AN OVERVIEW OF WATER QUALITY IN THE OLDMAN RIVER BASIN (1984-85)

Prepared by:

P.M. Cross and A.-M. Anderson

Environmental Quality Monitoring Branch
Environmental Assessment Division
Environmental Protection Services
Alberta Environment

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EXECUTIVE SUMMARY

The intensive monitoring of the Oldman River and its tributaries was conducted from April 1984 to March 1985. The study included chemical monitoring, biological monitoring of algae, macrophytes and benthic invertebrates, and testing for accumulation of metals and organic contaminants in the sediments. The establishment of baseline conditions indicate the current status of the basin, including the impact of present development. This forms a basis for comparison for any future impacts or developments.

The character of the Oldman River is strongly influenced by the input from tributaries, cities and irrigation return flows. Tributaries provide a significant portion of the flow of the Oldman River. In 1984, the Castle and Crowsnest rivers provided 63% of the flow of the Oldman River at Brocket. The St. Mary and Belly rivers provided 38% of the flow of the Oldman River at Lethbridge. The river basin geology of these tributaries was an important component in defining water chemistry in the Oldman River. The major ions, sodium, sulphate, chloride and potassium, were the most significant factor in characterising the water chemistry. Of secondary and tertiary importance were the calcium bicarbonate interaction and discharge (reflected by particulate variables), respectively.

The major source of dissolved phosphorus to the Oldman River was the Lethbridge sewage treatment plant. Its input of 87.7 tonnes/year represented 83% of the total input. Apart from changes in water chemistry, the impact on the river was shown in increased standing crops of benthic algae and phytoplankton and the sudden appearance of large numbers of tubificid worms downstream of Lethbridge.

Benthic invertebrate fauna at Fort Macleod also showed some evidence of an environmental disturbance. Numbers of mayfly, stonefly and caddisfly decreased unexpectedly.

In conclusion, the Oldman River changes from a foothill stream with clear, swift waters to a larger and slower moving river with finer sediments and higher silt loads. The influence of tributary streams and irrigation return flows is reflected in water chemistry. Municipal disturbances at Lethbridge are reflected in water chemistry, primary producers and benthic invertebrates.

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ACKNOWLEDGMENTS

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1.0 INTRODUCTION

There are three basic components to the surface water quality monitoring strategy for southern Alberta. The first provides the basic framework. It consists of routine chemical and biological monitoring at selected river locations for the identification of long term trends and continuous remote automatic monitoring at key points on the major rivers to detect spill events. The second component consists of an intensive monitoring program of each major river on a rotational basis. The final component consists of short term, more site specific sampling to address specific water quality questions.

This study of the Oldman River represents the second component of the overall monitoring strategy. It provides additional chemical monitoring of the river and its tributaries, biological monitoring of the algae, macrophytes and benthic invertebrates and testing of sediment for accumulation of metals and organic contaminants.

The Oldman River was studied intensively in 1984-85. This study provides additional information to the database collected from 1979 to 1982 (Cross, Hamilton and Charlton 1986; Charlton, Hamilton and Cross 1986). The earlier data collection concentrated on nutrients, primary producers and their inter-relationship. The focus of this study was broader and included a wider range of chemical analyses. As well, the river was sampled along a greater length and the tributaries and irrigation return flows were monitored in the same year. This allowed a better understanding of their impact on the river.

The collection of data from both the river and its tributaries in the same year is also important as a database for the water quality model - WQRRS. With the data collected in 1984-85, the model can be verified and recalibrated. This function is particularly important in view of the construction of the dam in the Three Rivers area of the Oldman River. The water quality model will be used to evaluate the effects of dam operation on water quality of the Oldman River downstream.

A planning study by Alberta Environment (1976) of the Oldman River gives considerable background information on the basin. The water quality section of the study summarized much of the early work on the basin and reached the following conclusions:

1. The upstream tributaries do not adversely affect the water quality of the Oldman River to a significant extent, while the Little Bow River may have a limited impact.
2. The City of Lethbridge and the two sugar-beet plants at Taber and Picture Butte were the major sources of waste discharge. These would adversely affect the river in terms of phosphate levels, algal growth and dissolved oxygen concentration.

The objectives of this report are first to document the current water quality in the Oldman River and its tributaries and irrigation return flows as they impinge on the river; second, to evaluate the water quality in terms of historical data and water quality objectives and third, to present an overview of the results of the zoobenthic surveys of the Oldman River in spring and fall of 1984.

2.0 METHODS

2.1 WATER CHEMISTRY SAMPLING SITES AND FREQUENCY

The Oldman River was monitored in this study from near Waldron's Corner to its confluence with the Bow River, a distance of 375 km (Figure 1). Sampling sites were established at seven mainstem river sites and thirteen tributary and irrigation return flows (Figure 1, Table 1). Long term monthly monitoring is carried out near Lethbridge and Taber and remote continuous monitoring is carried out near Fincastle (Figure 1, Table 1).

Computer data from Fincastle were lost from August to December 1984 because of operator error. Data from September to December 1983 were substituted for analysis. August data were averaged from 1980 and 1985, since monitor problems occurred in the intervening years.

The study was conducted from April 1984 to March 1985. The sampling frequency was designed to emphasize the higher discharge periods when water quality characteristics change more rapidly. Thus, the Oldman River and its major tributaries were sampled throughout the year; every two weeks from April to July 1984, every three weeks from August to October 1984 and monthly from November 1984 to March 1985. Ephemeral streams were sampled only in spring and irrigation return flows were sampled through the growing season.

2.2 PHYSICAL AND CHEMICAL PARAMETERS

Samples were collected at each site generally by walk-in access to a depth no greater than 0.5 m. Field measurements of dissolved oxygen (Hydrolab oxygen meter calibrated daily using Winkler

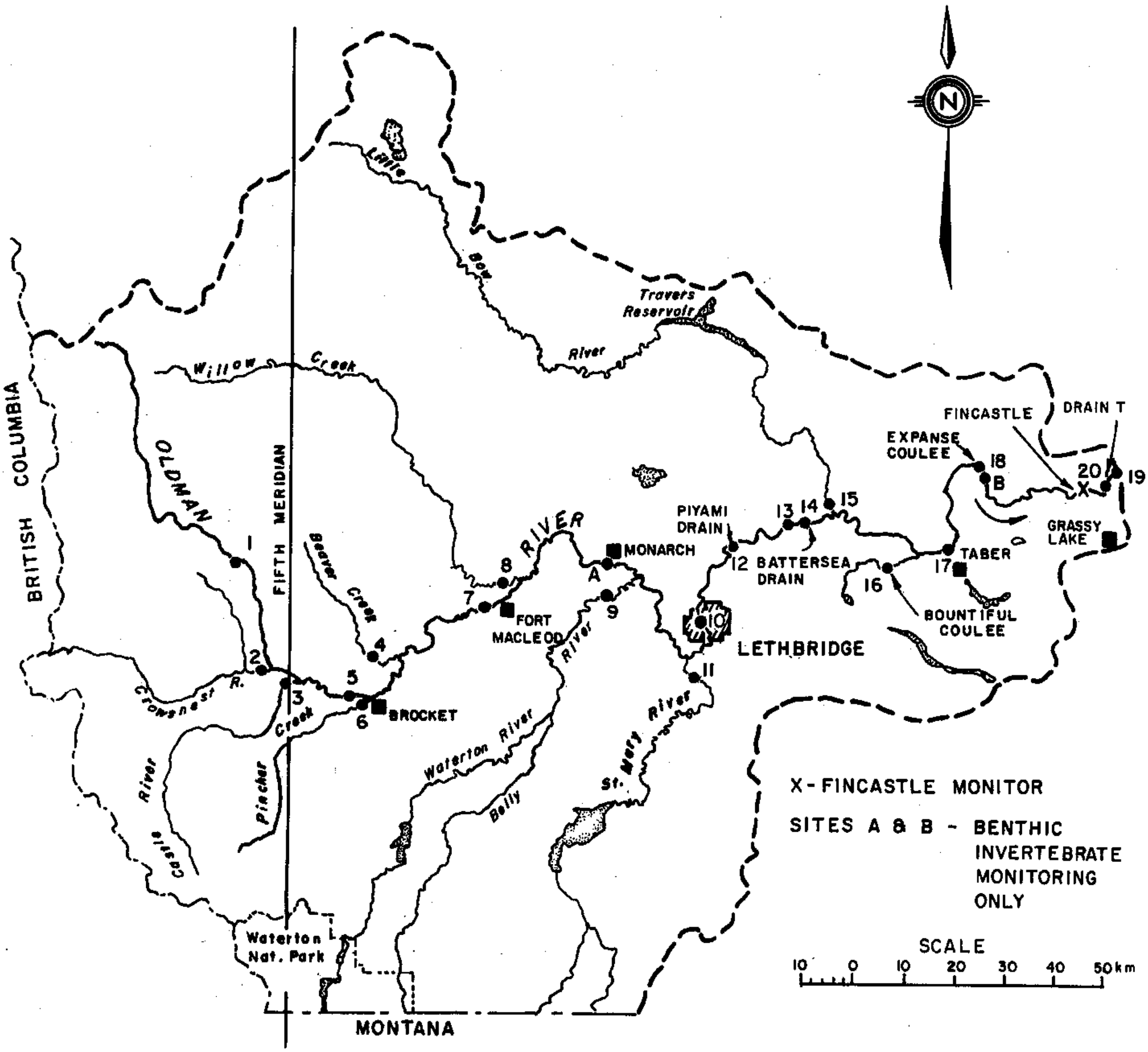

FIGURE 1 OLDMAN RIVER SAMPLING SITES

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TABLE 1 Location and NAQUADAT Code for Oldman River study sampling sites.

SITE	NAQUADAT CODE	RIVER DISTANCE (KM)	LOCATION
1	00AL05AA0200	375	Oldman River near Waldron's Corner
2	00AL05AA0700	339	Crowsnest River
3	00AL05AA1000	334	Castle River
4	00AL05AB0250	296	Beaver Creek
5	00AL05AB0150	317	Oldman River near Brocket
6	00AL05AA1700	312	Pincher Creek
7	00AL05AB0300	259	Oldman River near Fort Macleod
8	00AL05AB0350	247	Willow Creek
9	00AL05AD0550	202	Belly River
11	00AL05AE0400	169	St. Mary River
10	00AL05AD0750	155	Oldman River above Lethbridge
12	00AL05AD0900	129	Piyami Drain
13	00AL05AD1000	112	Oldman River below Lethbridge
14	00AL05AG0250	111	Battersea Drain
15	00AL05AC2250	99	Little Bow River
16	00AL05AG0350	75	Bountiful Coulee
17	00AL05AG0500	69	Oldman River above Taber
18	00AL05AG0650	44	Expanse Coulee
	00AL05AG0850	12	Oldman River at Fincastle
20	00AL05BN6000	5	Drain T
19	00AL05AG0900	0	Oldman River at the Mouth (Grassy Lake)

titration) and water and air (shaded) temperature (Fisher Brand 15-021B hand thermometer) were made and site characteristics were noted. Samples for metals analysis were collected only at four river sites; at Fort Macleod, above and below Lethbridge and at Grassy Lake.

Water samples were collected into triple-rinsed sample bottles. These were shipped daily to the Alberta Environmental Centre in Vegreville from April to June and to Chemex Laboratories in Calgary for the remainder of the study. Analytical methods are summarized in Table 2. One of the irrigation return flows, Drain T, was sampled by local personnel for a subset of the analytical parameters.

Bacteriological samples were shipped on ice within 24 hours for analysis by the Public Health Laboratory in Calgary. Samples were analyzed using membrane filtration techniques.

Water samples collected in June and October 1984 at three sites; above and below Lethbridge and at the confluence with the Bow River; were analyzed by Alberta Environmental Centre for priority pollutant extractables, organophosphorus and organonitrogen pesticides, organochlorine pesticides, chlorinated herbicide acids and polychlorinated biphenyls. The complete list of analyses is given in Appendix I.

Sediment samples were collected in early October 1984 at four mainstem river sites using an airlift sampler. The sediment slurry was settled for at least 24 hours before the supernatant was decanted. The sediment was transferred to acid washed glass jars and shipped to Chemex Laboratories for analysis.

TABLE 2 NAQUADAT Codes for water chemistry variables sampled during study.

VARIABLE		NAQUADAT CODE	VARIABLE		NAQUADAT CODE
TDS	- calculated	00203L	Chloride	- dissolved	17203L
	- measured	00205L	Potassium	- dissolved	19103L
Specific Conductance		02041L	Calcium	- dissolved	20110L
Temperature	- water	02062F	Coliforms	- total	36001L
	- air	02066F		- fecal	36011L
Turbidity		02074L	Metals-extractable	- beryllium	04304L
Carbon	- diss.organic	06107L		- magnesium	*12303L
	- diss.inorganic	06154L		- aluminum	13306L
Bicarbonate	- calculated	06202L		- chromium	24302L
Carbonate	- calculated	06301L		- manganese	25304L
Phenolic material		06537L		- iron	26302L
Chlorophyll	- phytoplankton	06720L		- cobalt	27303L
	- epilithon	06721L		- nickel	28302L
Nitrogen	- total Kjeldahl	07021L		- copper	29305L
	- nitrate+nitrite	07110L		- zinc	30305L
	- diss. ammonia	07562L		- cadmium	48302L
	- total	07602L		- lead	82302L
Oxygen	- dissolved	08102F	- total	- vanadium	23009L
	- biochemical demand	08202L		- chromium	24009L
	- chemical demand	08301L		- manganese	25003L
Alkalinity	- total	10101L		- cobalt	27009L
	- phenolphthalien	10151L		- nickel	28009L
pH		10301L		- copper	29009L
Residue	- non-filterable	10401L		- zinc	30009L
	- filterable	10451L		- arsenic	33005L
Hardness	- total	10605L		- selenium	34005L
Sodium	- dissolved	11103L		- molybdenium	42009L
Silica	- reactive	14011L		- cadmium	48009L
Phosphorus	- dissolved	15103L		- mercury	80015L
	- total	15421L	- dissolved	- arsenic	33104L
	- particulate	15901L			
Sulphate	- dissolved	16306L			

* Input code 12102L used for NAQUADAT storage to accomodate hardness calculation.

2.3 ALGAE AND MACROPHYTES

Benthic algae (epilithon) and phytoplankton samples were collected at mainstem river sites on each trip with the exception of benthic algae in February and March. At tributary sites, phytoplankton samples were taken every second trip. No samples were taken at irrigation return flow sites.

For phytoplankton chlorophyll, 1L of water was filtered in the shade through a 5.5 cm Whatman GFC filter. The sample was preserved with magnesium carbonate, wrapped in aluminum foil and stored on dry ice. The filtrate from this sample was filtered through a 0.45 μ Sartorius membrane filter for low level nutrient determinations.

For benthic algal chlorophyll determination, a maximum of 10 rocks were collected and brushed clean of algae. The resultant slurry of algae and distilled water was measured for volume and subsampled using a wide mouth 50 cc syringe. The subsample was filtered and preserved in the same way as the phytoplankton samples.

Macrophytes were not sampled because they were scarce at mainstem river sites.

2.4 BENTHIC INVERTEBRATES

Benthic invertebrates were sampled twice in the Oldman River; in early spring (April 9 to 11, 1984) and in the fall (October 1 to 3, 1984). Five replicate invertebrate samples were collected at nine locations; the seven chemistry sampling sites plus Site A near Monarch and Site B at Hwy. 36 (Figure 1). A modified Neill cylinder (Neill, 1938) with a sampling surface of 0.1 m^2 was used with a 0.210 mm mesh collecting net.

Sampling was restricted to erosional habitats (i.e. riffles) and locations were chosen to minimize differences in substrate characteristics, flow velocity, and sampling depth. The substrate at most sites consisted primarily of pebbles and cobbles mixed with sand and silt. Some sites, Waldron's Corner in particular, had a coarser substrate which also contained boulders. Filamentous algae occurred in samples collected at most sites downstream of Lethbridge in spring. They were also found further upstream, at Brocket, in fall. Macrophytes occurred in varying density at and below Monarch.

Samples were preserved in 4% formaldehyde immediately after collection. Later, in the laboratory, they were stained with Rose Bengal (Mason and Yevich 1967) and sieved. The residue on the finest sieve (0.213 mm mesh) was extracted using a solution of Ludox AM, a commercial preparation of silica sol. Ludox has been used successfully in the separation of marine zoobenthos samples (Jonge and Bauman 1977). The residue remaining after three extractions was examined and specimens which were not extracted were removed manually. Coarse fractions and Ludox-extracted fine fractions of each sample were sorted under a dissecting microscope at a magnification of 6 to 25 (objective) x 10 (ocular). Subsampling was performed on the fine fraction of samples which contained a large number of organisms. At least 5 subsamples (each representing 1/20 of the total sample volume) were obtained according to the method described in Wrona, Culp and Davies (1982). Invertebrates were counted and identified according to Bauman et al. (1977), Edmunds et al. (1976), Merritt and Cummins (1979 and 1984), Pennak (1953) and Wiggins (1977).

2.5 STATISTICAL ANALYSES

Dissolved phosphorus loading was calculated from phosphorus concentration and discharge data as the average of the following two formulae:

$$L_1 = \frac{\Sigma c_i q_i}{\Sigma q_i} \cdot k\ Q \qquad\qquad L_2 = \frac{\Sigma c_i q_i}{n} \cdot k$$

where
- L = loading in tonnes
- c_i = instantaneous concentration in $mg.L^{-1}$
- q_i = mean daily discharge in $m^3.s^{-1}$
- n = number of observations of both variables
- Q = mean discharge in $m^3.s^{-1}$
- k = constant for unit adjustment

The two formulae were averaged since each is an acceptable calculation for use with both instantaneous and daily data but results, because of discharge information, can vary.

Pearson's correlations using SPSS^x (SPSS Inc. 1983) were calculated for all water chemistry parameters. Principal components or factor analysis using SPSS^x was carried out on the chemistry data set to determine the set of components which account for the observed interrelations in the data. Variables from data sets which did not have a normal distribution were log(x+1) transformed before analysis. Pairwise deletion of missing values was used to include as many cases as possible in the analysis.

Benthic invertebrate data were tested for normality with the Kolmogorov-Smirnov test (Siegel 1956) using SPSS^x (SPSS Inc. 1983). Log(x+1) transformation of total invertebrate numbers was necessary to achieve normality in the distribution of the data set. A one-way analysis of variance (ANOVA-Sokal and Rohlf 1969) was performed on total invertebrate density and total number of invertebrate taxa to determine whether these variables differed significantly in their means between stations. If significant differences were found, the Student-Newman-Keuls test (SNK - Sokal and Rohlf 1969) was performed to determine which sites were different. Cluster and principal components analyses were performed on the entire benthic invertebrate data sets from both seasonal surveys (CLUSTAN-Wishart 1978). Log(x+1) transformed abundance data of benthic invertebrate were used.

3.0 RESULTS

Some overall generalities can be made about water quality results at mainstem river sites from this study. On an annual basis, concentrations of many of the chemical parameters tended to increase in a downstream direction. The exception was silica which decreased along the length of the river. Seasonally, chemical parameters reacted in two basic ways. Either no strong trends were apparent, or concentrations tended to be lower in June and higher through the winter.

3.1 PHYSICAL CONDITIONS

3.1.1. Discharge

Discharge measured in 1984 is compared with historical information at three sites on the Oldman River in Figure 2. Historical monthly mean data show peak flows in June, with flows in

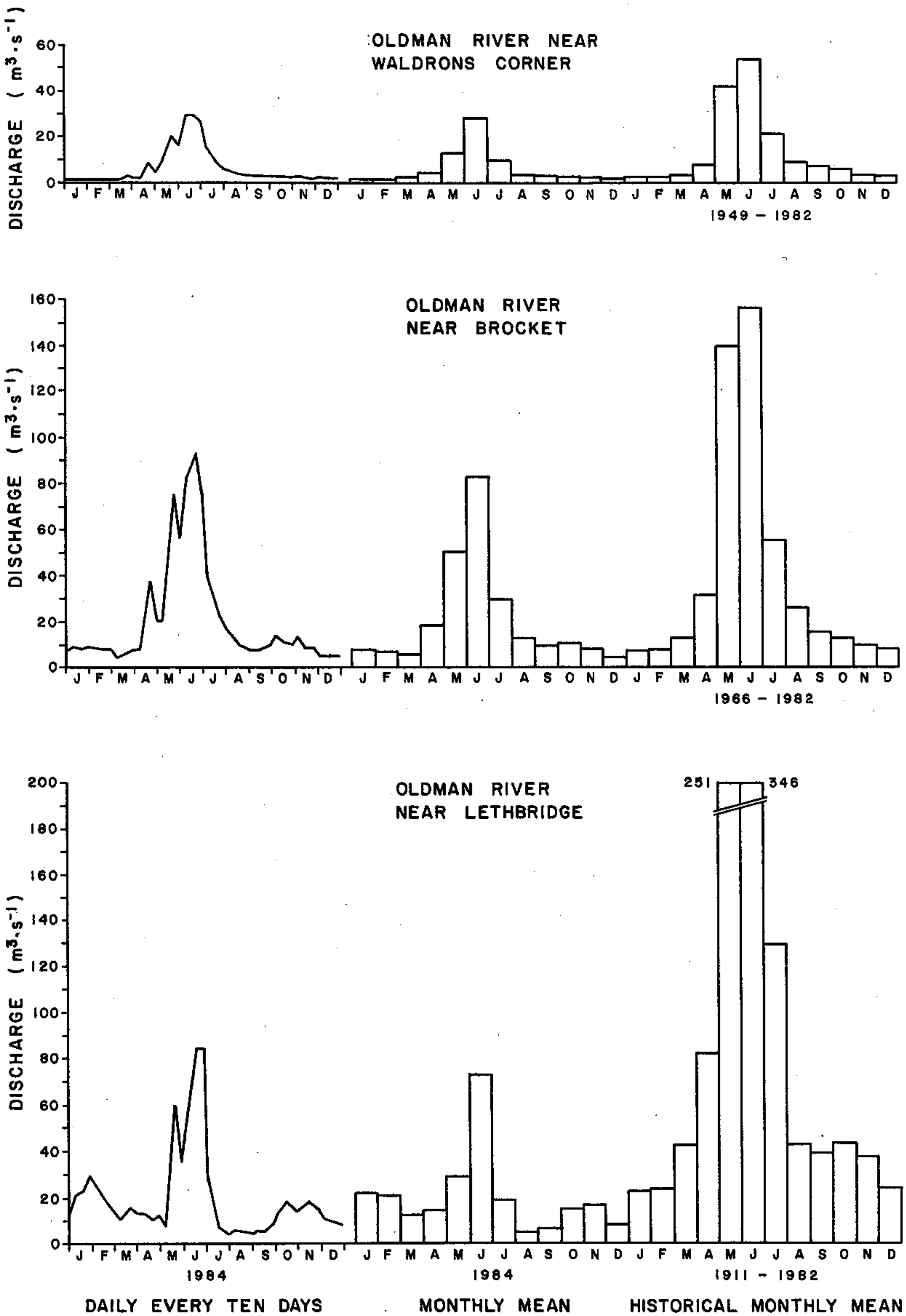

Figure 2. DISCHARGE IN THE OLDMAN RIVER

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May almost as high. Discharge measured in 1984 shows a similar seasonal trend, however mean monthly and annual flows were much lower than the historical means. At Waldron's Corner and Brocket annual flows in 1984 were 47% and 50% of the historical average. At Lethbridge the flow in 1984 was only 23% of the long term average. It should be noted that the historical period of record (1911 - 1982) includes many years prior to discharge regulation and irrigation in the Oldman River basin.

3.1.2 Water Temperature

Seasonal fluctuations in water temperature in the Oldman River, as illustrated by data from the remote monitor at Fincastle, are primarily controlled by climate (Figure 3). Temperatures were low in winter and maximum values as high as 26.2°C were measured in July. The large range of values measured in most months except during winter indicate the rapid response of the river to fluctuations in air temperature. Temperature in the upstream reaches of a river is generally expected to be cooler than in the downstream reaches.

A secondary degree of temperature fluctuation, the change over a single day, is illustrated by data from the remote monitor at Fincastle (Figure 4). The largest amplitude in daily temperature change shown here occurred in April (4.5°C).

3.1.3 Dissolved Oxygen and Oxygen Demand

Monthly average values of dissolved oxygen (D.O) at Fincastle (Figure 3) were lowest in January (4.7 $mg.L^{-1}$) and highest in October/November (11.3 $mg.L^{-1}$). Diurnal fluctuations in dissolved

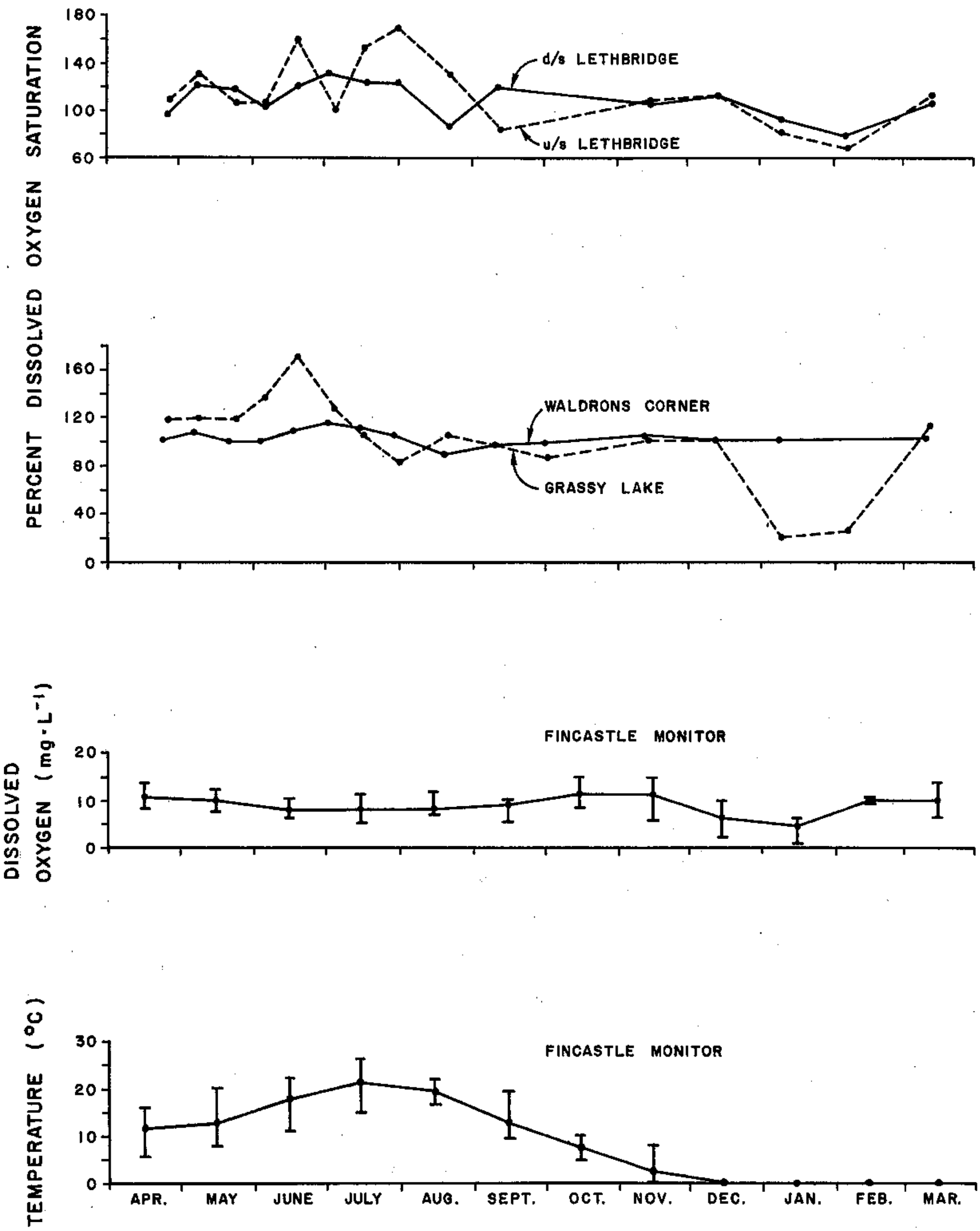

Figure 3. TEMPERATURE AND DISSOLVED OXYGEN IN THE OLDMAN RIVER.

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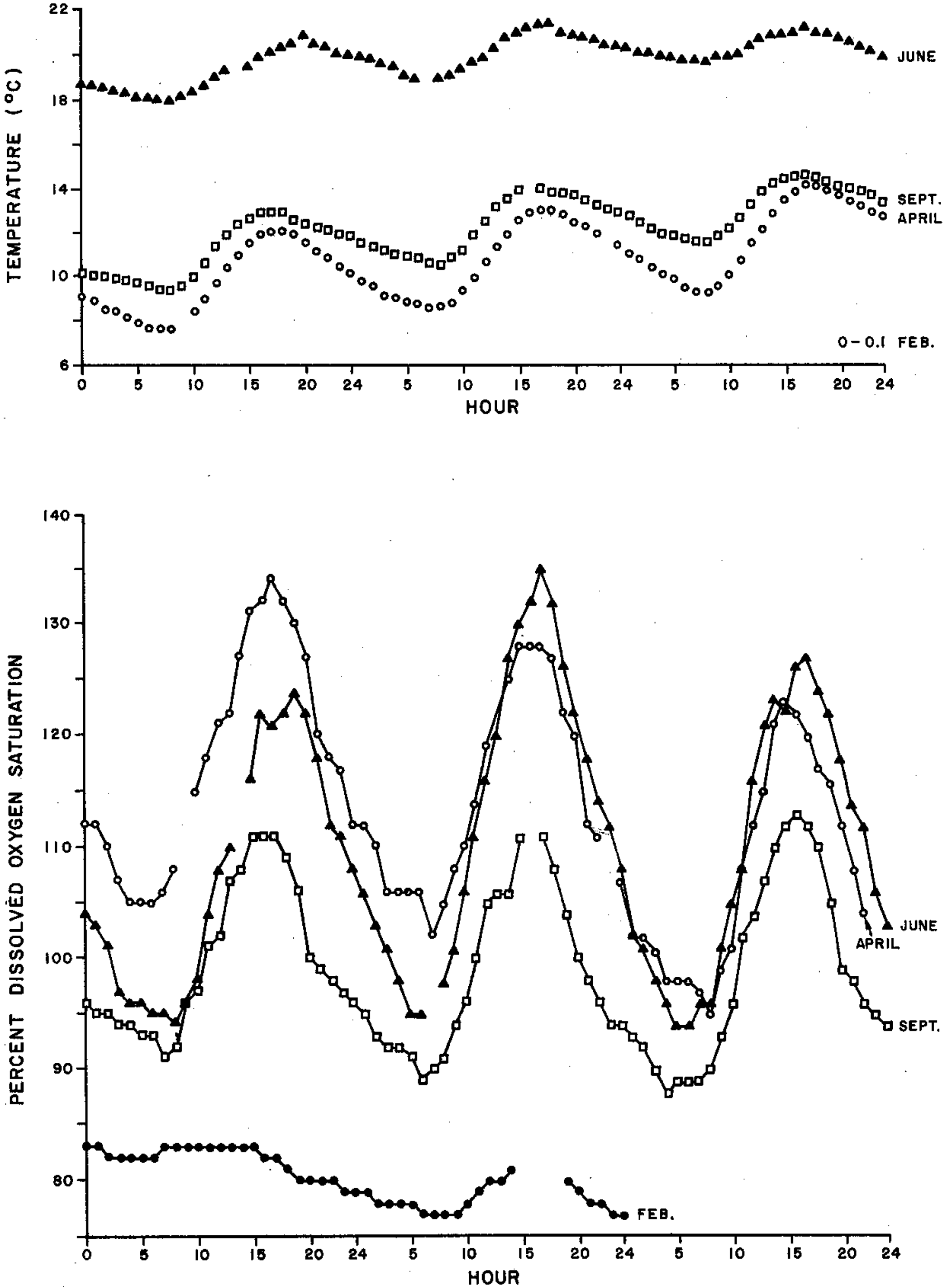

Figure 4. DIURNAL TEMPERATURE AND PERCENT DISSOLVED OXYGEN SATURATION AT FINCASTLE.

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oxygen concentration were large in all seasons except winter (Figure 5). These fluctuations were also shown when the controlling effect of temperature was removed and data were expressed as percent saturation (Figure 4).

Data collected at each study site are difficult to compare between sites, since they are biased by the time of sampling. Site specific seasonal trend analysis is more valid because sites tended to be sampled at approximately the same time throughout the study. Figure 3 illustrates the variability in trends along the length of the river. Percent saturation values generally ranged from 80% to 170%. Lowest dissolved oxygen saturation values were measured in January and February, particularly at Grassy Lake (Site 19).

Average annual concentrations of biochemical oxygen demand (Figure 6) increased from 0.76 $mg.L^{-1}$ at Waldron's Corner (Site 1) to 1.85 $mg.L^{-1}$ at Grassy Lake (Site 19). Chemical oxygen demand also showed an increase from 7.3 to 13.7 $mg.L^{-1}$. Unlike biochemical oxygen demand, the lowest annual value was measured near Fort Macleod (Site 7). In both cases there was a sharp increase in concentrations below Lethbridge (Site 13) and a decrease to the site at Taber (Site 17). Concentrations were 12.9 and 11.1 $mg.L^{-1}$ for chemical oxygen demand and 1.81 and 1.59 $mg.L^{-1}$ for biochemical oxygen demand, respectively.

There were no obvious seasonal trends in either chemical or biochemical oxygen demand at any of the sites (Figure 7). The one exception occurred at the site above Lethbridge which had lower concentrations of chemical oxygen demand from November to March.

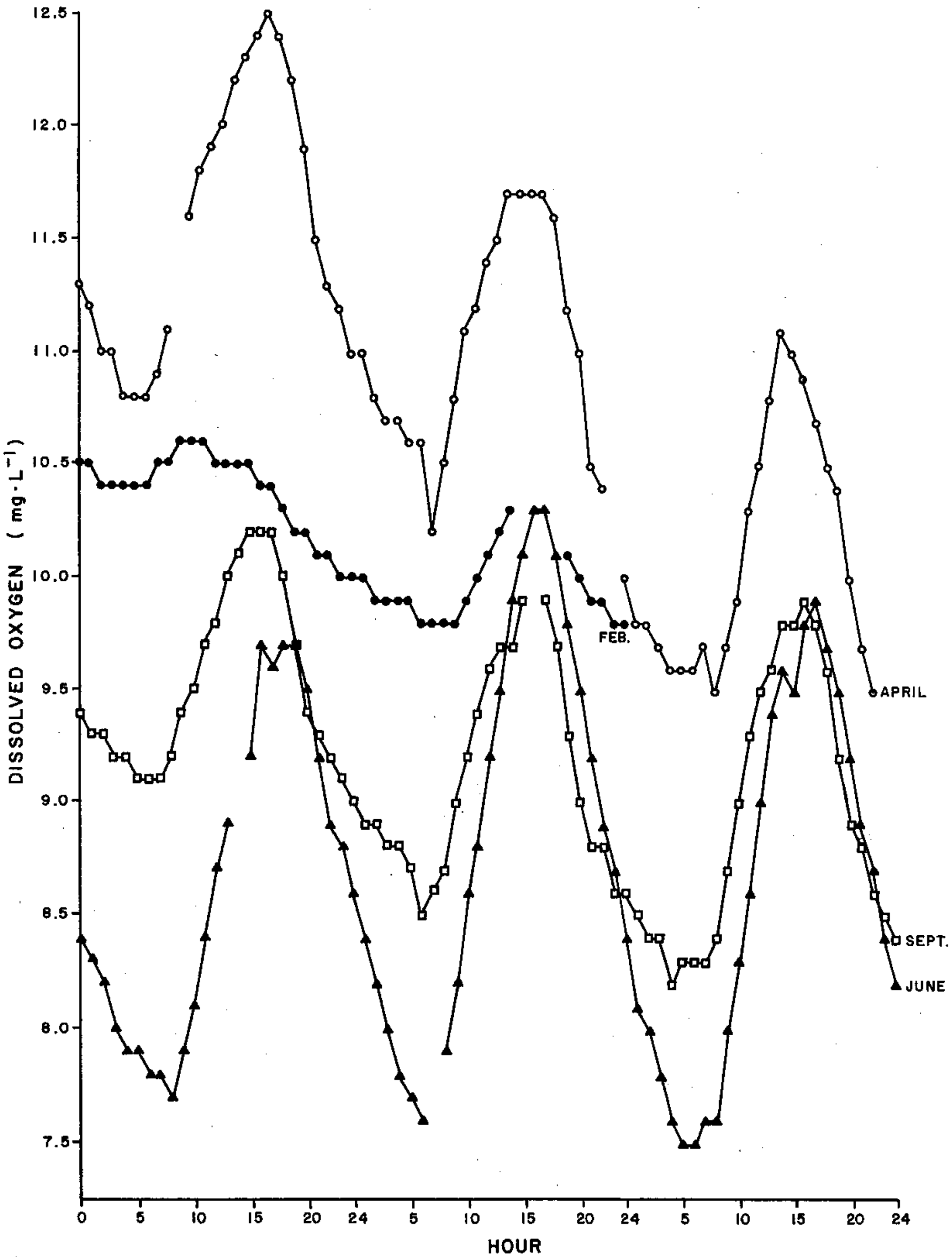

Figure 5 . DIURNAL DISSOLVED OXYGEN AT FINCASTLE .

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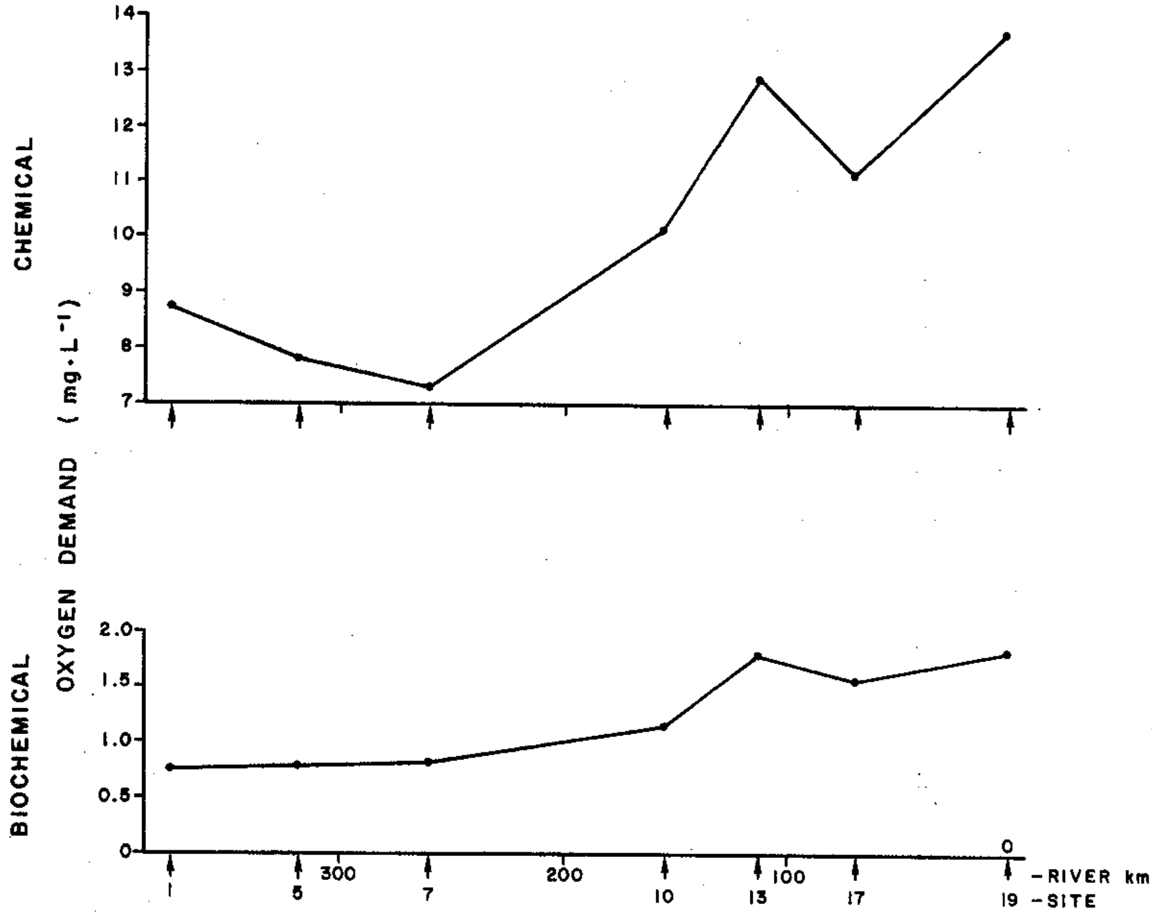

Figure 6. **AVERAGE ANNUAL CONCENTRATIONS OF OXYGEN DEMAND AT SITES ALONG THE OLDMAN RIVER.**

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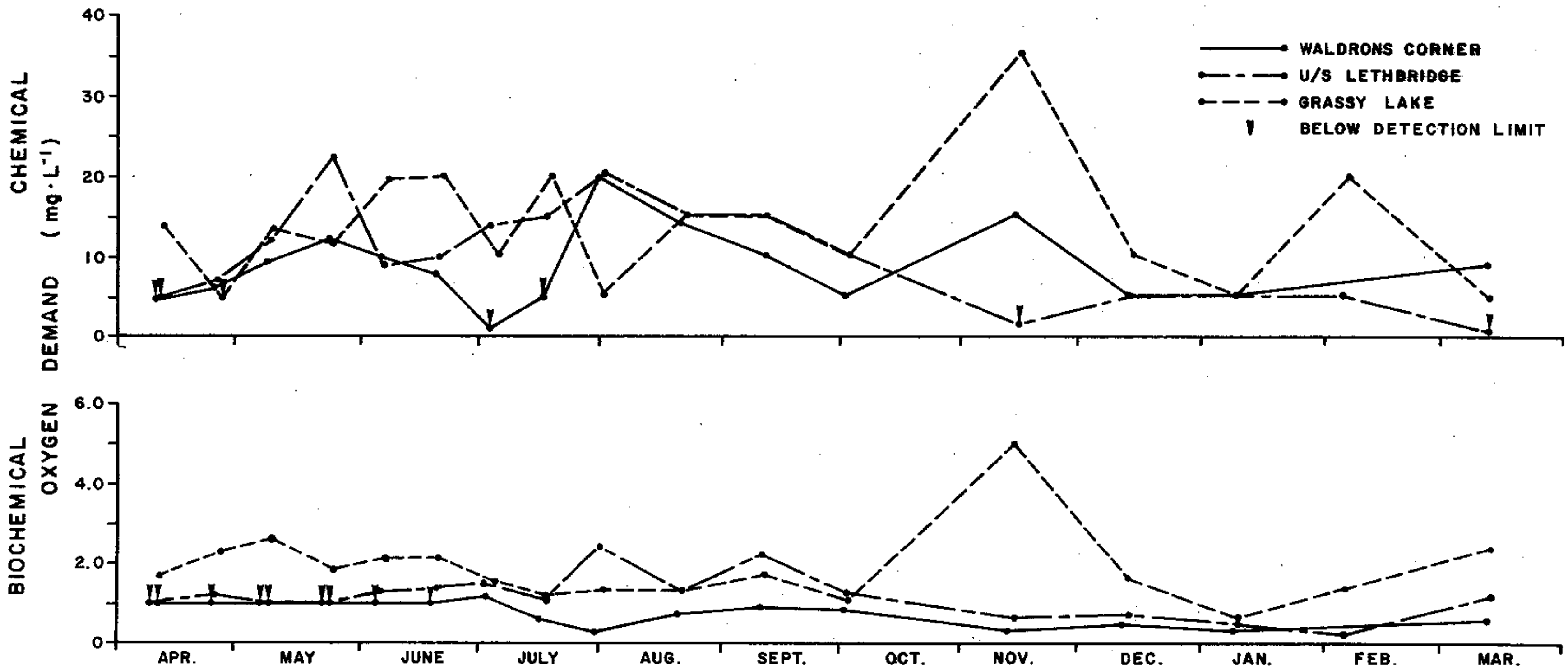

Figure 7. CONCENTRATIONS OF OXYGEN DEMAND AT REPRESENTATIVE SITES ON THE OLDMAN RIVER.

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3.1.4 Turbidity and Non-filterable Residue

Turbidity and non-filterable residue values in the Oldman River were highly correlated (r = 0.94). Values increased on an annual basis, from low values at Waldron's Corner (Site 1; 1.7 NTU for turbidity and 3.8 $mg.L^{-1}$ for non-filterable residue) to high values near Taber (Site 17; 11.3 NTU and 18.8 $mg.L^{-1}$, respectively; Figure 8). There was a decrease from Taber to Grassy Lake (Site 19; 7.3 NTU and 13.5 $mg.L^{-1}$, respectively). On a seasonal basis, values fluctuated more during April to September than through the remainder of the year (Figure 8). The exception was Site 1 at Waldron's Corner which had higher values through June and early July only.

3.2 WATER CHEMISTRY

3.2.1 Conductivity, Major Ions and Total Dissolved Solids

Conductivity, major ion concentrations and total dissolved solids followed the general trend of increasing values along the length of the Oldman River (Figure 9). There was, however, a slight decrease from Waldron's Corner (Site 1) to Brocket (Site 5) for several parameters and the degree of change was variable. Average values of conductivity ranged from 297 to 437 $\mu S.cm^{-1}$. Average values of total dissolved solids ranged from 169 to 258 $mg.L^{-1}$.

Potassium concentrations showed the least absolute increase along the length of the river (1.3 $mg.L^{-1}$). Bicarbonate concentrations showed an increase of 10 $mg.L^{-1}$ along the length of the river. Chloride was quite constant except for a marked increase in

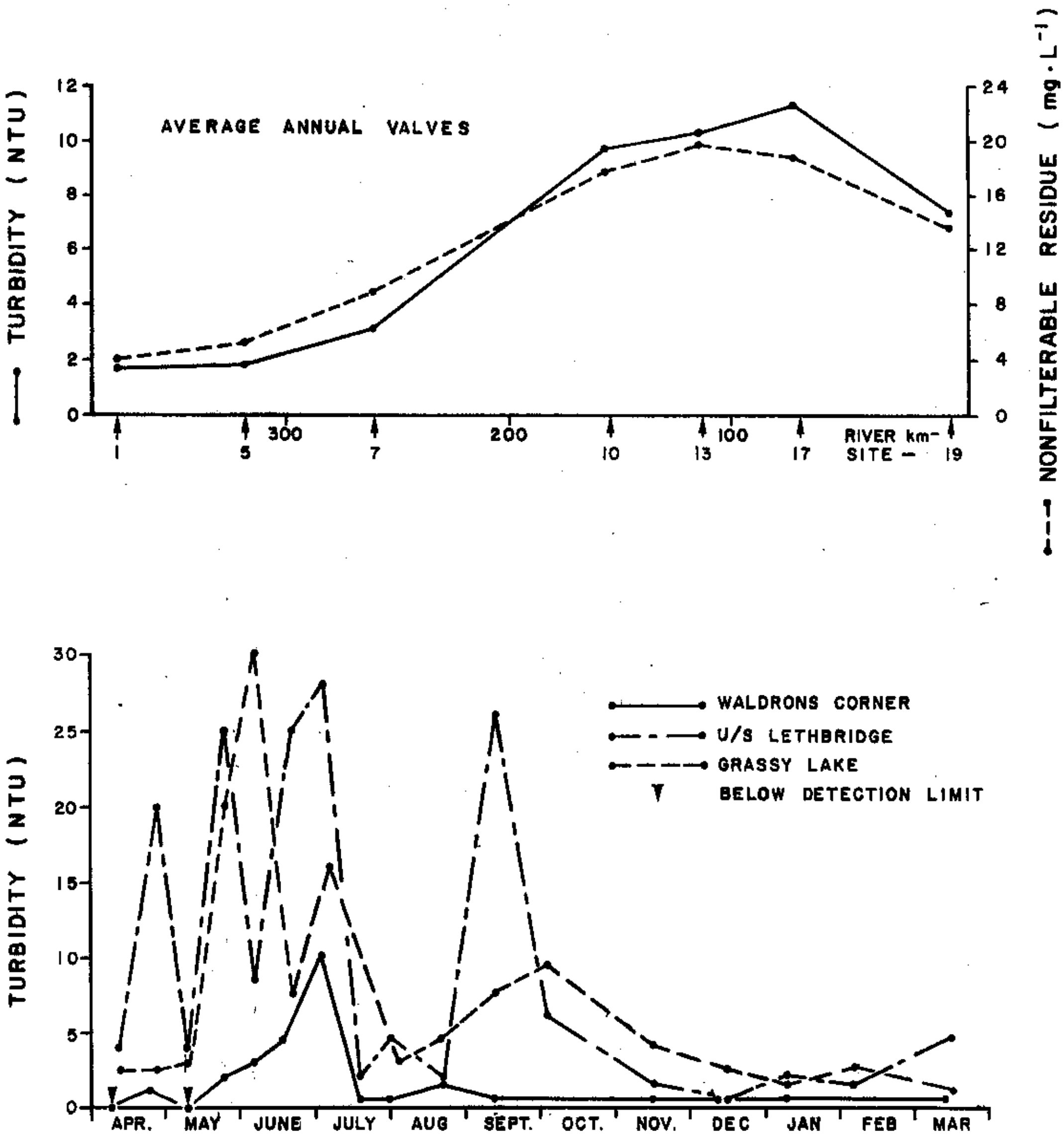

Figure 8. CONCENTRATIONS OF TURBIDITY AND NON-FILTERABLE RESIDUE IN THE OLDMAN RIVER.

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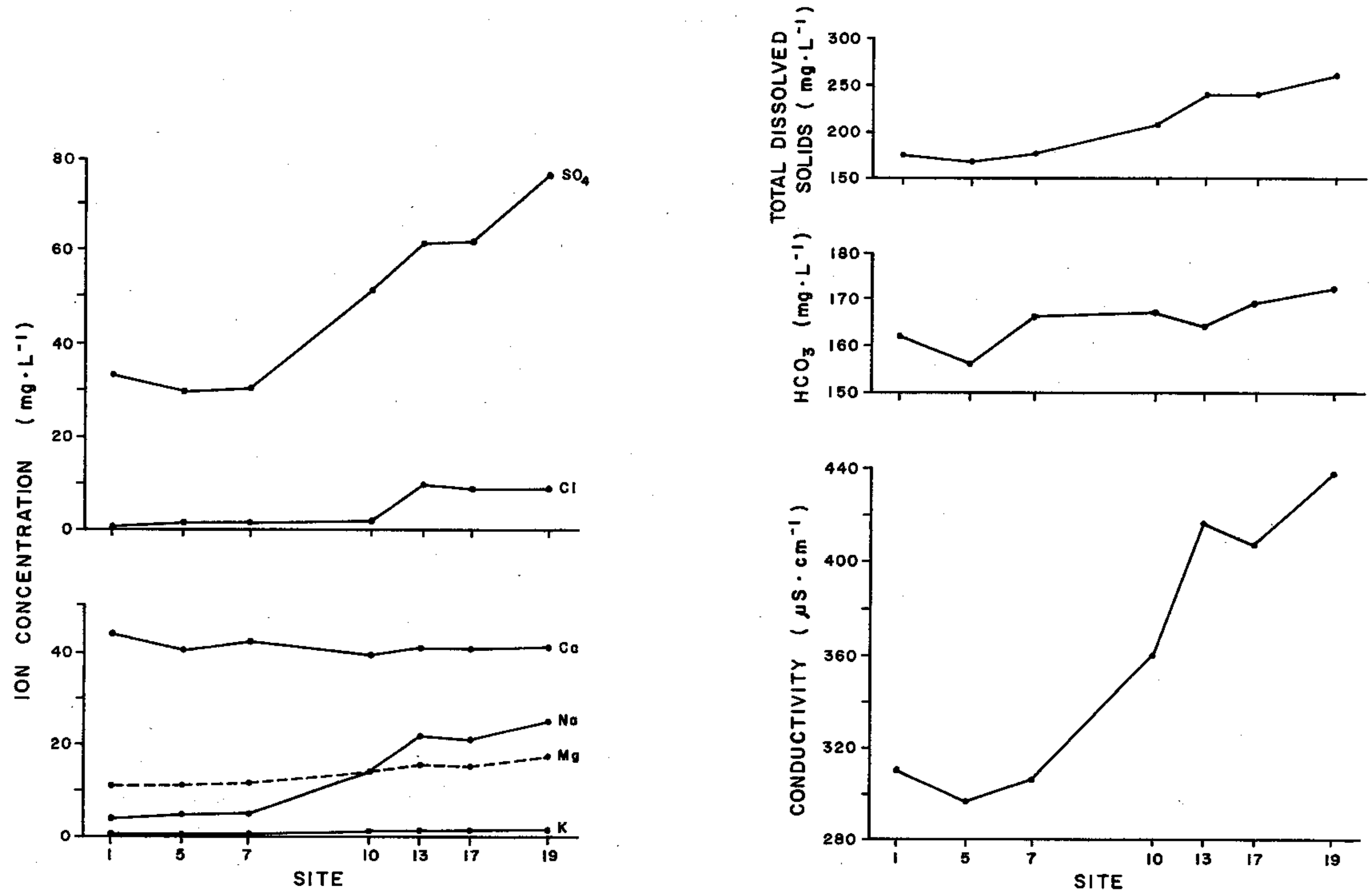

Figure 9. AVERAGE ANNUAL CONCENTRATIONS OF MAJOR IONS, TDS AND CONDUCTIVITY AT SITES ALONG THE OLDMAN RIVER.

concentration (7.5 $mg.L^{-1}$) from above to below Lethbridge (Sites 10 and 13). The concentration increases in sodium, sulphate, total dissolved solids and, to a lesser degree, magnesium were more rapid between Fort Macleod (Site 7) and Site 13 below Lethbridge than upstream. Further downstream, the change between Lethbridge and Taber (Site 17) was negligible, but concentrations increased again to Grassy Lake (Site 19). Conductivity followed a similar trend but there was a decrease between Lethbridge and Taber. Calcium concentrations did not show the same trends as the other major ions. Concentrations decreased slightly, overall, in a downstream direction.

The seasonal trends for conductivity, major ions and total dissolved solids were often similar at different sites. They were typified by low June values and higher values from October to April (Figure 10). The trends were not as strong for potassium at all sites nor for sodium and chloride at upstream sites. Concentrations were generally low in these cases.

Conductivity, magnesium, sodium and sulphate were strongly correlated ($r > 0.8$). Correlations between sodium and chloride and between calcium and bicarbonate were also strong.

3.2.2 Alkalinity and pH

Trends in alkalinity were similar to trends in conductivity both longitudinally and seasonally (Figures 11 and 12). The correlation coefficient between these two variables was $r = 0.74$.

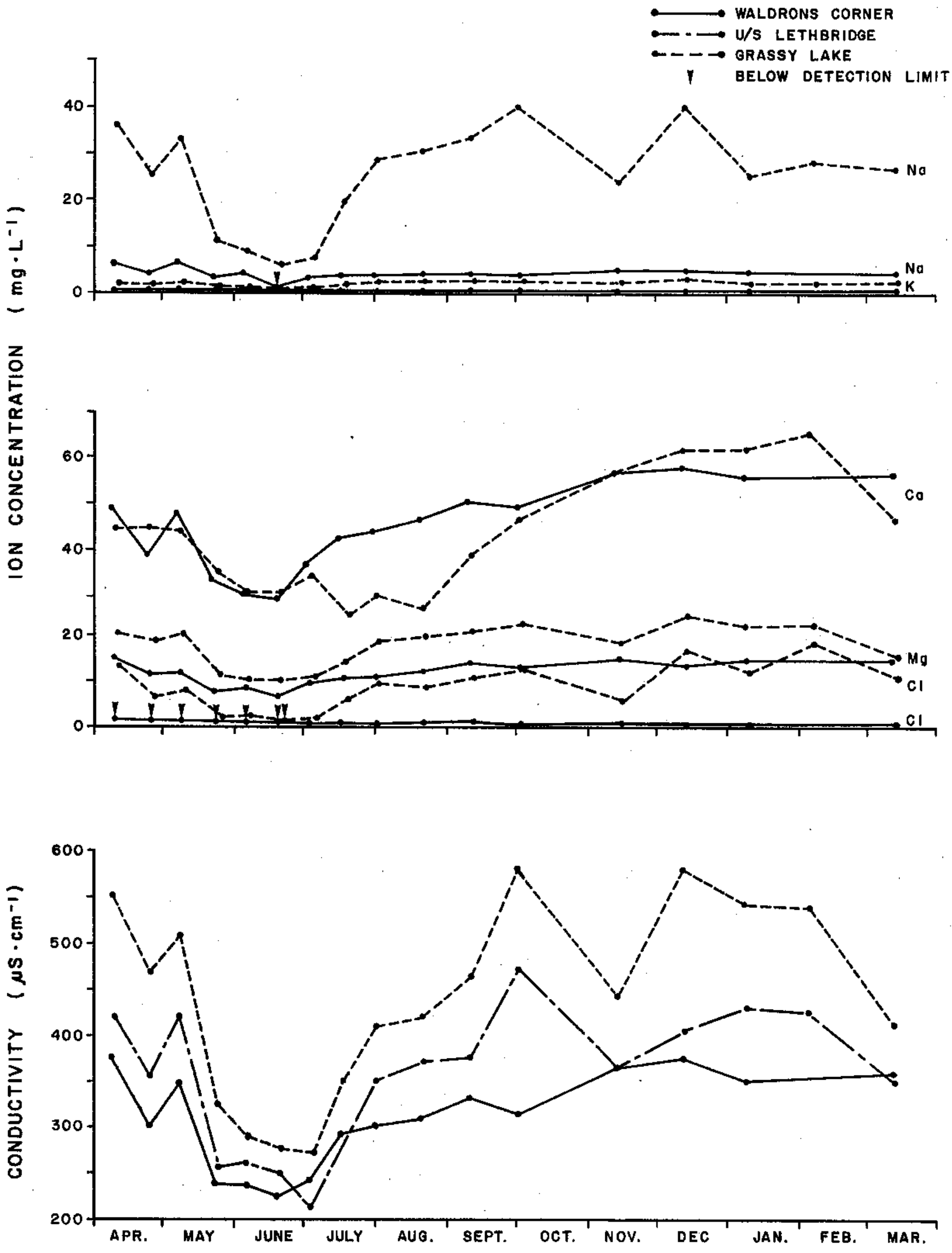

Figure 10a. CONCENTRATIONS OF MAJOR IONS, TDS AND CONDUCTIVITY AT REPRESENTATIVE SITES ON THE OLDMAN RIVER.

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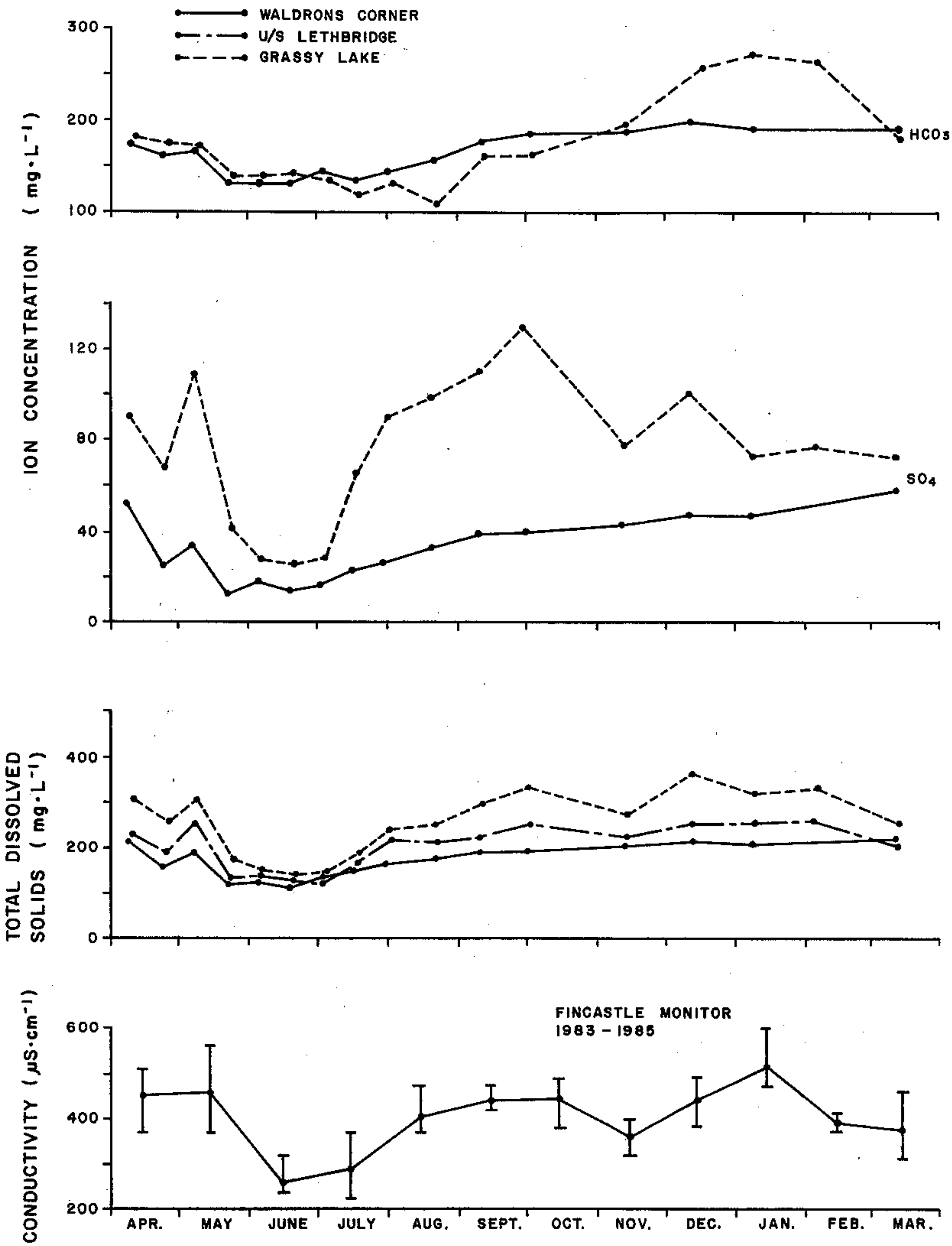

Figure 10b. CONCENTRATIONS OF MAJOR IONS, TDS AND CONDUCTIVITY AT REPRESENTATIVE SITES ON THE OLDMAN RIVER.

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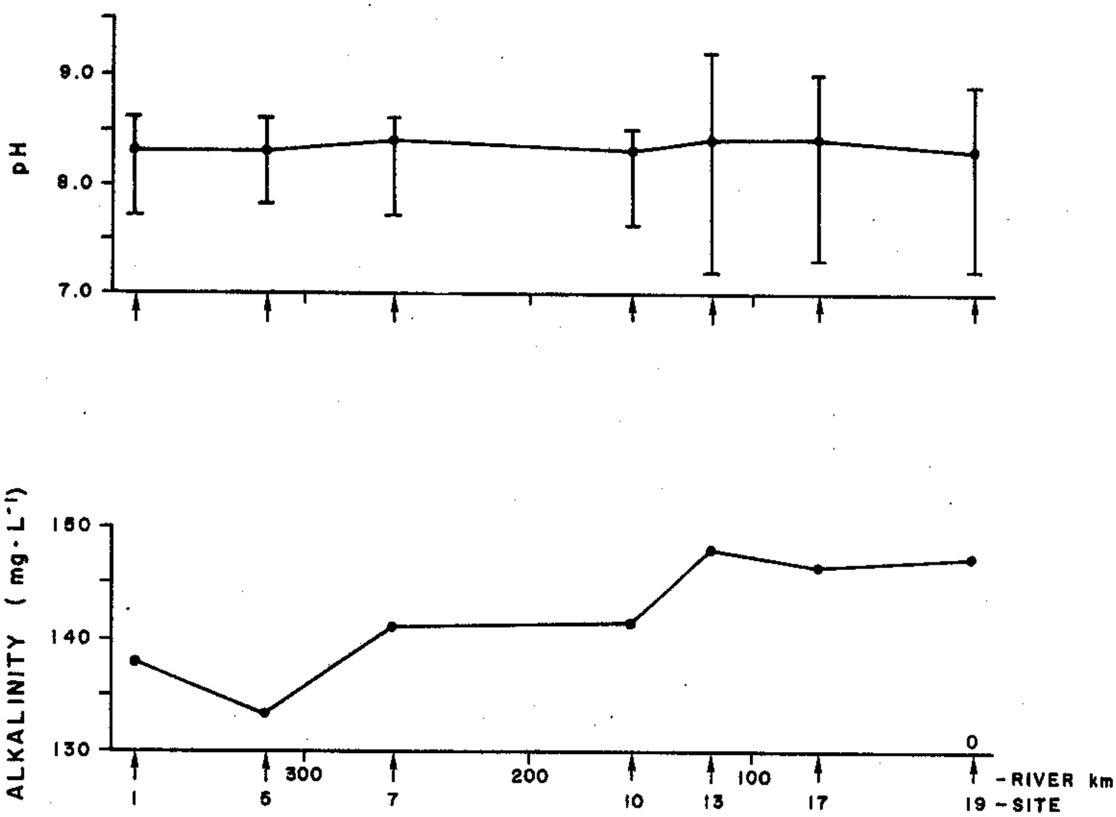

Figure 11. AVERAGE ANNUAL CONCENTRATIONS OF ALKALINITY AND MEDIAN pH AT SITES ALONG THE OLDMAN RIVER.

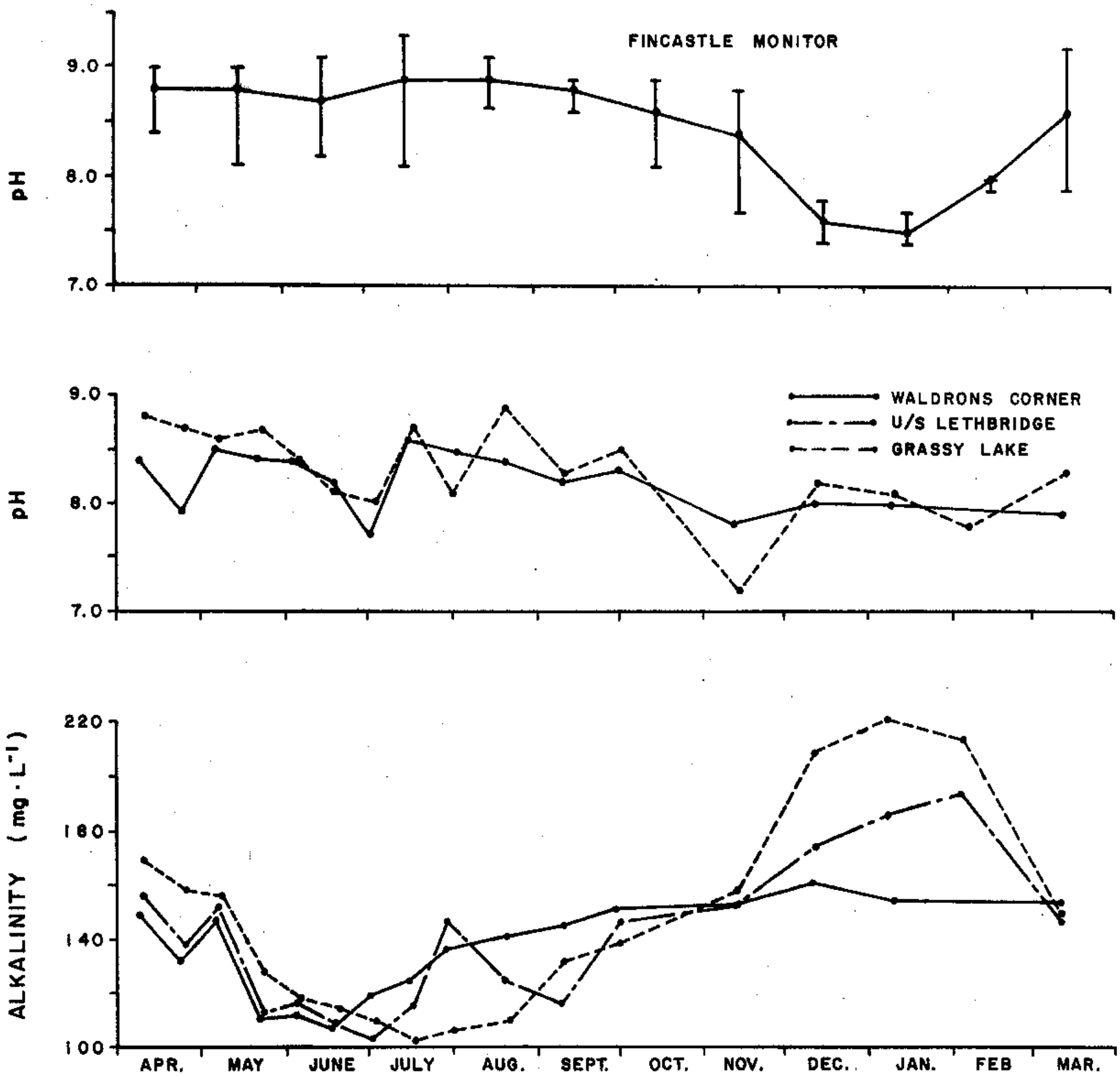

Figure 12. CONCENTRATIONS OF ALKALINITY AND pH AT REPRESENTATIVE SITES ON THE OLDMAN RIVER.

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Alkalinity was strongly correlated ($r > 0.8$) with calcium, bicarbonate and dissolved inorganic carbon. Average annual alkalinity ranged from 133 mg $CaCO_3.L^{-1}$ at Brocket (Site 5) to 146 mg $CaCO_3.L^{-1}$ at Taber (Site 17). On a seasonal basis, spring concentrations as low as 100 mg $CaCO_3.L^{-1}$ were measured, and winter values reached 222 mg $CaCO_3.L^{-1}$.

Values for pH ranged from 7.6 to 8.6 at Sites 1,5,7 and 10 above Lethbridge but the range was increased to 7.2 to 9.2 at Sites 13, 17 and 19 below Lethbridge (Figure 11). The median values were very similar at all the sites (8.3 - 8.4). Seasonal changes show generally lower pH values through the winter (Figure 12). Data from the continuous monitor at Fincastle illustrate this most clearly. The average pH in January was 7.5 and in August was 8.9.

3.2.3 Carbon

Concentrations of dissolved carbon forms increased slightly along the length of the Oldman River (Figure 13). Average annual concentrations for dissolved organic carbon increased from 1.4 to 3.0 $mg.L^{-1}$ while those for dissolved inorganic carbon increased from 29.6 to 33.7 $mg.L^{-1}$. Seasonally, dissolved organic carbon showed no trends (Figure 13). In contrast, concentrations of dissolved inorganic carbon were lower in June/July and higher in winter. Dissolved inorganic carbon correlated with alkalinity ($r = 0.81$).

3.2.4 Phenolics

Phenolics values were consistent along the length of the river with average concentrations between 0.003 and 0.006 $mg.L^{-1}$ (Figure 14). The values at the high end of the ranges were measured generally in early October 1984 and January 1985.

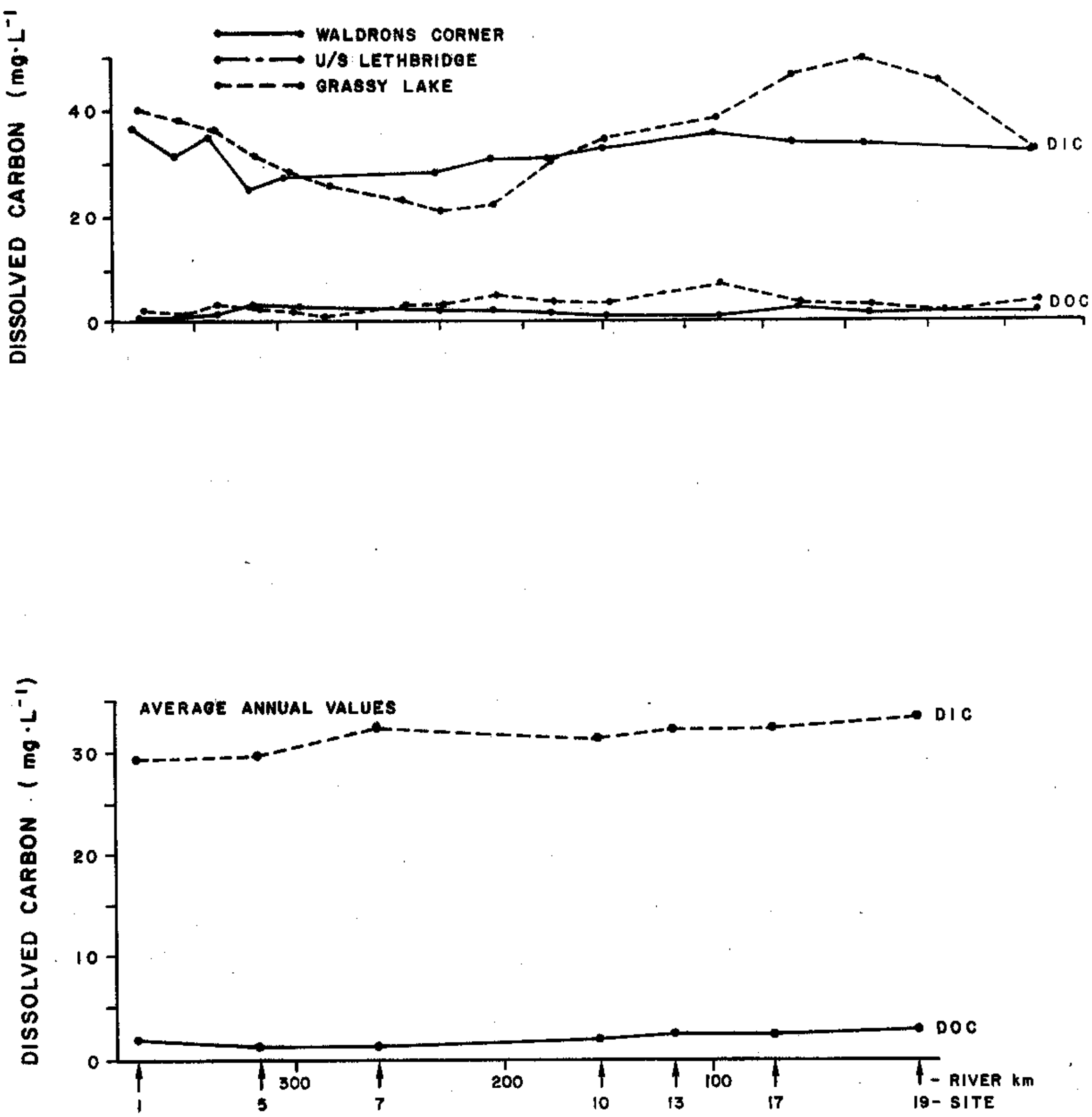

Figure 13. CONCENTRATIONS OF CARBON FORMS IN THE OLDMAN RIVER.

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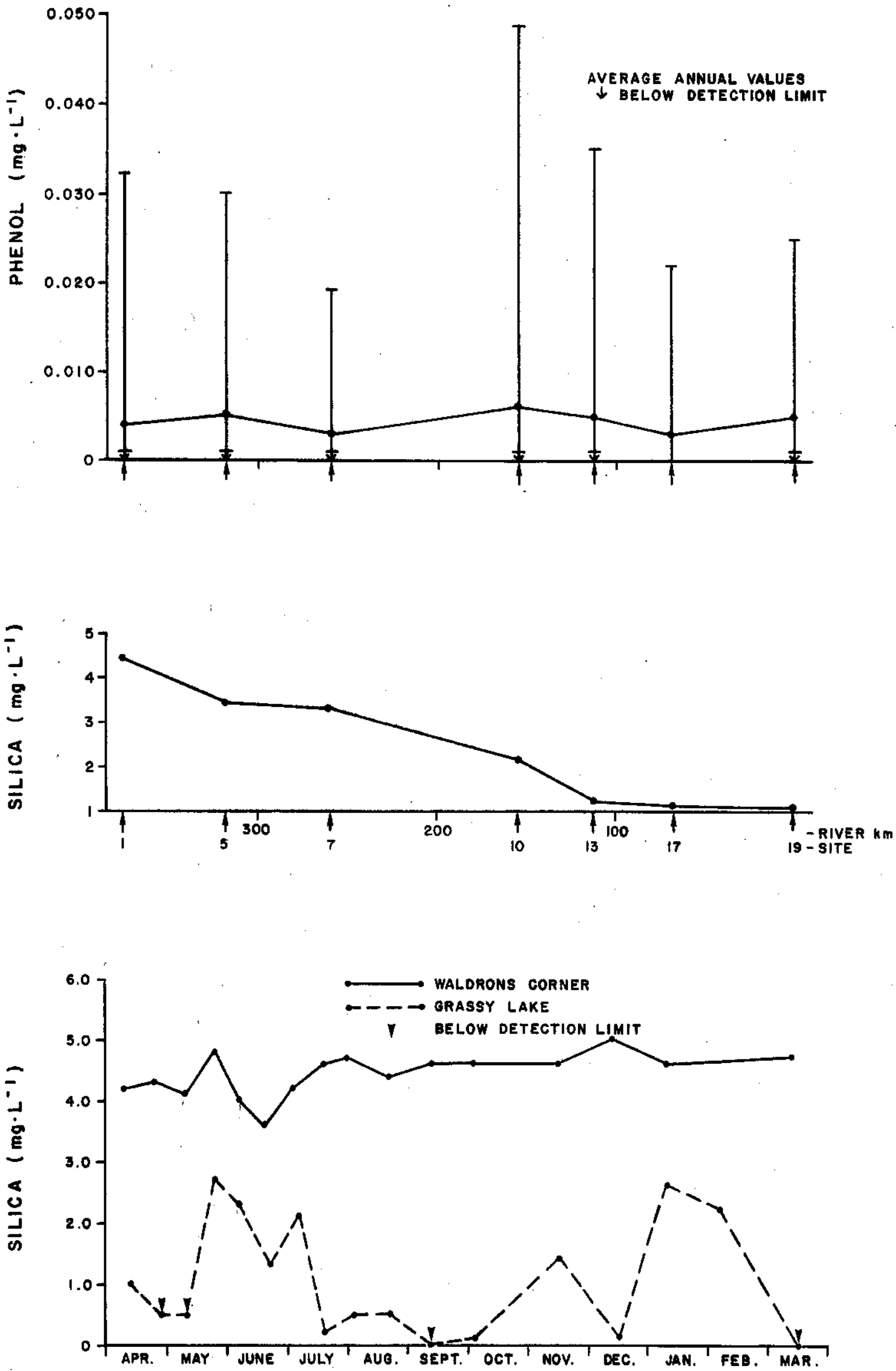

Figure 14. CONCENTRATIONS OF PHENOLICS AND SILICA IN THE OLDMAN RIVER.

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3.2.5 Silica

Silica decreased from an average annual concentration of 4.4 mg.L^{-1} at Waldron's Corner (Site 1) to 1.1 mg.L^{-1} at Taber and Grassy Lake (Sites 17 and 19; Figure 14). Seasonally there was little change at Waldron's Corner, while higher values at Grassy Lake were measured around June 1984 and in January and February 1985.

3.2.6 Nitrogen

The concentrations of nitrogen forms followed similar trends along the length of the river (Figure 15) though the correlation coefficients were not high ($r < 0.8$). Concentrations generally increased from Brocket (Site 5) to Lethbridge, with a large increase from above to below Lethbridge (Sites 10 and 13). The latter increase for nitrate/nitrite was from 0.070 to 0.152 mg.L^{-1} and that for ammonia was from 0.021 to 0.081 mg.L^{-1}. The trend was weaker for total Kjeldahl nitrogen, which increased from 0.382 mg.L^{-1} above to 0.532 mg.L^{-1} below Lethbridge. Annual average concentrations of nitrate/nitrite decreased from below Lethbridge (Site 13) to Grassy Lake (Site 19; 0.123 mg.L^{-1}). Concentrations of ammonia and total Kjeldahl nitrogen decreased to Taber (Site 17; 0.066 and 0.475 mg.L^{-1}, respectively) and increased to Grassy Lake (Site 19; 0.088 and 0.535 mg.L^{-1}, respectively). In the upstream reach between Waldron's Corner (Site 1) and Brocket (Site 5), a decrease in ammonia and total Kjeldahl nitrogen was mirrored by an increase in nitrate/nitrite.

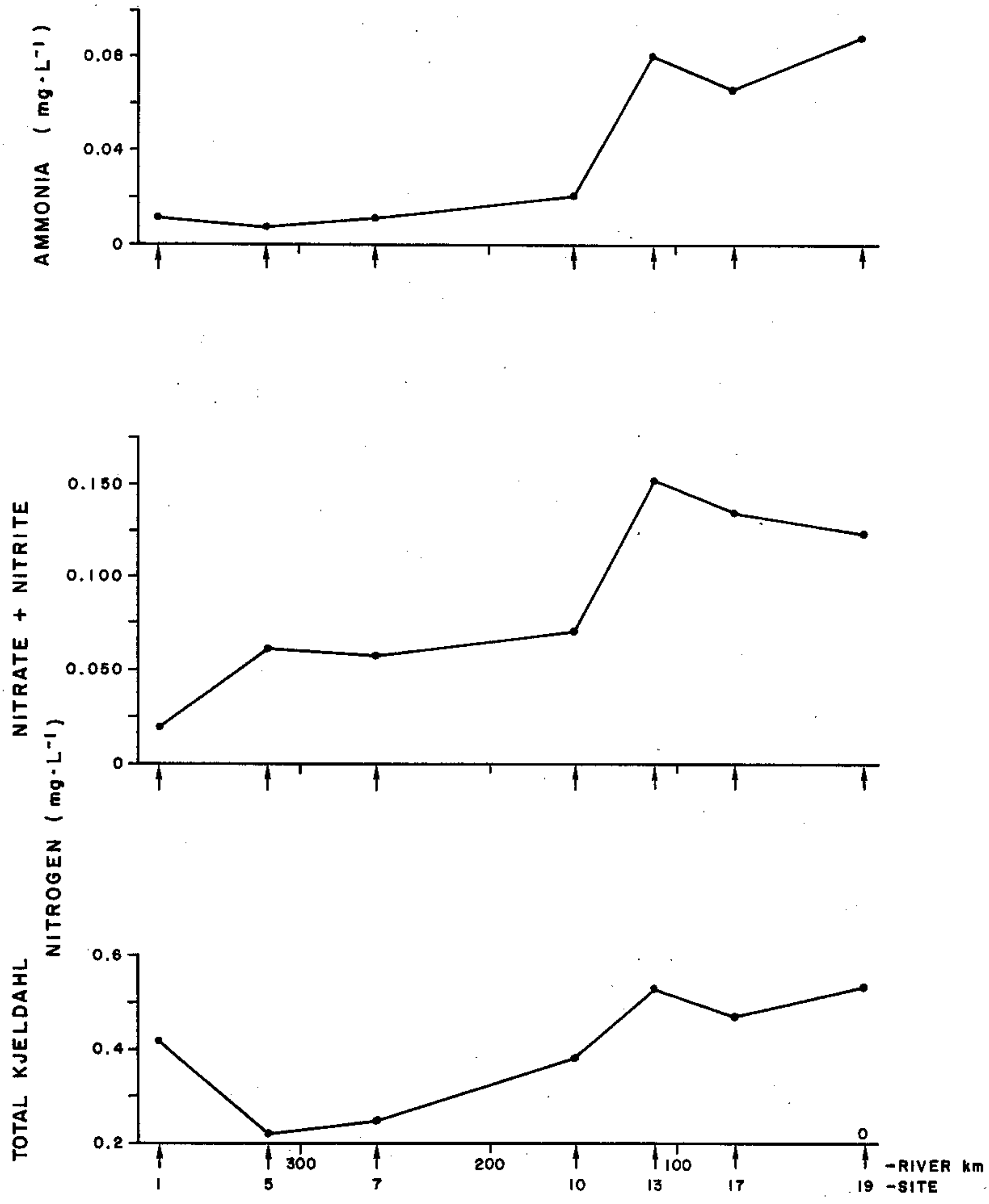

Figure 15. AVERAGE ANNUAL CONCENTRATIONS OF NITROGEN FORMS AT SITES ALONG THE OLDMAN RIVER.

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Seasonally, nitrogen concentrations were higher from November 1984 to February 1985 than in the remainder of the study year (Figure 16). This was particularly evident at Sites 13, 17 and 19 downstream of Lethbridge where the winter increase in ammonia and nitrate/nitrite was often dramatic. In contrast, the winter concentration increase for total Kjeldahl nitrogen at Grassy Lake (Site 19) was more gradual than that shown at Waldron's Corner (Site 1; Figure 16).

3.2.7 Phosphorus

Concentrations of total phosphorus and dissolved phosphorus were strongly correlated ($r = 0.90$) and show identical trends (Figures 17 and 18). Average annual concentrations at Site 1, 5, 7 and 10 above Lethbridge were low (0.010 to 0.035 $mg.L^{-1}$ for total phosphorus and 0.006 to 0.014 $mg.L^{-1}$ for dissolved phosphorus). Concentrations increased markedly below Lethbridge (Site 13; 0.275 $mg.L^{-1}$ and 0.239 $mg.L^{-1}$, respectively) and decreased to Grassy Lake (Site 19; 0.132 $mg.L^{-1}$ for total phosphorus and 0.103 $mg.L^{-1}$ for dissolved phosphorus). The changes in phosphorus concentration over the year were very low in the upstream reach of the river (Figure 18). At the sites further downstream, there was a distinct seasonal trend of higher concentrations from November to March.

Dissolved phosphorus loading values (Figure 19) in the Oldman River were higher at the sites downstream of Lethbridge (49.7 to 80.4 $tonnes.y^{-1}$), than at those upstream (1.6 to 9.0 $tonnes.y^{-1}$). The trends in dissolved phosphorus loading values upstream of Lethbridge reflect the significant inputs from tributaries between Waldron's

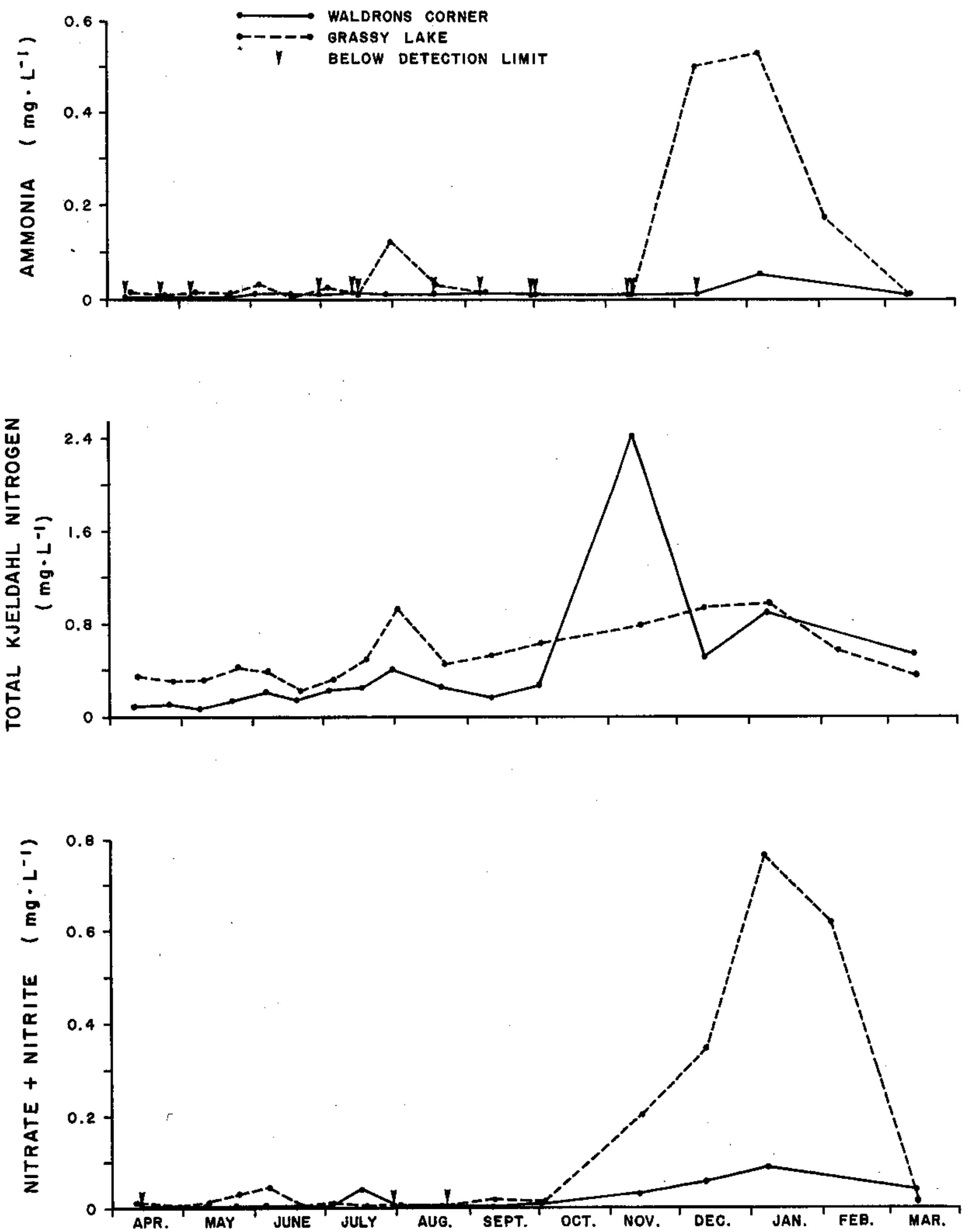

Figure 16. CONCENTRATIONS OF NITROGEN FORMS AT REPRESENTATIVE SITES ON THE OLDMAN RIVER.

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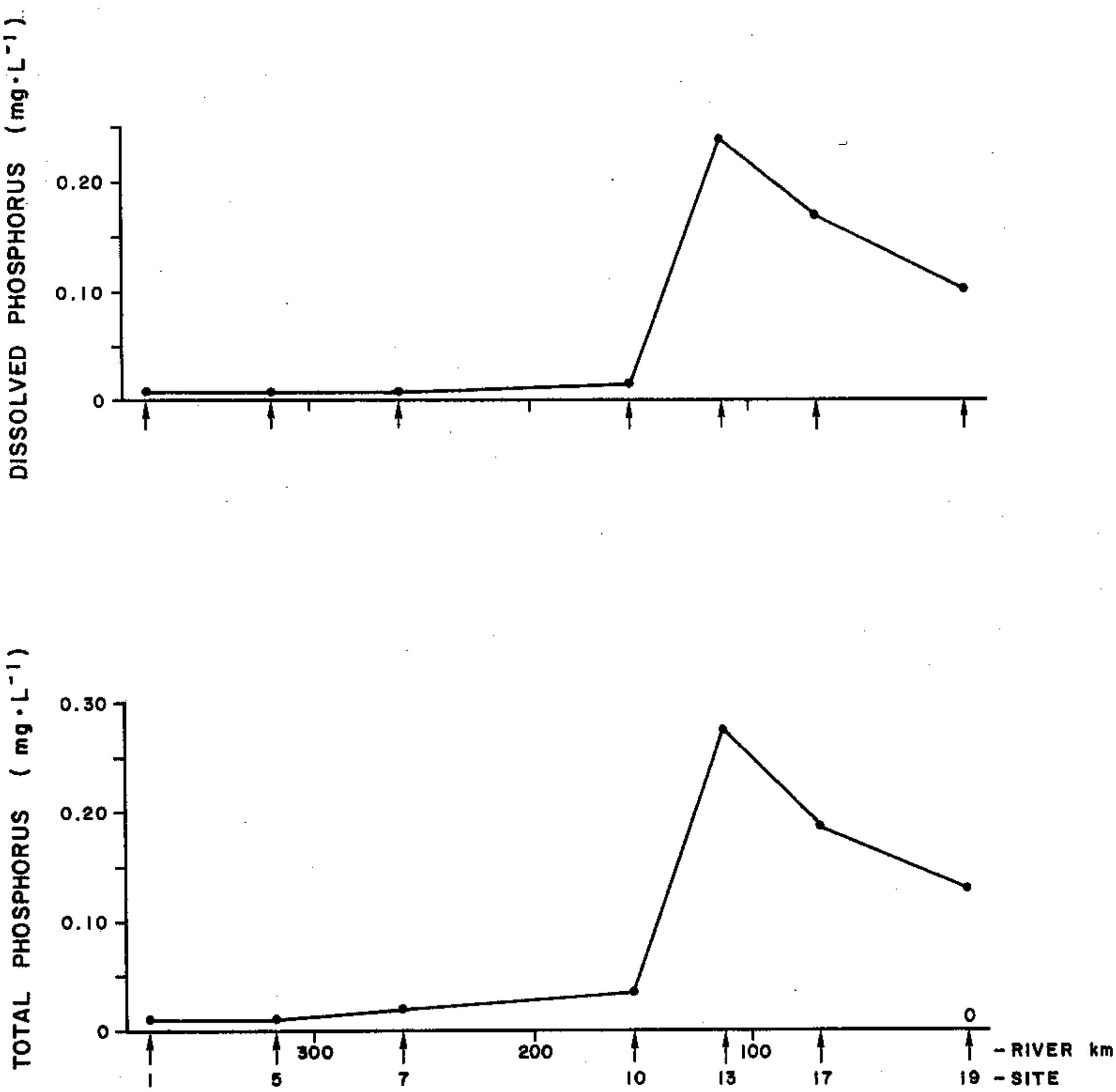

Figure 17. AVERAGE ANNUAL CONCENTRATIONS OF TOTAL AND DISSOLVED PHOSPHORUS AT SITES ALONG THE OLDMAN RIVER.

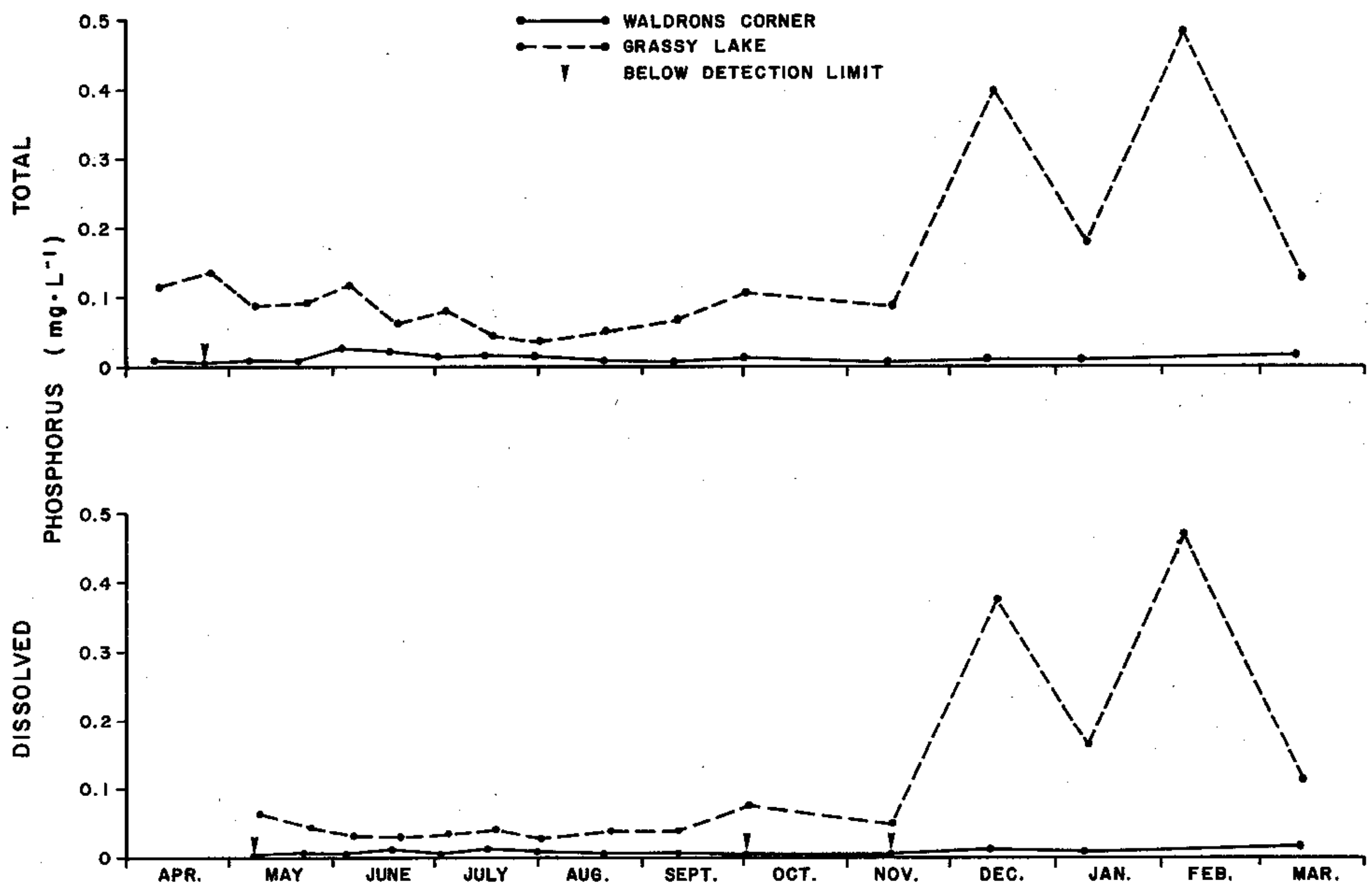

Figure 18. CONCENTRATIONS OF TOTAL AND DISSOLVED PHOSPHORUS AT REPRESENTATIVE SITES ON THE OLDMAN RIVER.

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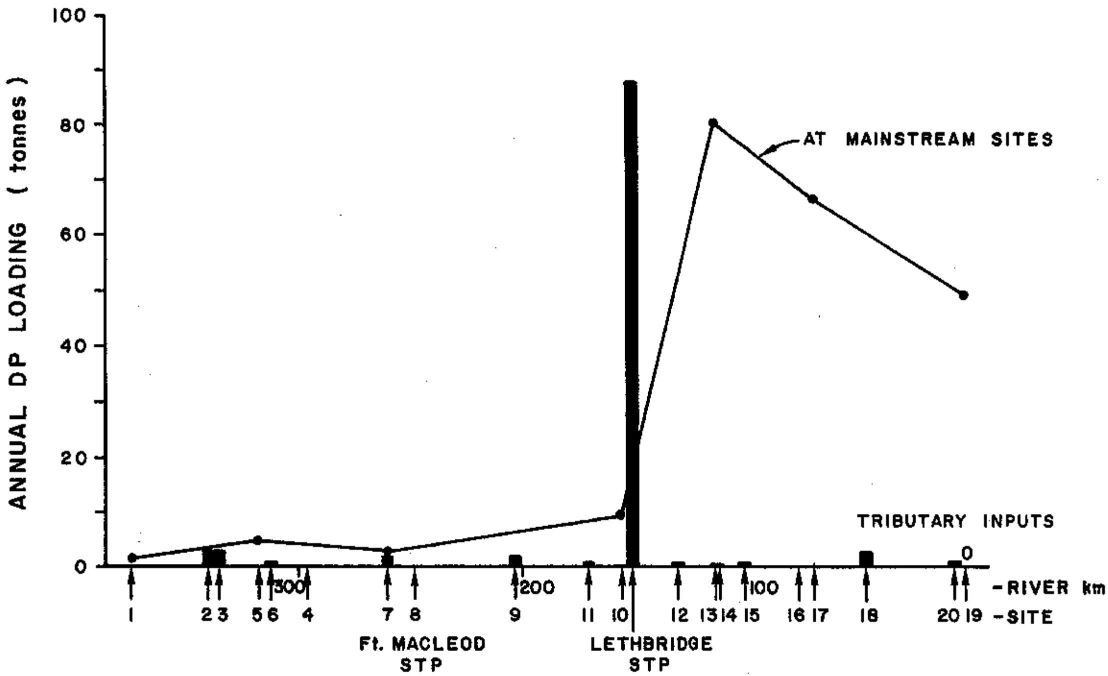

Figure 19. ANNUAL DISSOLVED PHOSPHORUS LOADING INPUTS AND CHANGES AT SITES ALONG THE OLDMAN RIVER.

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Corner (Site 1) and Brocket (Site 5) and between Fort Macleod (Site 7) and above Lethbridge (Site 10). Although the irrigation return flows contributed phosphorus to the river from Site 13 below Lethbridge to Site 19 at Grassy Lake, there was still a decrease in dissolved phosphorus loading along the length of the river.

The largest single loading to the Oldman River was from the Lethbridge sewage treatment plant (87.7 tonnes.y^{-1}). This represented 83% of the total input of dissolved phosphorus in the Basin. The major tributaries contributed 8% (8.5 tonnes.y^{-1}) and the irrigation return flows contributed 5% (5.0 tonnes.y^{-1}). The total contribution from Fort Macleod, minor tributaries and the Oldman River above the study area was 4% (2.1, 1.1 and 1.6 tonnes.y^{-1}, respectively).

The reach loading changes in dissolved phosphorus indicate the relative uptake or release along the river reach on an annual basis. These changes are derived by comparing the calculated phosphorus loading into a river reach with the measured loading at the downstream point in that reach. The reaches above Lethbridge show relatively low loading changes (-0.05 to +0.01 tonnes.km^{-1}). The reaches downstream of Lethbridge show higher loading changes (-0.28 to -0.39 tonnes.km^{-1}) indicating a stronger uptake of dissolved phosphorus.

3.2.8 Metals

Median, rather than average values, were used to express the central tendency (Table 3). This eliminates the bias of averaging in one or two very high values found in the typically skewed distribution of metals concentrations in rivers. Median values for six metals

TABLE 3 Summary of concentrations of metals in water at four sites on the Oldman River.

	FORT MACLEOD		ABOVE LETHBRIDGE		BELOW LETHBRIDGE		AT GRASSY LAKE	
	Median	Range	Median	Range	Median	Range	Median	Range
Fe	0.04	L0.01- 0.19	0.10	0.02- 0.46	0.120	0.01- 0.67	0.100	0.01- 0.69
Hg	L0.0001	L0.0001-0.0004	L0.0001	L0.0001-0.0003	L0.0001	L0.0001-0.0005	L0.0001	L0.0001-0.0005
Co	L0.001	L0.001- 0.005	L0.001	L0.001- 0.004	L0.001	L0.001- 0.004	L0.001	L0.001-L0.001
Cu	L0.001	L0.001- 0.002	0.0015	L0.001- 0.003	0.0015	L0.001- 0.004	L0.001	L0.001- 0.004
Ni	0.001	L0.001- 0.005	0.0015	L0.001- 0.007	0.001	L0.001- 0.010	0.002	L0.001- 0.007
Cd	L0.001	L0.001- 0.004	L0.001	L0.001- 0.003	L0.001	L0.001- 0.002	L0.001	L0.001- 0.002
Pb	0.002	0.001- 0.004	0.002	L0.002- 0.014	0.002	0.001- 0.006	0.002	0.001- 0.005
Zn	0.001	L0.001- 0.008	0.004	L0.001- 0.009	0.003	L0.001- 0.013	0.003	L0.001- 0.010
Al	0.105	0.040- 0.127	0.199	0.110- 0.372	0.123	0.040- 0.293	0.085	0.065- 0.378
Be	L0.001	L0.001-L0.001	L0.001	L0.001-L0.001	L0.001	L0.001-L0.001	L0.001	L0.001-L0.001
Mn	L0.01	L0.008- 0.019	0.016	L0.008- 0.040	0.020	L0.008- 0.170	0.020	0.022- 0.070
Cr	0.001	L0.001- 0.009	0.0015	L0.001- 0.008	0.0015	L0.001- 0.008	0.001	L0.001- 0.012
As	0.0004	0.0002-0.0037	0.0008	0.0003-0.0018	0.0009	0.0003-0.0020	0.0009	0.0006-0.0020
Se	L0.000	L0.000-L0.000	L0.000	L0.000-L0.000	L0.000	L0.000- 0.000	L0.000	L0.000- 0.000
Va	L0.002	L0.001- 0.009	0.002	L0.001- 0.010	0.001	L0.001- 0.007	0.002	L0.001- 0.009
Mo	L0.001	L0.001- 0.008	0.0025	L0.001- 0.007	0.0025	L0.001- 0.006	0.003	L0.001- 0.007

remained constant along the river (L0.0001 $mg.L^{-1}$ for mercury, L0.001 $mg.L^{-1}$ for cobalt, L0.001 $mg.L^{-1}$ for cadmium, 0.002 $mg.L^{-1}$ for lead, L0.001 $mg.L^{-1}$ for beryllium and L0.000 $mg.L^{-1}$ for selenium). Copper and chromium were slightly higher around Lethbridge than at Fort Macleod or at Grassy Lake (0.0015 vs L0.001 $mg.L^{-1}$ for copper and 0.0015 vs 0.001 $mg.L^{-1}$ for chromium). The remaining metals, except aluminum, were all lowest at Fort Macleod with higher values at one of the downstream sites. Aluminum concentrations were lowest at Grassy Lake and highest above Lethbridge. Iron and aluminum concentrations were the highest of the metals in the Oldman River with median values ranging from 0.04 to 0.12 $mg.L^{-1}$ and 0.085 $mg.L^{-1}$ to 0.199 $mg.L^{-1}$, respectively.

3.2.9 Organics and Priority Pollutants

Results from the scans for pesticides (organochlorine, organophosphorus and organonitrogen), chlorinated herbicide acids and polychlorinated biphenyls were all less than the limits given in Appendix I, at all three sites in both June and October. The priority pollutant extractables (Appendix I) were all less than the detection limit of 1.0 $\mu g.L^{-1}$ except bis(2-ethylhexyl)phthalate. Concentrations ranged from 1.0 to 3.2 $\mu g.L^{-1}$ (Table 4). Several other compounds were measured at concentrations below the detection limit. The compounds and the concentration ranges are given in Table 4.

3.3 BIOLOGICAL CONDITIONS

3.3.1 Coliform Bacteria

Average annual concentrations of coliform bacteria were higher at Sites 13, 17 and 19 below Lethbridge than at Sites 1, 5, 7 and 10 above Lethbridge (Figure 20). This was particularly true for

TABLE 4 Organics results in $\mu g.L^{-1}$ for water collected from the Oldman River in June and October 1984.

PARAMETER	ABOVE LETHBRIDGE JUNE	ABOVE LETHBRIDGE OCTOBER	BELOW LETHBRIDGE JUNE	BELOW LETHBRIDGE OCTOBER	GRASSY LAKE JUNE	GRASSY LAKE OCTOBER
Organochlorine Pesticides	*	*	*	*	*	*
Organophosphorus Pesticides	*	*	*	*	*	*
Organonitrogen Pesticides	*	*	*	*	*	*
Chlorinated Herbicide Acids	*	*	*	*	*	*
Polychlorinated Biphenyls	*	*	*	*	*	*
<u>Priority Pollutant Extractables</u>	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Except:						
bis(2-ethylhexyl)phthalate	–	1.2	3.2	1.0	1.5	1.0
hexadecanoic acid	–	0.01-0.1	–	0.01-0.1	0.01-0.1	0.01-0.1
phthalate ester, mol.wt>390	–	0.01-0.1	–	0.01-0.1	–	0.1-0.5
di-*n*-butyl phthalate	–	0.1-0.5	–	0.1-0.5	–	0.1-0.5
benzoyl substituted organic, mol.wt.>177	–	–	–	0.01-0.1	–	–
unsaturated hydrocarbon, mol.wt.>154	–	–	–	–	0.1-0.5	–
di-tertiarybutylmethylphenol	–	–	–	–	0.1-0.5	–

* less than concentrations listed in Appendix 1

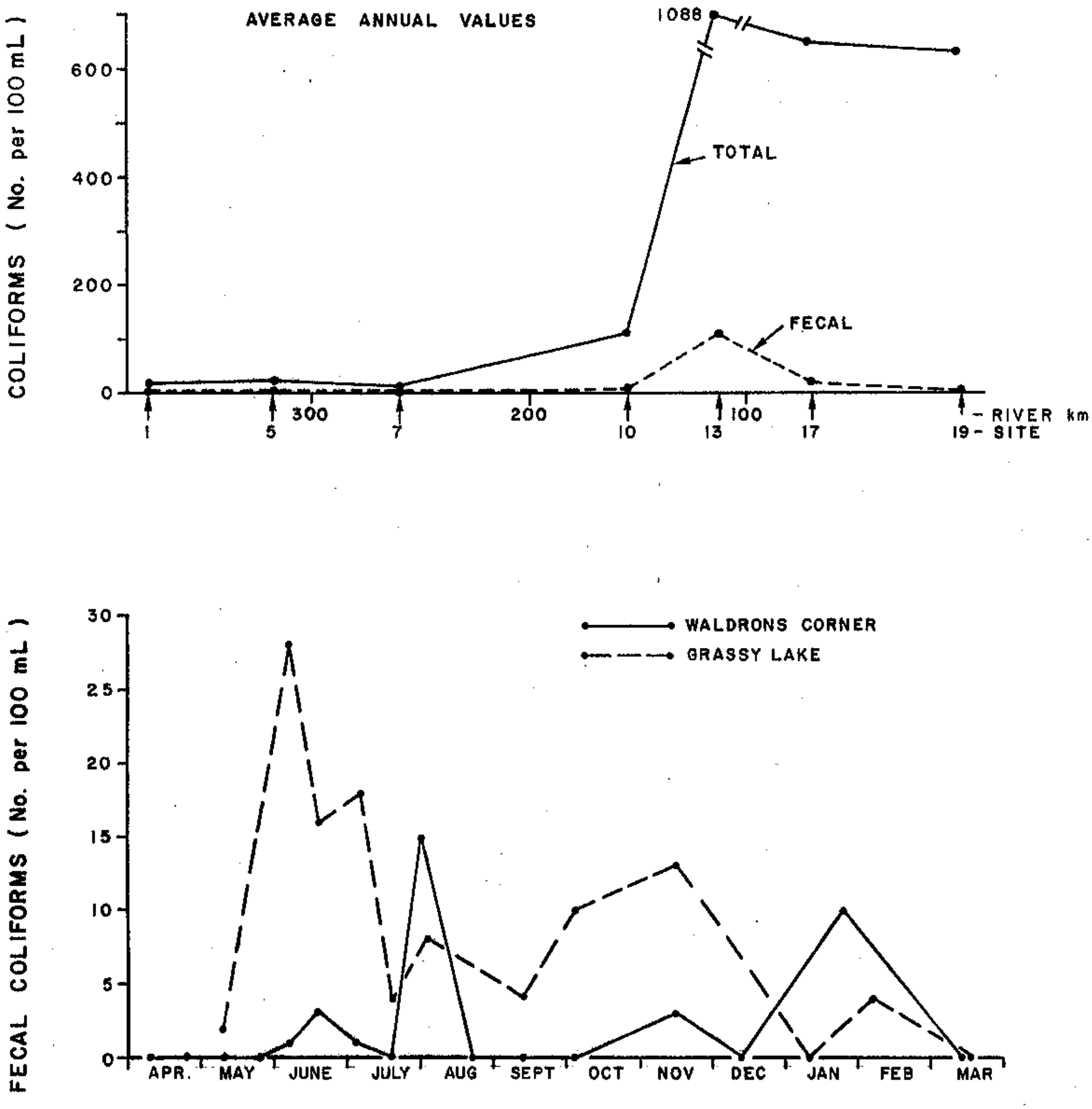

Figure 20. CONCENTRATIONS OF FECAL COLIFORM BACTERIA IN THE OLDMAN RIVER.

total coliform bacteria. Upstream of Lethbridge the range of annual average values for all the sites was 12 per 100 mL to 110 per 100 mL. Downstream of Lethbridge the comparable range was from 635 per 100 mL to 1088 per 100 mL. For fecal coliform bacteria, the site below Lethbridge had an annual average concentration of 107 per 100 mL, much higher than the values at all the other sites (2 to 26 per 100 mL). There were no strong seasonal trends in concentration change (Figure 19).

3.3.2 Algae

On an annual basis, standing crops of epilithon increased along the Oldman River from Waldron's Corner (Site 1; 22.9 mg chlorophyll $\underline{a}.m^{-2}$) to below Lethbridge (Site 13; 185.5 mg chlorophyll $\underline{a}.m^{-2}$). Concentrations decreased to Grassy Lake (Site 19; 103.8 mg chlorophyll $\underline{a}.m^{-2}$) where values were comparable to those at the site above Lethbridge (Figure 21).

Annual average phytoplankton standing crop values were relatively constant at Sites 1, 5, 7 and 10 above Lethbridge (0.6 to 1.2 mg chlorophyll $\underline{a}.m^{-3}$), increased at Lethbridge and stayed constant at Sites 13, 17 and 19 below Lethbridge (3.6 to 4.0 mg chlorophyll $\underline{a}.m^{-3}$).

Seasonally, phytoplankton standing crops were higher in spring and fall. This trend was shown more strongly in the lower reaches of the Oldman River (e.g. Grassy Lake) than in the upper reaches (e.g. Waldron's Corner; Figure 22). The standing crops of epilithon were also higher in spring and fall. The peak values measured in early October were much higher than those measured in April. Lowest values were measured in June at Waldron's Corner

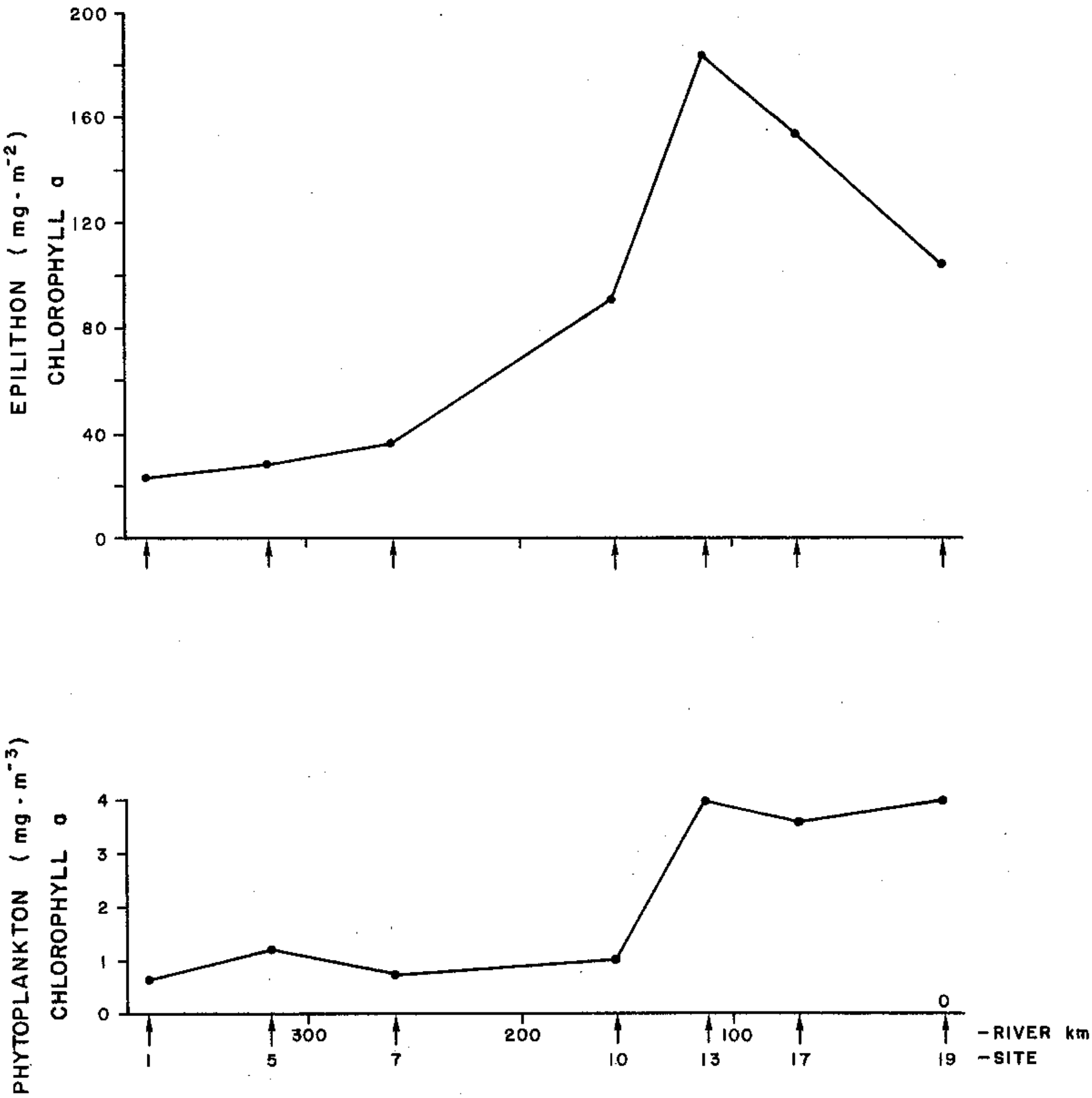

Figure 21. AVERAGE ANNUAL CONCENTRATIONS OF CHLOROPHYLL a AT SITES ALONG THE OLDMAN RIVER.

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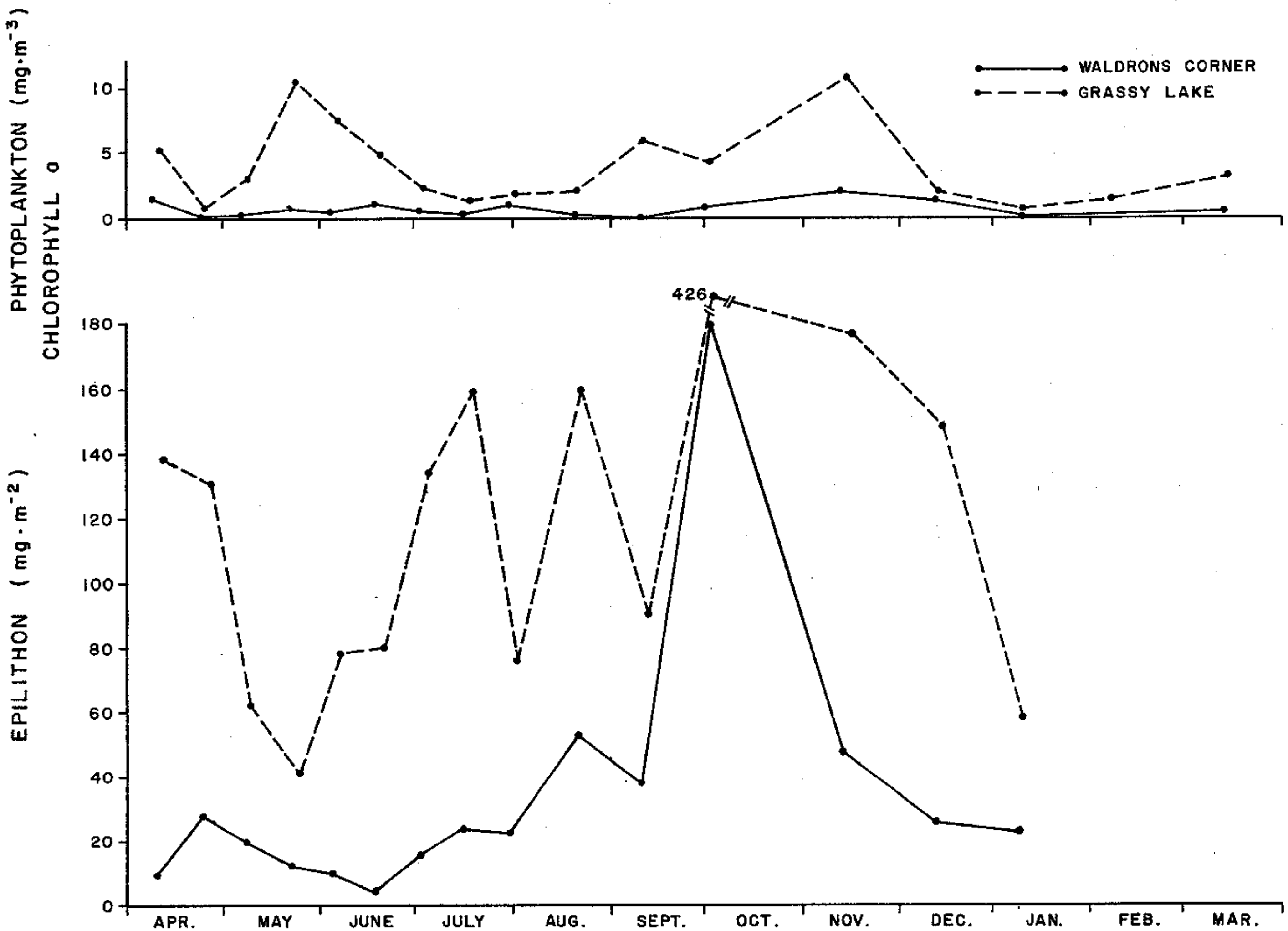

Figure 22. CONCENTRATIONS OF CHLOROPHYLL *a* AT REPRESENTATIVE SITES ON THE OLDMAN RIVER .

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(Site 1) and in May at Grassy Lake (Site 19). The seasonal trend at Grassy Lake also showed peak values (similar to those in April) during July and August.

3.3.3 Benthic Invertebrates

A summary of benthic invertebrate data is presented in Figure 23. The mean total numbers of invertebrates were significantly different (ANOVA, $p < 0.0001$; SNK $p < 0.05$) among sites. In the spring, the sites at Monarch (Site A) and above Taber (Site 17) had lower invertebrate densities than the other sites. In the fall, Grassy Lake (Site 19) had the lowest and below Lethbridge (Site 13), the highest invertebrate densities.

The mean number of taxonomic groups also varied significantly among sites (ANOVA, $p < 0.0001$; SNK, $p < 0.05$). Fort Macleod (Site 7) generally had lower numbers of taxa than the other sites. These numbers were not significantly lower than above Taber (Site 17) or at Grassy Lake (Site 19) in the spring, or than at Brocket (Site 2), above Lethbridge (Site 10) and at Grassy Lake (Site 19) in the fall.

Ephemeroptera (mayflies), Trichoptera (caddisflies), Chironomidae (midges) and Oligochaeta (bristle worms) were the four taxonomic groups which dominated the invertebrate assemblies of the Oldman River in the spring and fall of 1984 (Figure 24); other taxa (e.g. Plecoptera, miscellaneous Diptera and Mollusca) were of relatively minor numerical importance.

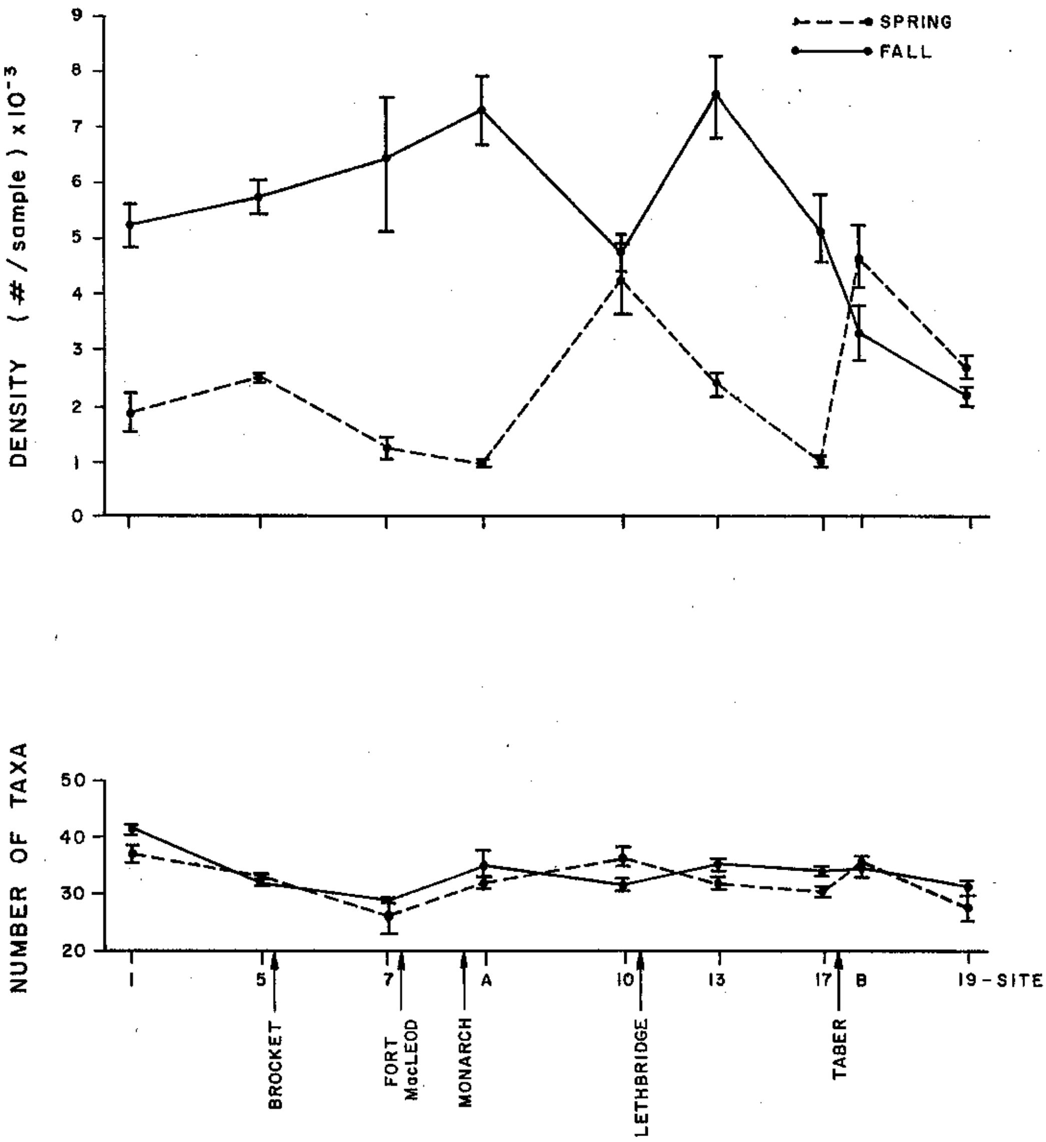

Figure 23. SUMMARY PARAMETERS FOR BENTHIC INVERTEBRATE DATA FROM THE OLDMAN RIVER.

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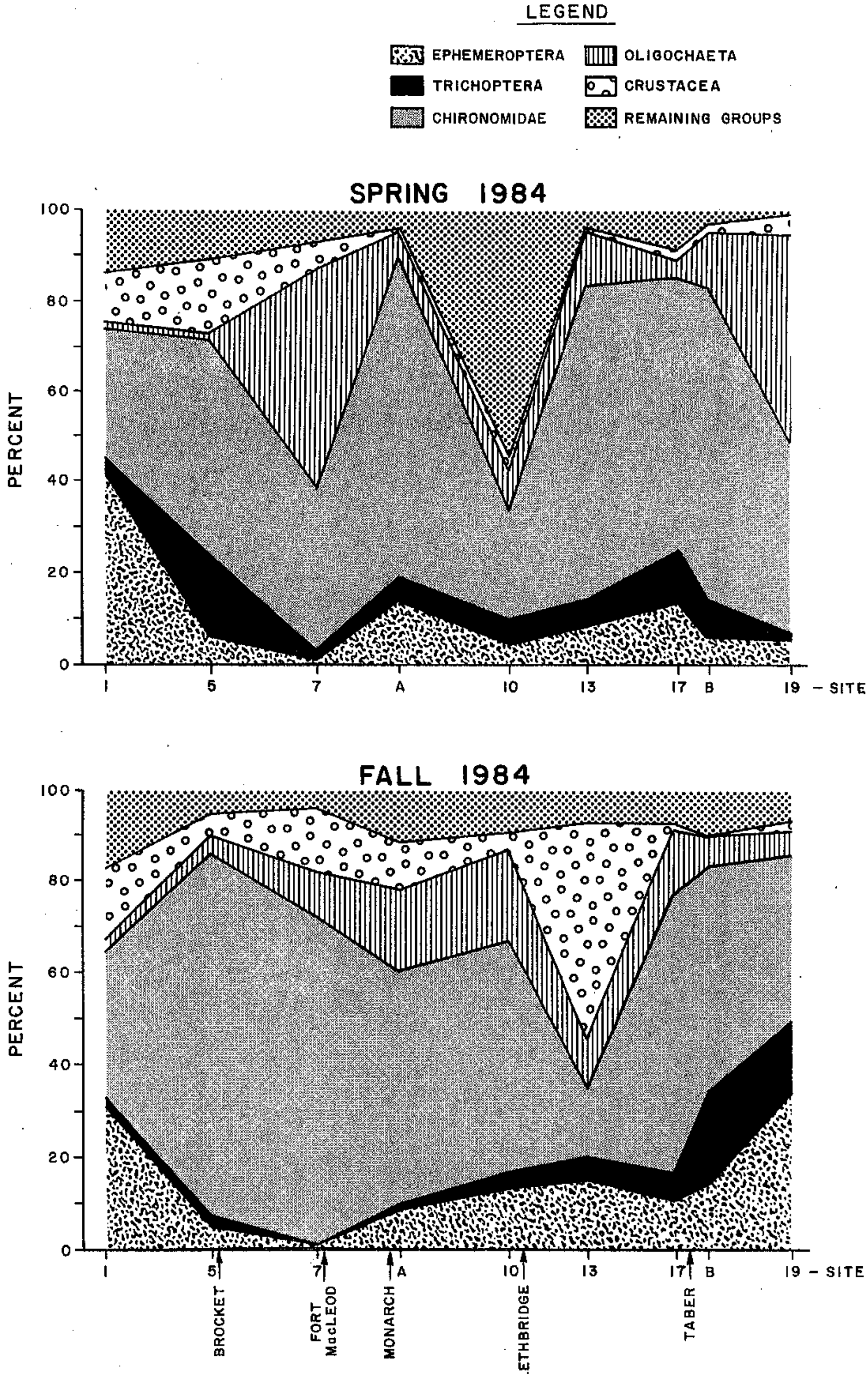

Figure 24. PERCENTAGE CONTRIBUTION OF MAJOR TAXA TO TOTAL NUMBER OF BENTHIC INVERTEBRATES IN THE OLDMAN RIVER .

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3.3.3.1 Ephemeroptera

In the spring, mayflies represented 45% of total invertebrate numbers at Waldron's Corner (Site 1) compared with only 1 to 14% at the remaining sites. Changes in the composition of the mayfly assemblage which occurred along the Oldman River were typical. The two upstream sites (Waldron's Corner and Brocket) had a diverse and abundant mayfly population, primarily dominated by *Baetis*/Baetidae. Also occurring were several *Ephemerella* species belonging to the subgenera *Ephemerella*, *Drunella*, and *Caudatella*. Two species, *E*.(*C*) *hystrix* and *E*.(*C*) *heterocaudata* were recorded in the latter subgenus. *Cinygmula*, *Epeorus*, and *Rhithrogena* were the most typical Heptageniidae at upstream sites, but the distribution of the latter genus stretched as far downstream as Lethbridge (Site 10). *Paraleptophlebia* was also typical of the two furthest upstream sites. Fort Macleod (Site 7), the next site downstream, had unexpectedly low mayfly numbers; however, the insect nymphs were abundant again at Monarch. The mayfly assembly was notably different here from that at Waldron's Corner (Site 1) or at Brocket (Site 5). Although *Baetis*/Baetidae was still abundant, *E*. (*Ephemerella*) had now become dominant; *Epeorus* and *Paraleptophlebia* did not occur any more, but *Ephemera*, *Stenonema* and *Tricorythodes* were present instead. This taxon composition persisted further downstream: *Baetis*/Baetidae occurred only occasionally downstream of Lethbridge and *Ephemera*, *Stenonema*, *Tricorythodes* and *E*. *Ephemerella* were the dominant taxa.

The mayfly distribution pattern in the fall was rather similar to that for the spring. Large Baetis/Baetidae populations typified Waldron's Corner (Site 1) and Brocket (Site 5) but other taxa such as E. (Drunella), E. (Ephemerella), Epeorus, Rhithrogena, Paraleptophlebia, Caenis, and Ameletus were also well represented at these two sites. Mayflies represented 31 and 5% of the total numbers at Waldron's Corner and Brocket, respectively. As in the spring, the mayfly density was notably reduced at Fort Macleod (Site 7). The next site, Monarch, had a completely different mayfly association which was typified by three taxa which characterize the downstream reaches of the Oldman River. Ephemera, Stenonema, but Tricorythodes in particular, became increasingly abundant in a downstream direction. Mayflies represented approximately 10% of the invertebrate numbers at most of these sites although Grassy Lake had relatively more mayflies (Site 19; 34%).

3.3.3.2 Trichoptera

In the spring 1 to 18% of the benthic invertebrates in the Oldman River were trichopteran larvae. The upstream sites (Waldron's Corner and Brocket) were typified by Rhyacophila, Lepidostoma and Arctopsyche. As with mayflies, caddisfly numbers were very low at Fort Macleod (Site 7). The trichopteran fauna was dominated by Oecetis, Nectopsyche and in particular by Hydropsychidae, (i.e. Cheumatopsyche, Hydropsyche and immatures) between Monarch and Grassy Lake (Site 19). Helicopsyche occurred frequently in samples taken at or downstream of Monarch, but numbers were usually low. Brachycentrus and Hydroptila had a scattered distribution throughout the study area.

Caddisflies were relatively unimportant at the two upstream sites in the fall. Lepidostomatidae was the most abundant family at Waldron's Corner (Site 1). In addition to this family Hydropsychidae (Cheumatopsyche, Hydropsyche and immatures), Hydroptilidae and Oecetis occurred in relatively high numbers at Brocket (Site 5). Low trichopteran numbers typified Fort Macleod (Site 7). Monarch had fairly large numbers of Oecetis and Nectopsyche; these two taxa, together with Hydroptilidae and Hydropsychidae became increasingly important in a downstream direction. Below Taber, for example, a mean trichopteran density of 629 specimens per sample or 19% of the total invertebrate numbers was recorded.

3.3.3.3 Chironomidae

In the spring Chironomidae was generally the most abundant family in the Oldman River zoobenthos; it represented 24 to 70% of the total numbers. The virtual absence of Chironomini at Waldron's Corner and Brocket (only 8 specimens were recorded at the first site and none at the second site), clearly separated these two sites from sites further downstream which all had mean densities well above 100 specimens per sample. At sites further downstream, Chironomini were usually numerically dominant, but Orthocladiinae, Tanytarsini and Tanypodinae were well represented. Except for the absence of Chironomini at upstream sites and for the more frequent occurrence of Coryoneurini and Diamesinae at downstream sites (i.e. below Monarch), there was little evidence of a longitudinal pattern among the chironomid sub-families or tribes. However, it is quite possible that such a pattern was masked by the level of taxonomic identification used.

In the fall, Chironomidae usually represented more than 30% (up to 79% at Brocket) of the total invertebrate numbers. One exception was below Lethbridge (Site 13) where only 15% of the invertebrates were chironomid larvae. In contrast to the spring samples, Chironomini were found at Waldron's Corner (Site 1) and Brocket (Site 5) in the fall. Very high Chironomini numbers were found at Fort Macleod (Site 7) where the family dominated the benthic invertebrate assembly numerically. Tanytarsini which were abundant at the furthest upstream sites, tended to decrease in numbers in a downstream direction.

3.3.3.4 Oligochaeta

In the spring, Naididae, Lumbriculidae and Enchytraeidae were three Oligochaete families which occurred at Waldron's Corner (Site 1) and Brocket (Site 5). Their numbers were relatively low and they represented only approximately 1% of the total invertebrate numbers. Of the three families present at the upstream sites, Naididae was the only one that persisted downstream. These small worms became quite important at Fort Macleod (Site 7) and at Grassy Lake (Site 19) where they represented 46 and 47% of the total invertebrate numbers, respectively. Tubificidae was a fourth family which occurred regularly downstream of Lethbridge, but relatively high densities were reached only at Site 13, just below Lethbridge.

Enchytraeidae, Naididae and Tubificidae were the three Oligochaete families recorded in the fall samples. Naidids occurred throughout the study area, and they were numerically dominant. They were particularly abundant at Monarch, but their numbers tended to be generally high between Fort Macleod (Site 7) and Taber (Site 17).

Tubificidae followed a longitudinal pattern comparable to that followed in the spring. A few worms were found at the sites above Lethbridge, but it was at Site 13 that they became truly important. In contrast to the spring survey, tubificids had a less erratic distribution at downstream sites and were generally more abundant.

3.3.3.5 Remaining Groups

Among the remaining groups, Crustaceae (Ostracoda in particular) were quite abundant at certain sites. The mean densities at Waldron's Corner (Site 1) and Brocket (Site 5) were 148 (9% of total numbers) and 404 (17% of total numbers) specimens per sample, respectively. Crustaceans were also one of the most important remaining groups in the fall. Their numbers, were as high as 3583 specimens per sample or 46% of the total invertebrate density (i.e. Site 13 below Lethbridge). Ostracoda and Copepoda were common in the upstream reaches; cladocera appeared in large numbers at Fort Macleod (Site 7) and remained abundant as far downstream as Site 13 below Lethbridge. In the spring, Site 10 above Lethbridge was typified by the presence of large numbers of Acari (water mites; 2356 specimens per sample) which represented close to 50% of the total numbers.

Although their numbers were usually low, Plecoptera (stoneflies) followed a consistent pattern in the Oldman River. Numbers were highest at Waldron's Corner (Site 1) and Brocket (Site 5) and decreased rapidly downstream. Very few specimens were found below Fort Macleod (Site 7). Capniidae, Chloroperlidae, and *Claassenia sabulosa* were the most common taxa at upstream sites; Perlodidae was the only plecopteran recorded downstream of Lethbridge.

Mollusc numbers were usually low in the Oldman River, but the distribution of all families followed a similar pattern: molluscs increased in numbers in a downstream direction.

3.3.3.6 Multivariate Analyses - Spring

The results of multivariate analyses of spring data are presented in Figure 25. All replicate samples from one site formed individual clusters. This intra-site clustering (not presented in the dendrogram) indicates a high level of similarity between samples of one site. This suggests good replication at each site. The cluster dendrogram shows that Brocket (Site 5) and Waldron's Corner (Site 1) are more similar to each other than to the other sites. Among the remaining sites, Site 13 below Lethbridge and Site 17 near Taber have a different benthic invertebrate association.

The first principal component explains 20% of the sample variance and separates Waldron's Corner and Brocket (Table 5). These sites have high positive mean scores unlike the remaining sites which have low positive or, negative mean scores. The first two sites have relatively large numbers of *Paraleptophlebia*, *Lepidostoma*, Chloroperlidae, Baetidae, *Epeorus*, Simuliidae, *Arctopsyche*, *Antocha*, *Atherix*, *Wiedemannia*, *Claassenia sabulosa*, and Turbellaria, while the remaining sites are more typified by Chironomini, *Oecetis*, *Ephemera*, *Tricorythodes*, *Stenonema*, chironomid pupae, and Lepidoptera.

The second principal component accounts for 9% of the sample variance and separates Waldron's Corner (negative score) from Brocket (positive scores). *Claassenia sabulosa*, *Antocha*, *Cinygmula*, *E.* (*Drunella*), *Wiedemannia*, and Heptageniidae typify Waldron's Corner

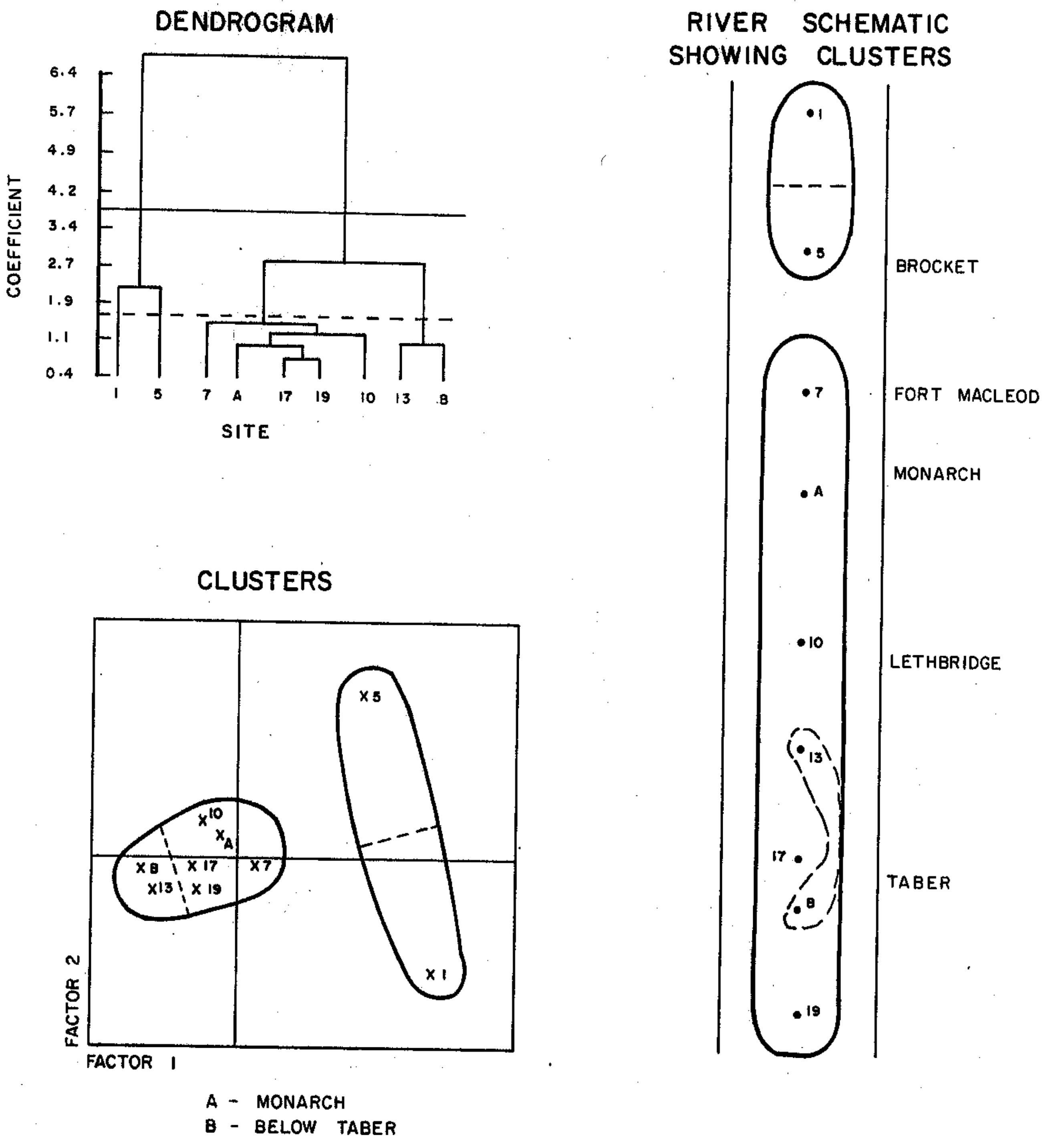

FIGURE 25. RESULTS OF PRINCIPAL COMPONENTS ANALYSIS OF BENTHIC INVERTEBRATE DATA FROM THE OLDMAN RIVER IN SPRING, 1984.

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TABLE 5 Results of principal components analysis of benthic invertebrate data from the Oldman River in Spring, 1984.

	VECTOR 1		VECTOR 2		VECTOR 3
Eigenvalue	19.95		8.59		7.03
Percentage Variance	28.50		12.28		10.04
Variance explained by individual taxa:					
Paraleptophlebia	0.195	Hemerodromia	0.277	Orthocladiinae	0.293
Lepidostoma	0.191	Cheumatopsyche	0.253	Hydropsyche	0.284
Chloroperlidae	0.190	Ceraclea	0.246	E. (Ephemerella)	0.278
Baetidae	0.181	Capniidae	0.235	Diamesinae	0.263
Epeorus	0.171	Elmidae	0.217	Perlodidae	0.215
Simulidae	0.171	Hydroptila	0.198	Heptageniidae	0.199
Arctopsyche	0.167	Chelifera	0.191	Lepidoptera	0.194
Antocha	0.165	Rhithrogena	0.161	Pisidium	0.186
Atherix	0.164			Cheumatopsyche	0.177
Wiedemannia	0.162	Heptageniidae	-0.154	Physidae	0.175
Classenia sabulosa	0.158	Wiedemannia	-0.171	Planorbidae	0.170
Turbellaria	0.150	Ephemerella (Drunella)	-0.174	Mermithoidea	0.163
		Cinygmula	-0.174	Turbificidae	0.162
Lepidoptera	-0.157	Antocha	-0.188	Nectopsyche	0.157
Chironomid pupae	-0.164	Classenia Subulosa	-0.192	Hydroptila	0.150
Stenonema	-0.171				
Tricorythodes	-0.175			Naididae	-0.167
Ephemera	-0.176			Leptoceridae	-0.178
Oecetis	-0.183				

Hemerodromia, Cheumatopsyche, Ceraclea, Capniidae, Elmidae, Hydroptila, Chelifera and Rhithrogena typify Brocket.

The third principal component explains 7% of the remaining variance and separates Site 13 below Lethbridge and Site B below Taber from all other sites downstream of Brocket. Higher numbers of Orthocladiinae, Hydropsyche, E. (Ephemerella), Diamesinae, Perlodidae, Heptageniidae, Lepidoptera, Pisidium, Cheumatopsyche, Physidae, Planorbidae, Mermithoidea, Tubificidae, Nectopsyche, and Hydroptila are typical of the two sites below Lethbridge and below Taber while the other sites downstream of Brocket have higher naidid and leptocerid densities.

3.3.3.7 Multivariate Analyses - Fall

As for spring, replicates at each site clustered together. Three major clusters were defined (Figure 26). The first cluster groups Waldron's Corner and Brocket. The second cluster groups the next three sites from Fort Macleod to above Lethbridge. The third cluster groups all sites from below Lethbridge (Site 13) to Grassy Lakes (Site 19). The first cluster contains two sub-clusters of Waldron's Corner and Brocket.

The first principal component accounts for 22% of the sample variance (Table 6). It distinguishes Waldron's Corner (Site 1) and Brocket (Site 5) from sites further downstream. Epeorus, Lepidostomatidae, E. (Drunella), Leptophlebiidae, Antocha, Tanytarsini, Baetidae, Chloroperlidae, Wiedemannia, Turbellaria, Perlidae, Rhyacophilidae, Atherix, Ameletus, Perlodidae and Plecoptera are

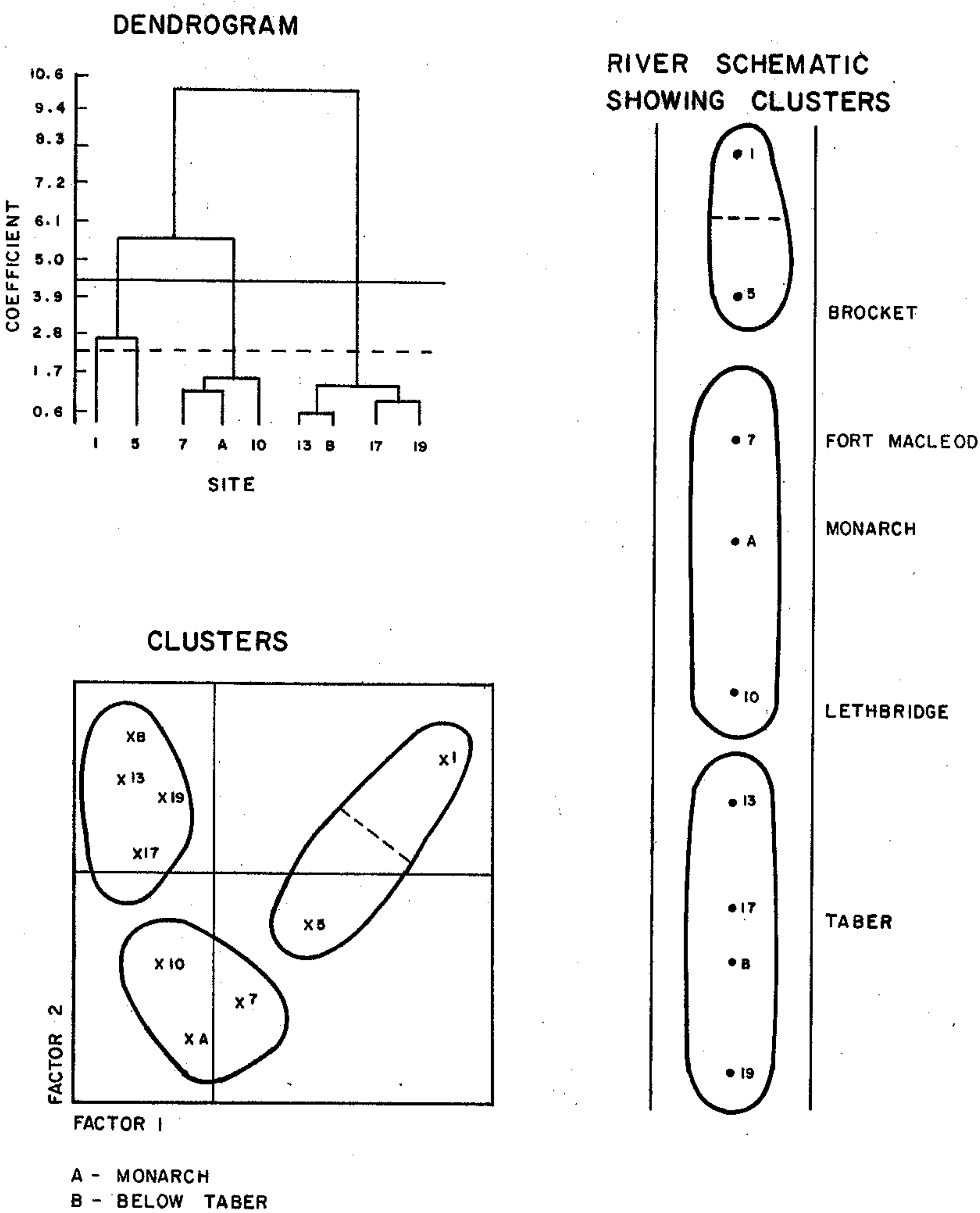

FIGURE 26. RESULTS OF PRINCIPAL COMPONENTS ANALYSIS OF BENTHIC INVERTEBRATE DATA FROM THE OLDMAN RIVER IN FALL, 1984

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TABLE 6 Results of principal components analysis of benthic invertebrate data from the Oldman River in Fall, 1984.

	VECTOR 1		VECTOR 2		VECTOR 3
Eigenvalue	21.90		9.81		6.23
Percentage Variance	33.18		14.86		9.44
Variance explained by individual taxa:					
Epeorus	0.196	Hydropsychidae	0.231	Paraleptophlebia	0.251
Lepidostomatidae	0.191	Hydropsyche	0.230	Rhithrogena	0.230
E. (Drunella)	0.178	Mermithoidea	0.222	Plecoptera indet.	0.195
Leptophlebiidae	0.174	Lepidoptera	0.210	Hydroptilidae	0.192
Antocha	0.173	Tubificidae	0.193	Chloroperlidae	0.191
Tanytarsini	0.169	Pisidium	0.180	Hydropsychidae	0.189
Baetidae	0.169	Cheumatosyche	0.163	Capniidae	0.179
Chloroperlidae	0.164	Heptageniidae	0.162	Perlodidae	0.159
Wiedemannia	0.164			Heptagenia	0.158
Turbellaria	0.163	Caenis	-0.151	Chelifera	0.153
Perlidae	0.162	Acari	-0.173		
Rhyacophilidae	0.159	Tanypodinae	-0.185	Atherix	-0.154
Atheriix	0.158	Nematoda indet.	-0.190	Ameletus	-0.154
Ameletus	0.155	Odonata	-0.191	Wiedemannia	-0.159
Perlodidae	0.154	Elmidae	-0.209	Rhyacophilidae	-0.161
Plecoptera indet.	0.151	Naididae	-0.245	Antocha	-0.172
				Nectopsyche	-0.176
Ferrissia	-0.152			Leptophleaiidae	-0.181
Physidae	-0.160			Nematoda indet.	-0.186
Stenonema	-0.174			Coelenterata	-0.218
Tricorythodes	-0.181			Chironomini	-0.227
Oecetis	-0.185				
Ephemera	-0.187				

typical of the two upstream sites while Ephemera, Oecetis, Tricorythodes, Stenonema, Physidae, and Ferrissia typify the downstream sites.

The second principal component, which accounts for another 15% of the sample variance separates Fort Macleod (Site 7) Monarch (Site A) and above Lethbridge (Site 10) from the four sites downstream of Lethbridge. The first site group generally has denser populations of Naididae, Elmidae, Odonata, Nematoda, Tanypodinae, Acari and Caenis, while Hydropsychidae immatures, Hydropsyche, Mermithoidea, Lepidoptera, Tubificidae, Pisidium, Cheumatopsyche and Heptageniidae are more abundant at the second site group.

The third principal component explains 9% of the sample variance and makes a sharp distinction between Waldron's Corner (Site 1) with larger populations of Chironomini, Coelenterata, Nematoda, Leptophlebiidae, Nectopsyche, Antocha, Rhyacophylidae, Wiedemannia, Ameletus, and Atherix and Brocket (Site 5) which is more typified by larger populations of Paraleptophlebia, Rhithrogena, Plecoptera, Hydroptilidae, Chloroperlidae, Hydropsychidae, Capniidae, Perlodidae, Heptageniidae, and Chelifera.

3.4 SEDIMENTS

Organics which were below detection in the sediments at all sites include polychlorinated biphenyls, priority pollutant extractables, the chlorinated herbicides; 2,4-D and 2,4,5-T, Dicamba, Diclofop-methyl and MCPA (Table 7). Hydrocarbons and Picloram were below detection limits below Lethbridge (Site 13) and at Grassy Lake (Site 19) but

TABLE 7 Organics and heavy metal chemistry results in $\mu g.g^{-1}$ for sediments collected from the Oldman River in October, 1984.

PARAMETERS	WALDRON'S CORNER	ABOVE LETHBRIDGE	BELOW LETHBRIDGE	AT GRASSY LAKE
Priority Pollutant Extractables	L1.0	L1.0	L1.0	L1.0
Elemental Sulphur S_8, S_7, S_6	Observed at Saturation Concentrations exceeding trace levels.			
PCB's	L0.5	L0.5	L0.5	L0.5
Hydrocarbons			L1.0	L1.0
Aliphatis Hydrocarbons (Molecular weight greater than 200)	1-10	1-5		
<u>CHLORINATED HERBICIDE ACIDS SCAN</u>				
2,4-D	L0.01	L0.01	L0.01	L0.01
Dicamba (Banvel*)	L0.01	L0.01	L0.01	L0.01
Diclofop-methyl (Hoe Grass*)	L0.002	L0.002	L0.002	L0.002
MCPA	L0.01	L0.01	L0.01	L0.01
Picloram (Tordon*)	0.07	0.08	L0.01	L0.01
2,4,5-T	L0.005	L0.005	L0.005	L0.005
<u>METALS</u>				
Arsenic (As)		5.30	3.45	4.00
Cadmium (Cd)		0.70	0.40	0.60
Copper (Cu)		15.5	8.7	13.7
Iron (Fe)		15,200	10,360	16,500
Chromium (Cr)		20.0	14.0	26.8
Manganese (Mn)		420.	252.	517.
Zinc (Zn)		91.0	46.9	82.5
Aluminum (Al)		1810.	839.	1730.
Lead (Pb)		38.	19.0	30.
Nickel (Ni)		17.	9.0	17.0
Mercury (Hg)		0.030	0.015	0.025

L = less than
* = Registered Trade Mark

were detected at the two upstream sites. Elemental sulphur was measured at all sites.

Metal concentrations in the sediments were consistently lowest at Site 13 below Lethbridge. Highest concentrations were measured at Site 10 above Lethbridge with the exception of iron, chromium and manganese.

3.5 TRIBUTARIES

Water chemistry for the tributaries of the Oldman River are presented in three sections. Tributaries are grouped according to their period of flow and hence sampling regime.

3.5.1 Castle, Crowsnest, St. Mary and Belly Rivers

The Castle, Crowsnest, St. Mary and Belly rivers were sampled from April 1984 to March 1985 at the same frequency as the mainstem sites (Table 8).

Dissolved oxygen, biochemical oxygen demand and chemical oxygen demand were similar for the four rivers. Dissolved oxygen was high (averaging 10.3 to 12.0 $mg.L^{-1}$) and oxygen demand was low (0.6 to 1.2 $mg.L^{-1}$ for BOD and 6.2 to 10.4 $mg.L^{-1}$ for COD). Oxygen demand in the Castle River was lower than in the other three rivers.

Turbidity values in the Crowsnest and Castle rivers showed a lower range of values (L0.1 to 42.0 NTU) than in the St. Mary and Belly rivers (1.2 to 42.0 NTU).

Conductivity, total dissolved solids and major ion concentrations in the Castle River were the lowest of the four rivers (Table 8). Conductivity, total dissolved solids, magnesium, potassium

TABLE 8 Summary of water chemistry for the major tributaries of the Oldman River (Units are $mg.L^{-1}$ with exceptions noted).

PARAMETER	CASTLE		CROWSNEST		ST. MARY		BELLY	
	Mean	Range n = 17	Mean	Range n = 17	Mean	Range n = 17	Mean	Range n = 17
DO	11.3	7.6- 13.8	12.0	9.2 - 14.5	10.9	8.2- 14.5	10.3	6.8- 13.7
COD	6.2	L0.1- 10.0	8.9	L1. - 20.0	10.4	L5.0- 19.0	8.3	L1.0- 19.0
BOD	0.6	0.1- 1.0	1.2	0.7 - 1.9	1.1	0.3- 2.0	1.0	0.3- 4.2
TURBIDITY[1]	1.3	L0.1- 4.5	2.0	L0.1 - 5.5	5.6	2.0- 15.0	6.5	1.2- 42.0
CONDUCTIVITY	245	169 - 357	380	310 - 464	440	320 -599	355	180 -440
NA	2	L1 - 4	6	2 - 9	32	21 - 46	14	2.9- 19.0
CA	32	20 - 44	54	44 - 68	34	19 - 47	38	25 - 51
MG	11	6 - 14	14	10 - 17	17	13 - 20	16	9 - 19
K	0.5	0.4 - 0.6	0.7	0.5 - 1.0	1.5	1.0- 2.1	1.0	0.5 - 1.3
CL	0.8	0.2 - 1.2	2.2	L1.0 - 3.8	1.8	1.2- 3.0	1.6	0.5 - 2.1
SO_4	15	7 - 21	49	30 - 71	89	58 - 139	47	11 - 62
HCO_3	141	99 - 181	185	143 -232	161	109 - 205	169	113 - 212
TDS	132	85 - 170	221	171 -283	258	191 - 335	203	105 - 241
ALKALINITY	118	81 - 148	158	130 -190	137	100 - 168	145	93 - 176
pH[3] (Field)	7.9	6.5-8.6	8.1	6.9-8.9	8.1	7.0-9.0	7.9	7.0-8.4
(Lab)	8.2	7.6-8.6	8.4	7.7-8.7	8.4	7.2-8.6	8.4	7.5-8.6
DIC	26.7	19.4-31.5	39.9	29.0-96.2	30.7	22.0-38.2	33.5	25.0-41.8
DOC	1.2	L0.4-2.7	1.9	0.7-8.2	2.5	1.0-4.0	1.7	L0.4-3.0
PHENOLICS	0.007	L0.001-0.055	0.005	L0.001-0.039	0.007	L0.001-0.044	0.006	L0.001-0.047
COLIFORMS-Total[4]	12	0 - 60	306	0-2516	100	0-1000	38	0 - 372
-Fecal[4]	2	0 - 9	24	0- 258	7	0- 41	12	0 - 160
SI	4.1	3.3-4.4	2.5	0.2- 5.2	0.8	0.1- 2.2	1.6	0.6 - 7.0
TKN	0.167	0.040-0.460	0.376	0.200-1.100	0.364	0.210-0.600	0.321	0.140-0.520
NIT	0.038	0.005-0.090	0.224	L0.003-0.900	0.088	0.002-0.430	0.079	L0.003-0.335
NH_3	0.010	L0.002-0.030	0.026	0.004-0.100	0.018	L0.002-0.080	0.032	L0.002-0.163
TP	0.010	L0.003-0.022	0.035	0.010-0.067	0.020	0.007-0.049	0.018	0.006-0.073
DP	0.007	L0.002-0.016	0.022	0.004-0.066	0.011	L0.002-0.020	0.009	0.002-0.021

Notes
1 - NTU
2 - $uS.cm^{-1}$
3 - pH units (median)
4 - # per 100 mL

and chloride were similar in the Crowsnest, Belly and St. Mary rivers. Sodium concentrations showed distinct differences. Annual average values in the St. Mary River were the highest (32 $mg.L^{-1}$) and values in the Crowsnest River were the lowest (6 $mg.L^{-1}$). Calcium in the Crowsnest River was much higher (54 $mg.L^{-1}$) than in the other three rivers (32 to 38 $mg.L^{-1}$). Sulphate in the St. Mary River was higher (89 $mg.L^{-1}$) than in the Crowsnest and Belly rivers (49 and 47 $mg.L^{-1}$, respectively), which were higher than Castle River values (15 $mg.L^{-1}$). Bicarbonate concentrations were highest in the Crowsnest River (185 $mg.L^{-1}$) and intermediate in the St. Mary and Belly rivers (161 and 169 $mg.L^{-1}$, respectively).

Castle River values for alkalinity, pH, dissolved inorganic carbon and dissolved organic carbon were lowest of the four rivers. Annual average alkalinity values ranged from 118 mg $CaCO_3.L^{-1}$ in the Castle River to 158 mg $CaCO_3.L^{-1}$ in the Crowsnest River. Dissolved organic carbon and pH values were similar in the four rivers (averaging 1.2 to 2.5 $mg.L^{-1}$ and 7.9 to 8.1, respectively). Dissolved inorganic carbon concentrations were higher (39.9 $mg.L^{-1}$) in the Crowsnest River than in the St. Mary and Belly rivers (30.7 and 33.5 $mg.L^{-1}$, respectively).

Average annual phenolics concentrations ranged from 0.005 to 0.007 $mg.L^{-1}$ in the four rivers. Coliform bacteria concentrations were lowest in the Castle River averaging 12 per 100 mL for total and 2 per 100 mL for fecal. They were highest in the Crowsnest River averaging 306 per 100 mL and 24 per 100 mL, respectively. Silica concentrations on average ranged from 0.8 $mg.L^{-1}$ in the St. Mary River to 4.1 $mg.L^{-1}$ in the Castle River.

Nitrogen and phosphorus concentrations were generally lowest in the Castle River and highest in the Crowsnest River. The exception was ammonia which was highest in the Belly River. Average phosphorus concentrations ranged from 0.010 to 0.035 $mg.L^{-1}$ for total phosphorus and from 0.007 to 0.022 $mg.L^{-1}$ for dissolved phosphorus. Average nitrogen concentrations ranged from 0.167 to 0.376 $mg.L^{-1}$ for total Kjeldahl nitrogen, from 0.038 to 0.224 $mg.L^{1}$ for nitrate/nitrite and from 0.010 to 0.032 $mg.L^{-1}$ for ammonia.

3.5.2 Pincher, Beaver and Willow Creeks

Pincher, Beaver and Willow creeks were sampled from April to July, though one February sample was collected from Willow Creek (Table 9). This February sample accounts for the low dissolved oxygen value of 4.5 $mg.L^{-1}$ while average concentrations were high (10.5 to 10.8 $mg.L^{-1}$). Oxygen demands were generally higher in these three tributaries than in the four tributaries discussed previously.

Turbidity values were higher in Pincher Creek (11.6 NTU) than in Beaver or Willow creeks (3.0 and 3.1 NTU). Conductivity, total dissolved solids and most major ions were lowest in Pincher Creek and highest in Beaver Creek. The exceptions were calcium and chloride concentrations which were lowest in Willow Creek. Average values of conductivity ranged from 367 to 912 $\mu S.cm^{-1}$ and total dissolved solids ranged from 195 to 552 $mg.L^{-1}$.

Alkalinity, pH and dissolved carbon values were generally higher in these three creeks than in the other four rivers. Average values ranged from 151 to 345 mg $CaCO_3.L^{-1}$ for alkalinity, from

TABLE 9 Summary of water chemistry for the minor tributaries of the Oldman River (Units are $mg.L^{-1}$ with exceptions noted).

PARAMETER	PINCHER Mean	PINCHER Range n = 9	BEAVER Mean	BEAVER Range n = 6	WILLOW Mean	WILLOW Range n = 10
DO	10.8	9.0 - 11.8	10.8	10.5 - 11.0	10.5	4.5 - 12.9
COD	12.6	L5.0 - 20.0	21.8	18.1 - 24.8	16.2	7.0 - 30.0
BOD	2.4	L1.0 - 6.9	1.5	L1.0 - 2.5	1.9	L1.0 - 5.0
TURBIDITY[1]	11.6	L0.1 - 30.0	3.0	2.0 - 4.0	3.1	0.8 - 5.5
CONDUCTIVITY	367	279 - 507	912	707 -1071	507	430 - 638
NA	13	5 - 27	72	50 - 92	44	33 - 66
CA	40	30 - 47	56	50 - 66	33	18 - 71
MG	15	10 - 23	45	35 - 55	24	21 - 31
K	1.8	1.2 - 2.9	6.4	5.4 - 7.3	3.4	2.6 - 4.4
CL	5.5	2.0 - 13.0	8.0	4.0 - 11.0	3.0	L1.0 - 5.9
SO_4	41	19 - 78	157	94 - 221	57	47 - 65
HCO_3	167	136 - 222	405	324 - 455	259	212 - 441
TDS	195	145 - 287	552	411 - 682	303	259 - 425
ALKALINITY	151	124 - 190	345	288 - 385	231	196 - 362
pH[3] (Field)	8.3	7.6 - 8.5	7.9	7.8 - 8.0	8.5	7.9 - 8.8
(Lab)	8.5	8.0 - 8.9	8.4	8.2 - 8.6	8.5	8.0 - 8.9
DIC	36.1	30.2 - 40.0	84.9	66.2 - 97.5	58.2	50.0 - 86.4
DOC	2.1	0.9 - 2.9	7.2	5.8 - 8.2	3.9	2.2 - 8.2
PHENOLICS	0.002	0.001-0.003	0.004	0.003-0.004	0.002	L0.001 - 0.004
COLIFORMS-Total[4]	88	8 - 288	41	8 - 84	155	6 - 490
-Fecal[4]	20	0 - 98	9	0 - 27	48	1 - 198
SI	1.2	L0.5 - 3.0	1.9	0.7 - 2.9	1.9	0.3 - 5.1
TKN	0.416	0.100 - 1.080	0.600	0.50 - 0.70	0.505	0.300 - 0.930
NIT	0.015	L0.001 - 0.074	0.005	0.003- 0.008	0.037	0.005 - 0.120
NH_3	0.014	L0.002 - 0.062	0.013	0.006- 0.019	0.080	0.006 - 0.310
TP	0.103	0.044 - 0.185	0.038	0.025- 0.054	0.025	0.010 - 0.064
DP	0.048	0.022 - 0.100	0.019	0.014- 0.020	0.016	0.008 - 0.040

1 - NTU
2 - $uS.cm^{-1}$
3 - pH units (median)
4 - # per 100 mL

8.4 to 8.5 for pH, from 36.1 to 84.9 $mg.L^{-1}$ for dissolved inorganic carbon and from 2.1 to 7.2 $mg.L^{-1}$ for dissolved organic carbon. Phenolics average concentrations ranged from 0.002 to 0.004 $mg.L^{-1}$ and coliform bacteria counts were highest in Willow Creek and lowest in Beaver Creek (155 per 100 mL to 41 per 100 mL for total coliform bacteria and 48 per 100 mL to 9 per 100 mL for fecal coliform bacteria).

Silica concentrations were lower (1.2 $mg.L^{-1}$) and phosphorus concentrations were higher (0.103 $mg.L^{-1}$ for total phosphorus and 0.048 $mg.L^{-1}$ for dissolved phosphorus) in Pincher Creek than in the other two creeks. Total Kjeldahl nitrogen concentrations ranged from 0.416 $mg.L^{-1}$ in Pincher Creek to 0.600 $mg.L^{-1}$ in Beaver Creek while ammonia and nitrate/nitrite concentrations were highest in Willow Creek (0.080 $mg.L^{-1}$ and 0.037 $mg.L^{-1}$, respectively).

3.5.3 Irrigation Return Flows

Irrigation return flows were sampled once in early May and at the same frequency as the mainstem sites from June to October.

Average dissolved oxygen concentrations (Table 10) in the irrigation return flows were high (8.8 to 9.8 $mg.L^{-1}$) and average oxygen demands were moderate (1.4 to 3.2 $mg.L^{-1}$ and 13.0 to 48.9 $mg.L^{-1}$ for biochemical and chemical oxygen demands, respectively). Average turbidity ranged from 18.1 NTU in Expanse Coulee to 43.0 NTU in Bountiful Coulee to a very high value of 392.3 NTU in Piyami Drain.

TABLE 10 Summary of water chemistry for the irrigation return flows to the Oldman River (Units are mg.L^{-1} with exceptions noted).

PARAMETER	PIYAMI DRAIN Mean	PIYAMI DRAIN Range n = 6	BATTERSEA DRAIN Mean	BATTERSEA DRAIN Range n = 8	LITTLE BOW RIVER Mean	LITTLE BOW RIVER Range n = 9
DO	9.1	8.1 - 10.4	9.8	8.0 - 12.2	9.8	8.2 - 12.9
COD	48.9	5.0 - 123.2	13.0	10.0 - 18.3	17.8	L5.0 - 27.3
BOD	3.2	1.6 - 7.3	1.6	0.7 - 2.2	2.3	1.0 - 4.2
TURBIDITY[1]	392.3	30.0 -1200.0	40.1	2.4 - 80.0	36.9	5.8 - 70.0
CONDUCTIVITY	397	340 - 500	480	368 - 660	424	360 - 470
NA	12	7 - 16	22	11 - 64	25	18 - 45
CA	47	39 - 61	54	41 - 99	37	31 - 43
MG	15	12 - 19	28	15 - 68	19	16 - 22
K	3.0	1.5 - 6.4	2.3	1.2 - 4.0	1.8	1.2 - 2.2
CL	1.9	L1.0 - 3.2	4.3	2.0 - 12.0	4.6	3.0 - 6.4
SO_4	59	41 - 86	153	48 - 467	83	68 - 119
HCO_3	180	160 - 209	168	137 - 199	163	145 - 177
TDS	230	185 - 308	352	208 - 804	253	213 - 302
ALKALINITY	154	131 - 194	147	131 - 163	139	122 - 160
pH[3] (Field)	8.2	7.8 - 8.4	8.2	7.2 - 8.4	8.0	7.8 - 9.0
(Lab)	8.2	7.7 - 8.5	8.4	7.9 - 8.6	8.4	7.5 - 8.6
DIC	38.6	36.7 - 39.9	33.4	25.0 - 40.1	32.1	28.0 - 37.0
DOC	4.4	2.4 - 8.5	3.6	2.5 - 4.6	3.6	1.7 - 4.5
PHENOLICS	0.005	L0.002 - 0.013	0.005	L0.001 - 0.018	0.006	L0.001 - 0.026
COLIFORMS-Total[4]	4608	540 - 20000	1207	190 - 4400	800	10 - 2600
-Fecal[4]	247	80 - 460	297	70 - 790	75	0 - 400
SI	5.9	3.7 - 12.2	2.3	0.4 - 3.3	2.0	1.0 - 3.9
TKN	1.450	0.660 - 3.450	0.695	0.380 - 1.480	0.672	0.400 - 1.340
NIT	0.044	0.044 - 0.091	0.086	0.010 - 0.300	0.008	L0.001 - 0.016
NH_3	0.093	0.016 - 0.370	0.021	L0.01 - 0.04	0.010	L0.001 - 0.020
TP	0.838	0.190 - 2.55	0.087	0.025 - 0.170	0.063	0.022 - 0.103
DP	0.103	0.028 - 0.380	0.021	0.016 - 0.028	0.018	0.011 - 0.022

1 - NTU
2 - uS.cm^{-1}
3 - pH units (median)
4 - # per 100 mL

TABLE 10 Continued

PARAMETER	BOUNTIFUL COULEE Mean	BOUNTIFUL COULEE Range n = 9	EXPANSE COULEE Mean	EXPANSE COULEE Range n = 9	DRAIN T Mean	DRAIN T Range n = 9
DO	8.8	7.1 - 10.0	9.3	7.8 - 10.6		
COD	13.3	L1.0 - 25.0	24.0	5.0 - 53.8	16.8	10.6 - 30.5
BOD	1.4	0.6 - 2.5	2.4	1.5 - 3.5		
TURBIDITY[1]	43.0	3.4 - 150.0	18.1	0.1 - 40.0		
CONDUCTIVITY	260	230 - 326	884	490 -2310	392	344 -475
NA	6	4 - 11	77	35 - 260	17	15 - 20
CA	30	24 - 33	61	33 - 139	33	26 - 44
MG	11	10 - 13	38	22 - 102	18	17 - 20
K	1.1	0.8 - 1.4	4.4	2.5 - 11.0	2.8	2.1 - 3.5
CL	0.9	0.6 - 1.1	10.4	6.0 - 24.0	5.6	5.0 - 6.0
SO_4	24	14 - 47	316	129 -1095	68	61 - 82
HCO_3	132	108 - 145	173	101 - 264	156	130 -192
TDS	140	123 - 183	591	311 -1760	221	196 -270
ALKALINITY	113	99 - 128	152	115 - 216	129	112 -158
pH[3] (Field)	7.9	7.6 - 8.4	8.3	8.1 - 9.0		
(Lab)	8.3	7.9 - 8.5	8.5	8.2 - 9.1	8.1	7.7 - 8.5
DIC	25.2	21.0 - 30.0	33.2	23.0 - 46.0		
DOC	1.9	1.1 - 2.7	6.2	3.3 - 11.8		
PHENOLICS	0.003	L0.001 - 0.016	0.004	0.001 - 0.008		
COLIFORMS-Total[4]	104	24 - 300	245	0 - 700		
-Fecal[4]	19	0 - 84	33	0 - 90		
SI	1.3	0.2 - 1.9	2.4	0.6 - 3.9	1.7	L0.5 - 2.6
TKN	0.468	0.320 - 0.760	0.822	0.540 - 1.440	0.686	0.500 - 1.080
NIT	0.017	L0.003 - 0.050	0.014	0.003 - 0.040		
NH_3	0.015	L0.01 - 0.02	0.019	L0.01 - 0.04	0.029	0.012 - 0.048
TP	0.125	0.031 - 0.370	0.122	0.069 - 0.200	0.080	0.034 - 0.200
DP	0.014	0.007 - 0.034	0.046	0.017 - 0.077		

1 - NTU
2 - $uS.cm^{-1}$
3 - pH units (median)
4 - # per 100 mL

Conductivity, total dissolved solids and major ion concentrations were lowest in Bountiful Coulee and highest in Expanse Coulee. Conductivities on average ranged from 260 to 884 $\mu S.cm^{-1}$ and average total dissolved solids ranged from 230 to 591 $mg.L^{-1}$. Battersea Drain and Little Bow River were relatively similar in terms of higher values of sodium (22 to 25 $mg.L^{-1}$) and chloride (4.3 to 4.6 $mg.L^{-1}$). Bicarbonate and total dissolved solids values were high in Battersea Drain, though less than in Expanse Coulee.

Bountiful Coulee showed lower concentrations of alkalinity (113 mg $CaCO_3.L^{-1}$) and dissolved carbons (25.2 $mg.L^{-1}$ for inorganic and 1.9 $mg.L^{-1}$ for organic) than the other irrigation return flows (129 to 154 mg $CaCO_3.L^{-1}$, 32.1 to 38.6 $mg.L^{-1}$ and 3.6 to 6.2 $mg.L^{-1}$, respectively). The same trends held for phenolics, coliform bacteria and silica. Average annual values for the return flows were 0.003 to 0.006 $mg.L^{-1}$ for phenolics, 104 to 4608 per 100 mL for total coliform bacteria and 19 to 297 per 100 mL for fecal coliform bacteria. Silica values in Piyami Drain (5.9 $mg.L^{-1}$) were generally higher than in the other drains (1.3 to 2.4 $mg.L^{-1}$).

Nutrient concentrations were generally lowest in Little Bow River and highest in Piyami Drain. Average concentrations ranged from 0.063 to 0.838 $mg.L^{-1}$ for total phosphorus and from 0.014 to 0.103 $mg.L^{-1}$ for dissolved phosphorus. For nitrogen forms, average concentrations ranged from 0.468 to 1.45 $mg.L^{-1}$ for total Kjeldahl, 0.008 to 0.086 $mg.L^{-1}$ for nitrate/nitrite and 0.010 to 0.093 $mg.L^{-1}$ for ammonia.

3.6 PRINCIPAL COMPONENTS ANALYSIS

Principal components analysis defined six to eight significant factors (eigenvalue greater than 1) to determine the variance in the chemistry data. The first two or three factors from annual and seasonal analysis are summarized in Table 11.

On an annual basis, the first factor included the variables sodium, sulphate, chloride and potassium and explained 34.3% of the variance. The second factor explained a further 22.0% of the variance and included bicarbonate, alkalinity, calcium, nitrate, temperature, hardness and dissolved inorganic carbon. The third factor, defined by turbidity and non-filterable residue accounted for 8.1% of the variance.

The results on a seasonal basis show the changing importance of different variables in explaining the variance. In spring the carbon interactions were most important, followed by the particulate variables. Organics take third place. In summer the major ions became more important but particulates remained a secondary factor. The calcium carbonate interaction dropped to third factor. Principal components in fall and winter fell less distinctly into readily explained groups. Many variables grouped in the first factor in these two seasons, but in general major ions were most significant.

3.7 WATER QUALITY CRITERIA

Water quality objectives have been established for surface water (Alberta Environment 1977), freshwater fish (Longmore and Stenton 1981) and public water supply (Hamilton 1983). Many concentration objectives for data collected in this study are the same in the three guidelines (Table 12). In several cases the public water supply

TABLE 11 Results of principal components analysis of water chemistry from the mainstem sites on the Oldman River

FACTOR	EIGENVALUE	% OF VARIANCE	PRINCIPAL COMPONENTS COEFFICIENT < 0.8	PRINCIPAL COMPONENTS COEFFICIENT 0.6-0.8
Annual				
1	11.65	34.3	Na, SO_4, CL, K	Si(-), Cond, Mg, DP, Epi, TP, Res, BOD
2	7.49	22.0	HCO_3, Alk, Ca, Nit, Temp(-), Hard, DIC	NH_3, TN
3	2.74	8.1	Turb, NFR	Fe
Spring				
1	12.91	38.0	DIC, Alk, Hard, Cond, HCO_3, Mg, Res, Ca, SO_4	Na
2	9.14	26.9	PP, NFR, Turb	Fe, FCol, NH_3, TKN, TN
3	2.94	8.7	DOC, Phen	COD, Temp
Summer				
1	12.73	37.4	Na, K, SO_4, Cond, Cl, Mg, TKN, TN	Si(-), DP, Hard, TCol, Epi, Temp, TP
2	5.90	17.4	NFR, Fe, PP, Turb	Nit
3	3.07	9.0	Ca, Alk	HCO_3
Fall				
1	14.45	42.5	K, Na, Si(-), SO_4, PP TCol, Cl, Res, Mg, NFR, Cond	TP, Turb, DP, DOC, Phyt, Epi
2	7.22	21.2	Hard	DIC, Temp(-), Ca, HCO_3 DO, Alk, pH(-), Nit, Phyt
Winter				
1	18.47	54.3	Res, K, Na, Cond, Cl, Mg, SO_4, Alk, HCO_3 Hard, TP, BOD, Turb, Nit, NH_3	DP, TN, DIC, Si(-), COD, NFR, Ca
2	3.79	11.2		TCol, FCol, Phyt
3	2.66	7.8		DO, Epi

TABLE 12 Comparison of water quality objectives for surface water, freshwater fish and public water supply (units are $mg.L^{-1}$ with exceptions noted).

PARAMETER	SURFACE WATER	FRESHWATER FISH	PUBLIC WATER SUPPLY
Arsenic	0.01	0.05	0.05
Beryllium		1.1	
Cadmium	0.01	0.001	0.005
Chloride			250
Chromium	0.05	0.05	0.05
Coliforms - fecal[1]	200 (1000)		1000
- total[1]	1000 (5000)		5000
Copper	0.02	0.04	1.0
Fluoride	1.5		1.5
Iron	0.3	0.3	
Lead	0.05	0.05	0.05
Manganese	0.05	1.0	0.05
Mercury	0.0001	0.0001	0.001
Nickel		0.025	
Nitrate		6.8	10.0
Nitrite		0.6	1.0
Nitrogen	1.0		
Oxygen	5.0	5.0	
pH[2]	6.5 - 8.5	6.5 - 8.5	6.5 - 8.5
Phenolics	0.005	0.001	0.002
Phosphorus (as P)	0.05	0.03	
Selenium	0.01	0.05	0.01
Sulphate			500
Temperature[3]		22/25	
Zinc	0.05	0.3	5

1 - # per 100 mL
2 - pH units
3 - °C

criteria are less stringent since these waters are processed before use. Where objectives differ between surface water and freshwater fish, the former has lower requirements for arsenic, copper, manganese, selenium and zinc. The latter has lower requirements for cadmium, phenolics and phosphorus.

Hamilton (1983) discussed the freshwater fish and public water supply objectives relative to historical data within the Oldman River Basin. He concluded that despite the fact that exceedances were measured for many criteria for freshwater fish, the parameters of primary concern were temperature, dissolved oxygen and un-ionized ammonia. Reasons for the exceedances for other parameters might be the unreliability of some analyses in earlier years, particularly for metals or the high natural concentrations found in the Basin for iron, manganese, nitrogen and phosphorus.

3.7.1 Mainstem River Sites

A comparison between water quality objectives and data collected from the Oldman River during the study is presented in Table 13 as percentage exceedances. The bacteriological data were difficult to evaluate since the main criteria were based on five samples taken in less than 30 days and our sampling program did not meet this frequency requirement. They can, however, be evaluated on the relative basis of percent exceedance. The evaluation is made at two levels. From Alberta Environment (1977), the less stringent (non-contact) level is for "waters to be withdrawn for treatment and distribution as a potable supply or used for outdoor recreation other than direct contact". The more stringent level is for "waters used for direct contact recreation or vegetable crop irrigation".

TABLE 13 Summary of percentage exceedances of water quality criteria for mainstem sites on the Oldman River.

WATER QUALITY PARAMETER	MAINSTEM SITES						
	WALDRON'S CORNER	BROCKET	FORT MACLEOD	LETHBRIDGE ABOVE	LETHBRIDGE BELOW	TABER	GRASSY LAKE
Surface Water Objectives							
Bacteriology-contact (non-contact)							
total coliform	0	0	0	6	38	23	8
fecal coliform	0	0	0	0	8	7	0
Dissolved Oxygen	0	0	0	0	0	0	12
pH (Lab)	6	18	12	0	41	35	35
Organic Chemicals							
phenolics	25	18	12	18	18	12	18
Toxic Chemicals							
arsenic	--	--	0	0	0	0	0
cadmium	--	--	0	0	0	0	0
chromium	--	--	0	0	0	0	0
lead	--	--	0	0	0	0	0
mercury	--	--	20	6	13	0	12
selenium	--	--	0	0	0	--	0
Inorganic Chemicals							
copper	--	--	0	0	0	0	0
iron	0	0	0	12	6	6	6
manganese	--	--	0	0	7	0	6
nitrogen (TKN)	6	0	0	0	6	0	0
phosphorus	0	0	6	25	100	94	82
zinc	--	--	0	0	0	0	0
Freshwater Fish Objectives[1]							
Beryllium	--	--	0	0	0	--	0
Cadmium	--	--	7	6	13	0	6
Copper	--	--	0	0	0	0	0
Nickel	--	--	0	0	0	0	
Nitrate + Nitrite	0	0	0	0	0	0	0
Phenolics[2]	60	54	45	67	69	54	75
Phosphorus	0	0	12	44	100	100	100
Temperature[3]			23.8	22.2	24.8		
Public Water Supply[1]							
Chloride	0	0	0	0	0	0	0
Phenolics	25	24	18	29	41	24	41
Sulphate	0	0	0	0	0	0	0

[1] - parameters not previously evaluated or parameters with violations at a different objective concentration than previously evaluated
[2] - 4-6 values of L0.002 omitted from calculations
[3] - maximum measured value (°C)

Surface water quality objectives were exceeded at most sites along the length of the Oldman River for phenolics (12-25%) and pH (0-41%). Mercury was not sampled at the two upstream sites, but concentrations exceeded surface water quality objectives at all of the other sites (6-20%) except at Taber. Objectives which were exceeded mostly at the downstream river sites from Lethbridge to Grassy lake include coliform bacteria (0-38%), iron (6-12%) and phosphorus (6-100%).

Freshwater fish objectives for phenolics were exceeded at every site (54-75%). Cadmium was exceeded at most sites sampled (0-13%) as was phosphorus at the sites from Fort Macleod to Grassy Lake (12-100%). Phenolics objectives for public water supply were also exceeded at all sampling sites (18-41%).

3.7.2 Tributaries

Surface water objectives were exceeded most consistently for pH (6-50%) in all the tributuries and phenolics (18-25%) in the Castle, Crowsnest, St. Mary and Belly rivers (Table 14). Objectives for phosphorus were exceeded at five of the tributaries (6-89%). Water quality in the Crowsnest River exceeded objectives for six different parameters while four objectives were exceeded in the Belly River, Pincher and Willow creeks.

Phenolics objectives were exceeded in all tributaries for both freshwater fish objectives (45-100%) and public water supply (25-100%). Phosphorus objectives for freshwater fish were exceeded at all sites except in the Castle River.

TABLE 14 Summary of percentage exceedances of water quality criteria for tributaries of the Oldman River Basin.

WATER QUALITY PARAMETER	CASTLE	CROWSNEST	ST. MARY	BELLY	PINCHER	BEAVER	WILLOW
<u>Surface Water Objectives</u>							
Bacteriology-contact (non-contact)							
total coliform	0	6	0	0	0	0	0
fecal coliform	0	6	0	0	0	0	0
Dissolved Oxygen	0	0	0	0	0	0	11
pH (Lab)	6	29	12	12	33	17	50
Organic Chemicals							
phenolics	24	18	18	25	0	0	0
Inorganic Chemicals							
iron	0	0	0	0	11	17	0
nitrogen (TKN)	0	6	0	0	11	0	0
phosphorus	0	24	0	6	89	17	10
<u>Freshwater Fish Objectives</u>[1]							
Nitrate + Nitrite	0	0	0	0	0	0	0
Phenolics[2]	54	29	54	64	50	100	83
Phosphorus	0	65	12	6	100	67	30
Temperature[3]			23.7		24.1		26.1
<u>Public Water Supply</u>[1]							
Chloride	0	0	0	0	0	0	0
Phenolics	29	29	41	38	25	100	40
Sulphate	0	0	0	0	0	0	0

[1] - parameters not previously evaluated or parameters with violations at a different objective concentration than previously evaluated
[2] - 4-6 values of L0.002 omitted from calculations
[3] - maximum measured value (°C)

3.8 HISTORICAL AND LONG TERM TRENDS

Long-term monitoring has been carried out on the Oldman River at two sites, above Lethbridge and near Taber. The long-term monitoring site near Taber was at a bridge crossing (Hwy. 36) further downstream of the study site above Taber. Nevertheless, a comparison of study data with median historical data from 1974-1983 show that concentrations are quite similar (Table 15). The exceptions were iron and aluminum at both sites, which are much lower in this study, and phosphorus at Taber, which is much higher in this study.

The discrepancy between iron and aluminum values measured historically and in this study, are strongly influenced by the different sampling frequencies. The study data include many more samples from winter months when concentrations were low. The high phosphorus values near Taber in the study reflect the very low dilution of the input from the Lethbridge sewage treatment plant in this low flow year.

A further investigation of historical trends in water quality parameters was carried out by comparing the mean annual concentrations from 1978 to 1984 at the long term monitoring sites to the study data collected in 1984-85 (Table 16). Very few consistent trends were found over the long term. At Lethbridge dissolved phosphorus was higher in 1984-85 than in any other year. Similar results were shown for phenolics, mercury and arsenic. At the Taber sites chloride concentrations were higher in the study than in historical years. Both total and dissolved phosphorus were higher and ammonia was lower than historical data.

TABLE 15 Comparison of median values from historical (1974-1983) and study data from above Lethbridge and Taber on the Oldman River (units are $mg.L^{-1}$ with exceptions noted).

PARAMETER	ABOVE LETHBRIDGE HISTORICAL	ABOVE LETHBRIDGE STUDY	BELOW TABER HISTORICAL	BELOW TABER *STUDY
Dissolved Oxygen	10.6	10.5	10.0	10.1
Turbidity[1]	7.5	4.4	7.2	7.0
NFR	12.0	8.8	7.0	15.6
Na	13.5	14.5	19.0	24.8
Ca	40.7	36.4	41.3	39.0
Mg	15.8	16.0	16.6	16.5
K	1.1	1.0	1.6	1.8
Cl	1.7	1.8	4.7	8.0
SO_4	48.0	55.0	55.0	65.0
Fe	0.73	0.10	0.29	0.08
Conductivity[2]	374	368	402	402
pH[3]	8.2	8.3	8.3	8.4
Alkalinity	136.	148.	136.	144.
DOC	2.0	2.0	2.2	2.4
DIC	31.0	31.4	31.0	33.3
TP	0.024	0.024	0.085	0.143
DP	0.004	0.010	0.031	0.128
Si	2.7	2.1	1.1	0.89
Phenolics	0.001	L0.002	0.001	L0.002
Coliforms - total[4]	82	51	188	130
- fecal[4]	9	2	22	10
TKN	0.500	0.360	0.600	0.480
$NO_2 + NO_3$	0.050	0.014	0.060	0.024
NH_3	L0.100	L0.010	L0.100	L0.016
Hg	L0.00002	L0.0001	L0.00002	L0.0001
Co	L0.002	L0.001	L0.002	0.001
Cu	0.002	0.0015	0.0015	--
Ni	L0.002	0.0025	0.003	--
Cd	L0.001	L0.001	L0.001	L0.001
Pb	L0.004	0.002	L0.004	L0.002
Zn	0.0075	0.005	0.003	0.002
Al	0.860	0.199	0.160	--
Mn	0.05	L0.01	0.02	0.03
Cr	L0.015	0.001	L0.015	0.003
As	L0.0005	0.0006	0.0005	0.0010
Se	0.0006	L0.000	0.0005	--
Va	0.001	0.002	0.001	L0.001
Mo	L0.10	0.0025	L0.10	--

1 - NTU
2 - $uS.cm^{-1}$
3 - pH units
4 - # per 100 mL
* - Study sampling site was above Taber

TABLE 16 Comparison of mean annual water chemistry data at the long term monitoring sites above Lethbridge and below Taber from 1978 to 1984 with study data from the Oldman River (units are $mg.L^{1}$ with exceptions noted).

PARAMETER	1978	1979	1980	1981	1982	1983	1984	STUDY
ABOVE LETHBRIDGE								
Turbidity[1]	100.5	27.4	10.5	19.1	23.2	17.1	5.0	9.7
NFR	199	97	15	45	36	36	9	17.6
Na	11.7	17.0	14.1	13.9	12.0	12.7	14.1	14.0
Ca	41.1	43.5	41.3	42.0	39.0	37.2	35.5	39.5
Mg	15.1	17.3	16.4	16.6	14.5	14.4	14.4	14.4
K	1.3	1.6	1.4	1.1	1.2	1.1	1.0	1.7
Cl	1.5	1.9	2.2	1.7	1.8	1.6	1.8	1.7
SO_4	41.4	55.8	48.8	45.1	39.8	44.8	49.6	51.0
Conductivity[2]	355	420	409	393	330	333	365	372
pH[3]	8.2	8.2	8.2	8.3	8.2	8.3	8.1	8.2
Alkalinity	130	138	135	148	136	132	137	141
DOC	2.4	2.2	2.1	2.2	2.1	1.8	1.2	2.0
DIC	30.8	34.1	31.7	--	--	--	--	31.4
TP	0.210	0.077	0.025	0.038	0.054	0.050	0.022	0.035
DP	0.009	0.008	0.009	0.005	0.008	0.006	0.009	0.014
Si	3.2	3.0	2.4	2.8	2.6	2.2	1.5	2.2
TKN	0.150	--	--	--	--	--	--	0.382
NH_3	L0.100	0.108	L0.100	L0.100	L0.100	L0.100	L0.100	0.021
NIT	0.118	0.119	0.088	0.065	0.107	0.025	0.042	0.070
Phenolics	0.001	0.001	0.001	0.002	0.002	0.003	0.003	0.006
Coliforms - total[4]	1548	196	25	65	69	378	48	110
- fecal[4]	870	39	48	9	45	68	16	8
Hg[5]	--	L0.020	0.023	0.022	0.022	0.020	L0.02	0.100
As	0.0005	0.0008	0.0005	0.0006	0.0005	0.0008	0.0005	0.0010
Se	0.0007	0.0007	0.0007	0.0007	0.0006	0.0006	0.0006	L0.000
BELOW TABER								
Turbidity[1]	29.7	23.1	13.5	35.7	17.2	17.4	8.7	11.3
NFR	67	55	23	90	42	30	13.5	18.8
Na	20.7	21.8	18.3	19.1	17.5	18.7	21.1	21.6
Ca	42.6	44.8	43.5	43.2	41.7	38.9	39.0	40.9
Mg	15.8	18.1	17.6	17.2	15.9	15.6	15.3	15.7
K	1.8	2.2	1.6	1.6	1.6	1.5	1.4	1.6
Cl	3.7	6.2	6.1	5.2	5.8	5.7	7.4	8.6
SO_4	44.8	60.5	56.6	52.0	49.7	53.4	68.4	61.7
Conductivity[2]	411	453	455	427	377	373	417	406
pH[3]	8.1	8.1	8.3	8.3	8.1	8.4	8.2	8.4
Alkalinity	148	137	143	150	142	139	138	146
DOC	3.7	2.8	2.5	2.6	2.5	2.1	1.6	2.5
DIC	29.4	35.2	34.7	--	--	--	--	32.6
TP	0.142	0.112	0.094	0.116	0.121	0.108	0.110	0.188
DP	0.017	0.073	0.061	0.036	0.069	0.058	0.077	0.171
Si	2.7	2.6	1.3	1.7	1.8	0.8	0.9	1.1
TKN	1.033	--	--	--	--	--	--	0.475
NH_3	L0.100	0.254	0.158	0.109	0.117	0.118	0.160	0.066
NIT	0.118	0.160	0.151	0.091	0.161	0.061	0.080	0.134
Phenolics	0.002	0.002	0.001	0.001	0.002	--	0.002	0.003
Coliforms - total[4]	3067	528	918	327	836	184	447	659
- fecal[4]	223	95	96	54	95	19	68	26
Hg[5]	--	0.022	0.024	0.021	L0.020	--	0.021	L0.100
As	0.0006	0.0009	0.0007	0.0006	0.0005	0.0010	0.0010	0.0010
Se	0.0005	0.0007	0.0006	0.0006	0.0006	0.0005	0.0005	--

1 - NTU
2 - $uS.cm^{-1}$
5 - $ug.L^{-1}$
3 - pH units
4 - # per 100 mL
* - Study sampling site was above Taber

4.0 DISCUSSION AND CONCLUSIONS

4.1 BASELINE CONDITIONS

Many of the objectives of the intensive monitoring program of the Oldman River are related to the establishment of a reliable database. These baseline conditions indicate the current status of the basin, including the impact of present development and form a basis for comparison with any future impacts or development.

The water chemistry of the Oldman River is strongly defined by the river basin geology. The most significant factor defining the river is the major ion composition of sodium, sulphate, chloride and potassium. The calcium bicarbonate interaction provides a strong secondary definition of the river. The influence of discharge on the water chemistry can clearly be seen in the third factor, turbidity.

An earlier study of the Oldman River (Cross et al. 1986) showed that the high flows in spring dominated the water chemistry in that season. In contrast, with low flow conditions measured in 1984, the importance of particulate matter in defining the variance in water chemistry is reduced.

Limnological studies on the Oldman River from 1979 to 1982 measured the concentrations of many of the same variables which were measured in this study (Cross et al. 1986; Charlton et al. 1986). The earlier study was carried out at three sites; above Lethbridge (Site 10), below Lethbridge (Site 13) and at the confluence with the Bow River (Site 19). A direct comparison of average annual concentrations for the river between this study and the 1979-82 study indicates that conductivity, alkalinity, dissolved organic carbon and dissolved inorganic carbon were similar (404 versus 418 $\mu S.cm^{-1}$, 145 versus 141 $mg.L^{-1}$, 2.5 versus 3 $mg.L^{-1}$ and 32.4 versus 32.5 $mg.L^{-1}$, respectively). The range of values for pH was also comparable. Values upstream of Lethbridge were 7.6 to 8.5 versus 7.6 to 8.6 for the 1984-85 and the 1979-82 studies, respectively. Downstream of Lethbridge the range was 7.2 to 9.2 in both studies (Cross et al. 1986).

Several variables were higher or lower in this study than in the previous study. The lower turbidity measured in this study (1.7 - 11.3 NTU in 1984-85 versus 56 JTU in 1979-82) resulted from lower flows carrying less particulates in 1984-85. Dissolved phosphorus and chloride concentrations were higher in this study. Average annual concentrations of phosphorus at the three comparable sites ranged from 0.006 to 0.091 $mg.L^{-1}$ in 1979-82 and from 0.014 to 0.239 $mg.L^{-1}$ in 1984-85. Comparable average chloride concentrations were 3.5 $mg.L^{-1}$ and 6.4 $mg.L^{-1}$, respectively. These results may also reflect the lower flows in 1984-85 providing less dilution to inputs from the Lethbridge sewage treatment plant, tributary flows and irrigation return flows.

Concentrations of silica and nitrate/nitrite were lower in this study compared to 1979-82. Silica values averaged 1.5 $mg.L^{-1}$ and 2.3 $mg.L^{-1}$, respectively and average nitrate/nitrite ranged from 0.070 to 0.152 $mg.L^{-1}$ and from 0.12 to 0.15 $mg{\bullet}L^{-1}$, respectively. These differences were well within the range of historical values measured and merely reflect annual variability.

The standing crops of benthic algae in this study were higher than those in the previous study. The average concentrations from this study were 90, 185 and 104 mg chlorophyll $\underline{a}.m^{-2}$ as compared to the average concentrations from the 1979-82 study which were 47, 83 and 22 mg chlorophyll $\underline{a}.m^{-2}$ at the sites above Lethbridge, below Lethbridge and at the confluence with the Bow River, respectively (Charlton et al. 1986). This difference can be attributed to some degree to the relatively fewer winter samples collected in the 1984-85 study. Standing crops of benthic algae are low in winter and more winter samples would tend to lower the averages for 1984-85. Benthic algal standing crops are also highly variable from year to year.

Standing crops of phytoplankton were similar between the two studies. Average annual concentrations were 1.0, 4.0 and 3.9 mg chlorophyll $\underline{a}.m^{-3}$ in this study and 3, 7 and 4 mg chlorophyll $\underline{a}.m^{-3}$ in 1980-81 at the sites above Lethbridge, below Lethbridge and at the confluence with the Bow River, respectively.

Dissolved phosphorus loading inputs from the Lethbridge sewage treatment plant in this study were comparable to the results from 1980 and 1981 (Cross et al. 1986; Table 17). The contributions were 87.7 tonnes versus 82.0 and 108.9 tonnes, respectively. Similarly the contribution from return flows was fairly similar; 5.0 tonnes in 1984, 3.1 tonnes in 1980, and 3.7 tonnes in 1981.

TABLE 17 Comparison of 1984-85 data with 1980 and 1981 data* for annual dissolved phosphorus loading, reach loading and the dissolved phosphorus inventory.

MAINSTEM SITES	1984 - 85 REACH LENGTH (km)	1984 - 85 ANNUAL LOADING (tonnes)	1984 - 85 LOADING CHANGE (tonnes.km^{-1})	1980 ANNUAL LOADING (tonnes)	1980 LOADING CHANGE (tonnes.km^{-1})	1981 ANNUAL LOADING (tonnes)	1981 LOADING CHANGE (tonnes.km^{-1})
Waldron's		1.56					
	58		-0.04				
Brocket		4.76					
	58		-0.05				
Fort Macleod		2.76					
	104		+0.01				
above Lethbridge		9.00		10.4		34.2	
	43		-0.39		-0.82		-1.60
below Lethbridge		80.36		57.7		74.8	
	43		-0.34				
Taber		66.42			-0.20		-0.24
	69		-0.30				
confluence		46.68		38.0		50.9	

YEAR	ANNUAL PHOSPHORUS LOADING IN TONNES: UPSTREAM	TRIBUTARIES	IRRIGATION RETURN	SEWAGE: FT. MACLEOD	SEWAGE: LETHBRIDGE	STORMWATER & INDUSTRIAL
1984-85	1.6	9.6	5.0	2.1	87.7	--
1980	10.4	--	3.1	--	82.0	2.3
1981	34.2	--	3.7	--	108.9	2.3

* Data from Cross, Hamilton and Charlton, 1986.

The major difference in the two studies was the inclusion in the 1984-85 study of the portion of the Oldman River Basin upstream of Lethbridge. Thus the 1984-85 study inputs from tributaries, Fort Macleod and the Oldman River above the study area (13.3 tonnes) can be compared to the upstream inputs in the 1980 and 1981 study of 10.4 tonnes and 34.2 tonnes.

The dissolved phosphorus loading change in the reach from above to below Lethbridge was lower in 1984-85 (-0.39 tonnes.km^{-1}) than in 1980 or 1981 (-0.82 and -1.60 tonnes.km^{-1}, respectively). The reaches downstream of the site below Lethbridge had fairly similar loading changes in 1984-85 (-0.29 tonnes.km^{-1}) as in 1980 (-0.20 tonnes.km^{-1}) and in 1981 (-0.24 tonnes.km^{-1}). Overall, from Lethbridge to the confluence with the Bow River the uptake of dissolved phosphorus in 1984-85 (52 tonnes) was similar to that in 1980 (58 tonnes) and lower than in 1981 (96 tonnes).

4.2 IMPACT OF CITIES AND TRIBUTARIES

The character of the Oldman River is strongly influenced by the input from cities, tributaries and irrigation return flows. In the upstream reaches, the Castle and Crowsnest rivers provided 63% of the flow of the Oldman River at Brocket in 1984. The Castle River generally had low concentrations of major ions and nutrients. The Crowsnest River was an important source of calcium bicarbonate, coliforms and nutrients.

The two other major tributaries, St. Mary and Belly rivers, enter the Oldman River between Fort Macleod and Lethbridge. Their volume of flow in 1984 was 38% of the Oldman River flow at Lethbridge. Within this reach of the river, oxygen demand and turbidity increase as do sodium, sulphate and conductivity. Nutrients are also added in this reach of the river, but the impacts are small.

The strong impact of Lethbridge on the Oldman River can be seen in the dramatic increase in river concentrations of nitrogen, phosphorus, oxygen demand, sodium, chloride, sulphate, total dissolved solids, conductivity, coliforms and alkalinity. This impact is also shown in the increased standing crops of phytoplankton and epilithic algae. The impact of irrigation return flows is less dramatic on an average annual basis, but increases in sodium, magnesium, sulphate, total dissolved solids, conductivity, total Kjeldahl nitrogen and ammonia are shown.

4.3 BENTHIC INVERTEBRATES

Longitudinal and seasonal patterns of variables such as the mean total number of invertebrates per site or the mean number of invertebrate taxa per site are rather inconsistent. This inconsistency suggests that site to site differences are a greater determinant in the pattern of the variables than longitudinal or seasonal changes in the river. Most major taxonomic groups do not show greater consistency in longitudinal changes either, but mayflies and stoneflies tend to be more abundant in upstream reaches while oligochaetes tend to be more numerous in mid-stream reaches, and caddisflies, and molluscs tend to reach higher numbers downstream.

The consistent decrease in mayfly, stonefly and caddisfly numbers in both seasonal surveys at Fort Macleod is unexpected and may be indicative of an environmental disturbance. Little response to the effect of enrichment from municipal waste water discharges from major urban centres (i.e. Lethbridge) can be identified at the level of variables which summarize zoobenthic data (i.e. total density, number of taxa, major groups).

Longitudinal patterns in the Oldman River are definitely more evident when detailed taxonomic data are examined. Cluster and principal components analyses, the two multivariate techniques which were used to analyze detailed taxonomic data, yield a similar site classification of the Oldman River. The taxa which are the main determinants of this site classification have a pattern which is typical of a river which flows through different vegetation zones, in this case the Boreal Zone, and the Prairie Zone (some parts of which are used as rangeland, for agriculture or for urban development). The invertebrate fauna changes rapidly from one typical of foothill streams with clear, swift waters to a fauna which is typical of larger and slower moving waters with finer sediments and higher silt loads.

Although the occurrence of Tubificidae is undoubtedly related to natural changes in the river, the sudden appearance downstream of Lethbridge of large numbers of these oligochaetes which are known for their positive response to organic enrichment, suggests a response to the city's discharges to the river.

Molluscs and Hydropsychidae represent two groups of invertebrates which feed primarily on algae and detritus particles. Their increase in density in the downstream reaches of the Oldman River is related to the presence of larger algal standing stocks and the settling of larger amounts of suspended particles.

4.4 WATER QUALITY CRITERIA

Within the Oldman River Basin, pH and phenolics exceed surface water quality objectives most frequently. This may reflect that objectives are unrealistic for the natural water chemistry of this Basin, a situation that is recognized in the Alberta Surface Water Quality Objectives (Alberta Environment, 1977).

The natural level of phenolics may be high because of the breakdown of organic material. The objectives consider water supply which is affected by aesthetic values of taste and odour, but toxic concentrations are much higher than those objectives. For example, McKee and Wolf (1963) suggest that 0.2 $mg.L^{-1}$ would not interfere with fish and aquatic life, though objective levels are 0.001 $mg.L^{-1}$.

The influence of human activity is apparent in results for phosphorus and coliform bacteria. The objectives for these two parameters are exceeded most frequently below Lethbridge.

The surface water objective for iron and the freshwater fish objective for cadmium are typically exceeded in the spring. These occurrences may be related to sediment carried during high flow periods. The sources for iron appear to be restricted to the basin from Lethbridge to Grassy Lake.

The sources for mercury are less easily explained. The objective is exceeded in December or January during a low flow period. This may indicate a natural source of mercury within the Basin.

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APPENDIX I Analytical list for organics and priority pollutants.

COMPOUND	DETECTION LIMIT $ug.L^{-1}$
Organophosphorus Pesticides	
Aspon®	0.50
Crufomate (Ruelene®)	2.00
Dasanit® (Fensulfothion)	4.00
DDVP® (Dichlorovos, Vapona®)	0.20
DEF®	0.05
Demeton (Systox®)	7.00
Dimethoate (Cygon®)	0.15
Di-Syston® (Disulfoton)	25.00
Ethion	0.05
Fenthion®	1.25
Fenitrothion	0.05
Fonofos (Dyfonate®)	0.05
Guthion®	2.00
Malathion®	0.17
Methyl Parathion	0.05
Methyl Trithion®	0.25
Mevinphos® (Phosdrin®)	0.20
Mocap®	0.15
Paraoxon®	0.10
Parathion	0.06
Phorate (Thimet®)	0.20
Ronnel (Fenchlorphos®)	0.10
Tetrachlorvinphos (Gardona®)	0.03
Organonitrogen Pesticides	
Atrazine	1.00
Aminocarb (Matacil®)	100.00
Bromacil (Isocil)	0.05
Cobex® (Dinitramine®)	0.03
Cyanazine	0.03
Diazinon®	0.50
Dinoseb®	0.15
Metribuzin	0.03
Prometryne	1.50
Propanil	0.70
Propazine	1.00
Simazine	1.00
Terbacil	0.10
Trifluralin (Treflan®)	0.03

COMPOUND	DETECTION LIMIT ug.L^{-1}
Organochlorine Pesticides	
Aldrin	0.500
α-Chlordane	0.010
υ-Chlordane	0.010
Captan	0.050
Dacthal® (Chlorthal Methyl)	0.010
o,p' - DDD	0.010
p,p' - DDD	0.010
o,p' - DDE	0.010
p,p' - DDE	0.010
o,p' - DDT	0.020
p,p' - DDT	0.020
Diallate (Avadex®)	0.800
Dieldrin	0.010
Dursban® (Lorsban®, Chlorpyrifos)	0.040
α-Endosulfan	0.010
B-Endosulfan	0.010
Endrin	0.010
Heptachlor	0.020
Heptachlor epoxide	0.010
Hexachlorobenzene (HCB)	0.030
α-Hexachlorocyclohexane	0.010
B-Hexachlorocyclohexane	0.040
υ-Hexachlorocyclohexane (Lindane)	0.010
δ-Hexachlorocyclohexane	0.010
Kelthane® (Dicofol)	0.030
Methoxychlor	0.030
Mirex	0.010
Perthane®	0.300
Ramrod® (Propachlor)	0.200
Triallate (Avadex BW®)	0.040
Chlorinated Herbicide Acids	
2,4-D	0.20
Dicamba	0.20
Diclofop-methyl (Hoe Grass®)	0.20
MCPA	0.20
Picloram	0.30
2,4,5-T	0.20
Polychlorinated Biphenyls	
Arochlor 1016	0.10
Arochlor 1221	0.20
Arochlor 1232	0.10
Arochlor 1242	0.05
Arochlor 1248	0.05
Arochlor 1254	0.05
Arochlor 1260	0.10
Arochlor 1262	0.10
Arochlor 1268	0.05

Priority Pollutant Extractables (all detection limits are 1.0 $ug.L^{-1}$)

Acid Groups
Benzoic Acid
4-Chloro-m-cresol
2-Chlorophenol
2,4-Dichlorophenol
2,4-Dimethylphenol
4,6-Dinitro-o-cresol
2,4-Dinitrophenol
Hexadecanoic acid
2-Nitrophenol
4-Nitrophenol
Pentachlorophenol
Phenol
2,4,5-Trichlorophenol
2,4,6-Trichlorophenol

Base Neutral Group
Polynuclear Aromatics
Acenaphthene
Acenaphthylene
Anthracene
Benz(a)anthracene
Benzo(k)fluoranthene
Benzo(ghi)perylene
Benzo(a)pyrene
Chrysene
Dibenz(ah)anthracene
Fluoranthene
Fluorene
Indeno(1,2,3-cd)pyrene
Naphthalene
Perylene
Phenanthrene
Pyrene

Base Neutral Group (cont'd)
Chloroorganics
Chlorobenzene
2-Chloronaphthalene
1,2-Dichlorobenzene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
Hexachlorobenzene
Hexachlorobutadiene
Hexachlorocyclopentadiene
Hexachloroethane
1,2,4-Trichlorobenzene
Nitroaromatics
Benzidine
3,3'-Dichlorobenzidine
2,4-Dinitrotoluene
2,6-Dinitrotoluene
1,2-Diphenylhydrazine
Nitrobenzene
N-Nitrosodimethylamine
N-Nitrosodiphenylamine
N-Nitrosodi-n-propylamine
Halo ethers
4-Bromophenyl phenyl ether
Bis(2-chloroethoxy)methane
Bis(2-chloroethyl)ether
Bis(2-chloroisopropyl)ether
2-Chloroethyl vinyl ether
4-Chlorophenyl phenyl ether
Phthalate Esters
Butylbenzyl phthalate
Di-n-butylphthalate
Diethylphthalate
Dimethylphthalate
Di-n-octylphthalate
Bis(2-ethylhexyl)phthalate