089	57 15 08 111 21 54	Tributary to Muskeg River, 4.8 km upstream from Hartley Creek	1977	7

continued . . .

Table 8. Concluded.

Watershed	Code (00AT07-)	Latitude N. Longitude W. (D M S)	Description	Period of Record	Number of Samples
	DA0090	57 15 34 111 27 53	Hartley Creek, 0.4 km above confluence with Muskeg River, WSC gauge	1976-81	53[a]
	DA0091	57 15 42 111 19 18	Tributary leading to Kearl Lake	1976-77	10
	DA0092	57 16 15 111 15 01	Kearl Lake outlet	1976-78	10
	DA0093	57 16 28 111 13 30	Kearl Lake inlet	1976-77	7
	DA0094	57 20 41 111 07 50	Muskeg River, 22.5 km upstream from Stanley Creek	1976-77	6
	DA0095	57 06 06 111 23 07	Hartley Creek, SW fork 16 km from junction with SE fork	1976-77	10
	DA0096	57 04 22 111 11 18	Hartley Creek, SE fork 21 km from junction with SW fork	1976-77	8
Steepbank	DA0060	57 00 17 111 24 53	Steepbank River, 7.2 km upstream from mouth, WSC gauge	1976-80	39[a]
Firebag	DC0010	57 38 30 111 10 30	Firebag River, WSC gauge	1976-79	31[a]
	DC0011	57 44 35 111 21 03	Firebag River near mouth	1977	3
	DC0020	57 17 20 110 27 50	Lost Creek, 0.8 km above mouth, WSC gauge	1976-78	9
Richardson	DD0020	58 21 48 111 14 14	Richardson River WSC gauge	1977-79	15[a]

[a] Sites with sufficient numbers to be analysed.

5.2.2.1 Routine parameters. A summary of routine parameters for the region is presented in Appendix 10.4 (Table 62).

Surface waters of the Richardson River are relatively low in pH levels (6.7 to 7.8), poor in buffering capacity (alkalinity, maximum 47 mg/L) and low in conductivity (maximum 100 uS/cm). These water quality values, which are characteristic of surface waters flowing over granite rock of the Precambrian Shield, clearly differed from waters of other drainages (Steepbank, Firebag, and Muskeg) which lie within sedimentary rock of the Interior Plain. Surface waters of the Steepbank, Muskeg, and Firebag watersheds were relatively high in pH values (max. range 8.1 to 8.7), well buffered (alkalinity maximum 184 to 362 mg/L) with elevated conductivity levels (max. range 320 to 704 uS/cm). Values of filterable residue (total dissolved solids) varied directly with conductivity.

The relative contribution of major ions is presented in Figure 26. The extent of the ion concentration reflected in the Stiff diagrams illustrates the low conductivity and restricted range of ion values in the Richardson River compared to levels in the Steepbank, Muskeg, and Firebag watersheds. Calcium bicarbonate was the dominant dissolved salt in all watersheds.

Other differences between granite and sedimentary rock include the thickness of overlying top soil and weathering of rock material. Soil layers in the Precambrian Shield are thin and the rock material erodes slowly. Soil layers overlying sedimentary rock are thick and high in organic content; slumping of river banks contributes to the sediment load. Thus, median values of total organic carbon (3 mg/L) and total inorganic carbon (10 mg/L) observed in the Richardson River were noticeably lower than corresponding values for the other watersheds. The muskeg drainage of the Firebag, Muskeg, and Steepbank contributes to the organic carbon in the three watersheds.

Non-filterable residue (suspended solids) tends to vary directly with discharge levels. Thus, maximum residue values are recorded during spring runoff or other storm events. Again, values for the Richardson River were consistently lower than the other watersheds

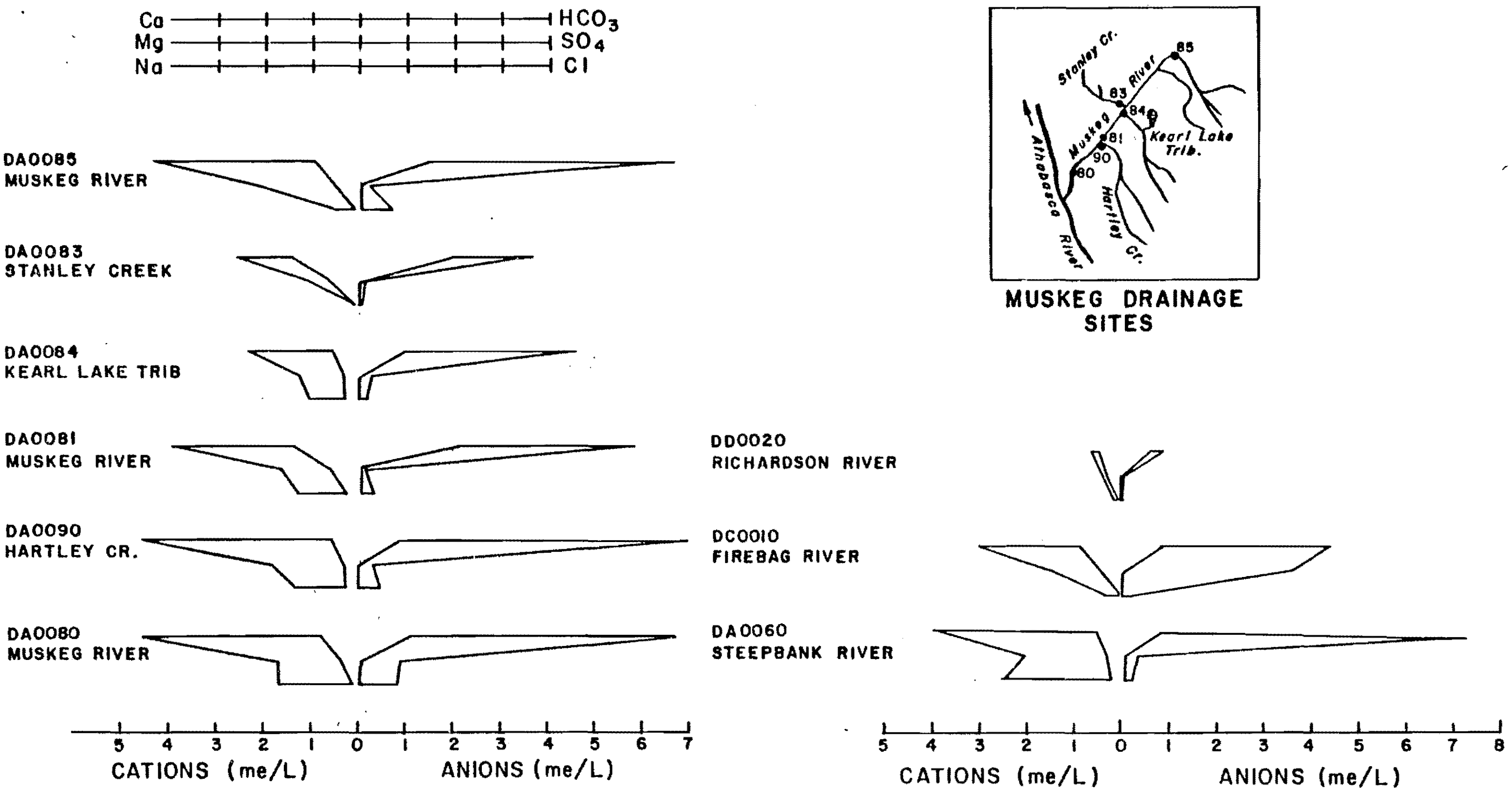


Figure 26. Maximum and minimum values (me/L) of major ions in rivers of the east.

(Appendix 10.4, Table 62). The maximum value of non-filterable residue was recorded in Hartley Creek (459 mg/L).

Colour is a measure of water clarity. Maximum values were lower in the Richardson (50 units) and Firebag (90 units) than in the Steepbank (180 units), Muskeg (140 units), or Hartley Creek (140 units).

Sources of phenolic material include industrial and municipal wastes as well as decaying plant material. Values for the Richardson River were below the detection limit. Maximum recorded values for the other sampling sites exceeded the Alberta surface water objectives (0.0005 mg/L). Similarly, oil and grease values for the Richardson River (max. 0.7 mg/L) were substantially lower than for the other rivers (max. range 2.1 to 12.9 mg/L). Highest oil and grease levels were recorded for the Muskeg River.

5.2.2.2 Nutrients. Phosphorus and nitrogen are the major nutrients controlling plant growth. Accordingly, the constituents in surface water vary seasonally.

Total phosphorus and orthophosphate phosphorus (PO_4-P) are the two forms of phosphorus recorded in Appendix 10.4 (Table 63). Although total phosphorus increases with increasing discharge, it is the particulate not the dissolved portion which increases substantially as a result of runoff. PO_4-P increases as a result of enrichment (natural or domestic sewage). Total phosphorus values of the Richardson River (max. 67 ug/L) were less than the other rivers within the eastern region (max. range 138 to 330 ug/L), reflecting the low levels of erosion from granite material. The PO_4-P values for the Richardson River (max. 42 ug/L) were within the range recorded for the other sampling sites (max. range 28 to 150 ug/L). Highest values were recorded in the Steepbank Rivers.

Nitrate/nitrite, ammonia, and total kjeldahl nitrogen are the three forms of nitrogen regularly recorded in surface waters. Total kjeldahl nitrogen is a measure of total organic nitrogen plus ammonia. Inorganic nitrogen includes ammonia and nitrate/nitrite nitrogen. Nitrogen forms vary seasonally as a function of dilution at high discharge levels, temperature, uptake by plants, and loss to the atmosphere.

Richardson River ammonia values (max. 0.1 mg/L) were lower than the other sampling sites (0.2 to 3.9 mg/L). Values for other nitrogen forms in the Richardson River were within the range recorded at other sampling sites (Appendix 10.4, Table 63).

5.2.2.3 Metals. Concentrations of metals in surface waters are attributed to weathering of surficial material and groundwater discharge, as well as municipal and industrial wastes. The metals, which were predominant in surface waters of the eastern region, were iron, manganese, aluminum, and arsenic (Appendix 10.4, Table 64). Concentrations of boron, cadmium, chromium, lead, selenium, and silver in the rivers were all less than the Alberta Surface Water Objectives.

Median values of iron concentrations exceeded the Alberta objectives (300 ug/L or 0.3 mg/L) for all five eastern tributaries. The range of iron concentrations for the rivers are as follows:

Code	River	Range Fe (mg/L)
DA0060	Steepbank	0.42 to 3.70
DA0080	Muskeg	0.35 to 10.50
DA0090	Hartley	0.40 to 10.70
DC0010	Firebag	0.07 to 2.06
DD0020	Richardson	0.36 to 0.82

Iron concentrations typically vary directly with discharge, and suspended material is a result of weathering processes. The maximum iron concentration of the Richardson River was lower than the other tributaries and was related presumably to the lower erosion levels characteristic of granite rock.

Manganese is similar to iron in its chemical behaviour and is often found in association with iron (McNeely et al. 1979). Maximum manganese concentrations in surface waters of the Steepbank (500 ug/L), Muskeg (2300 ug/L), Hartley (2150 ug/L), and the Firebag (790 ug/L) rivers exceeded the Alberta Surface Water Objectives of 50 ug/L.

Manganese concentrations in the Richardson River were within the provincial guidelines.

Aluminum concentrations in surface waters are limited to soluble salts. The maximum values of the eastern tributaries (except the Steepbank River) were less than 1000 ug/L (Appendix 10.4, Table 64) which is within the range of aluminum concentrations in most surface waters (McNeely et al. 1979). The maximum aluminum value (5600 ug/L) was recorded in the Steepbank River during runoff (1978 May 03).

Non-compliance with surface water objectives was noted for arsenic, copper, and mercury. Arsenic concentrations exceeded the ASWO (0.01 mg/L) in the Steepbank, Muskeg, Hartley, and Firebag Rivers. Most elevated values were recorded in winter months. Mercury concentrations exceeded the objectives (0.1 ug/L) in all five major tributaries.

5.2.3 Benthic Invertebrates

A summary of benthic invertebrate studies conducted in streams throughout the eastern region is presented in Table 9. Because several projects were initiated by proponents of oil sands development including Alsands (Mayhood et al. 1981; Corkum and McCart 1981), Petro Canada (Corkum and McCart 1981) and Sandalta (O'Neill et al. 1982), sampling sites were frequently restricted to lease areas. Other invertebrate studies were conducted to provide baseline data prior to oil sands development or as part of larger projects on aquatic resources (Barton and Wallace 1980; Walder et al. 1980).

Clearly, there was no consistant approach to the study of invertebrates with regard to type of sampler, sampling effort, mesh size through which samples were washed, or sample frequency. Also, no one sampler can be used with equal efficiency in erosional and depositional habitats. For example, kick nets, cylinder and surber samplers were used in erosional habitats; Ekman grab and airlift pumps were used in depositional habitats. Sampler selection is discussed in detail by Merritt et al. (1978) and Mayhood et al. (1981).

Table 9. Summary of benthic invertebrate studies in streams of the east.

Water Body	Reference	Sample Year	Sampler Mesh Size	Sites	Month/Season	Habitat[a]	Dominant Taxa
Steepbank River	Barton & Wallace (1980)	1976-77	Kick - 15 min. 500 um	7 2	05, 07, 10, 01	E D	Chironomidae, Ephemeroptera Lower Phyla[b], Oligochaeta
			Surber 202 um	2	06 to 10	E	Ephemeroptera, Simuliidae, Oligochaeta
			Airlift 202 um	1	06 to 10	D	Chironomidae
	Walder et al. (1980)	1978	Kick ? um	3 1	spring, fall "	E D	Not indicated[c] "
Muskeg River	Barton & Wallace (1980)	1976-77	Kick - 15 min. 500 um	6 3	05, 07, 10 01	E	Ephemeroptera, Chironomidae
	Corkum & McCart (1981)	1980	Airlift - 60s 500 um	8	09	D	Chironomidae, Mollusca, Oligochaeta
	Corkum & McCart (1982)	1981	Airlift - 30s 500 um	3	03, 05, 07, 10	D	Mollusca, Oligochaeta
			Kick - 30s 500 um	1	03, 05, 07, 10	E	Ephemeroptera, Trichoptera
	Crowther & Lade (1981)	1979	Cylinder 250 um	2 1	07, 08, 09 07, 08	E D	Trichoptera, Ephemeroptera, Chironomidae Diptera, Amphipoda
	Mayhood et al. (1981)	1980	Multiplate[d]	8	07, 08, 10[e]	E/D	Ephemeroptera, Hydra

continued . . .

Table 9. Continued.

Water Body	Reference	Sample Year	Sampler Mesh Size	Sites	Month	Habitat	Dominant Taxa
			Ekman 470 um	5	04, 06, 07, 08,10	D	Oligochaeta, Ceratopogonidae
			Cylinder 770 um	2	04, 06, 07, 08, 10	E	Elmidae, Plecoptera, Trichoptera
			Kick - 30s 770 um	5	04	E/D	Simuliidae, Elmidae
	Walder et al. (1980)	1979	Kick ? um	3 2	09 09	E D	Not indicated[c] "
Stanley Creek	Corkum & McCart (1981)	1980	Airlift - 60s 500 um	1	09	D	Chironomidae, Oligochaeta
Hartley Creek	Crowther (1979)	1976-77	Surber 250 um	3	05 to 10	E	Not indicated[c]
			Cylinder 250 um	3	05 to 10	E	Not indicated[c]
			Airlift 250 um	1	05 to 10	D	Not indicated[c]
			Ekman 250 um	1	05, 07 to 10	D	Not indicated[c]
	Hartland-Rowe et al. (1979)	1977	Cylinder 250 um	1	05, 07, 08	E	Chironomidae, Trichoptera, Ephemeroptera
			Surber 250 um	1	05, 07, 08,	E	"

continued . . .

Table 9. Concluded.

Water Body	Reference	Sample Year	Sampler Mesh Size	Sites	Month	Habitat	Dominant Taxa
	Mayhood et al. (1981)	1980	Ekman 470 um	1	04, 06, 07, 08, 10	D	Oligochaeta, Ceratopogonidae
			Kick - 30s 770 um	1	04	D	Simuliidae, Elmidae
	O'Neil et al. (1982)	1981	Cylinder 250 um	1	05, 07, 09	E	Chironomidae, Trichoptera
			Ekman 250 um	2	05, 07, 09	D	Chironomidae, Oligochaeta Nemata, Mollusca
	Walder et al. (1980)	1979	Kick ?um	4	09	D	Not indicated[c]
Firebag River	Walder et al. (1980)	1978	Kick ? um	4	Spring, fall	E	Not indicated[c]
				1	Spring, fall	D	Not indicated[c]
Marguerite River	Walder et al. (1980)	1978	Kick ? um	3	Spring, fall	E	Not indicated[c]
				2	Spring, fall	D	Not indicated[c]

[a] Habitat: E, erosional; D, depositional.

[b] Lower Phyla includes Porifera, Cnidaria, Turbellario, Nematoda, Nematomorpha, Hirudinea, Mollusca, Tardigrada, Crustacea.

[c] Relative abundance not indicated, but list of taxa provided in original report.

[d] Multiplate (Hester-Dendy) artificial sampler.

[e] Multiplate samplers positioned in river during May/June and retrieved in July, August, and October; many samples in August and October were lost.

? = Mesh size not reported.

Differences in faunal composition recorded in eastern tributaries reflect differences between erosional and depositional habitats (Table 9). Erosional habitats are characterized by shallow, swift flowing, well oxygenated water with a streambed of coarse substrates. Depositional habitats are characterized by deep, slow flowing water often low in oxygen and with a streambed of fine (organic, sand, silt) substrates. Clean water organisms such as Ephemeroptera, Plecoptera, Trichoptera, and Orthocladiinae occur in erosional habitats. Oligochaeta, Chironominae, and Mollusca are typically found in depositional habitats.

Because of differences in sampling techniques and level of taxonomic identification, and lack of access to the raw data, a summary of analyses of invertebrates or factors influencing their distribution will not be presented.

5.3 RELATIONSHIPS AMONG PARAMETERS

The objective was to develop relationships between water quality constituents and discharge. Since specific conductance is a function of discharge, a correlation analysis was performed between conductivity and other water quality parameters to select those few significant parameters from the suite available for subsequent analysis with reference to discharge.

Results from the correlation analysis performed using median values of water quality parameters (listed in Appendix 10.4, Tables 62 to 64) indicated that ammonia, iron, and manganese were significantly correlated with conductivity ($P<0.01$). These four parameters were used to develop regression relationships with discharge, using data from each sampling date. Relationships were developed for the Richardson (DD0020), Firebag (DC0010), Muskeg (DA0080), and Steepbank (DA0060) rivers using linear, log/linear, and log/log transformations of the data.

Equations with the best fit (i.e., least variability and highest R^2) were selected and are presented in Table 10. The

Table 10. Summary of regression equations of conductivity (SC), ammonia (NH_3), iron (Fe), and manganese (Mn) with discharge for the major eastern rivers. Equations with the best fit of the data were of the following format:

linear	$Y = A + Bx$	(1)
log/linear	$Y = Ae^{Bx}$	(2)
log/log	$Y = Ax^{B}$	(3)

where: A = intercept, B = slope, Y = dependent variable (water quality); and
X = independent variable (discharge), df = degrees of freedom.

Water Body	Equation Format (1, 2, 3)	df (n-2)	Y	A	B	R^2	p ($Ho:B_1=0$)
Richardson (DD0020)	3	13	SC	216.80	-0.334	.47	L0.01
	1	11	NH_3	88.38	-4.067	.33	L0.05
	2	12	Fe	481.06	0.011	.05	ns
	1	12	Mn	53.85	-1.293	.27	ns
Firebag (DC0010)	3	31	SC	531.13	-0.332	.69	L0.001
	1	24	NH_3	73.70	-0.855	.11	ns
	1	26	Fe	420.44	10.560	.35	L0.001
	1	26	Mn	29.77	0.398	.16	L0.05
Muskeg (DA0080)	3	66	SC	498.70	-0.397	.69	L0.001
	3	66	NH_3	205.00	-0.835	.29	L0.001
	3	66	Fe	1822.56	-0.445	.36	L0.001
	3	66	Mn	260.86	-1.012	.44	L0.001
Steepbank (DA0060)	3	37	SC	637.78	-0.649	.89	L0.001
	2	33	NH_3	61.81	-0.101	.21	L0.01
	1	37	Fe	835.07	54.381	.21	L0.01
	2	37	Mn	28.25	0.091	.40	L0.001

L = less than.

significance of each regression equation was tested by determining if the slope differed significantly from zero.

There was a significant inverse relationship between conductivity and discharge for four rivers. Thus, conductivity levels were high during low flow periods and vice versa. The four regression analyses were compared using analysis of covariance. However, since residual variances among rivers were heterogeneous (Bartlett's test for more than two groups), further comparisons of slope and intercept were inappropriate.

Ammonia concentrations were also inversely correlated with discharge, with highest concentrations of ammonia being present in winter months. The regression equation between variables was not significant for the Firebag River, but significant associations were established for the Richardson, Muskeg, and Steepbank rivers. Because the residual variances among the Richardson, Muskeg, and Steepbank rivers were heterogeneous, a statistical comparison among the regression lines was not conducted. There was, however, a trend for ammonia levels to decrease more rapidly with discharge in the Richardson River than in the Muskeg or Steepbank rivers.

There were no significant predictable relationships between either iron and discharge or manganese and discharge for the Richardson River. Iron and manganese typically increase in surface waters as a result of weathering of the surficial material. Because soil layers overlying granite rocks are usually thinner than soils overlying sedimentary rocks, no significant association between parameters was anticipated in the Richardson watershed.

There was a significant direct relationship between iron and manganese with discharge in the Firebag and Steepbank rivers. Surprisingly, there was an inverse relationship between these parameters in the Muskeg River, indicating that groundwater inputs may have elevated levels of iron and manganese.

5.4 IMPACT OF DEVELOPMENT

Several short-term monitoring programs were established throughout the Muskeg basin in response to anticipated oil sands development. Although development has ceased because of unfavourable economic conditions, one company (Alsands Energy Limited) had cleared and drained land from both mine and plant sites in 1980. A study conducted by Mayhood et al. (1981) was designed to determine the effect of mine and plant drainage on the Muskeg River.

Two events related to the development occurred during the environmental study:

1. Flood. Overflow of plant and mine site drainage ditches (April 1980) resulted in the inundation of surrounding lands and subsequent elevated levels of suspended sediments and turbidity in the Muskeg River.
2. Eutrophication. Fertilizer application to the mine site drainage area resulted in temporary nutrient enrichment in the Muskeg River.

After these events, changes were noted in the benthic algae and invertebrates in the Muskeg River. Changes in the benthic invertebrate community which occurred during the June sampling period may have resulted from the April flood. In June, total benthic invertebrate biomass and the abundance of detritivores and predators were reduced in the Muskeg River about 100 m downstream from the drainage site. Although algal biomass (cell volume) was enhanced as a result of enrichment, no change in algal community composition was noted. These biological responses were short term, with levels returning to pre-flood conditions on subsequent sampling trips. A settling pond and stepped drainage ditch were constructed by the industry, improving the quality of the drainage water during flood events.

6. THE WEST

Watersheds which are west of the Athabasca mainstem include the Beaver-Poplar, MacKay, Ells, and several tributaries draining the east slopes of the Birch Mountains. Sampling programs were not established in the McIvor or Buckton watersheds, both of which are located in the northern portion of the region.

6.1 BASIN FEATURES

6.1.1 Land Formations

Land formations of the western region delineated by Turchenek and Lindsay (1982) are presented in Figure 27.

The Boreal Mixedwood and Northern Boreal ecoregions occur within the western region. The Northern Boreal Ecoregion occupies the northwest portion of the study area which includes the McIvor basin and Namur, Gardinar, and Eaglenest lakes, as well as the headwater reaches of several streams. The Boreal Mixedwood Forest occupies the remaining area of the region.

The east slope streams originate in the Birch Mountain Uplands of the Northern Boreal Forest where there are extensive areas of organic soils. The downstream portions of the rivers lie within the Boreal Mixedwood Forest, flowing through poorly drained soils of the Buckton Plain. The Pierre, Eymundson, and Asphalt rivers flow through the Embarras Plain to the Athabasca River. The downstream portion of the Calumet lies within the Muskeg River Plain.

Peat deposits occupy 60 to 80% of the Muskeg River Plain. Here, the surficial deposits overlie the oil sands of the McMurray Formation or limestone of the Devonian Waterways Formation. In contrast, the northern Embarras Plain is characterized by sandy outwash deposits with a few (ca. 10%) peatland areas and, in some places, large migrating dunes. Underlying Devonian rock results in the formation of sinkholes.

The Ells and the MacKay rivers flow through the same physiographic regions from headwater (Wabasca-Athabasca Lowland) and

LEGEND:

1C	BRULE PLAIN
1D	McMURRAY LOWLAND
1H	DOVER PLAIN
1I	MacKAY PLAIN
1J	FORT HILLS UPLAND
3A	WABASCA PLAIN
3C	DUNKIRK PLAIN
3D	THICKWOOD HILLS UPLAND
6A	MUSKEG RIVER PLAIN
6B	EMBARRAS PLAIN
6C	BUCKTON PLAIN
6D	ATHABASCA DELTA PLAIN
7A	BIRCH MOUNTAINS UPLAND
7B	BIRCH MOUNTAINS ESCARPMENT
7C	GARDINER UPLAND
7D	McIVOR PLAIN

LEGEND:

CRETACEOUS – Upper

Ks	SMOKY GROUP – shale ; marine
Kd	DUNVEGAN FORMATION – sandstone , siltstone , silty shale ; deltaic to marine
Ksh	SHAFTESBURY FORMATION – shale ; marine

CRETACEOUS – Lower

Kpl	PELICAN FORMATION – sandstone ; marine
Kj	JOLI FOU FORMATION – shale ; marine
Kg	GRAND RAPIDS FORMATION – sandstone , siltstone , shale , coal ; shoreline complex
Kc	CLEARWATER FORMATION – shale , siltstone , sandstone ; marine
Km	McMURRAY FORMATION – sandstone , siltstone , oil impregnated ; nonmarine to deltaic

DEVONIAN – Upper

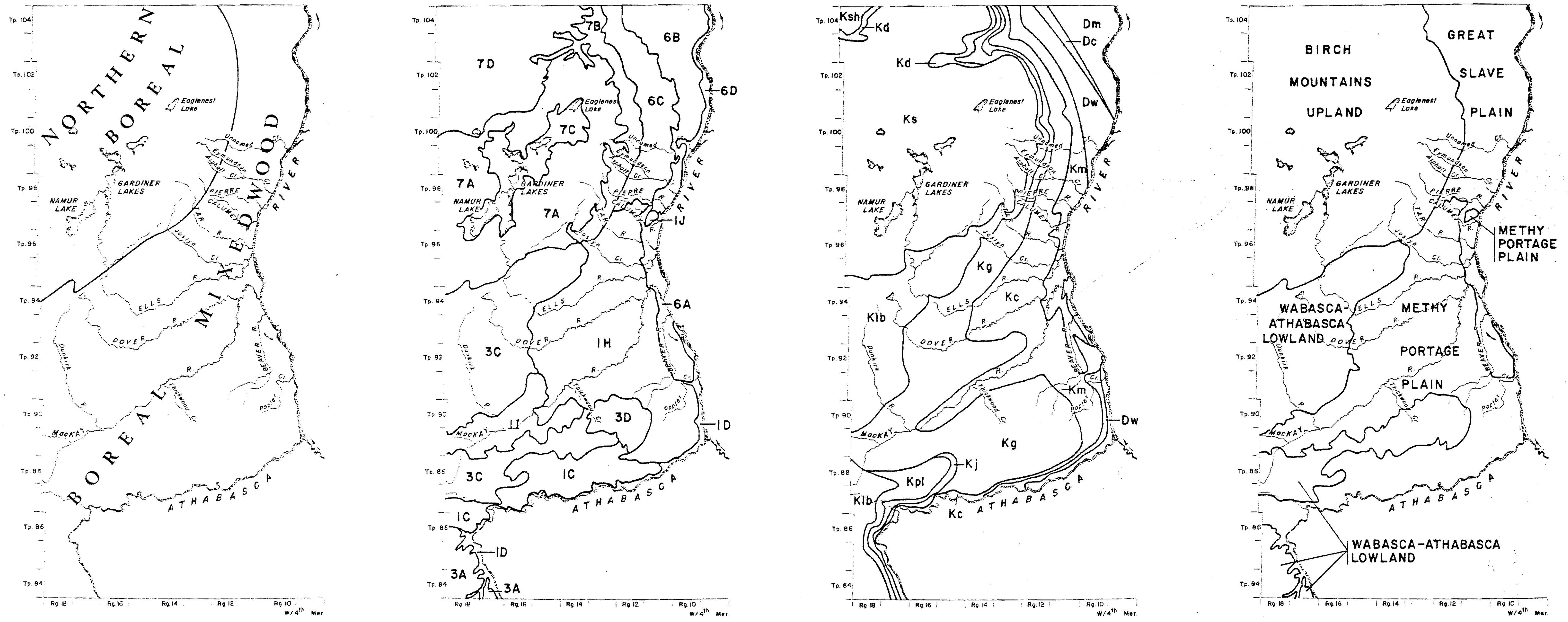
Dw	WATERWAYS FORMATION – shale , limestone ; marine
Dc	CARIBOU MEMBER , SLAVE POINT FORMATION – limestone ; minor shale , gypsum ; marine

DEVONIAN – Middle

Dm	METHY FORMATION – dolomite , dolomite limestone ; minor anhydrite and gypsum ; marine to evaporitic

CRETACEOUS – Upper and Lower

Klb	LABICHE FORMATION – shale , silty shale ; marine



ECOREGION

ECODISTRICT

GEOLOGY

PHYSIOLOGY

Scale – 1 : 150000

Figure 27. Land formations of the western region.
(Adapted from Turchenek and Lindsay, 1982)

middle (Methy Portage Plain) to downstream (Great Slave Plain) reaches. The Poplar-Beaver Creek drainage lies within the Methy Portage Plain (upstream and downstream reaches) and the Great Slave Plain (middle reaches).

Peat deposits and associated wetland vegetation occur in 80 to 90% of the headwater drainage area of the Ells and MacKay rivers. Peatlands occupy only 20 to 40% of the Methy Portage Plain (specifically the Dover Plain). Soils of the Dover Plain are characteristically saline. The Muskeg River Plain of the Great Slave Plain is characterized by glaciofluvial sands overlying oil sands and limestone.

6.1.2 Watersheds

Four major watersheds occur along the west bank of the Athabasca River, north of Fort McMurray, including (Figure 28):

1. Beaver-Poplar Creek;
2. MacKay River (including Dunkirk and Dover rivers);
3. Ells River;
4. Several rivers draining the east slope of the Birch Mountains (Tar River, Pierre River, Asphalt Creek, and Eymundson Creek).

The Beaver-Poplar Creek Diversion was constructed in 1977 to divert water from the mining operations of Syncrude Canada Ltd. A dam constructed on the slow flowing Beaver River formed the Beaver Reservoir. Diversion canals drain water from the reservoir to Ruth Lake and from the lake into Poplar Creek Reservoir. Water draining the reservoir enters (via a spillway) Poplar Creek which subsequently flows into the Athabasca River. Four streams which originally entered Beaver Creek now enter a channel which is called the West Interceptor Ditch. Three of the streams flow north of the plant site to the original Beaver Creek. The fourth stream flows southward to the Beaver Creek Reservoir.

The MacKay River watershed (5517 km^2) is the largest basin in the west bank region (Sekerak and Walder 1980). The MacKay River flows northeasterly for 200 km with an average gradient of 0.2% and drains an area of 2350 km^2. The Dunkirk (2183 km^2) and Dover (984 km^2) sub-basins

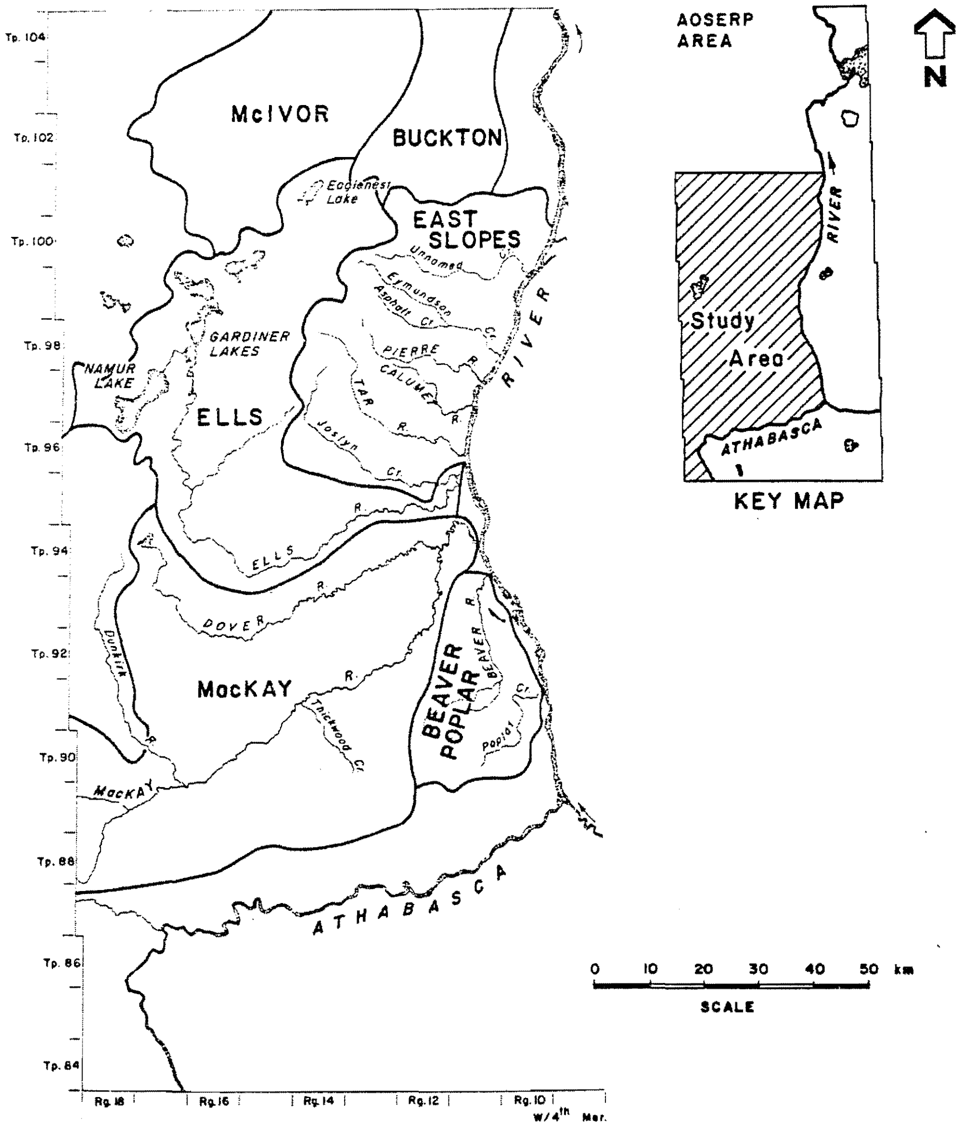


Figure 28. West surface water drainage.
(Adapted from Neill and Evans, 1979)

drain muskeg areas. The Dunkirk flows 150 km southeasterly and enters the MacKay River 89 km upstream from its confluence with the Athabasca River. The Dover flows northeasterly and enters the MacKay River 16 km upstream from its mouth.

The Ells River watershed (2707 km^2) has a mean gradient of 0.2% (Northwest Hydraulics Consulting Ltd. 1975; Hickman et al. 1980). Joslyn (264 km^2) and Chelsea (202 km^2) creeks are the two major sub-basins within the watershed. Lakes in the Birch Mountain headwaters also drain (1191 km^2) into the Ells River. The high storage capacity of the basin, owing to large lake and muskeg areas, moderates surface runoff and maintains high base flows in winter.

East draining streams of the Birch Mountain uplands include:

1. Tar River (324 km^2);
2. Calumet River (179 km^2);
3. Pierre River (137 km^2);
4. Unnamed River (337 km^2); and
5. Eymundson Creek (303 km^2).

Permafrost conditions probably contribute to valley wall instability in the Birch Mountain region. Characteristic stream bank slumping results in high sediment loads for the rivers.

6.1.3 Physical Description of the Study Streams

Beaver Creek Reservoir (max. depth 8 m) and Poplar Reservoir (max. depth 16 m) are the two lentic areas formed by the diversion scheme of Syncrude Canada Ltd. Groundwater discharge from the mine enters the Beaver Creek Reservoir and ultimately enters the Athabasca River via diversion canals through Ruth Lake, Poplar Creek Reservoir, and Poplar Creek.

Prior to diversion, the lower section of Poplar Creek was characterized as a slow moving meandering stream with sand/silt substrates. This section of Poplar Creek was subsequently channelized to receive increased flows (Noton and Chymko 1978).

The MacKay River is characterized by depositional and erosional habitats. Sekerak and Walder (1980) subdivided the MacKay

River into seven reaches including five relatively long (26 to 46 km) upstream and two short (1.4 to 3 km) downstream reaches (Figure 29). The two depositional upstream reaches of the MacKay River are characterized by a gradual slope (0.5 to 0.7 m/km), pools, fine substrates, and stable banks. The middle three reaches are steeper (1.3 to 2.4 m/km) with a series of riffles and pools, variable substrates depending on current regime, and unstable banks. The two downstream reaches of the river flow through a canyon with high (40 to 50 m) valley walls. The current regime is swirling and the streambed is composed of coarse substrates. Bitumen is present in valley walls and stream substrates.

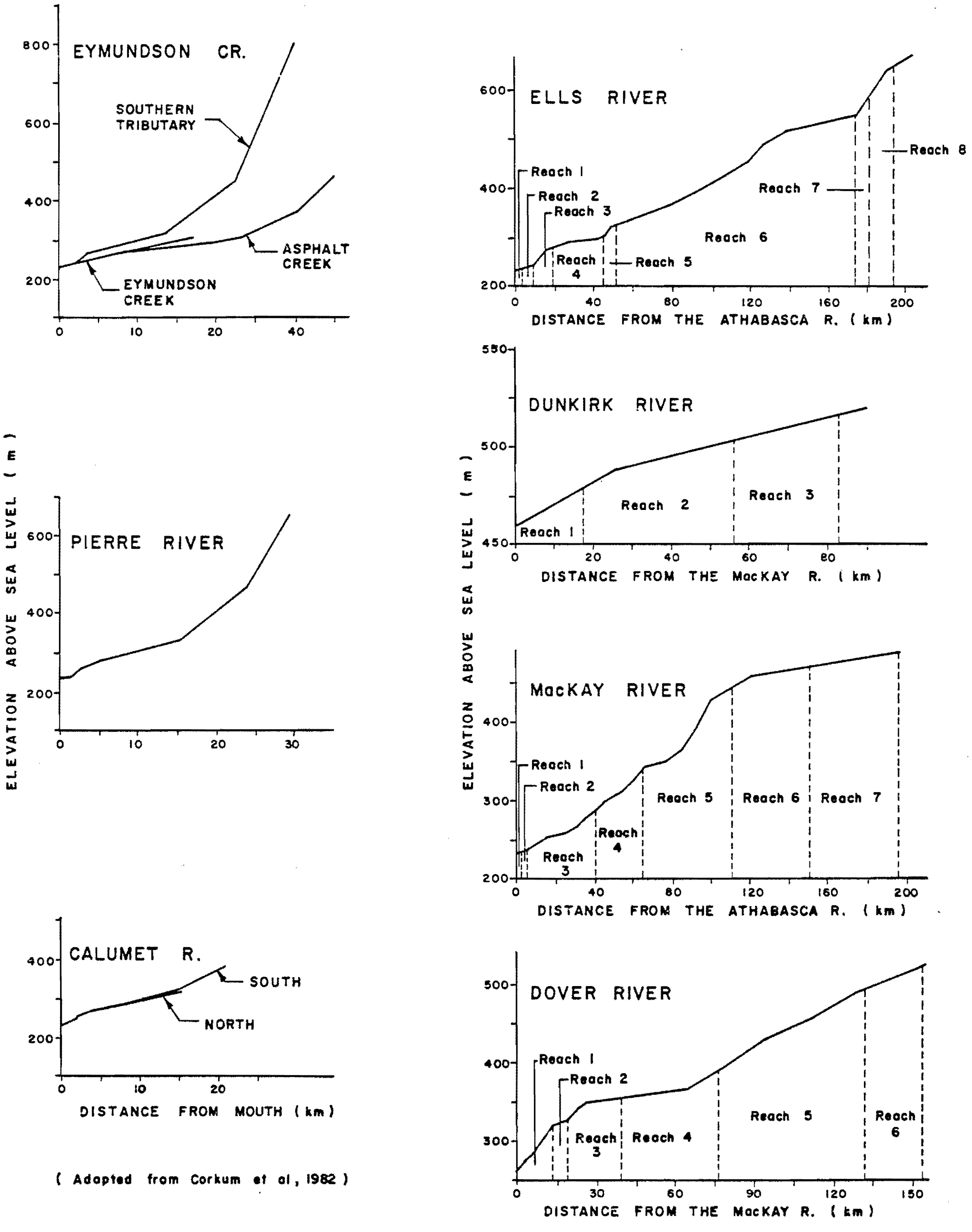
The Ells River is variable in slope throughout its length (Sekerak and Walder 1980). The gradient of the headwater reaches (ca. 20 km) which drain the Birch Mountains are very steep (5.0 to 7.2 m/km) with a series of riffles and pools as well as coarse substrates. In the mid portion of the Ells River (ca. 130 km) the gradient is reduced (1.9 to 4.1 m/km), but erosional conditions (riffles, coarse substrates) prevail. There is a shift to depositional habitats in the downstream section of the river.

Corkum et al. (1982) outlined the reach characteristics of streams draining the east slope of the Birch Mountains. The headwaters and mid regions of the Pierre and Asphalt rivers are characterized by erosional habitats (steep gradient, coarse substrates, riffles). In contrast, upper Eymundson Creek and the Calumet River are depositional for most of their lengths. The channel of the Calumet is ill-defined and beaver activity has impounded large areas of surrounding forests. All streams are depositional at their confluence with the Athabasca River.

6.2 BASELINE DATA

6.2.1 Discharge

Of the several gauging stations established within the western region, three were selected for study (Table 11; Figure 4). The



(Adapted from Corkum et al, 1982)

(Adapted from Sekerak and Walder , 1980)

Figure 29. Elevation profiles of rivers in the western region .

Table 11. Water Survey of Canada river gauging stations in the west.

Station	Description	Drainage Area (km^2)	Gauge Location (Lat N/Long W)			Period of Record	Gauge Type[a]
07DA005	Beaver River near Fort MacKay	454	57	06	00	1961-66	RS Reg 75
			111	38	00	1972-74	MC
						1975	M
07DA007	Poplar Creek	151	56	54	50	1972	M Reg 76
			111	27	35	1973-83	RC
07DA010	Ells River below Gardiner Lakes	1380	57	22	30	1975-78	RC
			112	33	40		
07DA011	Unnamed Creek near Fort McMurray	274	57	39	31	1975-79	RC
			111	31	11	1980-83	RS
07DA012	Asphalt Creek	148	57	32	20	1975-77	RC
			111	40	36		
07DA013	Pierre River	123	57	27	55	1975-77	RC
			111	39	14		
07DA014	Calumet River	183	57	24	12	1975-77	RC
			111	40	57		
07DA015	Tar River	301	57	21	14	1975-77	RC
			111	45	29		
07DA016	Joslyn Creek	257	57	16	27	1975-79	RC
			111	44	30	1980-83	RS
07DA017	Ells River near mouth	2410	57	16	04	1973-83	RC
			111	42	51		
07DA018	Beaver River above Syncrude	165	56	56	29	1975-77	RC
			111	33	54	1979-83	RC
07DA019	Tar River (upper station)	103	57	29	05	1976-77	RC
			112	01	10		
07DB001	MacKay River near Fort MacKay	5550	57	12	38	1972-83	RC
			111	41	36		
07DB002	Dover River near mouth	963	57	10	12	1975-77	RC
			111	47	38		

[a] R = recording gauge; S = seasonal operation; C = continuous operation.

selected stations were downstream locations on the Poplar, MacKay, and Ells rivers where flow was measured using a continuous recording gauge.

Mean daily discharge (1 in 5 days) is presented for Poplar Creek (1976 to 1982), the MacKay River (1976 to 1980) and the Ells River (1976 to 1978) (Figures 30, 31, and 32). The period of discharge record was selected to correspond to the water quality sampling regime.

Mean annual discharge for Poplar Creek ranged from 0.35 to 1.79 m^3/s during a seven-year period (1976 to 1982). Maximum mean monthly flows occurred during late summer in 1976 (September, 5.94 m^3/s), 1978 (September, 9.20 m^3/s) and 1980 (August, 5.54 m^3/s). Maximum mean monthly flows during spring runoff ranged from 0.72 to 9.93 m^3/s during the seven years. There is no flow during winter.

Since the Poplar/Beaver Creek diversion, the discharge regime at Poplar Creek is typically bimodal. During the open water season, saline groundwater that enters the Beaver Creek Reservoir is diluted and eventually flows into the Athabasca River via Poplar Creek. In the fall, water levels in the Beaver Creek Reservoir are lowered, increasing flow in Poplar Creek. Subsequently, no reservoir (saline) release occurs over the winter months despite the continous groundwater discharge to the reservoir.

The MacKay River watershed has the largest drainage area (5550 km^2) within the western region. The mean annual discharge ranged from 5.89 to 18.17 m^3/s during the five-year period (1976 to 1980). Maximum mean monthly flows ranged from 14.57 to 65.94 m^3/s over the five years. Peak flows occurred as a result of spring runoff (1976, 1979) or summer rainstorms (1977, 1978, 1980). Minimum winter flows ranged from 0.2 to 0.4 m^3/s.

Maximum mean monthly flow in the Ells River occurred in April (21.5 m^3/s), July (7.81 m^3/s), and May (16.22 m^3/s) in 1976, 1977, and 1978, respectively. Minimum daily discharge ranged from 0.40 to 0.91 m^3/s during the three years.

Flow from most of the streams originating in the Birch Mountains (Tar, Calumet, Pierre, Asphalt/Eymundson) enters the Athabasca mainstem directly. Joslyn Creek enters the Ells River before draining

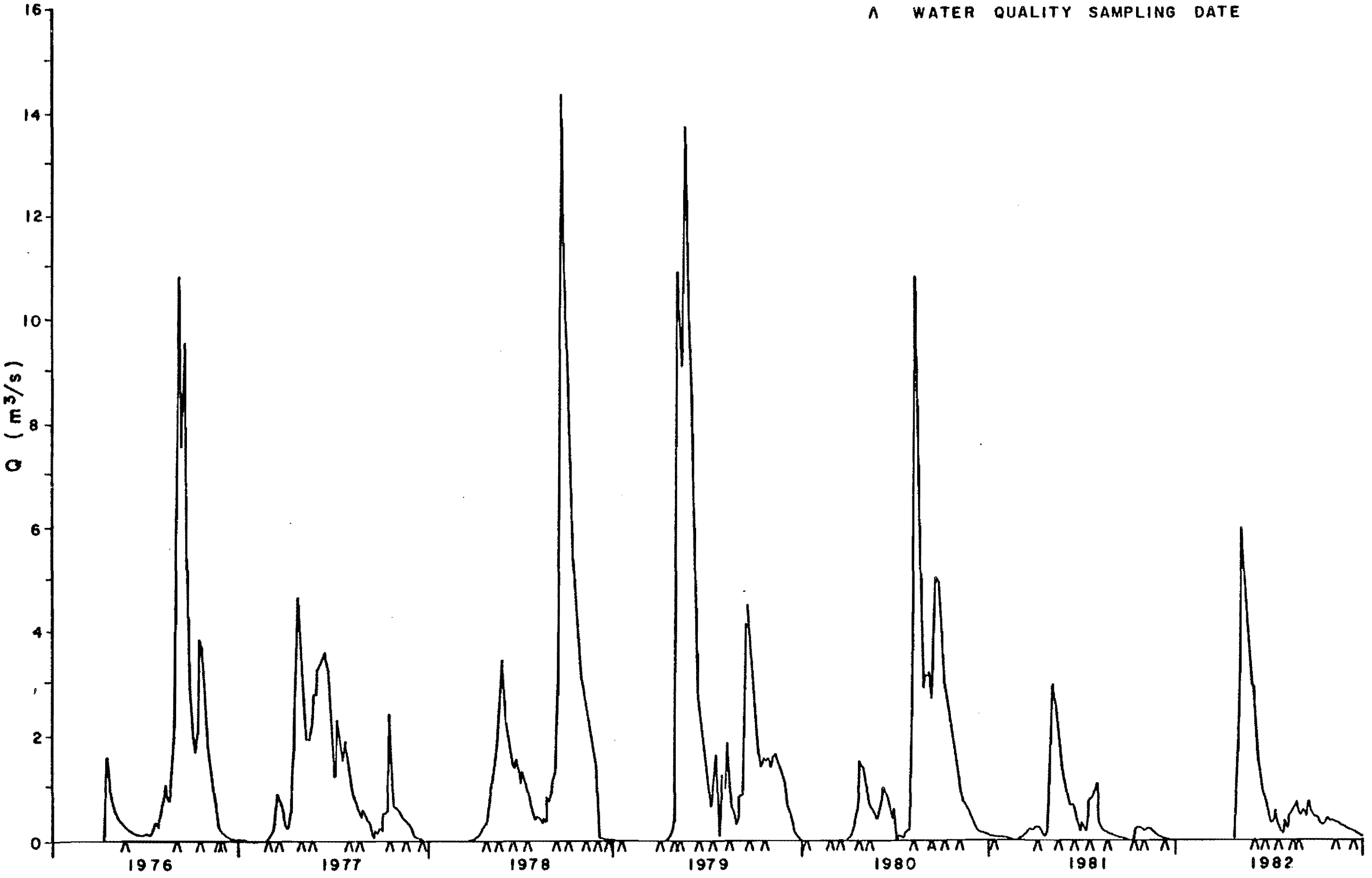


Figure 30. Daily discharge (1 in 5 days) in Poplar Creek (WSC Station No. 07DA007), 1976-1982 .

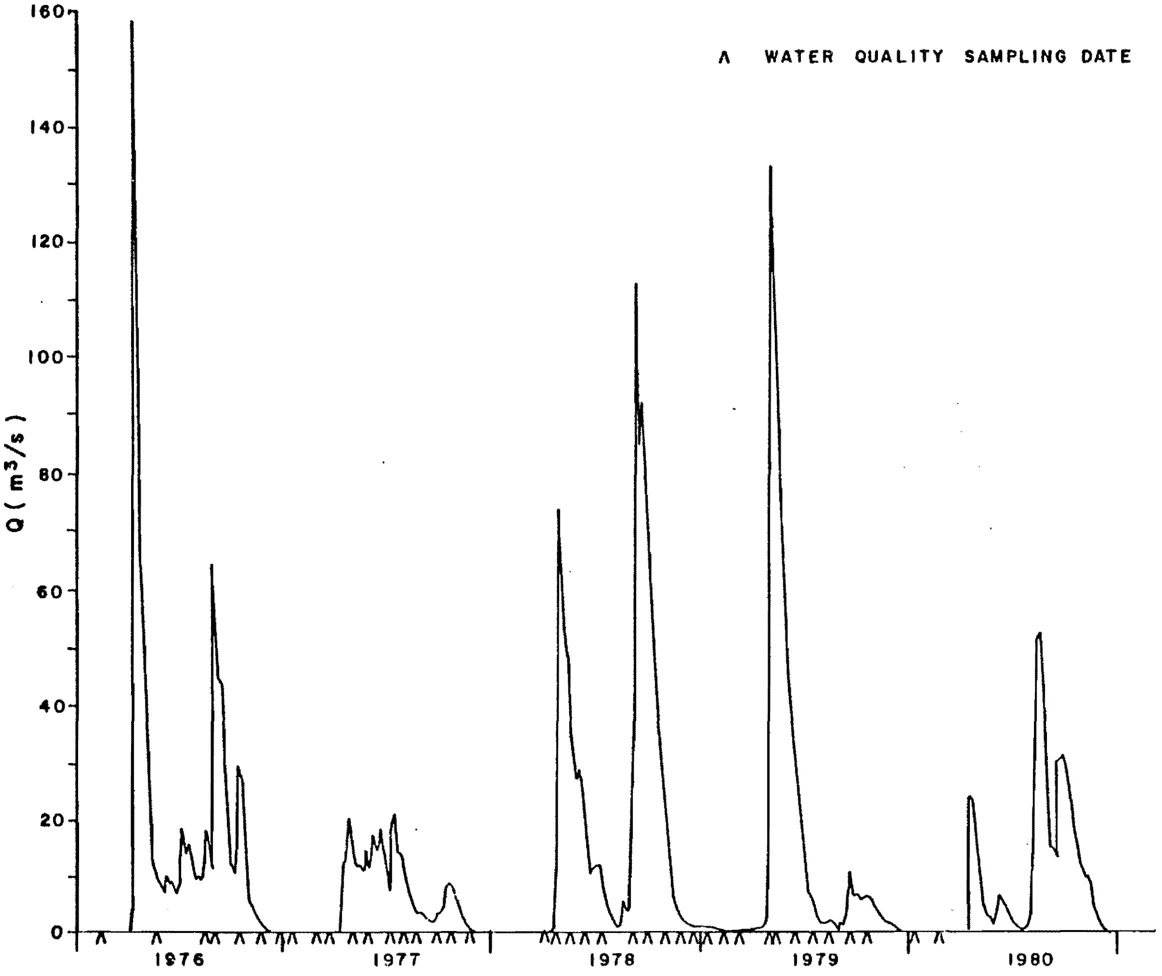


Figure 31. Daily discharge (1 in 5 days) in the MacKay River (WSC Station No. 07DB001), 1976 - 1980

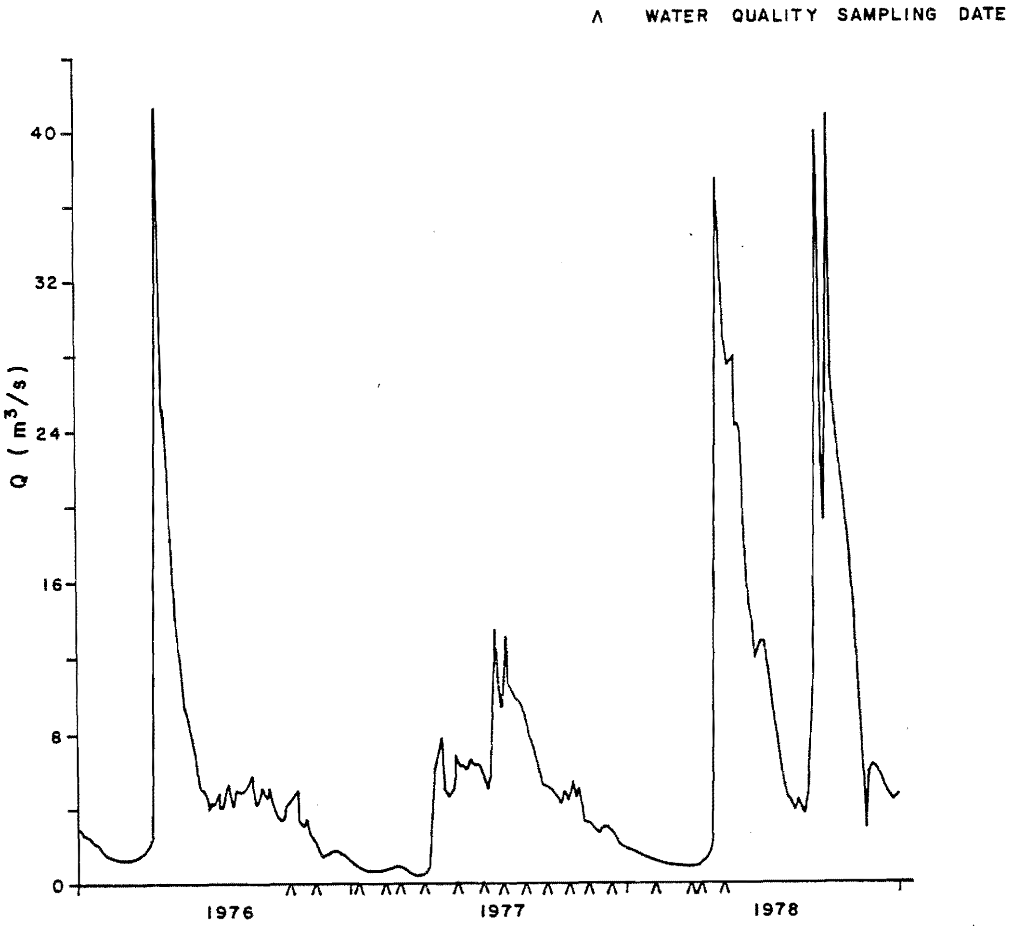


Figure 32. Daily discharge (I in 5 days) in the Ells River (WSC Station No. 07DA017), 1976 - 1978 .

into the mainstem. Patterns of discharge regime for the Pierre River and Asphalt Creek show that flow contribution of these streams is minor compared to other rivers of the western region (Figures 33 and 34).

6.2.2 Water Quality

The description of all water quality sampling sites and period of record are presented in Table 12. A tabular summary of water quality constituents is presented for 20 sites for which there were sufficient data (more than 10 samples) (Appendix 10.5, Tables 63 to 65).

6.2.2.1 Routine parameters. The surface waters of the western region are neutral to alkaline (Appendix 10.5, Table 65). Most surface waters in the region are classified as hard (121 to 180 ug/L) to very hard (>180 mg/L) (McNeely et al. 1979). Softer waters were characteristic of sites along the Ells River and Thickwood Creek as indicated by median hardness values ranging from 59 to 90 mg/L.

Total salt concentration as a measure of specific conductivity was exceptionally high in Poplar Creek, Beaver River, Calumet River, and Eymundson Creek compared to other rivers in the region (Figures 35, 36, and 37). The elevated saline concentrations in these rivers are a function of groundwater inputs.

Dissolved sodium chloride salts were dominant in the Beaver River, Calumet River, and Poplar Creek. Sodium and calcium bicarbonates were prevalent in the Dover and MacKay rivers; magnesium and bicarbonate were dominant in Eymundson Creek. In other streams of the region, calcium bicarbonate was the major dissolved salt.

Suspended particulate material in the water was measured by turbidity and non-filterable residue (NFR) tests. Streams draining the Birch Mountains had elevated median values of these constituents (Appendix 10.5, Table 65). Bank slumping along these streams contributes to the suspended particulates. Elevated maximum levels of turbidity and NFR were noted at sites on the Beaver River, Bridge Creek, and the MacKay River (Hwy. 63), but likely were related to soil erosion as a result of industrial activity or road construction.

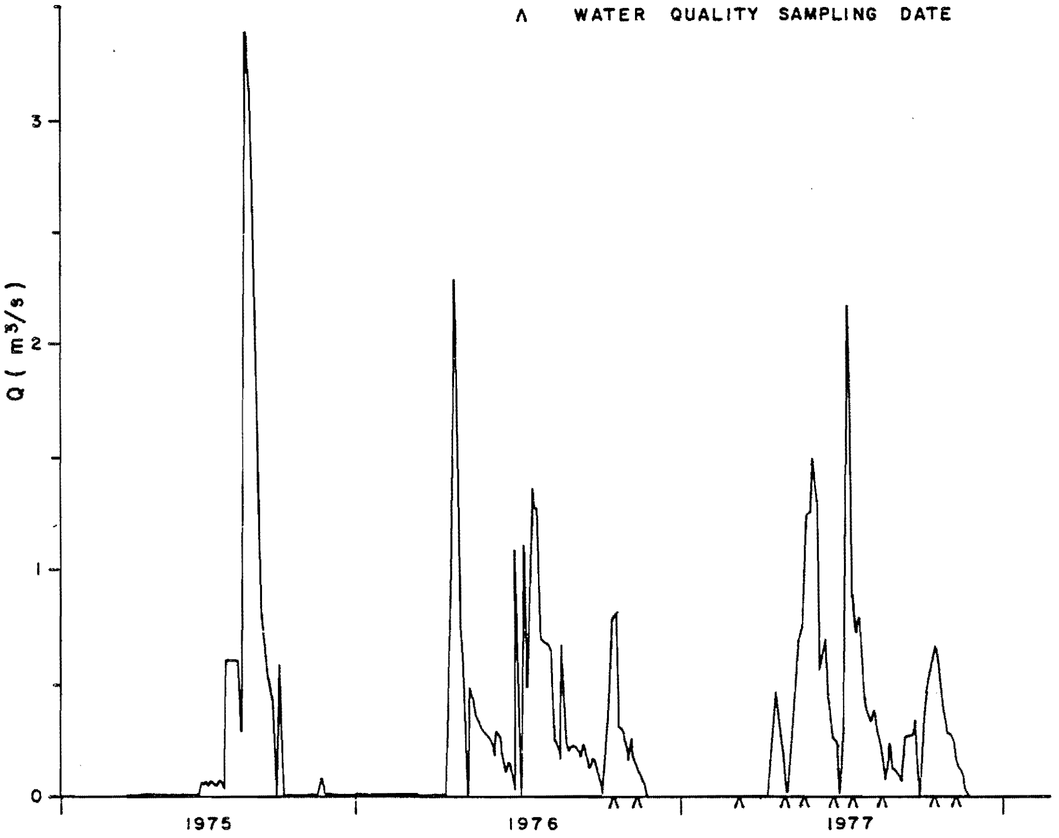


Figure 33. Daily discharge (1 in 5 days) in the Asphalt Creek (WSC Station No. DA0120), 1975-1977 .

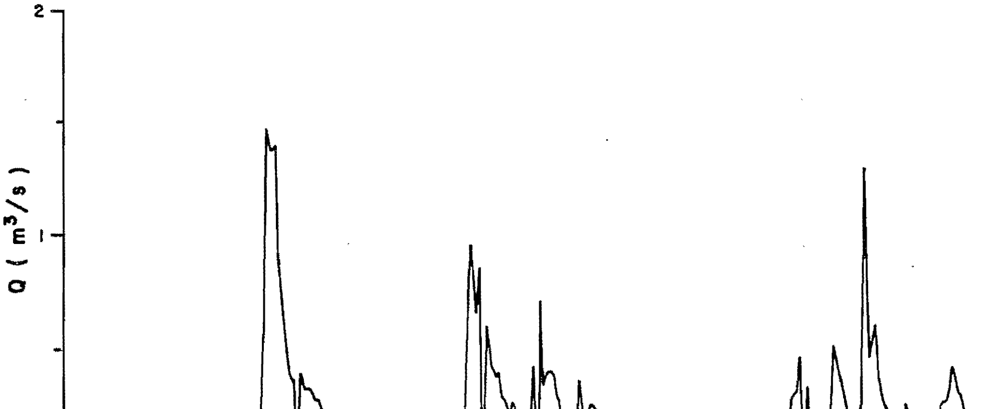


Figure 34. Daily discharge (1 in 5 days) in the Pierre River (WSC Station No. DA0130), 1975-1977 .

Table 12. Description, period of record, and number of samples obtained for water quality sampling stations within the western region. See Figure 4 for location of sites.

Watershed	Code (OOAT07-)	Latitude N Longitude W (D M S)	Description	Period of Record	Number of Samples
Poplar Creek	DA0070	56 54 50 111 27 16	Poplar Creek at Hwy. 63	1976-83	39[a]
Beaver River Bridge Creek	DA0179	57 0 58 111 37 28	Beaver River inside Syncrude	1976	2
	DA0180	56 56 29 111 33 54	Beaver River above Syncrude	1977-78	18[a]
	DA0181	57 6 54 111 37 22	Beaver River at Hwy. 63	1976-78	21[a]
	DA0182	57 7 17 111 37 30	Bridge Creek Diversion at Hwy. 63	1976-80	32[a]
	DA0183	57 7 9 111 36 20	Bridge Creek before confl. Athabasca	1980-81	17[a]
MacKay	DB0011	57 12 38 111 41 36	MacKay River at Hwy. 63	1976-80	40[a]
	DB0020	57 10 12 111 47 38	Dover River 3.2 km above confl. MacKay	1976-78	17[a]
	DB0030	56 51 20 112 42 40	Dunkirk River near Ft. MacKay	1976-79	29[a]
	DB0040	56 53 55 112 10 15	Thickwood Creek above confl. MacKay	1976-78	15[a]
Ells	DA0098	57 18 23 111 40 20	Ells River near the mouth	1976-79	13[a]
	DA0100	57 22 30 112 33 40	Upper Ells River below Gardiner L.	1976-79	27[a]

continued . . .

Table 12. Continued.

Watershed	Code (00AT07-1)	Latitude B Longitude W (D	M	S)	Description	Period of Record	Number of Samples
	DA0160	57 111	16 44	27 30	Joslyn Creek 3.2 km above Ells River	1976-79	22*
	DA0170	57 111	16 42	4 51	Lower Ells River 3.2 km above confl. Joslyn	1976-78	18*
Rivers draining east slopes of Birch Mountains	DA0110	57 111	39 31	31 11	Unnamed Creek north of Fort McMurray	1976-79	17*
	DA0111	57 111	39 21	31 12	Small trib. to Unnamed Creek	1976	1
	DA0115	57 111	39 31	30 14	Unnamed Creek near the mouth	1976	2
	DA0150	57 111	21 45	14 29	Lower Tar River	1976-78	15*
	DA0151	57 111	19 40	20 55	Tar River near mouth	1976	3
	DA0190	57 112	29 1	5 10	Upper Tar River	1976-78	12*
	DA0130	57 111	27 39	55 14	Pierre River	1976-78	12*
	DA0131	57 111	27 37	1 29	Pierre River near mouth	1976	4
	DA0120	57 111	32 40	20 36	Asphalt Creek near Fort MacKay	1976-77	10*
	DA0121	57 111	33 39	10 20	Eymundson Ck upstream of Asphalt	1976-77	11*
	DA0122	57 111	29 34	27 7	Eymundson at the mouth	1976	1
	DA0140	57 111	24 40	12 57	Calumet River near Fort MacKay	1976-78	13*

continued . . . .

Table 12. Concluded.

Watershed	Code (00AT07-1)	Latitude B Longitude W (D	M	S)	Description	Period of Record	Number of Samples
	DA0141	57 111	24 39	38 57	Calumet River near the mouth	1976	6

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[a] Sites with sufficient samples to be used in analysis.

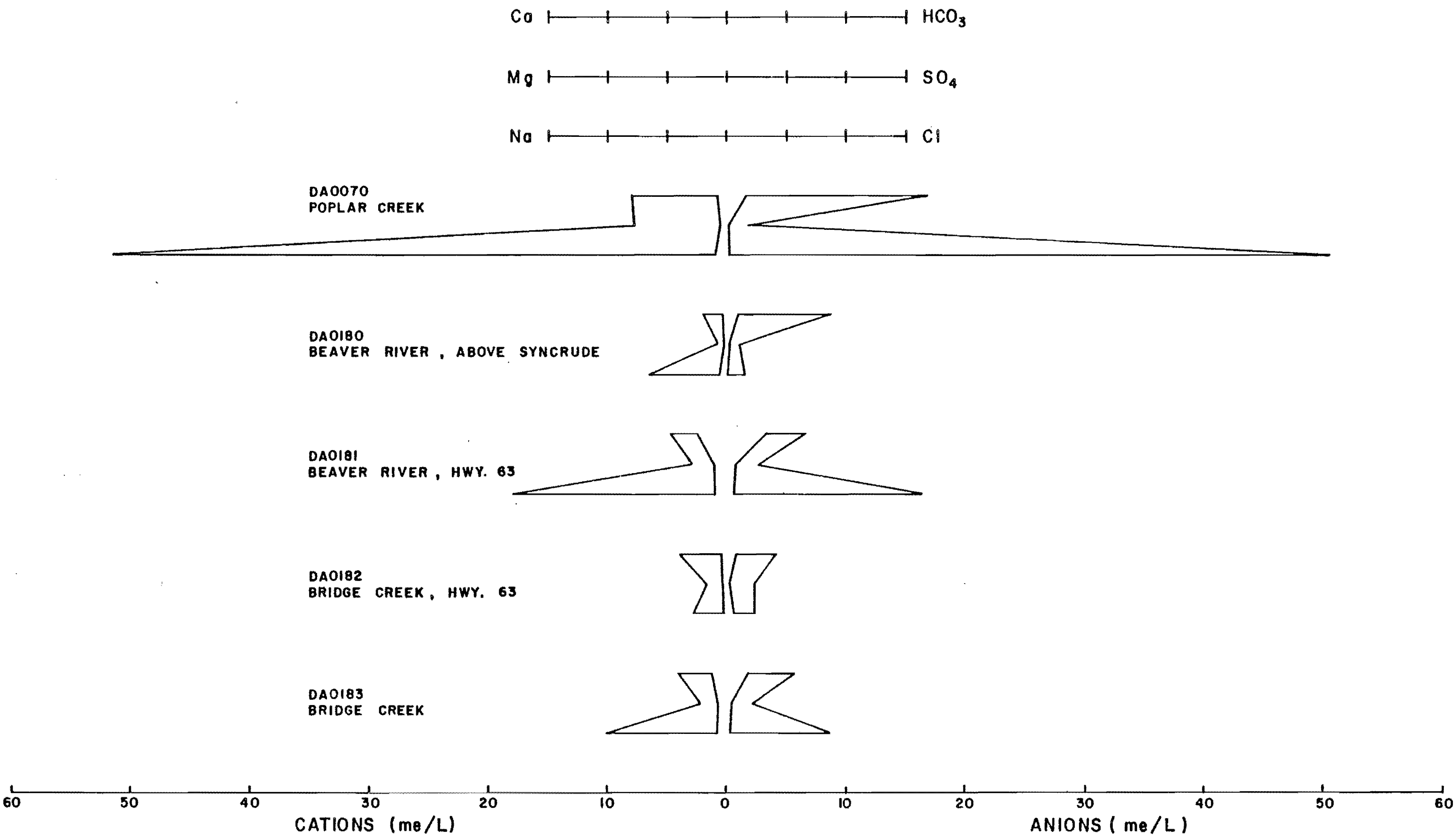


Figure 35. Maximum and minimum values (me/L) of major ions in the Beaver - Poplar drainage.

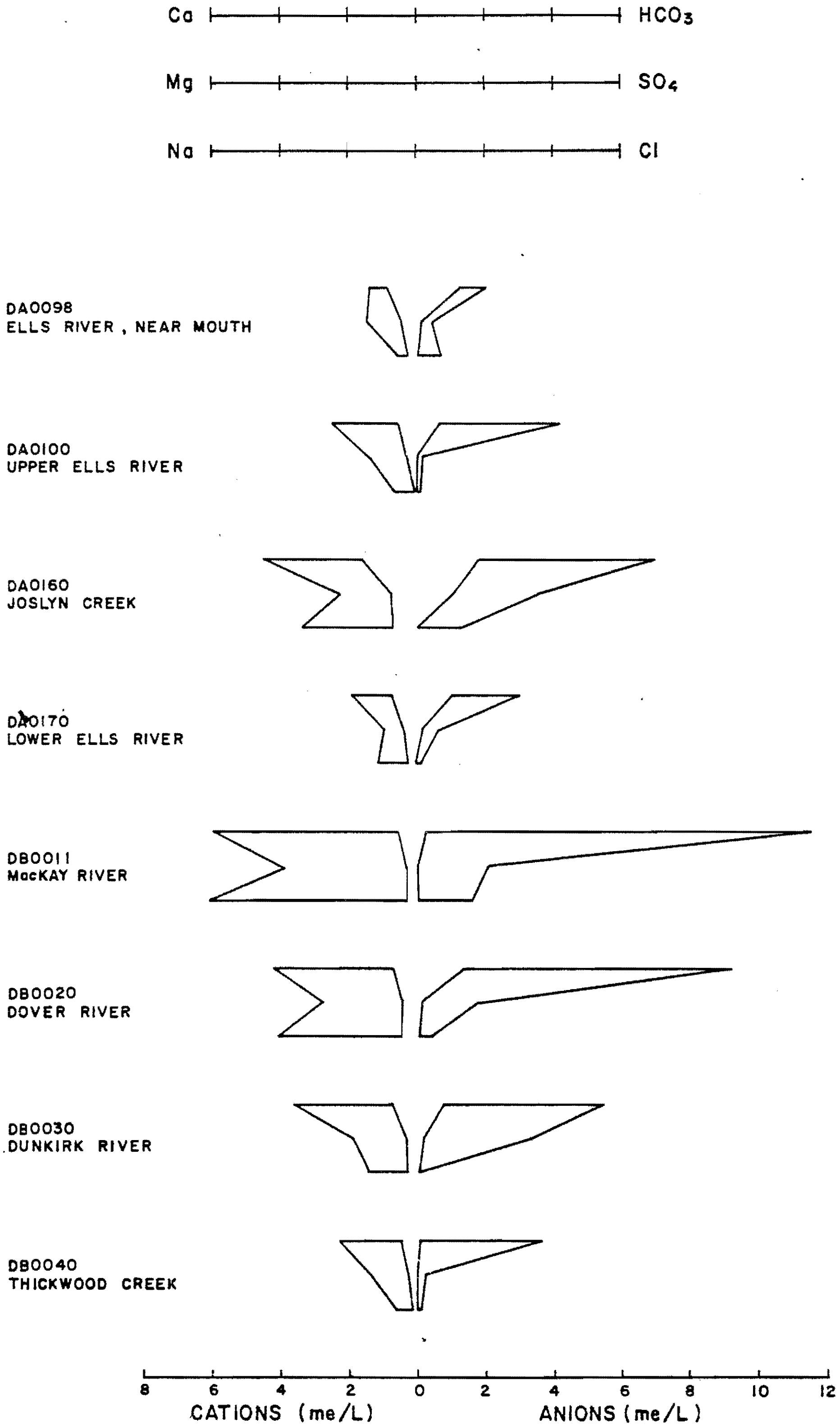


Figure 36. Maximum and minimum values (me/L) of major ions in the Ells and MacKay drainages.

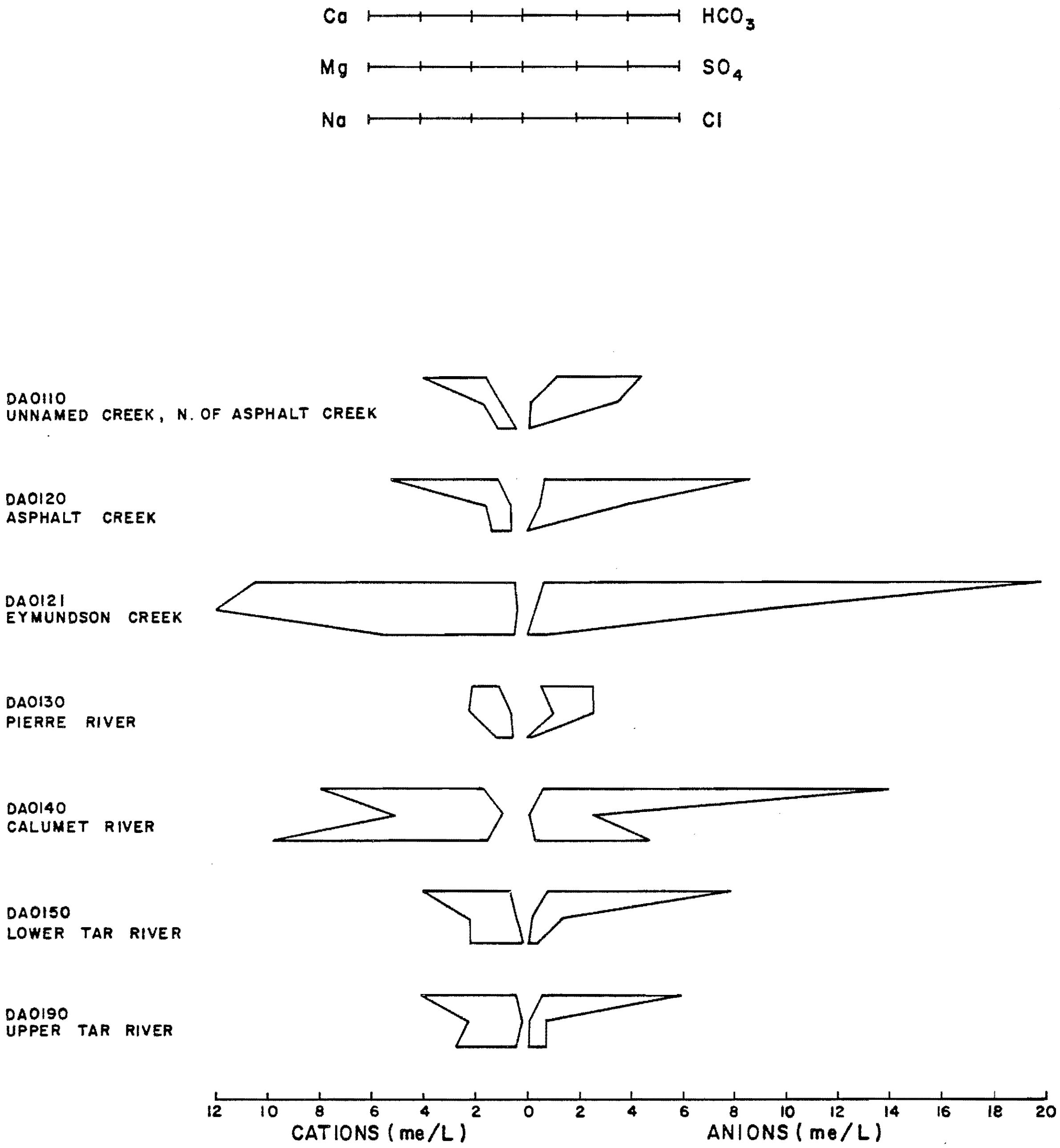


Figure 37. Maximum and minimum values (me/L) of major ions in streams draining the east slopes of the Birch Mountains .

Total organic carbon is a measure of biological activity. Elevated levels were prevalent in surface waters throughout the region, but particularly in the Calumet and Beaver/Bridge Rivers (Appendix 10.5, Table 65).

The presence of phenols as well as oil and grease in surface waters is the result of industrial and municipal activity. Elevated levels of these parameters occurred at river sites associated with oil sands development. Median values of phenolic material for Poplar Creek (DA0070) and Bridge Creek (DA0183) were 0.003 mg/L and 0.006 mg/L, respectively. Median values for all other river sites were less than or equal to 0.001 mg/L. The median value of oil and grease for Bridge Creek (DA0183) was 1.4 mg/L. Median values for all other river sites were less than 1.0 mg/L.

6.2.2.2 Nutrients. Major forms of phosphorus and nitrogen are presented in Appendix 10.5 (Table 66).

Elevated concentrations of total phosphorus were exhibited in the Asphalt, Eymundson, Calumet, lower Tar, and Josyln Rivers. The median (113 to 150 ug/L) and maximum (360 to 720 ug/L) values of total phosphorus for these streams draining the Birch Mountains may reflect erosional processes within the watershed. Similarly high concentrations of total phosphorus were recorded for the Beaver and Dunkirk rivers (Appendix 10.5, Table 66).

Orthophosphate phosphorus (PO_4-P), an indicator of enrichment, exhibited the highest median values in the Calumet (37 ug/L) and MacKay (24 ug/L) rivers. Median values at all other sites ranged from less than 10 to 20 ug/L. The highest maximum values were recorded at sites on the Beaver River above Syncrude Canada Ltd. (235 ug/L) as well as on the Dunkirk (180 ug/L), MacKay (100 ug/L), and Joslyn (110 ug/L) rivers.

Total kjeldahl nitrogen (TKN) is a measure of inorganic (ammonia) and organic nitrogen. Median TKN values for rivers in the western region ranged from 0.78 to 2.45 mg/L. Sites with the highest median TKN concentrations were located on the Calumet (2.45 mg/L) and

Eymundson (1.86 mg/L) rivers. Maximum TKN concentrations ranged from 1.68 to 7.85 mg/L. High concentrations were recorded for the upper Ells (7.85 mg/L), Asphalt (5.60 mg/L), Eymundson (5.10 mg/L), lower Tar (4.40 mg/L), and Calumet (4.23 mg/L) rivers.

Median ammonia concentrations ranged from 0.03 to 0.35 mg/L. Sites on the Calumet River (0.35 mg/L) and Beaver River at Hwy. 63 (0.19 mg/L) exhibited the highest median concentrations of ammonia. Maximum concentrations of ammonia ranged from 0.05 to 1.14 mg/L, with sites on Poplar Creek (1.14 mg/L) and the Calumet River (0.88 mg/L) exhibiting the highest values.

Nitrate/nitrite nitrogen is another form of inorganic nitrogen. Median concentrations of nitrate/nitrite nitrogen ranged from less than 0.01 to 0.09 mg/L. Sites on the lower (0.09 mg/L) and upper (0.06 mg/L) Ells River exhibited highest median values. The maximum concentrations of nitrate/nitrite nitrogen ranged from 0.06 to 1.0 mg/L. Highest values were recorded in Thickwood Creek (1.0 mg/L), a tributary of the Mackay River, and the MacKay mainstem (0.69 mg/L).

The east-draining rivers of the Birch Mountains were more productive in terms of total phosphorus and organic nitrogen than other rivers of the western region. In contrast, the Beaver/Poplar and MacKay drainages exhibited higher concentrations of PO_4-P and inorganic nitrogen than the other rivers.

6.2.2.3 Metals. Summary data of metals in surface waters of the western region are presented in Appendix 10.5 (Table 67). Of these, seven are considered to be potentially toxic when present in excessive amounts including arsenic, cadmium, lead, mercury, selenium, and silver.

The median range of arsenic concentrations in the western rivers was from less than 0.05 to 1.2 ug/L, well below the surface water objective of 10 ug/L. Maximum values ranged from 1.5 to 17.3 ug/L. Lower Tar River (17.3 ug/L), Poplar Creek (16 ug/L) and the MacKay River at Hwy. 63 (13 ug/L) exhibited maximum values which exceeded the objective.

The ASWO for cadmium is 10 ug/L. The median values are less than or equal to 1 ug/L for all rivers. Maximum values for most sites ranged from 1 to 6 ug/L. One site, Poplar Creek (16 ug/L), exceeded the ASWO.

The median values of chromium ranged from less than 3 to 4 ug/L, well below the objective of 50 ug/L. However, the range of maximum values of chromium was 5 to 205 ug/L. The three sites which exceeded the objectives were located within the Beaver/Poplar drainage (Appendix 10.5, Table 67).

Median values for lead concentrations were less than or equal to 2 ug/L for all sites. Maximum values for 19 of 20 sites ranged from 3 to 48 ug/L. The maximum lead concentration at Poplar Creek (175 ug/L) exceeded the ASWO of 50 ug/L.

Median values of mercury concentration at all sites were less than 0.1 ug/L, below the ASWO of 1 ug/L. Maximum values of mercury concentration which exceeded the objective were recorded at five sites including the Bridge (6.4 ug/L), Calumet (4.6 ug/L), Eymundson (2.7 ug/L), MacKay (2.1 ug/L), and Poplar (1.6 ug/L) rivers.

Dissolved selenium concentrations for median and maximum values at all 20 river sites were below the ASWO of 10 ug/L.

Median values of silver for river sites within the region were less than 1 to 2 ug/L. The range of maximum concentrations for 18 of 20 sites was 1 to 9 ug/L. Poplar Creek (28 ug/L) and the lower Tar (70 ug/L) exhibited high silver concentrations compared to the other 18 sites. Only the lower Tar River exceeded the ASWO of 50 ug/L.

In summary, the median concentrations of potentially toxic substrates were below the ASWO for all rivers examined within the western region. Of the seven metals, dissolved selenium was the only constituent with maximum values below the ASWO. In several instances the objectives were exceeded. Poplar Creek is of interest because maximum concentrations exceeded the ASWO for five potentially toxic metals including arsenic, cadmium, chromium, lead, and mercury.

Other non-toxic metals detected in surface waters are frequently related to weathering of rock material. This group consists of aluminum, boron, cobalt, copper, iron, manganese, nickel, vanadium, and zinc.

Median values of aluminum concentrations in western rivers ranged from 40 to 328 ug/L with the exception of Asphalt Creek (1095 ug/L). Maximum concentrations ranged from 210 to 14 700 ug/L. Since aluminum is not considered to be a health problem in surface waters, objectives have not been established.

The median values of boron concentrations ranged from 60 to 340 ug/L, below the ASWO of 500 ug/L. The maximum values ranged from 100 to 1080 ug/L. Sites with boron concentrations exceeding the ASWO were located within the Beaver/Poplar, MacKay, and Birch Mountain east slope drainages (Appendix 10.5, Table 67).

No surface water objectives exist for cobalt. Median values ranged from less than 1 to 2 ug/L. Maximum values at most sites within the region ranged from 1 to 14 ug/L. Asphalt (28 ug/L) and Poplar (31 ug/L) creeks exhibited higher values.

Copper concentrations (median values) ranged from 1 to 8 ug/L, below the ASWO of 20 ug/L. Maximum values at most sites ranged from 4 to 33 ug/L with two sites, lower Tar River (114 ug/L) and the MacKay River (180 ug/L), exhibiting notably higher concentrations.

The ASWO for iron (300 ug/L) and manganese (50 ug/L) were established for aesthetic reasons because of taste and staining properties of the metals at high concentrations. Median (range 300 to 4325 ug/L) and maximum (range 1650 to 52 500 ug/L) values of iron exceeded the objectives at all river sites. Median manganese values ranged from 19 to 370 ug/L. Here, 14 of 20 sites representing streams draining the Birch Mountains and the Beaver/Poplar watershed exceeded the objectives. Maximum values (range 69 to 6550 ug/L) exceeded the objectives at all sites.

Nickel, vanadium, and zinc are frequently associated with oil sands. No ASWO exist for nickel or vanadium. Median values of nickel concentrations ranged from <2 to 12 ug/L. Maximum nickel concentrations ranged from <2 to 46 ug/L, with Asphalt and Eymundson Creeks exhibiting the highest values. Median values of vanadium were low (range<1 to 1 ug/L). Maximum concentrations ranged from 1 to 24 ug/L, with the Beaver River at Hwy. 63 exhibiting the highest value.

The ASWO for zinc is 50 ug/L. Median values for all sites (range 3 to 30 ug/L) were within the objectives. Maximum values (24 to 155 ug/L) exceeded the objectives at sites within all watersheds throughout the region.

6.2.3 Benthic Invertebrates

A summary of benthic invertebrate studies, which were conducted in the Beaver/Poplar and MacKay rivers and streams of the Birch Mountain drainages, is presented in Table 13. Sampler type, mesh size, and sample frequency differed among studies conducted in the three drainages.

Surveys conducted on the MacKay River (McCart et al. 1978) and streams of the Birch Mountains (Corkum et al. 1982) were baseline studies. These studies provide a base against which future changes can be compared. The benthic surveys conducted on the Beaver/Poplar drainage to determine the effects of stream discharge on the biota (Noton and Chymko 1978; Boerger 1983, 1984) were impact studies.

Taxonomic differences of invertebrates among sample sites in the baseline studies reflected differences in habitat type (erosional versus depositional). Corkum et al. (1982) categorized organisms into taxonomic and functional feeding groups and related the groups to habitat types. The relative abundance of invertebrates was more similar among sites within the same habitat than among sites within the same drainage.

Noton and Chymko (1978) summarized changes in aquatic resources of water bodies associated with the Beaver/Poplar Creek diversion scheme. The initial effect of the spillway discharge was an increase in the relative abundance of benthic invertebrates in Poplar Creek downstream from the confluence with the spillway.

Table 13. Summary of benthic invertebrate studies in streams of the west.

Water Body	Reference	Sample Year	Sampler Mesh Size	Sites	Month	Habitat[a]	Dominant Taxa
Beaver Creek	Noton & Chymko (1978)	1977	Ekman 600 um	1	05,07,10	E	Chironomidae, Ephemeroptera (*Caenis*) Oligochaeta.
Poplar Creek	Noton & Chymko (1978)	1977	Cylinder 250 um	3	03 to 11	E	Above diversion: Chironomidae, Plecoptera, Trichoptera, Ephemeroptera Below diversion: Chironomidae, Trichoptera, Simuliidae.
	Boerger (1983)	1974-1982	Artificial[b] sampler 250 um	4	06, 07	E	Above spillway: Simuliidae, Chironomidae, Ephemeroptera (Baetidae). Below diversion: Chironomidae, Ephemeroptera (Baetidae).
	Boerger (1984)	1983	"	4	06	E	Above spillway: Chironomidae, Ephemeroptera (Baetidae) Below diversion: Simuliidae, Chironomidae, Ephemeroptera (Baetidae).
MacKay River	McCart et al. (1978)	1977	Surber 600 um	3	05 to 09	E	Oligochaeta, Chironomidae, Ephemeroptera, Plecoptera, Trichoptera
			Artificial sampler 600 um	3	05 to 09	E	Ephemeroptera, Chironomidae
East draining streams of Birch Mts: Calumet, Pierre, Asphalt, Eymundson	Corkum et al. (1982)	1981	Airlift - 30s 500 um	12	06	D	Sphaeriidae, (*Pisidium*), Oligochaeta, Chironomidae (*Procladius*)
			"	7	08, 09/10	D	" "
			Kick - 30s 500 um	6	06	E	Ephemeroptera (*Baetis*), Diptera (Simuliidae, *Metacnephia*, Plecoptera (*Nemoura*), Trichoptera (*Brachycentrus*)
			"	10	08, 09/10	E	" "

[a] Habitat; E, Erosional; D, depositional.

[b] Artificial sampler: cylindrical wire barbecue baskets (length: 27 cm, diameter: 18 cm), each filled with 20 to 30 rocks.

[c] Artificial sampler: rock-filled wire baskets (McCart et al. 1977).

Boerger (1983, 1984) showed that following the initial enhanced response by the biota to the spillway discharge, the rate of increase invertebrate density and taxa declined. Boerger (1983) suggested that increases in biota were a function of increased flow, temperature, and detritus from the epilimnetic discharge over the spillway as well as substrate changes resulting from channelization. Saline mine depressurization water released into Beaver Creek Reservoir had no significant effect on the benthos in Poplar Creek.

6.3 RELATIONSHIPS AMONG PARAMETERS

To select possible water quality parameters which may have significant associations with discharge, a correlation analysis was performed between conductivity (a known correlate of discharge) and other water quality constituents. Variables that would be autocorrelated with conductivity (ions) were not included in the analysis.

Results from the correlation analysis using median values of water quality constituents showed that only total inorganic carbon (TIC) was significantly correlated with conductivity at the 0.01 level.

Relationships among conductivity, TIC, and discharge were estimated using data from all sampling dates for the Poplar, Ells, and MacKay rivers. Regression analyses were performed using linear, log/linear, and log/log transformations of the data. Equations from those transformations yielding the best fit (i.e., least variable and highest R^2) were selected and are presented in Table 14.

There was an inverse significant relationship between both TIC and conductivity with discharge for all three drainages. Thus, levels of conductivity and TIC were high when discharge levels were low.

Because the residual variances among the rivers were heterogeneous (Bartlett's test, $p < 0.05$), comparisons among intercepts and slopes of the three regressions were considered inappropriate.

There was, however, a trend for conductivity levels to decrease more rapidly with discharge in Poplar Creek and the MacKay

Table 14. Summary of regression equations of conductivity (SC) and total inorganic carbon (TIC) with discharge for Poplar Creek, and Ells and MacKay rivers. Equations with the best fit of the data were of the following log/log format:

$$Y = AX^B$$

where: A = intercept, B = slope, Y = dependent variable (water quality), X = independent variable (discharge).

River	df (n-2)	Y	A	B	R^2	p (Ho: $B_1 = 0$)
Poplar	57	SC	723.4	-0.588	.31	L0.001
(DA0070)	27	TIC	38.6	-0.227	.32	L0.001
Ells	16	SC	311.1	-0.302	.73	L0.001
(DA0170)	16	TIC	27.5	-0.289	.59	L0.001
MacKay	38	SC	801.9	-0.465	.83	L0.001
(DA0140)	32	TIC	76.4	-0.465	.86	L0.001

L = less than.

River than in the Ells River. The TIC appeared to decrease more rapidly with discharge in the MacKay River than in the other two rivers.

7. THE SOUTH

The southern region encompasses an area of 4700 km^2 extending south of Fort McMurray from the Athabasca and Clearwater rivers to the AOSERP boundary. There are ten rivers, several tributaries, and lakes within the region. A detailed report on Gregoire Lake is in progress (Akena in prep.) and will not be considered in this report. This study focuses on six major rivers (Horse, Hangingstone, Saline, Surmount, Christina, and Clearwater) for which there is an adequate water quality data set. References will be made to other streams in the region depending on available data.

7.1 BASIN FEATURES

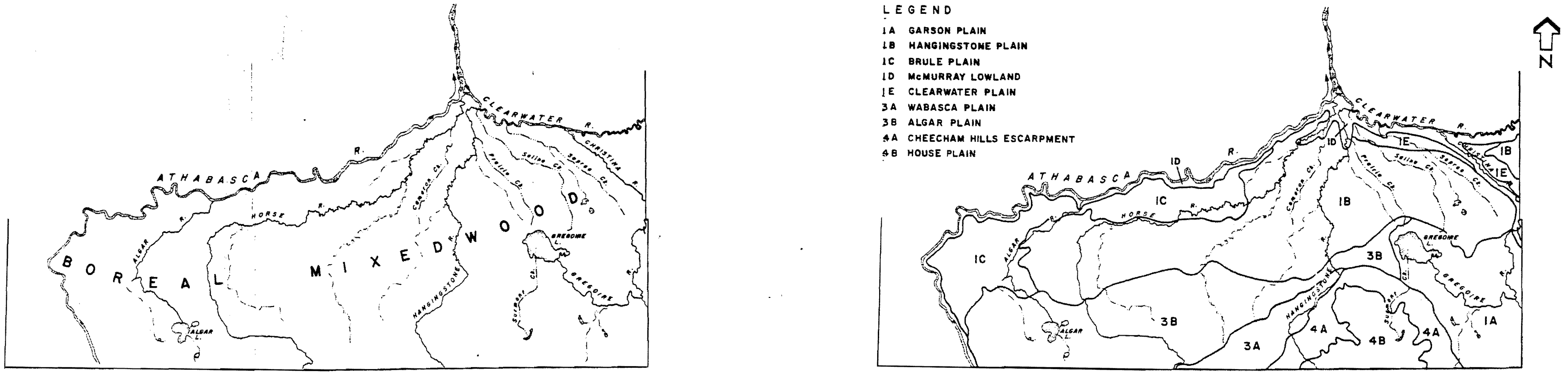
7.1.1 Land Formations

Land formations of the southern region, adapted from Turchenek and Lindsay (1982), are presented in Figure 38. The region occurs within the Boreal Mixedwood Forest, much of which is poorly drained low lying muskeg.

The bedrock geology of the Athabasca and Clearwater river valleys is characterized by limestone and shale. This narrow band at the northern boundary of the region constitutes the Waterways Formation of the Devonian period (Paleozoic era). Most of the southern region, however, is characterized by younger Cretaceous rocks (sandstone and shale) of the Mesozoic era.

Most of the tributaries in the south are low gradient rivers that meander through flood plains. The smaller tributaries, which drain muskeg areas, consist of a series of beaver ponds (Tripp and Tsui 1980). The downstream reaches of the six study rivers lie within the Methy Portage Plain, an undulating plain with low to moderate relief. White spruce and aspen forests are most common in the upland regions of the plain. Wetlands of low lying areas are characterized by black spruce and organic soils.

Where the Horse River enters the Athabasca mainstem and the Hangingstone and Christina join the Clearwater, the channels cut through



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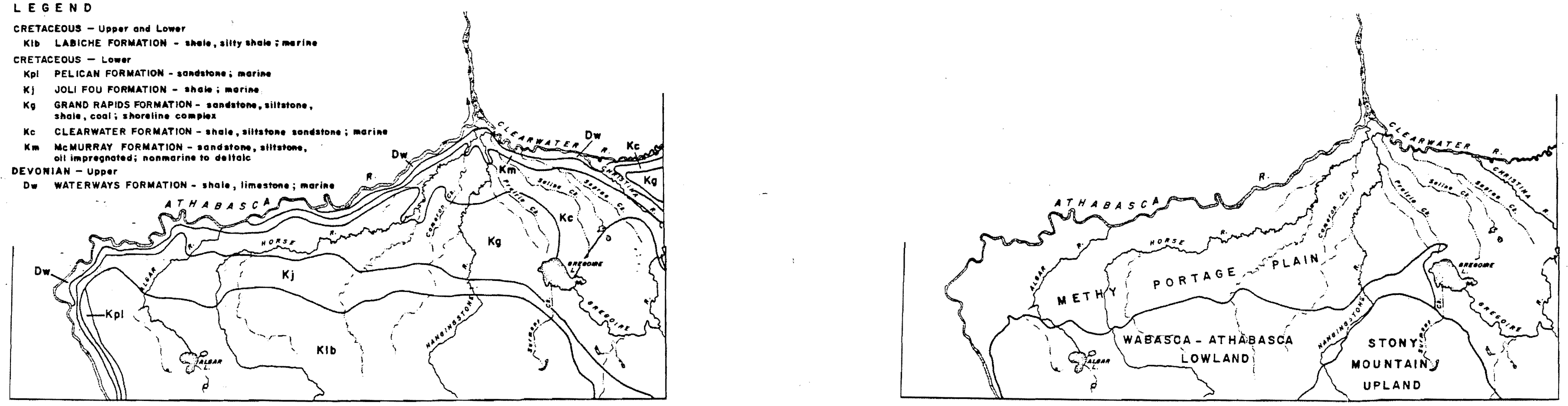

GEOLOGY

PHYSIOLOGY

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Figure 38. Land formations of the southern region.

(adapted from Turchenek and Lindsay 1982) steep valleys. Shrubs occupy the bottom lands; spruce and aspen, the valley walls. No vegetation occurs on the steep valley walls.

7.1.2 Watershed

Major drainage systems in the region include the Clearwater, Christina, Hangingstone, and Horse rivers (Figure 39). The following description of these rivers is summarized from Griffiths 1973; Northwest Hydraulics Consulting Ltd. 1975; Tripp and McCart 1979; and Tripp and Tsui 1980.

The Clearwater River drainage basin is 31 598 km^2 of which 16 572 km^2 occurs within Alberta (Northwest Hydraulics Consulting Ltd. 1975). The Clearwater flows a distance of about 65 km within the AOSERP study area before its confluence with the Athabasca River at Fort McMurray.

The large number of lakes within the Clearwater basin reduces runoff and moderates flood peaks (Northwest Hydraulics Consulting Ltd. 1975). However, during spring breakup, ice jams may develop on the Athabasca and Clearwater rivers, causing flood conditions in Fort McMurray.

The Christina River, a major tributary of the Clearwater River, drains an area of 13 380 km^2 and flows a distance of 326 km (Griffiths 1973; Northwest Hydraulics Consulting Ltd. 1975). Only the downstream 27 km of the Christina River occurs within the AOSERP study area.

The Gregoire River is the major tributary of the Christina River within the AOSERP study area. The Gregoire flows 83 km from Gregoire Lake to the confluence of the Christina River, draining 978 km^2 of the Christina basin. The Gregoire River meanders over fine substrate until near its mouth, where it cuts through a steep valley to the Christina River.

The Hangingstone River basin drains an area of 1074 km^2 (Northwest Hydraulics Consulting Ltd. 1975). The river originates near the southern boundary of the AOSERP study area and flows 98 km before

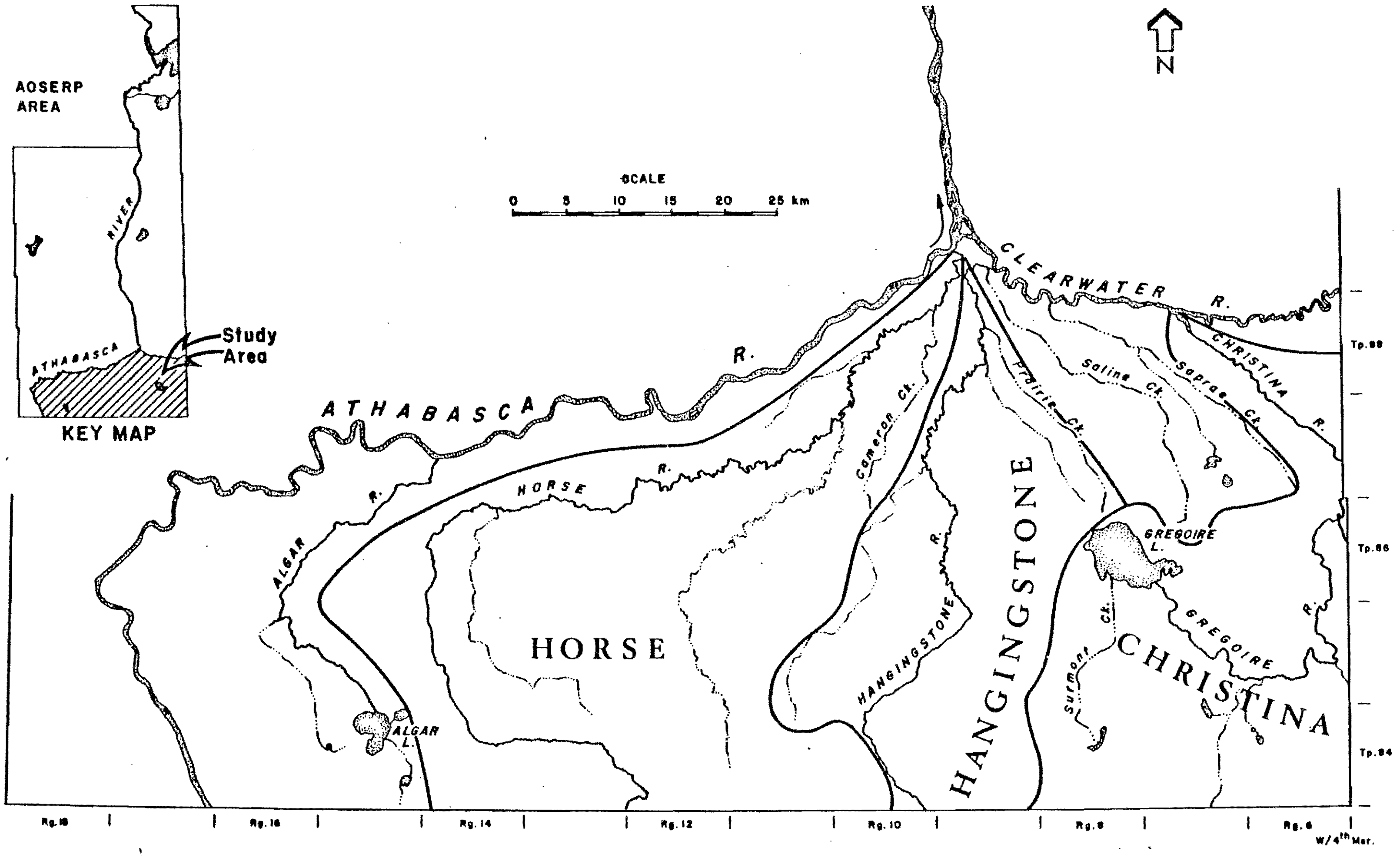

Figure 39. South surface water drainage.

(adapted from Nelli and Evans 1979)

joining the Clearwater River near Fort McMurray. In the upper reach, stream gradient is reduced and the river meanders over fine sandy substrates. Stream gradient increases again near the mouth as the river cuts through a steep valley to the floodplain of the Clearwater River.

The Horse River basin drains an area of 2154 km^2, most of which occurs outside of the AOSERP study area. The Horse River originates in muskeg, flowing 200 km before joining the Athabasca River at Fort McMurray. About 1 km upstream of the confluence, outcrops of the McMurray Formation occur along the valley, forming steep bituminous banks.

7.1.3 Physical Description of Study Streams

One important aspect of the study streams is the shift from depositional to erosional habitats near their confluence with the Athabasca and Clearwater mainstems. The increase in slope near the mouths of these streams is observed in the elevation profiles presented in Figure 40.

The tributary streams (the Surmount River being the exception) originate in the plains and meander over mud substrates and through beaver ponds, with occasional stretches of fast flowing waters occurring over coarse substrates. The Hangingstone has a steeper gradient along its length than the other tributaries. Running water over coarse substrates in confined channels near the mouth of the tributary streams is more typical of headwater reaches in eastern deciduous forests or the foothills of the Rocky Mountains. The difference, however, is in the increased stream width, higher flows, less overhanging vegetation, and occasional slumping of valley walls in the downstream areas of the southern AOSERP tributaries.

7.2 BASELINE DATA

7.2.1 Discharge

The Water Survey of Canada has operated gauging or stage recorders at six locations within the south region, including four sites

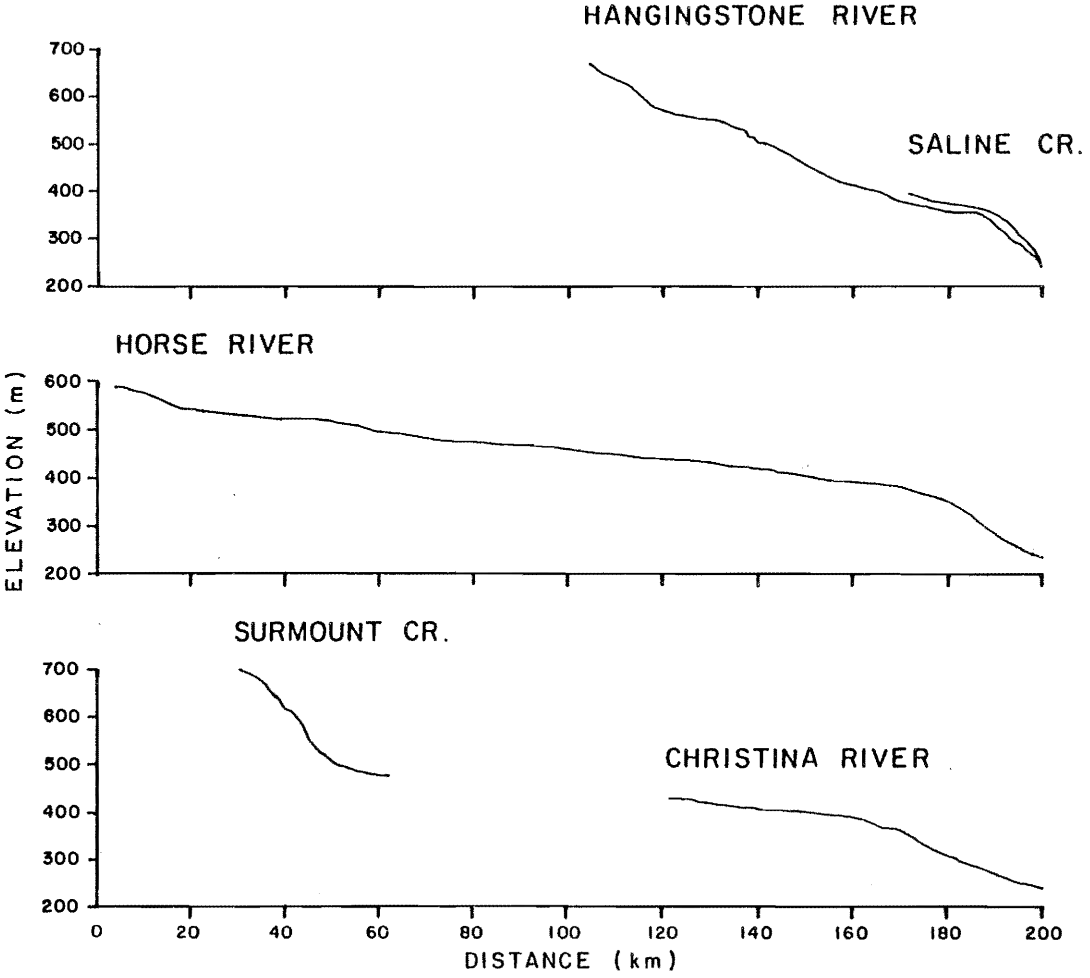

Figure 40. Elevation profiles of southern tributaries.
(Adapted from Tripp and Tsui, 1980)

on the Clearwater River and one on each of the Horse and Hangingstone rivers (Table 15). The Hangingstone near Fort McMurray (07CD004) and the Clearwater River near Draper (07DC001) were selected for the study because continuous recording gauges were operated over the longest period, including the dates when water samples were collected. The location of the Hangingstone and Clearwater stations are indicated on Figure 4.

Mean daily discharge (1 in 5 days) is presented for the Hangingstone (1976 to 1982) and Clearwater (1976 to 1981) rivers in Figures 41 and 42, respectively.

Discharge levels in the Hangingstone River typically peaked at spring breakup, decreased over the summer months, and increased during autumn freshets before declining to winter base flows. Peak discharge levels were typically 22 to 24 m^3/s; higher levels were recorded in 1976 and 1980. Winter base flows ranged from 0.1 to 0.4 m^3/s.

The same discharge pattern of fluctuations was evident in the Clearwater River. Here, maximum discharge levels were about 300 m^3/s with levels of up to 600 m^3/s. In 1976 and 1977 summer flows also were elevated. Winter base flows ranged from 40 to 100 m^3/s.

7.2.2 Water Quality

The description and period of record for the water quality sampling stations are presented in Table 16. The station locations also are indicated in Figure 4.

Water quality data are summarized for the seven sampling stations in the region, 1976 to 1983 (Appendix 10.6, Tables 68 to 70). The data are presented and discussed by parameter group (routine, nutrients, and metals).

7.2.2.1 Routine parameters. This parameter grouping includes inorganic ions, suspended paticulates, organic constituents, phenols, and oil and grease. Summary data are presented in Appendix 10.6 (Table 66).

Table 15. Water survey of Canada gauging stations in the southern region.

Station	Description	Drainage Area (km^2)	Gauge Location Lat. N/Long. W (D	M	S)	Period of Record	Gauge Type[a]
07CC001	Horse R. - Abasands	2181	56	42	29	1930-31	MS
			111	23	40	1975-78	RC
07CD005	Clearwater R. above Christina R.	17172	56	42	40	1966-75	RS
			110	55	40	1976-78	RC
07CD001	Clearwater R. at Draper	30562	56	40	50	1930-31	MS
			111	15	00	1958-pres	RC
07CD003	Clearwater R. at Upper Wingdam	-	56	42	00	1960-61,62	MC*
			111	20	00	1963-74	
07CD002	Clearwater R. below Waterways	-	56	43	10	1950-64,65	MS*
			111	20	50	1966-75	
07CD004	Hangingstone R. at Ft. McMurray	914	56	42	18	1965-69	MS
			111	21	20	1970-pres.	MC

[a] M = Manual gauge
R = Recording gauge
C = Continuous
S = Seasonal
* = Only stage (water level) information

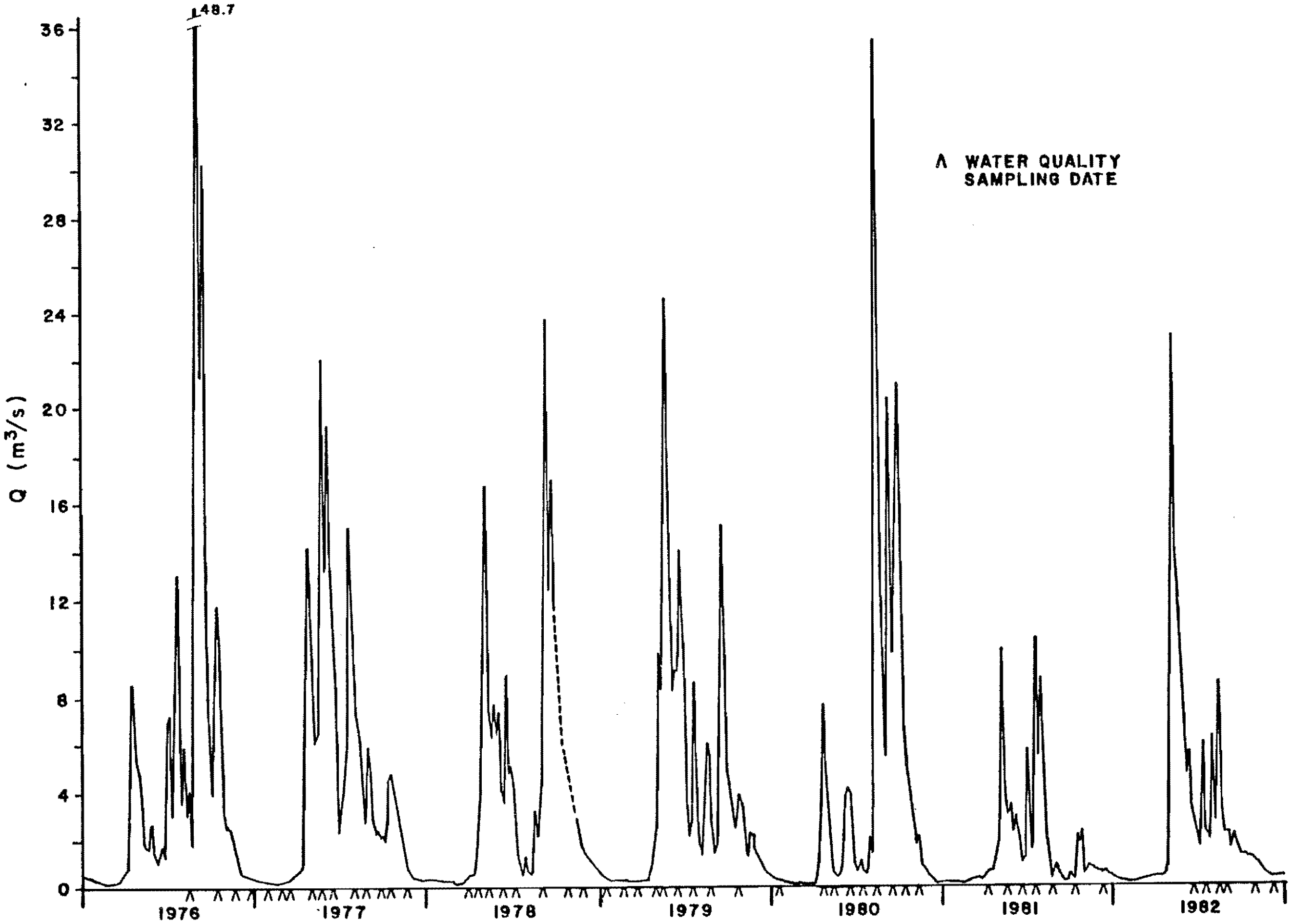

Figure 41. Daily discharge (1 in 5) in the Hangingstone River, 1976 - 1982.

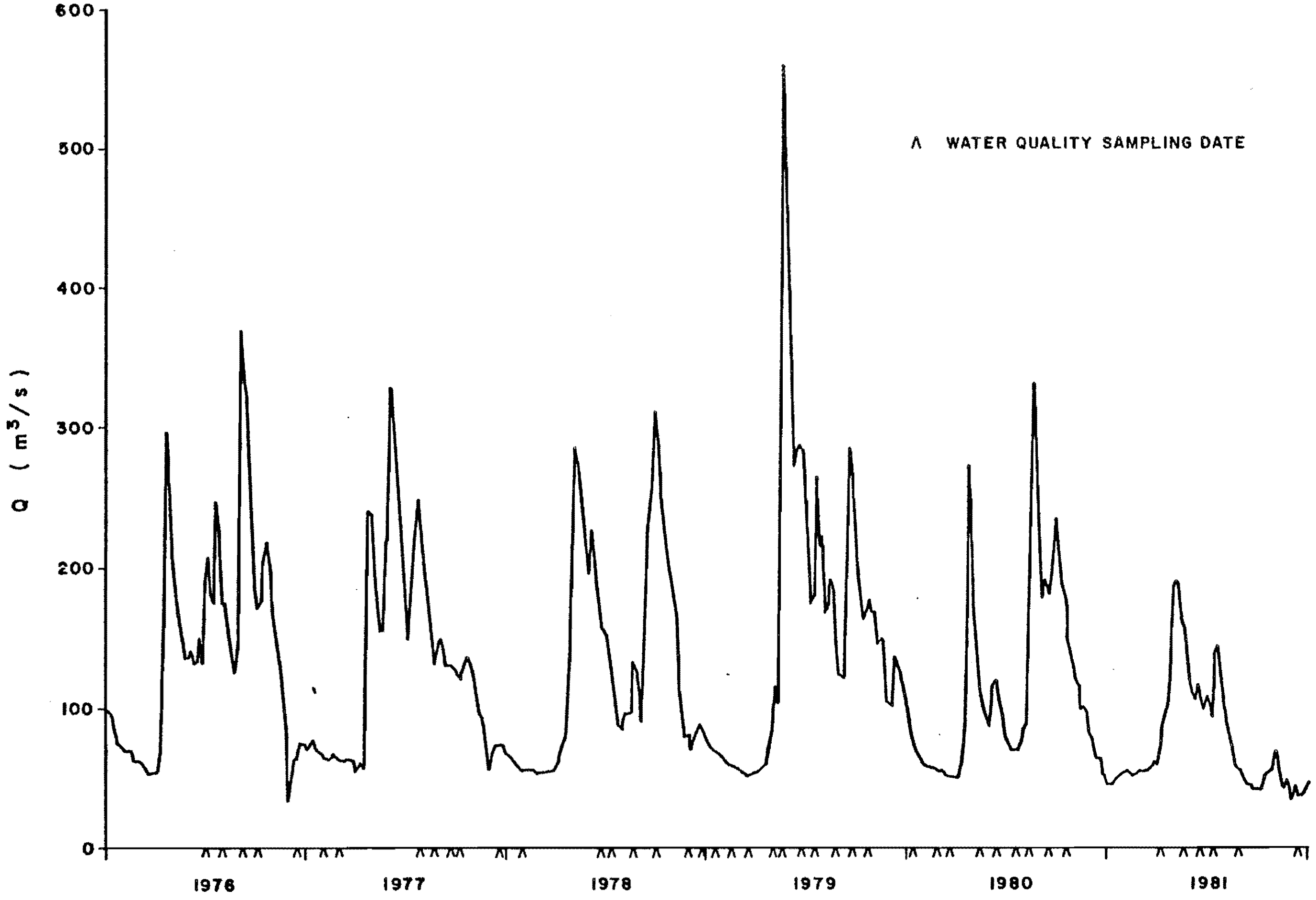

Figure 42. Daily discharge (1 in 5 days) in the Clearwater River at Draper, 1976 - 1981.

Table 16. Description and period of record for water quality sampling stations within the southern region.

Code (00AT07-)	Latitude N Longitude W (D	M	S)	Description	Period of Record	Number of Samples
CC0030	56 111	42 23	20 40	Horse R. at Abasands Park 3.2 km above confluence with Athabasca River	1976-77	5
CC0300	56 111	43 23	06 40	Horse R. near Fort McMurray 100 m above confluence with Athabasca River	1977-79	15
CD0040	56 111	42 21	18 20	Hangingstone R. at Hwy. 63	1976-83	67
CD0100	56 111	42 20	10 38	Saline Creek	1976-77	8
CD0100	56 111	41 19	53 02	Clearwater R. 2 km above Waterways	1976-81	50
CE2000	56 111	27 03	01 45	Surmount Creek about 3.2 km above Gregoire Lake	1978-83	47
CE2191	56 111	39 02	30 30	Christine R. above confluence with Clearwater R.	1978-79	10

Alkalinity (max. range 191 to 407 mg/L) and hardness (max. range 177 to 355 mg/L) concentrations were elevated in the Horse, Hangingstone, Saline, and Christina rivers. Lower levels of these parameters occurred in the Clearwater (alkalinity max. 95 mg/L; hardness max. 109 mg/L), and Surmount rivers (alkalinity max. 132 mg/L; hardness max. 132 mg/L). Maximum levels of pH ranged from 8.0 to 9.6 for all rivers.

The relative dominance of major ions for each water quality site is presented in Figure 43. The figure represents the relative contribution of each major ion and an approximation of the total ion content.

The ranking of ion dominance (measured in me/L) in five of seven rivers of the south region is as follows:

cations: calcium > magnesium > sodium
anions: bicarbonate > sulphate > chloride

Exceptions include the Clearwater and Christina rivers where sodium and chloride ions predominated. Sodium ions also were prevalent in the Hangingstone River. Total ion concentration appears to be related to bedrock geology (i.e., specific conductance is highest in the Hangingstone River and Saline Creek). The three water quality sites with elevated sodium and chloride ions are located within Devonian rock formations.

Ion concentration is inversely related to discharge. The maximum and minimum ion values presented in Figure 43 represent two discharge regimes. Maximum ion concentrations are evident during winter base flows. Minimum concentrations occur at spring runoff or during flood conditions.

Colour is a measure of water clarity and has no direct chemical significance (Hem 1970). The brown colour of rivers in the AOSERP region is due to the inflow of humic and fulvic acids from surrounding muskeg. The maximum colour values in the Hangingstone (160 mg/L), Clearwater (120 mg/L), Surmont (200 mg/L), and Christina (130 mg/L) rivers reflect muskeg characteristics of the watershed.

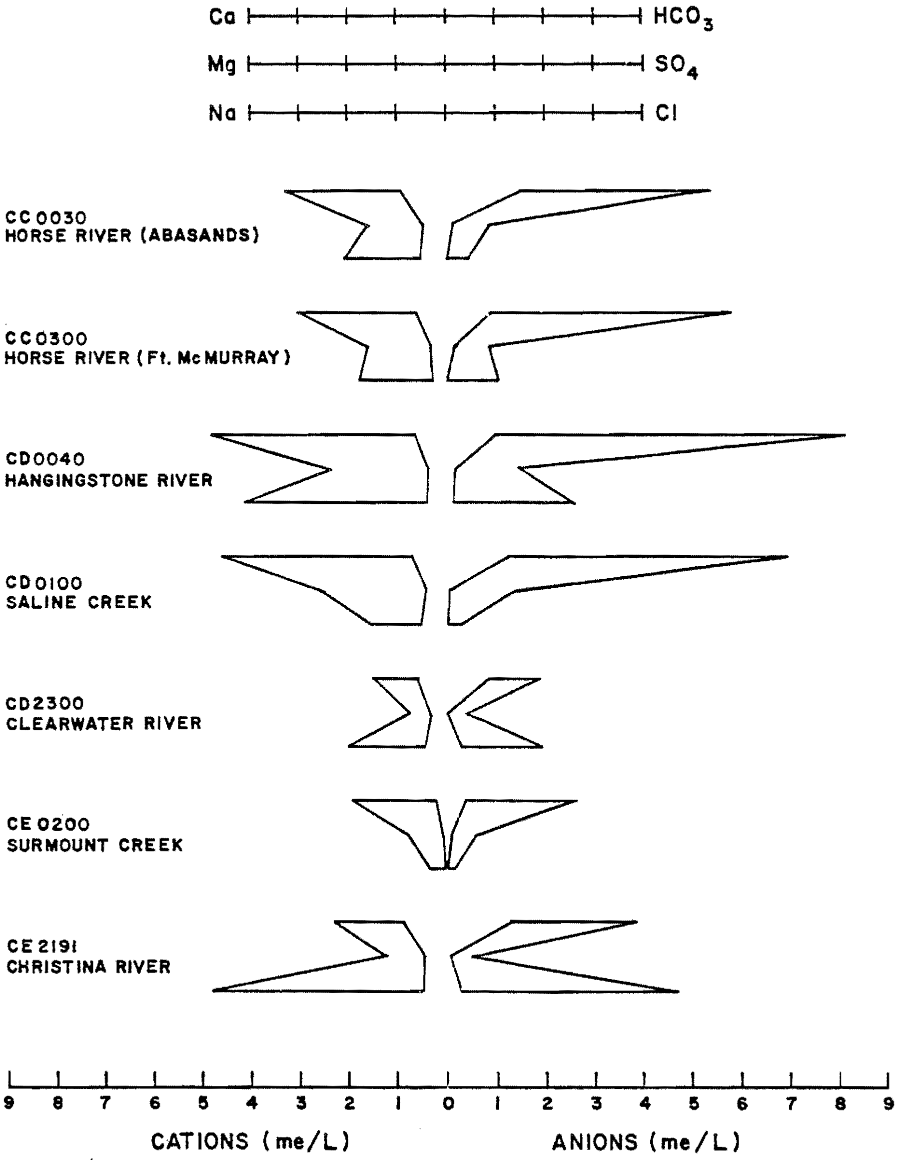

Figure 43. Maximum and minimum values (me/L) of major ions in rivers of the south.

Total organic carbon is related to the biological activity in the river. No differences were detected among these productive rivers (Appendix 10.6, Table 68).

Phenolic compounds at very high levels may be toxic to fish and at lower levels may cause fish tainting and taste problems. Sources of phenols include industrial and municipal wastes as well as decaying plant material. Maximum values of recorded phenol levels in the Hangingstone, Saline, Clearwater, and Christina rivers exceeded the Alberta surface water objective of 0.005 mg/L.

Sources of oil and grease include industrial and municipal wastes. Maximum values (6.5 mg/L) were detected in the Hangingstone River. Surface water objectives have not been established for oil and grease.

7.2.2.2 Nutrients. Phosphorus is frequently considered to be the nutrient that controls plant life. Total phosphorus and orthophosphate phosphorus (PO_4-P)are the two forms of phosphorus presented in Appendix 10.6 (Table 69).

Total phosphorus values were high, with median values exceeding the objective of 50 ug/L at all sites. A maximum value of 1300 ug/L was recorded at the Hangingstone River, 1980 August 04. Most values at this site ranged from 30 to 230 ug/L, with higher values occurring in spring during runoff.

Orthophosphates are the potentially available form of phosphorus. Typically, concentrations are lowest in summer when uptake by plants occurs. Maximum concentrations occur in fall and winter when plants die. Highest maximum values were recorded in the Horse (100 mg/L), Hangingstone (123 ug/L), and Saline (220 ug/L) rivers.

Ammonia, nitrate/nitrite nitrogen, and total kjeldahl nitrogen (TKN) are the three forms of nitrogen presented in Appendix 10.6 (Table 69). Forms of inorganic nitrogen are ammonia and nitrate/nitrite nitrogen. Total kjeldahl nitrogen is total organic nitrogen plus ammonia. In the presence of oxygen, ammonia may be converted to nitrate by a process of nitrification. Also, nitrite is rapidly converted to nitrate in the presence of oxygen.

Only the Hangingstone, Clearwater, and Surmount sites had sufficient numbers of samples to denote seasonal trends. No detectable seasonal trends in TKN were noted among the sites. Maximum ammonia and nitrate/nitrite concentrations, however, occurred in winter and spring. The highest maximum value of ammonia was recorded in the Clearwater River (0.73 mg/L). The highest maximum value of TKN (9.15 mg/L) and nitrate/nitrite nitrogen (0.66 mg/L) was recorded in the Hangingstone River. The maximum concentration of ammonia recorded in the Hangingstone River was 0.45 mg/L.

7.2.2.3 Metals. The data for 16 metal parameters are summarized in Appendix 10.6 (Table 70). Median values of nine metals (cadmium, chromium, cobalt, lead, mercury, nickel, selenium, silver, vanadium) were below the detection limit.

Copper concentrations exceeded surface water objectives in four rivers (Horse River at Abasands, Hangingstone River, Clearwater River and Surmont Creek). Maximum concentrations in the Hangingstone (43 ug/L) and Clearwater (32 ug/L) rivers occurred in summer. Maximum values of copper in Surmount Creek (48 ug/L) occurred in spring. Maximum values of copper in the Horse River at Abasands (21 ug/L) occurred in winter.

Median values for manganese and iron equalled or surpassed the surface water objectives. Guidelines for these two parameters were established for aesthetic reasons. Both substances, which are naturally derived from river sediments and weathered bedrock, may impart a taste to water, and stain fabrics and porcelain. Manganese may be taken up by plants and therefore concentrations vary seasonally.

7.2.3 Benthic Invertebrates

Tripp and Tsui (1980) reported that 80% of benthic invertebrates in the southern tributary streams was dominated by aquatic insects. Both species diversity (Shannon 1948) and average number of taxa were greater in erosional habitats. Cleanwater taxa were abundant in these habitats. Representative taxa included Ephemeroptera (Baetis, Heptagenia, Rhithrogena), Trichoptera (Brachycentrus, Glossosoma, Hydropsyche) and Chironomidae (Cricotopus, Cryptochironomus, Eukiefferiella, Microtendipes, Rheotanytarsus, Thienemanniella).

Tripp and Tsui (1980) suggested that the mean density of invertebrates was related more to longitudinal river changes than to changes in substrate. However, diversity and average number of taxa were typically higher in coarse substrates and lower in muskeg or sand substrates. Diversity and standing crop were highest in summer (August 1978).

Data presented by Tripp and Tsui (1980) were analysed to determine differences in aquatic invertebrates collected in August 1978 from river sites characterized by erosional habitats:

Stream	Number of sites
Algar	1
Cameron	1
Christina	1
Gregoire	1
Hangingstone	8
Horse	4
Saline	2
Saprae	3
Surmount	2

Emphasis was placed on Ephemeroptera (mayflies) because they were the most common cleanwater forms. Because the mayfly genus, Baetis, occurs in both erosional and depositional habitats, a correction factor (mayfly ratio) was included.

A one-way analysis of variance (ANOVA) was used to determine differences among sites for various biological components including:

1. % mayflies (mayfly density/total invertebrate density x 100);

2. mayfly ratio (mayfly density - Baetis density/total density);
3. total density;
4. diversity (Shannon and Weaver 1949); and
5. total number of taxa.

To satisfy the assumptions of the ANOVA, the data were transformed according to Sokal and Rohlf (1969) as follows: ratios (#1 and 2), arcsin $(p)^{\frac{1}{2}}$ and total density, ln (x+1). No transformations were performed on diversity or total number of taxa.

Results indicated that there were no differences in any of the components among the nine rivers (Algar, Cameron, Christina, Gregoire, Hangingstone, Horse, Saline, Saprae, and Surmount). However, if one outlier (Hangingstone River, site 5) is excluded from the analysis, there is a significant difference ($p < 0.05$) in the number of taxa among rivers. Significantly more taxa were present in the Hangingstone, Horse, and Christina rivers; fewer taxa were present in Saline Creek.

7.3 RELATIONSHIPS AMONG PARAMETERS

7.3.1 Water Quality and Discharge

Relationships were established between water quality parameters and discharge levels for the Hangingstone (CD0040) and Clearwater (CD2300) rivers. Results of the correlation analysis indicated that, of all water quality parameters (median values), none was significantly correlated with conductivity at the 0.01 level. Therefore, only relationships between conductivity and discharge were analysed for the two rivers.

The relationships were analysed using linear, log/linear, and log/log transformations of the data. The significance of each regression was tested by determining if the slope differed significantly from zero. The log/log transformation yielded the highest R^2 and best fit to the data for both Hangingstone and Clearwater rivers (Table 17).

Relationships were examined to determine if the regressions of conductivity on discharge were the same in the Hangingstone and

Table 17. Summary of regression equations of conductivity with discharge for the Clearwater and Hangingstone rivers. Equations with the best fit of the data were of the following log/log format:

$$Y = Ax^B$$

where: A = intercept, B = slope, Y = dependent variable (conductivity), X = independent variable (discharge).

River	df (n-2)	A	B	R^2	p (Ho: $B_1 = 0$)
Clearwater (DC2300)	43	1821	-0.445	0.71	L0.001
Hangingstone (CD0040)	41	602	-0.574	0.71	L0.001

L = less than.

Clearwater rivers. The residual variances between rivers were heterogenous (F-test for two samples) (i.e., the variances of the two samples were not equal and so comparisons could not be made).

7.3.2 Relationships between Map Parameters and Biological Components

A multiple regression analysis was used to determine the influence of land formations (physiology) and channel features (distance from river mouth, slope, width, elevation) on the benthic invertebrate community of nine rivers (n=27 sites). Five dependent variables were examined including percent mayflies, mayfly ratio (mayflies - Baetis/ total density), total density, diversity, and number or taxa. Separate tests were performed for land formations and channel features. Data used in both analyses are presented in Table 18.

The percent mayflies, mayfly ratio, and total density were unrelated to any channel features. Invertebrate diversity increased with elevation ($R^2=0.20$, $P < 0.05$) but was unrelated to other factors. The number of taxa increased with distance from river mouth ($R^2=0.15$, $P < 0.05$), but also was unrelated to other features.

There were no relationships between land formations and the percent mayflies, mayfly ratio, density, or the number of taxa. Diversity, however, was significantly lower ($P \leq 0.05$) in sites located within the Methy Portage Plain than in other regions.

In summary, there were no particularly strong relationships between the map parameters and the biological community.

Table 18. Data set used in multiple regression analysis relating map parameters and biological components. Data obtained from Tripp and Tsui (1980) and Turchenek and Lindsay (1982).

River	Percent Mayflies	Mayfly Ratio	Density (no/m²)	Diversity Index	Taxa	Slope	Dist.[a] (km)	Width (m)	Elev.[b] (m)	P.R.[c]
Algar	16.52	.144	817	2.42	20	.36	5	4	455	01
Cameron	10.17	.096	1848	1.59	20	4.62	1	2	200	01
Christina	34.52	.312	1373	2.50	34	.20	1	65	235	01
	9.59	.080	1168	2.43	30	.20	11	60	270	01
	7.38	.028	2111	2.35	32	.29	21	60	300	01
	30.02	.162	643	3.06	31	.48	27	35	335	01
Gregoire	40.06	.202	312	2.59	20	.56	2	31	390	01
Hangingstone	1.16	.007	2675	1.22	25	.80	1	28	250	01
	15.93	.058	772	2.00	30	.46	7	31	300	01
	25.52	.083	192	2.70	21	.15	15	32	355	01
	42.65	.203	748	3.00	37	.32	33	19	385	01
	45.10	.117	51	1.70	5	.27	42	15	420	01
	10.18	.024	285	3.20	27	.55	59	13	505	10
	6.74	.000	712	3.10	30	.20	69	13	550	10
	3.50	.000	200	2.60	15	.22	81	7	575	10
	25.54	.364	3359	3.00	50	.35	98	6	670	00
Horse	48.84	.147	1331	2.54	29	.38	1	35	250	01
	3.09	.015	3079	2.60	36	.12	28	30	380	01
	3.55	.036	338	1.84	12	.10	88	20	450	01
	13.83	.114	1424	2.82	32	.10	140	14	505	10
Saline	52.10	.000	119	1.14	5	.10	1	11	275	01
	27.93	.123	179	2.38	12	.17	18	5	375	01
Saprae	39.02	.333	387	2.30	16	1.25	1	8	250	01
	28.87	.288	194	2.41	15	1.25	5	6	318	00
Surmount	2.16	.022	4128	1.70	16	.18	1	7	480	01
	13.62	.084	213	2.37	18	.70	13	8	520	00
	5.91	.040	592	2.66	26	.80	23	4	650	00

[a] Distance from mouth.
[b] Elevation.
[c] Physiographic Regions: Methy Portage Plain, 01; Wabasca-Athabasca Lowland, 10; and Stony Mountain Upland, 00.

8. OVERALL ANALYSIS OF WATER QUALITY PARAMETERS

The purpose of providing an overall analysis of the four subregions (north, east, west and south) is to use information on water quality parameters to determine patterns of variability in river sites throughout the AOSERP study area. The analysis of such a large data set is facilitated by the use of mulivariate statistics. Principal component and cluster analyses were used to delineate those sites with similar water quality characteristics.

Three types of water quality parameters were analysed:

1. Routine parameters (including major inorganic ions and suspended particulates);
2. Nutrients, and
3. Metals.

The analysis was based on the median values of water quality parameters for each of 43 to 44 sampling sites in the study area (Table 19).

8.1 ROUTINE PARAMETERS

Median values of 18 routine parameters representing 44 sites were analysed using principal component and cluster analysis. The first two principal components (PC1 and PC2) accounted for 68.2% of the variance in the data, of which the first component accounted for 48.4% (Table 20). Specific conductivity and silica had the highest and lowest coefficients, respectively, for the first principal component. Thus, river sites with high values of conductivity and low values of silica have high scores on PC1. In contrast, river sites with low values of conductivity and high levels of silica have lower scores on PC1.

Another source of variability was the second principal component (19.8% of the variation). Here, non-filterable residue (NFR) had the highest positive coefficient and total alkalinity had the most highly significant negative contribution (Table 20).

The relationships among sites are displayed as a dendrogram (Figure 44) and as a bivariate plot of factor scores for each site (Figure 45). Three major groupings designated as A, B, and C emerge

Table 19. Site numbers with corresponding NAQUADAT codes which were used in the cluster and principal component analysis of water quality parameters (R, routine; N, nutrient; M, metal).

Site Number R+N	Site Number M	NAQADAT Code	Sub-region (N,E,W,S,)	Site Number R+N	Site Number M	NAQUADAT Code	Sub-region
1	1	DD0090	N	23	22	DA0110	W
2	2	DD0212	N	24	23	DA0120	W
3	3	KF0100	N	25	24	DA0121	W
4	4	KF0101	N	26	25	DA0130	W
5	5	KF0140	N	27	26	DA0140	W
6	6	NA0030	N	28	27	DA0150	W
7	7	KF0200	N	29	28	DA0160	W
8	8	KF0201	N	30	29	DA0170	W
9	9	DD0080	N	31	30	DA0180	W
10	10	MD2000	N	32	31	DA0181	W
11	11	DA0060	E	33	32	DA0182	W
12	12	DA0080	E	34	33	DA0183	W
13	13	DA0081	E	35	34	DA0190	W
14	14	DA0083	E	36	35	DB0011	W
15	15	DA0084	E	37	36	DB0020	W
16	16	DA0085	E	38	37	DB0030	W
17	17	DA0090	E	39	38	DB0040	W
18	18	DC0010	E	40	39	CC0300	S
19	19	DD0020	E	41	40	CD0040	S
20	20	DA0070	W	42	41	CD2300	S
21	-	DA0098	W	43	42	CE2000	S
22	21	DA0100	W	44	43	CE2121	S

Table 20. Principal component coefficient (loadings) for the first two components (PC1 and PC2): routine parameters.

Parameter	PC1	PC2
pH	.183	.034
Total alkalinity	.252	-.332
Hardness	.315	-.071
Conductivity	.329	.073
Turbidity	.052	.368
Silica	.039	-.166
Calcium	.305	-.066
Magnesium	.320	.095
Sodium	.266	.110
Potassium	.266	.172
Fluoride	.224	.199
Bicarbonate	.253	-.331
Chloride	.151	.233
Sulphate	.196	.365
Total organic carbon	.165	-.188
Total inorganic carbon	.192	-.325
Filterable residue	.327	.075
Non-filterable residue	.093	.421
Eigenvalues	8.71	3.56
% total variance	48.42	19.79
Cumulative % t.v.	48.42	68.21

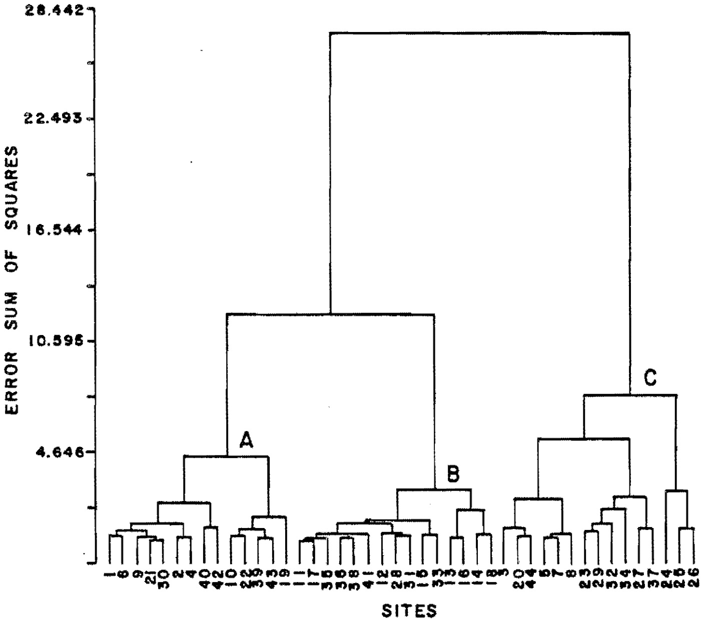

Figure 44. Cluster analysis of routine parameters at sample sites within the four subregions. Similarity is measured by error sum of squares.

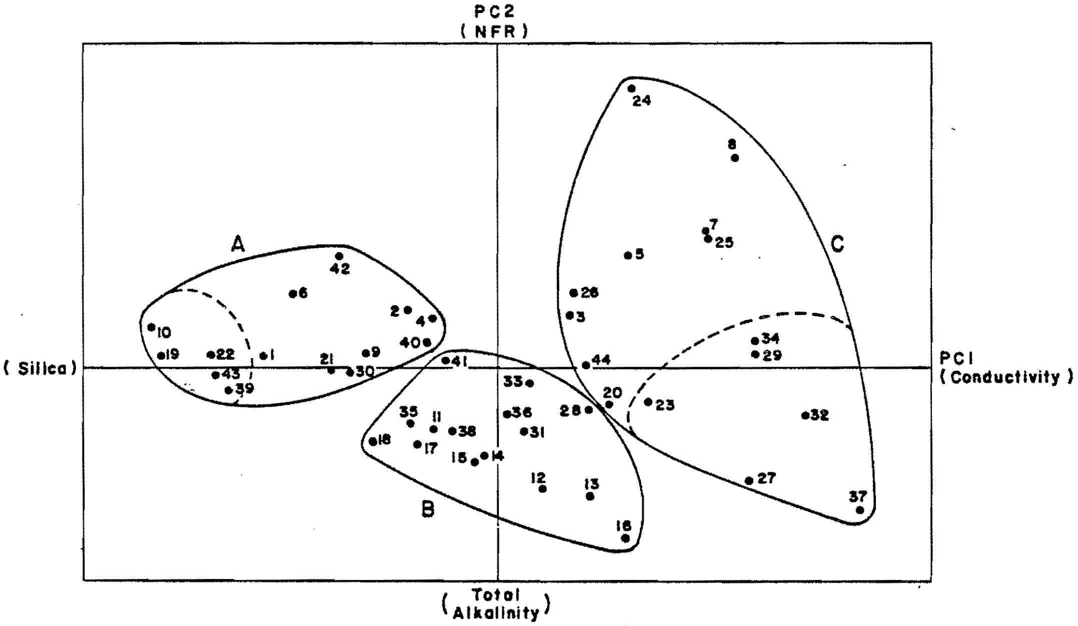

Figure 45. Principal component ordination of sampling sites using routine parameters from the four subregions. Dashed lines enclose subgroups of river sites. Chemical labels on axes are from Table 20.

from the cluster analysis of the routine parameters. Sites that have similar values of water quality parameters will form a cluster on the bivariate plot. Sites within clusters have been delineated on a map of the study area (Figure 46).

The mean ± standard error of the routine parameters with the highest and lowest coefficients (i.e., conductivity, silica, NFR, and alkalinity) for PC1 and PC2 are presented in Table 21. The range of values for these parameters encountered within the AOSERP study area are typical of lotic conditions throughout Alberta.

Sites within group A have characteristically low values of conductivity, silica, and alkalinity, with moderate levels of suspended solids and turbidity (Table 21). Suspended sediments and turbidity reduce light levels available for algal productivity. Representative group A sites included those in the northeast (Lake Athabasca Delta), west (Ells River, Thickwood Creek), and south (Horse, Clearwater, and Surmount rivers) regions. Many of these sites occurred on archean (granite) or devonian bedrock and are less productive than rivers which flow over cretaceous rock.

Group B sites had the lowest NFR and highest silica values; conductivity levels were moderate (Table 21). Substrates at these sites receive maximum available light for algal growth and abundant levels of silica for diatom production. These sites, therefore, should represent areas of maximum productivity within the region. Representative waterways of the eastern region include Muskeg, Steepbank, Firebag, and Tar rivers. The Hangingstone and MacKay mainstem also are included within this group.

Group C sites are categorized as having maximum values of conductivity, NFR, and alkalinity; silica concentrations are moderate (Table 21). These river sites are often highly turbid and maintain a high sediment load, factors which reduce light available for photosynthesis. Furthermore, substrate interstices are filled with sediment which reduce the effective habitat available to benthic

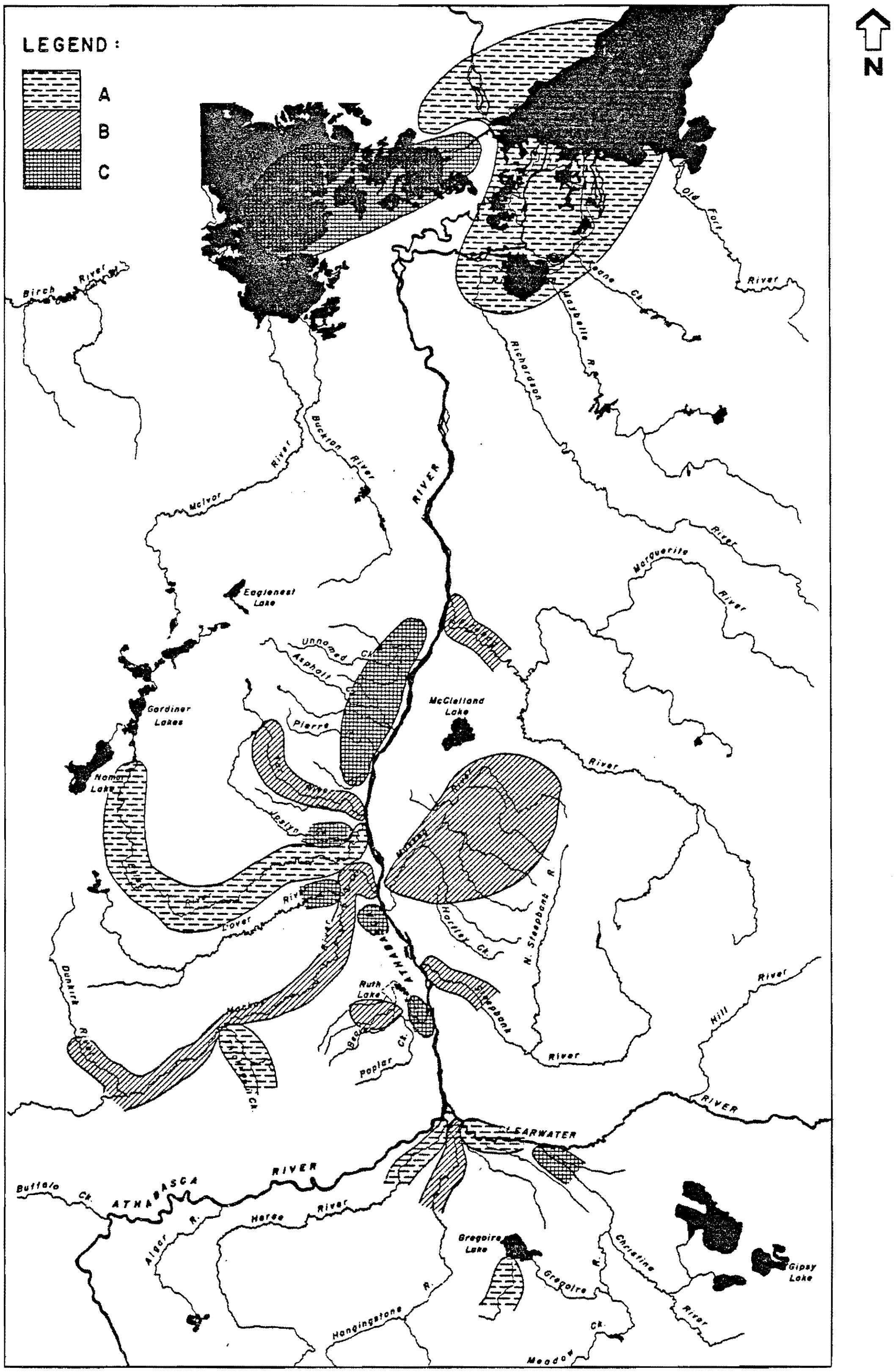

Figure 46. Site groupings based on principal component analysis using median values of routine parameters .

Table 21. Mean (± standard error) of routine parameters indicated by the highest and lowest loading coefficients for the first two principal components. Groups are indicated in Figures 46 and 47.

Group (No. of Sites)	Parameters			
	Conductivity (uS/cm)	Silica (mg/L)	NFR (mg/L)	Total Alkalinity (mg/L)
A (n = 15)	169.2 ± 15.76	5.6 ± 0.83 (4.9 ± 0.49)[a]	14.5 ± 3.16	73.0 ± 6.41
B (n = 15)	276.7 ± 14.43	8.6 ± 0.71	8.9 ± 1.50	143.9 ± 7.70
C (n = 15)	449.9 ± 15.94	6.9 ± 0.74	20.9 ± 3.91	142.6 ± 14.69

[a] Site 19 (Richardson River) detailed from calculation.

invertebrates. Representative sites are lakes and channels of the northwest region and river sites draining the east slopes of the Birch Mountains.

8.2 NUTRIENTS

Clustering techniques were applied to 44 sites using median values of nutrient parameters, including total phosphorus (TP), orthophosphate, nitrate/nitrite nitrogen, total kjeldahl nitrogen (TKN), and ammonia. The cumulative per cent variability removed by the first two principal components was 64.0%, representing PC1 (34.4%) and PC2 (29.6%) (Table 22).

Total phosphorus and nitrate/nitrite nitrogen had the highest and lowest coefficients, respectively, for the first principal component. Thus, sites with characteristically high concentrations of TP and low concentrations of nitrate/nitrite nitrogen have high factor scores on PC1. For the second principal component, nitrate/nitrite nitrogen had the highest positive coefficient and TKN had the most negative coefficient. Sites with high nitrate/nitrite nitrogen values have high factor scores on PC2.

The relationships among sites, each of which is represented by a factor score, are presented as a bivariate plot of PC1 and PC2 (Figure 48). Sites with similar values of TP, TKN, and nitrate/nitrites form clusters on the bivariate plot. Most sites were clustered at the intersection of the two components. High median values of nitrate/nitrite nitrogen were noted for the Horse River (site 40, 0.2 mg/L) and Surmount Creek (site 43, 0.32 mg/L). Thus, these two sites are distinct from other sites on the bivariate plot.

Results from a cluster analysis of the data are displayed as a dendrogram in Figure 47. Again, sites 40 and 43 are distinct. Site 30 (lower Ells River) also is isolated from the other sites. The median value of ammonia at site 30 was 0.35 mg/L; the range of ammonia concentrations for the other 43 sites was 0.03 to 0.19 mg/L. Median values of other nutrients recorded for site 30 were within the range of the concentrations of the other sampling sites.

Table 22. Principal component coefficients (loadings) for the first two components (PC1 and PC2): nutrient parameters.

Parameter	PC1	PC2
Total phosphorus	.610	-.083
Orthophosphate	.501	.514
Nitrate/nitrite	.100	.691
Total kjeldahl nitrogen	.579	-.375
Ammonia	.178	-.333
Eigenvalues	1.72	1.48
% of total variance	34.44	29.60
Cumulative % t.v.	34.44	64.04

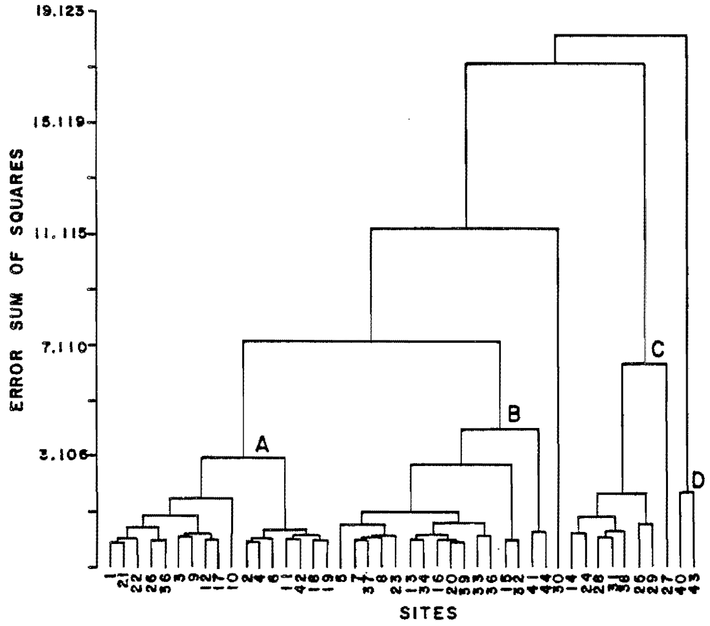

Figure 47. Cluster analysis of nutrients at sample sites within the four subregions . Similarity is measured by error sum of squares .

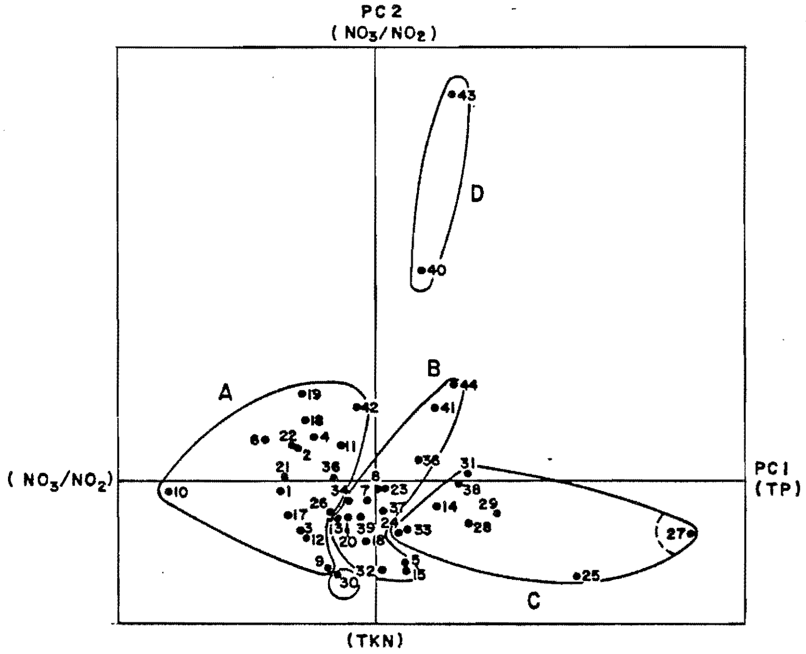

Figure 48. Principal component ordination of sampling sites using nutrient parameters from the four subregions . Chemical labels on axes are from Table 22 .

The mean ± standard error of the nutrients with highest and lowest coefficients (i.e., TP, nitrate/nitrite, and TKN) for PC1 and PC2 are presented for each of the three major groups (A, B, and C) (Table 23). These groups are also delineated on a map of the study area (Figure 49).

TKN is a measure of organic nitrogen and ammonia, both of which are important in biological activity. Inorganic forms of nitrogen include ammonia, nitrates, and nitrites. With adequate oxygen, ammonia is converted to nitrate by a nitrification process. Nitrite is rapidly converted to nitrate in the presence of oxygen.

Total phosphorus (inorganic and organic phophorus) is a measure of both dissolved and particulate forms. The dissolved form which is biologically available can be a limiting factor for plant growth (McNeely et al. 1979). Orthophosphates represent the dissolved form of phosphorus. Although median values of TP increased substantially from group B (62.2 ug/L ± 3.23) to group C (117.7 ug/L ± 9.69), relatively minor increases occurred in orthophosphate (group B, 15.7 ± 1.80; group C, 19.1 ± 2.45).

Group A sites were characterized by relatively low concentrations of TP and TKN compared to other AOSERP sites. Representative sites include the Athabasca Delta in the northeast, the Ells, Upper Tar, and Thickwood Creeks in the west and Firebag, Steepbank and Clearwater rivers in the east.

Group B sites had moderate concentrations of TP and high levels of nitrate/nitrite nitrogen and TKN (Table 23) which suggests that representative streams are productive. Sites in this category include lakes and channels of the northwest, the Muskeg watershed (excluding Stanley Creek), Hangingstone River, Poplar Creek, lower MacKay River, and Joslyn Creek.

Group C sites reflected conditions with the highest TP and TKN values; nitrate/nitrite nitrogen values are lowest (Table 23). Stanley Creek in the eastern region and several tributaries in the west (Asphalt, Calumet, lower Tar, Dunkirk, and Beaver rivers) are representative sites.

Table 23. Mean (± standard error) of nutrients indicated by the highest and lowest loading coefficients for the first two principal components. Groups are indicated in Figures 48, 49, and 50.

Group (No. of Sites)	Parameters TP (ug/L)	 NO_3NO_2 (ug/L)	 TKN (ug/L)
A (n = 17)	46.2 ± 3.61	34.9 ± 5.35	804.7 ± 62.59
B (n = 15)	62.2 ± 3.23	36.8 ± 5.61	1179.3 ± 48.26
C (n = 9)	117.8 ± 9.69	25.6 ± 6.04	1173.3 ± 168.90

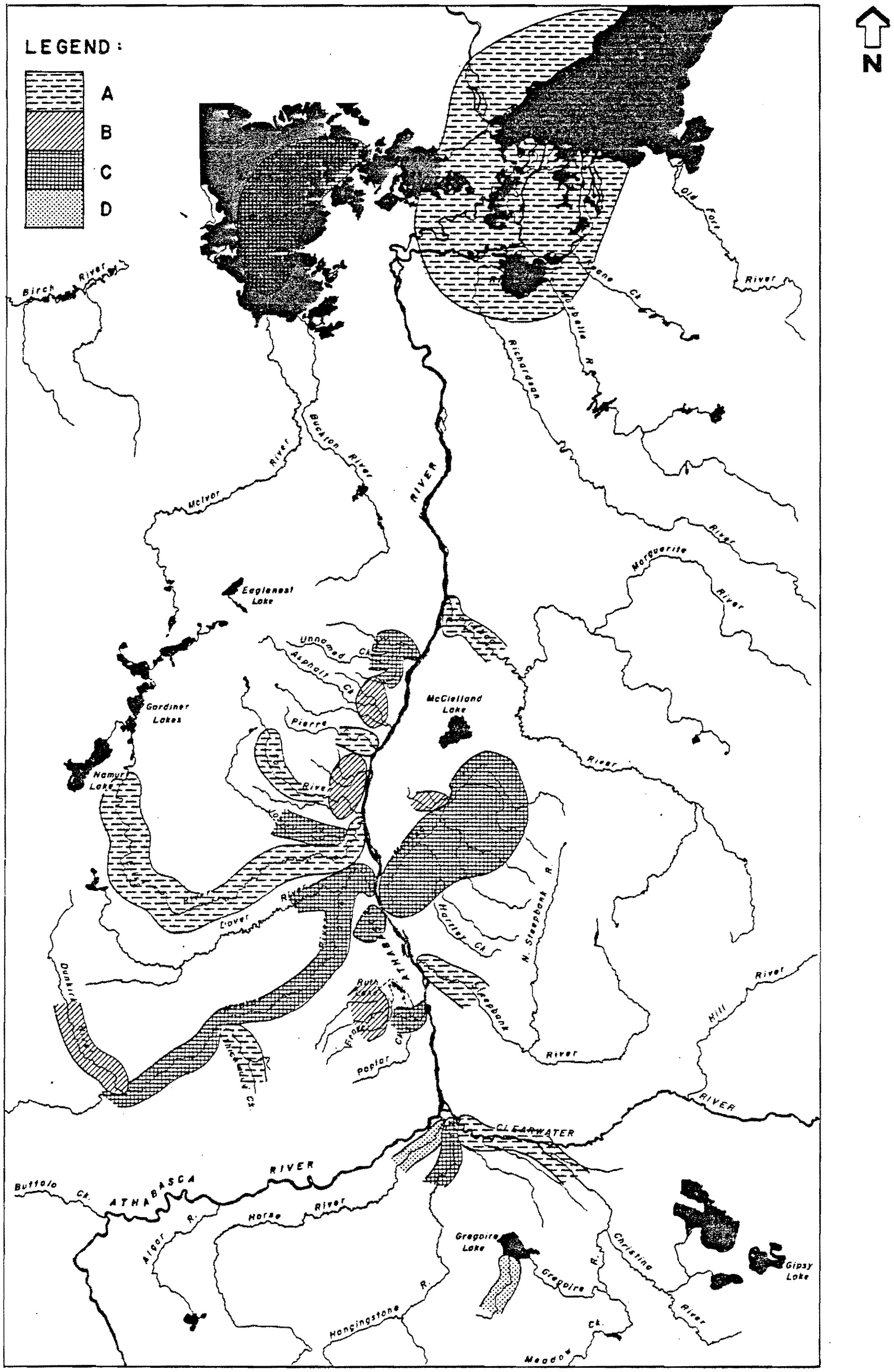

Figure 49. Site groupings based on principal component analysis using median values of nutrients.

Alberta Surface Water Objectives for total phosphorus and nitrogen are 50 ug/L and 1.0 mg/L, respectively. No surface water objectives are available for nitrogen components. The mean of all median values of TP within clusters B and C exceeded the surface water objectives. The elevated values of TP, however, are not necessarily related to increased eutrophication. Rather, the apatite (biologically unavailable) form of phosphorus increases with runoff. Thus, rivers draining the east slope of the Birch Mountains which have high TP values will have correspondingly high levels of suspended sediment.

8.3 METALS

Cluster and principal component techniques were applied to 43 sites using median values of seven metals including aluminum, arsenic, boron, copper, iron, manganese, and zinc. One site (DA0098, mouth of the Ells River) was deleted because of insufficient data. The seven metals, which were selected from the full suite typically analysed, exhibited values larger than the laboratory detection limit.

The first (46.6%) and second (20.9%) principal components accounted for a cumulative per cent variability of 67.5% (Table 24). Zinc (along with iron) and boron had the highest and lowest coefficients, respectively, for PC1. Boron and aluminum had the highest positive and negative coefficients, respectively, for PC2.

The relationships among sites were displayed as a bivariate plot of factor scores of each site (Figure 51). The dendrogram illustrates relationships among sites indicated by the cluster analysis (Figure 50). Sites within clusters have been delineated on a map of the study area (Figure 52).

The bivariate plot and dendrogram reveals that there are three major groups (A, B, and C). Group A consists of 21 similar sites. Group C consists of 16 sites, 14 of which occur together and two (site 27, the lower Tar; site 28, Joslyn Creek) which are distinct. Group B consists of two subgroups, both quite distinct from either groups A or C.

Table 24. Principal component coefficients (loadings) for the first two components (PC1 and PC2): metal parameters.

Parameter	PC1	PC2
Aluminum	.426	-.381
Arsenic	.257	.328
Boron	.183	.576
Copper	.399	-.363
Iron	.463	.335
Manganese	.344	.294
Zinc	.476	-.292
Eigenvalue	3.26	1.47
% total variance	46.57	20.95
Cumulative % t.v.	46.57	67.53

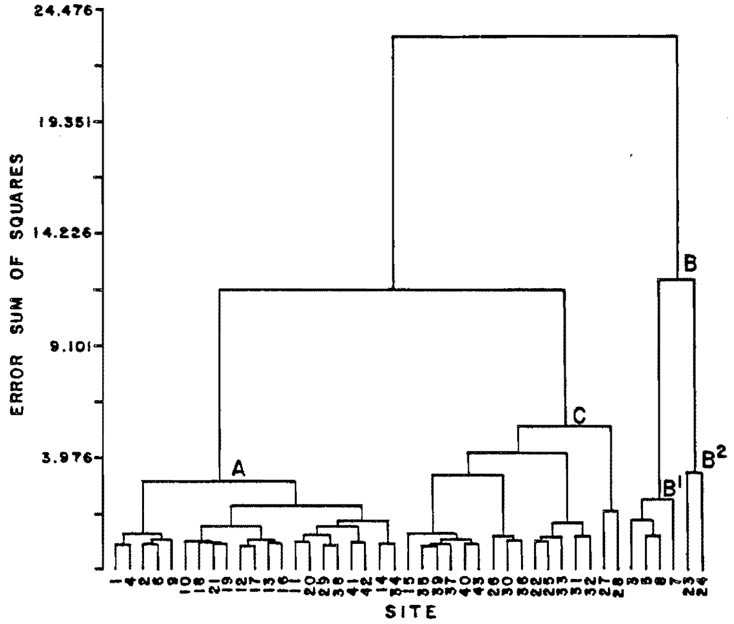

Figure 50. Cluster analysis of metals at sample sites within the four subregions. Similarity is measured by error sum of squares.

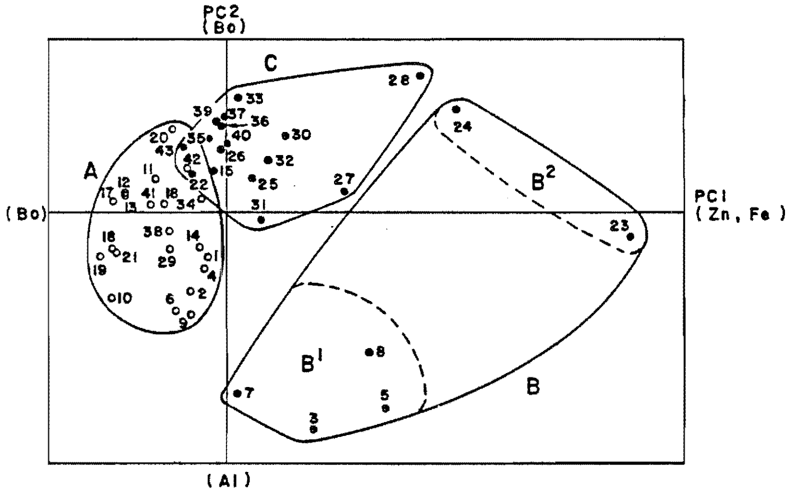

Figure 51. Principal component ordination of sampling sites using metal parameters from the four subregions. Chemical labels on axes are from Table 24.

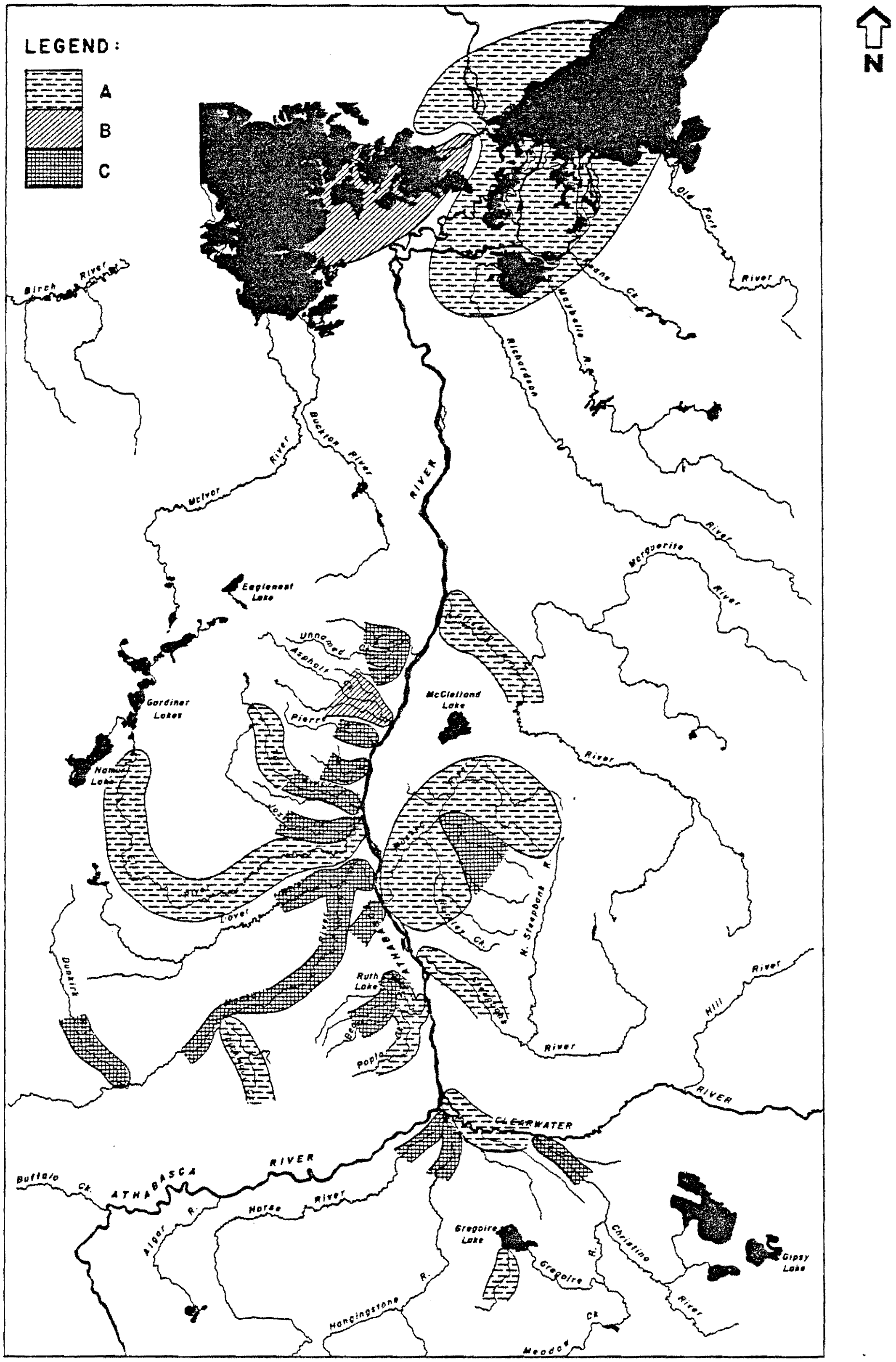

Figure 52. Site groupings based on principal component analysis using median values of metals.

The mean ± standard error of the metals (zinc, iron, boron, and aluminum) with the highest and lowest coefficients for the first two principal components are presented in Table 25. Values for zinc and boron are within the Alberta Surface Water Guidelines of 50 ug/L and 500 ug/L, respectively. No guidelines are available for aluminum. The iron values exceed the surface water objectives of 300 ug/L for all groups (A, B, and C). There are, however, few adverse effects of iron to man (McNeely et al. 1979). Elevated levels of iron in surface waters typically result from the weathering of rocks.

Group A sites exhibited low levels of zinc, iron, and boron with moderate levels of aluminum (Table 25). Representative sites include the Athabasca Delta of the northeast, as well as the Firebag, Muskeg (excluding Kearl Lake tributary), Steepbank, and Clearwater rivers. Other sites include the Ells River, upper Tar, Thickwood, and Poplar creeks in the west, and Surmount Creek in the south.

Group B sites exhibited the highest levels of zinc and iron compared to group A and C (Table 25). Levels of boron were moderate, whereas concentrations of aluminum were relatively low. Sites 23 (Asphalt Creek) and 24 (Eymundson Creek) within group B had the two highest values for iron (site 23, 4230 ug/L; site 24, 4200 ug/L) and zinc (site 23, 30 ug/L; site 24, 22 ug/L) in the study area. These two sites, which represent the Asphalt watershed, form a distinct subgroup within group B. Other sites within this group include the lakes and channels of the northwest.

Group C sites had the highest levels of boron, but moderate levels of zinc, iron, and aluminum compared to the other groups (Table 25). Representative sites occur predominately in the west (Beaver, MacKay, Dunkirk, and Dover rivers and streams draining the east slopes of the Birch Mountains) and south (the Horse, Hangingstone, and Christina rivers). The Kearl Lake tributary is the only stream from the eastern region within group C. Elevated concentrations of boron were noted frequently in winter when they are associated with groundwater inputs. Many of the sites in group C correspond to groupings B and C of

Table 25. Mean (± standard error) values of metals for sites within groups determined by principal component analysis. The metals listed represented the highest and lowest loading coefficients for the first two principal components. Groups are indicated in Figures 50, 51, and 52.

Group	Zn (ug/L)	Fe (ug/L)	Bo (ug/L)	Al (ug/L)
A (n = 21)	6.8 ± 0.49	827.9 ± 68.29	88.1 ± 10.52	129.2 ± 20.74
B (n = 6)	21.7 ± 2.88	2192.5 ± 653.51	116.7 ± 22.46	600.8 ± 118.56
B'(n = 4)	19.5 ± 3.66	1181.2 ± 212.25	82.5 ± 7.50	575.0 ± 42.87
C (n = 16)	9.5 ± 0.93	1619.7 ± 210.12	192.5 ± 17.69	157.5 ± 21.48

the routine parameters (i.e., sites which exhibited elevated saline inputs from groundwater sources).

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10. APPENDICES

10.1 LIST OF CHEMICAL PARAMETERS ANALYSED AND THE ASSOCIATED CODE FOR WHICH STANDARD METHODS ARE DESCRIBED (ENVIRONMENT CANADA 1974) (TABLE 26)

Table 26. List of chemical parameters analysed and the associated code for which standard methods are described (Environment Canada 1974). Unless otherwise specified, all units are in mg/L.

Parameter	Code
pH	10301L
Total alkalinity as $CaCO_3$	10101L
Phenolphthalein alkalinity as $CaCO_3$	10151L
Total hardness as $CaCO_3$	10602L
Specific conductivity (uS/cm)	02041L
Turbidity (JTU)	02073L
True colour (relative units)	02021L
Silica	14101L
Calcium	20103L
Magnesium	12102L
Sodium	11102L
Potassium	19102L
Bicarbonate	06201L
Carbonate	06301L
Chloride	17203L
Sulphate	16306L
Dissolved oxygen	08101L
Total organic carbon	06001L
Filterable residue	10451L
Nonfilterable residue	10401L
Total inorganic carbon	06051L
Phenolic material	06532L
Oil and grease (petroleum ether extraction)	06521L
Oil and grease (freon extraction)	06524L
Total phosphorus	15406L
Orthophosphate phosphorus	15256L
Total kjeldahl nitrogen	07013L

continued . . .

Table 26. Concluded.

Parameter	Code
Ammonia	07555L
Nitrate and nitrite nitrogen	07110L
Aluminum, extractable	13302L
Arsenic, dissolved	33104L
Boron, dissolved	05105L
Cadmium, extractable	48302L
Chromium hexavalent	24101L
Cobalt, extractable	27302L
Copper, extractable	29305L
Iron, extractable	26304L
Lead, extractable	82302L
Manganese, extractable	25304L
Mercury, total	80015L
Nickel, extractable	28302L
Selenium, dissolved	34102L
Silver, extractable	47302L
Vanadium, total	23002L
Zinc, extractable	30305L

10.2 SEASONAL SUMMARY OF ROUTINE WATER QUALITY PARAMETERS (TABLES 27 TO 38), NUTRIENTS (TABLES 39 TO 44), COLIFORMS (TABLES 45 TO 46), AND METALS (TABLES 47 TO 58), FOR 12 SITES ALONG THE ATHABASCA RIVER.

Table 27. Seasonal summary of routine water quality parameters for site CC0012 (centre) on the Athabasca River (1976 to 1983). Winter (November 1 to April 15), spring (April 16 to June 30), summer (July 1 to August 31), fall (September 1 to October 31).

	pH				Total Alkalinity (mg/L)			Hardness (mg/L)			Conductivity (uS/cm)		
	n	med	min	max	n	med	max	n	med	max	n	med	max
Winter	2	-	7.4	8.4	2[a]	158	164	2	168	183	2	365	369
Spring	9	7.9	7.5	8.3	10	101	116	10	106	118	10	226	308
Summer	12	8.0	7.5	8.4	14	98	106	14	106	126	14	219	278
Fall	7	8.0	7.3	8.2	8	98	114	8	109	121	8	240	269
ASWO	6.5 to 8.5												
CDWG	6.5 to 8.5												

	Calcium (mg/L)			Magnesium (mg/L)			Sodium (mg/L)			Potassium (mg/L)		
	n	med	max	n	med	max	n	med	max	n	med	max
Winter	2	47	51	2	13	14	2	12	16	2	1.7	2.0
Spring	10	30	34	10	7	9	10	6	9	10	0.9	3.6
Summer	14	30	36	14	8	9	14	5	11	14	0.8	1.5
Fall	8	30	33	8	8	9	8	7	9	8	0.7	1.1
ASWO												
CDWG												

	Bicarbonate (mg/L)			Chloride (mg/L)			Sulphate (mg/L)			Total Organic Carbon (mg/L)		
	n	med	max	n	med	max	n	med	max	n	med	max
Winter	2	192	200	2	4	5	2	36	36	2	7	9
Spring	10	119	139	10	2	3	9	19	26	10	10	30
Summer	14	118	129	14	2	3	12	17	37	14	11	18
Fall	8	119	139	8	2	3	8	20	28	8	8	26
ASWO					250			500				
CDWG												

	Filterable Residue (mg/L)			Non-filterable Residue (mg/L)			Phenolic Material (mg/L)			Oil and Grease (mg/L)		
	n	med	max	n	med	max	n	med	max	n	med	max
Winter	2	243	251	2	5	31	2	0.002	0.003	2	0.3	1.5
Spring	10	150	165	10	326	1490	10	0.004	0.041	8	1.0	3.3
Summer	14	139	171	14	202	1022	13	0.003	0.005	10	1.0	2.2
Fall	8	150	161	8	16	139	8	0.002	0.011	5	0.4	0.9
ASWO								0.005				
CDWG												

[a] If n = 2, median value = minimum value.

Table 28. Seasonal summary of routine water quality parameters for site DA0203 (left bank) on the Athabasca River (1976 to 1983). Winter (November 1 to April 15), spring (April 16 to June 30), summer (July 1 to August 31), fall (September 1 to October 31).

	pH				Total Alkalinity (mg/L)			Hardness (mg/L)			Conductivity (uS/cm)		
	n	med	min	max	n	med	max	n	med	max	n	med	max
Winter	4	7.7	7.6	8.1	4	163	179	4	177	197	4	439	477
Spring	8	7.8	7.5	8.0	9	100	121	9	104	121	9	235	370
Summer	8	7.9	7.5	8.2	10	98	110	10	105	121	10	221	284
Fall	6	7.9	7.5	8.0	7	106	113	7	116	131	7	266	294
ASWO		6.5 to 8.5											
CDWG		6.5 to 8.5											

	Calcium (mg/L)			Magnesium (mg/L)			Sodium (mg/L)			Potassium (mg/L)		
	n	med	max	n	med	max	n	med	max	n	med	max
Winter	4	48	54	4	14	15	4	18	51	4	0.1	1.5
Spring	9	29	34	9	8	10	9	6	13	9	0.8	1.5
Summer	10	30	34	10	8	9	10	5	12	10	0.1	1.4
Fall	7	32	35	7	9	11	7	8	10	7	0.1	1.3
ASWO												
CDWG												

	Bicarbonate (mg/L)			Chloride (mg/L)			Sulphate (mg/L)			Total Organic Carbon (mg/L)		
	n	med	max	n	med	max	n	med	max	n	med	max
Winter	4	198	218	4	12	49	4	42	50	4	6	7
Spring	8	122	147	9	2	11	8	18	37	9	9	13
Summer	7	118	134	10	2	2	8	16	23	10	10	18
Fall	6	130	138	7	4	5	6	25	28	7	5	9
ASWO					250			500				
CDWG												

continued . . .

Table 28. Concluded.

	Filterable Residue (mg/L)			Nonfilterable Residue (mg/L)			Phenolic Material (mg/L)			Oil and Grease (mg/L)		
	n	med	max	n	med	max	n	med	max	n	med	max
Winter	4	260	300	4	3	5	4	0.002	0.014	4	0.4	0.8
Spring	9	147	205	9	181	304	9	0.002	0.004	8	0.5	1.1
Summer	10	136	159	10	205	1042	10	0.002	0.009	8	0.4	1.2
Fall	7	153	163	7	10	43	7	0.002	0.003	6	0.6	1.1
ASWO								0.005				
CDWG												

Table 29. Seasonal summary of routine water quality parameters for site DA0203 (right bank) on the Athabasca River (1976 to 1983). Winter (November 1 to April 15), spring (April 16 to June 30), summer (July 1 to August 31), fall (September 1 to October 31).

	pH				Total Alkalinity (mg/L)			Hardness (mg/L)			Conductivity (uS/cm)		
	n	med	min	max	n	med	max	n	med	max	n	med	max
Winter	4	7.5	7.3	8.3	4	104	150	4	102	166	4	394	457
Spring	8	7.8	7.4	7.9	9	83	118	9	86	114	9	236	383
Summer	8	7.8	7.5	8.1	10	80	100	10	85	103	10	229	273
Fall	7	7.9	7.5	8.0	8	98	135	8	106	152	8	290	364
ASWO		6.5 to 8.5											
CDWG		6.5 to 8.5											

	Calcium (mg/L)			Magnesium (mg/L)			Sodium (mg/L)			Potassium (mg/L)		
	n	med	max	n	med	max	n	med	max	n	med	max
Winter	4	26	45	4	8	13	4	32	38	4	0.6	1.2
Spring	9	24	29	9	6	10	9	13	16	9	0.8	1.4
Summer	10	24	30	10	6	7	10	14	17	10	0.9	1.2
Fall	8	28	42	8	8	12	8	16	23	8	0.4	1.2
ASWO												
CDWG												

	Bicarbonate (mg/L)			Chloride (mg/L)			Sulphate (mg/L)			Total Organic Carbon (mg/L)		
	n	med	max	n	med	max	n	med	max	n	med	max
Winter	4	123	183	4	44	52	4	18	41	4	6	7
Spring	8	98	144	9	12	17	8	14	32	9	9	13
Summer	9	95	115	10	12	18	8	14	17	10	9	19
Fall	7	119	164	8	16	26	7	21	31	8	6	11
ASWO					250			500				
CDWG												

continued . . .

Table 29. Concluded.

	Filterable Residue (mg/L)			Non-filterable Residue (mg/L)			Phenolic Material (mg/L)			Oil and Grease (mg/L)		
	n	med	max	n	med	max	n	med	max	n	med	max
Winter	4	240	279	4	4	5	4	0.003	0.005	4	0.8	1.4
Spring	9	134	190	9	67	349	9	0.002	0.004	8	0.6	1.9
Summer	10	138	162	10	56	1044	10	0.002	0.015	8	0.7	3.2
Fall	8	174	221	8	10	98	7	0.002	0.004	7	0.5	1.8
ASWO								0.005				
CDWG												

Table 30. Seasonal summary of routine water quality parameters for site DA0205 (1976 to 1983). Winter (November 1 to April 15), spring (April 16 to June 30), summer (July 1 to August 31), fall (September 1 to October 31).

	n	pH med	pH min	pH max	Total Alkalinity (mg/L) med	Total Alkalinity (mg/L) max	Hardness (mg/L) med	Hardness (mg/L) max	Conductivity (uS/cm) med	Conductivity (uS/cm) max
Winter	7	7.7	7.5	8.2	164	172	176	187	432	486
Spring	7	7.7	7.5	8.1	98	124	107	125	257	387
Summer	6	7.9	7.4	8.2	98	106	103	115	213	281
Fall	3	7.8	7.6	7.9	97	103	105	110	257	269
ASWO		6.5 to 8.5								
CDWG		6.5 to 8.5								

	n	Calcium (mg/L) min	Calcium (mg/L) max	Magnesium (mg/L) med	Magnesium (mg/L) max	Sodium (mg/L) med	Sodium (mg/L) max	Potassium (mg/L) med	Potassium (mg/L) max
Winter	7	48	50	14	15	20	27	1.0	1.6
Spring	7	31	34	8	11	7	14	0.1	1.6
Summer	6	29	33	7	8	5	6	0.1	1.1
Fall	3	30	30	8	9	11	12	0.1	0.1
ASWO									
CDWG									

	n	Bicarbonate (mg/L) med	Bicarbonate (mg/L) max	Chloride (mg/L) med	Chloride (mg/L) max	Sulphate (mg/L) med	Sulphate (mg/L) max	Total Organic Carbon (mg/L) med	Total Organic Carbon (mg/L) max
Winter	7	200	209	17	24	42	47	6	7
Spring	7	119	151	4	8	21	38	10	13
Summer	6	114	129	2	3	15	18	12	19
Fall	3	118	125	8	8	19	25	10	11
ASWO				250		500			
CDWG									

continued . . .

Table 30. Concluded.

		Filterable Residue (mg/L)		Non-filterable Residue (mg/L)		Phenolic Material (mg/L)		Oil and Grease (mg/L)	
	n	med	max	med	max	med	max	med	max
Winter	7	255	290	4	7	0.006	0.013	2.2	0.4
Spring	7	150	200	169	324	0.002	0.005	0.1	1.1
Summer	6	122	140	240	1056	0.002	0.009	1.1	2.5
Fall	3	140	150	12	20	0.002	0.003	0.1	0.5
ASWO						0.005			
CDWG									

Table 31. Seasonal summary of routine water quality parameters for site DA0205 (right bank) on the Athabasca River (1976 to 1983). Winter (November 1 to April 15), spring (April 16 to June 30), summer (July 1 to August 31), fall (September 1 to October 31).

		pH			Total Alkalinity (mg/L)		Hardness (mg/L)		Conductivity (uS/cm)	
	n	med	min	max	med	max	med	max	med	max
Winter	6	7.6	7.2	8.0	129	160	134	158	384	464
Spring	6	7.8	7.4	8.0	82	91	84	98	216	262
Summer	6	8.0	7.4	8.1	86	97	91	103	218	276
Fall	3	7.6	7.4	7.9	90	97	97	104	261	275
ASWO		6.5 to 8.5								
CDWG		6.5 to 8.5								

		Calcium (mg/L)		Magnesium (mg/L)		Sodium (mg/L)		Potassium (mg/L)	
	n	med	max	med	max	med	max	med	max
Winter	6	36	44	11	13	30	36	1.2	1.4
Spring	6	23	30	6	8	10	14	0.4	1.4
Summer	6	26	29	6	8	8	9	0.1	1.0
Fall	3	27	28	8	8	12	14	0.1	0.1
ASWO									
CDWG									

		Bicarbonate (mg/L)		Chloride (mg/L)		Sulphate (mg/L)		Total Organic Carbon (mg/L)	
	n	med	max	med	max	med	max	med	max
Winter	6	157	195	32	40	27	37	6	6
Spring	6	100	111	8	14	15	21	8	13
Summer	6	104	118	6	8	12	16	12	19
Fall	3	109	118	11	13	17	21	10	11
ASWO				250		500			
CDWG									

continued . . .

Table 31. Concluded.

	n	Filterable Residue (mg/L)		Non-filterable Residue (mg/L)		Phenolic Material (mg/L)		Oil and Grease (mg/L)	
		med	max	med	max	med	max	med	max
Winter	6	231	273	3	30	0.002	0.023	0.8	2.0
Spring	6	125	143	74	274	0.002	0.007	0.2	1.0
Summer	6	124	140	194	298	0.002	0.003	0.7	1.4
Fall	3	140	150	10	16	0.006	0.007	0.1	0.3
ASWO						0.005			
CDWG									

Table 32. Seasonal summary of routine water quality parameters for site DA0206 (left bank) on the Athabasca River (1976 to 1983). Winter (November 1 to April 15), spring (April 16 to June 30), summer (July 1 to August 31), fall (September 1 to October 31).

	pH				Total Alkalinity (mg/L)			Hardness (mg/L)			Conductivity (uS/cm)		
	n	med	min	max	n	med	max	n	med	max	n	med	max
Winter	11	7.7	7.5	8.4	11	148	168	11	161	179	11	411	489
Spring	11	7.7	7.5	7.9	12	96	114	12	104	116	12	226	321
Summer	10	7.8	7.2	8.1	13	96	104	13	104	117	13	222	278
Fall	9	7.8	7.4	8.0	10	102	120	10	109	161	10	269	363
ASWO		6.5 to 8.5											
CDWG		6.5 to 8.5											

	Calcium			Magnesium			Sodium			Potassium		
	n	med	max	n	med	max	n	med	max	n	med	max
Winter	11	44	49	11	13	14	11	26	37	11	1.4	2.3
Spring	12	30	32	12	8	10	12	8	14	12	1.1	1.9
Summer	13	29	33	13	7	9	13	6	10	13	0.1	1.1
Fall	10	30	45	10	8	12	10	11	17	10	0.6	1.1
ASWO												
CDWG												

	Bicarbonate (mg/L)			Chloride (mg/L)			Sulphate (mg/L)			Total Organic Carbon (mg/L)		
	n	med	max	n	med	max	n	med	max	n	med	max
Winter	11	180	205	11	27	47	11	36	39	11	7	9
Spring	11	116	139	12	4	9	11	20	36	12	10	24
Summer	12	122	128	13	2	6	10	16	34	13	10	19
Fall	9	124	167	10	8	16	9	23	32	10	7	13
ASWO					250			500				
CDWG												

continued . . .

Table 32. Concluded.

	Filterable Residue (mg/L)			Non-filterable Residue (mg/L)			Phenolic Material (mg/L)			Oil and Grease (mg/L)		
	n	med	max	n	med	max	n	med	max	n	med	max
Winter	11	249	285	11	6	62	10	0.002	0.013	11	0.8	3.2
Spring	12	148	280	12	95	1760	12	0.002	0.006	11	0.8	3.0
Summer	13	139	166	13	225	1012	12	0.002	0.018	10	0.8	3.5
Fall	10	152	216	10	14	51	10	0.002	0.009	9	0.4	2.1
ASWO								0.005				
CDWG												

Table 33. Seasonal summary of routine water quality parameters for site DA0206 (right bank) on the Athabasca River (1976 to 1983). Winter (November 1 to April 15), spring (April 16 to June 30), summer (July 1 to August 31), fall (September 1 to October 31).

	pH				Total Alkalinity (mg/L)			Hardness (mg/L)			Conductivity (uS/cm)		
	n	med	min	max	n	med	max	n	med	max	n	med	max
Winter	10	7.7	7.3	8.3	10	138	165	10	143	172	10	404	479
Spring	9	7.7	7.5	8.1	10	88	128	10	92	101	10	223	273
Summer	10	7.8	7.2	8.1	12	92	104	12	100	106	12	231	276
Fall	8	7.8	7.4	8.0	9	98	118	9	105	128	9	257	292
ASWO		6.5 to 8.5											
CDWG		6.5 to 8.5											

	Calcium (mg/L)			Magnesium (mg/L)			Sodium (mg/L)			Potassium (mg/L)		
	n	med	max	n	med	max	n	med	max	n	med	max
Winter	10	39	46	10	11	14	10	28	36	10	1.6	2.0
Spring	10	26	30	10	7	8	10	10	14	10	1.0	1.6
Summer	12	28	31	12	7	8	12	9	13	12	0.1	1.0
Fall	9	29	35	9	8	9	9	11	16	9	0.6	0.8
ASWO												
CDWG												

	Bicarbonate (mg/L)			Chloride (mg/L)			Sulphate (mg/L)			Total Organic Carbon (mg/L)		
	n	med	max	n	med	max	n	med	max	n	med	max
Winter	10	168	201	10	22	50	10	28	41	10	8	9
Spring	9	107	129	10	9	12	10	16	21	10	8	23
Summer	11	111	120	12	7	9	10	14	21	12	11	19
Fall	8	122	144	9	11	16	8	20	24	9	9	15
ASWO					250			500				
CDWG												

continued . . .

Table 33. Concluded.

	Filterable Residue (mg/L)			Non-filterable Residue (mg/L)			Phenolic Material (mg/L)			Oil and Grease (mg/L)		
	n	med	max	n	med	max	n	med	max	n	med	max
Winter	10	240	280	10	4	10	10	0.001	0.020	10	0.9	3.4
Spring	10	140	148	10	77	1686	10	0.002	0.004	9	0.6	2.7
Summer	12	142	164	12	177	932	12	0.002	0.005	10	1.0	1.5
Fall	9	150	179	9	15	38	9	0.003	0.026	8	0.6	1.1
ASWO								0.005				
CDWG												

Table 34. Seasonal summary of routine water quality parameters for site DA0207 (left bank) on the Athabasca River (1976 to 1983). Winter (November 1 to April 15), spring (April 16 to June 30), summer (July 1 to August 31), fall (September 1 to October 31).

	pH				Total Alkalinity (mg/L)			Hardness (mg/L)			Conductivity (uS/cm)		
	n	med	min	max	n	med	max	n	med	max	n	med	max
Winter	16	7.8	7.5	8.3	16	146	180	16	159	191	16	404	543
Spring	10	7.8	7.6	8.1	11	98	130	11	105	151	11	221	300
Summer	11	7.9	7.3	8.2	13	101	107	13	104	118	13	221	277
Fall	9	7.6	7.4	8.0	10	100	135	10	108	154	10	253	361
ASWO		6.5 to 8.5											
CDWG		6.5 to 8.5											

	Calcium (mg/L)			Magnesium (mg/L)			Sodium (mg/L)			Potassium (mg/L)		
	n	med	max	n	med	max	n	med	max	n	med	max
Winter	16	43	49	16	13	20	16	24	42	16	1.5	3.2
Spring	11	30	41	11	7	12	11	7	15	11	1.6	3.4
Summer	13	30	33	13	7	10	13	6	15	13	0.6	1.2
Fall	10	30	42	10	8	12	10	10	18	10	0.6	1.1
ASWO												
CDWG												

	Bicarbonate (mg/L)			Chloride (mg/L)			Sulphate (mg/L)			Total Organic Carbon (mg/L)		
	n	med	max	n	med	max	n	med	max	n	med	max
Winter	16	178	219	16	20	47	16	34	49	16	8	35
Spring	10	118	158	11	4	8	10	20	46	11	11	24
Summer	12	120	129	13	3	5	11	16	33	13	10	14
Fall	9	121	164	10	6	16	9	18	32	10	10	25
ASWO					250			500				
CDWG												

continued . . .

Table 34. Concluded.

	Filterable Residue (mg/L)			Non-filterable Residue (mg/L)			Phenolic Material (mg/L)			Oil and Grease (mg/L)		
	n	med	max	n	med	max	n	med	max	n	med	max
Winter	16	244	357	16	4	128	16	0.004	0.017	16	1.1	1.8
Spring	11	146	203	11	108	1554	11	0.003	0.016	10	0.8	2.4
Summer	13	137	167	13	195	876	13	0.003	0.008	11	1.2	8.2
Fall	10	151	216	10	26	95	9	0.001	0.008	9	0.7	1.4
ASWO								0.005				
CDWG												

Table 35. Seasonal summary of routine water quality parameters for site DA0207 (right bank) on the Athabasca River (1976 to 1983). Winter (November 1 to April 15), spring (April 16 to June 30), summer (July 1 to August 31), fall (September 1 to October 31).

	pH				Total Alkalinity (mg/L)			Hardness (mg/L)			Conductivity (uS/cm)		
	n	med	min	max	n	med	max	n	med	max	n	med	max
Winter	6	7.8	7.6	8.3	6	140	164	6	152	180	6	381	478
Spring	8	7.8	7.4	8.0	9	92	110	9	99	109	9	220	353
Summer	10	7.9	7.4	8.2	12	93	105	12	100	108	12	224	275
Fall	7	7.9	7.5	8.2	8	100	134	8	106	149	8	264	364
ASWO		6.5 to 8.5											
CDWG		6.5 to 8.5											

	Calcium (mg/L)			Magnesium (mg/L)			Sodium (mg/L)			Potassium (mg/L)		
	n	med	max	n	med	max	n	med	max	n	med	max
Winter	6	40	49	6	12	14	6	23	31	6	1.3	1.6
Spring	9	27	31	9	7	10	9	9	14	9	0.1	1.6
Summer	12	28	30	12	7	8	12	8	14	12	0.4	1.1
Fall	8	29	40	8	8	12	8	14	20	8	0.8	1.1
ASWO												
CDWG												

	Bicarbonate (mg/L)			Chloride (mg/L)			Sulphate (mg/L)			Total Organic Carbon (mg/L)		
	n	med	max	n	med	max	n	med	max	n	med	max
Winter	6	171	200	6	24	32	6	31	45	6	6	63
Spring	8	110	134	9	8	10	8	16	32	9	10	22
Summer	11	115	123	12	7	9	10	16	26	12	11	20
Fall	7	124	163	8	10	18	7	22	31	8	8	15
ASWO					250			500				
CDWG												

continued . . .

Table 35. Concluded.

	Filterable Residue (mg/L)			Non-filterable Residue (mg/L)			Phenolic Material (mg/L)			Oil and Grease (mg/L)		
	n	med	max	n	med	max	n	med	max	n	med	max
Winter	6	236	277	6	3	6	6	0.004	0.018	6	0.8	1.1
Spring	9	145	190	9	73	1702	9	0.003	0.012	8	1.1	3.1
Summer	12	134	165	12	146	874	12	0.002	0.011	10	1.0	2.2
Fall	8	157	220	8	21	43	8	0.002	0.013	7	0.6	1.0
ASWO								0.005				
CDWG												

Table 36. Seasonal summary of routine water quality for site DA0208 (left bank) on the Athabasca River (1976 to 1983). Winter (November 1 to April 15), spring (April 16 to June 30), summer (July 1 to August 31), fall (September 1 to October 31).

	pH				Total Alkalinity (mg/L)			Hardness (mg/L)			Conductivity (uS/cm)		
	n	med	min	max	n	med	max	n	med	max	n	med	max
Winter	4	7.6	7.5	7.8	4	141	149	4	149	156	4	404	428
Spring	4	7.6	7.4	8.0	5	96	102	5	108	113	5	242	252
Summer	3	8.0	7.8	8.0	6	98	107	6	102	116	6	222	260
Fall	4	7.8	7.4	8.0	5	104	134	5	109	157	5	274	363
ASWO		6.5 to 8.5											
CDWG		6.5 to 8.5											

	Calcium (mg/L)			Magnesium (mg/L)			Sodium (mg/L)			Potassium (mg/L)		
	n	med	max	n	med	max	n	med	max	n	med	max
Winter	4	40	42	4	12	12	4	25	26	4	1.2	1.5
Spring	5	30	34	5	7	9	5	9	12	5	1.1	1.5
Summer	6	28	33	6	8	8	6	6	9	6	0.4	1.2
Fall	5	31	43	5	9	12	5	14	20	5	0.6	1.1
ASWO												
CDWG												

	Bicarbonate (mg/L)			Chloride (mg/L)			Sulphate (mg/L)			Total Organic Carbon (mg/L)		
	n	med	max	n	med	max	n	med	max	n	med	max
Winter	4	172	181	4	26	29	4	30	34	4	6	7
Spring	4	113	120	5	6	9	4	20	26	5	9	12
Summer	5	112	128	6	5	7	4	16	22	6	10	19
Fall	4	127	163	5	9	17	4	24	32	5	6	11
ASWO					250			500				
CDWG												

continued . . .

Table 36. Concluded.

	Filterable Residue (mg/L)			Non-filterable Residue (mg/L)			Phenolic Material (mg/L)			Oil and Grease (mg/L)		
	n	med	max	n	med	max	n	med	max	n	med	max
Winter	4	238	255	4	4	4	4	0.012	0.027	4	0.8	2.1
Spring	5	148	154	5	63	276	5	0.002	0.004	4	0.9	1.8
Summer	6	147	164	6	89	382	6	0.002	0.007	4	0.7	0.9
Fall	5	155	224	5	12	40	5	0.002	0.024	4	0.3	0.5
ASWO								0.005				
CDWG												

Table 37. Seasonal summary of routine water quality parameters for site DA0208 (right bank) on the Athabasca River (1976 to 1983). Winter (November 1 to April 15), spring (April 16 to June 30), summer (July 1 to August 31), fall (September 1 to October 31).

	pH				Total Alkalinity (mg/L)			Hardness (mg/L)			Conductivity (uS/cm)		
	n	med	min	max	n	med	max	n	med	max	n	med	max
Winter	5	7.5	7.4	7.7	5	144	172	5	157	186	5	426	510
Spring	4	7.7	7.6	7.9	5	92	99	5	99	102	5	245	280
Summer	4	7.8	7.7	8.0	6	96	105	6	102	105	6	228	260
Fall	4	7.8	7.4	8.0	5	101	133	5	108	158	5	283	360
ASWO			6.5 to 8.5										
CDWG			6.5 to 8.5										

	Calcium (mg/L)			Magnesium (mg/L)			Sodium (mg/L)			Potassium (mg/L)		
	n	med	max	n	med	max	n	med	max	n	med	max
Winter	5	42	49	5	13	15	5	27	35	5	1.0	2.4
Spring	5	28	29	5	7	8	5	10	13	5	1.1	1.7
Summer	6	28	29	6	8	9	6	8	10	6	0.4	1.0
Fall	5	30	44	5	9	12	5	14	19	5	0.7	1.1
ASWO												
CDWG												

	Bicarbonate (mg/L)			Chloride (mg/L)			Sulphate (mg/L)			Total Organic Carbon (mg/L)		
	n	med	max	n	med	max	n	med	max	n	med	max
Winter	5	175	209	5	31	33	5	33	42	5	6	7
Spring	4	112	113	5	7	10	4	19	23	5	9	16
Summer	5	115	123	6	6	8	3	14	17	6	10	18
Fall	4	125	162	5	11	18	4	24	31	5	6	10
ASWO					250			500				
CDWG												

continued . . .

Table 37. Concluded.

	Filterable Residue (mg/L)			Non-filterable Residue (mg/L)			Phenolic Material (mg/L)			Oil and Grease (mg/L)		
	n	med	max	n	med	max	n	med	max	n	med	max
Winter	5	260	290	5	5	66	5	0.006	0.011	5	0.3	2.8
Spring	5	144	164	5	49	223	5	0.003	0.005	4	0.8	1.4
Summer	6	154	165	6	71	340	6	0.002	0.005	4	0.8	1.6
Fall	5	163	219	5	11	39	5	0.002	0.007	4	0.3	1.0
ASWO								0.005				
CDWG												

Table 38. Seasonal summary of routine water quality parameters for site DD0010 (centre) on the Athabasca River (1976 to 1983). Winter (November 1 to April 15), spring (April 16 to June 30), summer (July 1 to August 31), fall (September 1 to October 31).

	pH				Total Alkalinity (mg/L)			Hardness (mg/L)			Conductivity (uS/cm)		
	n	med	min	max	n	med	max	n	med	max	n	med	max
Winter	8	7.6	7.3	8.2	8	148	242	8	160	262	8	486	726
Spring	4	7.7	7.5	7.9	4	94	100	4	102	113	4	234	259
Summer	4	7.7	7.6	7.9	4	88	108	4	94	115	4	218	346
Fall	5	7.7	7.6	7.8	5	95	110	5	106	125	5	247	340
ASWO		6.5 to 8.5											
CDWG		6.5 to 8.5											

	Calcium (mg/L)			Magnesium (mg/L)			Sodium (mg/L)			Potassium (mg/L)		
	n	med	max	n	med	max	n	med	max	n	med	max
Winter	8	44	60	8	13	27	8	31	55	8	1.2	3.1
Spring	4	29	31	4	7	9	4	10	12	4	1.0	1.9
Summer	4	26	33	4	7	8	4	8	22	4	0.6	1.4
Fall	5	30	35	5	7	9	5	10	23	5	0.7	0.9
ASWO												
CDWG												

	Bicarbonate (mg/L)			Chloride (mg/L)			Sulphate (mg/L)			Total Organic Carbon (mg/L)		
	n	med	max	n	med	max	n	med	max	n	med	max
Winter	8	180	295	8	34	65	8	36	62	8	7	11
Spring	4	115	122	4	7	10	4	18	24	4	10	13
Summer	4	107	131	4	6	23	4	16	33	4	12	19
Fall	5	116	134	5	9	27	5	16	26	5	13	16
ASWO					250			500				
CDWG												

continued . . .

Table 38. Concluded.

	Filterable Residue (mg/L)			Non-filterable Residue (mg/L)			Phenolic Material (mg/L)			Oil and Grease (mg/L)		
	n	med	max	n	med	max	n	med	max	n	med	max
Winter	8	290	450	8	5	49	8	0.003	0.006	8	1.0	5.9
Spring	4	154	159	4	101	143	4	0.008	0.001	4	0.7	1.3
Summer	4	130	219	4	163	406	4	0.002	0.002	4	0.4	2.4
Fall	5	153	195	5	33	50	5	0.002	0.002	5	1.0	1.4
ASWO								0.005				
CDWG												

Table 39. Seasonal summary of nutrients for sites CC012 (centre) and DD0010 (centre) on the Athabasca River (1976 to 1983). Winter (November 1 to April 15), spring (April 16 to June 30), summer (July 1 to August 31), fall (September 1 to October 31).

	Total Phosphorus (ug/L)			Orthophosphate (ug/L)			TKN (mg/L)			Ammonia (mg/L)			Nitrate/Nitrite (mg/L)		
CC0012	n	med	max	n	med	max	n	med	max	n	med	max	n	med	max
Winter	2[a]	21	27	2	19	21	2	0.42	1.46	2	0.03	0.06	2	0.11	0.14
Spring	9	193	2500	10	25	44	5	0.89	2.60	10	0.03	0.18	9	0.06	0.42
Summer	14	132	620	14	13	37	8	0.80	1.34	14	0.04	0.29	13	0.02	0.09
Fall	8	32	151	8	10	35	4	0.58	0.74	7	0.01	0.02	8	L0.01[b]	0.02
DD0010															
Winter	8	34	38	8	16	24	3	0.54	0.80	8	0.09	0.25	8	0.24	0.35
Spring	4	150	310	4	18	24	2	1.06	1.10	4	0.03	0.04	4	0.36	0.68
Summer	4	69	345	4	10	53	2	0.48	0.60	4	0.03	0.05	4	0.05	0.08
Fall	5	49	50	5	15	15	4	0.54	0.74	5	0.04	0.05	5	0.01	0.03
ASWO		50													
CDWG															

[a] If n = 2, median value = minimum value.
[b] L = less than.

Table 40. Seasonal summary of nutrients for sites DA0203 (left and right banks) on the Athabasca River (1976 to 1983). Winter (November 1 to April 15), spring (April 16 to June 30), summer (July 1 to August 31), fall (September 1 to October 31).

	Total Phosphorus (ug/L)			Orthophosphate (ug/L)			TKN (mg/L)			Ammonia (mg/L)			Nitrate/Nitrite (mg/L)		
DA0203	n	med	max	n	med	max	n	med	max	n	med	max	n	med	max
(left bank)															
Winter	4	23	150	4	14	20		ND[a]		4	0.07	0.44	4	0.23	0.56
Spring	9	113	340	9	24	75	2[b]	0.72	0.75	9	0.05	0.10	9	0.01	0.27
Summer	10	178	630	10	12	21	2	0.27	0.42	10	0.03	0.12	10	0.01	0.02
Fall	7	26	47	7	10	14	1	0.18		7	0.02	0.04	7	0.01	0.03
(right bank)															
Winter	4	34	42	4	20	28		ND		4	0.06	0.08	4	0.23	0.29
Spring	9	85	380	9	20	75	2	0.72	0.82	9	0.04	0.08	9	L0.01[c]	0.18
Summer	10	137	530	10	12	24	2	0.29	0.56	10	0.04	0.38	10	0.01	0.02
Fall	8	34	87	8	9	22	1	0.26		8	0.01	0.02	8	L0.01	0.01
ASWO		50													
CDWG															

[a] No data.
[b] If n = 2, median value = minimum value.
[c] L = less than.

Table 41. Seasonal summary of nutrients for sites DA0205 (left and right banks) on the Athabasca River (1976 to 1983). Winter (November 1 to April 15), spring (April 16 to June 30), summer (July 1 to August 31), fall (September 1 to October 31).

DA0205	Total Phosphorus (ug/L) n	med	max	Orthophosphate (ug/L) n	med	max	TKN (mg/L) n	med	max	Ammonia (mg/L) n	med	max	Nitrate/Nitrite (mg/L) n	med	max
(left bank)															
Winter	7	29	30	7	15	19		ND[a]		7	0.07	0.17	7	0.18	0.27
Spring	7	150	590	7	23	80		ND		7	0.07	0.22	7	0.01	0.26
Summer	6	220	560	6	11	28		ND		6	0.03	0.08	6	0.04	0.08
Fall	3	38	52	3	16	18		ND		3	L0.01[b]	0.02	3	L0.01	0.01
(right bank)															
Winter	6	30	61	6	20	21		ND		6	0.04	0.09	6	0.21	0.28
Spring	6	81	180	6	17	69		ND		6	0.03	0.08	6	L0.01	0.06
Summer	6	172	470	6	12	36		ND		6	0.03	0.05	6	0.03	0.09
Fall	3	41	52	3	19	23		ND		3	L0.01	0.01	3	L0.01	0.01
ASWO		50													
CDWG															

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[a] No data.

[b] L = less than.

Table 42. Seasonal summary of nutrients for sites DA0206 (left and right banks) on the Athabasca River (1976 to 1983). Winter (November 1 to April 15), spring (April 16 to June 30), summer (July 1 to August 31), fall (September 1 to October 31).

	Total Phosphorus (ug/L)			Orthophosphate (ug/L)			TKN (mg/L)			Ammonia (mg/L)			Nitrate/Nitrite (mg/L)		
DA0206	n	med	max	n	med	max	n	med	max	n	med	max	n	med	max
(left bank)															
Winter	11	28	47	11	18	22	4	0.49	0.56	11	0.05	0.34	11	0.19	0.44
Spring	12	100	1400	12	15	80	5	0.71	3.25	12	0.04	0.20	12	0.03	0.32
Summer	13	118	650	13	11	28	4	0.60	0.81	13	0.03	0.15	12	0.01	0.08
Fall	10	35	58	10	12	22	3	0.46	0.56	10	0.02	0.13	10	L0.01[a]	0.01
(right bank)															
Winter	10	30	46	10	19	28	5	0.60	0.74	10	0.07	0.13	10	0.18	0.36
Spring	10	102	1250	10	13	29	4	0.68	2.10	10	0.04	0.19	10	0.02	0.08
Summer	12	156	510	12	12	26	5	0.49	0.92	12	0.04	0.09	12	0.03	0.05
Fall	9	37	56	9	12	22	3	0.64	0.68	9	0.01	0.03	9	L0.01	0.01
ASWO		50													
CDWG															

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[a] L = less than.

Table 43. Seasonal summary of nutrients for sites DA0207 (left and right banks) on the Athabasca River (1976 to 1983). Winter (November 1 to April 15), spring (April 16 to June 30), summer (July 1 to August 31), fall (September 1 to October 31).

	Total Phosphorus (ug/L)			Orthophosphate (ug/L)			TKN (mg/L)			Ammonia (mg/L)			Nitrate/Nitrite (mg/L)		
DA0207	n	med	max	n	med	max	n	med	max	n	med	max	n	med	max
(left bank)															
Winter	16	30	85	16	18	44	9	0.68	1.40	16	0.08	0.70	16	0.19	0.50
Spring	11	132	1300	11	18	52	6	0.79	3.00	11	0.04	0.20	11	0.03	0.30
Summer	13	115	610	13	9	25	6	0.70	1.58	13	0.03	0.12	13	0.02	0.11
Fall	10	34	63	10	8	19	5	0.56	2.00	8	0.01	0.10	10	0.01	0.02
(right bank)															
Winter	6	28	46	6	13	23	2	0.64[a]	0.68	6	0.07	0.13	6	0.17	0.37
Spring	9	130	1300	9	15	90	4	0.92	2.50	9	0.06	0.19	9	L0.01[b]	0.32
Summer	12	162	580	12	10	33	5	0.96	1.12	12	0.03	0.50	12	0.02	0.09
Fall	8	37	66	8	13	21	3	0.50	0.62	8	0.02	0.05	8	0.01	0.02
ASWO		50													
CDWG															

[a] Minimum value.
[b] L = less than.

Table 44. Seasonal summary of nutrients for sites DA0208 (left and right banks) on the Athabasca River (1976 to 1983). Winter (November 1 to April 15), spring (April 16 to June 30), summer (July 1 to August 31), fall (September 1 to October 31).

DA0208	Total Phosphorus (ug/L)			Orthophosphate (ug/L)			TKN (mg/L)			Ammonia (mg/L)			Nitrate/Nitrite (mg/L)		
	n	med	max	n	med	max	n	med	max	n	med	max	n	med	max
(left bank)															
Winter	4	24	26	4	16	18		ND[a]		4	0.06	0.22	4	0.19	0.30
Spring	5	136	290	5	28	33	2[b]	0.66	1.00	5	0.02	0.04	5	0.01	0.06
Summer	6	92	300	6	11	16	2	0.41	0.55	6	0.07	0.36	6	0.01	0.07
Fall	5	37	58	5	8	23		ND		5	0.03	0.08	5	0.02	0.03
(right bank)															
Winter	5	28	80	5	17	20		ND		5	0.09	0.22	5	0.20	0.24
Spring	5	112	193	5	24	34	2	0.80	0.86	5	0.01	0.03	5	0.01	0.04
Summer	6	116	305	6	9	15	2	0.38	0.46	6	0.04	0.05	6	0.01	0.06
Fall	5	34	59	5	8	21		ND		5	0.03	0.05	5	0.01	0.02
ASWO		50													
CDWG															

[a] No data.
[b] If n = 2, median value = minimum value.

Table 45. Summary of total coliforms (NAQUADAT parameter code: 36001L) for 12 sites along the Athabasca mainstem. Units are recorded as most probable number (MPN) per 100 mL. Winter (November 1 to April 15), spring (April 16 to June 30), summer (July 1 to August 31), fall (September 1 to October 31).

Code		Winter			Spring			Summer			Fall	
(00AT07-)	n	med	max	n	med	max	n	med	max	n	med	max
CC0012 (centre)	1		34	9	33	2400[a]	12	168	920	7	119	320[a]
DA0203 (left)	4	54	320	9	58	2400	7	100	1600	7	42	320
DA0203 (right)	4	15	85	9	33	350	8	205	2400	8	52	320
DA0205 (left)	7	122	320	7	79	2400	5	160	920	3	320	320
DA0205 (right)	6	90	320	6	57	350	6	90	540	3	241	320
DA0206 (left)	11	115	320	12	39	2400	13	46	920	10	138	420
DA0206 (right)	9	104	320	10	47	2400	12	90	920	9	49	690
DA0207 (left)	16	126	320	10	33	920	12	57	920	10	54	146
DA0207 (right)	6	256	540	9	130	2400	11	49	2400	8	34	490
DA0209 (left)	4	256	320	5	41	55	6	23	1600	5	41	550
DA0208 (right)	5	212	320	5	27	64	6	48	920	5	29	540
DD0010 (centre)		ND[b]			ND			ND			ND	

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[a] If value = 320 or MPN/mL is greater than 320 or 2400, respectively.

[b] No data, but for purpose of analysis DA0208 (right bank) values were assigned to DD0010 (centre).

Table 46. Summary of fecal coliforms (NAQUADAT parameter code: 36011L) for 12 sites along the Athabasca mainstem. Units are recorded as most probable number (MPN) per 100 mL. Winter (November 1 to April 15), spring (April 16 to June 30), summer (July 1 to August 31), fall (September 1 to October 31).

Code		Winter			Spring			Summer			Fall	
(00AT07-)	n	med	max	n	med	max	n	med	max	n	med	max
CC0012 (centre)	1		18	9	5	110	12	14	140	7	5	33
DA0203 (left)	4	46	160	9	15	540	7	33	350	7	5	8
DA0203 (right)	4	2	30	9	11	23	8	38	920	8	4	12
DA0205 (left)	7	35	160	7	17	33	5	17	102	3	4	4
DA0205 (right)	6	6	60	6	6	33	6	22	78	3	4	7
DA0206 (left)	11	50	81	12	10	79	13	23	80	10	4	8
DA0206 (right)	9	11	49	10	13	170	12	13	79	9	3	11
DA0207 (left)	16	32	240	8	16	130	12	14	130	10	8	49
DA0207 (right)	6	76	135	9	26	70	11	13	170	8	4	9
DA0208 (left)	4	19	32	5	13	22	6	5	17	5	4	8
DA0208 (right)	5	16	90	5	9	26	6	6	27	5	4	6
DD0010 (centre)		ND[a]			ND			ND			ND	

[a] No data, but for purpose of analysis DA0208 (right bank) values were assigned to DD0010 (centre).

Table 47. Seasonal summary of metals for site CC0012 (centre) on the Athabasca River (1976 to 1983). Winter (November 1 to April 15), spring (April 16 to June 30), summer (July 1 to August 31), fall (September 1 to October 31). All values in ug/L.

	Aluminum (Ext)[a]			Arsenic (Dis)[b]			Boron (Dis)		
Season	n	med	max	n	med	max	n	med	max
Winter	2[d]	110	160	2	0.2	0.6	2	40	50
Spring	9	1080	11400	9	1.3	21.0	3	3	90
Summer	12	740	3300	12	0.9	7.8	5	40	60
Fall	7	210	1240	6	0.7	10.0	3	130	150
ASWO[c]					10			500	
CDWG					50			5000	

	Copper (Ext)			Iron (Ext)			Manganese (Ext)		
Season	n	med	max	n	med	max	n	med	max
Winter	2	1	3	2	270	460	2	10	28
Spring	10	5	40	9	3400	28000	10	145	740
Summer	14	6	24	12	2550	15000	14	119	520
Fall	8	1	3	7	440	4350	8	31	93
ASWO		20			300			50	
CDWG		1000			300			50	

	Nickel (Ext)			Vanadium (Tot)			Zinc (Ext)		
Season	n	med	max	n	med	max	n	med	max
Winter	2	1	35	2	1	1	2	3	71
Spring	9	4	35	10	2	10	10	12	120
Summer	10	4	33	10	2	15	13	9	82
Fall	5	6	8	6	1	3	8	2	21
ASWO								50	
CDWG								5000	

[a] Extractable.
[b] Dissolved.
[c] ASWO = Alberta Surface Water Objectives, CDWG = Canadian Drinking Water Guidelines.
[d] If n = 2, median value = minimum value.

Table 48. Seasonal summary of metals for site DA0203 (left bank) on the Athabasca River (1976 to 1983). Winter (November 1 to April 15), spring (April 16 to June 30), summer (July 1 to August 31), fall (September 1 to October 31). All values in ug/L.

Season	Aluminum (Ext)			Arsenic (Dis)			Boron (Dis)		
	n	med	max	n	med	max	n	med	max
Winter	4	15	120	4	0.8	1.3	ND[a]		
Spring	8	845	1500	8	0.9	4.0	2[b]	40	60
Summer	8	915	1510	7	0.9	2.6	2	20	20
Fall	6	100	180	6	0.6	0.7	1		20
ASWO					10			500	
CDWG					50			5000	

Season	Copper (Ext)			Iron (Ext)			Manganese (Ext)		
	n	med	max	n	med	max	n	med	max
Winter	4	1	1	4	230	310	4	14	20
Spring	9	3	12	8	1430	4900	9	92	170
Summer	10	4	29	8	2400	12000	10	85	450
Fall	7	1	4	6	310	650	7	25	49
ASWO		20			300			50	
CDWG		1000			300			50	

Season	Nickel (Ext)			Vanadium (Tot)			Zinc (Ext)		
	n	med	max	n	med	max	n	med	max
Winter	4	2	5	4	1	2	4	4	8
Spring	8	4	11	8	1	7	9	11	39
Summer	8	3	24	10	2	10	10	10	56
Fall	6	1	1	7	1	1	7	2	18
ASWO								50	
CDWG								5000	

[a] No data.
[b] If n = 2, median value = minimum value.

Table 49. Seasonal summary of metals for site DA0203 (right bank) on the Athabasca River (1976 to 1983). Winter (November 1 to April 15), spring (April 16 to June 30), summer (July 1 to August 31), fall (September 1 to October 31). All values in ug/L.

Season	Aluminum (Ext)			Arsenic (Dis)			Boron (Dis)		
	n	med	max	n	med	max	n	med	max
Winter	4	20	70	4	0.5	3.4	ND[a]		
Spring	8	580	1200	8	1.2	3.5	2[b]	50	60
Summer	8	690	950	8	0.9	2.5	2	10	50
Fall	7	150	330	7	0.6	1.4	1		20
ASWO					10			500	
CDWG					50			5000	

Season	Copper (Ext)			Iron (Ext)			Manganese (Ext)		
	n	med	max	n	med	max	n	med	max
Winter	4	1	1	4	370	600	4	15	30
Spring	9	2	8	8	1270	4300	9	80	450
Summer	10	4	27	8	2375	9500	10	98	370
Fall	8	1	3	7	610	1470	8	28	80
ASWO		20			300			50	
CDWG		1000			300			50	

Season	Nickel (Ext)			Vanadium (Tot)			Zinc (Ext)		
	n	med	max	n	med	max	n	med	max
Winter	4	1	1	4	2	3	4	2	2
Spring	8	1	13	9	1	6	9	7	25
Summer	8	4	18	10	1	5	10	8	56
Fall	7	1	3	8	1	2	8	2	8
ASWO								50	
CDWG								5000	

[a] No data.

[b] If n = 2, median value = minimum value.

Table 50. Seasonal summary of metals for site DA0205 (left bank) on the Athabasca River (1976 to 1983). Winter (November 1 to April 15), spring (April 16 to June 30), summer (July 1 to August 31), fall (September 1 to October 31). All values in ug/L.

	Aluminum (Ext)			Arsenic (Dis)			Boron (Dis)		
Season	n	med	max	n	med	max	n	med	max
Winter	1		60	7	0.4	8.0	ND[a]		
Spring	1		690	7	2.2	5.9	ND		
Summer	ND			6	0.8	2.4	ND		
Fall	ND			3	0.5	0.7	ND		
ASWO					10			500	
CDWG					50			5000	

	Copper (Ext)			Iron (Ext)			Manganese (Ext)		
Season	n	med	max	n	med	max	n	med	max
Winter	7	1	2	7	220	280	7	18	27
Spring	7	5	11	7	1260	4700	7	110	240
Summer	6	6	29	6	2500	11500	6	214	430
Fall	3	1	1	3	580	710	3	27	60
ASWO		20			300			50	
CDWG		1000			300			50	

	Nickel (Ext)			Vanadium (Tot)			Zinc (Ext)		
Season	n	med	max	n	med	max	n	med	max
Winter	7	1	4	7	2	8	7	2	4
Spring	7	2	11	7	1	7	7	10	56
Summer	6	8	21	6	2	13	6	11	52
Fall	3	1	5	3	1	1	3	2	5
ASWO								50	
CDWG								5000	

[a] No data.

Table 51. Seasonal summary of metals for site DA0205 (right bank) on the Athabasca River (1976 to 1983). Winter (November 1 to April 15), spring (April 16 to June 30), summer (July 1 to August 31), fall (September 1 to October 31). All values in ug/L.

Season		Aluminum (Ext)			Arsenic (Dis)			Boron (Dis)	
	n	med	max	n	med	max	n	med	max
Winter	ND[a]			6	0.4	2.8	ND		
Spring	ND			6	0.8	1.8	ND		
Summer	ND			6	0.7	2.3	ND		
Fall	ND			3	0.6	0.7	ND		
ASWO					10			500	
CDWG					50			5000	

Season		Copper (Ext)			Iron (Ext)			Manganese (Ext)	
	n	med	max	n	med	max	n	med	max
Winter	6	1	1	6	365	630	6	39	70
Spring	6	3	4	6	1185	3700	6	78	130
Summer	6	5	27	6	545	10500	6	164	390
Fall	3	1	1	3	630	680	3	26	60
ASWO		20			300			50	
CDWG		1000			300			50	

Season		Nickel (Ext)			Vanadium (Tot)			Zinc (Ext)	
	n	med	max	n	med	max	n	med	max
Winter	6	1	1	6	2	4	6	2	3
Spring	6	1	7	6	1	6	6	5	10
Summer	6	4	18	6	1	11	6	8	46
Fall	3	1	1	3	1	1	3	1	3
ASWO								50	
CDWG								5000	

[a] No data.

Table 52. Seasonal summary of metals for site DA0206 (left bank) on the Athabasca River (1976 to 1983). Winter (November 1 to April 15), spring (April 16 to June 30), summer (July 1 to August 31), fall (September 1 to October 31). All values in ug/L.

Season	Aluminum (Ext) n	Aluminum (Ext) med	Aluminum (Ext) max	Arsenic (Dis) n	Arsenic (Dis) med	Arsenic (Dis) max	Boron (Dis) n	Boron (Dis) med	Boron (Dis) max
Winter	11	40	180	11	0.6	2.4	4	55	70
Spring	10	885	12800	11	1.1	26.0	3	50	200
Summer	10	870	2000	10	1.8	3.8	2[a]	40	50
Fall	9	250	670	9	0.6	1.2	2	115	180
ASWO					10			500	
CDWG					50			5000	

Season	Copper (Ext) n	Copper (Ext) med	Copper (Ext) max	Iron (Ext) n	Iron (Ext) med	Iron (Ext) max	Manganese (Ext) n	Manganese (Ext) med	Manganese (Ext) max
Winter	11	1	3	11	360	1000	11	19	49
Spring	12	4	40	11	1430	34500	12	70	1060
Summer	13	6	30	10	2950	12000	13	120	460
Fall	10	1	2	9	520	1110	10	37	54
ASWO		20			300			50	
CDWG		1000			300			50	

Season	Nickel (Ext) n	Nickel (Ext) med	Nickel (Ext) max	Vanadium (Tot) n	Vanadium (Tot) med	Vanadium (Tot) max	Zinc (Ext) n	Zinc (Ext) med	Zinc (Ext) max
Winter	11	1	4	11	1	9	11	6	39
Spring	11	3	50	12	1	10	12	12	160
Summer	10	6	25	13	1	11	13	12	54
Fall	9	1	3	10	1	3	10	3	67
ASWO								50	
CDWG								5000	

[a] If n = 2, median value = minimum value.

Table 53. Seasonal summary of metals for site DA0206 (right bank) on the Athabasca River (1976 to 1983). Winter (November 1 to April 15), spring (April 16 to June 30), summer (July 1 to August 31), fall (September 1 to October 31). All values in ug/L.

		Aluminum (Ext)			Arsenic (Dis)			Boron (Dis)	
Season	n	med	max	n	med	max	n	med	max
Winter	10	55	220	10	0.4	1.6	5	50	70
Spring	8	170	11700	9	1.0	24.0	2[a]	60	90
Summer	10	915	2300	10	1.8	4.9	2	40	80
Fall	8	220	540	8	0.7	6.0	2	90	100
ASWO					10			500	
CDWG					50			5000	

		Copper (Ext)			Iron (Ext)			Manganese (Ext)	
Season	n	med	max	n	med	max	n	med	max
Winter	10	1	3	10	415	670	10	13	56
Spring	10	2	60	9	1150	31500	10	60	920
Summer	12	5	28	10	2420	11000	12	140	420
Fall	9	1	2	8	595	1230	9	31	74
ASWO		20			300			50	
CDWG		1000			300			50	

		Nickel (Ext)			Vanadium (Tot)			Zinc (Ext)	
Season	n	med	max	n	med	max	n	med	max
Winter	9	1	4	9	1	1	10	4	26
Spring	9	2	30	10	1	8	10	8	140
Summer	10	6	14	12	1	13	12	9	47
Fall	7	1	5	8	1	2	9	2	58
ASWO								50	
CDWG								5000	

[a] If n = 2, median value = minimum value.

Table 54. Seasonal summary of metals for site DA0207 (left bank) on the Athabasca River (1976 to 1983). Winter (November 1 to April 15), spring (April 16 to June 30), summer (July 1 to August 31), fall (September 1 to October 31). All values in ug/L.

	Aluminum (Ext)			Arsenic (Dis)			Boron (Dis)		
Season	n	med	max	n	med	max	n	med	max
Winter	10	100	230	16	0.5	4.2	9	60	210
Spring	6	1125	2900	10	1.3	27.0	4	55	120
Summer	6	1215	14700	11	0.9	9.7	4	45	60
Fall	5	530	940	8	1.0	5.0	4	70	140
ASWO					10			500	
CDWG					50			5000	

	Copper (Ext)			Iron (Ext)			Manganese (Ext)		
Season	n	med	max	n	med	max	n	med	max
Winter	16	1	5	16	370	1450	16	27	34
Spring	11	5	40	10	1056	34000	11	100	1060
Summer	13	6	28	11	2900	12000	13	129	490
Fall	10	1	3	9	780	25000	10	36	69
ASWO		20			300			50	
CDWG		1000			300			50	

	Nickel (Ext)			Vanadium (Tot)			Zinc (Ext)		
Season	n	med	max	n	med	max	n	med	max
Winter	15	1	4	15	1	6	16	6	260
Spring	10	4	40	11	2	13	11	27	183
Summer	10	6	20	13	3	12	13	12	54
Fall	8	3	6	9	1	2	10	6	33
ASWO								50	
CDWG								5000	

Table 55. Seasonal summary of metals for site DA0207 (right bank) on the Athabasca River (1976 to 1983). Winter (November 1 to April 15), spring (April 16 to June 30), summer (July 1 to August 31), fall (September 1 to October 31). All values in ug/L.

	Aluminum (Ext)			Arsenic (Dis)			Boron (Dis)		
Season	n	med	max	n	med	max	n	med	max
Winter	2[a]	40	70	6	0.7	11.0	2	50	50
Spring	4	700	12200	8	1.6	22.0	3	50	110
Summer	7	1250	2900	10	1.7	5.5	3	60	70
Fall	3	350	500	7	0.6	1.1	2	70	100
ASWO					10			500	
CDWG					50			5000	

	Copper (Ext)			Iron (Ext)			Manganese (Ext)		
Season	n	med	max	n	med	max	n	med	max
Winter	6	1	4	6	285	400	6	12	30
Spring	7	5	60	8	1955	33500	9	120	990
Summer	12	4	27	10	3150	11600	12	114	380
Fall	8	1	7	7	580	1230	8	26	60
ASWO		20			300			50	
CDWG		1000			300			50	

	Nickel (Ext)			Vanadium (Tot)			Zinc (Ext)		
Season	n	med	max	n	med	max	n	med	max
Winter	6	2	2	6	2	8	6	2	13
Spring	7	3	40	8	2	7	9	15	150
Summer	10	4	20	12	2	11	12	14	49
Fall	7	1	3	8	1	2	8	4	40
ASWO								50	
CDWG								5000	

[a] If n = 2, median value = minimum value.

Table 56. Seasonal summary of metals for site DA0208 (left bank) on the Athabasca River (1976 to 1983). Winter (November 1 to April 15), spring (April 16 to June 30), summer (July 1 to August 31), fall (September 1 to October 31). All values in ug/L.

	Aluminum (Ext)			Arsenic (Dis)			Boron (Dis)		
Season	n	med	max	n	med	max	n	med	max
Winter	3	40	70	4	0.4	0.5	ND[a]		
Spring	4	1100	1400	4	1.1	3.0	1		100
Summer	4	475	1050	4	1.0	2.2	2[b]	10	20
Fall	4	110	240	4	0.6	0.7	ND		
ASWO					10			500	
CDWG					50			5000	

	Copper (Ext)			Iron (Ext)			Manganese (Ext)		
Season	n	med	max	n	med	max	n	med	max
Winter	4	1	1	4	260	360	4	10	21
Spring	5	3	11	4	1635	4270	5	78	200
Summer	6	4	8	4	1745	5900	6	100	225
Fall	5	1	1	4	655	730	5	40	53
ASWO		20			300			50	
CDWG		1000			300			50	

	Nickel (Ext)			Vanadium (Tot)			Zinc (Ext)		
Season	n	med	max	n	med	max	n	med	max
Winter	3	1	1	4	1	2	4	1	3
Spring	4	2	9	5	1	4	5	5	16
Summer	4	4	7	6	1	2	6	8	19
Fall	4	1	10	5	1	1	5	3	6
ASWO								50	
CDWG								5000	

[a] No data.
[b] If n = 2, median value = minimum value.

Table 57. Seasonal summary of metals for site DA0208 (right bank) on the Athabasca River (1976 to 1983). Winter (November 1 to April 15), spring (April 16 to June 30), summer (July 1 to August 31), fall (September 1 to October 31). All values in ug/L.

	Aluminum (Ext)			Arsenic (Dis)			Boron (Dis)		
Season	n	med	max	n	med	max	n	med	max
Winter	5	50	720	5	0.4	1.0	ND[a]		
Spring	4	640	2500	4	0.8	1.9	2[b]	70	90
Summer	4	445	1030	4	1.2	2.2	2	10	20
Fall	4	100	340	4	0.6	4.0	ND		
ASWO					10			500	
CDWG					50			5000	

	Copper (Ext)			Iron (Ext)			Manganese (Ext)		
Season	n	med	max	n	med	max	n	med	max
Winter	5	1	2	5	340	460	5	13	53
Spring	5	3	12	4	1530	3530	5	68	170
Summer	6	3	9	4	1875	6100	6	72	240
Fall	5	1	1	4	495	770	5	30	70
ASWO		20			300			50	
CDWG		1000			300			50	

	Nickel (Ext)			Vanadium (Tot)			Zinc (Ext)		
Season	n	med	max	n	med	max	n	med	max
Winter	5	1	5	5	1	3	5	4	6
Spring	4	1	7	5	1	10	5	9	13
Summer	4	2	7	6	1	1	6	8	22
Fall	4	1	3	5	1	1	5	2	4
ASWO								50	
CDWG								5000	

[a] No data.
[b] If n = 2, median value = minimum value.

Table 58. Seasonal summary of metals for site DD0010 (Centre) on the Athabasca River (1976 to 1983). Winter (November 1 to April 15), spring (April 16 to June 30), summer (July 1 to August 31), fall (September 1 to October 31). All values in ug/L.

Season	Aluminum (Ext) n	Aluminum (Ext) med	Aluminum (Ext) max	Arsenic (Dis) n	Arsenic (Dis) med	Arsenic (Dis) max	Boron (Dis) n	Boron (Dis) med	Boron (Dis) max
Winter	8	50	250	5	0.5	10.0	2[a]	40	60
Spring	4	550	1400	2	1.8	2.0	1		40
Summer	4	635	1250	2	1.6	2.8	1		30
Fall	5	140	380	1		0.4	3	70	100
ASWO					10			500	
CDWG					50			5000	

Season	Copper (Ext) n	Copper (Ext) med	Copper (Ext) max	Iron (Ext) n	Iron (Ext) med	Iron (Ext) max	Manganese (Ext) n	Manganese (Ext) med	Manganese (Ext) max
Winter	8	2	3	8	405	520	8	23	240
Spring	4	6	13	4	2650	5230	4	83	160
Summer	4	4	9	4	1285	6600	4	94	262
Fall	5	1	6	5	720	1300	5	38	55
ASWO		20			300			50	
CDWG		1000			300			50	

Season	Nickel (Ext) n	Nickel (Ext) med	Nickel (Ext) max	Vanadium (Tot) n	Vanadium (Tot) med	Vanadium (Tot) max	Zinc (Ext) n	Zinc (Ext) med	Zinc (Ext) max
Winter	8	1	2	8	2	5	8	6	9
Spring	4	5	14	4	2	7	4	13	17
Summer	4	4	7	4	1	2	4	34	75
Fall	5	2	7	5	1	1	4	6	42
ASWO								50	
CDWG								5000	

[a] If n = 2, median value = minimum value.

10.3 WATER QUALITY DATA SUMMARY OF ROUTINE PARAMETERS (TABLE 59), NUTRIENTS (TABLE 60), AND METALS (TABLE 61) FOR WATER BODIES IN THE NORTHERN REGION.

Table 59. Northern region water quality data summary (routine parameters), 1976 to 1980. See Figure 4 for site location.

Code[a]	Site Description	pH				Total Alkalinity (mg/L)			Phenolic Alkalinity (mg/L)			Total Hardness (mg/L)		
		n	med	min	max	n	med	max	n	med	max	n	med	max
DD0090	Jackfish Creek	12	7.7	7.0	8.0	12	71	106	12	0.0	L0.1	12	69	100
DD0212	Big Point Channel	48	7.8	7.4	8.3	48	100	156	48	L0.1[b]	L0.1	48	106	180
KF0100	Mamawi Lake Channel	13	7.9	7.5	8.3	13	118	153	13	0.0	L0.1	13	147	189
KF0101	Chenal des Quatre Fourches	33	7.7	7.3	8.3	33	100	152	33	L0.1	L0.1	33	113	174
KF0140	Prairie River	12	7.8	7.6	8.3	12	110	210	12	0.0	L0.1	12	149	294
NA0030	Riviere des Rochers	50	7.7	6.8	8.1	50	68	98	50	L0.1	L0.1	50	75	114
KF0200	Lake Claire (near Birch River)	12	7.9	7.1	8.1	12	106	194	12	L0.1	L0.1	12	154	307
KF0201	Lake Claire (west of Willow Point)	11	7.8	7.3	8.3	11	99	193	11	0.0	L0.1	11	162	425
DD0080	Richardson Lake (center)	10	7.7	7.3	8.0	10	92	158	10	0.0	L0.1	10	98	171
MD2000	Lake Athabasca - Sandy Point	8	7.5	6.7	7.8	8	33	58	8	0.0	L0.1	8	35	63
ASWO			6.5 to 8.5											
CDWG			6.5 to 8.5											

continued . . .

Table 59. Continued.

Code	Conductivity (uS/cm)			Turbidity (JTU)			True Colour (Rel Units)			Silica (mg/L)			Calcium (mg/L)		
	n	med	max	n	med	max	n	med	max	n	med	max	n	med	max
DD0090	12	150	238	12	9	86	6	20	60	12	6.9	14.8	12	19	28
DD0212	48	245	520	26	28	130	22	25	70	34	5.6	10.8	46	30	50
KF0100	13	400	575	13	34	350	6	28	150	13	4.1	17.5	13	40	50
KF0101	33	273	500	19	17	380	19	35	300	31	4.3	10.5	33	33	48
KF0140	12	443	945	12	48	425	6	93	280	12	3.9	14.2	12	40	78
NA0030	50	176	323	26	29	160	43	20	200	33	4.5	10.2	50	21	33
KF0200	12	500	950	12	40	262	7	60	270	12	3.1	13.5	12	43	85
KF0201	11	548	1200	11	61	475	5	80	280	11	2.9	11.5	11	46	126
DD0080	10	215	300	9	18	120	4	23	45	10	5.4	14.0	10	28	45
MD2000	8	82	152	9	4	33	4	L5	10	8	3.0	15.3	8	10	17
ASWO CDWG															

continued . . .

Table 59. Continued.

Code	Magnesium (mg/L)			Sodium (mg/L)			Potassium (mg/l)			Fluoride (mg/L)		
	n	med	max	n	med	max	n	med	max	n	med	max
DD0090	12	6	8	12	5	8	12	0.8	1.7	10	0.05	0.11
DD0212	48	8	14	46	12	40	46	1.1	2.0	11	0.09	6.00
KF0100	13	11	16	13	29	53	13	1.8	3.2	10	0.13	0.19
KF0101	33	8	15	33	16	36	33	1.3	2.7	12	0.13	0.20
KF0140	12	11	25	12	38	92	12	2.5	4.5	10	0.16	0.31
NA0030	50	5	8	50	8	23	50	1.0	1.8	11	0.07	0.12
KF0200	12	11	23	12	46	91	12	3.1	4.4	10	0.18	0.34
KF0201	11	12	27	11	53	110	11	3.4	5.8	9	0.20	0.45
DD0090	10	7	14	10	8	12	10	1.5	2.0	7	0.10	0.12
MD2000	8	3	5	8	3	5	8	1.0	1.2	6	0.06	0.09
ASWO											1.5	
CDWG											1.5	

continued . . .

Table 59. Continued.

Code	Bicarbonate (mg/L)			Carbonate (mg/L)			Chloride (mg/L)			Sulphate (mg/L)		
	n	med	max	n	med	max	n	med	max	n	med	max
DD0090	12	87	129	12	0	0	12	4	6	12	6	14
DD0212	48	121	190	48	0	0	48	9	47	48	18	41
KF0100	13	144	186	13	0	0	13	28	80	13	36	76
KF0101	33	122	185	33	0	0	33	17	50	33	24	54
KF0140	12	133	103	12	0	0	12	47	106	12	50	120
NA0030	50	83	119	50	0	0	50	8	26	50	12	44
KF0200	12	129	237	12	0	0	12	55	130	12	81	180
KF0201	11	121	235	11	0	0	11	72	160	11	87	268
DD0080	10	112	192	10	0	0	10	6	9	10	13	22
MD2000	8	40	70	8	0	0	8	4	6	8	4	8
ASWO												
CDWG								250			500	

continued . . .

Table 59. Continued.

	Dissolved Oxygen (mg/L)			Total Organic Carbon (mg/L)			Filterable Residue (mg/L)			Non-filterable Residue (mg/L)		
Code	n	med	max	n	med	max	n	med	max	n	med	max
DD0090	10	6.3	10.5	12	6	11	12	99	156	12	12	69
DD0212	30	8.8	17.2	44	9	36	46	152	300	46	41	1374
KF0100	10	7.2	15.6	12	9	31	13	264	379	13	19	97
KF0101	13	8.1	12.2	27	10	28	33	167	330	33	29	514
KF0140	12	10.1	15.2	12	17	61	12	269	625	12	33	410
NA0030	21	9.3	16.0	45	7	17	49	108	184	48	32	413
KF0200	12	9.9	15.0	12	22	61	12	330	627	12	31	219
KF0201	10	10.1	14.6	11	17	51	11	329	792	11	43	432
DD0080	8	9.4	14.2	10	12	15	9	138	198	9	14	126
MD2000	9	9.6	10.3	9	4	6	8	50	100	9	3	35
ASWO												
CDWG												

continued . . .

Table 59. Concluded.

Code	Total Inorganic Carbon (mg/L)			Phenolic Material (mg/L)			Oil and Grease (mg/L)[c]		
	n	med	max	n	med	max	n	med	max
DD0090	12	14	22	-	-	-	-	-	-
DD0212	21	21	31	41	0.002	0.032	41	0.8	2.5
KF0100	12	23	36	6	0.001	0.002	6	1.1	2.2
KF0101	24	21	35	27	0.001	0.019	26	0.5	1.3
KF0140	12	24	45	-	-	-	-	-	-
NA0030	24	14	22	41	0.002	0.022	42	0.9	3.8
KF0200	12	26	38	-	-	-	-	-	-
KF0201	11	18	42	3	L0.001	L0.001	5	1.2	2.2
DD0080	10	18	33	-	-	-	-	-	-
MD2000	9	9	15	4	L0.001	L0.001	5	1.2	1.9
ASWO					0.005				
CDWG					0.002				

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[a] Rivers, 00AT07-; Lakes, 01AT07-.

[b] L = less than.

[c] Petroleum ether method.

Table 60. Northern region water quality data summary (nitrogen and phosphorus).

Code[a]	Site Description	Total Phosphorus (ug/L)			Orthophosphate (ug/L)		
		n	med	max	n	med	max
DD0090	Jackfish Creek	12	40	93	12	9	18
DD0212	Big Point Channel	47	55	930	47	14	235
KF0100	Mamawi Lake Channel	13	51	390	12	6	280
KF0101	Chenal des Quatre Fourches	33	65	470	32	14	360
KF0140	Prairie River	12	70	310	12	9	31
NA0030	Riviere des Rochers	48	48	370	48	12	70
KF0200	Lake Claire (near Birch R.)	12	71	370	12	13	30
KF0201	Lake Claire (west of Willow Pt.)	11	80	230	11	10	180
DD0080	Richardson Lake (center)	9	42	138	9	6	19
MD2000	Lake Athabasca - Sandy Pt.	9	12	40	9	4	9
ASWO			50				
CDWG							

Code	Total Kjeldahl N (mg/L)			Ammonia (mg/L)			Nitrate & Nitrite		
	n	med	max	n	med	max	n	med	max
DD0090	12	0.86	1.90	11	0.03	0.17	12	0.03	0.27
DD0212	33	0.60	1.40	47	0.04	1.10	47	0.04	0.66
KF0100	13	1.06	3.26	12	0.03	0.10	12	0.02	0.34
KF0101	31	0.59	9.15	32	0.05	0.16	32	0.06	0.36
KF0140	12	1.62	6.04	11	0.06	0.34	12	0.03	0.27
NA0030	47	0.50	6.00	47	0.02	0.11	49	0.04	0.80
KF0200	12	1.12	3.33	11	0.04	0.15	12	0.03	0.24
KF0201	11	1.16	3.35	11	0.05	0.08	11	0.07	0.20
DD0080	9	1.40	1.78	8	0.05	0.31	9	L0.01	0.17
MD2000	9	0.37	1.20	8	0.03	0.14	9	0.01	0.08
ASWO									
CDWG									

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[a] Rivers, 00AT07-; Lakes, 01AT07-.

Table 61. Northern region water quality data summary (metals). All values in ug/L.

Code[a]	Site Description	Aluminum (Ext)[b]			Arsenic (Dis)[c]			Boron (Dis)			Cadmium (Ext)		
		n	med	max	n	med	max	n	med	max	n	med	max
DD0090	Jackfish Creek	10	256	1400	11	0.8	2.1	6	50	50	6	L1[e]	L1
DD0212	Big Point Channel	44	250	3400	48	0.6	10.0	21	40	140	26	L1	6
KF0100	Mamawi Lake Channel	10	480	3900	12	0.4	2.8	7	60	70	7	L1	L1
KF0101	Chenal des Quatre Fourches	31	290	3850	28	0.8	8.0	7	50	90	19	L1	3
KD0140	Prairie River	10	645	30400	12	0.6	5.1	12	90	280	6	L1	9
NA0030	Riviere des Rochers	46	280	3850	49	0.6	6.0	7	10	80	25	L1	2
KF0200	Lake Claire (near Birch River)	10	525	2850	12	0.1	2.7	6	90	210	6	L1	L1
KF0201	Lake Claire (west of Willow Point)	9	650	6900	11	0.9	3.6	7	90	220	6	L1	L1
DD0080	Richardson Lake (center)	8	320	7200	10	0.4	1.2	5	60	120	6	1	2
MD2000	Lake Athabasca - Sandy Point	7	120	440	9	0.4	1.5	4	40	L50	4	L1	L1
ASWO[d]						10			500			10	
CDWG						50			5000			5	

continued . . .

Table 61. Continued.

Code	Chromium (Ext)			Cobalt (Ext)			Copper (Ext)			Iron (Ext)		
	n	med	max	n	med	max	n	med	max	n	med	max
DD0090	10	L3	8	4	L2	L2	12	3	7	12	1025	4500
DD0212	29	L3	13	8	L2	3	47	3	150	47	700	17000
KF0100	10	L3	10	4	L2	L2	13	6	94	13	770	12500
KF0101	25	L3	14	5	L2	2	33	3	33	33	730	9600
KF0140	10	3	25	4	L2	2	12	8	13	12	1545	15100
NA0030	28	L3	10	4	L2	4	50	3	260	50	660	9650
KF0200	9	L3	11	4	L2	2	12	6	26	12	860	8000
KF0201	9	L3	26	4	L2	4	11	8	63	11	1550	14700
DD0080	8	3	9	5	L2	3	10	3	21	10	825	4750
MD2000	8	L3	3	3	L2	L2	8	2	13	8	155	3500
ASWO		50						20			300	
CDWG		50						1000			300	

continued . . .

Table 61. Continued.

Code	Lead (Ext)			Manganese (Ext)			Mercury (Total)			Nickel (Ext)		
	n	med	max	n	med	max	n	med	max	n	med	max
DD0090	12	L2	6	12	35	97	12	L0.1	0.3	10	L2	9
DD0212	47	3	15	47	48	870	47	L0.1	0.9	44	2	30
KF0100	13	L2	4	13	27	260	13	0.1	1.3	10	3	20
KF0101	33	L2	13	33	39	260	32	L0.1	0.6	31	2	21
KF0140	12	2	9	12	33	440	12	L0.1	0.9	10	4	13
NA0030	50	L2	17	50	30	195	49	L0.1	1.2	47	1	13
KF0200	12	L2	5	12	33	245	11	0.2	9.0	10	4	7
KF0201	11	L2	7	11	28	295	11	L0.1	0.8	9	5	15
DD0080	10	L2	6	10	29	135	9	L0.1	L0.1	9	L2	5
MD2000	8	L2	3	8	6	540	9	L0.1	0.2	7	L2	4
ASWO		50			50			0.1				
CDWG		50			50			1.0				

continued . . .

Table 61. Concluded.

Code	Selenium (Dis)			Silver (Ext)			Vanadium (Tot)			Zinc (Ext)		
	n	med	max	n	med	max	n	med	max	n	med	max
DD0090	11	L0.2	L0.5	5	L1	L1	12	L1	1	10	9	310
DD0212	33	L0.2	0.8	7	L1	L1	47	L1	20	47	10	430
KF0100	13	L0.2	L0.5	4	L1	L1	13	L1	2	10	27	81
KF0101	26	L0.2	0.8	4	L1	L1	33	L1	32	31	9	130
KF0140	12	0.4	1.1	4	L1	L1	11	1	7	10	24	44
NA0030	32	L0.2	0.5	3	L1	L1	48	L1	9	47	8	440
KF0200	12	0.2	L2.0	4	L1	L1	12	L1	4	10	11	33
KF0201	11	0.2	0.9	4	L1	L1	11	L1	3	9	16	464
DD0080	10	L0.2	L0.5	5	L1	L1	9	L1	3	9	11	53
MD2000	9	L0.2	0.4	3	L1	L1	8	L1	L1	7	7	195
ASWO		10			50						50	
CDWG		10			50						5000	

[a] Rivers, 00AT07-; Lakes, 01AT07-.
[b] Extractable.
[c] Dissolved.
[d] ASWO = Alberta Surface Water Objectives.
CDWG = Canadian Drinking Water Guidelines.
[e] L = less than.

10.4 WATER QUALITY DATA SUMMARY OF ROUTINE PARAMETERS (TABLE 62), NUTRIENTS (TABLE 63), AND METALS (TABLE 64) FOR WATER BODIES IN THE EASTERN REGION

Table 62. Eastern region water quality data summary (routine parameters), 1976 to 1982. See Figure 4 for site locations.

Code (00AT07-)	Site Description	pH				Total Alkalinity mg/L			Phenol Alkalinity mg/L		
		n	med	min	max	n	med	max	n	med	max
DA0060	Steepbank River	39	7.8	7.0	8.7	39	125	362	39	0.0	27.2
DA0080	Muskeg River at WSC gauge	77	7.8	7.2	8.6	75	173	333	75	0.1	10.4
DA0081	Muskeg R. upst. Hartley Ck.	17	7.5	7.1	8.5	17	197	304	17	0.1	6.0
DA0083	Stanley Creek	11	7.6	7.2	8.4	11	152	184	11	0.0	0.0
DA0084	Kearl Lake tributary	16	7.3	7.1	8.1	16	144	230	16	0.0	0.0
DA0085	Muskeg R. 11.2 km above Stanley Ck.	26	7.5	7.1	8.2	26	200	327	26	0.0	0.1
DA0090	Hartley Creek at WSC gauge	53	7.7	7.2	8.6	53	129	348	53	0.1	23.2
DC0010	Firebag River at WSC gauge	31	7.6	5.6	8.4	31	112	219	31	0.0	1.0
DD0020	Richardson River at WSC gauge	15	7.3	6.7	7.8	15	40	47	15	0.0	0.1
	ASWO		6.5 to 8.5								
	CDWG		6.5 to 8.5								

continued . . .

Table 62. Continued.

Code	Total Hardness (mg/L)			Conductivity (uS/cm)			Turbidity (JTU)		
(00AT07-)	n	med	max	n	med	max	n	med	max
DA0060	39	114	289	39	240	704	38	6	114
DA0080	75	162	308	75	325	596	62	5	66
DA0081	17	178	274	17	372	563	13	8	18
DA0083	11	161	185	11	300	320	8	2	11
DA0084	16	123	181	16	273	400	14	2	26
DA0085	26	202	328	26	362	610	23	6	47
DA0090	53	111	317	53	227	660	44	4	320
DC0010	31	112	227	31	202	433	29	3	46
DD0020	14	40	47	15	85	100	15	3	19

ASWO

CDWG

continued . . .

Table 62. Continued.

Code (00AT07-)	True Colour (Rel. Units)			Silica (mg/L)			Calcium (mg/L)		
	n	med	max	n	med	max	n	med	max
DA0060	10	90	180	39	6.2	15.8	39	30	76
DA0080	44	80	140	75	8.6	25.0	75	44	90
DA0081	15	70	100	17	9.8	18.7	17	52	78
DA0083	-	-	-	11	12.9	19.0	11	45	52
DA0084	-	-	-	16	7.2	14.4	16	32	47
DA0085	8	65	100	26	11.8	17.3	26	56	88
DA0090	29	80	140	53	7.1	17.3	53	30	91
DC0010	9	35	90	31	15.0	29.6	30	29	60
DD0020	7	20	50	15	14.7	18.0	14	10	12

ASWO

CDWG

continued . . .

Table 62. Continued.

Code (00AT07-)	Magnesium (mg/L)			Sodium (mg/L)			Potassium (mg/L)		
	n	med	max	n	med	max	n	med	max
DA0060	39	10	25	39	14	58	39	1.0	2.4
DA0080	75	11	90	75	12	38	74	0.8	2.6
DA0081	17	13	20	17	12	30	16	1.2	2.3
DA0083	11	10	13	11	2	2	11	0.9	1.5
DA0084	16	11	15	16	19	24	16	1.8	3.3
DA0085	26	15	27	26	6	13	26	1.2	2.6
DA0090	53	9	22	53	14	30	52	0.7	2.5
DC0010	31	10	19	30	4	9	30	0.8	2.0
DD0020	15	4	4	15	2	2	15	0.8	1.0
ASWO									
CDWG									

continued . . .

Table 62. Continued.

Code (00AT07-)	Fluoride (mg/L)			Bicarbonate (mg/L)			Carbonate (mg/L)		
	n	med	max	n	med	max	n	med	max
DA0060	32	0.10	0.32	39	153	441	39	0	33
DA0080	49	0.12	0.23	75	211	406	75	0	12
DA0081	2	0.13	0.16	17	240	356	17	0	7
DA0083	8	0.14	0.19	11	185	224	11	0	0
DA0084	13	0.10	0.15	16	176	280	16	0	0
DA0085	15	0.12	0.61	26	243	399	26	0	0
DA0090	34	0.10	0.24	53	157	424	53	0	28
DC0010	30	0.10	0.17	31	137	267	31	0	1
DD0020	15	0.07	0.09	15	49	57	15	0	0
ASWO		1.5							
CDWG		1.5							

continued . . .

Table 62. Continued.

Code (00AT07-)	Chloride (mg/L)			Sulphate (mg/L)			Dissolved Oxygen (mg/L)		
	n	med	max	n	med	max	n	med	max
DA0060	36	2	8	39	7	16	14	9.2	17.5
DA0080	75	4	30	75	4	42	54	8.4	13.6
DA0081	17	3	13	17	4	7	14	6.5	9.8
DA0083	11	0	1	11	3	5	6	5.7	9.3
DA0084	16	2	6	16	6	14	7	8.6	13.4
DA0085	26	2	6	26	4	9	13	4.6	8.4
DA0090	53	3	17	53	5	14	38	8.7	14.4
DC0010	31	2	7	31	4	18	11	8.3	16.4
DD0020	15	1	2	15	4	5	-	-	-
ASWO									
CDWG									

continued.

Table 62. Continued.

Code (00AT07-)	Total Organic Carbon (mg/L)			Filterable Residue (mg/L)			Nonfilterable Residue (mg/L)		
	n	med	max	n	med	max	n	med	max
DA0060	39	20	33	38	141	436	39	8	171
DA0080	68	23	53	72	200	365	72	4	72
DA0081	17	22	34	17	243	358	17	5	25
DA0083	11	10	17	11	181	228	11	13	73
DA0084	16	34	41	16	172	240	16	5	51
DA0085	26	24	45	26	234	385	26	5	78
DA0090	53	24	96	53	141	420	53	5	459
DC0010	31	10	24	30	132	166	31	4	70
DD0020	14	3	12	15	57	67	15	10	38
ASWO					0.005				
CDWG									

continued . . .

Table 62. Concluded.

Code (00AT07-)	Total Inorganic Carbon (mg/L)			Phenolic Material (mg/L)			Oil and Grease (mg/L)		
	n	med	max	n	med	max	n	med	max
DA0060	33	28	78	34	0.001	0.010	33	0.3	2.4
DA0080	45	33	69	60	0.002	0.025	66	0.7	3.5
DA0081	2	29	37	17	0.004	0.017	17	1.0	2.4
DA0083	11	28	38	8	0.003	0.020	8	0.1	6.6
DA0084	16	28	47	10	0.001	0.018	10	1.0	5.5
DA0085	18	43	77	20	0.005	0.015	19	0.4	12.9
DA0090	35	26	74	34	0.004	0.022	33	0.8	2.8
DC0010	31	22	53	24	0.001	0.014	22	0.5	2.1
DD0020	14	10	12	1	-	0.001	2	0.4	0.7
ASWO					0.005				
CDWG					0.002				

Table 63. Eastern region water quality data summary (nitrogen and phosphorus), 1976 to 1982.

Code (00AT07-)	Site Description	Total Kjeldahl N (mg/L)			Ammonia (mg/L)			Nitrate & Nitrite (mg/L)		
		n	med	max	n	med	max	n	med	max
DA0060	Steepbank River	36	0.89	2.28	35	0.04	0.20	39	0.04	0.41
DA0080	Muskeg River at WSC gauge	69	1.13	3.00	70	0.07	0.60	69	0.01	0.31
DA0081	Muskeg R. upst. Hartley Ck.	15	0.96	1.50	17	0.08	0.80	17	0.01	0.09
DA0083	Stanley Creek	11	0.75	2.45	11	0.08	0.29	11	0.01	0.10
DA0084	Kearl Lake tributary	16	1.50	2.57	16	0.16	0.50	16	0.04	0.27
DA0085	Muskeg R. 11.2 km above Stanley Ck.	26	1.12	5.50	26	0.10	3.90	26	0.02	0.14
DA0090	Hartley Creek at WSC gauge	50	0.98	4.05	51	0.04	0.29	53	0.01	0.42
DC0010	Firebag River at WSC gauge	27	0.60	5.40	26	0.05	0.18	30	0.05	0.40
DD0020	Richardson River at WSC gauge	15	0.55	1.58	13	0.03	0.10	14	0.07	0.29
ASWO										
CDWG										

continued . . .

Table 63. Concluded.

Code (00AT07-)	Total Phosphorus (ug/L)			Orthophosphate (ug/L)		
	n	med	max	n	med	max
DA0060	36	48	220	36	19	150
DA0080	71	30	190	69	10	41
DA0081	17	54	138	17	13	28
DA0083	11	140	320	11	16	90
DA0084	16	49	200	16	13	90
DA0085	26	64	250	26	12	68
DA0090	53	33	330	53	10	60
DC0010	28	44	180	28	18	60
DD0020	14	47	67	14	18	42
ASW0		50				
CDWG						

Table 64. Eastern region water quality data summary (metals), 1976 to 1982. All values in ug/L.

Code (00AT07-)	Site Description	Aluminum (Ext) n	Aluminum (Ext) med	Aluminum (Ext) max	Arsenic (Dis) n	Arsenic (Dis) med	Arsenic (Dis) max	Boron (Dis) n	Boron (Dis) med	Boron (Dis) max	Cadmium (Ext) n	Cadmium (Ext) med	Cadmium (Ext) max
DA0060	Steepbank River	39	80	5600	28	0.5	700	22	180	480	23	L1[a]	1
DA0080	Muskeg River at WSC gauge	66	40	58	72	0.4	20	37	120	260	28	L1	L1
DA0081	Muskeg River upst. Hartley Cr.	15	50	69	16	0.3	7	15	90	140	15	L1	L1
DA0083	Stanley Creek	9	70	200	8	0.5	3	11	90	220	11	3	L1
DA0084	Kearl Lake tributary	13	77	390	14	1.0	4	16	150	320	16	L1	3
DA0085	Muskeg R. 11.2 km above Stanley Ck	22	40	220	23	0.4	5	21	100	230	22	L1	L1
DA0090	Hartley Creek at WSC gauge	48	55	700	49	0.4	3	49	120	480	20	L1	L1
DC0010	Firebag River at WSC gauge	29	50	480	28	0.4	3	25	60	180	20	L1	3
DD0020	Richardson River at WSC gauge	14	55	390	15	0.4	1	9	30	80	8	1	1
ASWO						10			500			10	
CDWG						50			5000			5	

Code (00AT07-)	Chromium (Ext) n	Chromium (Ext) med	Chromium (Ext) max	Cobalt (Ext) n	Cobalt (Ext) med	Cobalt (Ext) max	Copper (Ext) n	Copper (Ext) med	Copper (Ext) max	Iron (Ext) n	Iron (Ext) med	Iron (Ext) max
DA0060	30	L3	10	23	L2	6	39	2	30	39	860	3700
DA0080	68	L3	16	38	L2	6	69	L1	26	69	980	10500
DA0081	15	L3	7	15	L2	L2	17	L1	3	17	1300	3250
DA0083	10	L3	7	9	L2	5	11	5	47	11	860	4450
DA0084	13	L3	7	15	L2	6	16	4	95	16	850	2100
DA0085	22	L3	8	22	L2	2	26	2	15	26	1265	5050
DA0090	48	L3	8	33	L2	3	54	1	28	53	770	10700
DC0010	27	L3	6	21	L2	30	29	2	26	29	630	2060
DD0020	13	L3	4	8	L2	2	14	1	17	14	600	820
ASWO		50						20			300	
CDWG		50						1000			300	

continued . . .

Table 64. Continued.

	Lead (Ext)			Manganese (Ext)			Mercury (Tot)			Nickel (Ext)		
Code (00AT07-)	n	med	max	n	med	max	n	med	max	n	med	max
DA0060	39	L2	28	39	35	500	35	L0.1	0.6	39	L2	5
DA0080	69	L2	30	69	49	2300	69	L0.1	0.4	69	L1	10
DA0081	17	L2	8	17	90	1170	17	L0.1	2.1	17	L1	6
DA0083	11	L2	8	11	120	705	10	L0.1	3.6	11	L2	4
DA0084	16	L2	15	16	40	280	16	L0.1	0.3	16	L2	7
DA0085	26	L2	9	26	100	598	26	L0.1	4.3	26	L2	9
DA0090	53	L2	7	54	35	2150	51	L0.1	0.7	53	L1	13
DC0010	29	L2	9	29	36	790	27	L0.1	1.3	29	L2	3
DD0020	14	L2	5	14	32	54	15	L0.1	0.2	14	L1	L2
ASWO		50			50			0.1				
CDWG		50			50			1.0				

continued . . .

Table 64. Concluded.

Code (00AT07-)	Selenium (Dis) n	 med	 max	Silver (Ext) n	 med	 max	Vanadium (Tot) n	 med	 max	Zinc (Ext) n	 med	 max
DA0060	29	0.2	1.4	21	1	5	34	1	3	39	6	58
DA0080	69	0.2	0.9	55	1	9	66	1	5	69	5	91
DA0081	14	0.2	2.1	11	1	8	16	1	3	17	3	50
DA0083	9	0.5	1.3	8	5	5	8	1	1	9	7	17
DA0084	14	0.3	0.6	14	3	5	14	1	1	13	7	62
DA0085	23	0.2	0.9	18	1	5	23	1	4	22	7	43
DA0090	46	0.2	0.9	25	1	5	51	1	3	53	4	48
DC0010	28	0.2	0.5	19	1	5	26	1	3	30	4	43
DD0020	15	0.2	0.5	8	1	1	14	1	1	14	5	34
ASWO		10			50						50	
CDWG		50			50						5000	

10.5 WATER QUALITY DATA SUMMARY OF ROUTINE PARAMETERS (TABLE 65), NUTRIENTS (TABLE 66), AND METALS (TABLE 67) FOR WATER BODIES IN THE WESTERN REGION

Table 65. Western region water data summary (routine parameters), 1976 to 1980. See Figure 4 for site locations.

Code (00AT07-)	Site Description	pH				Total Alkalinity (mg/L)			Phenol Alkalinity (mg/L)			Total Hardness (mg/L)		
		n	med	min	max	n	med	max	n	med	max	n	med	max
DA0070	Poplar Ck. at Hwy. 63	65	7.8	7.2	8.4	65	163	834	65	L0.1	5.6	65	124	785
DA0098	Ells R. near the mouth	13	7.7	7.3	8.1	13	83	105	13	L0.1	L0.1	13	88	137
DA0100	Upper Ells R.	27	7.3	6.9	8.1	27	57	212	27	0.0	L0.1	27	59	191
DA0110	Unnamed Ck., N of Ft. MacKay	17	7.9	7.3	8.4	17	160	222	17	0.0	1.6	17	170	280
DA0120	Asphalt Ck. near Ft. MacKay	10	7.5	7.2	8.0	10	59	435	10	0.0	0.0	10	158	398
DA0121	Eymundson Ck. upstr. Asphalt	11	7.5	6.6	8.1	11	82	1000	11	0.0	0.0	11	178	1126
DA0130	Pierre R., N of Ft. MacKay	11	7.7	7.1	7.9	11	78	130	11	0.0	0.0	11	139	165
DA0140	Calumet R. near Ft. MacKay	13	7.9	7.6	8.3	13	204	702	13	0.0	0.0	13	156	651
DA0150	Lower Tar R., NW of Ft. MacKay	15	7.8	7.0	8.3	15	156	392	15	0.0	0.0	15	149	313
DA0160	Joslyn Ck. above Ells R.	22	7.9	7.2	8.6	22	172	356	22	0.0	24.8	22	197	336
DA0170	Lower Ells R., above Joslyn	18	7.7	7.2	8.3	18	92	150	18	0.0	0.0	18	90	140
DA0180	Beaver R. above Syncrude	18	7.8	7.0	8.3	18	167	434	17	0.0	0.0	18	111	163
DA0181	Beaver R. at Hwy. 63	21	7.9	7.4	8.5	21	190	328	20	0.0	5.0	21	228	392
DA0182	Bridge Ck. diversion at Hwy. 63	32	7.6	7.1	8.6	32	129	242	32	L0.1	28.0	32	123	276
DA0183	Bridge Ck. at Beaver R.	17	7.8	7.3	8.5	17	185	284	17	L0.1	7.8	17	210	311
DA0190	Upper Tar R., NW of Ft. MacKay	12	7.7	7.1	8.2	12	115	298	12	0.0	0.0	12	119	317
DB0011	MacKay R. at Hwy. 63	40	7.8	6.9	8.5	40	128	577	40	0.0	L0.1	40	121	493
DB0020	Dover R. above MacKay R.	17	7.9	7.5	8.4	17	268	462	17	0.0	4.8	17	191	339
DB0030	Dunkirk R. near Ft. MacKay	29	7.6	6.7	8.5	29	125	273	29	0.0	10.8	29	124	267
DB0040	Thickwood Ck. above MacKay R.	15	7.3	6.8	7.8	15	56	182	15	0.0	0.0	15	64	182
ASWO			6.5 to 8.5											
CDWG			6.5 to 8.5											

continued . . .

Table 65. Continued.

Code	Conductivity (uS/cm)			Turbidity (JTU)			True Colour (Rel Units)			Silica (mg/L)			Calcium (mg/L)		
	n	med	max	n	med	max	n	med	max	n	med	max	n	med	max
DA0070	65	400	6640	45	8	78	31	100	150	62	5.5	17.9	62	32	161
DA0098	13	190	250	13	7	23	11	30	90	13	3.0	9.	13	23	28
DA0100	27	120	400	24	2	40	9	35	80	27	2.3	12.5	27	16	50
DA0110	17	362	600	15	5	42	5	35	50	17	11.9	15.8	17	46	79
DA0120	10	431	810	8	151	890				10	9.7	21.0	10	39	105
DA0121	11	426	2800	11	24	440				11	11.2	104.0	11	48	210
DA0130	11	350	442	9	4	147				11	9.0	14.3	11	35	43
DA0140	13	460	1920	12	3	60				13	9.2	23.2	13	40	160
DA0150	15	370	710	13	24	570				15	8.7	18.8	15	38	80
DA0160	22	444	800	20	46	216	11	70	180	22	7.7	14.5	22	55	90
DA0170	18	194	370	16	3	279				18	3.1	9.9	18	24	38
DA0180	18	317	810	16	7	1800				18	7.7	13.6	18	28	40
DA0181	21	510	2100	18	8	41	5	15	160	21	6.3	8.9	21	63	98
DA0182	24	309	700	30	22	185	12	145	340	32	5.1	12.5	32	32	79
DA0183	17	553	1630	11	10	62	13	50	200	15	5.2	8.8	17	59	82
DA0190	12	221	595	10	3	12				12	6.7	16.2	12	32	82
DB0011	40	286	1370	39	9	370	19	130	280	40	6.0	20.0	38	32	120
DB0020	17	499	920	15	8	64				17	6.9	15.7	17	46	84
DB0030	29	233	595	26	8	86	9	140	280	29	8.7	14.5	28	33	72
DB0040	15	110	360	12	6	69				15	5.4	17.1	15	17	46

ASWO
CDWG

continued . . .

Table 65. Continued.

Code (00AT07-)	Magnesium (mg/L)			Sodium (mg/L)			Potassium (mg/L)			Fluoride (mg/L)		
	n	med	max	n	med	max	n	med	max	n	med	max
DA0070	65	11	93	62	50	1185	63	1.7	8.1	25	.11	.17
DA0098	13	7	18	13	10	13	13	1.0	1.3	13	.07	1.00
DA0100	27	5	16	27	3	15	27	0.9	1.3	27	.09	.14
DA0110	17	14	20	17	15	25	17	2.8	4.1	17	.27	.40
DA0120	9	14	19	10	21	30	10	2.5	4.5	10	.35	.45
DA0121	11	14	146	11	24	128	11	4.1	26.5	11	.38	.60
DA0130	11	12	14	11	24	26	11	3.5	4.6	11	.34	.90
DA0140	13	14	61	13	46	225	13	2.9	10.5	13	.19	.40
DA0150	15	13	28	15	22	50	15	1.9	4.5	15	.18	.38
DA0160	22	15	27	22	32	78	22	2.7	3.8	22	.26	.34
DA0170	18	7	11	17	12	26	18	1.3	2.2	18	.12	.16
DA0180	18	10	15	18	37	150	18	1.9	12.5	18	.13	.29
DA0181	21	17	36	21	36	413	21	3.1	8.0	21	.13	.24
DA0182	32	11	21	32	27	64	32	1.8	3.7	27	.11	.20
DA0183	17	16	26	17	47	230	17	1.8	3.3	8	.16	.24
DA0190	12	10	28	12	4	63	12	1.0	3.9	11	.14	.22
DB0011	40	11	47	39	23	140	38	1.6	6.2	30	.12	.30
DB0020	17	19	33	17	47	93	17	3.3	5.0	17	.21	.35
DB0030	29	10	23	28	13	32	28	1.4	3.5	28	.11	.24
DB0040	15	6	16	15	3	14	15	0.5	2.9	15	.06	.15
ASWO											1.5	
CDWG											1.5	

continued . . .

Table 65. Continued.

Code (00AT07-)	Bicarbonate (mg/L)			Carbonate (mg/L)			Chloride (mg/L)			Sulphate (mg/L)		
	n	med	max	n	med	max	n	med	max	n	med	max
DA0070	65	198	1016	65	0	7	63	33	1780	65	16	86
DA0098	13	101	128	13	0	0	11	2	26	13	17	24
DA0100	27	69	258	27	0	0	27	1	5	27	7	10
DA0110	17	193	270	17	0	2	17	1	2	17	56	170
DA0120	10	72	531	10	0	0	10	4	5	10	140	185
DA0121	11	100	1291	11	0	0	8	5	25	11	132	466
DA0130	11	95	158	11	0	0	11	4	6	11	80	124
DA0140	13	249	856	13	0	0	13	18	165	13	21	118
DA0150	15	190	478	15	0	0	15	3	9	15	28	63
DA0160	22	209	434	22	0	0	22	3	48	22	70	170
DA0170	18	112	183	18	0	0	18	2	5	18	16	30
DA0180	17	183	529	17	0	0	18	2	5	18	12	48
DA0181	20	231	400	20	0	6	21	27	575	21	55	120
DA0182	32	158	253	32	0	34	32	10	76	32	30	105
DA0183	17	225	346	17	0	9	17	38	310	17	59	103
DA0190	12	140	364	12	0	0	12	1	26	12	9	35
DB0011	40	156	703	40	0	0	40	6	57	40	21	100
DB0020	17	327	563	17	0	6	16	8	15	17	22	83
DB0030	29	152	333	29	0	13	28	2	3	29	23	159
DB0040	15	69	222	15	0	0	15	1	4	15	8	10
ASWO												
CDWG								250			500	

continued . . .

Table 65. Continued.

Code (00AT07-)	Dissolved Oxygen (mg/L)			Total Organic Carbon (mg/L)			Filterable Residue (mg/L)			Non-filterable Residue (mg/L)		
	n	med	max	n	med	max	n	med	max	n	med	max
DA0070	34	9.5	14.4	59	26	45	65	290	3984	65	9	323
DA0098	6	9.2	13.4	13	16	41	12	123	165	13	9	48
DA0100	3	6.4	8.2	27	13	25	27	75	264	26	4	86
DA0110	9	10.6	15.4	17	14	52	17	229	452	16	10	74
DA0120	6	9.7	14.7	10	14	21	10	266	502	10	58	1058
DA0121	4	6.0	8.6	11	29	50	11	328	1750	11	25	696
DA0130	7	10.6	13.6	11	18	34	11	225	260	11	7	253
DA0140	8	8.1	13.6	13	40	295	13	297	1178	13	4	77
DA0150	7	9.7	12.4	15	20	44	15	198	508	15	16	986
DA0160	13	8.9	13.0	22	23	56	22	286	528	22	25	172
DA0170	10	10.9	14.4	18	13	42	18	126	235	18	5	370
DA0180	9	8.6	11.4	17	21	147	18	184	538	18	8	1364
DA0181	11	9.8	13.0	21	18	85	21	345	1452	20	9	55
DA0182	15	9.3	13.0	32	37	84	32	200	462	32	22	378
DA0183	16	8.0	13.5	17	21	44	17	373	1005	17	12	126
DA0190	6	11.9	15.2	12	18	36	12	136	389	12	5	20
DB0011	20	8.8	14.0	40	30	59	39	198	862	40	8	547
DB0020	10	9.2	13.6	17	26	47	17	329	575	17	12	112
DB0030	2	3.3	3.7	29	28	44	28	152	400	29	6	124
DB0040	1	-	2.0	15	28	66	15	68	232	15	4	92
ASWO												
CDWG												

continued . . .

Table 65. Concluded.

Code (00AT07-)	Total Inorganic Carbon (mg/L)			Phenolic Material (mg/L)			Oil and Grease (mg/L)		
	n	med	max	n	med	max	n	med	max
DD0070	29	29	93	59	0.003	0.020	60	0.8	4.3
DA0098	13	19	22	13	0.001	0.015	12	0.9	1.6
DA0100	27	11	49	17	L0.001	0.020	18	0.4	1.6
DA0110	17	30	51	15	L0.001	0.022	14	0.5	2.2
DA0120	10	13	61	10	L0.001	0.020	10	0.4	1.7
DA0121	11	16	150	11	L0.001	0.007	9	0.5	2.0
DA0130	11	15	28	10	L0.001	0.029	10	0.4	1.0
DA0140	13	43	112	11	L0.001	0.026	11	0.5	1.4
DA0150	15	33	65	13	0.001	0.024	13	0.1	1.6
DA0160	22	33	81	20	L0.001	0.023	20	0.7	1.5
DA0170	18	19	25	14	L0.001	0.024	14	0.5	8.2
DA0180	17	30	105	14	L0.001	0.023	14	0.3	2.2
DA0181	21	36	95	18	L0.001	0.010	19	0.7	1.8
DA0182	27	27	57	29	0.001	0.031	30	0.7	4.9
DA0183	-	-	-	17	0.006	0.016	17	1.4	3.1
DA0190	12	24	70	11	L0.001	0.019	11	0.2	2.2
DB0011	34	26	90	32	L0.001	0.010	34	0.8	2.5
DB0020	17	56	92	13	L0.001	0.023	13	0.4	1.7
DB0030	29	25	62	20	L0.001	0.014	20	0.2	1.2
DB0040	15	15	36	9	L0.001	0.028	10	L0.1	4.4
ASWO					0.005				
CDWG					0.002				

[a] Petroleum ether method.

Table 66. Western region water quality data summary (nitrogen and phosphorus).

Code (00AT07-)	Site Description	Total Phosphorus (ug/L)			Orthophosphate (ug/L)		
		n	med	max	n	med	max
DA0070	Poplar Ck. at Hwy. 63	62	47	240	62	13	66
DA0098	Ells R. near mouth	11	37	170	11	10	34
DA0100	Upper Ells R.	27	37	150	27	13	40
DA0110	Unnamed Ck., N of Ft. MacKay	17	17	130	17	15	26
DA0120	Asphalt Ck. near Ft. MacKay	10	113	630	10	10	40
DA0121	Eymundson Ck. upstr. Asphalt	8	150	360	8	17	80
DA0130	Pierre R., N of Ft. MacKay	11	66	230	11	11	20
DA0140	Calumet near Ft. MacKay	13	124	720	13	37	72
DA0150	Lower Tar R., NW of Ft. MacKay	15	120	1400	15	19	50
DA0160	Joslyn Ck. above Ells	22	145	720	22	15	110
DA0170	Lower Ells R. above Joslyn	18	32	340	18	8	60
DA0180	Beaver R. above Syncrude	18	120	490	18	20	235
DA0181	Beaver R. at Hwy. 63	21	50	600	21	L10[a]	46
DA0182	Bridge Ck. diversion at Hwy 63	32	57	220	32	18	80
DA0183	Bridge Ck. Beaver R.	17	41	168	17	17	90
DA0190	Upper Tar R., NW of Ft. MacKay	12	70	243	12	14	50
DB0011	MacKay R. at Hwy. 63	37	65	260	37	24	100
DB0020	Dover R. above MacKay R.	17	69	300	17	13	39
DB0030	Dunkirk R. near Ft. MacKay	27	91	500	28	20	180
DB0040	Thickwood Ck. above MacKay R.	15	50	240	15	13	40
ASWO			50				
CDWG							

Code (00AT07-)	Total Inorganic Carbon (mg/L)			Phenolic Material (mg/L)			Oil and Grease (mg/L)		
	n	med	max	n	med	max	n	med	max
DD0070	29	29	93	59	0.003	0.020	60	0.8	4.3
DA0098	13	19	22	13	0.001	0.015	12	0.9	1.6
DA0100	27	11	49	17	L0.001	0.020	18	0.4	1.6
DA0110	17	30	51	15	L0.001	0.022	14	0.5	2.2
DA0120	10	13	61	10	L0.001	0.020	10	0.4	1.7
DA0121	11	16	150	11	L0.001	0.007	9	0.5	2.0
DA0130	11	15	28	10	L0.001	0.029	10	0.4	1.0
DA0140	13	43	112	11	L0.001	0.026	11	0.5	1.4
DA0150	15	33	65	13	0.001	0.024	13	0.1	1.6
DA0160	22	33	81	20	L0.001	0.023	20	0.7	1.5
DA0170	18	19	25	14	L0.001	0.024	14	0.5	8.2
DA0180	17	30	105	14	L0.001	0.023	14	0.3	2.2
DA0181	21	36	95	18	L0.001	0.010	19	0.7	1.8
DA0182	27	27	57	29	0.001	0.031	30	0.7	4.9
DA0183	-	-	-	17	0.006	0.016	17	1.4	3.1
DA0190	12	24	70	11	L0.001	0.019	11	0.2	2.2
DB0011	34	26	90	32	L0.001	0.010	34	0.8	2.5
DB0020	17	56	92	13	L0.001	0.023	13	0.4	1.7
DB0030	29	25	62	20	L0.001	0.014	20	0.2	1.2
DB0040	15	15	36	9	L0.001	0.028	10	L0.1	4.4
ASWO									
CDWG									

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[a] L = less than.

Table 67. Western region water quality data summary (metals). All values in ug/L.

Code (00AT07-)	Site Description	Aluminum (Ext)			Arsenic (Dis)			Boron (Dis)			Cadmium (Ext)		
		n	med	max	n	med	max	n	med	max	n	med	max
DA0070	Poplar Ck. at Hwy 63	48	100	970	63	0.6	16.0	49	200	710	46	L1[a]	16
DA0098	Ells R. near the mouth	13	70	310	11	0.5	3.2	1	-	100	2	1	1
DA0100	Upper Ells R.	27	40	450	25	L0.5	5.0	17	60	190	18	L1	2
DA0110	Unnamed Ck., N of Ft. MacKay	17	60	370	17	0.5	6.9	12	100	900	12	L1	L1
DA0120	Asphalt Ck., near Ft. MacKay	10	1095	11200	9	0.9	2.3	10	170	270	10	L1	2
DA0121	Eymundson Ck. upstr. Asphalt	11	210	4250	11	L0.5	1.5	11	200	900	10	L1	2
DA0130	Pierre R., N of Ft. MacKay	12	110	470	10	0.5	4.3	11	150	280	12	L1	L1
DA0140	Calumet R. near Ft. MacKay	13	50	210	13	0.6	6.2	13	260	690	13	L1	L1
DA0150	Lower Tar R., NW of Ft. MacKay	15	120	10800	14	0.8	17.3	15	170	310	15	L1	1
DA0160	Joslyn Ck. above Ells R.	22	325	6200	21	1.2	8.3	22	230	350	11	L1	3
DA0170	Lower Ells R. above Joslyn Ck.	18	93	14700	17	0.5	9.0	18	130	300	18	L1	3
DA0180	Beaver R. above Syncrude	18	328	1700	16	0.6	3.0	18	330	1080	18	L1	6
DA0181	Beaver R. at Hwy. 63	21	140	7700	19	0.7	2.3	21	100	710	21	L1	1
DA0182	Bridge Ck. diversion at Hwy. 63	32	240	2700	32	0.9	5.0	32	160	350	32	L1	L1
DA0183	Bridge Ck. at Beaver R.	15	100	780	17	0.7	2.5	15	150	200	15	L1	L1
DA0190	Upper Tar R., NW of Ft. MacKay	12	50	380	11	0.6	3.0	12	110	280	12	L1	L1
DB0011	MacKay R. at Hwy. 63	39	120	2600	30	0.8	13.0	33	210	590	20	L1	1
DB0020	Dover R. above MacKay R.	17	160	960	16	0.4	7.0	17	340	610	17	L1	2
DB0030	Dunkirk R. near Ft. MacKay	28	110	810	26	0.8	2.4	19	200	390	19	L1	4
DB0040	Thickwood Ck. above MacKay	15	140	500	13	L0.5	3.0	15	130	330	15	L1	1
ASWO						10			500			10	
CDWG						50			5000			5	

continued . . .

Table 67. Continued.

Code	Chromium (Ext)			Cobalt (Ext)			Copper (Ext)			Iron (Ext)		
(00AT07-)	n	med	max	n	med	max	n	med	max	n	med	max
DA0070	45	L3	75	45	L1	31	62	1	18	62	850	5000
DA0098	11	4	7	2	2	3	13	L1	7	13	650	1650
DA0100	27	L3	5	18	L2	2	27	2	21	27	300	2550
DA0110	16	L3	10	12	L2	L2	17	2	6	17	1150	1950
DA0120	10	3	31	10	2	28	10	6	33	10	4230	27700
DA0121	8	L3	10	8	L2	14	11	5	20	11	4200	8550
DA0130	12	L3	6	12	L2	4	12	3	16	12	1225	7100
DA0140	13	L3	12	13	L2	2	13	4	17	13	910	21000
DA0150	15	L3	23	15	L2	8	15	8	114	15	2500	52500
DA0160	22	3	32	11	L2	8	22	5	19	22	4325	14000
DA0170	18	L4	17	18	L2	4	18	3	33	18	510	7500
DA0180	18	L3	10	18	L2	8	17	4	27	18	1725	16000
DA0181	21	L3	205	21	L2	11	21	3	14	21	930	14000
DA0182	32	3	177	32	1	4	32	2	16	33	1500	6900
DA0183	15	3	7	15	L1	1	17	1	4	17	2020	14600
DA0190	12	L3	10	12	L2	L2	12	4	15	12	1295	3950
DB0011	32	L3	15	19	L2	6	38	3	180	38	1275	4700
DB0020	17	L3	13	17	L2	4	17	3	20	17	1370	2700
DB0030	27	L3	14	19	L2	L2	28	2	17	28	1860	5600
DB0040	15	L3	19	15	L2	L2	15	3	17	15	750	6500
ASWO		50						20			300	
CDWG		50						1000			300	

continued . . .

Table 67. Continued.

Code	Lead (Ext)			Manganese (Ext)			Mercury (Tot)			Nickel (Ext)		
(00AT07-)	n	med	max	n	med	max	n	med	max	n	med	max
DA0070	62	L2	175	62	109	6550	56	L0.1	1.6	62	L2	24
DA0098	13	L2	5	13	19	69	10	L0.1	0.1	13	1	10
DA0100	27	L2	7	27	29	310	27	L0.1	0.6	27	L2	3
DA0110	17	L2	8	17	193	480	17	L0.1	0.2	17	L2	8
DA0120	9	2	35	10	361	540	10	L0.1	L0.2	10	12	46
DA0121	9	L2	33	11	370	2000	8	L0.1	2.7	8	9	46
DA0130	12	L2	29	12	222	883	11	L0.1	0.2	12	4	21
DA0140	13	L2	14	13	75	4850	13	L0.1	4.6	13	L2	20
DA0150	15	L2	38	15	25	6400	15	L0.1	0.3	15	L2	26
DA0160	22	2	11	22	91	530	22	L0.1	L0.2	22	7	20
DA0170	18	L2	12	18	20	221	18	L0.1	0.3	18	L2	9
DA0180	18	L2	14	18	53	390	18	L0.1	0.9	18	L2	12
DA0181	20	L2	27	21	180	510	21	L0.1	0.2	21	L2	22
DA0182	32	L2	11	32	106	560	32	L0.1	6.4	32	L2	11
DA0183	17	L2	9	17	210	680	17	L0.1	0.3	17	2	12
DA0190	12	L2	3	12	105	500	12	L0.1	0.4	12	L2	L2
DB0011	38	L2	48	38	40	290	37	L0.1	2.1	38	L2	30
DB0020	17	L2	24	17	46	135	17	L0.1	0.3	17	L2	12
DB0030	28	L2	9	28	65	520	28	L0.1	0.3	28	L2	6
DB0040	15	L2	12	15	40	750	15	L0.1	0.7	15	L2	4
ASWO		50			50			0.1				
CDWG		50			50			1.0				

continued . . .

Table 67. Concluded.

Code	Selenium (Dis)			Silver (Ext)			Vanadium (Tot)			Zinc (Ext)		
(00AT07-)	n	med	max	n	med	max	n	med	max	n	med	max
DA0070	48	L0.2	0.8	24	L1	28	59	L1	11	64	6	93
DA0098	10	L0.2	0.4	1	-	L4	11	L1	2	13	3	28
DA0100	26	L0.2	0.9	19	L1	L5	26	L1	L1	27	6	88
DA0110	16	L0.2	L0.5	12	L1	L5	17	L1	L1	17	7	24
DA0120	9	L0.2	L0.5	10	1	L5	9	L1	4	10	30	155
DA0121	11	L0.5	0.6	8	L1	L5	8	L1	L1	10	22	66
DA0130	11	L0.2	0.9	12	L1	L5	11	L1	2	12	13	34
DA0140	13	L0.2	0.5	13	L1	L5	13	L1	1	13	10	96
DA0150	14	L0.5	0.9	15	2	70	14	L1	7	15	12	41
DA0160	21	0.4	1.3	11	L1	L5	21	1	13	22	14	39
DA0170	17	L0.2	0.5	19	L1	5	17	L1	5	18	11	54
DA0180	16	L0.2	0.8	18	L1	9	16	L1	22	18	11	45
DA0181	19	L0.2	1.0	21	L1	L5	19	L1	24	21	17	109
DA0182	32	L0.2	L0.5	32	L1	L5	30	L1	7	32	14	86
DA0183	15	L0.2	0.6	5	L1	1	17	L1	4	17	8	32
DA0190	11	L0.2	L0.5	12	L1	5	11	L1	L1	12	6	47
DB0011	31	L0.2	1.3	19	2	5	35	L1	7	40	6	42
DB0020	16	0.3	0.7	17	L1	L5	16	L1	2	17	9	67
DB0030	27	L0.2	0.7	20	L1	L5	26	L1	2	29	8	45
DB0040	12	0.2	0.5	15	L1	L5	13	L1	3	15	7	68
ASWO		10			50						50	
CDWG		50			50						5000	

[a] L = less than.

10.6 WATER QUALITY DATA SUMMARY OF ROUTINE PARAMETERS (TABLE 68), NUTRIENTS (TABLE 69), AND METALS (TABLE 70) FOR WATER BODIES IN THE SOUTHERN REGION

Table 68. Southern region water quality data summary (routine parameters), 1976 to 1983. See Figure 4 for site location.

Code (00AT07-)	Site Description	pH				Total Alkalinity (mg/L)			Phenol Alkalinity (mg/L)		
		n	med	min	max	n	med	max	n	med	max
CC0030	Horse R. at Abasands Park	5	7.8	7.0	8.3	5	250	271	5	0.0	0.
CC0300	Horse R. near Ft. McMurray	15	7.8	7.1	8.6	15	112	291	15	L0.1[a]	16.0
CD0040	Hangingstone River	66	7.8	7.1	8.6	66	105	407	66	L0.1	11.6
CD0100	Saline Creek	8	7.8	7.0	8.0	8	90	348	8	0.0	0.
CD2300	Clearwater River	50	8.0	6.2	9.6	50	63	95	50	L0.1	9.8
CE2000	Surmount Creek	45	7.3	6.6	8.3	45	55	132	45	L0.1	L0.1
CE2191	Christina River	10	7.8	7.5	8.5	10	138	191	10	L0.1	5.2
ASWO			6.5 to 8.5								
CDWG			6.5 to 8.5								

Code (00AT07-)	Site Description	Total Hardness (mg/L)			Conductivity (uS/cm)			Turbidity (JTU)		
		n	med	max	n	med	max	n	med	max
CC0030	Horse R. at Abasands Park	5	226	244	5	550	590	5	8	41
CC0300	Horse R. near Ft. McMurray	15	105	232	15	214	550	15	10	82
CD0040	Hangingstone River	66	99	344	66	276	960	63	11	770
CD0100	Saline Creek	8	80	355	8	183	720	7	46	280
CD2300	Clearwater River	50	63	109	50	191	411	47	10	450
CE2000	Surmount Creek	45	59	139	45	124	300	31	5	104
CE2191	Christina River	10	127	177	10	422	850	10	11	61
ASWO										
CDWG										

continued . . .

Table 68. Continued.

Code (00AT07-)	True Colour (Rel Units) n	med	max	Silica (mg/L) n	med	max	Calcium (mg/L) n	med	max
CC0030	0	-		5	15.5	16.4	5	46	66
DD0300	11	110	35	15	6.1	15.5	15	28	61
CD0040	15	100	160	53	7.3	21.2	62	27	95
CD0100	0	-		8	4.9	11.4	8	20	91
CD2300	14	38	120	49	8.2	112.0	50	16	30
CE2000	30	130	200	45	6.4	17.5	45	16	39
CE2191	10	48	130	10	8.8	11.5	10	33	46
ASWO									
CDWG									

Code (00AT07-)	Magnesium (mg/L) n	med	max	Sodium (mg/L) n	med	max	Potassium (mg/L) n	med	max
CC0030	5	18	19	4	29	47	4	2.2	3.2
CC0300	15	8	19	15	18	40	15	1.0	2.5
CD0040	66	8	28	63	22	93	61	1.3	5.3
CD0100	8	7	31	8	15	36	8	0.9	2.0
CD2300	50	5	9	50	22	45	49	0.9	1.8
CE2000	45	4	10	45	2	8	45	0.8	2.0
CE2191	10	11	15	10	45	110	10	1.0	1.9
ASWO									
CDWG									

continued . . .

Table 68. Continued.

Code (OOAT07-)	Fluoride (mg/L)			Bicarbonate (mg/L)			Carbonate (mg/L)		
	n	med	max	n	med	max	n	med	max
CC0030	4	0.16	0.23	5	305	330	5	0	0
CC0300	15	0.12	0.22	15	137	335	15	0	19
CD0040	34	0.13	0.32	66	128	496	66	0	14
CD0100	8	0.09	0.16	8	109	424	8	0	0
CD2300	40	0.09	0.78	50	76	116	50	0	12
CE2000	14	0.05	0.12	44	68	161	44	0	0
CE2191	10	0.10	0.18	10	168	233	10	0	6
ASWO		1.5							
CDWG		1.5							

Code (OOAT07-)	Chloride (mg/L)			Sulphate (mg/L)			Dissolved Oxygen (mg/L)		
	n	med	max	n	med	max	n	med	max
CC0030	5	11	16	5	28	40	1	-	9.5
CC0300	15	4	38	16	14	42	7	11.0	13.4
CD0040	65	16	91	63	20	71	36	9.8	14.8
CD0100	8	7	10	8	10	66	3	10.2	12.4
CD2300	50	25	68	50	7	19	27	10.0	13.6
CE2000	45	1	6	45	12	30	23	9.3	12.4
CE2191	10	60	165	10	14	24	5	10.5	13.3
ASWO		250			500				
CDWG									

continued . . .

Table 68. Concluded.

Code (00AT07-)	Total Organic Carbon (mg/L)			Filterable Residue (mg/L)			Nonfilterable Residue (mg/L)		
	n	med	max	n	med	max	n	med	max
CC0030	5	19	31	4	296	390	5	12	24
CC0300	16	26	44	15	141	363	15	14	174
CD0040	60	21	39	64	174	396	65	19	1904
CD0100	8	32	42	8	126	522	8	132	454
CD2300	50	10	83	50	147	231	50	20	1751
CE2300	35	17	33	38	84	181	36	6	226
CE2191	10	21	34	10	265	561	10	16	144
ASWO									
CDWG									

Code (00AT07-)	Total Inorganic Carbon (mg/L)			Phenolic Material (mg/L)			Oil and Grease[b] (mg/L)		
	n	med	max	n	med	max	n	med	max
CC0030	5	41	66	4	0.004	0.005	3	L0.1	L0.1
CC0300	15	22	70	14	L0.001	0.004	15	0.8	2.9
CD0040	34	23	72	57	0.003	0.021	53	0.8	6.5
CD0100	8	16	67	8	0.004	0.016	7	0.2	0.8
CD2300	31	14	22	46	0.002	0.012	44	0.6	3.0
CE2000	13	17	18	35	0.002	0.006	35	0.9	3.6
CE2191	10	28	46	10	L0.001	0.010	10	0.8	1.5
ASWO						0.005			
CDWG						0.002			

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[a] L = less than.

[b] Petroleum ether method.

Table 69. Southern region water quality data summary (nitrogen and phosphorus).

Code (00AT07-)	Site Description	Total Phosphorus (ug/L) n	med	max	Orthophosphate (ug/L) n	med	max
CC0030	Horse R. at Abasands Park	3	100	180	3	30	40
CC0300	Horse R. near Ft. McMurray	14	77	155	15	21	100
CD0040	Hangingstone River	62	74	1300	62	32	123
CD0100	Saline Creek	7	230	330	7	L10[a]	220
CD2300	Clearwater River	45	60	330	45	20	81
CE2000	Surmount Creek	36	54	740	35	40	90
CE2191	Christina River	10	72	170	10	29	64
ASWO		50					
CDWG							

Code (00AT07-)	Site Description	Total Kjeldahl N (mg/L) n	med	max	Ammonia (mg/L) n	med	max	Nitrate and Nitrite (mg/L) n	med	max
CC0030	Horse R. at Abasands Park	3	0.80	0.81	3	0.06	0.12	5	0.23	0.37
CC0300	Horse R. near Ft. McMurray	14	0.99	1.68	13	0.04	0.07	15	0.25	0.37
CD0040	Hangingstone River	48	0.90	9.15	60	0.05	0.46	60	0.02	0.66
CD0100	Saline Creek	7	0.98	1.50	7	0.10	0.25	8	L0.01	0.01
CD2300	Clearwater River	44	0.70	2.61	43	0.04	0.73	50	0.04	0.31
CE2000	Surmount Creek	35	0.66	2.40	35	0.04	0.33	36	0.32	0.56
CE2191	Christina River	10	1.14	2.17	9	0.06	0.18	10	0.09	0.55
ASWO										
CDWG										

[a] L = less than.

Table 70. Southern region water quality data summary (metals). All values in ug/L.

Code (00AT07-)	Site Description	Aluminum (Ext)			Arsenic (Dis)			Boron (Dis)			Cadmium (Ext)		
		n	med	max	n	med	max	n	med	max	n	med	max
CC0030	Horse R. at Abasands Park	3	70	300	3	1.2	6	4	245	360	3	L1[a]	L1
CC0300	Horse R. near Ft. McMurray	14	195	1090	14	0.8	2	15	220	300	4	L1	L1
CD0040	Hangingstone River	58	240	8500	31	0.9	9	46	170	400	19	L1	3
CD0100	Saline Creek	8	192	7600	5	L0.5	3	8	140	300	8	L1	L1
CD2300	Clearwater River	48	170	4300	24	0.6	2	19	90	380	28	L1	2
CE2000	Surmount Creek	34	165	1820	36	0.8	12	35	90	170	34	L1	1
CE2191	Christina River	10	145	12100	10	0.8	1.5	9	140	160	0		
ASWO						10			500			10	
CDWG						50			5000			5	

Code (00AT07-)		Chromium (Ext)			Cobalt (Ext)			Copper (Ext)			Iron (Ext)		
		n	med	max	n	med	max	n	med	max	n	med	max
CC0030	Horse R. at Abasands Park	3	L3	3	3	L2	L2	3	3	21	3	1450	1850
CC0300	Horse R. near Ft. McMurray	15	3	12	4	L2	L2	14	2	5	14	1525	3550
CD0040	Hangingstone River	42	L3	36	19	L2	7	59	2	43	43	1400	37000
CD0100	Saline Creek	7	4	12	8	L7	3	8	7	16	8	3800	7600
CD2300	Clearwater River	26	L3	8	14	L2	9	50	1	32	50	1010	24000
CE2000	Surmount Creek	35	L3	95	35	L1	3	35	L1	48	36	1320	23000
CE2191	Christina River	10	5	18	0			10	2	6	10	1350	10600
ASWO			50						20			300	
CDWG			50						1000			300	

continued . . .

Table 70. Concluded.

Code (00AT07-)	Lead (Ext)			Manganese (Ext)			Mercury (Tot)			Nickel (Ext)		
	n	med	max	n	med	max	n	med	max	n	med	max
CC0030	3	L2	L2	3	40	45	3	L0.2	0.4	3	L2	2
CC0300	14	L2	5	14	50	430	15	L0.1	0.3	14	2	4
CD0040	59	L2	52	59	74	1900	57	L0.1	1.7	56	2	55
CD0100	8	2	8	8	76	190	7	L0.1	0.2	8	L2	12
CD2300	49	2	36	50	48	690	46	L0.1	1.4	47	L2	42
CE2000	35	L2	99	35	88	921	35	L0.1	1.5	35	1	12
CE2191	10	L2	16	10	65	315	10	0.1	0.3	10	L1	16
ASWO		50			50			0.1				
CDWG		50			50			1.0				

Code (00AT07-)	Selenium (Dis)			Silver (Ext)			Vanadium (Tot)			Zinc (Ext)		
	n	med	max	n	med	max	n	med	max	n	med	max
CC0030	3	L0.5	L0.5	4	L5	L5	2	-	1	5	4	37
CC0300	14	L0.2	L0.5	4	L1	L1	14	1	3	14	6	73
CD0040	32	0.2	0.5	20	L1	3	45	1	8	59	7	190
CD0100	6	0.5	0.9	7	L5	L5	6	2	6	8	22	61
CD2300	25	L0.2	35	14	L5	13	37	L1	10	49	5	87
CE2000	35	L0.2	0.8	30	L1	6	35	L1	7	35	6	140
CE2191	10	L0.2	100	10	L1	1	10	L1	10	10	3	33
ASWO		10			50						50	
CDWG		10			50						5000	

[a] L = less than.

LIST OF AOSERP RESEARCH REPORTS

1. AOSERP first annual report, 1975.
2. Walleye and goldeye fisheries investigations in the Peace-Athabasca Delta --1975.
3. Structure of a traditional baseline data system. 1976.
4. A preliminary vegetation survey of the AOSERP study area. 1976.
5. The evaluation of wastewaters from an oil sand extraction plant. 1976.
6. Housing for the north--the stackwall system; construction report--Mildred Lake tank and pump house. 1976.
7. A synopsis of thephysical and biological limnology and fishery programs within the Alberta oil sands area. 1977.
8. The impact of saline waters upon freshwater biota (a literature review and bibliography). 1977.
9. A preliminary investigation into the magnitude of foc occurrence and associated problems oil sands area. 1977.
10. Development of a research design related to archaeological studies in the Athabasca oil sands area. 1977.
11. Life cycles of some common aquatic insects of the Athabasca River, Alberta. 1977.
12. Very high resolution meteorological satellite study of oil sands weather: "a feasibility study". 1977.
13. Plume dispersion measurements from an oil sands extraction plant, March 1976.
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15. A climatology of low-level air trajectories in the Alberta oil sands area. 1977.
16. The feasibility of a weather radar near Fort McMurray, Alberta. 1977.
17. A survey of baseline levels of contaminants in aquatic biota of the AOSERP study area. 1977.

18. Interim compilation of stream gauging data to December 1976 for AOSERP. 1977.

19. Calculations of annual averaged sulphur dioxide concentrations at ground level in the AOSERP study area. 1977.

20. Characterization of organic constituents in waters and wastewaters of the Athabasca oil sands mining area. 1978.

21. AOSERP second annual report, 1976-77.

22. AOSERP interim report covering the period April 1975 to November 1978.

23. Acute lethality of mine depressurization water to trout-perch and rainbow trout: Volume I: 1979.

24. Air system winter field study in the AOSERP study area, February 1977.

25. Review of pollutant transformation processes relevant to the Alberta oil sands area. 1977.

26. Interim report on an intensive study of the fish fauna of the Muskeg River watershed of northeastern Alberta. 1977.

27. Meteorology and air quality winter field study in the AOSERP study area, March 1976.

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29. An inventory system for atmospheric emissions in the AOSERP study area. 1978.

30. Ambient air quality in the AOSERP study area, 1977.

31. Ecological habitat mapping of the AOSERP study area: Phase I. 1978.

32. AOSERP third annual report, 1977-78.

33. Relationships between habitats, forages, and carrying capacity of moose range in northern Alberta. Part I: moose preferences for habitat strata and forages. 1978.

34. Heavy metals in bottom sediments of the mainstem Athabasca River upstream of Fort McMurray: Volume I. 1978.

35. The effects of sedimentation on the aquatic biota. 1978.

36. Fall fisheries investigations in the Athabasca and Clearwater rivers upstream of Fort McMurray: Volume I. 1978.

37. Community studies: Fort McMurray, Anzac, Fort MacKay. 1978.

38. Techniques for the control of small mammal damage to plants: a review. 1979.

39. The climatology of the AOSERP study area. 1979.

40. Mixing characteristics of the Athabasca River below Fort McMurray-- winter conditions. 1979.

41. Acute and chronic toxicity of vanadium to fish. 1978.

42. Analysis of fur production records for registered traplines in the AOSERP study area, 1970-75.

43. A socio-economic evaluation of the recreational use of fish and wildlife resources in Alberta, with particular reference to the AOSERP study area. Vol. I: summary and conclusions. 1979.

44. Interim report on symptomology and threshold levels of air pollutant injury to vegetation, 1975 to 1978.

45. Interim report physiology and mechanisms of air-borne pollutant injury to vegetation, 1975 to 1978.

46. Interim report on ecological benchmarking and biomonitoring for detection of air-borne pollutant effects on vegetation and soils, 1975 to 1978.

47. A visibility bias model for aerial surveys of moose in the AOSERP study area. 1979.

48. Interim report on a hydrogeological investigation of the Muskeg River basin, Alberta. 1979.

49. The ecology of macrobenthic invertebrate communities in Harley Creek, northeastern Alberta.

50. Literature review on pollution deposition processes. 1979.

51. Interim compilation of 1976 suspended sediment data for the AOSERP study area. 1979.

52. Plume dispersion measurements from an oil sands extraction plant, June 1977.

53. Baseline states of organic constituents in the Athabasca River system upstream of Fort McMurray. 1979.

54. A preliminary study of chemical and microbial characteristics of the Athabasca River in the Athabasca oil sands area of northeastern Alberta. 1979.

55. Microbial populations in the Athabasca River. 1979.

56. The acute toxicity of saline groundwater and of vanadium to fish and aquatic invertebrates. 1979.

57. Ecological habitat mapping of the AOSERP study area (supplement): Phase I. 1979.

58. Interim report on ecological studies on the lower trophic levels of Muskeg rivers within the AOSERP study area. 1979.

59. Semi-aquatic mammals: annotated bibliography. 1979.

60. Synthesis of surface water hydrology. 1979.

61. An intensive study of the fish fauna of the Steepbank River watershed of northeastern Alberta. 1979.

62. Amphibians and reptiles in the AOSERP study area. 1979.

63. Analysis of AOSERP plume sigma data. 1979.

64. A review and assessment of the baseline data relevant to the impacts of oil sands developments on large mammals in the AOSERP study area. 1979.

65. A review and assessment of the baseline data relevant to the impacts of oil sands development on black bear in the AOSERP study area. 1979.

66. An assessment of the models LIRAQ and ADPIC for application to the Alberta oil sands area. 1979.

67. Aquatic biological investigations of the Muskeg River watershed. 1979.

68. Air system summer field study in the AOSERP study area, June 1977.

69. Native employment patterns in Alberta's Athabasca oil sands region. 1979.

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71. Lake acidification potential in the AOSERP study area. 1979.

72. The ecology of five major species of small mammals in the AOSERP study area: a review. 1979.

73. Distribution, abundance, and habitat associations of beavers, muskrats, mink, and river otters in the AOSERP study area, northeastern Alberta. 1979.

74. Air quality modelling and user needs. 1979.

75. Interim report on a comparative study of benthic algal primary productivity in the AOSERP study area. 1979.

76. An intensive study of the fish fauna of the Muskeg River watershed of northeastern Alberta. 1979.

77. Overview of local economic development in the Athabasca oil sands region since 1976. 1979.

78. Habitat relationships and management of terrestrial birds in northeastern Alberta. 1979.

79. The multiple toxicity of vanadium, nickel, and phenol to fish. 1979.

80. History of the Athabasca oil sands region, 1890 to 1960's. Volume I: socio-economic developments. Volume II: oral history. 1980.

81. Species distribution and habitat relationships of waterfowl in in northeastern Alberta. 1979.

82. Breeding distribution and behaviour of the White Pelican in the Athabasca oil sands area. 1979.

83. The distribution, foraging behaviour and allied activities of the White Pelican in the Athabasca oil sands area. 1979.

84. Investigations of the spring spawning fish populations in the Athabasca and Clearwater rivers upstream from Fort McMurray: Volume I. 1979.

85. An intensive surface water quality study of the Muskeg River watershed. Volume I: water chemistry. 1979.

86. An observational study of fog in the AOSERP study area. 1979.

87. Hydrogeological investigation of Muskeg River basin, Alberta. 1980.

88. Ecological studies of the aquatic invertebrates of the AOSERP study area of northeastern Alberta. 1980.

89. Fishery resources of the Athabasca River downstream of Fort McMurray, Alberta: Volume I. 1980.

90. A wintertime investigation of the deposition of pollutants around an isolated power plant in northern Alberta. 1980.

91. Characterization of stored peat in the Alberta oil sands area. 1980.

92. Fisheries and habitat investigations of tributary streams in the southern portion of the AOSERP study area. Volume I: summary and conclusions. 1980.

93. Fisheries and aquatic habitat investigations in the MacKay River watershed of northeastern Alberta. 1980.

94. A fisheries and water quality survey of ten lakes in the Richardson Tower area, northeastern Alberta. Volume I: methodology, summary, and discussion. 1980.

95. Evaluation of the effects of convection on plume behaviour in AOSERP study area. 1980.

96. Service delivery in the Athabasca oil sands region since 1961. 1980.

97. Differences in the composition of soils under open and canopy conditions at two sites close-in to the Great Canadian Oil Sands operation, Fort McMurray, Alberta. 1980.

98. Baseline condition of jack pine biomonitoring plots in the Athabasca oil sands area: 1976-1977.

99. Synecology and autecology of boreal forest vegetation in the AOSERP study area. 1980.

100. Baseline inventory of aquatic macrophyte species distributions in the AOSERP study area. 1980.

101. Woodland caribou population dynamics in northeastern Alberta. 1980.

102. Wolf population dynamics and prey relationships in northeastern Alberta.

103. Analysis of the leisure delivery system 1972-1979, with projections for future servicing requirements.

104. Review of requirements for air quality simulation models. 1980.

105. Approaches to the design of a biomonitoring program using arthropods as bioindicators for the AOSERP study area. 1980.

106. Meteorological factors affecting ambient SO_2 concentrations near an oil sands extraction plant. 1980.

107. Small mammal populations of northeastern Alberta. Volume I: populations in natural habitats. 1980.

108. Small mammal populations of northeastern Alberta. Volume II: populations in reclamation areas. 1980.

109. Symptomology and threshold levels of air pollutant injury to vegetation, 1979-1980.

110. Physiology and mechanisms of airborne pollutant injury to vegetation, 1979-1980.

111. Ecological benchmarking and biomonitoring for detection of airborne pollutant effects on vegetation and soils. 1980.

112. A study of human adjustment in Fort McMurray. Volume I: field study and results. 1980.

113. A laboratory study of long-term effects of mine depressurization groundwater on fish and invertebrates. 1980.

114. Aquatic biophysical inventory of major tributaries in the AOSERP study area. Volume I: summary report. 1980.

115. Report on an ecological survey of terrestrial insect communities in the AOSERP study area. 1980.

116. An assessment of benthic secondary production in the Muskeg River of northeastern Alberta. 1980.

117. Development of a chemically reactive plume model for application in the AOSERP study area. 1981.

118. Alberta Oil Sands Environmental Research Program, 1975-1980. A summary report. 1981.

119. Airshed management system for the Alberta oil sands. Volume I: A Gaussian frequency distribution model. 1981.

120. Airshed management system for the Alberta oil sands. Volume II: meteorological data.

121. The metabolism of selected organic compounds by microorganisms in the Athabasca River.

122. Soil inventory of the AOSERP study area. in prep.

123. Circulation of water and sediment in the Athabasca delta area. 1981.

124. Airshed management system for the Alberta oil sands. Volume III: validation and sensitivity studies.

125. The 1981 snowpack survey in the AOSERP study area. 1981.

126. Modelling the topographic effects on winds in the Alberta oil sands area. 1982.

127. Alberta Oil Sands Environmental Research Program annual report 1981/82. in prep.

128. A comparative study of benthic algal primary productivity in the AOSERP study area. 1982.

129. Athabasca Oil Sands precipitation chemistry studies: 1976-79 and 1981. 1982.

130. Climatological analysis of recent data from the Athabasca oil sands area. 1984.