Province of British Columbia
Ministry of Environment
ASSESSMENT AND PLANNING DIVISION

APD BULLETIN 20

KOOTENAY
AIR AND WATER QUALITY STUDY
PHASE II

Water Quality in the
Kootenay River Basin

Aquatic Studies Branch

Victoria, British Columbia
December 1981
File No. 0322512-1

Canadian Cataloguing in Publication Data

Rocchini, R. J. (Roland Jean), 1936-
Kootenay air and water quality study, phase II

Prepared by R.J. Rocchini and others of the Aquatic Studies Branch.
Issued 1981- by the Assessment and Planning Division.
Some v. issued in series: APD bulletin.
Includes bibliographies.
Contents: [6] Water quality in the Kootenay River basin / R.J. Rocchini ... [et al.]
ISBN 0-7719-8653-X (set). -- ISBN 0-7719-8851-6 (v.6)

1. Water quality - British Columbia - Kootenay region. 2. Air quality - British Columbia - Kootenay region. 3. Water - Pollution - British Columbia - Kootenay region. 4. Air - Pollution - British Columbia - Kootenay region. 5. Coal mine waste. I. British Columbia. Water Investigations Branch. II. British Columbia. Ministry of Environment. Assessment and Planning Division. III. British Columbia. Aquatic Studies Branch. IV. Title. [V. Title: Water quality in the Kootenay River basin. VI. Series: APD bulletin ; 20]

TD227.B7R53 363.7'39'0971145 C78-016075-4

First Printing 1981.

SUMMARY

This report updates previous Phase I reports which described water quality in the Kootenay River basin. The present report covers the basin from the source of the Kootenay River to its entry into the United States. It is a technical reference of discharges and other influences on water quality during the period 1975 to 1978.

The major influences on water quality were the discharge from Crestbrook Forest Industries Ltd.'s kraft mill at Skookumchuck, the discharges from Cominco Ltd.'s mining and fertilizer complex at Kimberley, and the impoundment of the river by the Libby Dam, 30 km south of the International Border in Montana. An influence which may occur in the future is the possible diversion, after 1984, of part of the Kootenay River into the Columbia River at Canal Flats. This diversion would, if it takes place, reduce the flows appreciably in the Kootenay River.

The kraft mill effluent discharged at Skookumchuk created problems of colour and, to a lesser degree, toxicity in the Kootenay River, especially at low river flow. Colour can interfere with domestic use of river water, and effluent toxicity can cause sublethal stress on aquatic life. There is a plan to dispose of the effluent mainly to ground, by the end of 1981, using a rapid infiltration system. This treatment should largely eliminate colour problems caused by the discharge, and should also reduce toxicity problems.

Effluents from a lead-zinc mine and fertilizer complex at Kimberley have affected the St. Mary River, and to a lesser degree the Kootenay River. Before 1975, the effluents had severely damaged aquatic life in the St. Mary River. After 1975, improvements in the fertilizer plant had a beneficial effect on the river. The pH levels in the St. Mary River were closer to normal and the fluoride levels were acceptable, except at times during low flow. Nutrient concentrations decreased, although they were still high enough to enhance algal growth. Heavy metals, especially iron, lead and zinc, showed some tendency to accumulate in sediments and fish, although in fish the metals were within limits recommended for human consumption. Since August, 1979, acid mine drainage and tailing pond overflows have been treated in a newly commissioned plant. This treatment reduces the load of heavy metals discharged and will create further improvements in the quality of the St. Mary River.

The Canadian portion of the Koocanusa Reservoir continued to show low

biological productivity, in spite of relatively high phosphorus loadings. This result was due partly to turbidity, introduced during freshet, which limited light penetration and hence algal growth. Other factors limiting productivity were fluctuating water levels, a low water residence time and a lack of strong thermal stratification. The reservoir will probably remain oligotrophic, as phosphorus loadings are reduced in the future. The Kootenay River diversion, if it proceeds, may change this situation by decreasing turbidity and stabilizing water levels.

Water sources with limited water availability are discussed. Water shortages could be created in the basin if the Kootenay River diversion proceeds, since up to two thirds of the mean annual flow at Canal Flats would be diverted to the Columbia River.

ACKNOWLEDGEMENTS

Thanks are due to the following for supplying data and information: Crestbrook Forest Industries Ltd., Cominco Ltd., Environment Canada, Health and Welfare Canada, B.C. Hydro and Power Authority, the Fish and Wildlife Branch, the Waste Management Branch, the Water Management Branch and the Environmental Laboratory of the B.C. Ministry of Environment.

Copies of this report may be obtained from the Map Library, Assessment and Planning Division, Ministry of Environment, Parliament Buildings, Victoria, B.C., V8V 1X5.

TABLE OF CONTENTS

Page

Page

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

This report describes the water quality of the Kootenay River, from its source in the Rocky Mountains to the point where it enters the U.S. as the Koocanusa Reservoir. The basin is located in the north-eastern part of the Kootenay region, as shown in Figure 1. The data which we present cover the period from 1975 to 1978.

The water quality of the basin prior to 1975 was evaluated in two Phase I reports[1, 2]. The Phase I study found that in the northern half of the basin, between the source and Skookumchuck, the water quality was generally good. Between Skookumchuck and the confluence with the St. Mary River, effluent from the Crestbrook Forest Industries pulp mill had caused colour, toxicity and fish tainting problems. In the St. Mary River effluents from Cominco's mining and fertilizer operations had severely damaged aquatic life. Downstream from the St. Mary River the water quality of the Koocanusa Reservoir, which extends 65 km into Canada, remained fairly good. This result was believed due to rapid flushing of pollutants discharged from the industries upstream.

Information in this report describes action taken to curtail some of the discharges and presents a more complete picture of the water quality situation. For data presentation the basin was divided into four sub-basins.

1.1 The Upper Kootenay River Basin

From the headwaters to Canal Flats.

1.2 The Lower Kootenay River Basin

Between Canal Flats and the confluence with the St. Mary River.

1.3 The St. Mary River

1.4 The Koocanusa Reservoir

This section includes the Kootenay River between the St. Mary River confluence and Wardner, and the Canadian portion of the Koocanusa Reservoir.

The last chapter of this report discusses water availability problems in the basin, between Canal Flats and the International Border.

2. THE UPPER KOOTENAY RIVER BASIN

2.1 Introduction

The upper Kootenay River basin drains an area of 5 390 km^2 in the Kootenay and Park Ranges of the Rocky Mountains (Figure 2). The Kootenay River leaves the Rocky Mountains and enters the Rocky Mountain Trench at Canal Flats, which was chosen as the terminus of this basin. Much of the northern half of the basin lies within Kootenay National and Mount Assiniboine Provincial Parks which occupy about 30 percent (1 600 km^2) of the basin. The flow in the Kootenay River at Canal Flats has ranged from 840 m^3/s during spring freshet to 6 m^3/s during winter, with a mean annual flow of 88 m^3/s[1,3].

2.2 Effluents and Non-Point Sources

As reported in Phase I[1], there were no significant sources of effluent in the upper Kootenay River basin up to 1978. A woodwaste landfill operated by Crestbrook Forest Industries Ltd. adjacent to the Kootenay River at Canal Flats (site B) was no longer in use and was to be rehabilitated[4].

Much of the southern half of the basin (Cross, Albert, Palliser and White River drainages) had been logged or was to be logged in the near future[1]. The influence of logging on water quality (i.e. primarily suspended sediment) has not been studied.

An open pit magnesite ($MgCO_3$) mine was proposed at the confluence of the Mitchell River and Assiniboine Creek in the Cross River basin (Figure 2) in 1976[5, 6, 7]. The proposal featured open pit mining of 180 000-450 000 tonnes of ore per year. The ore would then be transferred to a processing plant for milling and calcining. The location of the processing plant was not specified, but sites at the confluence of the Kootenay and Cross Rivers[5] and in the Columbia Valley between Radium Hot Springs and Canal Flats were being considered[7].

The proposed diversion of the Kootenay River into the Columbia River system at Canal Flats (Figure 2) would not have any effect on flow or water quality in the upper Kootenay River, unless a regulating dam (possibly at Gibralter Rock) were constructed on the upper Kootenay to provide more uniform flows for the diversion. Such a dam would have significant effects on the upper Kootenay River, but up to 1978 had not been seriously considered as an element of the proposed diversion[3, 8].

2.3 Water Quality

The Ministy of Environment monitored eight water quality sites in the Upper Kootenay River basin during Phase II. The sites are shown in Figure 2 and are described in Table 1. The data are summarized in Tables 2, 3 and 4. Site 0200020 (Table 4) was sampled monthly during Phase II and provides a good year-round description of the water quality of the Kootenay River. The other sites (Tables 2 and 3) were sampled only a few times (1 to 3 times) during the summer (June to September).

Tables 2, 3 and 4 show that the waters of the upper Kootenay River basin were alkaline. They ranged from medium hard to hard during spring and summer, to very hard during winter low flows[9]. For domestic purposes, the water could be classed as being good to fair with respect to hardness during spring and summer and poor during the winter[10]. Suspended solids and turbidity were typically low during the fall and winter, but reached fairly high levels (692 mg/L suspended solids, 140 J.T.U. turbidity) in the Kootenay River (site 0200020) during spring snowmelt. Higher suspended solids and turbidity persisted in the Kootenay River into July and August, suggesting that glaciers melting at high altitude were contributing sediments during the summer.

Metals and other toxic substances were very low at all sites. Total iron was high (up to 18.2 mg/L) in the Kootenay River at site 0200020 during spring freshet, but dissolved iron was very low. The high total iron values were not significant to water quality because they were due to a mineral form of iron contained in the suspended sediment load of the river[11].

Dissolved nitrogen (ammonia, nitrate and nitrite: <300 µg/L) and dissolved phosphorus (<3 µg/L) were very low in the upper Kootenay basin. Total phosphorus reached fairly high levels (up to 372 µg/L) during spring freshet due to the phosphorus content of the suspended sediments. Fecal coliforms, an indicator of fecal contamination, were very low in the upper Kootenay basin.

2.4 Conclusions and Recommendations

The water quality of the upper Kootenay River was generally good, but the water was hard and high in suspended solids and turbidity during spring and summer. The suspended solids are believed to be due to natural sources, but the influence of logging in the southern part of the basin has not been studied.

Further monitoring of water quality in the upper Kootenay basin is not recommmended unless specific development proposals are made. Site 0200020 on the Kootenay River at Canal Flats, has been used as a control site for the Crestbrook Forest Industries pulp mill at Skookumchuck, although another site closer to the mill is now being used.

3. THE LOWER KOOTENAY RIVER BASIN

3.1 Hydrology

This section of the river is shown in Figure 3. The flow of the Kootenay River between Canal Flats and the St. Mary River confluence is unregulated at present. Flows are typical of temperate regions with highest flows during spring runoff and lowest flows under ice-cover during the winter months. The mean monthly flows (18.5 to 306 m^3/s) at Canal Flats (Water Survey of Canada site 8NF002) for the 26 years of record[12], are shown in Figure 4. Seven-day average low flows at Canal Flats, determined for the 15 years of record, ranged from 11.2 m^3/s which could occur once in 16 years, to 21.7 m^3/s which could occur each year. The minimum daily recorded flow was 8.8 m^3/s on January 30, 1968[12].

Skookumchuck is approximately 30 km downstream from Canal Flats (Figure 3). Mean monthly flows (23.7 m^3/s to 517 m^3/s), from 1950 to 1976, are given in Figure 5. They show an average monthly increase of 31 percent over the flows at Canal Flats with monthly increases ranging from 22 percent in November to 43 percent in June. The minimum recorded mean monthly flow near Skookumchuck was 20.1 m^3/s in March, 1972, and the minimum recorded daily flow was 11.9 m^3/s on November 22, 1977[12].

The distribution of daily river flows near Skookumchuck, for the period January, 1972 to December, 1977, is plotted in Figure 6 as a cumulative distribution curve.

No flow data are available for the Kootenay River downstream from Skookumchuck and just upstream fom the St. Mary River. However, subtracting the flow in the St. Mary River at Wycliffe (Water Survey of Canada site 8NG012) from the flow at Fort Steele (Water Survey of Canada site 8NG065) for 1964 to 1976, gives a mean flow of about 133 m^3/s. This represents an increase of approximately 13 percent over the flow near Skookumchuck (mean flow of 118 m^3/s). Increases of up to 26 percent occur during low flow months.

The Columbia River Treaty will allow, after 1984, the diversion of up to 1.85 km^3 per year of water from the upper Kootenay River to the Columbia River at Canal Flats. The only limitation is that the flows in the Kootenay River downstream from the diversion must not be reduced to less than 5.7 m^3/s or the natural low flow (if less than 5.7 m^3/s). Case studies for the diversion of 57, 113 and 170 m^3/s have been investigated by B.C. Hydro[14]. Since the mean monthly flows at Canal Flats are less than 57, 113 and 170 m^3/s for 7, 9 and 10 months of the year, respectively (Figure 4), these diversions would have to take place during high flow periods, when the Columbia River downstream from Canal Flats is also experiencing high flow conditions. The flow in the Kootenay River at Canal Flats would be reduced to 5.7 m^3/s or natural low flow (if less than 5.7 m^3/s) for 7 to 10 months of the year, with these diversions[14].

3.2 Effluents and Non-Point Sources of Pollution

3.2.1 Introduction

The major effluent source in this section of the Kootenay River Basin, from 1975 to 1978, was the pulp mill operated by Crestbrook Forest Industries Ltd. at Skookumchuck. The location of the operation is shown on a detailed map in Figure 7. It is discussed in detail in the following subsections. Associated with the pulp mill were domestic sewage and solid wastes. The domestic sewage was collected in a large oxidation basin from which there was only a small positive discharge to Skookumchuck Creek (Figure 7). This discharge does not warrant further discussion. The solid waste disposal site, which operated under Pollution Control Permit PR-1756, was described in the Phase I report[2] and no further monitoring was recommended.

Domestic sewage from the towns in the area, (Skookumchuck, Ta Ta Creek and Wasa) was disposed of in septic tanks and tile fields and had a negligible effect on the Kootenay River[2]. The solid waste disposal site at Wasa was also considered in the Phase I report[2] and available data indicated that any adverse effect on groundwater or surface water was unlikely. Other possible non-point sources of pollution included logging activities, but any effects would be most apparent in the tributaries and no data are available. The type of information required to assess the effects of forestry on water quality was outlined in the Phase I study[2].

3.2.2 Crestbrook Forest Industries Ltd.'s Pulp Mill

a) Description of the Process and the Effluent Streams

Crestbrook Forest Industries Ltd. operates a bleached kraft pulp mill at

Skookumchuck on the Kootenay River (Figure 7). Daily production in 1978 was about 480 tonnes. Details of the mill process were given in the Phase I report[2]. The main components of the process are outlined in Figure 8. They are: kraft liquor pulping, liquor recovery, brown stock washing and screening and bleaching. Also shown in Figure 8 are the sources and treatment sequence of the effluent, as they existed up to 1978.

Effluent entered the general, alkali and acid sewers which were combined and called the process sewer. In the general sewer, the major flow was the overflow from the unbleached white water tank, although condensates from black liquor evaporation were also present. The alkali and acid sewers received effluents from the bleach plant. In the bleach plant, effluent from caustic extraction went to the alkali sewer, and effluent from the chlorination and chlorine dioxide stages flowed to the acid sewer. The total mill effluent in the process sewer was settled, aerated in a 5-day lagoon and discharged to the Kootenay River via a submerged diffuser.

b) History of Pollution Control Permit PE-240

The Province issued Permit PE-240 to Crestbrook Forest Industries Ltd. on August 12, 1968 for discharge of treated effluent to the Kootenay River. On October 8, 1971, the Permit was amended in order to improve the effluent quality and to achieve a reduction in effluent colour, by August 12, 1975. The Permit is discussed in the Phase I report as are some methods for reducing colour and toxic compounds.

Crestbrook Forest Industries Ltd. appealed the amended Permit, and the Pollution Control Board heard the appeal on July 3, 1975. The Board's decision, released August 11, 1975 was primarily concerned with colour because the other Permit parameters met or were close to the Level A Forestry Objectives then in use[15]. Improvement of the effluent colour was considered by the Board to be necessary for aesthetic reasons and for odour reduction and reduction of possible effects on the stream biota.

The Board instructed the Pollution Control Branch and the Company to undertake a joint study, including mill trials for colour removal. Results of the joint study, published in August, 1976[16], outlined steps for in-plant modifications to control spills and described a mill trial using a modified bleach sequence.

Spills of black liquor resulted from failures with the diffusion washers and inadequate storage of pulp before bleaching. Major improvements, completed by the fall of 1977, included the installation of conventional displacement-type drum washers, the addition of high density storage tanks for both bleached and unbleached pulp, and the piping of spent acid to the newly installed black liquor oxidizer.

In May, 1976, the Company carried out a mill trial in which the first extraction stage in the bleach plant was replaced by a sodium hypochlorite stage. Although effluent colour was reduced by 60 to 85 percent, pulp quality was decreased by 10 percent and chemical use was increased[16].

Treatment of the whole mill effluent by the rapid infiltration method was evaluated next. In this method the effluent from the 5-day aeration lagoons was pumped to a basin, overlying a prepared gravel bed, and allowed to percolate intermittently into the ground. Colour reduction was achieved by a combination of absorption of certain compounds onto the soil and their breakdown by aerobic action. Trials on rapid infiltration were started in July, 1977, at test basins located as shown in Figure 7. The trials gave a 95 percent reduction in colour at test wells adjacent to the Kootenay River[17]. A hydrogeological study[18] indicated that the soil could handle the total mill effluent flow (about 0.63 m^3/s), and that effluent would enter the river approximately 2-5 km downstream from the highway bridge. The location of additional basins required to handle the total mill effluent is shown in Figure 7.

The Pollution Control Permit was amended again July 3, 1979, requiring final effluent disposal by the rapid infiltration method. The Company was required to control effluent colour by October 31, 1981 so that the true colour of the Kootenay River water would not exceed background levels by more than 15 APHA units. The Company appealed to the Pollution Control Board, asking for more time to evaluate the rapid infiltration process. The Board denied the appeal in their ruling of November 7, 1979. The Company then appealed to the Lieutenant-Governor in Council, as allowed by the Pollution Control Act, and this appeal has yet to be heard. A decision to proceed with a rapid infiltration system was made recently. The system should be in operation by the end of 1981.

c) Presentation of Effluent Data

Crestbrook Forest Industries Ltd. sampled the influent (site 0225035) and effluent (site 0225036) of the settling pond and both the Company and the B.C. Ministry of Environment monitored the effluent discharged to the Kootenay River (site PE 0024001) from the 5-day aeration lagoon. Data obtained during the period January, 1975 to April, 1978 are summarized in Table 5. Results of the monthly regulatory bioassays from

January, 1975 to September, 1978 are given in Table 6. Also included in Table 5 are the revised Pollution Control Objectives for effluent from a kraft process[19]. The Level A objectives are equivalent to conditions required by the amended Permit, issued July 3, 1979.

Several of the parameters given in Table 5 were evaluated to determine whether changes occurred over the three and one-quarter year sampling period, and to assess the effectiveness of the treatment facilities. The mean monthly values (± standard error) for BOD_5 and suspended solids before and after treatment are presented in Figures 9 and 10. Mean monthly loadings of suspended solids and of BOD_5 and the corresponding calculated increase of suspended solids and decrease of dissolved oxygen in the Kootenay River are plotted in Figures 11 and 12. Figures 13 and 14 give the mean monthly levels (± standard error) for mill production, effluent flow and final effluent colour. Figure 14 also gives the effluent dilution in the river, assuming complete mixing. This was obtained by dividing the mean monthly river flows near Skookumchuck by the corresponding mean monthly effluent flows.

Average monthly river flows near Skookumchuck, based on the 26 years of record, and the mean monthly colour levels (± standard error) in the Kootenay River, upstream and downstream from Crestbrook Forest Industries Ltd., are given in Figure 6. The increase in river colour in relation to river flow and the distribution of daily river flows are shown in Figure 5.

d) Discussion of Effluent Data

The Pollution Control Board Appeal Decision of August 11, 1975 emphasized the need to reduce effluent colour. However, since January, 1975 the levels of several of the other parameters had also been high (Table 5). Only pH and temperature were consistently within Level A of the Forestry Objectives for kraft effluent[19]. Parameters which showed frequent high values and which warrant discussion are BOD_5, suspended solids, fecal and total coliforms, oil and grease, toxicity and colour. Levels of resin acids, phenols and tannin and lignin-like compounds were also high in the final effluent and are considered when discussing toxicity and colour.

(i) BOD_5

The effluent treatment, particularly aeration, substantially reduced the BOD_5 levels and variability (Table 5 and Figure 9). The overall mean was 50 mg/L, and equalled the level A Objective[19] of 7.5 kg/t. However, the mean monthly values for the period January, 1975 to April, 1978 exceeded Level A 41 percent of the time and 100 percent of the time since October, 1977. The consistently high values since October, 1977, were probably due to the increase in pulp production (Figure 13) and the installation of the more efficient displacement washers.

According to Figure 12, a reduction in dissolved oxygen levels of up to 2 mg/L was predicted for 11 of the 37 months, from January 1975 to December 1977, (i.e. each year during low river flow). The actual decrease during these eleven low river flow months from the upstream (0200175) to the downstream (0200048) sites was 0.34 ± 0.06 mg/L (mean ± standard error). The predicted decrease was greater because of water temperature. The BOD_5 determinations were carried out at 20^oC whereas the river-water temperature during low flow months was closer to 5^oC. From 20^oC to 5^oC, a fifty percent reduction in BOD_5 levels is expected for domestic sewage[20]. Assuming such a 50 percent reduction, the oxygen demand per second in the Kootenay River at maximum daily production (512 t), maximum daily BOD levels (18 kg/t) and minimum recorded mean monthly river flow (20.1 m^3/s) would be:

$$0.5\ \left(\frac{18 \times 512 \times 1\ 000}{86\ 400}\right) = 53.3\ g/s.$$

The resulting oxygen decrease would be $\frac{53.3}{20.1}$ = 2.7 mg/L which would not reduce the dissolved oxygen levels in the river below the minimum value (5 mg/L) required for the protection of aquatic life[21]. This prediction is conservative since it does not allow for oxygen supplied by reaeration. Some reaeration normally takes place in the river, except when it is covered with ice in the winter.

In July-August, 1978, Crestbrook Forest Industries Ltd. installed seven additional aerators in the lagoons, bringing the total to 25 or 625 HP. These were expected to augment the microbe oxygen supply, reduce the effluent BOD_5, and reduce effluent toxicity.

(ii) Suspended and Volatile Suspended Solids

The levels of suspended solids were greatly reduced by settling and further reduced during aeration (Figure 11). The overall mean of 85 mg/L, or 9.5 kg/t, was slightly below the level A objective (10 kg/t). However, the mean monthly levels of suspended solids discharged to the river still exceeded level A 39 percent of the time.

Sources of suspended solids within the process are indicated in Figure 8. High levels of suspended solids could also have resulted from process spills (as no recovery basin was present), dumping of excess lime mud not handled by reburning and not needed for neutralization, and reduction in settling from infrequent cleaning of the settling basins.

There does not appear to be a direct relationship between peak values of suspended solids and the period just before cleaning when the settling basins would have been most full (Figure 10). Since the suspended solids levels given in Figure 10 are expressed in terms of production (kg/t), artificially high values could have been recorded for low production days. Levels of suspended solids in the settling basin effluent (0225036), expressed in absolute concentration (mg/L), showed occasional high values[22] which were not related to the period of use of the two basins. This suggests that the peak levels of suspended solids may have been due to a combination of the factors outlined above.

Loadings of suspended solids (Figure 11) were averaged monthly because of the variation in pulp production rate, and the time lag between the discharge of raw effluent to the settling basin and the discharge of final effluent to the river. Increases in suspended solids in the Kootenay River (Figure 11) were obtained by dividing the mean monthly loadings (kg/d) by the mean monthly river flows near Skookumchuck (m^3/s)[23], and converting the results to mg/L. The results show that mean monthly loadings were quite variable, but that the maximum mean monthly increase of about 2 mg/L occurred consistently during low river flows. Increases of suspended solids in the river would have been slightly greater than 2 mg/L on individual days. Unless the suspended material settled out and accumulated near the effluent diffuser, and this was not observed[24], the suspended solids should have had a negligible effect on the Kootenay River[25].

The volatile portion of suspended solids represented primarily fibrous material and some biomass, such as bacteria and algae, from the aeration pond. It formed 67 2.0 (mean standard error) percent of the suspended solids. During low river flows, the volatile suspended solids could have increased in the Kootenay River by approximately 1.3 mg/L. This should not have affected the aquatic biota or any use of the Kootenay River water[25].

If the Kootenay River diversion proceeds, the river flow at Canal Flats could be reduced to 5.7 m^3/s and the flow near Skookumchuck to $1.31 \times 5.7 \simeq 7.5$ m^3/s. A flow near Skookumchuck of 7.5 m^3/s represents a decrease of approximately 70 percent of the historical mean monthly low flows. It would result in a hypothetical increase of suspended solids in the river of about 7 mg/L (100/30 x 2 mg/L ≈ 7 mg/L) and a corresponding increase of volatile, suspended solids of about 4.5 mg/L (0.67 x 7 ≈ 4.5), assuming direct discharge of the effluent to the river. Although values may be greater on individual days, these increases would not be expected to have an adverse effect on the aquatic biota[25] or on the existing use of the Kootenay River water.

(iii) Coliforms

Table 5 shows geometric mean values of 398 MPN/100 mL for fecal coliforms, and 5 995 MPN/100 mL for total coliforms in the final effluent. The domestic sewage from the pulp mill was discharged separately from the process effluent into Skookumchuck Creek. It is probable that many of the fecal coliforms were of the genus Klebsiella, which are not of fecal origin. Klebsiella meet the analytical criteria for fecal coliforms and could have multiplied in the carbohydrate-rich media supplied by pulp mill effluent. Some species of Klebsiella can cause urogenital and respiratory infections, and thus the presence of inordinately large numbers of these organisms in recreational waters may be a health hazard[26].

The high levels of total coliforms in the final effuent were probably due to vegetative-type coliforms from the wood being processed. These coliforms could have multiplied in the carbohydrate-rich effluent. Significant increases in the total coliform levels were apparent in the Kootenay River downstream from the pulp mill.

Monitoring of the fecal coliforms in the final effluent should continue, and if frequent high levels are observed in both the effluent and the receiving water, the species of coliforms present should be examined.

(iv) Oil and Grease

Oil and grease showed high levels in the effluent, with an overall average of 12 mg/L (Table 5). The mean value and 50 percent of the individual measurements exceeded the Pollution Control Objective for oil in effluent from sawmills and plywood mills[19] (10 mg/L). Kerosene, which was used at Crestbrook Forest Industries Ltd. as a pitch dispersant, could have accounted for the high levels of oil and grease[22], although hydrocarbons in general may also have contributed to the high values. Oily wastes reduce the palatability of fish and can have deleterious effects on aquatic organisms by coating the mucous membranes[21]. The levels of oil and grease should be reduced to less than 10 mg/L in the effluent.

(v) Toxicity and Toxic Components

The toxicity increased in 1978, perhaps due to the increased production (Figure 13) and the installation of more efficient displacement washers. Only two of the 15 bioassays conducted in the first eight months of 1978 met the 96-hour LC_{50} of 100 percent effluent, stipulated in the Objectives[19]. The remaining tests had LC_{50} values of 20 to 65 percent effluent (Table 6). The 96-hour LC_{50} is the concentration of effluent which results in 50 percent mortality of test fish after 96 hours.

Walden[27], in his review of the toxicity of pulp and paper effluents, noted that there is no sublethal stress in organisms at concentrations of bleached kraft mill effluent below 0.05 of the 96-hour LC_{50}. Using this criterion, we calculated hypothetical LC_{50} values for the effluent from Crestbrook Forest Industries Ltd. which would minimize sublethal stress. The calculation was done for three effluent and river flow conditions.

First, we used the minimum mean monthly dilution of the effluent in the Kootenay River, in the period January, 1975 to December, 1977. This dilution was 1:37 (Figure 14) or 2.6 percent effluent in the river. The LC_{50} value required to minimize sublethal stress under these conditions would be 2.6/0.05 = 52 percent effluent. This value was frequently attained in 1976 and 1977 but seldom in 1978 (Table 6).

Second, we assumed that the minimum mean monthly river flow near Skookumchuk (20.1 m^3/s) and the maximum effluent flow (0.6 m^3/s) occurred simultaneously. These conditions would give an effluent dilution in the river of $\frac{0.6 \times 100}{20.7} = 2.9$ percent and the LC_{50} required would be 2.9/0.05 = 58 percent effluent. This was seldom attained in 1978.

Third, we calculated the effluent dilution if the Kootenay River diversion proceeds and direct discharge of the effluent to the river continues. The river flows near Skookumchuck would be 7.5 m^3/s, based on 5.7 m^3/s at Canal Flats and a 31 percent increase at Skookumchuck. Using the mean effluent flow of 0.56 m^3/s (Table 5), the percent effluent in the river would be $\frac{0.56 \times 100}{8.06} = 6.9$ percent. The LC_{50} value necessary to limit the possibility of sublethal stress on organisms would be 6.9/0.05 = 138 percent, or no mortality in 100 percent effluent. No mortality in 100 percent effluent was found only in 2 (May and September) of the 15 bioassays conducted in 1978.

The above calculations assume complete mixing of the effluent and river water. They are also based on effluent flows which were estimated from the volume of make-up water used in the process each day. In spite of these approximations the results do suggest that during 1978, the organisms in the Kootenay River were stressed during low river flow by the effluent. They also indicate that LC_{50} values of at least 60 percent effluent should be consistently attained to minimize the possibility of sublethal stress, although an effluent flow gauge should be installed to confirm this figure. If the Kootenay River diversion proceeds and direct effluent discharge occurs, LC_{50} values of 100 percent effluent would be required.

The contribution of various compounds in kraft mill effluents to fish toxicity has been examined(27, 28). In pulping effluent, there are resin acids, unsaturated fatty acids and volatile reduced sulphur compounds which contribute to the toxicity. In bleach plant effluent, toxicity is caused by chlorinated lignin degradation products (tri and tetrachloroguaiacol) and chlorinated resin acids. When the effluent streams are combined, resin acids appear to be the major toxicant(27). Little or no toxicity has been attributed to tannin and lignin-like compounds and their phenolic degradation products(27), although phenol itself is toxic in low concentrations. Phenolics however, do cause tainting of fish(21) and tannin and lignin-like compounds contribute to effluent colour.

Resin acids, phenols and tannin and lignin-like compounds were monitored in the effluent from Crestbrook Forest Industries Ltd. (Table 5). The results for phenols include both phenol and phenolic degradation products of tannin and lignin-like compounds which do not contribute greatly to the effluent toxicity. The levels of resin acids were reduced by the treatment facilities (Table 5), although the levels in the final effluent were greater during the first four months of 1978 (lowest value 3.2 mg/L) than the range of values known to be toxic to aquatic organisms (1 to 2 mg/L)(21). These high values may partially explain the increased toxicity, at least during the first quarter of 1978.

Aeration of kraft effluent in a well-operated aeration lagoon reduces levels of resin acids substantially[28, 29]. Aeration does not, however, reduce the levels of chlorinated guaiacols and has only a limited effect on chlorinated resin acids. The concentration of these chlorinated compounds in the effluent from the pulp mill was not known, but studies at other British Columbia mills show that only resin acids are present at acutely lethal levels before aeration[28, 29]. Assuming similar conditions exist at Crestbrook Forest Industries Ltd., we can expect that the improved aeration from the additional aerators installed in July-August, 1978 will have reduced effluent toxicity.

Additional bioassays are required. If the LC_{50} values are not consistently greater than 60 percent effluent (or 100 percent if the Kootenay River diversion is to proceed), the concentrations of the toxic components present should be determined if direct discharge of the effluent to the river continues.

(vi) Colour

Colour has been the effluent parameter of greatest concern at Crestbrook Forest Industries Ltd. and studies investigating methods to reduce effluent colour have been ongoing since 1971. Studies were also being conducted by B.C. Research to assess the effect of effluent colour on periphyton productivity in the Kootenay River.

The overall mean effluent colour from January, 1975 to April 1978 was 1 890 colour units (Table 5). Figure 13 shows high monthly values in the first half of 1975, in the latter part of 1977 and the first quarter of 1978. In 1975, operational problems may have contributed to the high colour values. In October, 1975 the analytical procedure was changed to the method adopted by the Canadian Pulp and Paper Association (CPPA)[16], and thus the values before and after October, 1975 are not strictly comparable. The high levels in the latter part of 1977 and the first quarter of 1978 correspond to increases previously discussed for BOD_5 and toxicity. High colour was also probably due to the increase in pulp production (Figure 13) and the installation of the more efficient displacement washers.

The Pollution Control Objectives for kraft effluent quality[19] do not give colour levels, but do state that only a negligible increase should be apparent in the receiving water. This has not been the situation in the Kootenay River, downstream from the pulp mill. During low flows (November to April, inclusive), the mean monthly river colour increased 5 to 12.5 fold below Crestbrook (Figure 5).

The calculated reductions in effluent colour, required to achieve colour levels of 10, 15 and 20 CPPA colour units in the Kootenay River, downstream from Crestbook Forest Industries Ltd. (river site 0200048), are given in Table 7, assuming direct discharge of effluent. They are conservative estimates as they assume a linear relationship between colour reduction and river dilution whereas the relationship is more logarithmic as shown in Figure 6. The data in Table 7 suggest that a colour reduction of about 80 percent would be required during low river flows to achieve a downstream colour value of 10 CPPA units, a value which is still somewhat higher than upstream colour levels (Figure 5).

If the Kootenay River diversion proceeds, the effluent flow could be about 6.9 percent of the river flow, assuming direct discharge of effluent. This would be approximately three times the percentage (2.6 percent) in 1975-1978 during minimum mean monthly river flows. Effluent colour removal approaching 100 percent would be required to achieve downstream river values of 10 CPPA units.

The colour of kraft effluent is attributed to oxidation of tannin and lignin-like compounds and other organic wood extractives[30]. There is enhancement of the colour due to complexing of iron, coming from machinery corrosion. These compounds absorb blue and red wave lengths, with blue dominating, giving a visible brown colour[16]. Additional oxidation (biological or chemical) is required to reduce the colour. Oxidation and possibly adsorption are the processes occurring in the rapid infiltration method. Trial runs indicate that approximately 95 percent colour reduction can be achieved by rapid infiltration[17]. This method is being adopted as the practical solution to the colour problem at Crestbrook.

3.3 Water Quality

3.3.1 Presentation of the Data

B.C. Ministry of Environment and Crestbrook Forest Industries Ltd. have collected and analyzed water samples from four sites. The site locations are shown in Figures 3 and 7 and the site descriptions are given below:

- site 0200020: at Canal Flats, 30 km upstream from Crestbrook Forest Industries (corresponds to Water Survey of Canada site 8NF002)
- site 0200175: just downstream from Skookumchuck Creek confluence, 0.5 km upstream from Crestbrook Forest Industries.

site 0200048: at Highway 93/95 bridge, 2.5 km downstream from Crestbrook Forest Industries (corresponds to Water Survey of Canada site 8NG053)

site 0200019: at Wasa, 18 km downstream from Crestbrook Forest Industries, 21 km upstream from the St Mary River confluence.

Data obtained from these sampling sites during the period January, 1975 to June, 1978, inclusive, are summarized in Tables 8 and 9. Table 8 lists parameters of major interest and those affected by the pulp mill effluent. The remaining parameters are given in Table 9. The variations of sodium, suspended solids, turbidity, total phosphorus, inorganic nitrogen, phenols and tannin and lignin-like compounds with time at three sites are shown graphically in Figures 15 to 18.

Studies on the effect of effluent on periphyton growth and on stress to juvenile salmon were carried out by B.C. Research for the Council of Forest Industries in 1977-1978. The results of the study have not been released.

3.3.2 Discussion of Results

Of the parameters considered in Table 8, pH and dissolved oxygen showed the least change between sites upstream and downstream from the pulp mill. During low river flows, the dissolved oxygen was lower at the downstream site by about 0.3 mg/L. Other parameters of interest are discussed below.

a) Effluent Mixing and Dilution

Sodium salts are present in large quantities in kraft liquor and high levels of sodium were present in the effluent (Table 5). Sodium was used to determine the presence of effluent at the two river sites downstream from Crestbrook Forest Industries Ltd. Figure 15 shows the monthly sodium levels (one data point per month) at Canal Flats (site 0200020), and at sites 0200048 and 0200019, 2.5 and 18 km respectively, downstream from the pulp mill. The trend over the three and one-half years was consistent. Higher levels were found at the three sites during low river flows (November to April) than during high flow months with the highest values at site 0200048 and the lowest at site 0200020. The peak values occurred during February and March which were the months with the lowest mean monthly flows (24.4 and 23.7 m^3/s, respectively, Figure 4).

The concentrations of sodium at the two downstream sites, were expressed as a percent of the sodium concentration in the effluent. The following equation of Minns[31], which allows for the background river concentration, was used:

$$Cr = \left(\frac{Ca-Cb}{Ce-Cb}\right) \times 100$$

where Cr = relative concentration, as a percent of effluent concentration.
Ca = downstream concentration in the river.
Cb = background concentration in the river.
Ce = effluent concentration.

Results are plotted in Figure 15. The peak values at site 0200048 were in the range of 2.3 to 3.0 percent and were similar to calculated effluent dilutions (1 in 43 to 1 in 39 or 2.3 to 2.6 percent, Figure 13). These results suggest that complete mixing of the effluent occurred within 2.5 km of the pulp mill.

The relative concentration of sodium at Wasa (site 0200019), 18 km from the pulp mill showed peak values during low river flows of 1.5 to 1.9 percent. This result indicates that, in the 15.5 km stretch of river between sites 0200048 and 0200019, the effluent was further diluted by about 35 percent. These results show that sodium is useful in assessing the relative concentration of effluent in the river, especially in the absence of an effluent flow gauge at the mill.

b) Suspended Solids and Turbidity

The levels of suspended solids and turbidity increased at all sites during high river flows (Figure 16). There were insufficient data on suspended solids at sites downstream from the pulp mill to indicate if increases over upstream sites occurred. However, turbidity levels were consistently higher at site 0200048 than at the control site 0200175, just upstream from the mill, during low river flows. Considering turbidity as an indicator of suspended solids suggests that an increase in suspended solids occurred during low flows downstream from the pulp mill, but the levels would not adversely affect aquatic life and other water uses[25, 27].

The volatile suspended solids were considered representative of the fibrous material and biomass (bacteria, algae, etc.) from the pulp mill effluent. The values at site 0200048 ranged from 1 to 4 mg/L with one value of 14 mg/L in May, 1976. At these levels volatile suspended solids would not have interfered with any of the existing water uses.

c) Coliforms

Levels of fecal and total coliforms increased downstream from Crestbrook Forest Industries Ltd. Levels were less than 2 MPN/100 mL at the control site 0200175, and geometric mean values were 5.4 MPN/100 mL for fecal and 14 MPN/100 mL for total at Canal Flats. At site 0200048, downstream from the mill, the geometric means were 68 for fecal coliforms and 2 432 for total coliforms (Table 8).

As discussed in Section 3.2.2 d (iii), the fecal coliforms in the pulp mill effluent were not of fecal origin only, but probably included species of Klebsiella, which meet the analytical requirements for fecal coliforms. The total coliforms were attributed to vegetative-type coliforms. The overall median fecal coliform level of 36 MPN/100 mL was within the general objective of 200 MPN/100 mL for B.C. waters. But because occasional high levels of fecal coliforms were found (maximum over 24 000), and because some genera of Klebsiella can cause urogenital and respiratory infections, monitoring of fecal coliforms should continue.

d) Nutrients and Periphyton Productivity

The major nutrients required by aquatic vascular plants and algae (including attached algae or periphyton) are inorganic nitrogen, particularly ammonia and nitrates, and orthophosphate. These nutrients can also be toxic in high concentrations.

Inorganic nitrogen levels at the control sites were similar to levels at the two downstream sites (Figure 17). Total phosphorus levels were highest during high river flows, but the phosphorus was probably bound to particulate matter and unavailable as a nutrient. During the low river flows of 1976, 1977 and 1978, the total phosphorus levels were slightly higher at the two downstream sites, but were less than the general objective of 0.05 mg/L, below which nuisance plant and algae growth is avoided[32]. Dissolved orthophosphate phosphorus levels were consistently 0.003 mg/L or less at the three river sites (Table 8).

Phosphate was added to the aeration basin until 1976 and then only nitrogen was added to assist biological degradation of the effluent. To check nutrient availability for summer growth of algae would require daily analyses of the effluent and the receiving water for two weeks, just after ice-break up. A measure of effluent flow rate would also be needed.

Before 1975, studies showed increased periphyton biomass and altered periphyton species composition downstream from Crestbrook Forest Industries Ltd.[2]. No periphyton data were available after 1975. If increased periphyton biomass is observed in the future, and if nutrients are becoming available immediately after ice-breakup, a detailed periphyton study may be needed. The effect of effluent colour on periphyton productivity may also need study.

e) Phenols

The results for phenol were not truly quantitative because of the analytical procedure[33]. In the method used, all of the phenolics in the sample were referenced against phenol, and measured colorimetrically at the optimium wave length for phenol absorption. General comparisons of levels in the Kootenay River are reasonable because the source of phenolics was consistent. The phenolics present were the hydroxy-derivatives of benzene which resulted from partial oxidation of tannin and lignin-like compounds and other wood extractives.

Although there were limited control data from upstream sites, the results suggest that the levels of phenols increased downstream from Crestbrook Forest Industries Ltd. (Table 8). Figure 18 shows that the high values at the two downstream sites occurred during low river flows. The highest values (up to 0.029 mg/L) were at site 0200048, 2.5 km fom the pulp mill. Slightly lower levels (up to 0.024 mg/L) were found at Wasa (site 0200019), 18 km from the mill.

Phenolics contained in kraft effluent show limited toxicity, but can affect the taste and odour of water and taint fish flesh[21]. A value of 0.002 mg/L for phenols is suggested as an acceptable level for drinking water[21]. This value was exceeded by 76 percent of the measurements at site 0200048 and by 61 percent of the analyses at site 0200019.

Different phenols affect fish palatability at different concentrations. For example, 2,4-dichlorophenol can affect taste at levels as low as 0.001 to 0.005 mg/L[21]. The types of phenol present in the effluent from the pulp mill and in the Kootenay River were not known. However, levels in the river, particularly during low flows, were higher than levels found to cause tainting of fish. In 1971 and 1973, mountain whitefish and cutthroat trout caught downstream from Crestbrook Forest Industries Ltd. were found to be tainted[2]. The levels of phenols had not changed much since 1973, and therefore some fish may still have been tainted. No complaints of tainting had been received by the local office of the Fish and Wildlife Branch.

Rapid infiltration should remove some of the phenols, although this possibility was not examined during the trial runs. The ability of rapid infiltration to eliminate phenols should be assessed when the system is in operation.

f) Toxicity

Calculations with effluent data in Section 3.2.2 d (v) suggest that during low river flows, particularly in 1978, sublethal toxicity may have occurred downstream from the pulp mill. No data on the actual effects on the aquatic biota in the river were available.

g) Colour

There was a pronounced increase in river colour at site 0200048, 2.5 km downstream from Crestbrook Forest Industries Ltd. The increase was up to 40 CPPA colour units above background, as shown in Figure 5. At site 0200019, 18 km from the pulp mill, the level during low flows was 30 to 40 CPPA colour units compared to control values at site 0200175 of less than 10 CPPA colour units.

Partially oxidized tannin and lignin-like compounds and other wood extractives[30] from the pulp mill effluent were the major source of river colour. The monthly levels of tannin and lignin-like compounds at the control site (0200175) and the two downstream sites (0200048 and 0200019) were similar to the data for sodium (Figure 18). At the two downstream sites, the levels were highest during low river flows. The highest values were 2 to 5 mg/L at site 0200048, or 20 to 50 times the control values. There were slightly lower values (1.5 to 4 mg/L), except during January, 1978 (6 mg/L), at site 0200019 (Figure 18).

The colour constituents do not contribute to the effluent toxicity, as measured by LC_{50} values, because the acute toxicity can be reduced without reducing the colour.

Colour affects the use of water for domestic supplies, causes deleterious or possible long-term toxic effects on the aquatic biota and is aesthetically displeasing[34].

The acceptable limit for the colour of treated drinking water is 15 true colour units[21]. This value was almost always exceeded during low river flows (November to April, inclusive) at both of the downstream sites.

Deleterious effects of high colour levels on aquatic organisms include the inability of organisms, which selectively obtain food by sight, to find the appropriate food items. This could result in altered community structures.

There are two possible long-term toxic effects. First, colour may inhibit primary productivity, although increased periphyton biomass was observed downstream from the pulp mill before 1975[2]. Second, metals that complex with organic materials become available to plants and animals[34]. The organic components of colour may have complexed metals discharged in the St. Mary River, thus rendering the metals available to aquatic life in the Kootenay River, downstream from the St. Mary River confluence.

The actual effects of colour on aquatic life in the Kootenay River were not known, but the colour was aesthetically displeasing and colour removal would have been necessary before the water could be used for domestic purposes. To achieve 10 CPPA colour units at site 0200048, a colour which is slightly higher than upstream levels, a reduction in effluent colour of approximately 80 percent would have been required (Table 7). The rapid infiltration method may reduce effluent colour by up to 95 percent (Section 3.2.2 d (vi)).

3.4 Conclusions and Recommendations

3.4.1 Effluent Dilution and Mixing

Sodium was a useful indicator of effluent concentration in the Kootenay River, particularly as there was no effluent flow gauge at Crestbrook Forest Industries Ltd. Calculated concentrations showed that mixing of the effluent was complete 2.5 km downstream from the pulp mill. Without an effluent flow gauge, daily sodium analyses of the effluent and of the Kootenay River would be required for a period just after ice-breakup to assess effluent concentration in the river, assuming direct discharge of effluent to the river.

3.4.2 BOD_5

The BOD_5 in the Crestbrook Forest Industries Ltd.'s effluent frequently exceeded level A of the Forestry Objectives. The BOD_5 was high after October, 1977, when the inefficient bleach-plant washers were replaced and pulp production increased. Dissolved oxygen levels in the Kootenay River downstream from the pulp mill had sometimes been reduced. However, the dissolved oxygen was expected to remain above the minimum value needed for the protection of aquatic life, when maximum production and BOD_5 levels and minimum mean monthly river flows occurred simultaneously.

Additional aerators were installed to reduce the effluent BOD_5. Sampling for BOD_5 should continue to measure their effectiveness, if direct discharge of effluent to the river continues.

3.4.3 Suspended Solids, Turbidity and Volatile Suspended Solids

Suspended solids in the Crestbrook Forest Industries Ltd.'s effluent varied and often exceeded the levels stipulated in the Forestry Objectives. However, only a small increase in suspended solids was predicted in the river, downstream from the mill, based on effluent loadings. This prediction was supported by turbidity values, which were slightly greater downstream from the pulp mill during low river flows. The data suggest that suspended solids would have a negligible effect on the aquatic biota and water use, even if the Kootenay River diversion proceeded and there was direct effluent discharge.

More than half of the suspended solids in the effluent were volatile, presumably fibrous material and biomass (algae, bacteria etc.). Volatile suspended solids in the river were not expected to limit the existing water uses, even if the Kootenay diversion proceeded and there was direct effluent discharge.

Sampling for suspended solids and volatile suspended solids in the effluent and in the river should be continued to enable more accurate assessment of their effects. Turbidity analyses in the river should also be continued.

3.4.4 Coliforms

The domestic sewage from Crestbrook Forest Industries Ltd. was discharged separately from the pulp mill effluent. The fecal coliforms in the pulp mill effluent were believed to be due in part to the genus Klebsiella which are not of fecal origin, but which meet the analytical criteria for fecal coliforms. The total coliforms were attributed to vegetative-type coliforms in the wood. Because high levels of fecal coliforms were found occasionally, and because some species of Klebsiella can cause urogenital and respiratory infections, sampling for fecal coliforms in the effluent and the Kootenay River should continue. If high levels occur frequently, the species present should be determined.

3.4.5 Oil and Grease

Oil and grease levels in the pulp mill's effluent and in the Kootenay River were high, possibly due to the use of kerosene as a pitch dispersant. The levels in the effluent should be reduced.

3.4.6 Nutrients and Periphyton Productivity

Nutrient concentrations were similar upstream and downstream from Crestbrook Forest Industries Ltd. Total phosphorus levels were slightly higher at the downstream sites, during low river flows, but below levels which promote the nuisance growth of plants. No data after 1975 were available on periphyton productivity.

Nutrient analyses should be carried out on the effluent and the Kootenay River water, just after ice-breakup, to determine the potential nutrient availability for summer growth of periphyton, especially if direct discharge of effluent continues. This determination also requires the installation of an effluent flow gauge. Visual observations should be made of the periphyton to assess whether biomass is increasing downstream. Detailed studies may be required to measure the biomass increase and the species composition.

3.4.7 Phenols

The phenols present in the pulp mill's effluent were not identified. In the Kootenay River, particularly during low flows, the levels of phenols were high at distances up to 18 km from the pulp mill. These levels frequently exceeded drinking water criteria and levels which could cause tainting of fish. The phenols should be sampled in the effluent and at the three Kootenay River sites for ten consecutive days just after ice-breakup. These measurements will help determine loadings to the river.

Rapid infiltration should remove at least some of the phenols. When rapid infiltration proceeds, its effectiveness in reducing phenols should be assessed.

3.4.8 Toxicity

The toxicity of the effluent from Crestbrook Forest Industries Ltd. increased during the first eight months of 1978. It reached levels which could have caused sublethal stress in aquatic biota in the Kootenay River.

The resin acids are one of the major contributors to toxicity and their levels in the effluent and at the Kootenay River sites should be determined. Weekly bioassays should be conducted to measure 96-hour LC_{50} values if direct discharge continues. These values should be greater than 60 percent effluent (or 100 percent if the Kootenay River diversion proceeds) to minimize sublethal stress on the aquatic biota in the Kootenay River.

If direct discharge of the effluent continues, and if the suggested LC_{50} values are not consistently attained, the main toxic constituents present in the effluent should be identified. Methods to reduce toxicity can then be developed.

Rapid infiltration is expected to reduce the effluent toxicity. Once this treatment method is in place the toxicity, and if necessary, resin acid content of water from test wells should be measured.

3.4.9 Colour

Colour of the pulp mill's effluent was one of the main concerns. Significant increases in colour were apparent in the Kootenay River, particularly during low flow, for at least 18 km downstream from the pulp mill. The increased river colour was aesthetically displeasing and would have had to be removed before the water could be used domestically. High colour levels may also have affected the aquatic biota by decreasing light penetration, and thus primary productivity, and by reducing visibility for prey selection. In addition, the colour constituents may have complexed with metals making the metals more available for uptake by aquatic organisms.

These problems indicate that the colour levels should be reduced. An effluent colour reduction of about 80 percent (approaching 100 percent if the Kootenay River diversion proceeds) would be necessary to achieve river colour levels of 10 CPPA colour units just downstream from the pulp mill, assuming direct discharge of effluent. Rapid infiltration appears capable of reducing the effluent colour by approximately 95 percent.

3.4.10 Monitoring Program

a) Effluent

Frequent analyses of the important effluent parameters are necessary to assess changes with time and to calculate loadings. Changes are produced by variations in production and in-plant problems. The calculation of effluent loadings will require the installation of an effluent flow gauge.

During the ten-day intensive river sampling after ice-breakup the parameters listed below, except for resin acids and "other", should be measured daily. When the rapid infiltration method is used, these parameters should be measured in the rapid infiltration basin and in the test wells adjacent to the river at the suggested frequencies until the effectiveness of the basin is determined and consistent results are obtained. The frequencies should then be modified accordingly.

The following measurements, related to the effluent, are suggested:

production, daily	
effluent flow, daily	- an effluent flow gauge should be installed.
colour, daily	
sodium, daily	- only until an effluent flow gauge is installed and when assessing the rapid infiltration method.
suspended solids, weekly	
volatile suspended solids, weekly	
BOD_5, weekly	
fecal coliforms, weekly	- if frequent high levels are observed the species present should be determined.
	- if frequent low levels are found, analyses should be less often.

toxicity, weekly - until LC_{50} values greater than 60 percent (100 percent if the Kootenay River diversion proceeds) are consistently attained, then monthly.

phenols, weekly

tannin and lignin-like compounds, weekly

oil and grease, monthly

inorganic and total nitrogen, monthly

ortho- and total phosphorus, monthly

resin acids
- for quantitative results a gas chromatogram is necessary - the resin acids measured should be abietic, dehydroabietic, neoabietic, pimaric, isopimaric, sandaracopimaric and palustric.
- they should be measured at least once in the effluent and, when rapid infiltration is used, they should be measured in the effluent and in the test wells adjacent to the river.

other
- if the effluent toxicity is not reduced by treatment the effluent should be analyzed by gas chromatography to determine the concentrations of toxic constituents, other than resin acids. These may include:

  monochloro-dehydroabietic acid
  dichloro-dehydroabietic acid
  trichloroguaiacol
  tetrachloroguaiacol
  unsaturated fatty acids

b) Receiving Waters

Data collected from 1975 to 1978 indicate that several contaminants could have attained levels during low river flows that may have affected the aquatic biota, the domestic use of the water and the aesthetics of the river. In some cases, insufficient data were available. Intensive sampling for a ten-day period during low flow, just after ice-breakup, is therefore recommended. This will provide more precise data during "worst conditions", especially if direct discharge of the effluent is occurring.

The following parameters should be measured each day, for ten days, just after ice-breakup at the river sites 0200175, 0200048 and 0200019:

field measurements
- dissolved oxygen
- pH
- temperature

field observations
- foam
- odour
- oil and grease
- periphyton (during early summer)

laboratory analyses
- sodium (if an effluent flow gauge has not been installed)
- colour
- phenols
- tannin and lignin-like compounds
- suspended solids
- volatile suspended solids
- turbidity
- inorganic nitrogen (nitrate/nitrite, ammonia)
- ortho- and total phosphorus
- fecal coliforms
- resin acids - a gas chromatograph is required and the acids listed for the effluent should be measured.

c) Possible Savings With the Recommended Monitoring Program

The numbers of analyses of the effluent and Kootenay River performed by Crestbrook Forest Industries Ltd. and the B.C. Ministry of Environment from 1975 through 1978, and the numbers recommended for the future, are summarized in Table 10. The four years of data were valuable in assessing trends and isolating important parameters, but a considerable reduction in the number of routine analyses can now be made. For the effluent and river, the reductions are 64 and 78 percent respectively. Assuming an average cost of $14.00 per analysis, this reduction represents a mean yearly saving of about $67 000.

Not included in these calculations are the costs of the gas chromatographic analysis (less than $5 000), of sampling of the influent and effluent to the settling pond by the Company, and of sampling the rapid infiltration system when it is used.

4. THE ST. MARY RIVER

4.1 Hydrology of the St. Mary River

The St. Mary River flows southeast along the eastern slope of the Purcell Mountains for about 50 km to St. Mary Lake, and from the lake an additional 42 km to the Kootenay River at Fort Steele (Figure 3). It is typical of temperate-climate rivers with low flows under ice during the winter and high flows during spring snow melt. The mean monthly flows at the outlet of the lake (Water Survey of Canada site 8NG046) for 1946 to 1976 ranged from 6.8 m^3/s (February) to 175 m^3/s (June)[12]. Minimum and maximum daily discharges were 0.54 m^3/s on January 20, 1946 and 481 m^3/s on June 17, 1974[12].

At Wycliffe, 25 km from the lake outlet (Water Survey of Canada site 8NG012 and B.C. Ministry of Environment site 0200135, Figure 3), the mean monthly flows ranged from 8.9 m^3/s (February) to 230 m^3/s (June), as shown in Figure 19. The seven-day average low flows at Wycliffe for 1947 to 1972 varied from 4.4 m^3/s, which could occur once in 25 years, to 11.1 m^3/s, which could occur once a year[13]. Minimum and maximum daily discharges were 4 m^3/s on March 4, 1948 and 1 073 m^3/s on June 19, 1976[12].

4.2 Discharges to the St. Mary River

4.2.1 Introduction

The effluents from Cominco Ltd.'s Sullivan Mine, ore concentrator and fertilizer complex were the major discharges to the St. Mary River, from 1975 to 1978. Municipal effluent from the Kimberley sewage treatment plant (Figure 3) was also discharged to the St. Mary River. The municipal effluent from the Cranbrook sewage treatment plant was released to Joseph Creek (Figure 3) until June, 1977, but since then the effluent has been stored in a reservoir and used for spray irrigation of forage crops. The disposal of the effluent by spray irrigation is under Pollution Control Permit PE-4148, and there is no positive discharge to the creek. The prime concern is the water and nutrient balance among the water, crops and land.

Non-point sources of contaminants to the St. Mary River Basin included leachates from solid waste landfills at Kimberley and Cranbrook, nutrients from agricultural operations and suspended material from logging activities. These were discussed in the Phase I report[2]. The landfills and agricultural operations were not expected to have an adverse effect on water quality. The type of information required to assess the effects of logging on water quality was outlined[2], but no data are available so far.

The discharges from Kimberley and Cominco Ltd. are discussed in more detail in this section.

4.2.2 City of Kimberley Sewage Treatment Plant

a) History of the Plant

The situation at the plant up to 1975 was outlined in the Phase I report[2]. Before 1975, there was infiltration of surface water and groundwater into the Marysville collection system causing hydraulic overloading of the plant. There were also problems with the plant design resulting in poor effluent quality. The plant provided the equivalent of primary treatment.

In 1976 the possibility of treating the municipal effluent with Cominco Ltd.'s mine water and tailings pond overflows was studied, but separate systems were favoured. Substantial removal of surface water and groundwater infiltration to the Marysville collection system was achieved after 1977. An activated sludge plant went into operation in October, 1979, following an amendment to Permit PE-148 issued January 17, 1979. The effluent now meets the Permit conditions given in Table 11. It is discharged to the St. Mary River, just upstream from the confluence with Mark Creek.

b) Effluent Sampling Data

A summary of the effluent sampling data collected from 1975 to 1978 inclusive, is given in Table 12. The values are similar to those obtained before 1975. The BOD_5 and suspended solids frequently exceeded the permit levels (53 percent of BOD_5 values and 22 percent of suspended solids values were over Permit limits). Residual chlorine levels also frequently exceeded stipulated levels. Since the new plant went into operation these values now meet Permit conditions.

4.2.3 Cominco Ltd.

a) Effluent Treatment and Disposal

A detailed description of Cominco Ltd.'s operations at Kimberley was presented in the Phase I report[2]. The report outlined the source of effluents and their treatment, up to the end of 1975. The situation is updated in this section to the end of 1979.

The operations consist of a lead-zinc mine, a concentrator and a fertilizer plant. They are located on the north side of the St. Mary River, as depicted in Figure 20. By the end of 1975 there were seven main discharges, which were covered by Pollution Control Permit PE-189, issued in October, 1975. This Permit stipulated a program of improvements to upgrade the effluents. Cominco Ltd. appealed the Permit to the Pollution Control Board, mainly to obtain a three-year time extension to complete the improvements. In its decision of June, 1978, the Board granted a two-year extension, which meant that Permit conditions were to be met by December 31, 1980. Major changes, including installation of a treatment plant, were completed by August 1979, and an amended Permit will be issued to reflect this situation. Conditions of the present Permit are summarized in Table 13.

The history of the seven main sources of effluents from 1975 to the end of 1979, is reviewed briefly below.

(i) Mine Drainage, 3 700 Foot Portal

Mine drainage from this level in the mine was generally of fairly good quality, with most parameters generally within the range stipulated by the Mining Objectives[35]. It continues to be discharged, without treatment, to Kimberley Creek, a tributary of Mark Creek.

(ii) Mine Drainage, 3 900 Foot Portal

This effluent was acidic and contained relatively high levels of heavy metals. In 1975, it was combined with cooling water from a crusher, used to crush ore underground, and discharged without treatment to Mark Creek, a tributary of the St. Mary

River. Also discharged to the creek, in the same vicinity, were smaller amounts of mine car wash water, change room effluent and contaminated runoff from rock disposal sites. The runoff had been identified as streams 1, 2 and 3.

Since 1979 the mine drainage has been combined with the minor effluents, and fed by gravity pipeline to a treatment plant by the St. Mary River, outside Marysville. This pipeline follows Mark Creek, skirts the iron tailing pond and follows James Creek before entering the treatment plant. Decant from the iron and siliceous tailing ponds also flows to the treatment plant via the pipeline.

(iii) Siliceous Tailing Pond Overflow

Fine waste rock from the concentrator was discharged as a slurry to the siliceous tailing pond. Most of the solids settled in the pond and the overflow was decanted. The overflow entered James Creek, a tributary to the St. Mary River. Since 1979 the overflow enters the pipeline which conveys effluent to the treatment plant. There is a possibility that heavy rains or rapid snowmelt could cause effluent to overflow from the pond to James Creek for short periods. These overflows are expected to be rare.

(iv) Iron Tailing Pond Overflow

Iron sulphide was separated from the ore in the concentrator. A portion was used to produce sulphuric acid and the remainder was discharged to the iron tailing pond. The pond also overflowed to James Creek. Since 1979 the decant from the pond flows through the effluent pipe line to the treatment plant. The piping is arranged so that the iron pond can store effluent, including mine drainage, for a certain period. This enables regulation of flow before treatment, especially during spring freshet.

Surface runoff to the iron and siliceous ponds was diverted from the northern edge of the ponds by a ditch which drains to the fire pond. This is a small pond located just south of the concentrator. The fire pond also collected spills from the concentrator. Decant from the fire pond was recycled to the concentrator.

(v) Roaster Plant Effluent

In the fertilizer complex, iron sulphide was roasted to produce sulphur dioxide, which was then converted to sulphuric acid. This process produced waste iron oxide, which was discharged to the calcine pond. Until 1976 overflow from the calcine pond entered the gypsum pond. Since April, 1976, the calcine is dewatered before disposal and the water recycled, so there is now no overflow from the calcine pond.

Sulphur burning equipment was recently installed to produce sulphur dioxide. This resulted in the shutdown of two of the sulphide roasters and a reduction of 30 to 40 percent in the use of iron sulphide for acid production.

(vi) Gypsum Pond Overflow

In the fertilizer complex, phosphate rock was treated with sulphuric acid to produce phosphoric acid. Gypsum was the waste product of this reaction and was stored in two gypsum ponds. Since 1975 the overflow from these ponds is recycled to the fertilizer plant via a cooling pond. The cooling pond helps prevent fluoride buildup in the circuit.

There was some seepage from the gypsum ponds to James Creek and to Cow Creek, which both drain to the St. Mary River.

(vii) Fertilizer Complex Sewer 32

The fertilizer complex included a sulphuric acid plant, a phosphoric acid plant and a fertilizer plant. In the fertilizer plant, phosphoric acid was reacted with ammonia to produce fertilizers. The disposal of solid wastes from the fertilizer operation, namely calcine and gypsum, was carried out as discussed in Sections (v) and (vi) above. Most of the liquid waste from the operation was discharged to Mark Creek via Sewer 32. The quality of effluent in Sewer 32 has been slowly upgraded by a series of in-plant measures, such as recycling, spill collection and clarification.

(viii) Effluent Treatment Plant

Acid mine drainage and tailing pond overflows are piped to a treatment plant, which went into operation in August, 1979. The plant is located next to the Kimberley sewage treatment plant by the St. Mary River (Figure 20). The combined effluents are treated with slaked lime in a reactor to which compressed air is added. A sludge is formed containing the metal impurities. The sludge is separated in a clarifier, with the addition of flocculant. A large proportion of the high density sludge is recycled to the reactor. The remainder is pumped to settling ponds on the south side of the river. The clarified effluent from the treatment plant is discharged to the St. Mary River.

Preliminary data indicate that the plant is operating according to design and that effluent concentrations are within permit limits. Analysis of the data should be the subject of further progress reports.

b) Presentation of Effluent Data

Cominco Ltd. has sampled the effluents and Mark, James and Cow Creeks on a routine basis since the end of 1975. The B.C. Ministry of Environment has monitored the same sites, although less frequently. Table 14 gives the data for the three effluents discharged to Mark Creek and Table 15 the data for Mark Creek. The data for the overflows from the two tailing ponds which enter James Creek, and data for James and Cow Creeks, are given in Table 16.

The changes in the concentrations of contaminants in Sewer 32 are plotted for the period October 1975 to December 1978 in Figures 21 to 25. Graphs also show how the concentrations changed with reference to the Permit limits.

The diagrams in Figures 26, 27 and 28 show how the mean concentrations of certain contaminants, in the three effluents discharged to Mark Creek, altered the mean levels of these contaminants in Mark Creek. The data cover the period November 1975 to December 1978. The Permit levels are also given, as are the results of one-way analysis of variance and Newman-Keuls tests[58]. The statistical tests show whether there were significant differences ($P<0.05$) in the contaminant levels at each Mark Creek site.

The diagrams in Figures 29 and 30 give the mean and standard error of the concentration of certain contaminants in the overflows from the two tailings ponds and in James and Cow Creeks.

Mean loadings (for 1976 to 1978, inclusive) of ammonia, ortho-phosphate, fluoride, dissolved iron, dissolved lead, dissolved manganese, and dissolved zinc from the mine drainages, pond overflows and Sewer 32 are given in Table 17. The Table also shows the percent contribution from each discharge. Using the low mean monthly flow of the St. Mary River at Wycliffe (8.9 m^3/s, Section 4.1), the increases of these parameters in the St. Mary River, due to the total loadings, were calculated and listed in Table 17.

The Mining Objectives[35] and the Pollution Control Permit (Table 13) usually specify metal levels in the dissolved state. The percent of the total metal which is dissolved depends on pH. Therefore pH is important in discussing the fate of the metals from Cominco's effluents. Table 18 gives the mean percent (±standard error) of the iron and zinc in solution (calculated for samples where both the dissolved and total concentrations were measured) and the mean (±standard error) pH levels for all effluents and receiving waters. The data are for the period 1975 to 1978, inclusive, unless stated otherwise.

c) Discussion of the Effluent Data

The effluent data and the data for Mark, James and Cow Creeks are considered in this section. The creeks were not under Permit, but for part of the year they were composed largely of effluent.

(i) 3 700 Foot Portal Mine Water Discharging to Mark Creek

The concentrations of parameters under Permit were within Permit limits (Tables 13 and 14), except for 2 out of 53 dissolved iron measurements (1.7 and 14 mg/L compared to 1.00 mg/L). Dissolved iron was not considered to be a parameter of concern in this effluent stream because the mean loading was 0.08 kg/d, representing only 0.001 percent of the total loading of dissolved iron from Cominco Ltd. (Table 17).

Of the parameters not under permit, total solids was high (598 to 670 mg/L), due to a high dissolved fraction. This result was attributed largely to the sulphate concentration (53 to 311 mg/L). Sulphate was present because in the mining of sulphide ores the sulphide is oxidized to sulphate, in the presence of certain Thiobacillus bacteria and air. The sulphate concentration was used to calculate the dilution and mixing of the effluent in the St. Mary River, but sulphate had no particular impact on aquatic life.

(ii) 3 900 Foot Portal Mine Water and Associated Wastes Discharging to Mark Creek

Arsenic and effluent flow were the only parameters consistently within the Permit limits (Tables 13 and 14). The mean levels of fluoride (5.0 mg/L) and dissolved copper (0.21 mg/L) satisfied the Permit requirements, but 39 percent of the fluoride values and 7.8 percent of the copper values exceeded the Permit limits. All of the values for dissolved aluminum, iron, lead and manganese, and 99 percent of the dissolved zinc, 92 percent of the suspended solids and 89 percent of the ammonia values exceeded the Permit limits. The pH levels were consistently outside the given Permit range, on the acidic side.

Several other parameters, not under Permit, were measured (Table 14). Dissolved cadmium exceeded the most stringent level of the Mining Objectives (0.01 mg/L)[35]. All of the total mercury determinations were greater than the most stringent level (nil), but no value exceeded the least stringent level (5 μg/L) of the Objectives. Cyanide, molybdenum and oil and grease met the most stringent requirements and nickel and chromium satisfied the least stringent level of the Objectives.

The high values for calcium (91 to 288 mg/L) and magnesium (177 to 610 mg/L) accounted for the high hardness levels (938 to 2 950 mg/L, Table 14). Calcium and magnesium did not contribute to effluent toxicity, and were not present in sufficiently high concentrations in the St. Mary River (Table 19) to limit water usage[36].

The high levels of sulphate (522 to 6 440 mg/L) were indicative of mine wastes (see: 3 700-foot Portal Mine Water). Since sulphate is a relatively conservative ion (readily soluble and not biologically active), it was used to calculate the effluent dilution in the St. Mary River.

In addition to the dissolved metal analyses, as required by the Permit, total metal levels were measured on occasion (Table 14). However, due to the low pH (mean of 3.2 ± 0.02) the metals were present primarily in the dissolved form. For example, dissolved iron was 81 percent of the total iron and dissolved zinc was 93 percent of the total zinc (Table 18). The dissolved metal levels were therefore a good indication of the total metals discharged.

The effect of the Permit parameters and of dissolved cadmium, total mercury and sulphate from the 3 900-foot Portal Mine Water and associated wastes on water quality in Mark Creek is discussed in the sub-section on Mark Creek. These effects in Mark Creek apply to the end of 1978. In April, 1979, the 3 900-foot Portal Mine Water and associated wastes were diverted to the iron tailing pond. Changes in Mark Creek due to the diversion of these effluent streams are considered.

(iii) Sewer 32 Discharging to Mark Creek

Oil and grease was the only parameter (Table 14) consistently within the Permit limit, although only one of 58 cyanide determinations and four of 144 suspended solids values exceeded Permit levels. Values which frequently exceeded Permit limits included more than 90 percent of the values for pH, fluoride and ortho-phosphate, more than 75 percent of the values for ammonia and zinc, more than 50 percent of the values for effluent flow, iron and lead and 40 percent of the dissolved arsenic values.

Of the parameters not under Permit, only sulphate showed somewhat higher values (2.2 to 262 mg/L), to be expected in wastes from roaster and sulphuric acid plants. Aluminum, chromium, molybdenum and nickel satisfied the most stringent level of the Mining Objectives[35] and only one value each of dissolved cadmium and total mercury exceeded these Objectives levels.

The percent of the total metals in the dissolved state (Table 18) was variable (14.7 ± 10.5 percent dissolved for iron and 67.8 ± 10.6 percent dissolved for zinc) at the given pH (4.8 ± 0.07), and only a limited number of samples were analyzed for both dissolved and total levels. The dissolved values, which were listed in the Permit and which were frequently measured, were used when considering changes over time and when discussing the influence of the metals in the receiving waters.

Some in-plant treatment of the wastes discharged via Sewer 32 took place after September, 1975. Results are shown in Figures 21, 22, 23, 24 and 25, which plot the mean monthly levels of certain effluent parameters for the period October, 1975 to December, 1978. Although limited data were available for 1975, the plots suggest that the levels of fluoride and ortho-phosphate decreased following recycling of the evaporator condensates and impinger effluents from the phosphoric acid plant and of the overflow from the gypsum pond in October, 1975. Also, the pH values increased slightly over pre-October, 1975 values (2.8 to 3.1)[2]. However, the improved levels of fluoride, ortho-phosphate and pH still did not satisfy the Permit requirements. The levels of the other parameters under Permit, particularly the metals, were extremely variable over the three-year period. None of the changes in these levels appeared to correspond to any particular treatment carried out in the plant.

Miscellaneous in-plant improvements, such as pipe washing, spill control, etc. were continually being initiated. These steps may explain the consistent reductions in ammonia and fluoride and the increased values of pH in 1978, as well as the general trend of ortho-phosphate reduction. Decreased levels of ammonia, fluoride and ortho-phosphate in Sewer 32 were important to the St. Mary River because the effluent was the largest contributor of these contaminants to the river. For example, Sewer 32 contributed 75 percent of the ammonia, 91 percent of the fluoride and 99 percent of the ortho-phosphate discharged to the river (Table 17).

The results of acute-toxicity bioassays, conducted by B.C. Research[37, 38] on eight occasions between July, 1976 and February, 1978 on Sewer 32 are given in Table 19. The 96-hour LC_{50} varied from 0.64 to over 100 percent effluent concentration. B.C. Research attributed the variation primarily to the wide range of pH values. However, neutralization did not substantially reduce the toxicity on all occasions. Other parameters (e.g., fluoride, ammonia, ortho-phosphate) probably also contributed to the toxicity and the variable results, since these parameters varied extensively over the sampling period. The reduced toxicities in December, 1977 and February, 1978 corresponded to the reduced levels of ammonia and fluoride and increased pH at these times.

The influence of Sewer 32 on Mark Creek is discussed in the following subsection.

(iv) Mark Creek

Parameters exceeding Permit or Objective levels in effluents discharged to Mark Creek were identified in previous subsections (3 700-foot Portal Mine Water, 3 900-foot Portal Mine Water and Sewer 32). The parameters included pH, fluoride, ammonia, ortho-phosphate, sulphate, suspended solids, total mercury and dissolved aluminum, arsenic, cadmium, copper, iron, lead, manganese and zinc. The mean values of these parameters, measured from 1975 to 1978 in the three effluents and at three Mark Creek sites (0200037, 0200212 and 0200036, Figures 3 and 20) were illustrated in Figures 26, 27 and 28. Several conclusions can be drawn from the information contained in these Figures.

First, there was no significant difference in the mean levels of dissolved arsenic and total mercury among the three Mark Creek sites. This indicates that the discharges from Cominco Ltd. into Mark Creek were not affecting the levels of arsenic and mercury in Mark Creek.

Second, the mean levels of dissolved cadmium, copper and lead were significantly greater downstream from the mine water discharges (site 0200212) than at the upstream control site (0200037), but there was no significant difference between the levels at the control site and the site downstream from Sewer 32 (site 0200036). This indicates that the mine waters (particularly the 3 900-foot Portal Mine Water) and associated wastes were causing immediate increases in the levels of these parameters in Mark Creek, but that dilution by the effluent from Sewer 32 resulted in no net change in the concentrations entering the St. Mary River. Dissolved aluminum was also significantly greater downstream from the mine water discharges, but no data were available for site 0200036. The levels did not change in the St. Mary River (Table 21) suggesting that dissolved aluminum was also diluted by the effluent from Sewer 32.

Third, there were no significant differences in the mean concentrations of ammonia, fluoride and ortho-phosphate between the upstream control site and the site downstream from the mine water discharges, but the levels were significantly greater downstream from Sewer 32. This indicates that the effluent from Sewer 32 increased the levels of these parameters in Mark Creek. Consequently ammonia, fluoride and ortho-phosphate have had an important effect on the water quality of the St. Mary River.

These increases, due to the effluent from Sewer 32 and not to the mine waters, were consistent with the relative loadings from the three discharges. The effluent from Sewer 32 accounted for 75 percent of the total ammonia from Cominco's discharges, 81 percent of the fluoride and 99 percent of the ortho-phosphate (Table 17). The 3 900-foot Portal Mine Water and associated wastes accounted for only 19 percent of the ammonia, 6 percent of the fluoride and for none of the ortho-phosphate. The contribution from the 3 700-foot Portal Mine Water was negligible.

Fourth, the mean levels of suspended solids, sulphate, and dissolved iron, manganese and zinc were significantly increased downstream from the mine-water discharges. This was followed by a decrease downstream from Sewer 32, but the mean levels were still significantly greater than at the upstream control site. The values for pH showed a similar trend, with an increase in acid conditions shown by a reduction in pH. These changes indicate that the mine-water discharges (particularly the 3 900-foot Portal Mine Water and associated wastes) were contributing most to the increased levels and this conclusion is consistent with the relative loadings of dissolved iron and zinc. The 3 900-

foot Portal Mine Water and associated wastes accounted for 17 percent of the dissolved iron, 76 percent of the dissolved zinc, and 49 percent of the dissolved manganese discharged by Cominco, whereas Sewer 32 and the 3 700-foot Portal Mine Water accounted for 10 percent or less of these contaminants. The increases in Mark Creek indicate that suspended solids, sulphate, pH, and dissolved iron, manganese and zinc will have had an important effect on the water quality of the St. Mary River.

Of the 15 contaminants which were at high levels in the discharges to Mark Creek, nine (ammonia, fluoride, ortho-phosphate, suspended solids, sulphate, pH, and dissolved iron, manganese and zinc) had increased significantly (except pH which decreased) in Mark Creek at the confluence with the St. Mary River.

Another five contaminants which were at high levels in the discharges to Mark Creek (total mercury, dissolved arsenic, cadmium, copper and lead), did not increase their value significantly in Mark Creek and no significant change was noticed for dissolved aluminum. The increased flow in Mark Creek due to the effluents could have increased the loadings of these six contaminants to the St. Mary River. However, the maximum effluent flow of 0.65 m^3/s (0.123 + 0.0006 + 0.53 m^3/s, Table 14) represented only 6.8 percent of the minimum mean monthly flow in the St. Mary River at Wycliffe (8.9 m^3/s, Section 4.1), suggesting that the increased loadings would have been low. Overflows from the iron and siliceous tailing ponds also contributed several of these contaminants to the St. Mary River, but only lead was considered to be of importance to the river.

The removal of the 3 900-foot Portal Mine Water and associated wastes from Mark Creek should substantially improve the water quality of the creek. However, the sediment in Mark Creek contained high levels of metals downstream from Cominco's discharges[37, 38]. During high creek flows, the sediment may be resuspended and enter the St. Mary River. The metal levels in Mark Creek may thus vary after the removal of the 3 900-foot Portal Mine Water and associated wastes, since it will probably be several years before the metals are removed from the sediment. Monitoring of changes in the water and sediment are recommended, particularly for iron, lead and zinc.

(v) Iron Tailing Pond Overflow Discharging to James Creek

Of the eleven parameters under Permit, only fluoride and cyanide were consistently within the Permit limits, although only one of 52 ortho-phosphate analyses and one of 54 dissolved arsenic measurements exceeded the limits (Table 16). Seven percent of the suspended solids values and eleven percent of the dissolved copper values exceeded the Permit criteria, although the means for both parameters were within Permit limits. All of the dissolved iron and manganese results exceeded the Permit values, and over 80 percent of the pH, dissolved lead and dissolved zinc values were greater than allowed by the Permit. The mean effluent flow was well within the Permit limit, although 7 percent of the daily measurements were greater than the stipulated daily maximum flow.

Of the parameters not under Permit, less than 30 percent of the dissolved cadmium measurements satisfied the strictest level of the Mining Objectives[35] (0.01 mg/L). Less than a quarter of the dissolved aluminum analyses were within the strictest level of the objectives (0.5 mg/L). All of the ammonia results satisfied the least strict level (10 mg/L), but 47 percent exceeded the strictest level (1.0 mg/L). Fifty-five percent of the sulphate values were greater than 1 000 mg/L.

After April, 1979 the iron tailing pond also received the 3 900-foot Portal Mine Water and associated wastes. The concentrations of the metals in the overflow may therefore be greater now than the values to the end of 1978. However, by the end of 1979 the overflow was being treated.

(vi) Siliceous Tailing Pond Overflow Discharging to James Creek

Four of the 13 parameters under Permit (suspended solids, and dissolved aluminum, arsenic and copper) consistently satisfied the Permit limits (Table 16). The mean concentrations of cyanide, fluoride, ortho-phosphate and dissolved zinc were within the Permit requirements, although up to 24 percent of the individual determinations exceeded the Permit limits. All of the manganese values were greater than Permit limits, as were 89 percent of dissolved iron values, 61 percent of the ammonia values and 53 percent of the dissolved lead values. The dissolved lead values have, however, satisified the Permit requirements since mid-1977. Sixty-one percent of the pH values were below the lower Permit limit of 6.5. The mean annual effluent flow from 1975 to 1978 met the Permit requirement and only one percent of the daily flows exceeded the allowable daily maximum.

Total metal levels, although not limited by the Permit, were also measured. The percent of iron in the dissolved state (72%), of zinc in the dissolved state (76%) and the pH (6.3) are presented in Table 18, for comparison with the other effluent streams. The percent of each metal in solution was less than in the other effluent streams (due to increased pH), but a sufficient proportion was dissolved to enable the use of the more numerous dissolved metal values in calculating metal loadings to the St. Mary River (Table 17).

Dissolved cadmium was also measured and 46 percent of the individual values exceeded 0.01 mg/L, which is the more stringent level of the Mining Objectives[35]. The high sulphate levels (39 percent of values greater than 1 000 mg/L) were typical of mine wastes.

The results of acute-toxicity bioassays conducted by B.C. Research[37, 38] on the siliceous tailing pond supernatant, on eight occasions between July, 1976 and February, 1978 are given in Table 19. The 96-hour LC_{50} ranged from 2.82 to over 100 percent effluent concentration, and showed no trends.

The overflow from the siliceous tailing pond is now being treated with the overflow from the iron tailing pond and the 3 900-foot Portal Mine Water and associated wastes.

(vii) James Creek

James Creek received the overflows from the iron and siliceous tailing ponds, and these effluents accounted for about 75 percent of the flow in the creek (Table 16). The parameters measured in the tailing pond overflows, which were of concern, included ammonia, pH, sulphate, and dissolved cadmium, iron, lead, manganese and zinc.

Figures 29 and 30 indicate that the mean levels of pH, ammonia, and dissolved iron, manganese, lead and zinc in James Creek exceeded Permit limits for the effluents discharged to the creeks. The levels of other parameters measured in the creek were within Permit limits for the effluents. Dissolved cadmium was not measured in James Creek, but the levels showed no real change in the St. Mary River (Section 4.3).

The contaminants in James Creek which could have affected water quality in the St. Mary River were therefore ammonia, pH, sulphate, and dissolved iron, lead, manganese and zinc. Of the total contaminant loads to the St. Mary River, the overflows, and thus James Creek, contributed 6 percent of the ammonia, 82 percent of the dissolved iron, 45 percent of the dissolved lead, 47 percent of the dissolved manganese and 15 percent of the dissolved zinc (Table 17). These loadings may have increased after April, 1979 when the mine water from the 3 900-foot Portal was diverted to the iron tailing pond. The tailing pond overflows are now treated before being discharged to the St. Mary River. Limited data for James Creek suggest there were relatively high values of iron in the sediment of the creek. Gradual resuspension of the sediment could contaminate the St. Mary River with iron.

(viii) Cow Creek

Cow Creek did not receive effluent directly. However, iron tailings, from an iron tailing pond spill in the late 1950's, were still evident in the creek bed, and there was some seepage fom the west gypsum pond to the creek. The tailings and seepage water were affecting the water quality of Cow Creek (Table 16). The high average values for dissolved iron (322 mg/L), dissolved manganese (9.7 mg/L) and dissolved zinc (8.1 mg/L) were probably due to dissolution of these metals from the tailings in the stream bed, at the low average pH in the creek (3.9). The high average values for fluoride (2.3 mg/L) and sulphate (1 682 mg/L) indicated seepage from the gypsum pond.

The mean flow in Cow Creek was low (0.001 m^3/s), and flow occurred primarily between April and September. Mean daily loadings, calculated for these months, were 8.5 kg/d dissolved iron, 1.3 kg/d dissolved manganese, 0.3 kg/d dissolved zinc and 0.08 kg/d fluoride. These loadings represented less than one-half of one percent of the total loadings from Cominco's discharges. The effect of these contaminants from Cow Creek on the water quality of the St. Mary River was therefore considered to be negligible.

4.3 Water Quality of the St. Mary River

4.3.1 Presentation of the Data

There were three main sampling sites on the St. Mary River, as shown in Figure 3 and described below.

site 0200029: a control site located at Cominco's pump station, immediately upstream from the discharge of Cominco's new effluent treatment plant and Kimberley's sewage treatment plant.

site 0200132: immediately downstream from Kimberley's sewage treatment plant and 100 m upstream from the confluence with Mark Creek.

site 0200135: at Wycliffe, about 6.5 km downstream from all of Cominco's discharges, and 10.5 km downstream from the pump station (site 0200029).

Cominco Ltd. analyzed water samples from site 0200029 and site 0200135 on a regular basis, as stipulated by the Amended Permit issued October 9, 1975. The B.C. Ministry of Environment also sampled at these sites, although less frequently, and at site 0200132. Cominco's monitoring data were tabulated and briefly discussed by B.C. Research in two separate reports[37, 38]. They are included with the Provincial data in Tables 20 and 21 and discussed in this report.

The mean monthly levels of pH, fluoride, inorganic nitrogen (nitrate, nitrite and ammonia), ortho-phosphate, and dissolved iron, lead, manganese and zinc at sites 0200029 and 0200135, for 1975 to 1978 inclusive, are plotted in Figures 31 to 36. Similar data for sulphate are shown in Figure 37, together with the mean monthly relative concentration of sulphate at site 0200135, which is used to determine the effluent dilution.

B.C. Research, for Cominco Ltd., conducted in situ bioassays at sites 0200029 and 0200135. The Consultants also performed 96-hour LC_{50} bioassays of the river water at site 0200135 on eight occasions. The results are summarized in Table 19 and 22 and are considered when discussing toxicity.

4.3.2 Discussion of the Water Quality Data

The contaminants in Cominco's discharges, which could have affected the water quality of the St. Mary River, were identified in Section 4.2.3. They were pH, ammonia, fluoride, ortho-phosphate, sulphate and dissolved iron, lead,manganese and zinc. The mean levels of these parameters, from 1975 to 1978 inclusive (Table 20), increased in the St. Mary River downstream from Cominco Ltd. The data are discussed in this section. Other parameters which were measured in the St. Mary River (Table 21) include calcium, colour, copper and hardness. They increased slightly downstream from Cominco Ltd., but were at levels which should have neither affected aquatic life adversely nor limited water usage[36]. The data are not discussed further.

a) Effluent Dilution (Relative Concentration of Sulphate)

No flow data were available for Mark Creek and only limited data were available for Cow and James Creeks. These three creeks received effluent and seepage from the Cominco operation and discharged to the St. Mary River. To determine the effluent dilution in the St. Mary River, the relative concentration of sulphate was used. Sulphate is reasonably soluble and not biologically active, and was present in high concentrations in each of the effluents (Section 4.3.2). In the mine wastes, sulphate was formed by the action of Thiobacillus bacteria and air on sulphides. Sulphate was produced in a similar manner in the tailing ponds. Sulphate in Sewer 32 was typical of wastes from roaster and sulphuric acid plants.

The mean monthly concentration of sulphate in the river was expressed as a fraction of the sulphate concentration in the effluent. The following equation of Minns[31], which allows for the background river concentration was used.

$$Cr = \frac{Ca - Cb}{Ce - Cb}$$

where:
- Cr = relative concentration, as a fraction of effluent concentration.
- Ca = downstream concentration in the river.
- Cb = background concentration in the river.
- Ce = effluent concentration.

Site 0200135, in the St. Mary River downstream from the discharges, was used to obtain the values for Ca. Site 0200029 was the background site (Cb) and Ce values were the average of mean monthly values at site 0200036 (Mark Creek), site 0200213 (James Creek) and site 0200214 (Cow Creek).

The results are plotted in Figure 37 for the period November 1975 to December 1978. The levels of sulphate at the background site 0200029 were stable over the four-year period, whereas the concentrations and relative concentrations at site 0200135 showed cyclic trends with the highest values during low river flow (November to

March). At these times, Cr ranged from 0.02 (February 1977) to 0.032 (February 1978). This means that 2 to 3.2 percent of the river water at site 0200135 was effluent. Site 0200135 was 6.5 km downstream from the discharges, so that the effluent dilution nearer the discharges was probably less. In addition, visual observations of the river at the confluences with Mark, Cow and James Creeks showed that mixing did not occur until some distance downstream. Thus the proportion of effluent in the river could have been substantially greater than 3 percent in the vicinity of the discharges during low river flow.

To determine the effluent dilution more accurately, good flow data should be obtained at the mouths of Mark, Cow and James Creeks. To establish the river distance required for complete effluent mixing, sulphate levels should be measured at site 0200029, in the three creeks and at transects across the St. Mary River, at approximately 100 m intervals downstream from the creeks.

b) pH

The increase in pH at site 0200135 in May 1975, from about 4 to 7 (Figure 31), reflected the increased river flow in May. Before 1975, low pH values (about 3.5) were consistently observed during low river flows and higher values (about 6.5) were associated with higher flows[2, 39]. The stabilization of the pH levels at about 7, after May 1975 at site 0200135, may have been due to in-plant treatment of the effluents from the fertilizer complex. The pH in Sewer 32 had shown a slight increasing trend (Figure 21). Low pH values were found in the 3 900-foot Portal Mine Water (Table 14) and there was no change in its treatment in 1975. It therefore appears that Sewer 32 effluent may have prevented any dramatic decrease in pH of the St. Mary River during low river flows.

Although the pH levels 6.5 km downstream from Cominco Ltd. had increased, the mean monthly values between May 1975 and December 1978 were consistently less than those at the control site (Figure 31). The continuing improvements in the Sewer 32 effluent and the recent treatment of the mine water and tailing pond overflows should reduce the possibility of stress on the aquatic biota.

Increased pH levels have a favourable influence on metal concentrations because the percent of metal in solution is pH dependent. The decrease in the percent of dissolved iron (79 to 34 percent) and zinc (94 to 76 percent) corresponded to an increase in pH in May 1975 (4.0 to 7.0), as shown in Table 18. At the lower pH values, there was a higher concentration of dissolved metals (Figures 34, 35 and 36). These metals were therefore more readily available for uptake across the gills and other mucous membranes of aquatic biota. As the pH increased, the metals were precipitated, giving higher metal levels in the sediment or particulates in the water column. The effects of this change on biota and sediment resuspension during freshet are considered in Sections 4.4 and 4.5.

c) Fluoride

Consistently low values (about 0.10 mg/L) were found at the control site 0200029 (Figure 31). At the downstream site 0200135, high mean monthly values occurred at low river flow (November to April). Very high concentrations (15 to 33 mg/L) were found during the low flow period of January to April 1975, levels of 1.0 to 1.5 mg/L were observed for the low flow months between November 1975 and April 1978 and only slightly increased values (0.25 to 0.30 mg/L) were apparent for November-December 1978.

The high concentrations in January to April 1975 were typical of fluoride levels during low river flows before 1975[2, 39]. The reduced values during low flows after May 1975 corresponded to reduced fluoride concentrations in Sewer 32, brought about by in-plant treatment of the effluent at the fertilizer complex. The further reductions in fluoride levels during the low flow months November-December 1978 corresponded to similar reductions in fluoride levels in Sewer 32 (Figure 23) due to ongoing plant improvements.

Sewer 32 accounted for 91 percent or 340 kg/d (Table 17) of the loading of fluoride from Cominco's effluents. Thus, reductions in fluoride from Sewer 32 had a significant influence on the St. Mary River, as shown by the decreases outlined above. Using the total mean daily loading of fluoride from the effluents (374 kg/d), we calculated the expected increase in fluoride concentration in the St. Mary River during low mean monthly flow (8.9 m^3/s at site 0200135) to be 0.49 mg/L (Table 17). This was about one-half of the increase observed for the low flow months between November 1975 and April 1978. The source of the additional fluoride was not known, although fluoride levels at site 0200036 on Mark Creek, below Sewer 32, were significantly greater than levels for Sewer 32 (Figure 26). This discrepancy should be investigated.

Fluoride levels in the St. Mary River before May 1975 had an adverse effect on the aquatic biota downstream from Cominco Ltd[2]. The reduction in fluoride concentrations corresponded to an improvement in the condition of the aquatic biota (Section 4.5), although the downstream values during low flows were still about 10 to 15 fold greater than the control levels, until the fall of 1978. The 96-hour LC_{50} for fluoride using rainbow trout at 7.2°C is 5.9 to 7.5 mg/L, with decreasing values at higher temperatures[40]. Using an application factor of 0.05[41] gives a concentration of 0.30 mg/L (0.05 x 5.9), at which there should be no sublethal toxicity. This suggests that until the fall of 1978 the fluoride concentrations during low river flows may have been causing stress on the aquatic biota, particularly in the vicinity of the discharges.

The mean monthly levels of fluoride and 83 percent of the individual measurements since May 1975 were less than the criteria for continual use of the water for irrigation (1.0 mg/L) and for drinking (1.2 ± 0.2 mg/L)[42]. All of the values since March 1978 were less than 1.0 mg/L.

d) Nutrients (Nitrogen and Phosphorus)

The major nutrients required by aquatic plants and algae (including attached algae or periphyton) are ortho-phosphate phosphorus and inorganic nitrogen, particularly ammonia and nitrate. In high concentrations, these nutrients enhance eutrophication or stimulate increased plant and algal growth which can limit water usage.

Cyclic levels of inorganic nitrogen were apparent at both the upstream (0200029) and downstream (0200135) sites, with the higher levels associated with low river flow (Figures 32). At site 0200135, during the low flow months before 1978, the inorganic nitrogen levels (about 0.3 to 1.0 mg/L) were greater than at the control site (about 0.17 mg/L). They were attributed primarily to ammonia from Cominco's discharges. The reduced levels at site 0200135 in 1978, corresponded to the reduced ammonia concentrations in Sewer 32 (Figure 22), which contributed 74 percent or 104 kg/d of the ammonia from Cominco Ltd. (Table 17).

The downstream values of nitrate were within the criterion of 10 mg/L set for use of water in domestic water supplies[36]. The maximum ammonia concentration was 1.4 mg/L (Table 20). At a pH = 7.0 and a temperature = 5°C it corresponded to 0.12 percent or 0.002 mg/L (0.0012 x 1.4) of un-ionized ammonia, which is tenfold less than a level of 0.02 mg/L un-ionized ammonia required for protection of aquatic life[43]. The nitrite levels at both river sites were consistently less than 0.005 mg/L. The inorganic nitrogen components should therefore not limit the water use. However, the downstream concentrations of inorganic nitrogen exceeded those found in meso-eutrophic lakes (0.3 to 0.65 mg/L)[44], suggesting that nitrogen is not a limiting nutrient and that with high phosphorus levels, increased algae growth is possible.

The mean monthly levels of ortho-phosphate at the control site 0200029 were less than 0.02 mg/L, whereas at the downstream site 0200135, values as high as 6.3 mg/L were found in 1975. After 1975, the ortho-phosphate levels downstream from Cominco Ltd. decreased, although in 1976 and 1977 values of 0.25 to 0.35 mg/L were observed during low river flow months. Values less than 0.10 mg/L were found in 1978. The reduced ortho-phosphate concentrations were due to lower values in Sewer 32 (Figure 22), which contributed almost all of the ortho-phosphate from Cominco Ltd. (99 percent or 251 kg/d, Table 17).

The Kimberley sewage treatment plant was not the major continuous source of phosphorus as stated in the B.C. Research report[37]. Using the maximum ortho-phosphate level in the sewage effluent (3.24 mg/L, Table 12) and the maximum effluent flow (0.104 m^3/s, Table 12), the loading was 29 kg/d or only 11 percent of the total loading of ortho-phosphate from Cominco's discharges (Table 17).

Total phosphorus levels greater than 0.05 mg/L in flowing waters are associated with enhanced algae growth[32]. Levels less than 0.05 mg/L should minimize the growth of nuisance plants and algae. The ortho-phosphate levels, which do not include the phosphorus attached to particulates, and were thus less than total phosphorus levels (Table 20), greatly exceeded 0.05 mg/L during low flows before 1978. These high levels, with high inorganic nitrogen, caused increased periphyton biomass downstream from Cominco Ltd. (Section 4.5). The effect of nutrients from Cominco Ltd. on the Koocanusa Reservoir is discussed in Section 5.

Continued monitoring of the nutrients in the St. Mary River will determine whether the decrease in 1978 is maintained and whether further decreases occur with ongoing miscellaneous treatment of the wastes from the fertilizer complex.

e) Manganese

Except in early 1976, the values at the control site 0200029 were 0.05 mg/L or less, whereas at the downstream site 0200135, increased concentrations (about 0.3 to 0.6

mg/L) were consistently found during low river flow months (Figure 34). The highest value at site 0200135 was in April 1975, possibly due to the low pH at that time.

The objective for manganese in domestic water supplies is 0.05 mg/L to minimize undesirable qualities (e.g., brownish staining of laundry and objectionable tastes in beverages)[36]. Only 16 percent of the 35 total manganese determinations and 75 percent of the dissolved manganese levels at site 0200135 met this objective. At the control site, all of the total manganese values (36) were less than 0.02 mg/L and only three of the 70 dissolved manganese values exceeded 0.05 mg/L. However, all of the total and dissolved manganese determinations at both river sites were less than the range of tolerance values for freshwater aquatic life (1.5 to 1 000 mg/L).

Manganese was not considered to be a parameter of concern in the St. Mary River, although treatment of the mine water and tailing pond oveflows, which contributed 96.5 percent of the manganese from Cominco Ltd. (Table 17), should reduce the levels in the river.

f) Lead

A slight increase in the mean level of dissolved lead and a substantial increase in the mean level of total lead, from 1975 to 1978 inclusive, were found downstream from Cominco Ltd. (Table 20). The slight increase in the mean level of dissolved lead (from 0.005 to 0.007 mg/L) was due to some relatively high values (0.01 to 0.022 mg/L) recorded in January to April 1975. These values were typical of dissolved lead concentrations found during low river flows before 1975[39]. After May 1975, the dissolved lead concentrations were similar at the two river sites, namely less than 0.005 mg/L. The 3 900-foot Portal Mine Water and the iron tailing pond overflow contributed 81 percent of the dissolved lead from Cominco Ltd. (Table 17) and these effluents were unchanged up to the end of 1978. This suggests that the consistently low levels of dissolved lead measured since May 1975 were due to increased precipitation of the lead in solution from higher pH levels. Limited sediment data (Figures 38 and 39), showing increased levels of lead in the sediment downstream from Cominco Ltd. between 1973 and 1976, support the idea of increased precipitation.

The levels of total lead at the control site 0200029 were consistently less than or equal to the detection limit (0.001 mg/L, Figure 36). Downstream from Cominco Ltd., the levels increased and were highest during low river flows, particularly in 1975 and

1977-78 when values of about 0.07 to 0.1 mg/L were recorded (Figure 36). The total lead values represent the dissolved lead plus lead attached to particulates. Although the dissolved lead appeared to precipitate out, the total lead was not reduced, because of resuspension of the sediment.

The B.C. Research reports[37, 38] concluded that the concentrations of lead from March 1976 to April 1978 were below sublethal levels, and that the downstream levels were not above background levels. They measured and discussed only dissolved lead which, as noted above, had similar levels at the two river sites since May 1975. Dissolved lead was also less than the range of maximum acceptable concentrations for brook trout (0.039 to 0.084 mg/L[45]) and less than the toxic levels for various aquatic invertebrates[46]. However, the total lead levels during low river flows when the water temperature was lowest and fish less mobile, approached or exceeded the range of maximum acceptable concentrations for brook trout (0.058 to 0.119 mg/L[45]). Also, increased concentrations of lead were found in the sediment (Figure 38) and invertebrates (Table 23) downstream from Cominco Ltd., suggesting that additional quantities of lead were available to fish by ingestion.

One visible sublethal effect of lead in fish, which can also be lethal, is scoliosis (spinal deformities) often preceded by blacktail (darkening of the caudal peduncle)[45]. These symptoms were not recorded for the fish caught in the St. Mary River in July and October, 1977. The lead levels in the bone, which accumulates lead, were not measured. However, levels in the liver, which is one of the excretory pathways of lead, and in the muscle which is consumed, were measured. All of the values were less than the detection limits[38], probably due to the small sample weight analysed.

Limits of lead in fish recommended for human consumption are in the range of 2 to 10 µg/g wet weight or about 10 to 50 µg/g dry weight[47]. These limits may have been exceeded in the edible muscle of fish caught upstream (up to 41 µg/g dry weight) and downstream (up to 109 µg/g dry weight) from Mark Creek. However, due to uncertainties in the analysis and the likelihood that muscle does not accumulate lead to a substantial degree[45], these values were considered to be reliable. Similarly, potentially high values were found in the liver tissue (up to 245 µg/g dry weight)[38].

More accurate analyses of lead in the liver and muscle are needed to decide whether the fish are handling increased quantities of lead and whether the muscle can be consumed. Determination of lead levels in the bone and thorough examination of the fish for symptoms of blacktail and scoliosis would enable more definite conclusions concerning possible sublethal effects due to lead. Also, as noted in the B.C. Research report[38], information of the extent of movement and local residence time of the fish is necessary to relate the water quality data to the aquatic biota. The available data suggest that lead was not a parameter of major concern in the St. Mary River.

g) Iron

The data (Table 20, Figure 35) show that increases occurred in the mean levels of dissolved iron (0.08 mg/L to 0.98 mg/L) and total iron (0.175 mg/L to 3.47 mg/L), downstream from Cominco Ltd. (site 0200029 to site 0200135). There were high dissolved levels, over 1 mg/L, at site 0200135 during low river flows, particularly in 1975 (3.4 to 20 mg/L) when the river pH was low. These data are from Cominco Ltd. and the Province and differences were apparent in the two sets of data. Cominco Ltd. measured only dissolved iron concentrations and their results (mean 0.12 mg/L, range 0.05 to 0.50 mg/L) were consistently lower than the Province's results (mean 0.87 mg/L, range 0.1 to 6.5 mg/L) after May 1975. These differences may have been due to variations in sampling procedure and in the way samples were handled or preserved. The high values for dissolved iron at site 0200135 during low river flows, shown in Figure 35, reflect the Province's data. The increase in dissolved iron predicted for the St. Mary River during low river flows from effluent data, was 7.86 mg/L, and was greater than found by either Cominco Ltd. or the Province. The difference between predicted and actual values was probably due to precipitation of iron in the St. Mary River, where the pH levels were higher than in the creeks.

B.C. Research[38] summarized the literature values for iron concentrations which are lethal or which cause sublethal effects in rainbow trout, brook trout and several genera of invertebrates found in the St. Mary River. The values vary according to test species, pH, hardness and the form of iron present ($Fe(OH)_2$ and $FeSO_4$). The lowest 96-hour LC_{50} value was 0.32 mg/L ferrous sulphate for Ephemerella subvaria (a mayfly). It was exceeded in two of the 32 determinations by Cominco Ltd., between March 1976 and September 1978 (0.45 mg/L in May 1978 and 0.50 mg/L in April 1976), and in over one-half of the 29 measurements by the Province after May 1975. All of the Province's results during the low flow months of 1975 and previous to 1975[39] exceeded 0.32 mg/L dissolved iron. However, the relative abundance of various species of Ephemerella at both the upstream and downstream sites, particularly in 1977 (Section 4.5), suggested that the iron was not toxic to this genera of mayflies in the St. Mary River.

Sublethal effects of ferrous hydroxide on brook trout include reduced growth, increased susceptibility to disease and injury and increased winter mortality of the young. In the caddis fly Cheumatopsyche sp. reduced emergence occurs. These effects are produced at concentrations of 6 mg/L or greater of iron[38]. Concentrations of dissolved iron at site 0200135, greater than 6 mg/L, were found by the Province during low flow months before 1975[39], in 1975 and in March 1978. This information suggested that after May 1975, when the pH consistently increased and the dissolved iron levels decreased, the possibility of sublethal effects had been marginal.

One possible effect of the iron on the aquatic biota is reduced fish egg survival due to adsorption of iron on to the spawn. For the arctic cisco, 0.52 mg/L of iron reduced spawn survival[48]. It is not known to what extent spawning occurred in the St. Mary River downstream from Cominco Ltd., but the relatively fast river flow, and the presence of shallow areas and of gravel substrate suggested that potentially good redd areas should have been available. The iron coating of the gravel (Section 4.4) may have made these areas less attractive for spawning.

B.C. Research[37, 38] found increased levels of iron in the sediment (Figure 38) and invertebrates (Table 23), downstream from Cominco Ltd. These results indicated that iron was available to the fish by ingestion as well as by absorption from the water. Iron levels in the edible muscle of fish collected upstream and downstream from Mark Creek varied (Table 24), but were independent of sample location. There are no recommended values for allowable iron content in fish for human consumption. However, mammals are capable of handling excess iron, by using excess available bonding sites in the blood plasma and other tissues[49]. The iron levels in the liver of fish were also variable (Table 25), but higher values seemed to occur in the downstream fish. Since iron is stored in the liver and the liver is an excretory pathway, the results suggested that the downstream fish were handling greater quantities of iron than the upstream fish.

Over 99 percent of the iron discharged by Cominco Ltd. is from the 3 900-foot Portal Mine Water and tailing pond overflows (Table 17). Treatment of these effluent streams, which is now taking place, should reduce the dissolved iron in the St. Mary River to levels which eliminate the chance of sublethal toxicity. It is not known how long it will take to remove the iron from the sediment, although it should gradually be washed downstream and diluted during spring freshet.

h) **Zinc**

There were substantial increases in zinc concentration at site 0200135 downstream from Cominco, compared to site 0200029. The mean levels of dissolved zinc went from 0.011 mg/L to 0.23 mg/L, and that of total zinc from less than 0.006 mg/L to 0.38 mg/L (Table 20 and Figure 35). The monthly levels of dissolved zinc showed that the increase in the mean level, from 1975 to 1978 at site 0200135, was due to high values during low river flows (0.3 to 1.59 mg/L). The highest values were found during the low flow months of 1975 (0.44 to 1.59 mg/L) when the pH values were low. In March 1978, the dissolved zinc concentration at site 0200135 was also high (1.5 mg/L), when the pH was slightly reduced (Figure 31).

B.C. Research(38) gave literature values for zinc concentrations which are toxic or cause sublethal effects in rainbow trout, brook trout and several genera of invertebrates. The values were extremely variable, ranging from 0.0056 mg/L for avoidance reactions in rainbow trout to a 14-day LC_{50} of 32 mg/L for the stonefly Acroneuria lycorias. The lowest value (0.0056 mg/L) was less than the detection limit (0.01 mg/L) for Cominco's results at the control site, but it was substantially less than the values at the downstream site, particularly during low flows. This comparison indicates that sublethal effects or increased stress on the biota could have occurred.

The variability of the toxicity data is due in part to species differences, pH, dissolved oxygen, hardness and chemical form of the metal(48). Also, aquatic organisms can acquire a tolerance to zinc by increasing the synthesis of the protein metallothionein which stores zinc preventing it from interfering with required enzymes(50). The protein metallothionein is usually in the kidney and liver. The data for zinc levels in the livers of fish from the St. Mary River (Table 25), although limited, suggested higher levels in the fish downstream from Cominco. This result indicated that the downstream fish were handling more zinc. The increased levels of zinc in the sediment (Figure 38), invertebrates (Table 23) and water downstream from Cominco Ltd. would account for the greater quantities of zinc handled by the fish, through ingestion and absorption.

Zinc concentrations in the muscle of fish collected from the St. Mary River showed random variations with no suggestion of increased levels in the downstream fish (Table 24). All of the values were less than the recommended levels for human consumption(47) (100 µg/g wet weight or about 500 µg/g dry weight). Similar variations in zinc levels in the muscle of fish fom the Fraser River(51) and the Columbia River(52) have also been shown.

The 3 900-foot Portal Mine Water and overflows from the iron and siliceous tailing ponds contributed over 90 percent of the zinc from Cominco Ltd. Treatment of these effluents was started recently and should substantially reduce the loading of zinc to the St. Mary River, thus minimizing the possibility of sublethal effects on the fish. However, it is not known how long it will take for the sediment levels to be reduced. The detritivore inverterates could, for a period, obtain zinc from the sediment, making it available to the fish by ingestion.

i) Toxicity

B.C. Research conducted acute-toxicity bioassays (96-hour LC_{50} determinations) on the St. Mary River water from site 0200135, on eight occasions between July 1976 and February 1978[37, 38]. Results showed consistent non-acute toxicity (Table 19). Such results were expected because the contaminants which were present in high concentrations in the effluents were not at acutely toxic levels in the St. Mary River at site 0200135 during this period. However, several of the contaminants (e.g., fluoride until 1978, iron, lead and zinc) were at concentrations during low river flows at site 0200135, which could have imposed stress on the aquatic biota. Higher concentrations of these contaminants were expected closer to the discharges.

Sublethal bioassays or tests on stress to aquatic biota would be more appropriate for the St. Mary River water. Also, frequent 96-hour LC_{50} determinations on each of the effluent streams could be used to predict whether the combined effluents will cause sublethal toxicity on the aquatic biota in the St. Mary River. The 96-hour LC_{50} data were available only for the effluent from Sewer 32 and the siliceous tailing pond supernatant.

The results of the in situ fish-caging experiments (Table 22) were inconclusive because the use of only one cage at each of the two river sites prevented valid comparisons. Also, in two of the eight experiments, fish died at both locations and technical problems, such as ice buildup, were encountered[37, 38]. If future caging experiments are carried out, at least three cages per site should be used and at least one site should be closer to the discharges.

4.4 Substrate of the St. Mary River

4.4.1 Presentation of the Data

B.C. Research made visual observations of the substrate and collected samples in 1976 and 1977 from sites 0200029 and 0200135, and at the power line, about 16 km downstream from site 0200135 (Figure 3). The particle-size distributions of the samples from October 1976 and October 1977 were determined. The fractions less than 0.150 mm from the October, 1976 and July, September, and October, 1977 samples were analyzed for arsenic, cadmium, copper, iron, lead, mercury and zinc. The detailed results are tabulated and discussed in the B.C. Research reports[37, 38]. The particle sizes are summarized in Table 26 and the metals data in Figures 38 and 39.

4.4.2 Discussion of the Data

The substrate at the three river sites consisted primarily of heterogeneous cobbles, greater than 4 mm in diameter. The interstices were filled with silt and sand, namely fines less than 4 mm in diameter (Table 26). At the control site 0200029, the cobble and larger rock surfaces were clear, whereas at the downstream sites the cobbles and rocks were covered with flocculent material (probably iron hydroxide), algae and organic detritus[37, 38]. The visible presence of algae at the downstream sites reflected the high nutrient load from Sewer 32. The organic detritus apparent on the cobble and rock surfaces at the downstream sites was due largely to deciduous leaf-litter compost. At site 0200029, the leaf-litter was primarily coniferous. It was not as readily decomposed and did not adhere to the rock surfaces, although it was degraded by the time it was washed down to site 0200135.

The levels of iron, lead and zinc (Figure 38) and arsenic, copper and mercury (Figure 39) in the sediment increased downstream from Cominco Ltd. Cadmium levels were less than the detection limit in July 1977, but increased at the downstream sites in September and October 1977[38]. The higher metal concentrations were due to precipitation of dissolved metals in the discharges by the more alkaline river water. There was also the effect of flushing sediments with high metal levels from Mark, James and Cow Creeks into the St. Mary River. The settling of sediments containing metals was demonstrated by the 1977 data which showed increased metal concentrations at the downstream sites during the three months of reduced river flows.

At the downstream sites, the metal levels were less in October 1976 than in October 1977. This may have been due to the higher river flows in freshet of 1976 (maximum mean monthly flow 229.6 m^3/s) compared to 1977 (maximum mean monthly flow 113.8 m^3/s). The difference in river flows may also explain some differences in the metal levels at the two downstream sites. In 1976, the concentrations of five metals (iron, zinc, arsenic, copper and mercury) were higher at the power line than at site 0200135, suggesting that the sediment was washed downstream. The reverse occurred for seven metals (iron, lead, zinc, arsenic, copper, mercury and cadmium) in July and September 1977. However, in October 1977 the concentrations of arsenic, copper and iron were similar at the two downstream sites, the levels of lead, zinc and cadmium were greater at the power line and the level of mercury was higher at site 0200135.

Although seven metals showed increased levels in the sediment downstream from Cominco Ltd., only three (iron, lead and zinc) had much higher levels in the water (Section 4.3). However, metals in sediments were important because they could have been accumulated by benthic invertebrates, particularly detritivores (in the gut and adhering to the exoskeleton of insects)[38] and passed to the fish by ingestion. The seven metals measured in the sediment were also measured by B.C. Research[38] in four trophic levels of benthic invertebrates (algivores, filter-feeders, detritivores and carnivores). The results, although variable (Section 4.5, Table 23), showed definite increases in the levels of iron, lead and zinc in the downstream samples and suggested slight increases for arsenic. The cadmium results were inconclusive and the data for copper and mercury were inconsistent, showing increases and decreases in the different trophic levels at the downstream sites.

The metal content of the invertebrates did not alter the invertebrate populations in the river downstream from Cominco Ltd.[38]. However, for iron and zinc, the levels were higher in the water, sediment and invertebrates as well as in the livers of the fish collected downstream from Cominco Ltd. (Table 25), suggesting that fish were handling larger quantities of iron and zinc. For lead, levels were also higher in the water, sediment and invertebrates from the downstream site, but the fish tissue values were inconclusive. For cadmium the data were also inconclusive, although liver values exceeded those recommended for human consumption. For arsenic, values were less than the detection limit in all of the fish samples[38], and for copper and mercury there were no trends in the values, which were within the recommended levels for human consumption.

Monitoring of iron, lead and zinc in the sediment should be continued. The relationship between concentration in the sediment and river flow and the effect of the effluent treatment plant can then be established.

4.5 Aquatic Biology

4.5.1 Presentation of the Data

B.C. Research sampled periphyton (attached algae), benthic invertebrates and fish in 1976 and 1977 in the St. Mary River, at sites upstream and downstream from Cominco Ltd. The sampling apparatus and procedures are described in the B.C. Research reports[37, 38]. These reports also present and discuss all the data collected.

The periphyton samples were collected on four occasions in 1976 (May 3, September 2, October 1 and October 25-27) and on three occasions in 1977 (July 26, September 19 and October 18) from sites 0200029 and 0200135. Chlorophyll a, phaeopigment and biomass were measured as indicators of productivity and turnover. the species present were identified and their relative abundance noted. The results of the chlorophyll a, pigment and biomass analyses are summarized in Table 27. The abundance of the periphyton species present is given in Tables 28 and 29.

Benthic invertebrate samples were collected in barbecue basket samplers at sites 0200029 and 0200135 on the same seven occasions as the periphyton samples. Kick samples of invertebrates were also obtained in July and October 1977 from sites 0200029 and 0200135 and at the power line (Figure 3).

The four replicate basket samples from each location and for each date were sorted to order and the insects which comprised most of the orders were identified to family, genus or species. The biomass was determined and the species diversity calculated. A summary of the mean number of individuals (per m^2) in the families of insects and of the biomass and diversity results are given in Tables 30 and 31.

Four taxonomic groups from the kick samples were analyzed for heavy metals. They included Baetidae (a family of mayflies), Hydropsychidae (a family of caddis flies), Ephemerella (a genus of mayflies) and Plecoptera (stoneflies). They represented the following four trophic levels: algivores, filter-feeders, detritivores and carnivores. The results are summarized in Table 23.

The fish were collected by angling, electroshocking and trapping in trap nets and gillnets, at one location upstream from Mark Creek and nine locations between Mark Creek and the power line. They were collected in July and October 1977. The species were identified and the metal levels in the muscle and liver were measured. In presenting the results, the nine downstream locations were grouped together as one. A summary of these results is given in Tables 24 and 25.

4.5.2 Discussion of Periphyton Data

In both 1976 and 1977, the periphyton productivity, as indicated by chlorophyll a and biomass, was substantially greater downstream from Cominco Ltd. This result was believed to be caused by the nutrients from the fertilizer complex. Phaeopigment was also greater at Wycliffe and peaked in September at site 0200029 and in October at site 0200135, suggesting increased algae die-off after these times. There were more species of periphyton identified at site 0200135 (24 in 1976, 23 in 1977) than at the control site 0200029 (16 in 1976, 13 in 1977), although at both sites most of the species were Bacillariophyceae (diatoms). The most abundant species of these diatoms varied between sites and years (Tables 28 and 29). The species of Chlorophyceae (green algae, e.g., Zygnema sp.) showed similar variations. The data suggested relatively diverse populations at both river sites.

The reduced levels of ortho-phosphate in the St. Mary River, recorded in 1978 downstream from Cominco Ltd. (Figure 33), could have reduced the periphyton productivity at site 0200135. However, the phosphate levels in the sediment, although not known, were probably high and their release from the sediment may have influenced plant productivity. Monitoring of periphyton is recommended to test the effect on productivity of the reduced loading of nutrients from Cominco Ltd.

4.5.3 Discussion of Benthic Invertebrate Data

Immature insects were the most abundant component of all the samples, but differences in the populations were found between 1976 and 1977, and between the two river sites, particularly in 1976. At site 0200135, downstream from Cominco Ltd., there were fewer taxa present (from 5 to 22 in 1976; 17 to 24 in 1977) than at the control site (from 18 to 24 in 1976; 24 to 28 in 1977)[37, 38]. Generally, the biomass was slightly to substantially greater at the downstream site due to the greater number of chironomids, baetids (1977) and large Hydropsychidae (Table 30 and 31). These differences were reflected in lower diversity values at site 0200135, suggesting less stable populations.

In 1976, relatively consistent differences were found between the two sites. At the control site 0200029, the dominant families were Simuliidae, Baetidae, Chironomidae and Heptageniidae (Table 30). Simuliidae, Baetidae and Heptageniidae cling on or beneath clean rocks and cobbles and obtain food by filtering particulates (e.g., Simuliidae) or by grazing on the attached algae (e.g., Baetidae, Heptageniidae). The Chironomidae are an extremely diverse family and are found on rock surfaces or in the sediment.

At the downstream site, 0200135, the dominant families were Chironomidae, Hydropsychidae, Baetidae, Taeniopterygidae and Nemouridae(Table 30). Hydropsychidae obtain food by filtering large particulates. They have been observed in large numbers among heavy periphyton growth on rock surfaces in the lower Columbia River[52]. The stoneflies, Taeniopterygidae and Nemouridae, are detritivores found largely in the detritus among the rocks and cobbles. As noted above, the Baetidae are algivores which graze on the attached algae and the Chironomidae are an extremely diverse group. These differences in the dominant families found at the two river sites reflect the difference in the substrate (Section 4.4), brought about by discharges from Cominco Ltd. as well as by natural differences in organic detritus.

Differences in the invertebrate populations between the two river sites were less obvious in 1977 than in 1976, and the numbers of individuals and biomass were greater in 1977 than 1976. In 1977, Chironomidae and Baetidae were consistently the most abundant taxa at both river sites, although they were much more numerous at site 0200135. The mayflies, Ephemerellidae, were also relatively abundant at the two sites with greater numbers of individuals at site 0200135. The abundance of the other families varied with sampling period. For instance, the stonefly, Taeniopterygidae, and the caddis fly, Brachycentridae, were very numerous at the downstream site in September and October, as was the stonefly, Capniidae, in October. The.kick samples showed more large caddis flies, Hydropsychidae, downstream from Cominco Ltd., than did the basket samples, due perhaps to the position in the river of the basket samplers. Heptogeniidae (mayflies) was the only family that was present in consistently higher numbers at the control site. The main difference between the two river sites appeared to be the numbers of individuals in the dominant groups. The greater numbers at site 0200135 may have been due to the increased algal productivity and organic detritus at the downstream site, but the differences between 1976 and 1977 are difficult to explain on this basis because substrate varied little between the two years.

Although the levels of iron, lead and zinc were definitely greater in the invertebrates from the downstream sites (Table 23), these metals did not appear to be affecting the invertebrate populations.

If there is a decrease in algae productivity at the downstream site, the effect on the invertebrate populations should be tested by further sampling of the invertebrates.

4.5.4 Discussion of Fisheries Data

The five species of fish (cutthroat trout, brook trout, Dolly Varden, mountain whitefish and burbot), known by the Fish and Wildlife Branch to have been present in 1967, upstream and downstream from Cominco Ltd., were found by B.C. Research in 1977[38]. Four of these species (cutthroat trout, brook trout, Dolly Varden and burbot) were the most abundant species collected. The results suggested that conditions in the river were adequate for supporting fish. Other species which were found, both upstream and downstream from Mark Creek, were large scale suckers, squawfish and sculpins. Longnose dace and redside shiners were found at the downstream locations.

The levels of heavy metals in the muscle tissue were variable, with no discernible trends. Where absolute values were measured, they were within those recommended for human consumption[47]. The levels of iron and zinc in the livers, although variable, were generally higher in the downstream fish, suggesting that these fish were handling larger quantities of the metals. The variability in the results can be attributed to the absence of a natural barrier between the upstream and downstream sites, and to the lack of information on the movement and residence time of the fish at the various locations in the St. Mary River.

4.6 Conclusions and Recommendations

4.6.1 Effluent Sources and Quality

Cominco Ltd. and the Kimberley sewage treatment plant discharged effluent to the St. Mary River, with the major contribution coming from Cominco Ltd.

Up to the end of 1979, there were five net discharges from Cominco Ltd.: the 3 700-foot Portal Mine Water, the 3 900-foot Portal Mine Water, Sewer 32 and overflows from the iron and siliceous tailing ponds. After August, 1979, mine water from the 3 900-foot Portal and decant from the two tailing ponds were processed through a treatment plant before discharge to the St. Mary River.

The mine water from the 3 700-foot Portal met conditions of the Pollution Control Permit. From 1975 to 1979, mine water from the 3 900-foot Portal and tailing pond overflows usually exceeded Permit criteria. However, after startup of the treatment plant, preliminary data indicated that effluent characteristics were within Permit limits. Gradual improvements have been made in the quality of effluent from Sewer 32 which services the fertilizer complex. However, certain parameters such as ammonia, pH, fluoride and ortho-phosphate had exceeded Permit criteria in the period 1975 to 1979.

4.6.2 Receiving Water

Certain constituents of Cominco's discharges were at high levels in Mark Creek, James Creek and Cow Creek. They included ammonia, fluoride, ortho-phosphate, sulphate, iron, lead, manganese and zinc. The pH was on the acid side. The mean values of these parameters increased (pH decreased) compared to background levels in the St. Mary River, with the highest values being associated with low river flows.

a) Effluent Dilution (Relative Concentration of Sulphate)

The concentration of sulphate in the river, relative to the concentration in the effluent, was used to determine the effluent dilution in the St. Mary River at site 0200135, downstream from all the discharges. The relative concentration of sulphate was expressed as a ratio. The mean monthly relative concentration showed cyclic trends over the period November 1975 to December 1978, with high values (ratios of 0.02 to 0.03) during low river flow months. These relative concentrations during low river flows represented concentrations of 2 to 3 percent effluent in the river at site 0200135. Higher concentrations of effluent were expected closer to the discharges, particularly in the vicinity of Mark, James and Cow Creeks, where effluent streams appeared to be confined to the Cominco side of the river.

To determine the effluent dilution more accurately, the creek flows should be measured at the mouths of Mark, Cow and James Creeks. The river distance required for complete effluent mixing can be found by measuring sulphate levels at the control site 0200029 and in the three creeks, as well as at transects across the St. Mary River at approximately 100 m intervals downstream from the creeks.

b) pH

Before May, 1975, the pH levels in the St. Mary River downstream from Cominco Ltd., were about 3.5 to 4.0 during low river flow, and about 6.5 during higher river flows. After May 1975, the pH had been about 7, and relatively stable throughout the years, although consistently less than the pH at the control site. The change was attributed to a higher pH in Sewer 32, as no changes were observed in the other effluents.

The pH levels occurring after May 1975 should not have adversely affected the aquatic life. A reduction in dissolved metal levels in the river was probably due to increased metal precipitation caused by the higher pH levels. The treatment of the mine water effluent, now in progress, should further improve the river pH levels.

Measurement of pH in the effluents and river should be maintained to monitor improvements which are expected in the river in the future.

c) Fluoride

The fluoride concentrations in the St. Mary River were highest during low river flows. However, the peak levels decreased with improved treatment of the wastes from the fertilizer complex, which contributed over 90 percent of the fluoride loading from Cominco Ltd. During low flow before May, 1975, toxic levels of fluoride were present in the river downstream from Cominco Ltd. (15 to 33 mg/L). During the low flow months between November, 1975 and April, 1978, possible sublethal concentrations of fluoride were found (1.0 to 1.5 mg/L). Further improvements in the plant gave values during low flow in November-December, 1978, which should neither have caused adverse effects on the aquatic biota nor limited water usage.

Certain increases in fluoride at the mouth of Mark Creek to levels greater than in Sewer 32 warrant investigation. Also, the fluoride concentration in the St. Mary River should be monitored to determine whether the decreases observed in 1978 are maintained.

d) Nutrients

The major nutrients required by aquatic plants and algae are ortho-phosphate phosphorus and inorganic nitrogen, particularly ammonia and nitrate. Sewer 32 contributed about 75 percent of the ammonia and nearly 99 percent of the ortho-phosphate from Cominco Ltd. The Kimberley sewage treatment plant's contribution was up to 11 percent of the ortho-phosphate discharged by Cominco.

Both inorganic nitrogen and ortho-phosphate increased at the downstream river site during low river flows. The inorganic nitrogen, largely ammonia from Cominco Ltd., was not a limiting nutrient, and therefore did not limit algal growth. The ammonia and nitrate were not expected to have an adverse effect on the aquatic biota or to limit water usage. The ortho-phosphate levels in the river, downstream from Cominco Ltd., decreased from 1974 to 1978, following the general trend of ortho-phosphate phosphorus reduction in Sewer 32. However, the levels during low river flows (0.25 to 6.3 mg/L), greatly exceeded the level of total phosphorus which is associated with enhanced algal growth (0.05 mg/L). The levels in 1978 (less than 0.10 mg/L) may also have enhanced algal growth. These high levels probably caused an increase in periphyton (attached algae) downstream from Cominco Ltd. in 1976 and 1977.

Continued monitoring of the nutrients in the St. Mary River is necessary to see whether the decrease in 1978 is maintained and whether further decreases occur with ongoing improvements at the fertilizer complex. These data should be collected in conjunction with periphyton samples.

e) Manganese

Increased levels of dissolved manganese were found downstream from Cominco Ltd., particularly during low river flows. The levels often exceeded the recommended level of 0.05 mg/L for domestic water supplies, established to minimize undesirable taste and staining. All of the values were less than the reported range of tolerance values for freshwater aquatic life (1.5 to 1 000 mg/L).

Manganese was not considered to be a parameter of concern in the St. Mary River. Treatment of the 3 900-foot Portal Mine Water and the tailing pond overflows, which contributed 96.5 percent of the manganese from Cominco Ltd., should reduce the levels in the river. Continued monitoring of manganese is not recommended.

f) Lead

Before May, 1975, dissolved lead levels were higher downstream from Cominco Ltd., than at the control site, particularly during low river flows. After May 1975, the dissolved lead concentrations had been similar at the upstream and downstream sites. They were less than the range of maximum acceptable concentrations for brook trout and less than the toxic levels for various aquatic insects. The decreased dissolved lead levels in 1975 were attributed to the increased pH levels, which increased precipitation of dissolved lead.

The total lead levels from 1975 to 1978 inclusive, remained high during low river flows downstream from Cominco Ltd., and approached or exceeded the range of maximum acceptable concentrations for brook trout.

Although the levels of lead in the sediment and invertebrates increased downstream from Cominco Ltd., increasing the potential availability of lead to fish, no signs of sublethal effects of lead (scoliosis and blacktail) were observed in the fish. The lead analyses of the muscle and liver tissues were inconclusive.

The available data suggested that lead was not of major concern in the St. Mary River. However, more accurate analyses of lead in the liver and muscle would show whether the fish are handling increased quantities of lead and whether the muscle can be consumed. A knowledge of lead levels in the bone and a thorough examination of the fish for symptoms of blacktail and scoliosis would enable more definite conclusions concerning possible sublethal effects.

g) Iron

Dissolved and total iron increased substantially downstream from Cominco Ltd. High levels of dissolved iron were associated with low river flows, particularly in 1975 when the pH was low.

Sublethal effects of iron on the aquatic biota were considered to be marginal, although the iron hydroxide coating on the rocks downstream from Cominco Ltd. may have rendered these areas less attractive for spawning. If the rocks were used for spawning, adsorption of iron to the spawn may have reduced egg survival.

Iron in the sediment and invertebrates increased its availability to the fish, as reflected by the iron levels in the liver tissue of fish. The levels were variable, but higher values were usually found in the livers from the downstream fish, indicating that these fish were handling larger quantities of iron. There were no differences in iron levels in the muscle of fish from upstream and downstream locations and the levels did not limit human consumption.

Treatment of the mine water and tailing pond overflows should reduce the dissolved iron levels in the St. Mary River to values below sublethal toxicity levels. However, it is not known how long iron will remain in the sediment. Iron in the sediment may hinder spawning and contaminate fish via uptake by invertebrates which are ingested by the fish.

Continued monitoring of iron in the water, sediment, invertebrates and fish tissues is recommended. The periphyton should also be examined for iron levels. There were some differences in the dissolved iron data obtained by Cominco Ltd. and the Province. These differences should be resolved.

h) Zinc

Dissolved and total zinc increased substantially downstream from Cominco Ltd. The dissolved zinc values were higher during low river flows with the highest values corresponding to reduced pH levels.

Toxicity data from the literature suggested that during low river flows the dissolved zinc may have exerted stress on the biota. However, aquatic biota can acquire a tolerance to zinc by increasing the synthesis of the protein metallothionein in the liver (and kidney) which stores zinc, and thus prevent it from interfering with required enzymes. The zinc levels in the livers of fish collected downstream from Mark Creek were higher than in fish from upstream fish, indicating that the downstream fish were handling larger quantities of zinc. Zinc at the downstream site was in the water and invertebrates, the latter obtaining the zinc largely from the sediment.

The zinc levels in the muscle, although variable, showed no difference between the upstream and downstream fish and were within the recommended levels for human consumption of freshwater animal products.

Treatment of the 3 900-foot Portal Mine Water and the iron and siliceous tailing pond overflows will reduce the levels of zinc in the St. Mary River and minimize the possibility of sublethal effects on the fish. However, it is not known how long it will take for the zinc levels in the sediment to be reduced. The invertebrates, particularly the detritivores, could still obtain zinc from the sediment, making it available to the fish through the food chain.

Monitoring of the zinc levels in the water, sediment, invertebrates, periphyton and fish tissues is recommended.

i) Toxicity

Acute-toxicity bioassay tests, using St. Mary River water, showed consistent non-acute toxicity in the St. Mary River downstream from Cominco Ltd. Several parameters (e.g., fluoride until 1978, iron, lead and zinc) were at concentrations during low river flows which could have resulted in sublethal effects, including increased stress. Sublethal bioassays, or tests to determine the possibility of stress on the biota, should be conducted. Also, frequent 96-hour LC_{50} determinations on each of the effluent streams could be used to predict whether the combined effluents can be the cause of sublethal toxicity to the aquatic biota in the St. Mary River.

The fish-caging experiments showed inconclusive results and, as they were another measure of acute toxicity, they need not be repeated.

4.6.3 Substrate

The substrate for 22 km downstream from Cominco Ltd. was visibly different than at the upstream control site. At the control site, the cobble and rock surfaces were clean, whereas downstream they were coated with a flocculent material (probably iron hydroxide), algae (due to increased nutrients), and organic detritus (largely leaf-litter).

The concentrations of iron, lead, zinc, arsenic, copper, mercury and cadmium in the sediment were higher downstream from Cominco Ltd. The variation in the data appeared to be related to river flow. Of the seven metals which increased in the sediment, only three (iron, lead and zinc) increased in the aquatic invertebrates, although slight increases in arsenic were occasionally observed. Iron, lead and zinc also increased in the water downstream from Cominco Ltd. Iron and zinc levels in fish livers suggested that the fish collected downstream from Mark Creek were handling larger quantities of these metals.

The data for lead and cadmium in fish tisue were inconclusive, although cadmium levels in the livers from both upstream and downstream sites exceeded those recommended for human consumption. Arsenic was below the detection limit in all of the fish samples. Copper and mercury in fish showed no trends and were within the recommended levels for human consumption.

Continued monitoring of iron, lead and zinc in the sediment is recommended to determine the relationship between sediment concentrations and river flow and the expected decrease in river loadings following treatment of the plant effluents.

4.6.4 Periphyton

Periphyton productivity, as measured by chlorophyll a and biomass, increased significantly downstream from Cominco Ltd., due primarily to the high nutrient loadings from the fertilizer complex. The populations at the upstream and downstream sites were relatively diverse, and most of the species present were diatoms. There were variations in the abundant species of diatoms. The green alga, *Zygnema* sp., was very abundant at the control site in 1976, and several species of green algae were abundant at Wycliffe in 1977.

Continued monitoring of the periphyton populations is recommended to determine whether the reduced nutrient loadings from Sewer 32 alter the periphyton productivity. The phosphate and inorganic nitrogen levels in the sediment should also be measured to ascertain whether their release from the sediment would affect the periphyton productivity.

4.6.5 Benthic Invertebrates

The benthic invertebrate populations differed between the upstream and downstream sites, and changed from 1976 to 1977. At the downstream site, fewer taxa were present and several taxa (e.g., Chironomidae and Baetidae) were very abundant, particularly in 1977. This gave lower diversity values, and suggested less stable populations at the downstream site. In 1976, the difference in population between the two sites was related to the substrate type. At the control site, the dominant invertebrates were those associated with relatively clean rock surfaces and fine organic detritus, whereas at the downstream site, the abundant taxa were those associated with increased amounts of organic detritus, and not necessarily with relatively clean rock surfaces. In 1977, the number of individuals and the biomass at both sites were greater than in 1976, and the difference between the two sites was due primarily to the numbers of individuals in the same dominant taxa. The greater numbers at the downstream site may have been due to the greater periphyton productivity and organic detritus at the site. The difference from 1976 to 1977 was difficult to explain as the substrates varied little between the two years.

The levels of iron, lead and zinc increased in the four trophic levels of benthic invertebrates (algivores, filter-feeders, detritivores and carnivores), but the metals were not believed to affect the invertebrate populations. There were slight increases in arsenic in the downstream invertebrates, the cadmium data were inconclusive, and the results for copper and mercury were inconsistent, showing both increases and decreases in different trophic levels.

Continued monitoring of the benthic invertebrate populations is recommended to show whether changes in algal productivity affect the invertebrate populations and to monitor changes in the populations with changing conditions. The levels of iron, lead and zinc in the four trophic levels of invertebrates should also be analyzed, particularly if metal levels in the sediments decrease.

4.6.6 Fisheries

The most abundant species collected in 1977, upstream and downstream from Mark Creek, included cutthroat trout, brook trout, Dolly Varden and burbot. These species were known to have occurred in the past in the St. Mary River, suggesting that the conditions in the river were improving. In 1977, large scale suckers, squawfish and sculpins were also collected from both upstream and downstream locations, and longnose dace and redside shiners were found at the downstream locations.

Metal levels (iron, lead, zinc, arsenic, cadmium, mercury and copper) in the muscle of fish were similar upstream and downstream from Mark Creek, although the results were variable, and for some metals (lead, arsenic and cadmium) inconclusive. The levels of iron and zinc were higher in the livers of fish from the downstream locations, suggesting that these fish were handling larger quantities of iron and zinc. The lead and cadmium data were generally inconclusive, although certain cadmium levels in both upstream and downstream fish exceeded recommended levels for human consumption of livestock meat. Arsenic was less than the detection limit in all of the fish liver samples, and no trends were apparent for copper and mercury, which were within the recommended levels for human consumption.

Analyses of the muscle and liver of fish for iron, lead and zinc are recommended if the levels of these metals in the sediment and invetebrates do not show substantial decreases. The bone should also be analyzed for lead.

5. THE KOOCANUSA RESERVOIR

5.1 Kootenay River From the St. Mary River Confluence to Wardner

5.1.1 Hydrology of the River

The St. Mary River meets the Kootenay River just upstream from Fort Steele, and the Kootenay River continues south to Wardner, the upper limit of the Koocanusa Reservoir (Figure 3). At Fort Steele (Water Survey of Canada station 8NG 065), the mean monthly flow for 1963 to 1976 inclusive, ranged from 37.7 m^3/s in February to 750 m^3/s in June[12] (Figure 40). Approximately 70 percent of the flow was from the Kootenay River upstream from the St. Mary River confluence and 30 percent from the St. Mary River.

If the Kootenay River diversion proceeds, as described in Section 3.1, the flow of the Kootenay River at Canal Flats could be reduced to 5.7 m^3/s during low flow periods. Between Canal Flats and the St. Mary River confluence, the flow increased by about 44 percent, so that after the diversion the flow at the St. Mary River confluence would be approximately 8.2 m^3/s (5.7 x 1.44). The minimum mean monthly contribution from the St. Mary River (at Wycliffe) was 9.2 m^3/s (Section 4.1). Thus, with the diversion, the minimum Kootenay River flow below Fort Steele would be about 17.4 m^3/s (8.2 + 9.2), which is less than one-half of the present minimum mean monthly flow.

5.1.2 Discharges to the River

There were no significant discharges to the Kootenay River between the St. Mary River confluence and Wardner. There may have been some seepage fom septic tank tile fields and runoff from agricultural land, but their effect was expected to be minimal. The effluents from Crestbrook Forest Industries Ltd. (Section 3.2) and Cominco Ltd. (Section 4.2) were the major influences in this portion of the river.

5.1.3 Water Quality and Sediment Data

The Province has monitored the water quality at site 0200038, 11 km downstream from the St. Mary River confluence, every month from 1975 to 1978 (Figure 3). The monitoring data are summarized in Tables 32 and 33. Table 32 lists the parameters which were discussed in Section 3.2.2 on Crestbrook and Section 4.2.3 on

Cominco. Table 33 includes the remaining parameters which were measured. The monthly values of sodium and sulphate, total iron and fluoride, and phenols and colour are plotted in Figures 41, 42 and 43.

Sediment samples were collected from site 0200038 in October, 1975 and July and August, 1976. The results of the analyses are given in Table 34.

Parameters which could have limited water usage and affected the aquatic biota in the Kootenay River, downstream from Crestbrook Forest Industries Ltd. (Section 3.2.2), were colour, phenols and toxic constituents of pulp mill effluents such as resin acids. Sodium was also present in high concentrations and was a useful effluent tracer. In the St. Mary River the important parameters were pH, fluoride, nutrients (particularly ammonia and ortho-phosphate), iron, lead, zinc and sulphate, the last being considered as an effluent tracer. Except for resin acids, all these parameters were measured monthly at site 0200038.

a) Sodium and Sulphate

The presence of effluents from Crestbrook Forest Industries Ltd. and Cominco Ltd. at site 0200038 was suggested by the sodium and sulphate concentrations at this site (Figure 41). Sodium concentrations during low flows were 10 to 12 mg/L compared to values of 6 to 7 mg/L at site 0200020, upstream from Crestbrook Forest Industries Ltd. (Figure 15). In the St. Mary River, upstream from Cominco Ltd. (site 0200029), sulphate concentrations were consistently about 10 mg/L (Figure 37), whereas at site 0200038 values of 55 to 70 mg/L were found during low flow months (Figure 41).

b) Heavy Metals and pH

Dissolved and total zinc, total lead and pH, were slightly higher at site 0200038 (Table 33) than at site 0200029 (Table 20), upstream from Cominco Ltd. and at sites 0200020 and 0200175 (Tables 8 and 9), upstream from Crestbrook Forest Industries Ltd. The levels were within the drinking water criteria and should not have affected the aquatic biota[36]. The levels could increase if the Kootenay River diversion takes place, although the treatment plant recently installed at Cominco Ltd. should keep the increases minor.

The sediment at site 0200038 contained arsenic, copper, iron, lead, mercury and zinc within the range of values found in the sediment from the St. Mary River, upstream from Cominco Ltd. (Table 34). No comparative data were available for chromium, fluoride, manganese and phosphorus in the sediments.

c) Iron

The dissolved iron concentrations at site 0200038 were equal to or less than 0.1 mg/L, except for two values in February and March, 1975 (0.2 and 0.4 mg/L). Dissolved iron was therefore not considered to be of concern. The total iron levels were consistently high during freshet (2.6 to 6.0 mg/L from April to June), suggesting that the iron in the sediment from the St. Mary River was resuspended and washed downstream. However, iron in the sediment at site 0200038 was within the range of values found in sediments upstream from Cominco Ltd. (Table 34). The total iron levels in the water (Figure 42) exceeded values at site 0200029 (<0.1 to 0.7 mg/L) and were greater than the drinking water criterion (0.3 mg/L)[35]. The total iron could have affected fish egg survival due to adsorption to the spawn, but the extent of spawning in this section of the Kootenay River was expected to be small.

The levels of iron should be decreased by the recently installed treatment plant at Cominco Ltd., although future diversion of the Kootenay River at Canal Flats could counteract this effect. Continued monitoring is recommended.

d) Fluoride

High values (3.6 to 4.2 mg/L, Figure 42) in January to April, 1975, were typical of fluoride concentrations recorded during low flow periods before 1975. Such levels would have limited water usage and stressed the aquatic biota (Section 4.3.2). After May, 1975, the values were much lower (below 0.5 mg/L) because of changes in the St. Mary River brought about by improvements in the fertilizer complex. The lower concentrations at site 0200038 should neither have limited water usage nor affected aquatic biota. It is difficult to predict accurately how the Kootenay River diversion could affect the fluoride concentrations. Continued monitoring is recommended.

e) Phenols

Although the phenol data were not truly quantitative (Section 3.2.2) some general comments can be made. The monthly values increased during low flow months (Figure 43) to levels exceeding 0.002 mg/L, the level considered acceptable for drinking water. Phenols can also alter the taste and odour of water and taint fish flesh, but whether or not this had occurred in this section of the Kootenay River was not known. Rapid infiltration of the effluent from Crestbrook Forest Industries Ltd. to reduce effluent colour may also reduce phenol levels. The final effect on water quality if the diversion proceeds is not known, and continued monitoring is recommended.

f) Colour

Colour levels increased during low flows at site 0200038 (Figure 43). They exceeded colour levels at site 0200175 on the Kootenay River, upstream from Crestbrook Forest Industries Ltd. During the low flow months the levels exceeded the criterion of 15 colour units for drinking water and may have affected the water usage and aquatic biota as discussed in Section 3.2.2. Colour reduction of the effluent, as planned by Crestbrook Forest Industries Ltd. should reduce the colour to acceptable levels at site 0200038. Continued monitoring is recommended.

g) Nutrients

The nutrients (nitrogen and phosphorus) are discussed in the following Section on the Koocanusa Reservoir. At site 0200038, reduced levels, particularly of phosphorus, were apparent after 1975, corresponding to the improved treatment of the effluent from the fertilizer complex at Cominco Ltd.

5.1.4 Summary and Recommendations

Slight increases were apparent at site 0200038 for most of the parameters identified as important in the Kootenay River, downstream from Crestbrook Forest Industries Ltd., and in the St. Mary River, downstream from Cominco Ltd. After May, 1975, only colour, phenols and total iron were at levels which could have limited water use. No adverse effects on the aquatic biota were expected, although the effects would be difficult to predict exactly if the Kootenay River diversion proceeds. Treatment of effluent from Crestbrook Forest Industries Ltd. by rapid infiltration should improve colour and possibly phenol levels in the river. Also, the recently installed treatment plant at Cominco Ltd. should reduce the iron levels. Monitoring of colour, fluoride, phenols and total iron should be continued.

5.2 The Canadian Portion of the Koocanusa Reservoir

5.2.1 Introduction

The Kootenay River south of Wardner has been impounded by the Libby Dam which was built in Montana, approximately 30 km south of the International Border. The reservoir started to fill in March, 1972 and reached full pool in June, 1974.

The International Border divides the reservoir approximately in half. The water is used for power generation at Libby, and for flood control, and these uses created very large fluctuations in the level and hence the extent of the reservoir. For example, the maximum drawdown was 52 m and this reduced the volume in the reservoir from 7.2 km^3 to 1.1 km^3, and its surface area from 189 km^2 to 60 km^2. During low river flow, between the months of November and April, the drawdown was such that most of the Canadian part of the reservoir disappeared.

Data collected up to end of 1974, presented in the Phase I report(2), showed that in spite of the high phosphorus loadings to the reservoir which occurred at that time, the biological productivity was low. This result was believed due to a number of factors including thermal instability allowing deep mixing of the water, turbidity brought in from the Kootenay River limiting light penetration, loss of phosphate from the water column, and inflow of river water along the bottom of the reservoir keeping nutrients below the photic zone(2).

Data presented here are summarized from a detailed water quality report on the reservoir for the period 1972 to 1978(53).

5.2.2 Hydrology

The water entering the reservoir comes mainly from three rivers: the Kootenay River which contributed 62 percent of the mean annual flow, the Elk River which contributed 26 percent, and the Bull River which contributed 11 percent. The mean annual flow of the Kootenay River at Fort Steele was 185 m^3/s (Water Survey of Canada station 08NG 065). The flow varied widely depending on the amount of runoff. From 1975 to 1978 the mean annual flows of the Kootenay River were 164 m^3/s, 210 m^3/s, 178 m^3/s and 121 m^3/s.

The reservoir is used for both power generation and flood control. Up to 1974, while the reservoir was filling, operation of the reservoir was not consistent. After 1974 the changes in water level became more typical. The reservoir was usually full during August, September and October. Drawdown for power generation and flood control started in November and continued till April. The reservoir level then rose during May, June and July due to storage of spring runoff.

5.2.3 Physical and Chemical Characteristics

Samples were taken at three sites in the reservoir: site 0200100 just north of the International Border, site 0200101 a little north of the confluence of the Elk River, and site 0200169 about 15 km north of 0200101 (Figure 3). Each site was usually sampled once a month in the period June to October, when reservoir levels were high.

a) Temperature

There was no thermocline or discontinuity in the temperature profile. Winds, fluctuating water levels and a short water residence time (about 225 days) tended to prevent the formation of a strong thermocline.

Isotherms plotted against site and depth (Figure 44) show that cold inflowing water from the Kootenay River would be expected to flow along the bottom. The major flow therefore appeared to be along the floor of the reservoir.

b) Light

Light penetration into the reservoir may have been affected by the effluent from Crestbrook Forest Industries Ltd. and by suspended solids. The effect of the pulp mill effluent on light was probably minor. The measurement of water colour in the river showed no change on average[2]. More recent data indicated that at low river flow the colour near Wardner rose to levels which may have affected water use and aquatic biota (Section 5.1.3 and Figure 43). Since this change occurred during times of low algal growth, it was unlikely to have affected productivity in the reservoir.

Suspended solids had a major influence on light penetration. The extinction depth, as measured by Secchi disc, was less than 1 m during freshet in May and June (Table 35). The data also showed that the turbidity increased with depth, a result which was expected since inflowing turbid water flowed along the bottom. These factors limited light penetration and hence algal growth, especially in early summer.

An estimate of annual loading of suspended sediments is given in Table 36. Loadings from the Kootenay, Elk and Bull Rivers were obtained from single monthly samples and summed. The total annual load varied considerably from year to year, due mainly to large variations in river flows.

c) Oxygen

Oxygen concentrations, expressed as percent saturation, were generally greater than 75 percent at the bottom of the reservoir. High oxygen concentrations were maintained by a lack of stratification and good vertical mixing. There was very little gradient in the concentration from top to bottom.

d) Fluoride

Fluoride measurements at site 0200100 are plotted in Figure 45. Some peak values, between 0.4 and 0.5 mg/L, were meaured from 1973 to 1975. After 1975 values dropped to below 0.2 mg/L, probably as a result of recycling of effluent from the gypsum pond at Cominco's fertilizer plant in Kimberley. These lower levels should have had no detrimental effect on aquatic life.

e) Heavy Metals

Few measurements were made of heavy metals in the reservoir. Results for total iron showed that concentrations at site 0200100 were constant and did not exceed 0.2 mg/L from 1975 to 1978. Similar results were obtained for dissolved lead (0.001 mg/L) and dissolved zinc (0.0045 mg/L).

f) Phosphorus

The concentrations of total phosphorus at site 0200100 are given in Table 37, for various depths from 1973 to 1978. Up to 1975 the concentrations were quite high (from 0.046 to 0.123 mg/L) and reflected the high levels of phosphorus discharged by the Cominco fertilizer plant at Kimberley. From 1976 to 1978 the concentrations of total phosphorus at site 0200100 dropped substantially (Table 37). Similar decreases were measured upstream in the St. Mary River (Section 4.3.2). They were due to improvements at the fertilizer plant which led to less phosphorus being discharged via Sewer 32, the main source of phosphorus in the basin.

Although phosphorus is important for phytoplankton growth, the productivity in the reservoir was low, for reasons outlined in the introduction (Section 5.2.1). As the phosphorus concentrations continue to fall there is a likelihood that productivity will decrease further.

g) Nitrogen

Nitrogen was measured in the form of organic nitrogen, nitrate nitrogen and ammonia nitrogen. Each of these forms showed a distinct annual cycle, with higher concentrations in the spring, decreasing through the summer presumably from algal uptake.

Organic nitrogen was present in the highest concentration, averaging 0.089 mg/L over the period 1972 to 1978. Nitrate nitrogen averaged 0.053 mg/L over the same period and ammonia nitrogen was generally in the range of 0.010 to 0.015 mg/L.

Because of the high phosphorus loading to the reservoir the nitrogen to phosphorus ratio has always been low. From 1972 to 1975, the ratio ranged from 1.6 to 2.3 and then increased to 5.9 in 1976. Below a nitrogen to phosphorus ratio of 6, algal growth is considered to be limited by the availability of nitrogen, which is the situation that has occurred so far in the reservoir. With a ratio between 6 and 15 the nutrients are considered to be more or less in balance with algal requirements, and with a ratio over 15 growth depends on phosphorus availability.

h) Sediments

Sediments were sampled once at the three sites and the data are given in Table 38. The data indicated that fluoride, phosphorus and heavy metals tended to settle out in the reservoir. Concentrations in the sediments were quite low and the sediments were not considered to be contaminated.

5.2.4 Biological Characteristics

Biological sampling was carried out at the same time and at the same sites as water quality sampling. Only data from site 0200100 are presented in this summary. Data from the other two sites are not included because they were influenced by the river and were not typical of the reservoir.

a) Phytoplankton

From 1973 to 1977 the phytoplankton community was composed mainly of diatom species. The dominant genera often varied considerably from month to month. The biomass produced, expressed as mg/m^3, was a measure of reservoir productivity. The data on biomass are summarized in Table 39 for site 0200100, from 1973 to 1977.

The biomass increased from June to peak values in late summer or October. Peak values were generally less than 100 mg/m^3. On occasion, significant blooms occurred, especially in 1974 and 1975, giving a higher biomass. Values less than 100 mg/m^3 indicate oligotrophic conditions, or low productivity and values over 300 mg/m^3 indicate eutrophic conditions[54].

The chlorophyll a data, listed in Table 40, showed the same pattern as the biomass data. Values were generally in the range of 0.3 to 3 mg/m^3, indicating oligotrophic conditions[54]. Values above 10 mg/m^3, indicating eutrophic conditions[54], did not occur.

b) Zooplankton

The crustacean zooplankton community was made up mainly of Daphnia, with two copepod species (Cyclops and Diaptomus) gaining prominence at various times. The quantity of zooplankton, expressed as $organisms/cm^2$ of reservoir surface, was measured at two sites from 1973 to 1977. Results are summarized in Table 41 for site 0200100.

Zooplankton numbers up to about 170 $organisms/cm^2$ indicate oligotrophic conditions, and above 400 $organisms/cm^2$ they indicate eutrophic conditions[55]. In the Koocanusa Reservoir peak values were in the range 33-73 $organisms/cm^2$, occurring usually in July. The values indicated low productivity.

5.2.5 Discussion and Recommendations

The biological productivity in the Koocanusa Reservoir was limited more by physical factors than by the supply of nutrients. The main influence was turbidity, brought in with the freshet. The high suspended solids load limited light penetration and hence photosynthesis. The peak production of algae thus occurred towards the end of the summer, after the turbidity had decreased due to settling of suspended solids.

The lack of thermal stratification also limited productivity. There was a vertical movement of water which removed algae fom the photic zone at the surface and therebye limited photosynthetic production. The short residence time of water in the reservoir (225 days) meant that algae cells tended to be washed out quickly, resulting in lower productivity.

There was little appreciable change in productivity during the period 1972 to 1978. Although algal blooms were predicted because of the high phosphorus loadings to the reservoir, these had not occurred to any extent. The blooms of 1974 and 1975 did not contain particularly high concentrations of algal cells and no blooms had taken place after 1975. The drop in phosphorus loading due to pollution control measures taken at Cominco's fertilizer plant in Kimberley, coupled with the physical factors discussed above, indicated that productivity in the future would remain low. Whereas too high a productivity can lead to algal blooms and water quality deterioration, the reverse can lead to problems of low fishery productivity.

Since it is still difficult to predict how conditions will change, monitoring should be continued, although probably at a reduced level. For example, monitoring the border site only will probably suffice unless large changes, such as the Kootenay River diversion, take place. The diversion would decrease the suspended solids loads to the reservoir and thus increase the productivity. To a certain point this may be beneficial, but the increase could produce undesirable algal blooms and a rapid deterioration of water quality. Should the diversion proceed, or other changes of a similar magnitude occur, full scale monitoring should be resumed.

6. WATER AVAILABILITY

Water sources in the Kootenay River basin with limited water availability are discussed in this chapter. The data are summarized in Table 42. Sources in the basin between Canal Flats and the St. Mary River are shown in Figure 46, and between the St. Mary River and the International Border in Figure 47.

Thirteen of the 37 water-short sources in Table 42 were very small and provided less than 100 cubic decametres per annum (dam^3/a). The largest water-short sources were Skookumchuck (58 762 dam^3/a), Mark (34 780 dam^3/a), Norbury (20 576 dam^3/a) and Gold Creeks (14 510 dam^3/a). The majority of the water shortages (60 percent) were due to irrigation. About 20 percent of the shortages were due to domestic demand. These included shortages on Joseph and Gold Creeks which supplied the City of Cranbrook.

Conservation projects were the major users on Jim Smith Creek/Lake, Saugum Creek and Norbury Creek, while a diversion for land improvement (maintenance of water levels in Lazy Lake) was the major user on Lewis Creek. The Crestbrook Forest Industries Ltd. pulp mill was the major user of Skookumchuck Creek while Cominco Ltd. was the major user of Mark Creek. The water in the Bull River was reserved for power purposes above the Aberfeldie Dam, but interim water licences were obtainable with the consent of the Minister of Environment. The Water Act provides that water for domestic use and land improvement may be obtained from any stream to which a reserve applies.

The City of Cranbrook obtained its water supply from Joseph Creek, upper Gold Creek (via a diversion to Joseph Creek) and groundwater wells. This system was approaching the limit of its capacity (water conservation measures were necessary during 1977, a dry year) and additional water supplies were needed for the future. A 1965 water supply study recommended that Cranbrook develop the upper Moyie River for future water supply, and the City has since obtained water rights on the Moyie River. The Joesph-Gold Creek system had a fecal contamination problem that is believed to have been mainly due to cattle in the watershed, but there may have been other sources of contamination.

There is a possibility of water shortages along the Kootenay River if B.C. Hydro proceeds with the Kootenay River Diversion at Canal Flats. Under the Columbia

River Treaty, up to 1.85 cubic kilometres per annum (km^3/a) of water may be diverted from the Kootenay River at Canal Flats to the Columbia River system, after September 1984. This represents about two thirds of the mean annual flow in the Kootenay River at Canal Flats. The current proposal would reduce the flow in the Kootenay at Canal Flats to 5.7 m^3/s (the historical daily minimum flow) for 8 to 9 months of every year (i.e. August or September to April)[3].

A preliminary evaluation indicates that at reduced flows there might be irrigation water shortages between Canal Flats and the St. Mary River if all irrigable land was developed during the life of the diversion. B.C. Hydro and its consultants will be conducting further studies to assess the adequacy of reduced Kootenay River flows to meet water supply needs downstream from Canal Flats[8].

A preliminary assessment of the irrigation possibilities in the southwest portion of the Kootenay River valley has been made by the Ministry of Environment[57]. The study encompassed a 310 km^2 area, bounded by Lake Koocanusa in the west, the International Border in the south, the foot of the Galton Range and the Elk River in the east, and the community of Elko in the north. Approximately 19 200 ha of irrigable land was identified in the area. Irrigation water requirements were estimated to be 143 000 dam^3/a with a peak demand of 20 m^3/s. The major potential sources of irrigation water were the Elk River, 12 small streams draining the Galton Range in the Grasmere Valley, and groundwater. Lake Koocanusa was not considered as a potential source because, although there was enough water, the wide fluctuations in reservoir level during the irrigation season would have presented major problems in pumping.

The study assumed that 11 500 ha could be irrigated from the Elk River, 2 040 ha from the 12 streams along the Galton Range, and the balance from groundwater, although a test-well drilling program would be needed to assess the groundwater potential of the area. The initial development would probably be the irrigation of the remaining agricultural land in the Grasmere Valley. Preliminary estimates indicated that the 2 040 ha of irrigable land in the valley (780 ha of this was already irrigated) could be irrigated by the 12 streams draining the Galton Range. The streams would have to be diverted above the valley bottom to minimize seepage losses to groundwater. The high seepage losses in the lower portions of the streams indicated that the potential for groundwater supplies was good in the Grasmere Valley, and irrigation water could probably be obtained from wells if necessary. Three creeks and one spring in the Grasmere Valley were water short due to irrigation demands (Table 42 and Figure 47).

AUTHORS

R.J. Rocchini, M.A.Sc., P.Eng.: Study Coordinator.

L.A. Gregory, M.Sc., Biologist: Discharges, Water Quality and Aquatic Biology.

L.W. Pommen, M.Sc., P. Eng.: Discharges, Water Quality and Availability.

R.N. Nordin, Ph.D., Biologist: Limnology.

REFERENCES

1. Ministry of Environment, Kootenay Air and Water Quality Study Phase I, Water Quality in Region 3, The Upper Kootenay River Basin, Victoria, April, 1976.

2. Ministry of Environment, Kootenay Air and Water Quality Study Phase I, Water Quality in Region 4, The Lower Kootenay River Basin, Victoria, March, 1976.

3. B.C. Power and Hydro Authority, Hydroelectric Design Division, Kootenay River Diversion Project, Preliminary Engineering Assessment, Vol. I and II, Report No. 813, October, 1977.

4. Waste Management Branch File PR-2554, Crestbrook Forest Industries Ltd., Canal Flats, Victoria, B.C.

5. Waste Management Branch Files PRE APP GEN(B) and PRE APP GEN(M), Baymag Mines Ltd., Cranbrook, B.C.

6. Ministry of Industry and Small Business Development, The Kootenay Report 76, A Summary Report of Development Possibilities in the Kootenay Region of B.C., 1976.

7. Entech Environmental Consultants Ltd., Kootenay River Diversion, Initial Environmental Evaluation, Volume IV, Economic Environment, Vancouver, B.C., January, 1978.

8. Entech Environmental Consultants Ltd., Kootenay River Diversion, Initial Environmental Evaluation, Volumes I, II and III, Vancouver, B.C., January, 1978.

9. Environment Canada, Surface Water Quality in Canada, An Overview, Inland Waters Directorate, Water Quality Branch, Ottawa, 1977.

10. Canada Department of National Health and Welfare, Canadian Drinking Water Standards and Objectives 1968, Ottawa, October, 1969.

11. Kittrell, F.W., A Practical Guide to Water Quality Studies of Streams, U.S. Dept. of the Interior, Federal Water Pollution Control Administration (CWR-5), 1969.

12. Water Survey of Canada, Inland Waters Directorate, Historical Streamflow Summary, B.C. to 1976, Ottawa, 1977.

13. Water Survey of Canada, Inland Waters Directorate, Low Flows in B.C., Annual 7-Day Averages, Vancouver, 1974.

14. B.C. Hydro and Power Authority, Hydroelectric Design Division, Kootenay River Diversion Project, Preliminary Engineering Assessment, Vol. 1 and 2, Report No. 813, October, 1977.

15. Pollution Control Board, Pollution Control Objectives for the Forest Products Industry of B.C., Victoria, B.C., 1972.

16. Joint Crestbrook Forest Industries Ltd.-Pollution Control Branch Colour Committee, A Report on Investigation of Methods to Reduce Effluent Colour, August, 1976.

17. Swaney, J.M., Bleached Kraft Mill Effluent Colour Removal by the Rapid Infiltration Technique, Crestbrook Forest Industries Ltd., November, 1978.

18. Webster, A., The Hydrogeological Suitability of a Proposed Site for Rapid Infiltration of Pulp Mill Effluent, Crestbrook Forest Industries Ltd., October, 1978.

19. Pollution Control Board, Pollution Control Objectives for the Forest Products Industry of B.C., Victoria, B.C., 1977.

20. Nemerow, N.L., Scientific Stream Pollution Analysis, Scripta Book Company, Washington, D.C., 1974.

21. U.S. National Academy of Sciences, U.S. National Academy of Engineering, Water Quality Criteria 1972, A Report of the Committee on Water Quality Criteria, Washington, D.C., 1972.

22. Waste Management Branch File PE-240, Crestbrook Forest Industries Ltd., Victoria, B.C.

23. Water Survey of Canada, Inland Waters Directorate, Ottawa, Surface Water Data, B.C., 1972 to 1977.

24. Crozier, R.J., Waste Management Branch, Nelson, Personal Communication, 1979.

25. Lee, E., Mueller, J., Walden, C., Non-Settleable Suspended Solids: Their Impact on Receiving Waters, Pulp and Paper Canada, Vol. 79, October, 1978.

26. Huntley, B.E., Jones, A.C., Cabelli, U.J., Klebsiella Densities in Waters Receiving Wood Pulp Effluents, J. Water Pollution Control Federation, Vol. 48, pp. 1766-1771, 1976.

27. Walden C.C., Review Paper: The Toxiciy of Pulp and Paper Mill Effluent and Corresponding Measurement Procedures, Water Research, Vol. 10, pp. 639-664, 1976.

28. Leach, J.M., Mueller, J.C., Walden, C.C., Identification and Removal of Toxic Materials from Kraft and Groundwood Pulp Mill Effluent, Process Biochemistry, January-February, 1976.

29. Rogers, I.H., Mahood, H.W., Removal of Fish-Toxic Organic Solutes From Whole Kraft Effluent by Biological Oxidation and the Role of Wood Furnish Extractives, Fish. Res. Bd. of Canada, Tech. Report No. 434, 1974.

30. Browning, B.L., Editor, The Chemistry of Wood, Interscience Publishers, 1963.

31. Minns, C.K., Analysis of a Pulp and Paper Mill Effluent Plume, J. Fish. Res. Bd. of Canada, Vol. 34, pp. 776-783, 1977.

32. Inland Waters Directorate, Environment Canada, Surface Water Quality in Canada-An Overview, Ottawa, 1977.

33. Environmental Laboratory, A Laboratory Manual for the Chemical Analysis of Waters, Wastewaters, Sediments and Biological Materials, 2nd Edition, Min. of Environment, Vancouver, B.C., February, 1976.

34. Rush, R.J., Shannon, E.E., Review of Colour Removal Technology in the Pulp and Paper Industry, Water Pollution Control Directorate, Economic and Technical Review Report, EPS 3-WP-76-5, 1976.

35. Pollution Control Board, Pollution Control Objectives for the Mining, Smelting and Related Industries of B.C., Victoria, 1979.

36. U.S. Environmental Protection Agency, Quality Criteria for Water, Washington, D.C., 1976.

37. B.C. Research, Biological Monitoring of the St. Mary River, March 1976-April 1977, Project No. 1-05-766, Vancouver, B.C., June 1977.

38. B.C. Research, Biological Monitoring of the St. Mary River, March 1977-April 1978, Project No. 1-05-766, Vancouver, B.C., June, 1978.

39. Clark, M.J.R., A Trend Study of Air and Water Quality in B.C., Waste Management Branch, Ministry of Environment, Victoria, B.C., May, 1978.

40. Andelovic, J.W., Sigler, W.F., Neuhold, J.M., Temperature and Fluorosis in Rainbow Trout, J. Water Poll. Control Fed., Vol. 33, No. 4, pp. 371-381, 1961.

41. Sprague, J.B., Review Paper, Measurement of Pollutant Toxicity to Fish, III, Sublethal Effects and "Safe" Concentrations, Water Research, Vol. 5, pp. 245-266, 1971.

42. Clark, M.J.R., A Compilation of Water Quality Criteria, Waste Management Branch, Ministry of Environment, Victoria, B.C., May 1980.

43. Trussell, R.P., The Percent Un-Ionized Ammonia in Aqueous Ammonia Solutions at Different pH Levels and Temperatures, J. Fish. Res. Bd. Canada, Vol. 29, pp. 1505-1507, 1972.

44. Vollenweider, R.A., The Scientific Basis of Lake and Stream Eutrophication, with Particular Reference to Phosphorus and Nitrogen as Factors in Eutrophication, Technical Report to O.E.C.D., Paris, DAS/CSI 68.27, pp. 1-182, 1968.

45. Holcombe, G.W., Benoit, D.A., Leonard, E.N., McKim, J.M., Long Term Effects of Lead Exposure on Three Generations of Brook Trout (Salvelinus fontinalis), J. Fish. Res. Bd. of Canada, No. 33, pp. 1731-1741, 1976.

46. Spehar, R.L., Anderson, R.L., Fiandt, J.T., Toxicity and Bioaccumulation of Cadmium and Lead in Aquatic Invertebrates, Environ. Poll., Vol. 15, pp. 195-207, 1978.

47. Health and Welfare Canada, Health Protection Branch, Inspection Services, Victoria, B.C., January, 1977.

48. Clarke, R. McV., A Summary of Toxicity Information for Major Effluent Components from Inorganic Chemical Industries, Resource Management Branch, Central Region, Environment Canada, Technical Report No. CEN/T-74-9, 1974.

49. Harper, H.A., Review of Physiological Chemistry, Lange Medical Publications, 12th Ed., Los Altos, California, 1969.

50. Brown, D.A., Parsons, T.R., Relationship Between Cytoplasmic Distribution of Mercury and Toxic Effects to Zooplankton and Chum Salmon (Oncorhynchus keta) Exposed to Mercury in a Combined Ecosystem, J. Fish. Res. Bd. Canada, Vol. 35, pp. 880-884, 1978.

51. Northcote, P.G., Johnston, N.T., Tsumura, K., Trace Concentrations in Lower Fraser River Fishes, Westwater Research Centre, Technical Report No. 7, Vancouver, B.C., June, 1975.

52. B.C. Ministry of Environment, Kootenay Air and Water Quality Study Phase II, Water Quality in the Lower Columbia River Basin, Victoria, B.C., April, 1979.

53. Crozier, R.J., Nordin, R.N., The Canadian Portion of Koocanusa Reservoir: Post Impoundment Water Quality 1972-1978, Ministry of Environment, Victoria, B.C., In Preparation.

54. Wetzel, R.G., Limnology, W.B. Saunders Company, Toronto, p. 353, 1975.

55. Patalas, K., J.Fish. Res. Bd. Can., Vol. 29, pp. 1451-1462, 1972.

56. Associated Engineering Services Ltd., Cranbrook Water Supply, January, 1965.

57. B.C. Ministry of Environment, Inventory and Engineering Branch, Preliminary Assessment of Irrigation Possibilities in the East Kootenay Valley, File No. 0290650-F, Draft Report.

58. Zar, J.H., Biostatistical Analysis, Prentice-Hall, Englewood Cliffs, N.J., 1974.

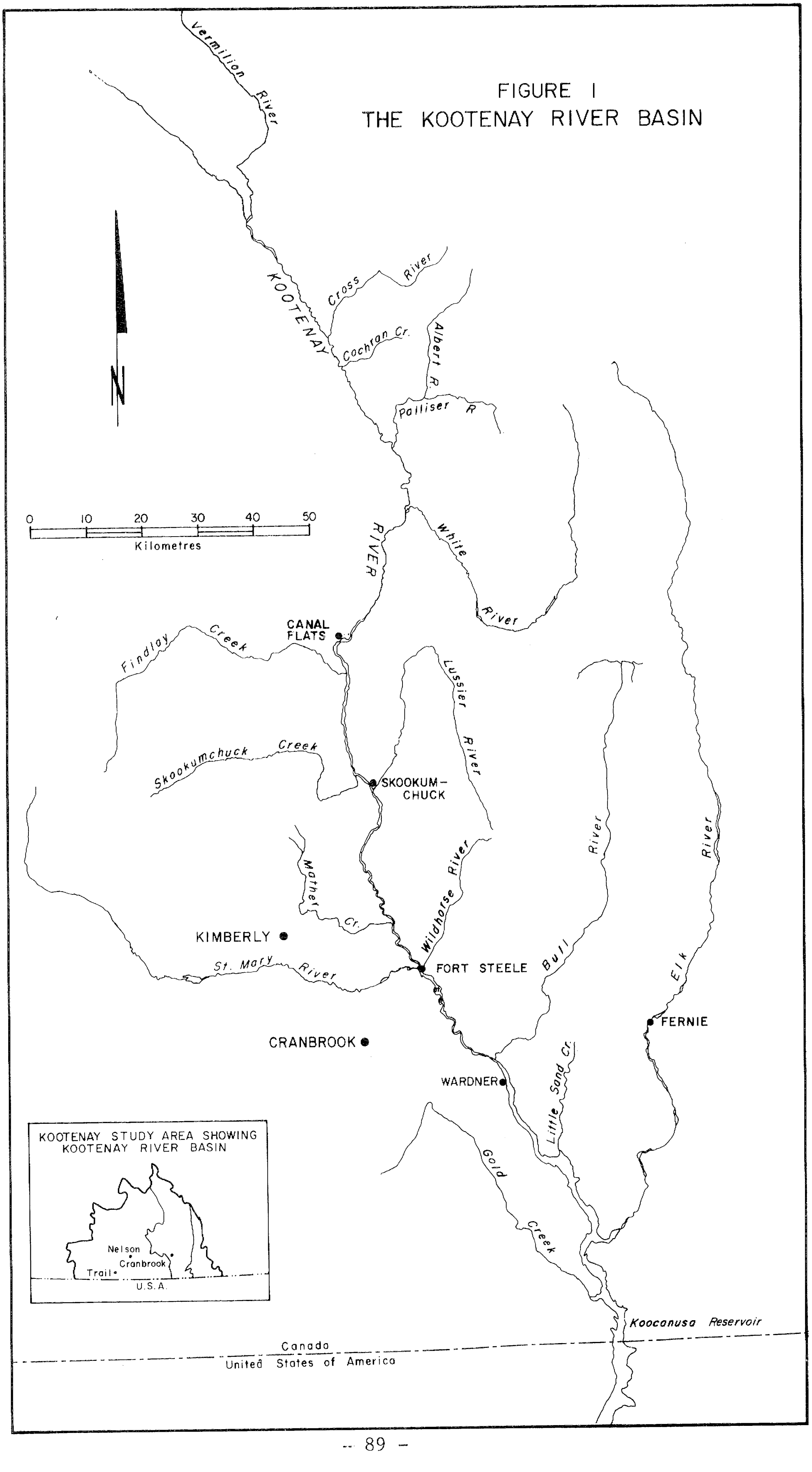
FIGURE I
THE KOOTENAY RIVER BASIN
N
0 10 20 30 40 50
Kilometres
Vermilion River
KOOTENAY RIVER
Cross River
Cochran Cr.
Albert R.
Palliser R
White River
CANAL FLATS
Findlay Creek
Lussier River
Skookumchuck Creek
SKOOKUM-CHUCK
Mather Cr.
Wildhorse River
KIMBERLY
St. Mary River
FORT STEELE
Bull River
Elk River
FERNIE
CRANBROOK
WARDNER
Little Sand Cr.
Gold Creek
KOOTENAY STUDY AREA SHOWING KOOTENAY RIVER BASIN
Nelson
Cranbrook
Trail
U.S.A.
Koocanusa Reservoir
Canada
United States of America

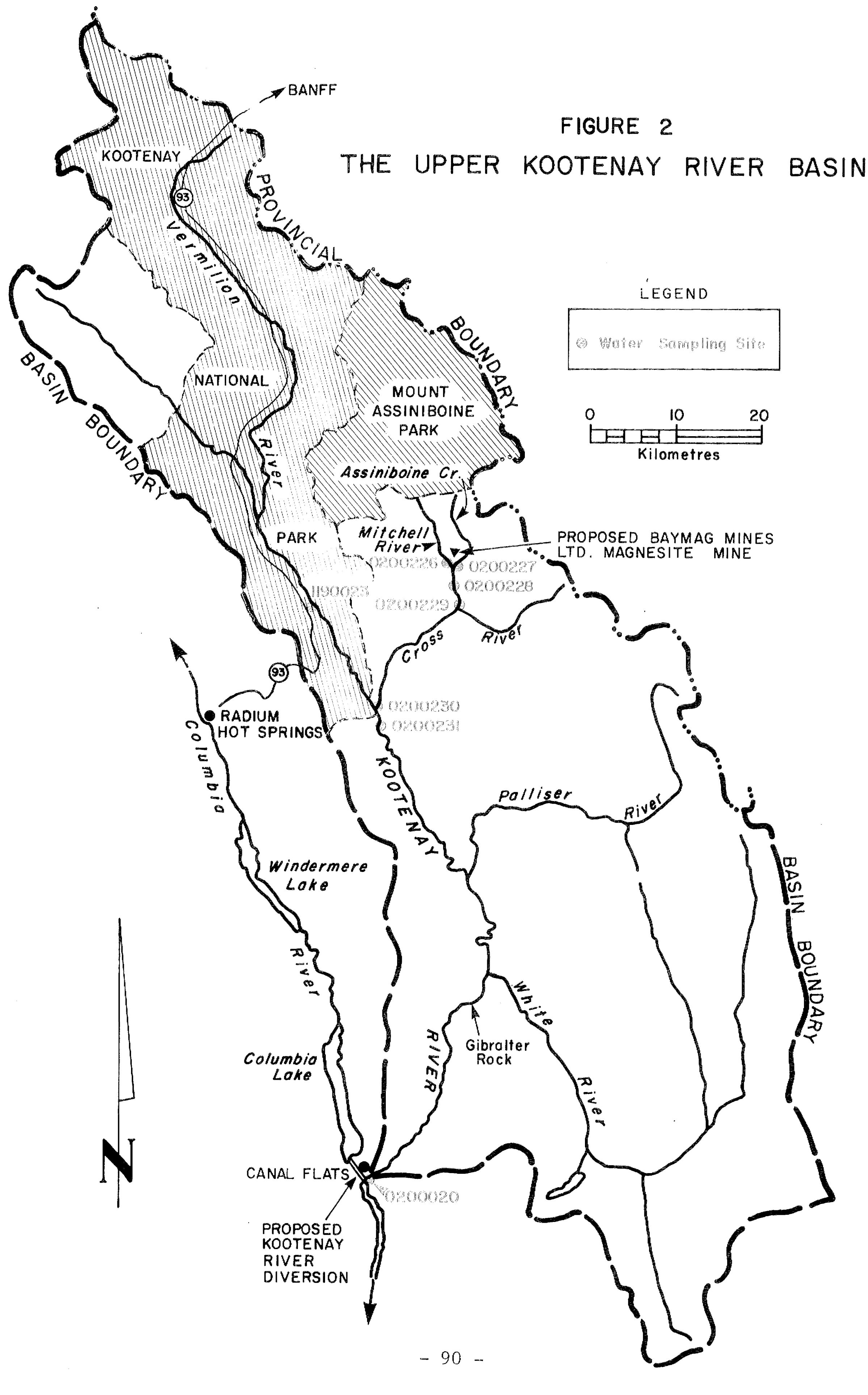
FIGURE 2
THE UPPER KOOTENAY RIVER BASIN
LEGEND
Water Sampling Site
0
10
20
Kilometres
BANFF
KOOTENAY
NATIONAL
PARK
PROVINCIAL
BOUNDARY
BASIN BOUNDARY
MOUNT ASSINIBOINE PARK
Vermilion
River
Assiniboine Cr.
Mitchell River
PROPOSED BAYMAG MINES LTD. MAGNESITE MINE
0200226
0200227
0200228
0200229
1190023
Cross
River
0200230
0200231
93
RADIUM HOT SPRINGS
Columbia
KOOTENAY
RIVER
Palliser
River
Windermere Lake
River
White
River
Gibralter Rock
Columbia Lake
CANAL FLATS
0200020
PROPOSED KOOTENAY RIVER DIVERSION
N

FIGURE 3

THE LOWER KOOTENAY RIVER BASIN, THE ST. MARY RIVER AND KOOCANUSA RESERVOIR

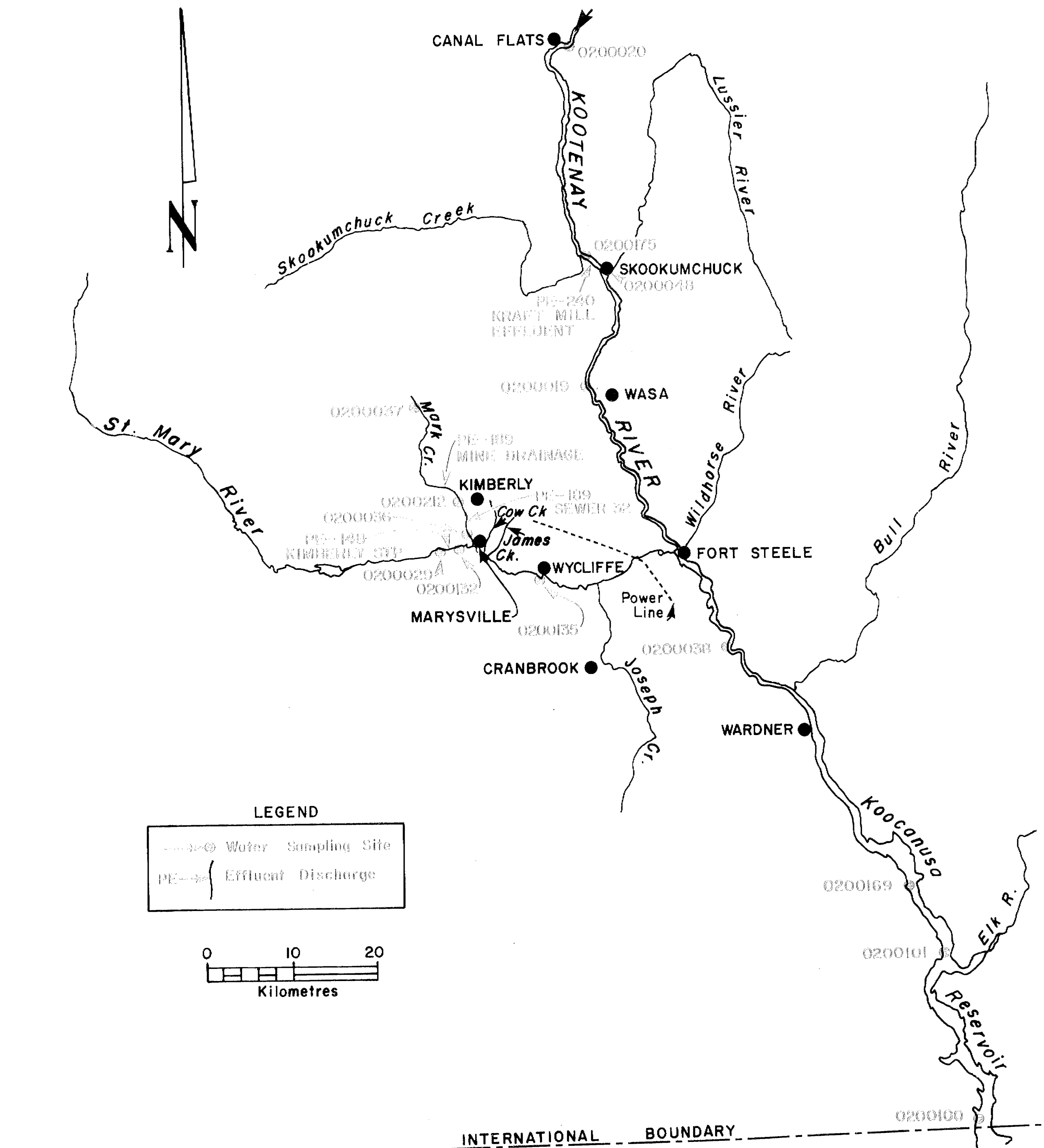

FIGURE 4

MEAN MONTHLY FLOW OF THE KOOTENAY RIVER AT CANAL FLATS (1939-1950 and 1963-1976)

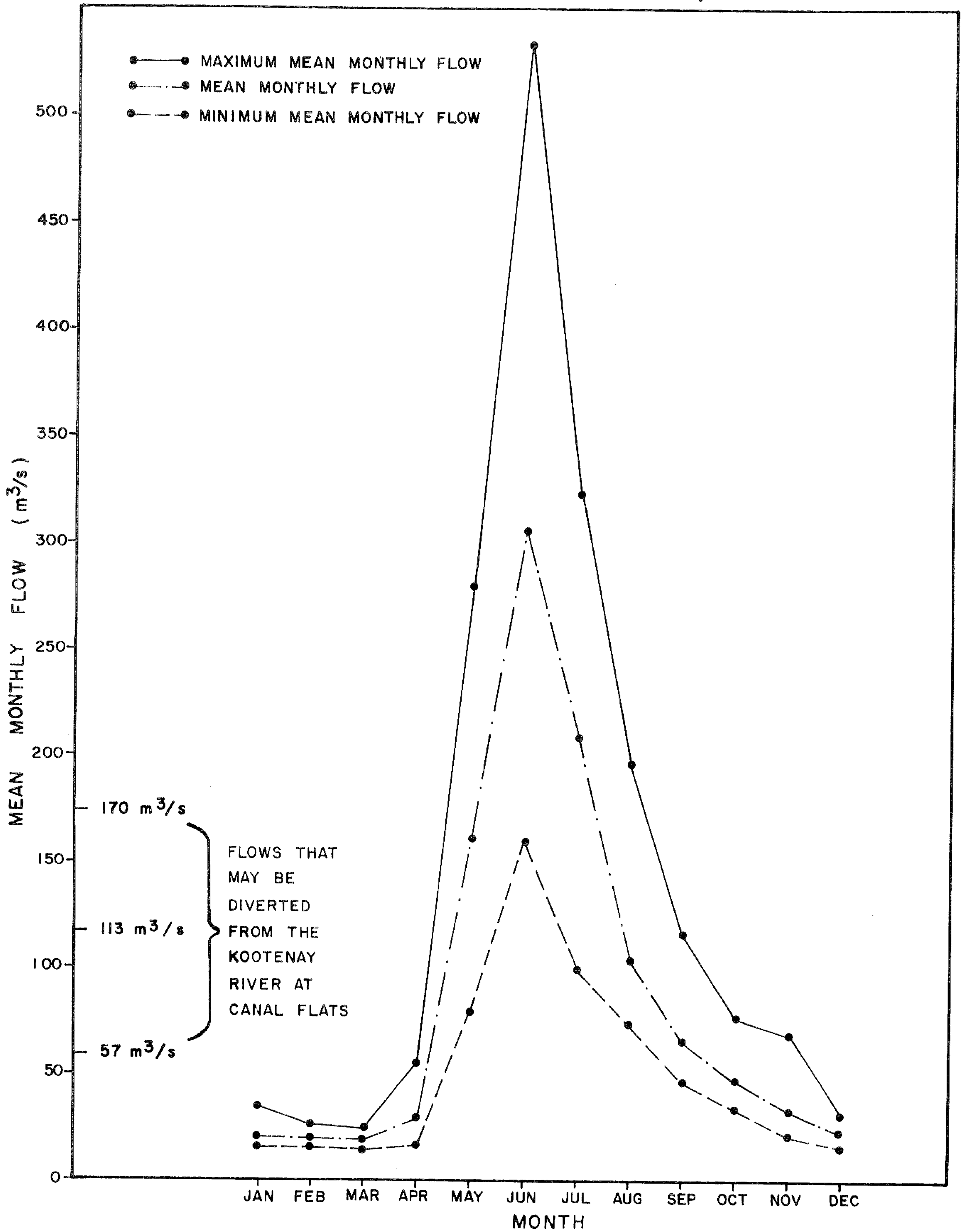

FIGURE 5

KOOTENAY RIVER FLOW AND COLOUR NEAR SKOOKUMCHUCK

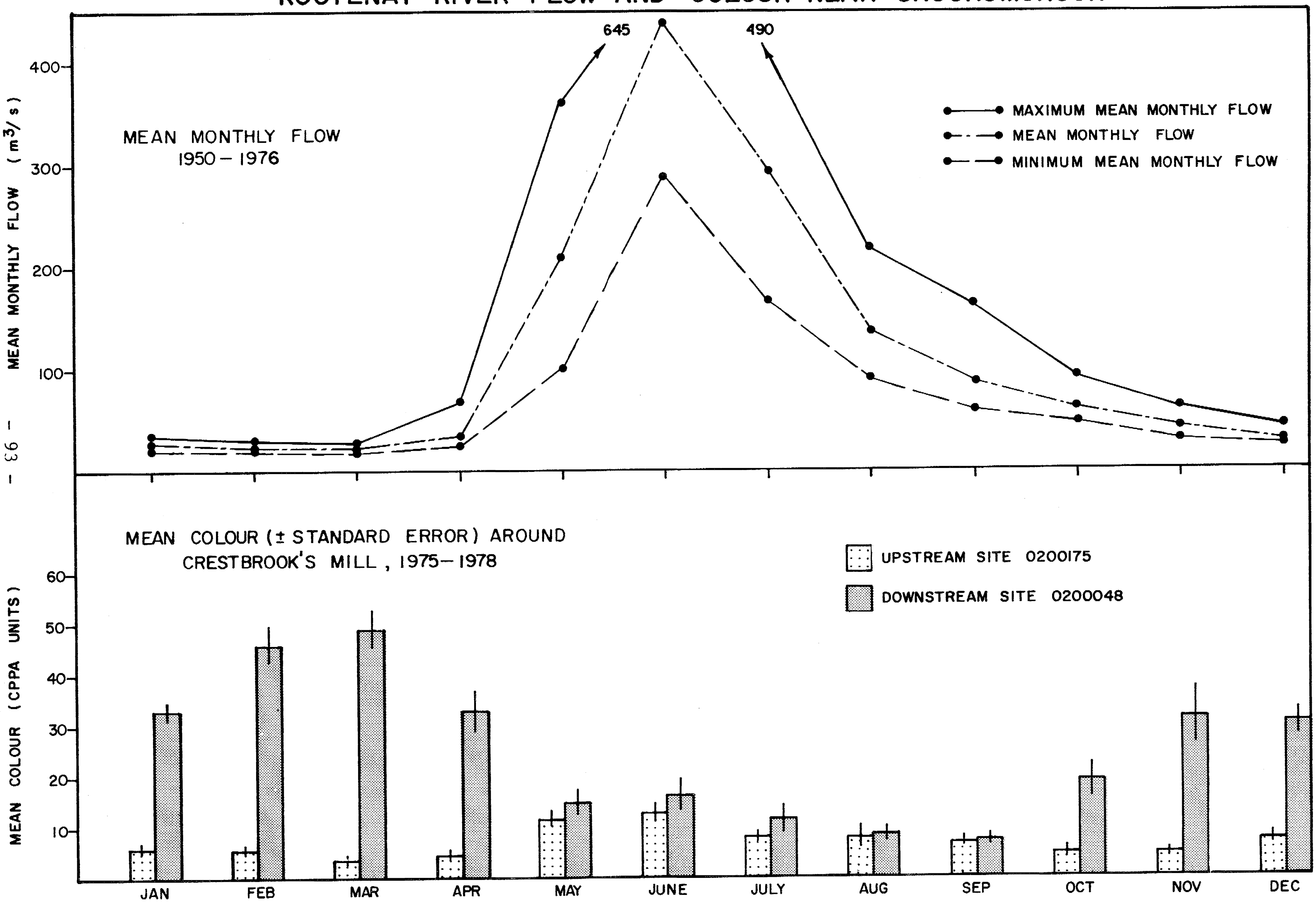

FIGURE 6

RIVER COLOUR AND FLOW JUST DOWNSTREAM FROM THE CRESTBROOK PULP MILL

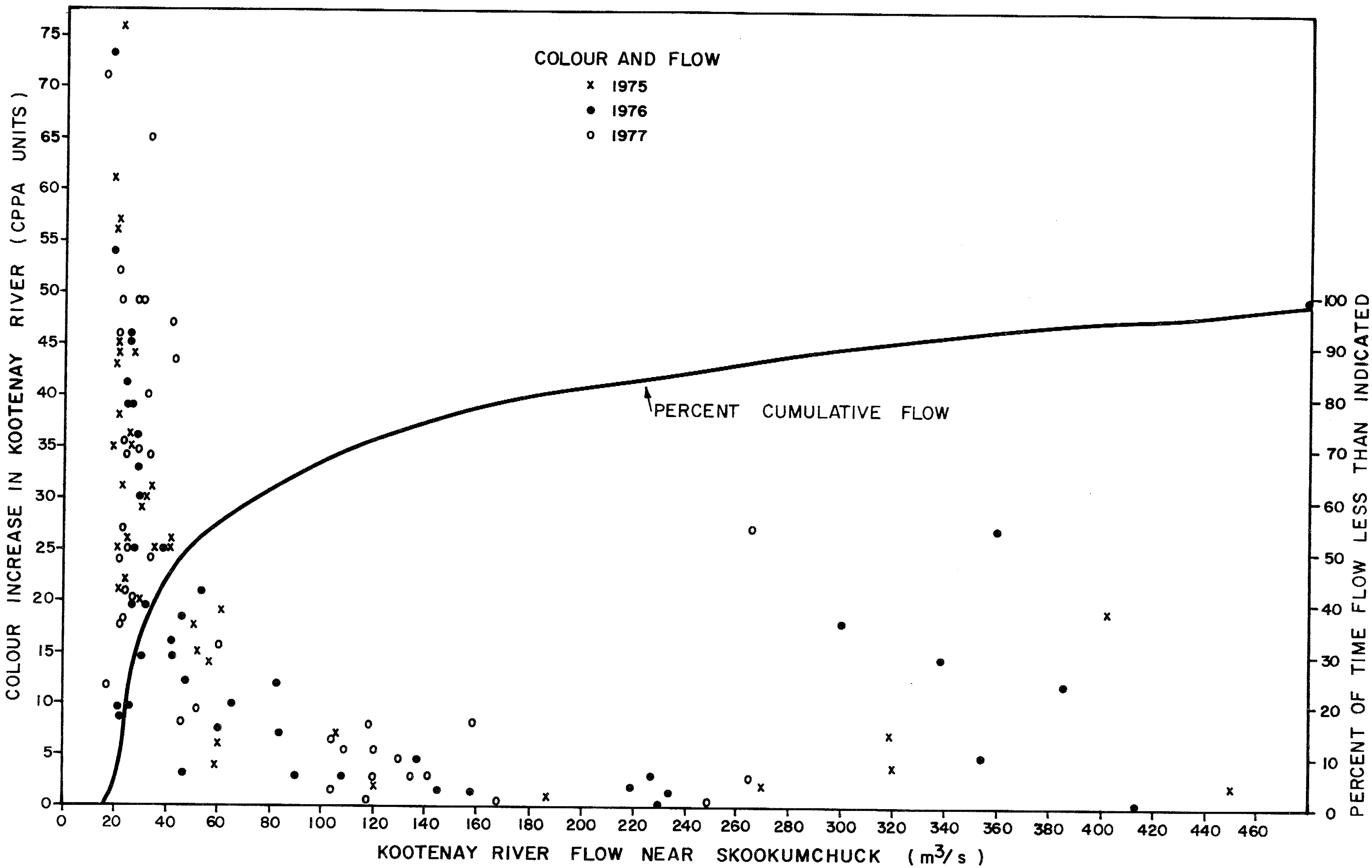

FIGURE 7

PLAN OF OPERATIONS AT CRESTBROOK FOREST INDUSTRIES LTD.

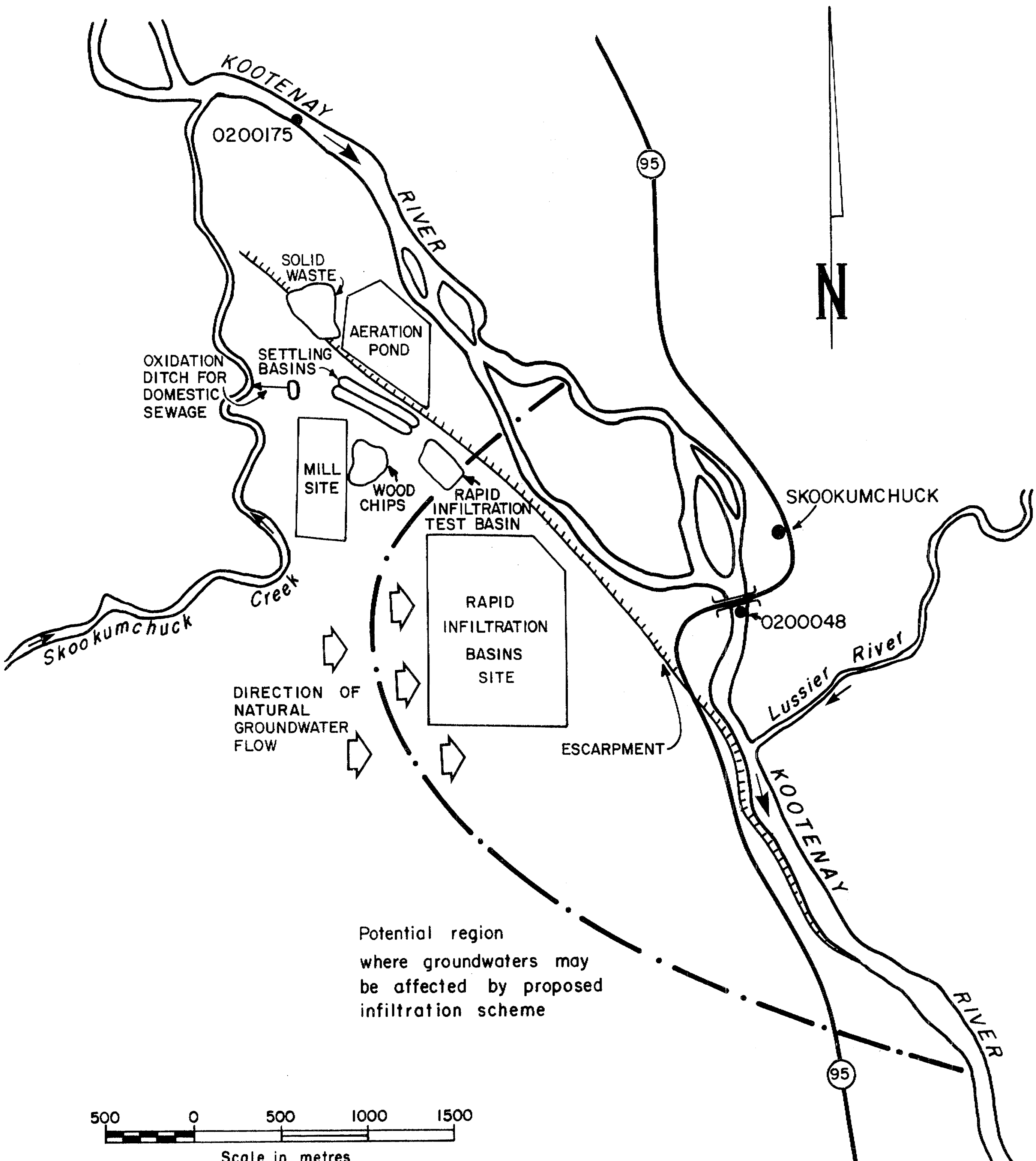

FIGURE 8

SIMPLIFIED FLOW DIAGRAM OF CRESTBROOK FOREST INDUSTRIES LTD. PULP MILL

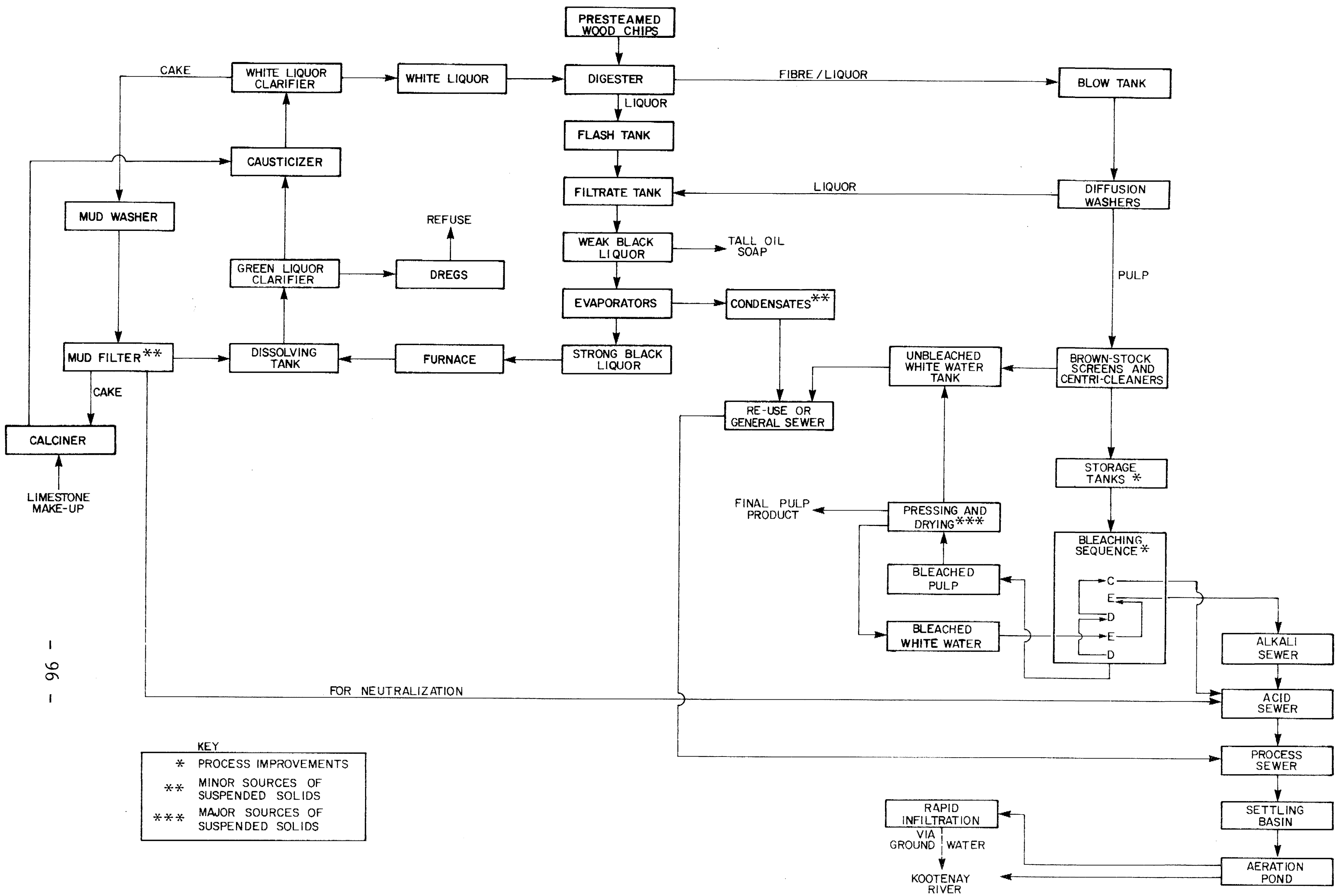

FIGURE 9
MEAN MONTHLY BOD_5 LOADINGS IN CRESTBROOK'S PULP MILL EFFLUENT

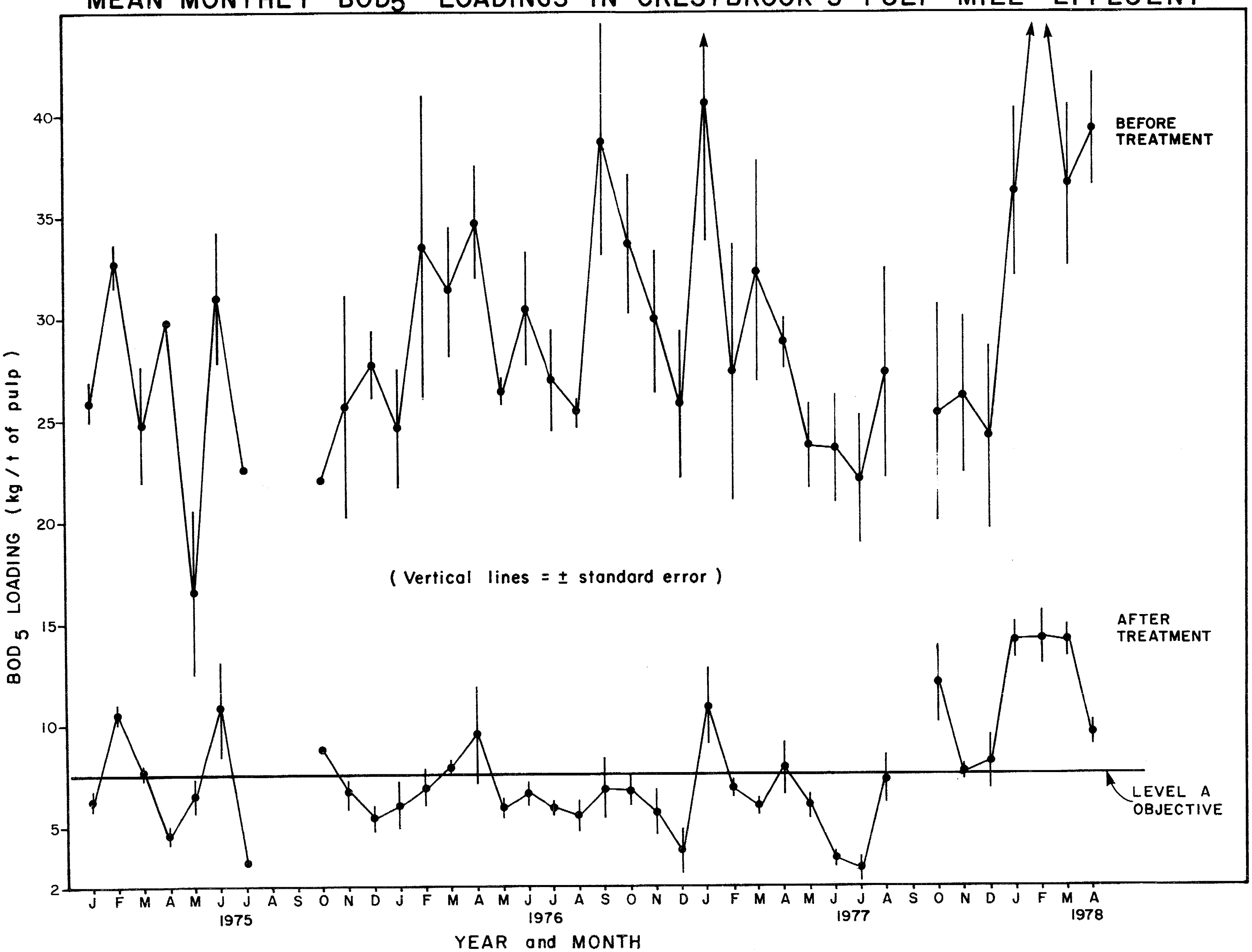

FIGURE 10

MEAN MONTHLY SUSPENDED SOLIDS LOADINGS IN CRESTBROOK'S PULP MILL EFFLUENT

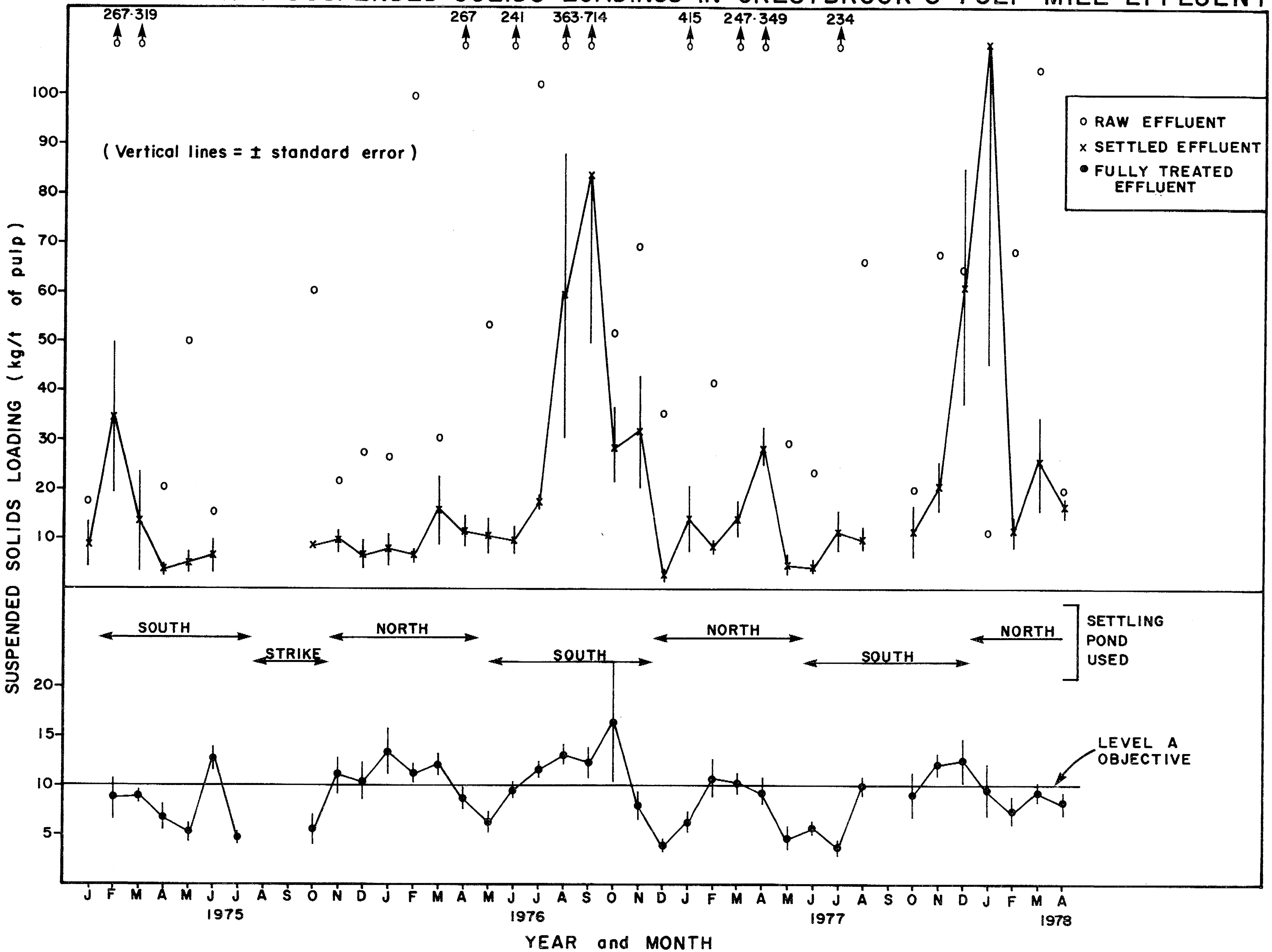

FIGURE 11

MEAN MONTHLY LOADINGS OF SUSPENDED SOLIDS FROM CRESTBROOK'S PULP MILL TO THE KOOTENAY RIVER

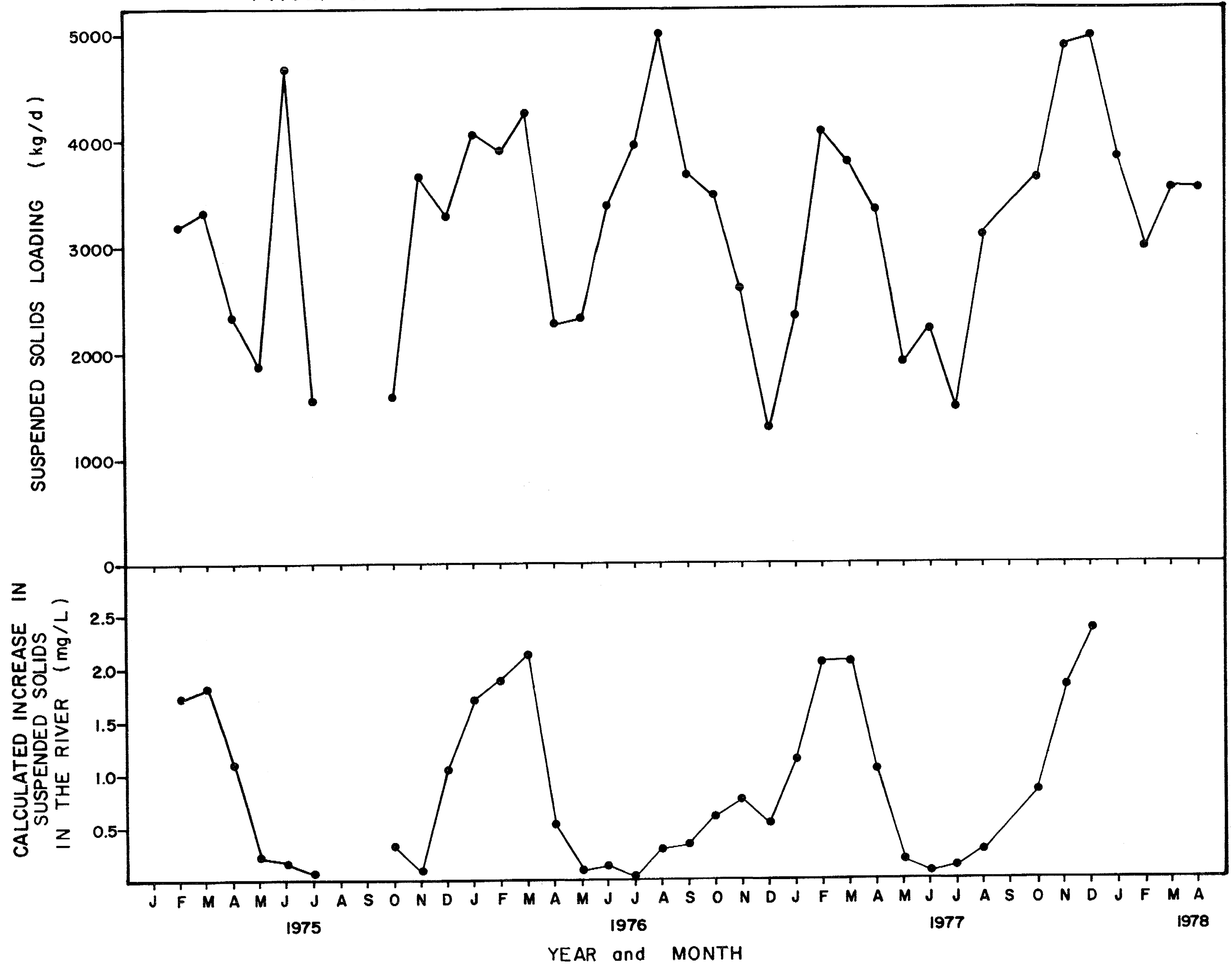

FIGURE 12

MEAN MONTHLY LOADING OF BOD_5 FROM CRESTBROOK'S MILL AND THE EFFECT ON OXYGEN IN THE KOOTENAY RIVER

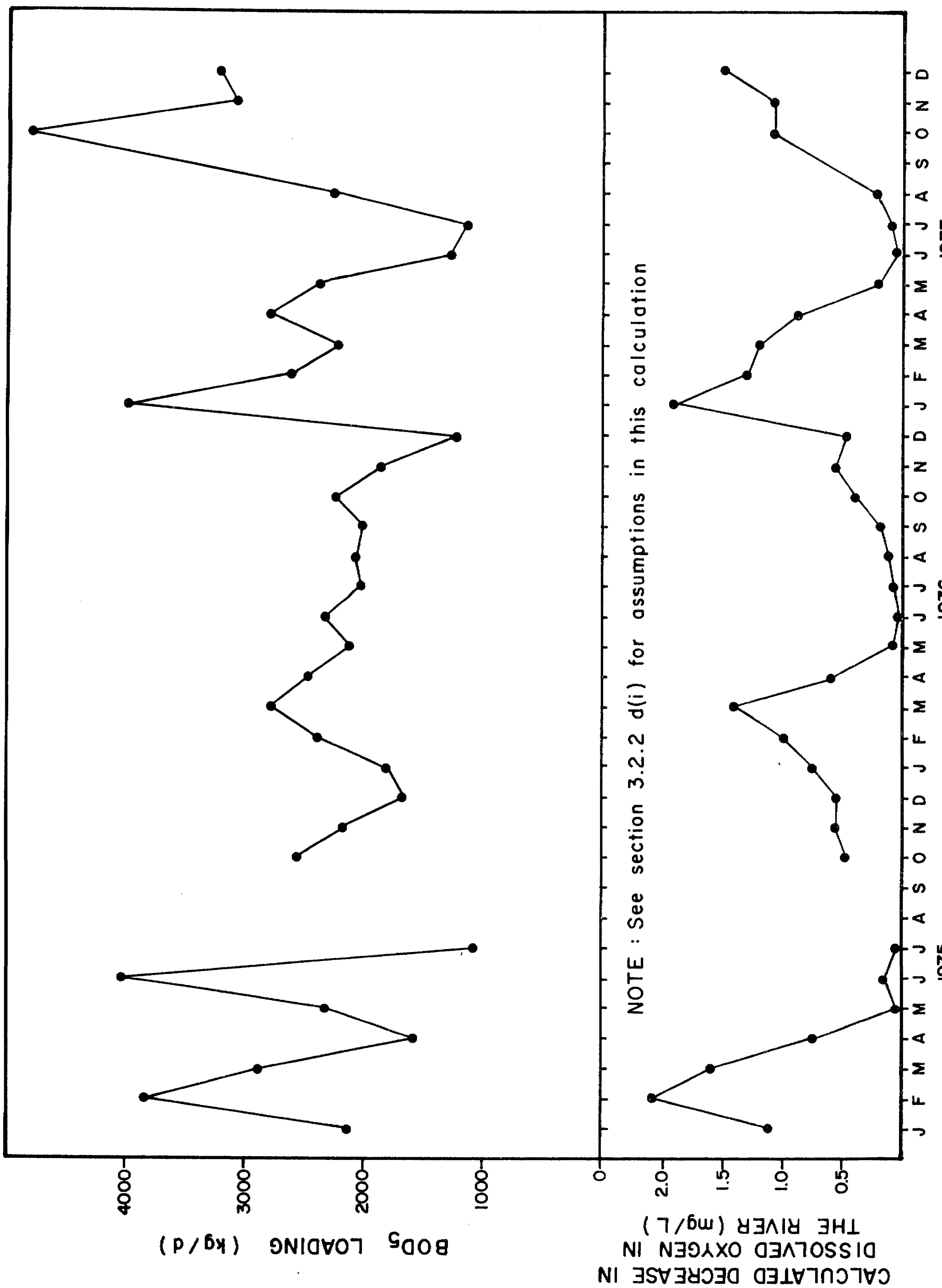

FIGURE 13

MEAN MONTHLY EFFLUENT COLOUR AND PULP PRODUCTION AT CRESTBROOK'S MILL

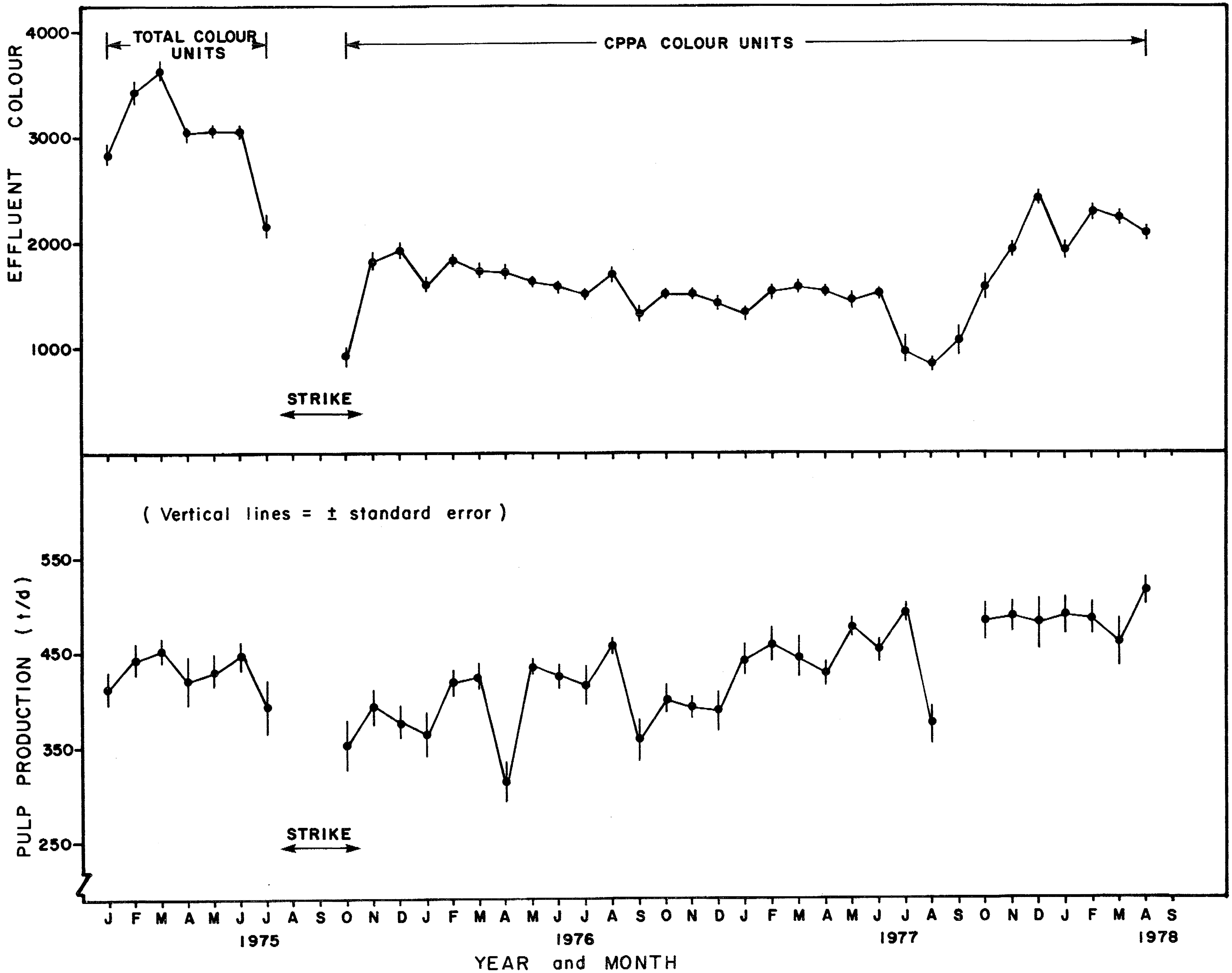

FIGURE 14

MEAN MONTHLY FLOW AND DILUTION OF CRESTBROOK'S EFFLUENT IN THE KOOTENAY RIVER

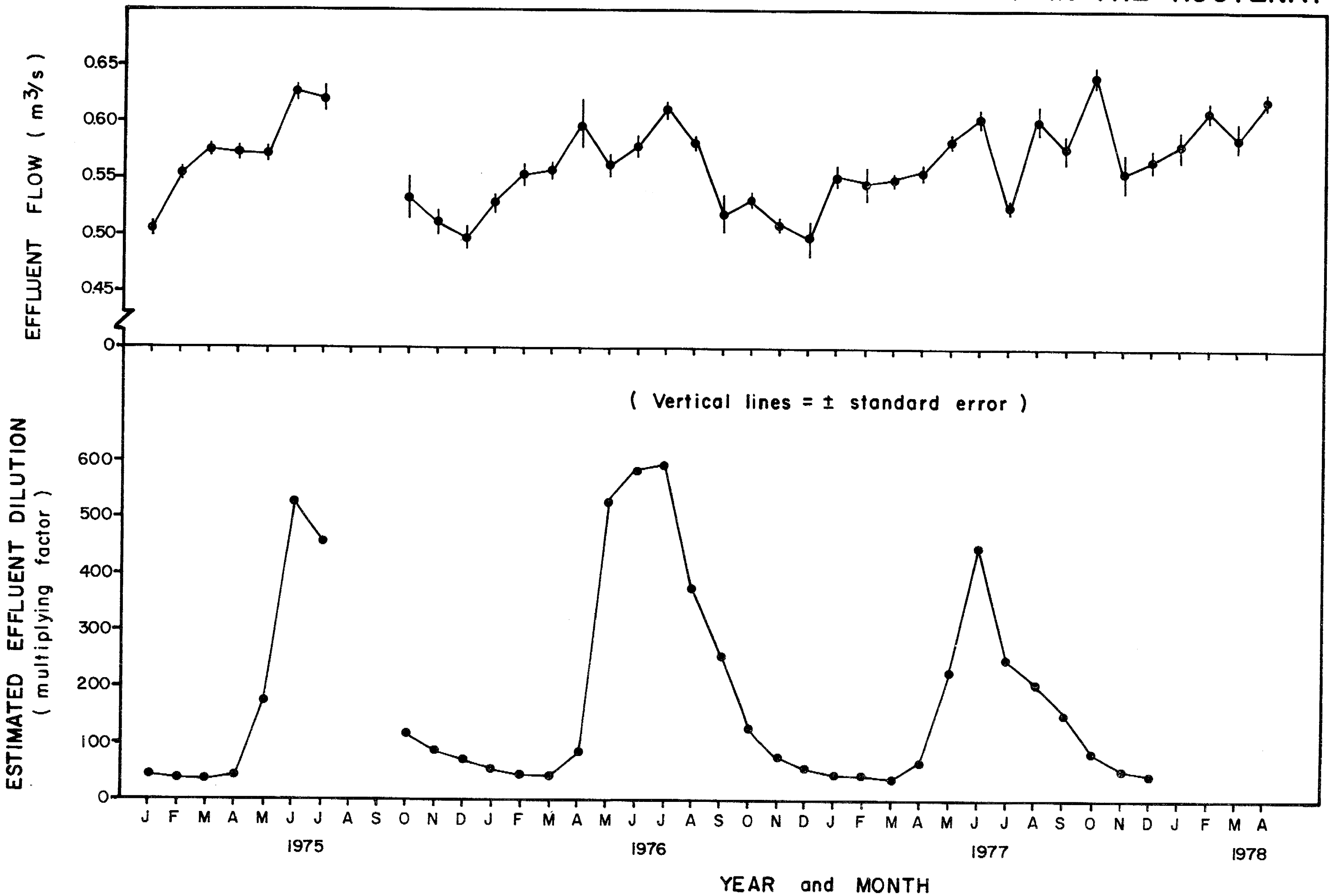

FIGURE 15

SODIUM LEVELS IN THE KOOTENAY RIVER

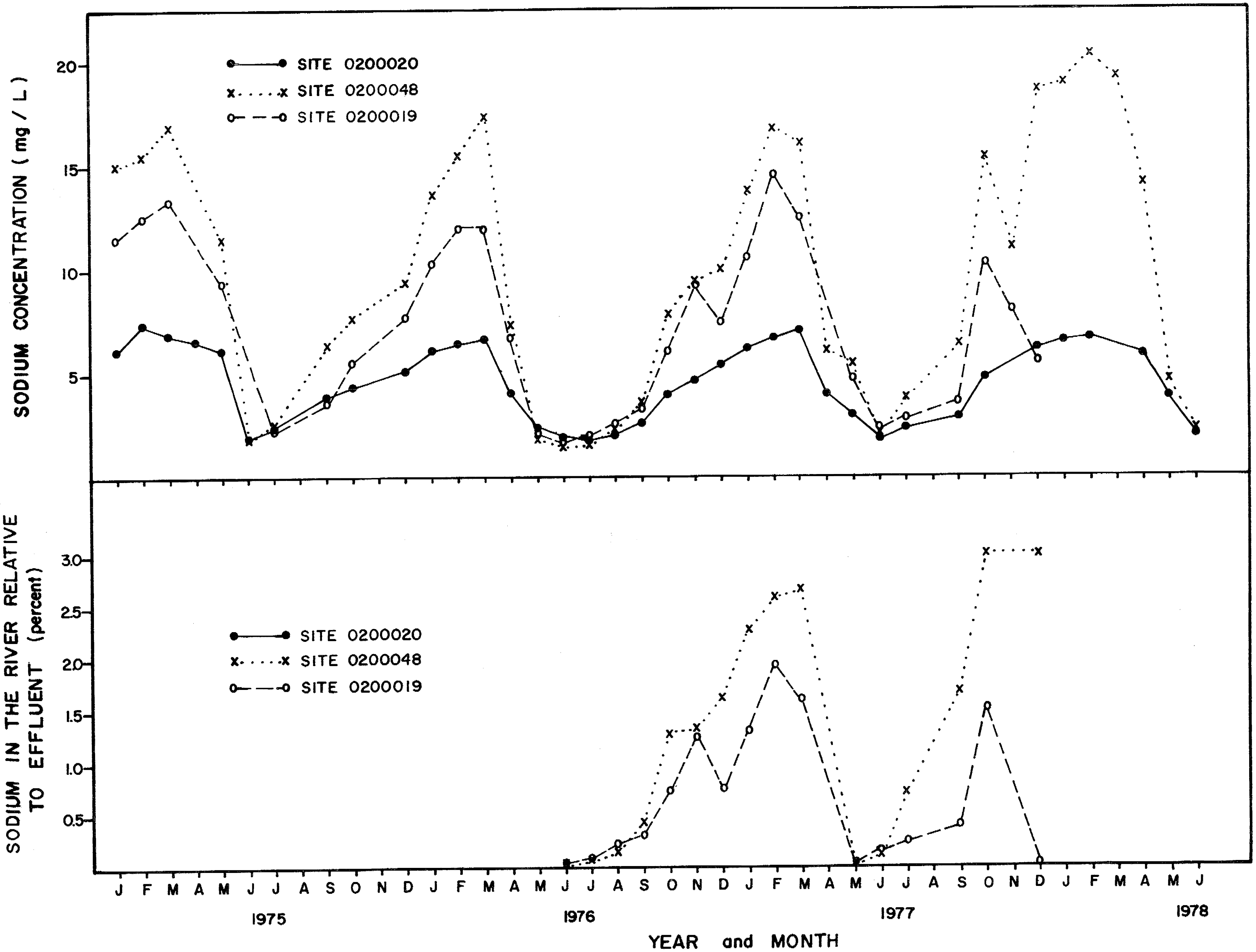

FIGURE 16
SUSPENDED SOLIDS AND TURBIDITY IN THE KOOTENAY RIVER AROUND CRESTBROOK'S MILL

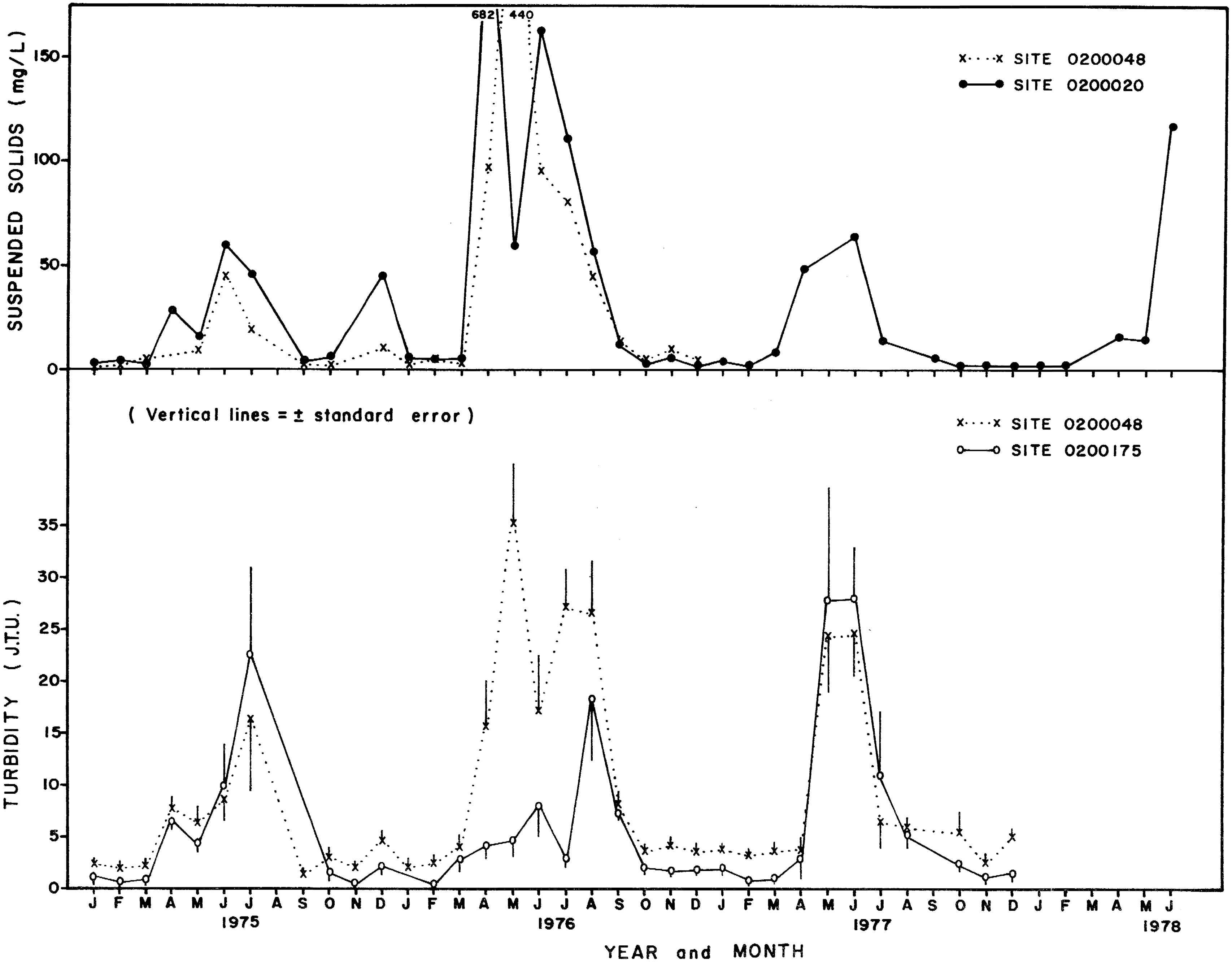

FIGURE 17

INORGANIC NITROGEN AND TOTAL PHOSPHORUS IN THE KOOTENAY RIVER AROUND CRESTBROOK'S MILL

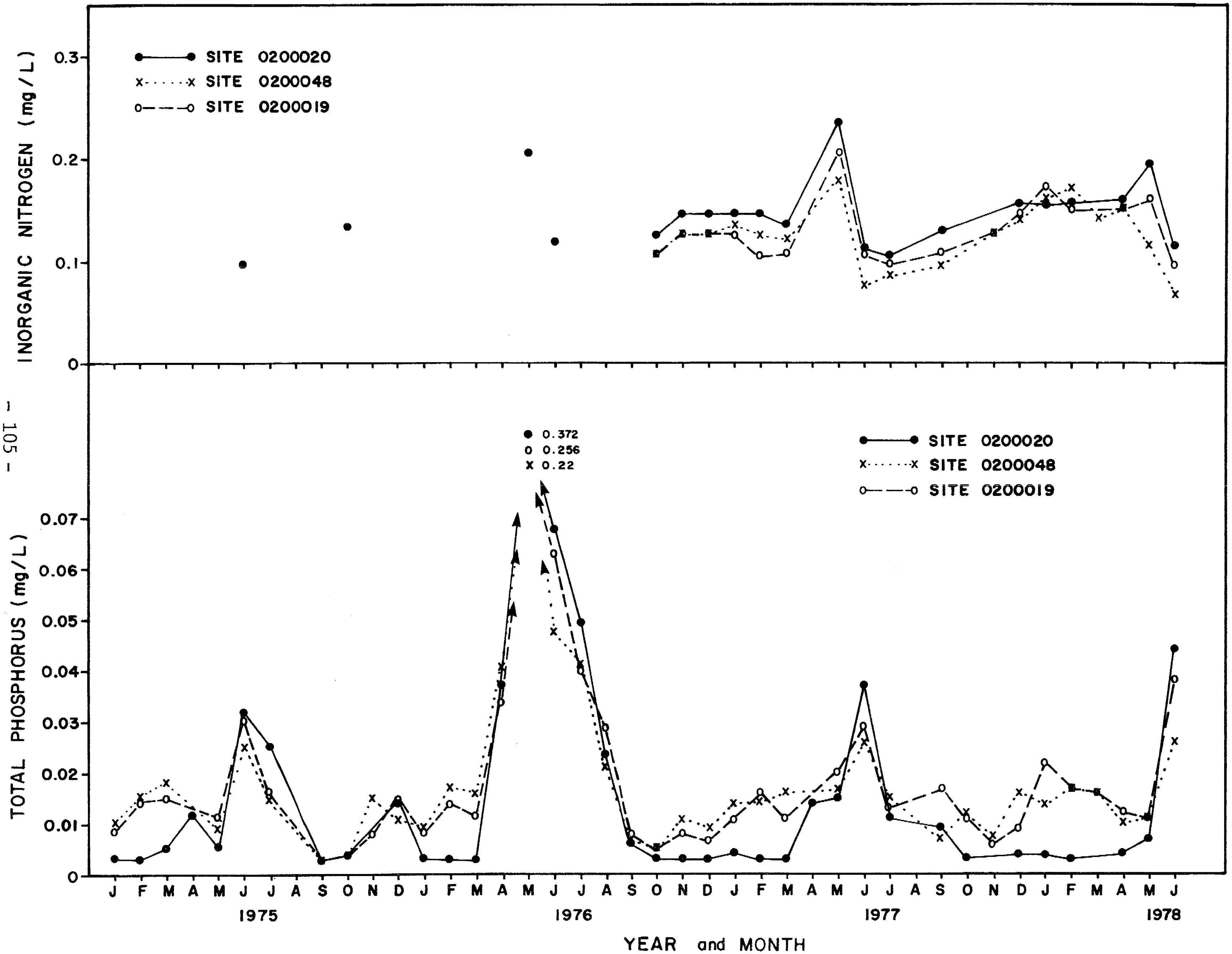

FIGURE 18

PHENOLS AND TANNIN AND LIGNIN IN THE KOOTENAY RIVER AROUND CRESTBROOK'S MILL

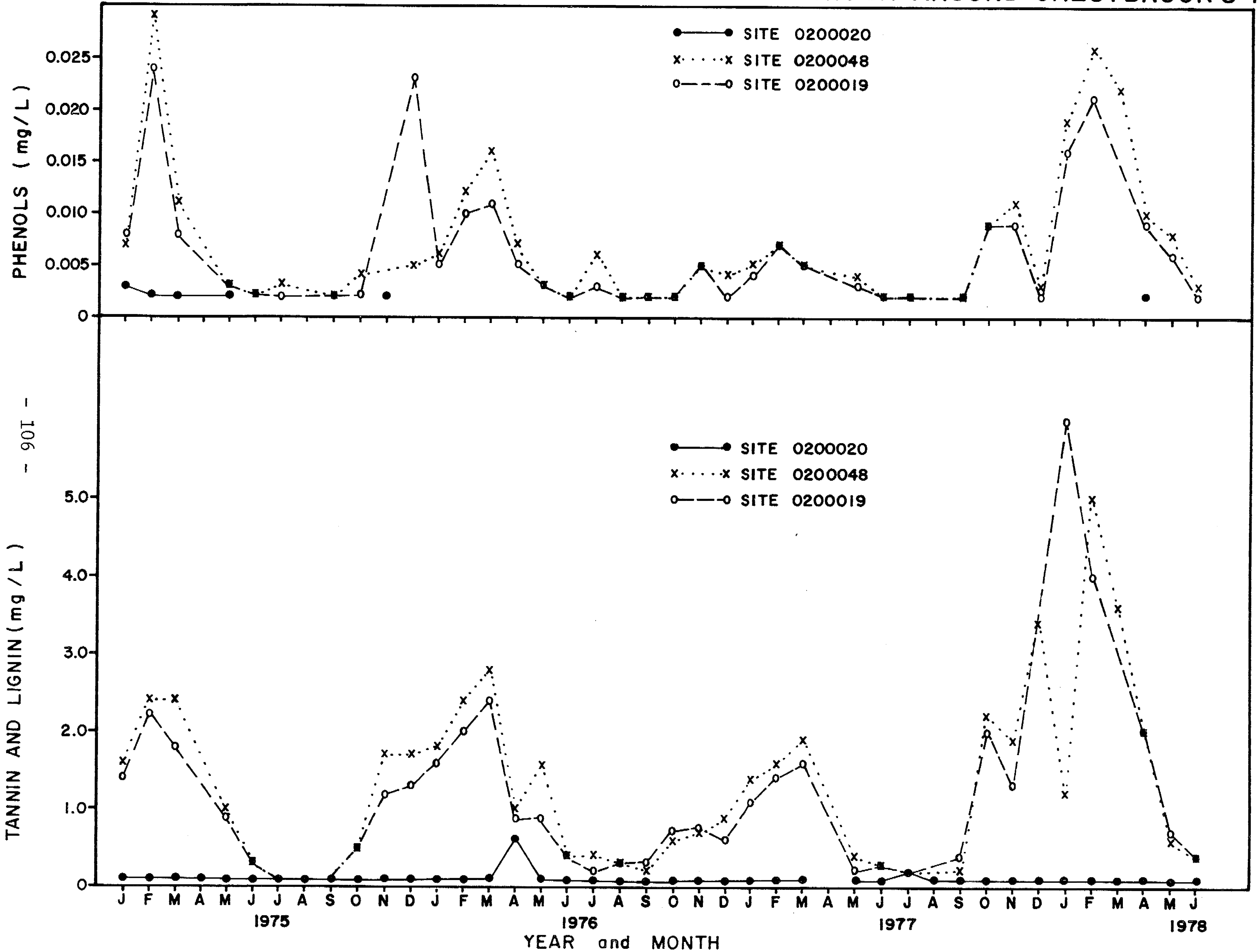

FIGURE 19

MEAN MONTHLY FLOW OF THE ST. MARY RIVER AT WYCLIFFE (1914-1917 and 1946-1976)

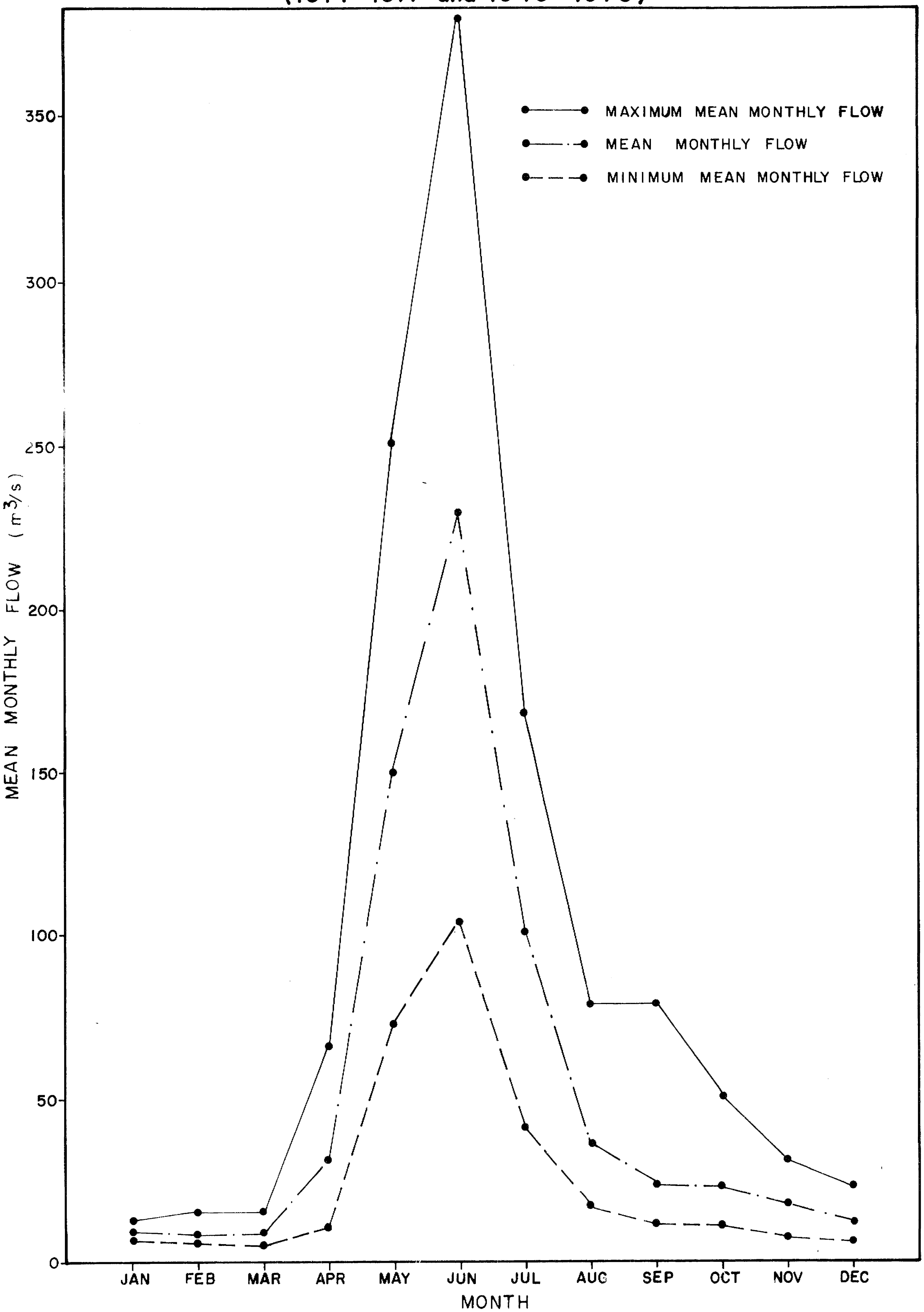

FIGURE 20
DIAGRAMMATIC VIEW OF COMINCO'S OPERATIONS

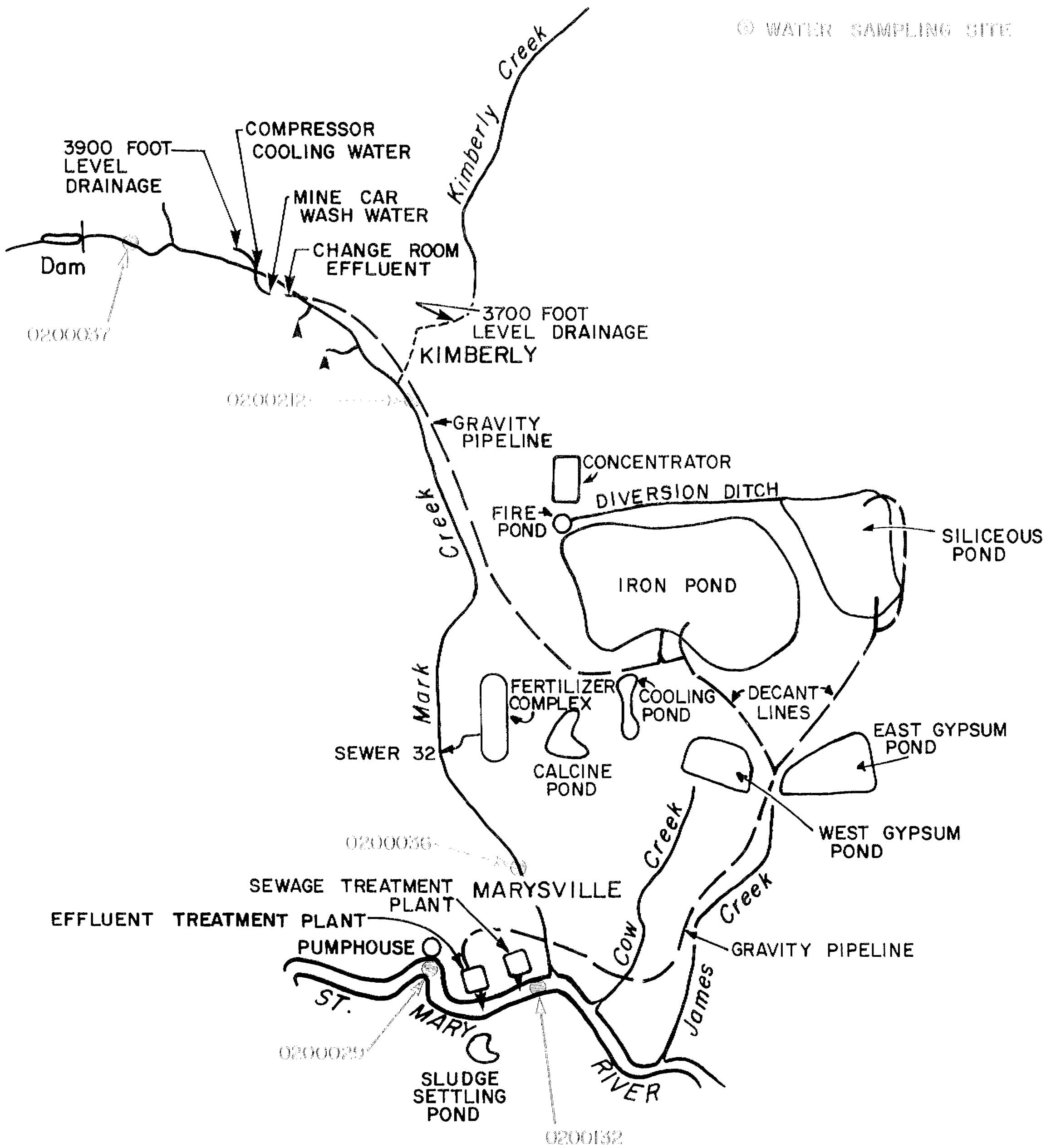

FIGURE 21

MEAN MONTHLY FLOW AND pH OF COMINCO'S FERTILIZER EFFLUENT (SEWER 32)

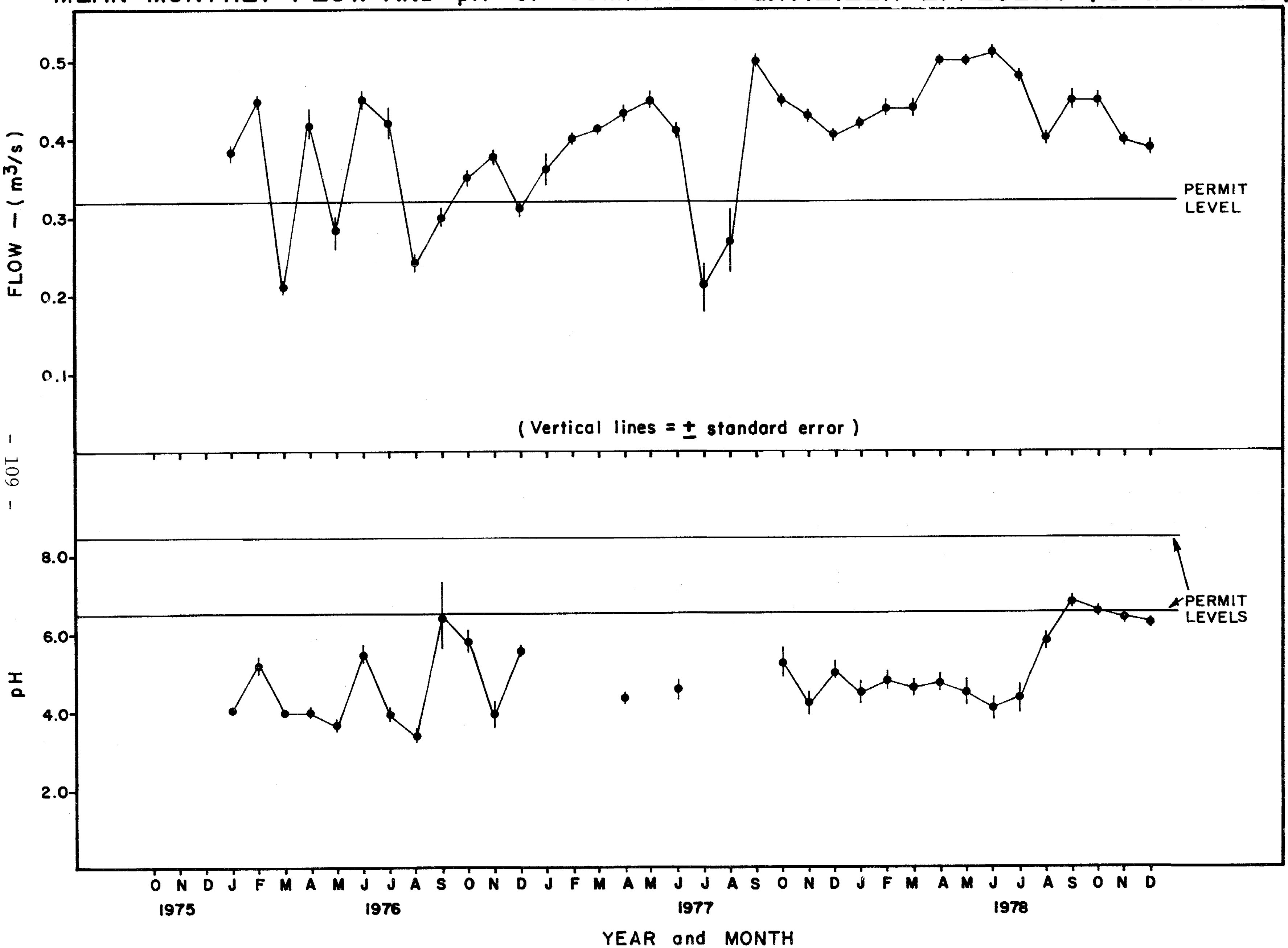

FIGURE 22

MEAN MONTHLY ORTHOPHOSPHATE AND AMMONIA CONCENTRATIONS IN COMINCO'S FERTILIZER EFFLUENT (SEWER 32)

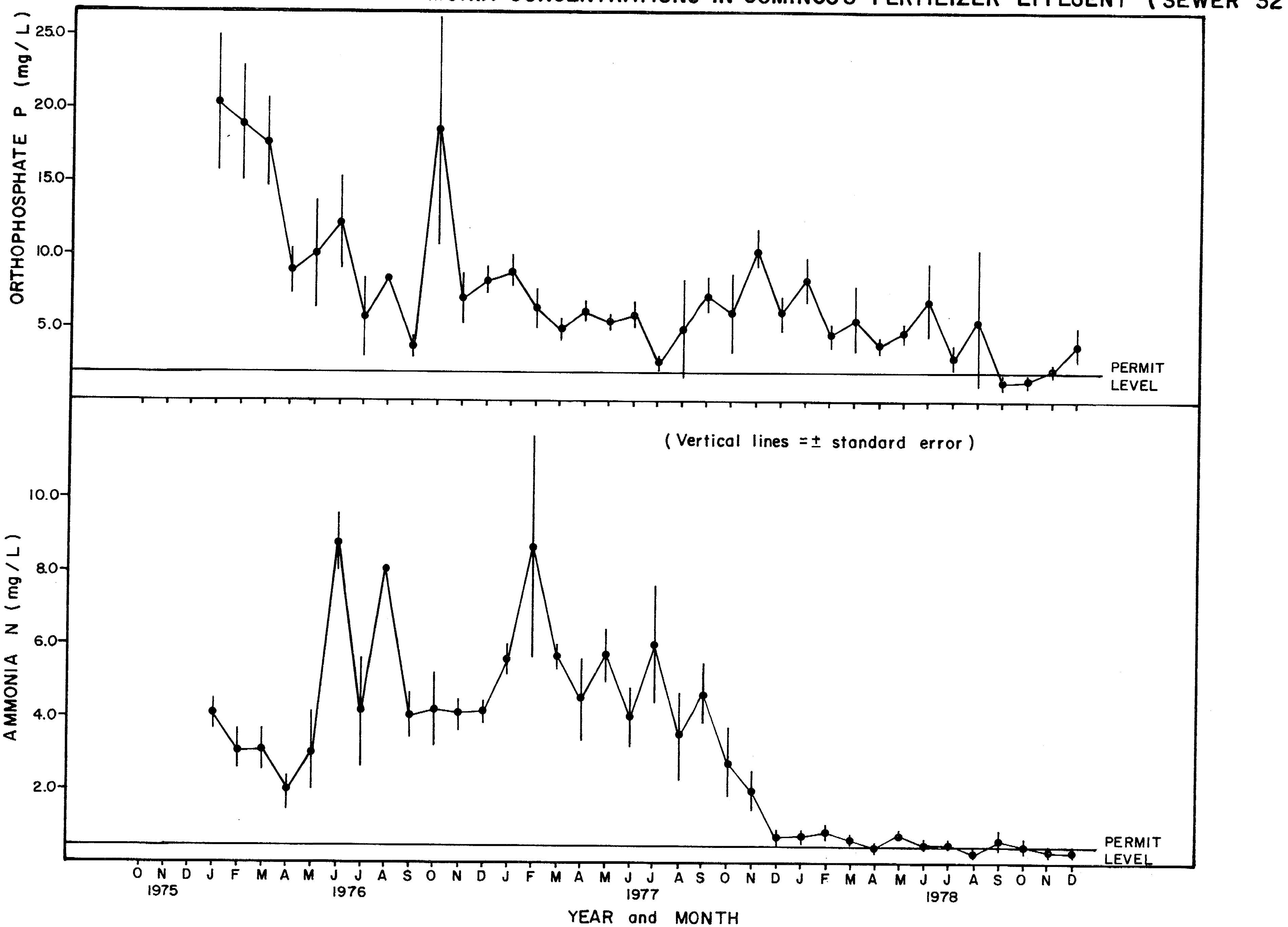

FIGURE 23

MEAN MONTHLY FLUORIDE CONCENTRATION IN COMINCO'S FERTILIZER EFFLUENT (SEWER 32)

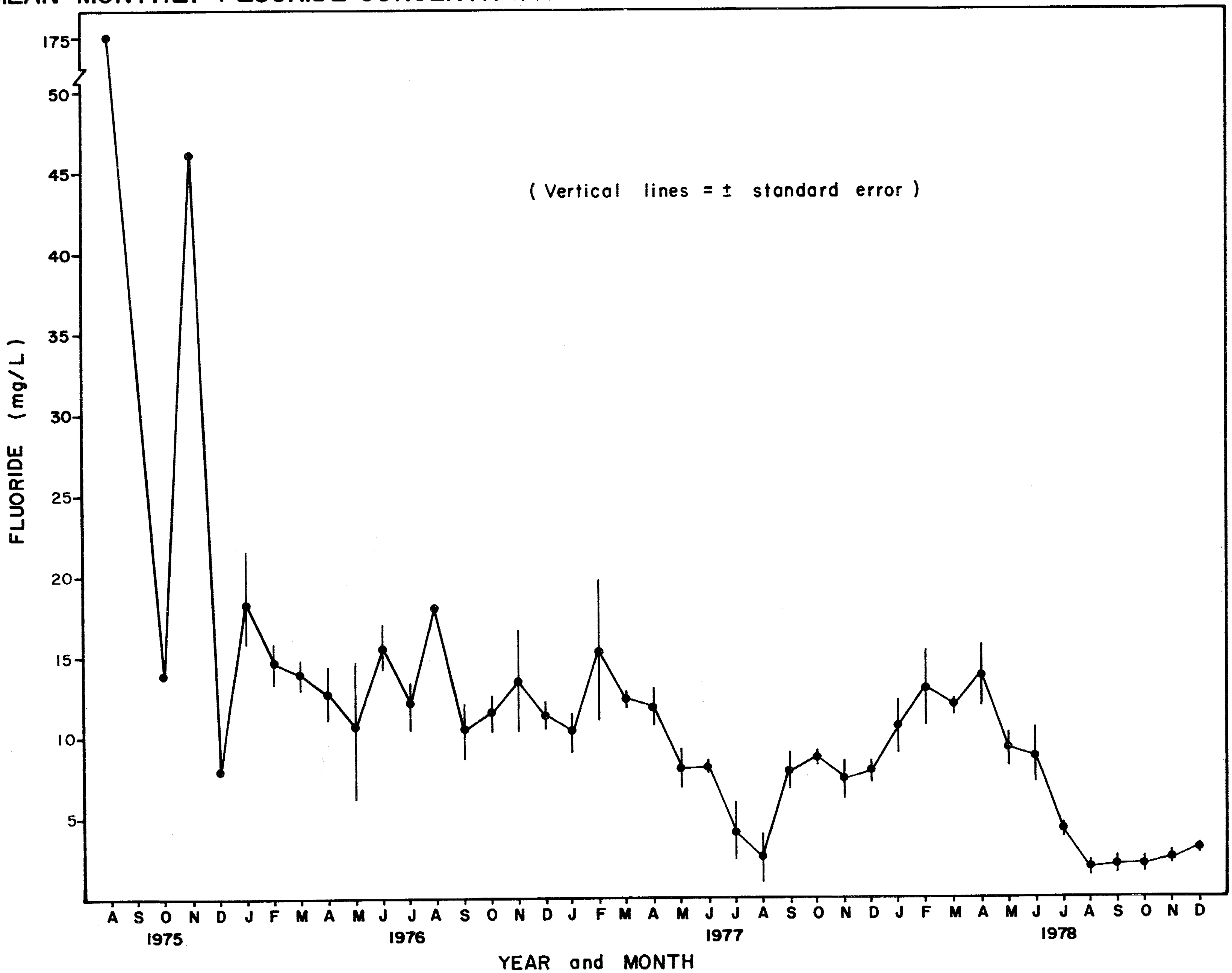

FIGURE 24

MEAN MONTHLY LEAD AND ZINC CONCENTRATIONS IN COMINCO'S FERTILIZER EFFLUENT (SEWER 32)

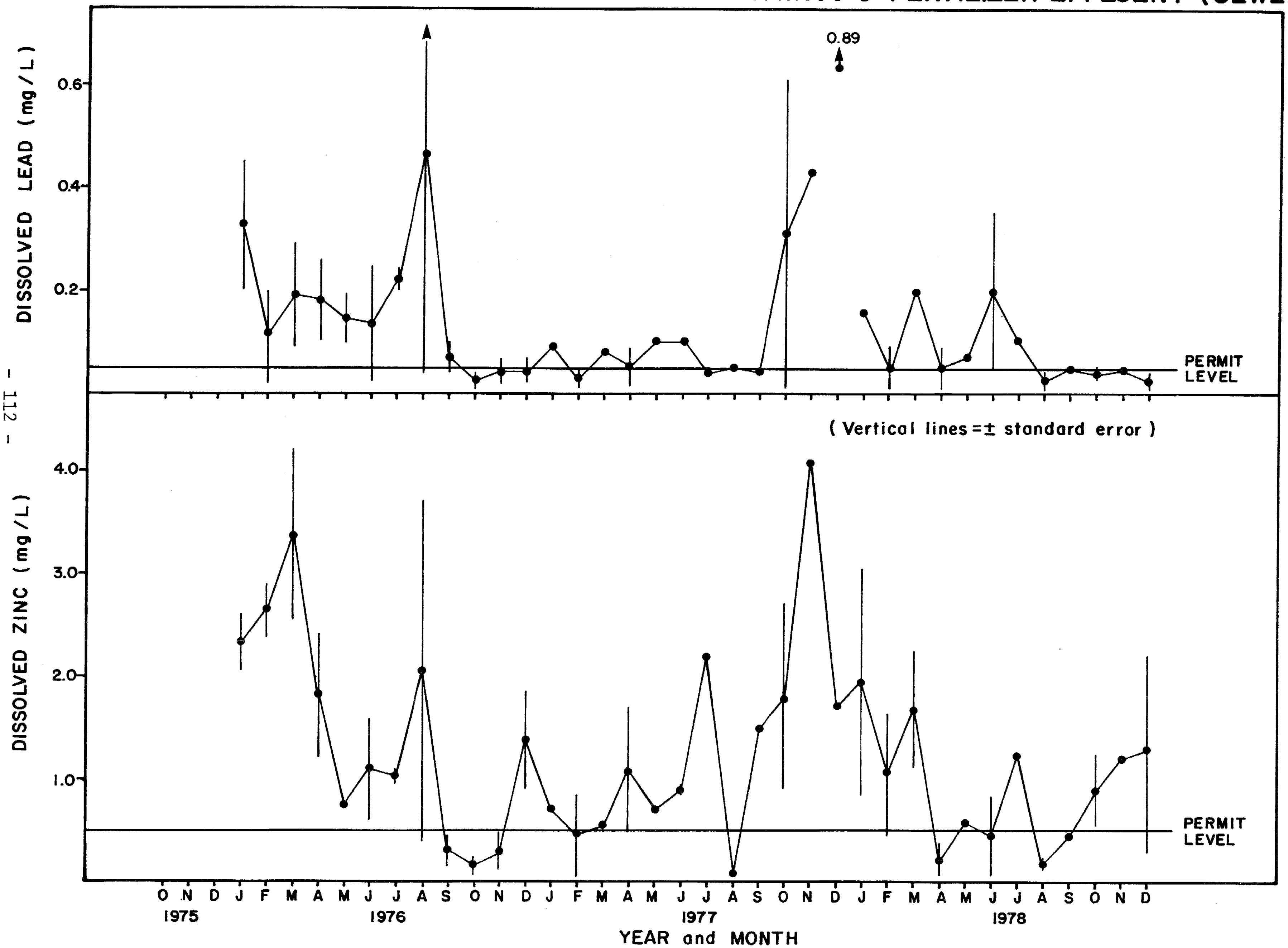

FIGURE 25

MEAN MONTHLY ARSENIC AND IRON CONCENTRATIONS IN COMINCO'S FERTILIZER EFFLUENT (SEWER 32)

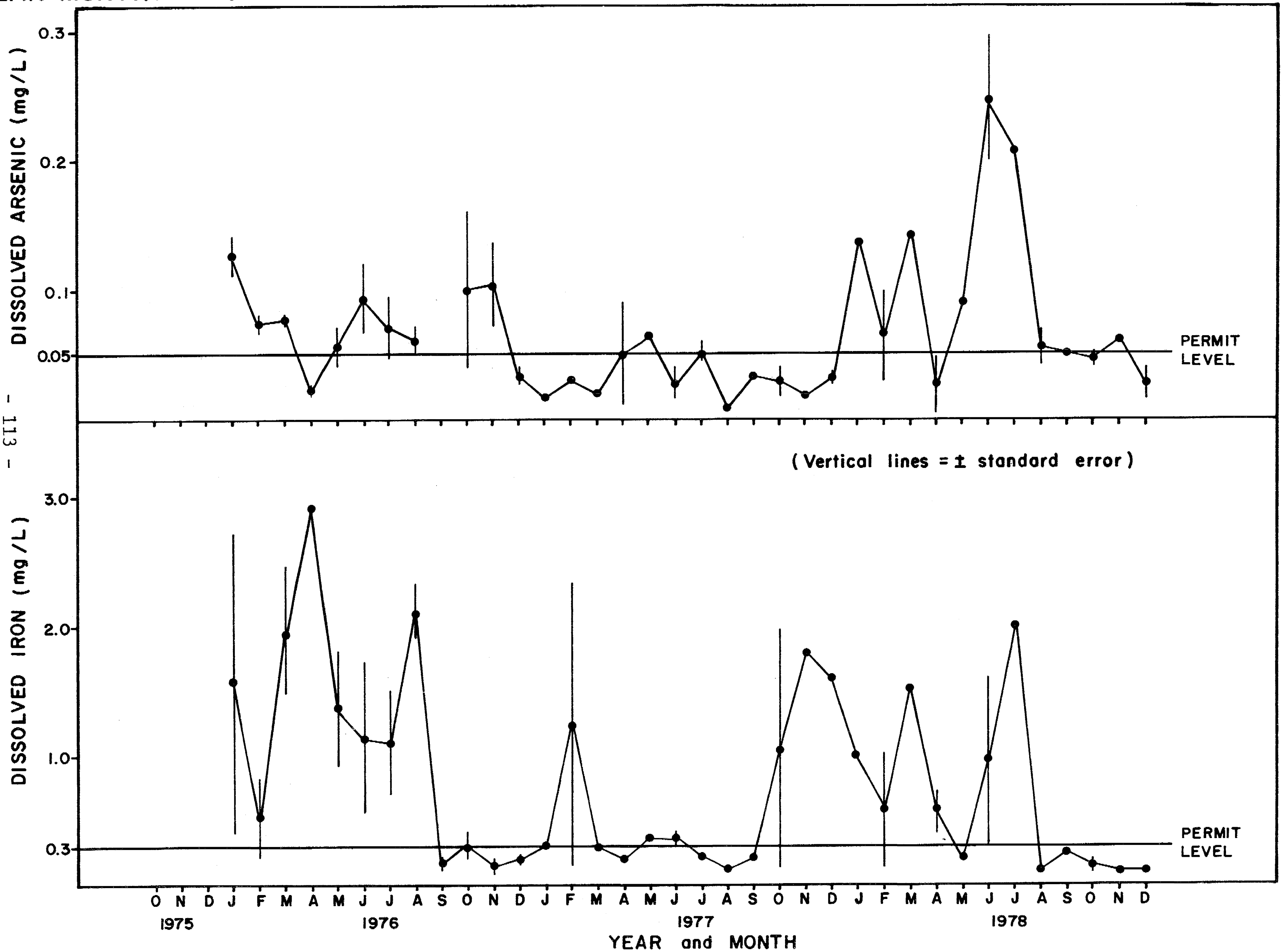

FIGURE 26

MEAN FLOW AND CONTAMINANT LEVELS IN MARK CREEK AND DISCHARGES TO MARK CREEK, 1975-1978

A = MARK CREEK, CONTROL, SITE 0200037

B_1 = 3900 FOOT PORTAL

B_2 = 3700 FOOT PORTAL

C = MARK CREEK, DOWNSTREAM FROM B_1 and B_2, SITE 0200212

D = SEWER 32

E = MARK CREEK, DOWNSTREAM FROM D, SITE 0200036

| VERTICAL LINES = ± STANDARD ERROR

* = SIGNIFICANT DIFFERENCE FOUND AMONG CREEK SITES (A, C and E are compared)

---- = PERMIT LEVEL (Level A for Cd and Hg)

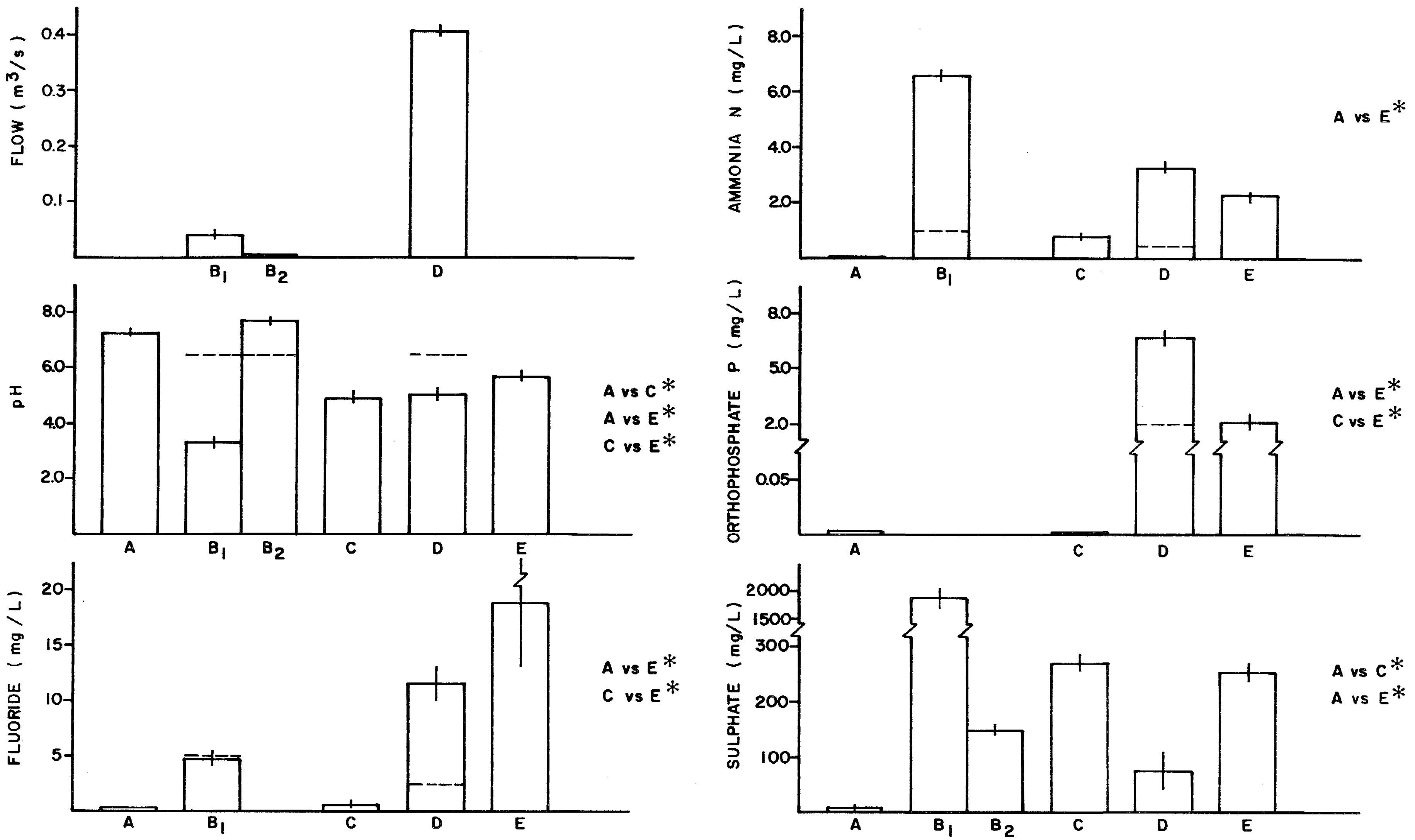

FIGURE 27

MEAN CONTAMINANT LEVELS IN MARK CREEK AND DISCHARGES TO MARK CREEK, 1975 – 1978

A = MARK CREEK, CONTROL, SITE 0200037
B_1 = 3900 FOOT PORTAL
B_2 = 3700 FOOT PORTAL
C = MARK CREEK, DOWNSTREAM FROM B_1 and B_2, SITE 0200212
D = SEWER 32

E = MARK CREEK, DOWNSTREAM FROM D, SITE 0200036
| VERTICAL LINES = ± STANDARD ERROR
* = SIGNIFICANT DIFFERENCE FOUND AMONG CREEK SITES (A, C and E are compared)
--- = PERMIT LEVEL (Level A for Cd and Hg)

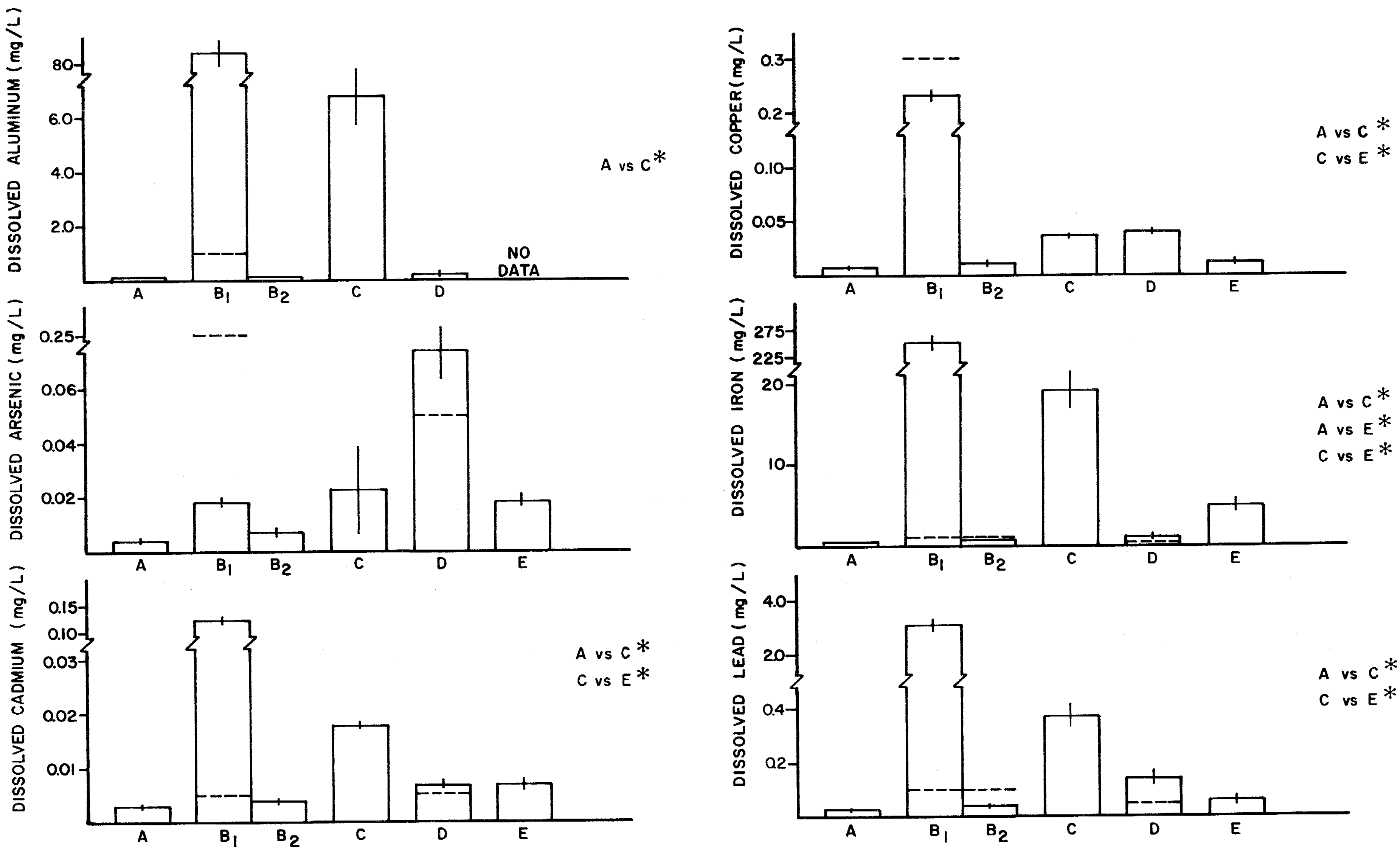

FIGURE 28

MEAN CONTAMINANT LEVELS IN MARK CREEK AND DISCHARGES TO MARK CREEK, 1975-1978

A = MARK CREEK, CONTROL, SITE 0200037
B_1 = 3900 FOOT PORTAL
B_2 = 3700 FOOT PORTAL
C = MARK CREEK, DOWNSTREAM FROM B_1 and B_2, SITE 0200212
D = SEWER 32

E = MARK CREEK, DOWNSTREAM FROM D, SITE 0200036
| VERTICAL LINES = ± STANDARD ERROR
* = SIGNIFICANT DIFFERENCE FOUND AMONG CREEK SITES (A, C and E are compared)
---- = PERMIT LEVEL (Level A for Cd and Hg)

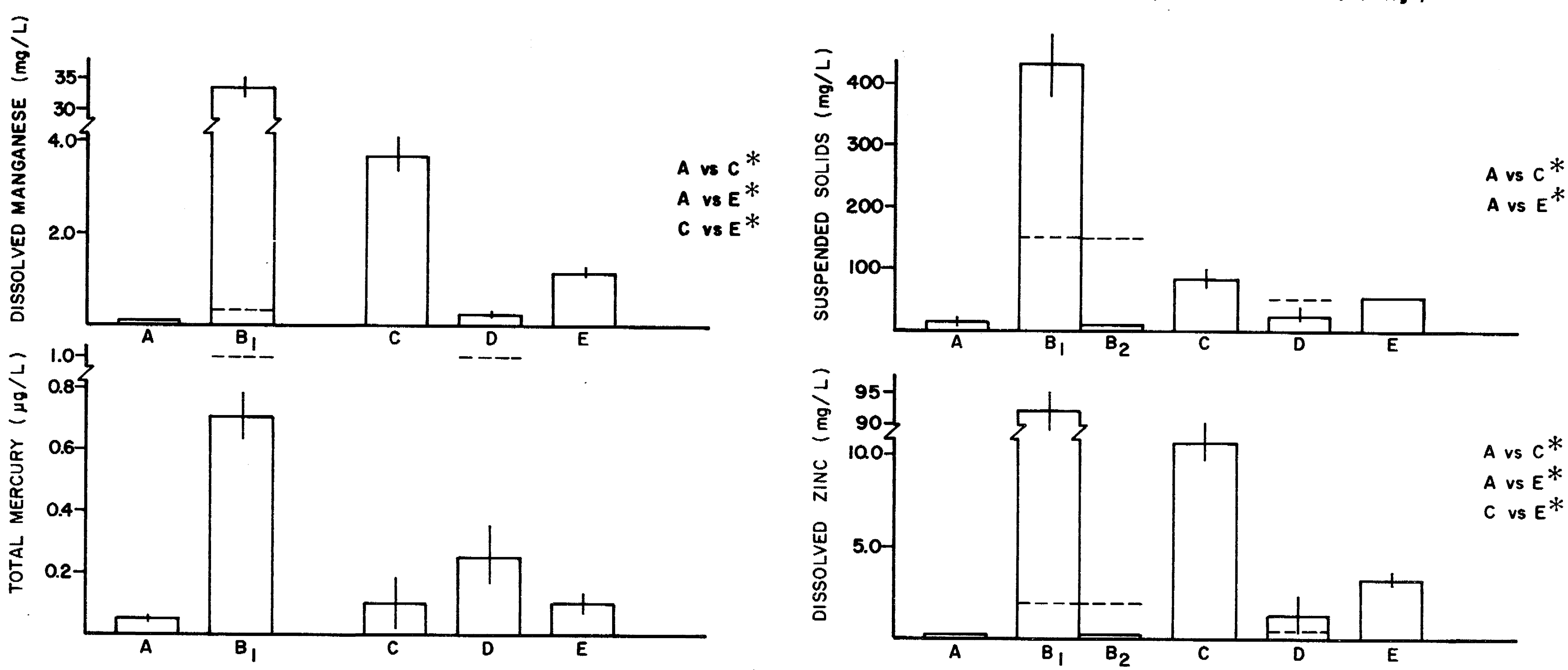

FIGURE 29
MEAN CONTAMINANT LEVELS IN TAILING POND OVERFLOWS AND ASSOCIATED CREEKS

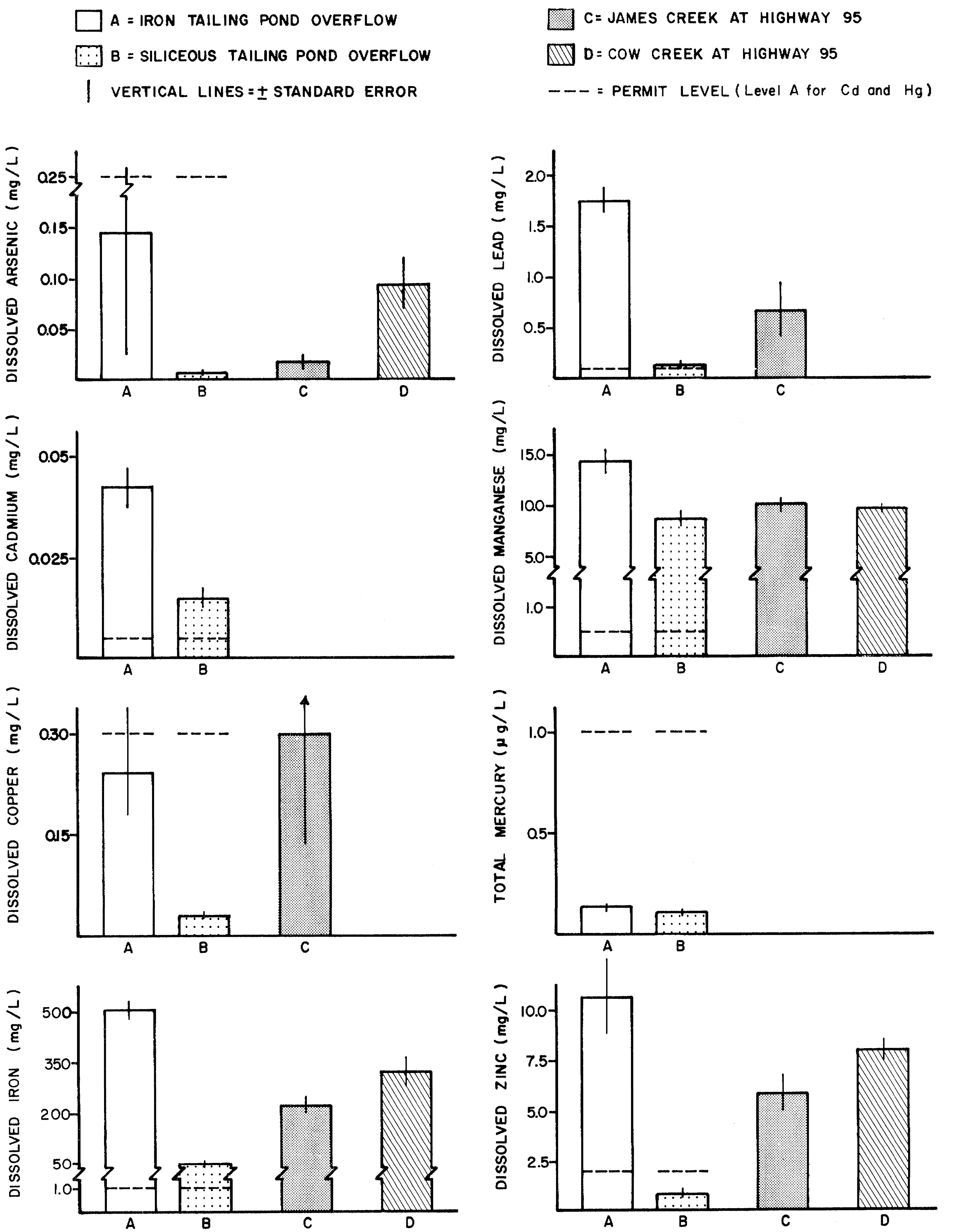

FIGURE 30

MEAN FLOW AND CONTAMINANT LEVELS IN TAILING POND OVERFLOWS AND ASSOCIATED CREEKS

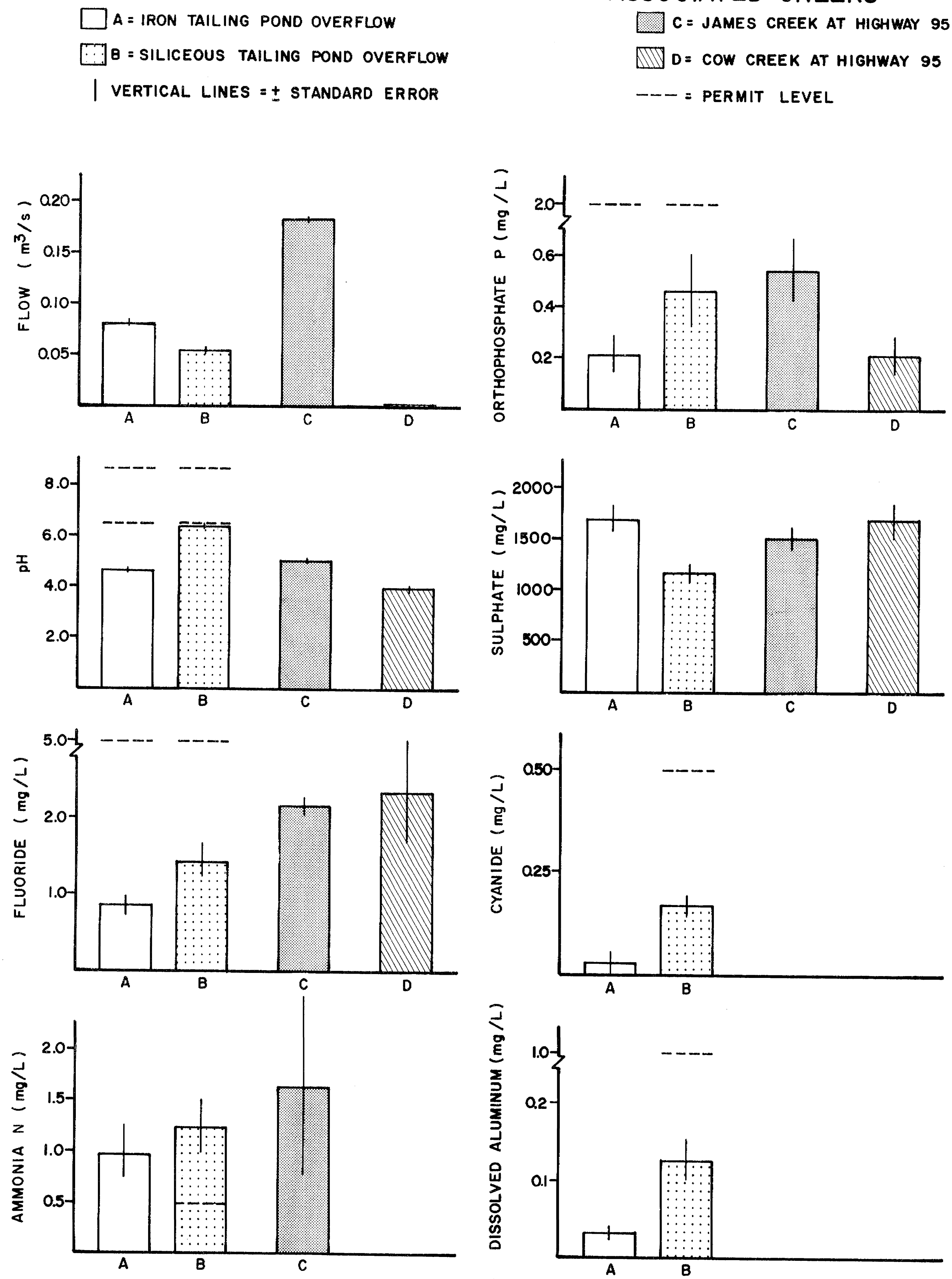

FIGURE 31

pH AND FLUORIDE IN THE ST. MARY RIVER AROUND COMINCO

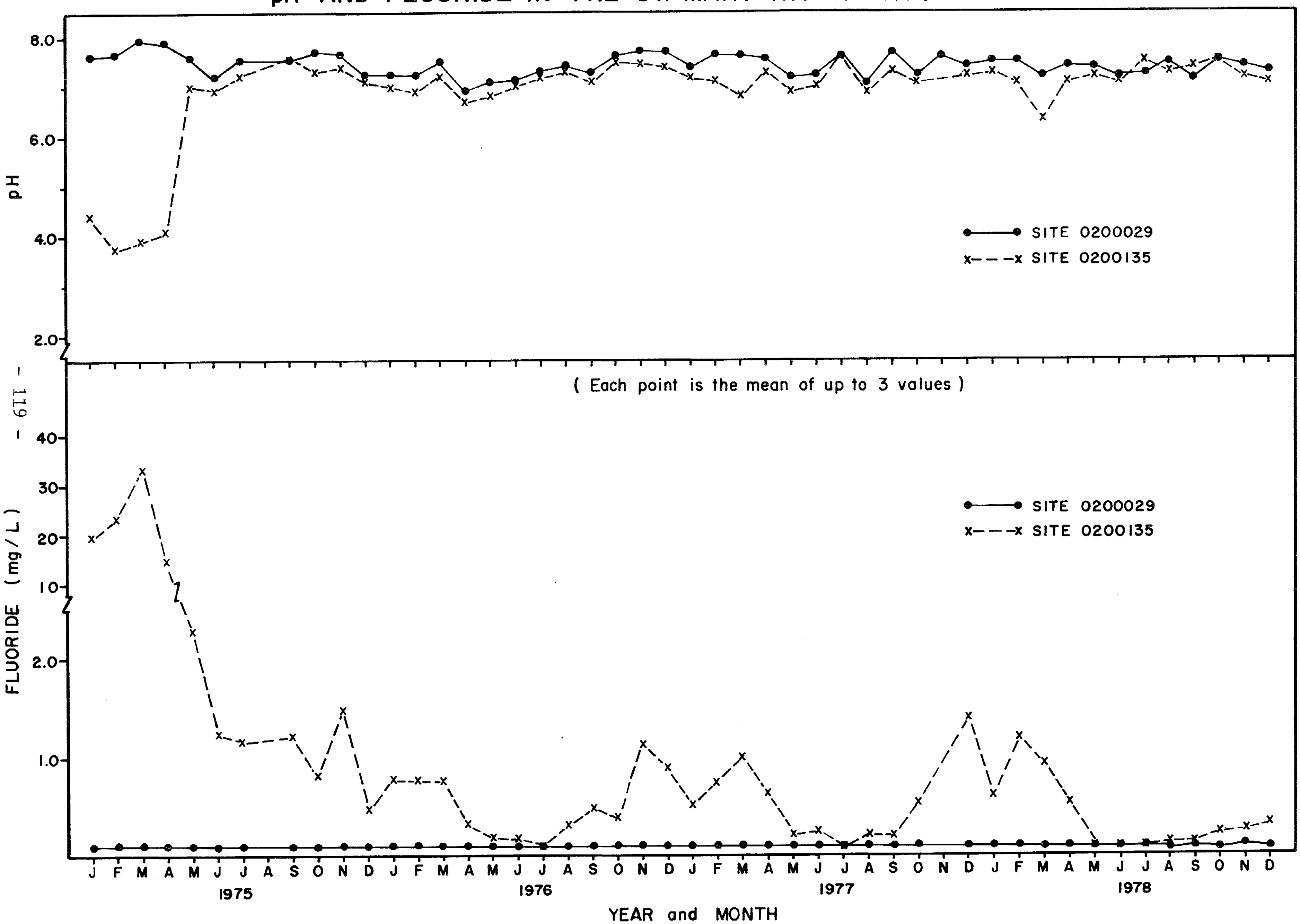

FIGURE 32

INORGANIC NITROGEN IN THE ST. MARY RIVER AROUND COMINCO

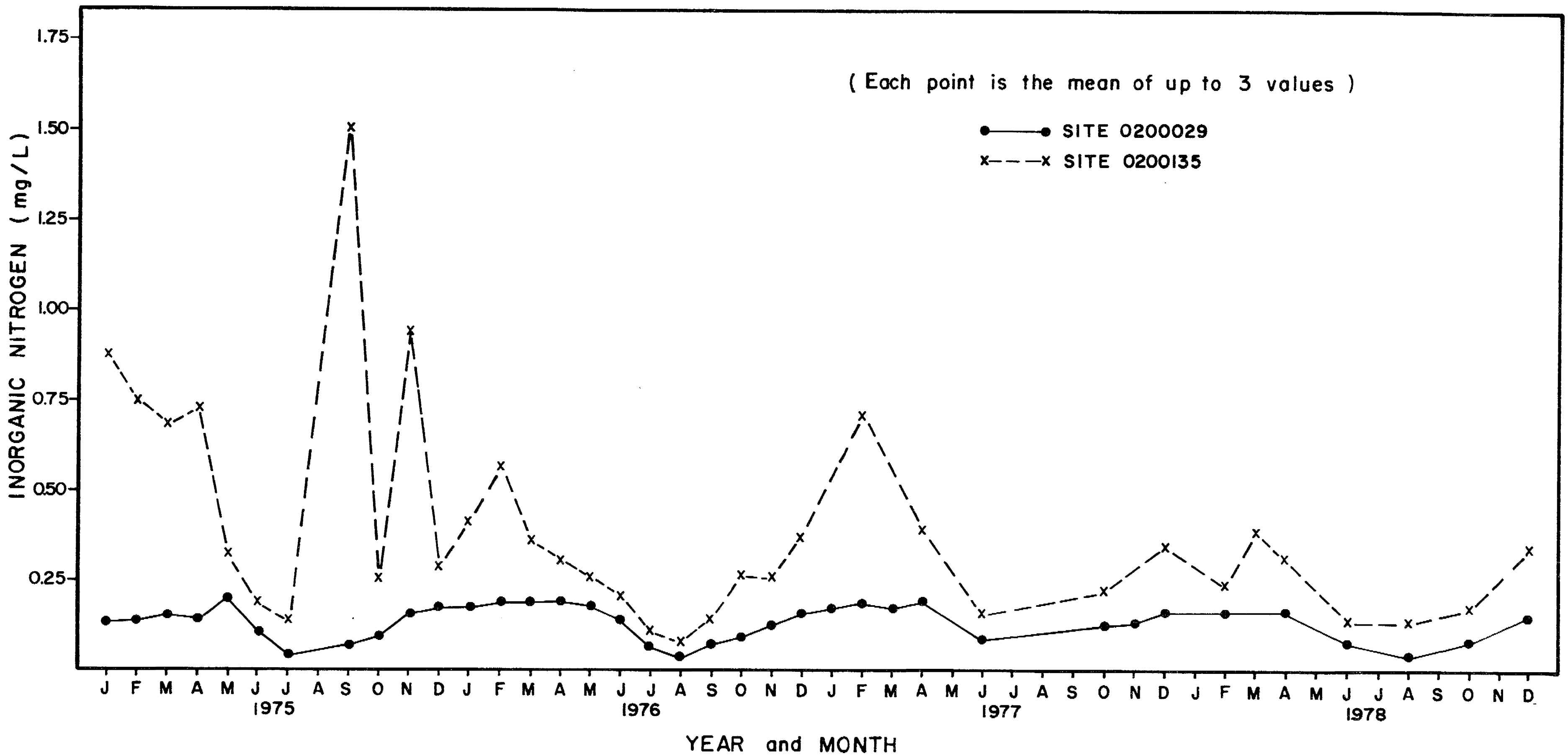

FIGURE 33

ORTHOPHOSPHATE IN THE ST. MARY RIVER AROUND COMINCO

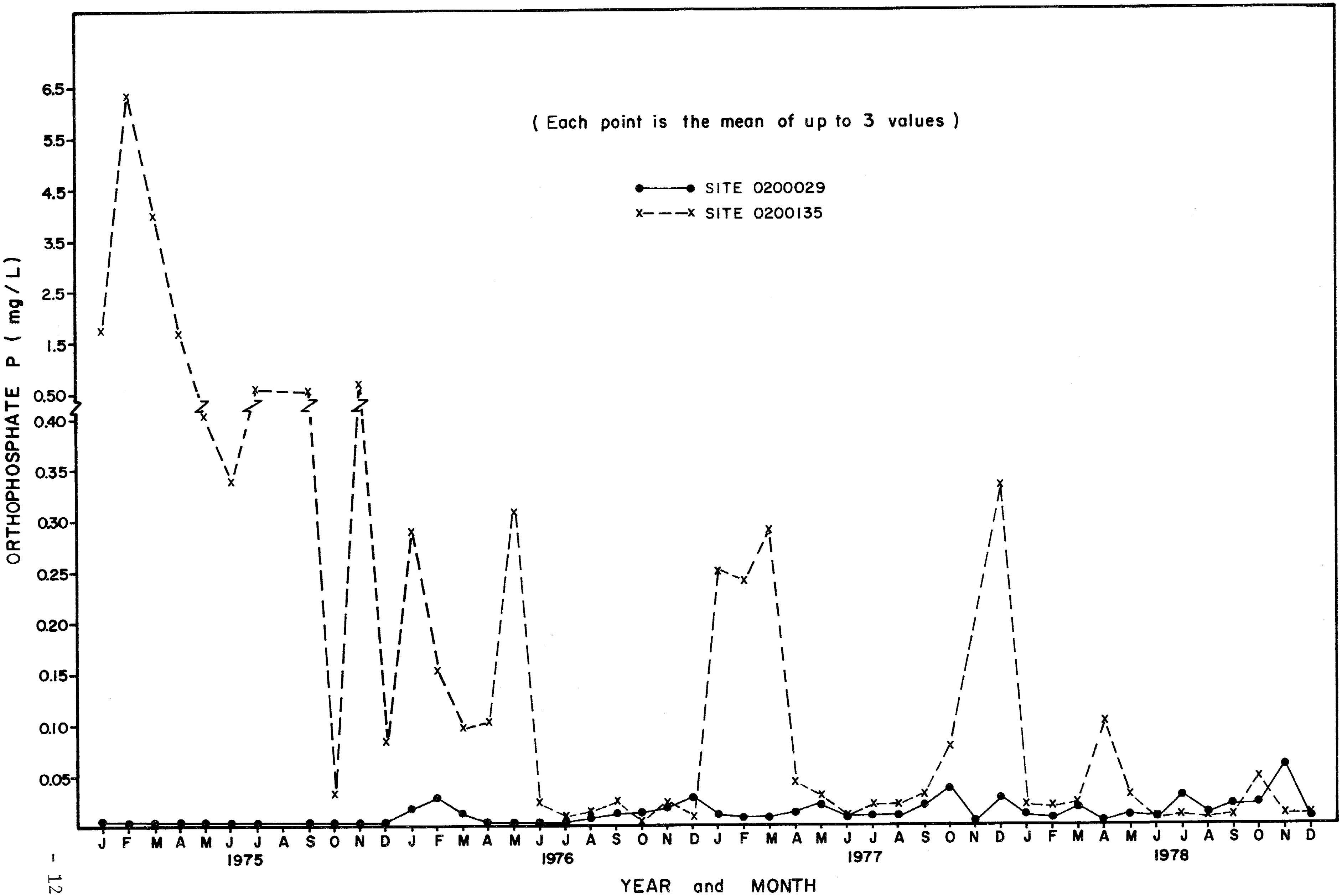

FIGURE 34

MANGANESE IN THE ST. MARY RIVER AROUND COMINCO

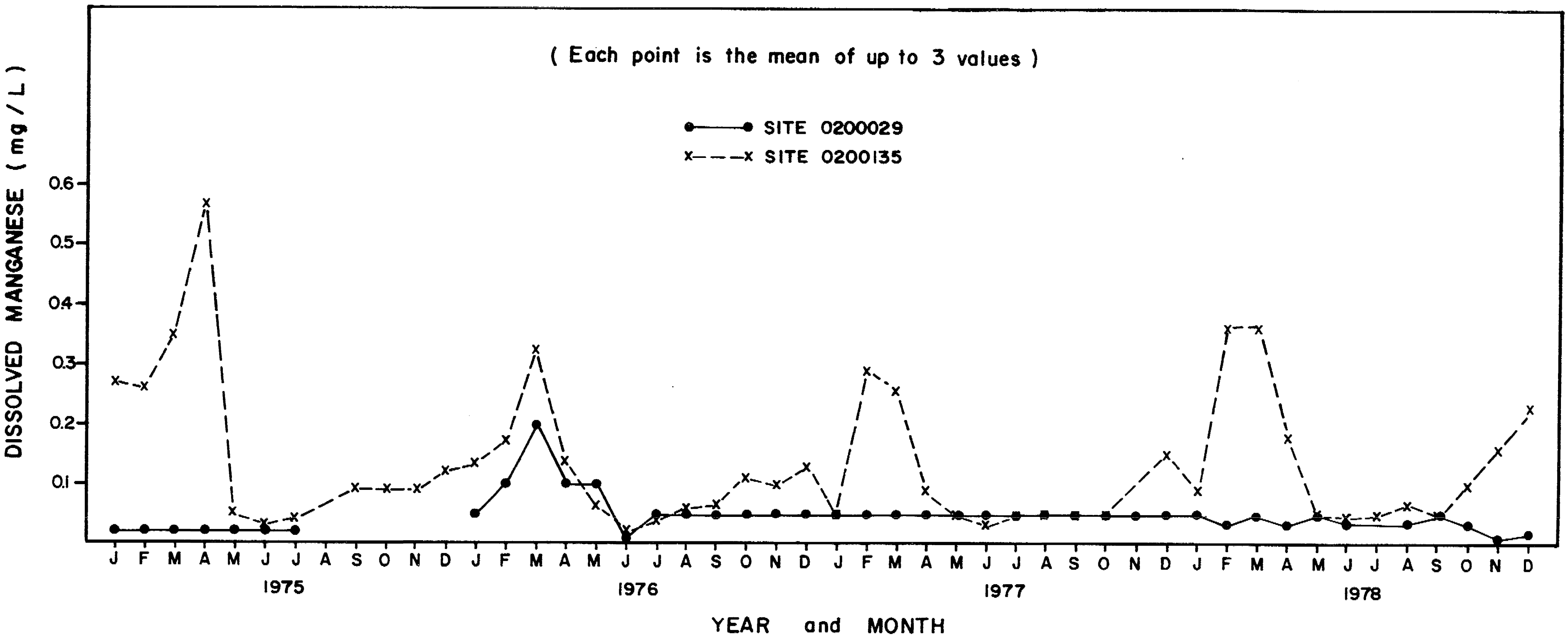

FIGURE 35

ZINC AND IRON IN THE ST. MARY RIVER AROUND COMINCO

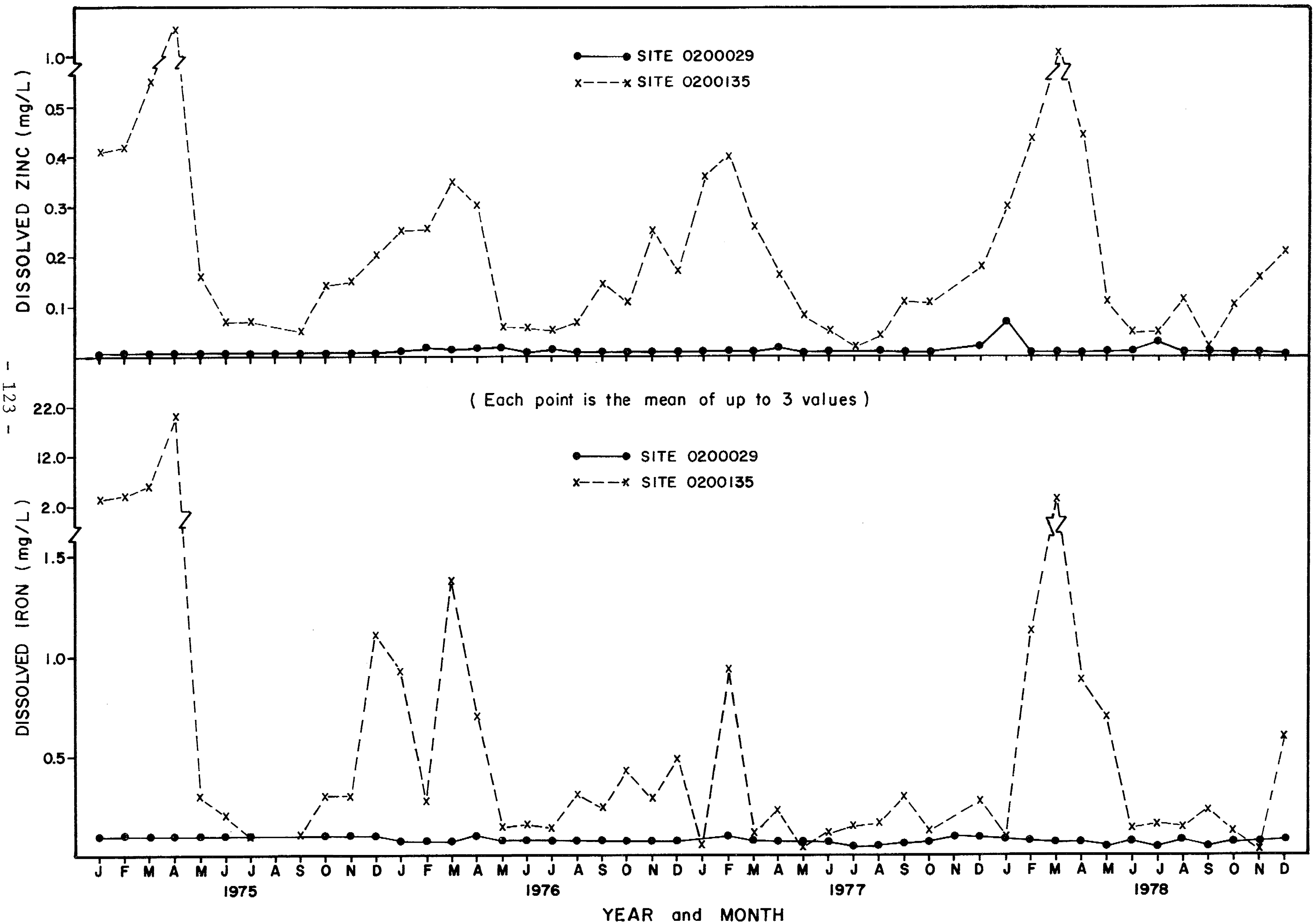

FIGURE 36
LEAD IN THE ST. MARY RIVER AROUND COMINCO

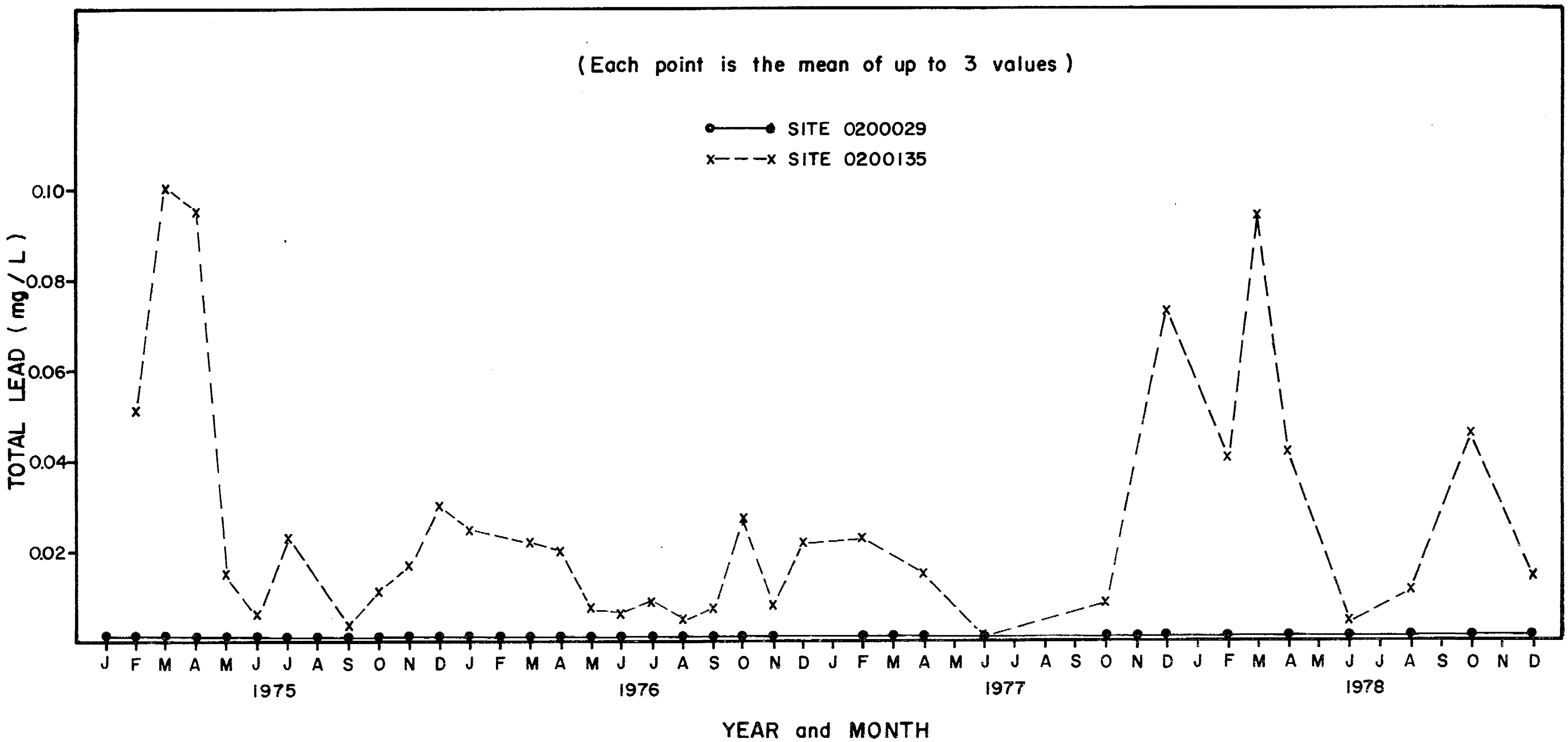

FIGURE 37
SULPHATE LEVELS IN THE ST. MARY RIVER

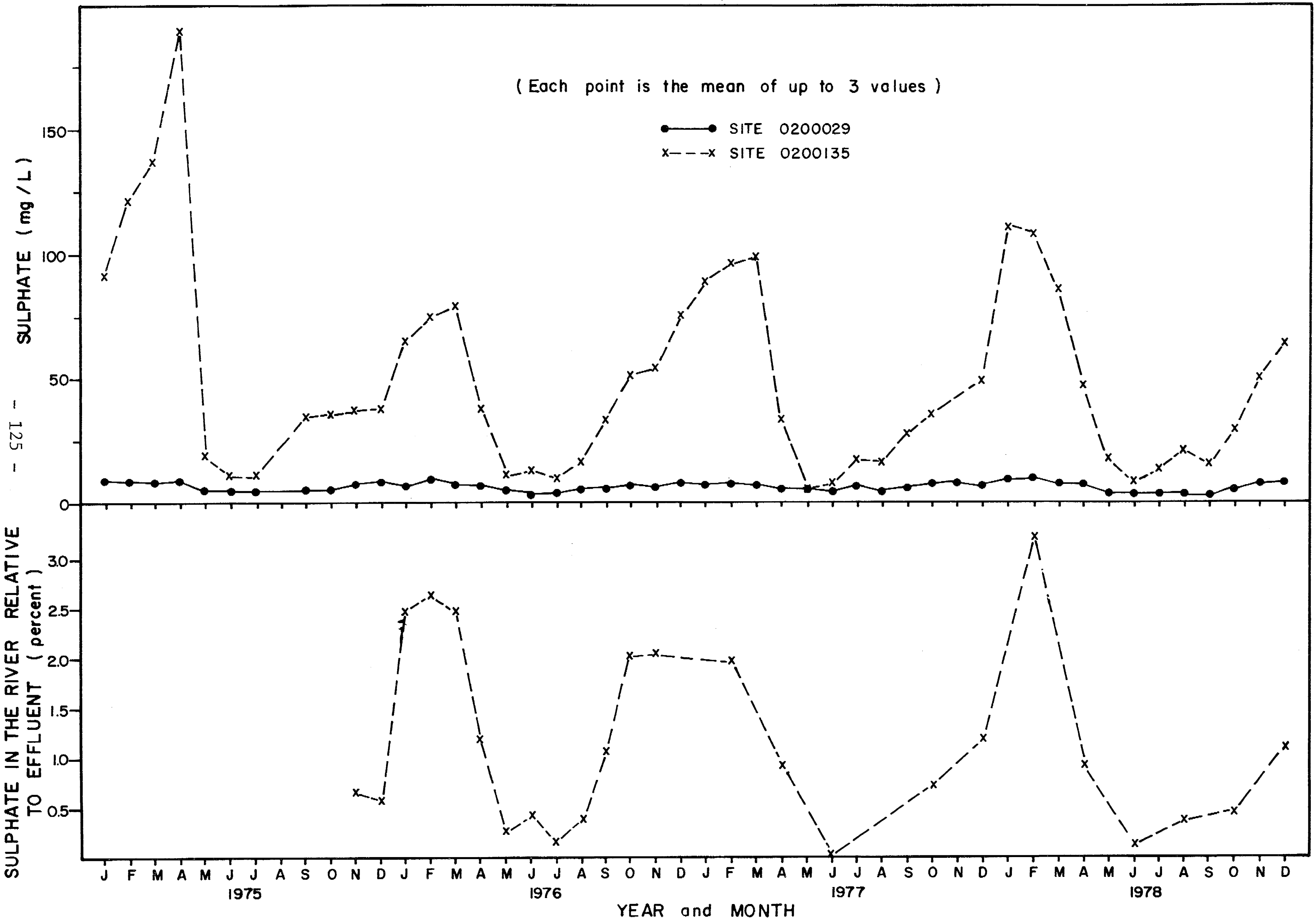

FIGURE 38

HEAVY METALS IN SEDIMENTS FROM THE ST. MARY RIVER

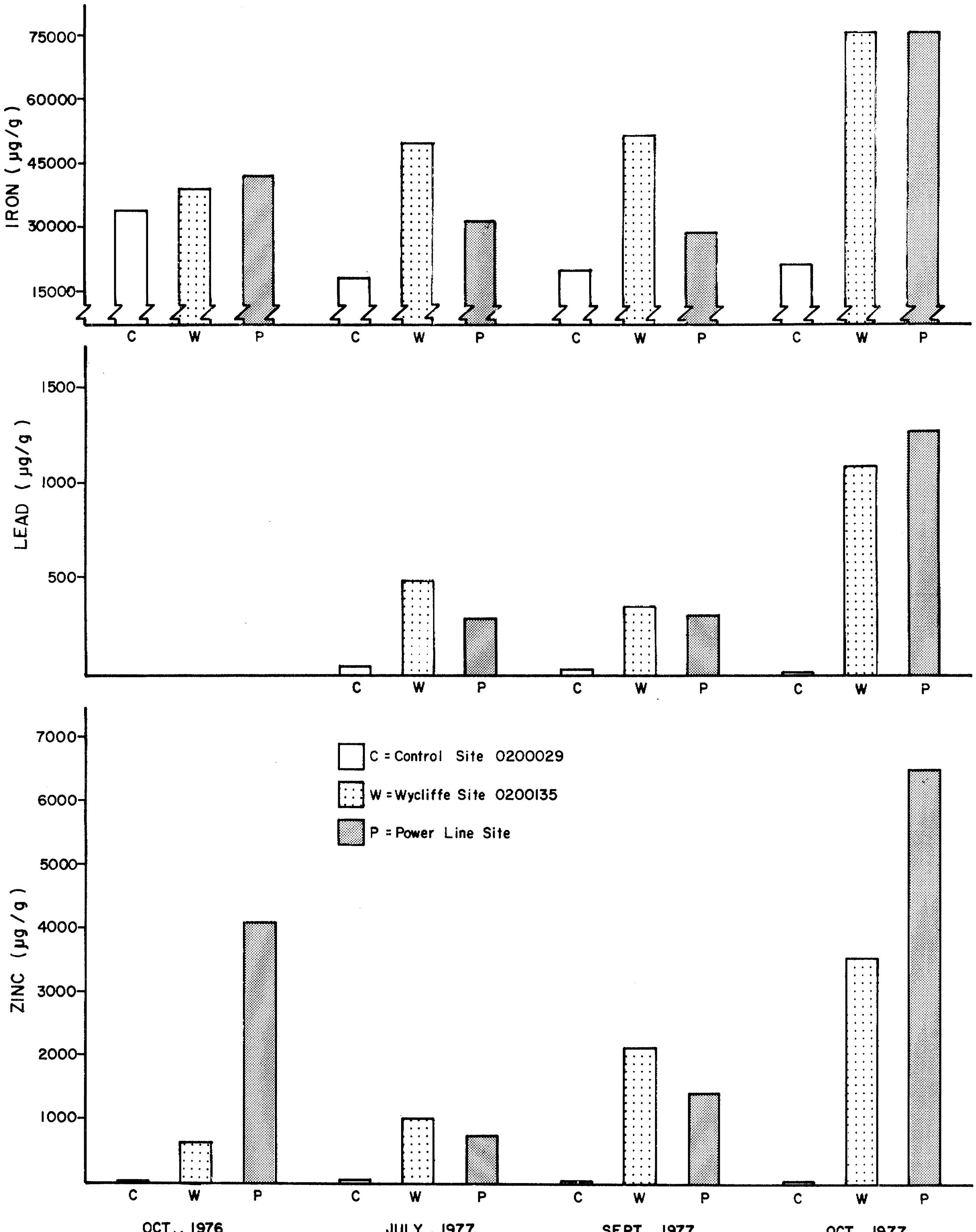

FIGURE 39

HEAVY METALS IN SEDIMENTS FROM THE ST. MARY RIVER

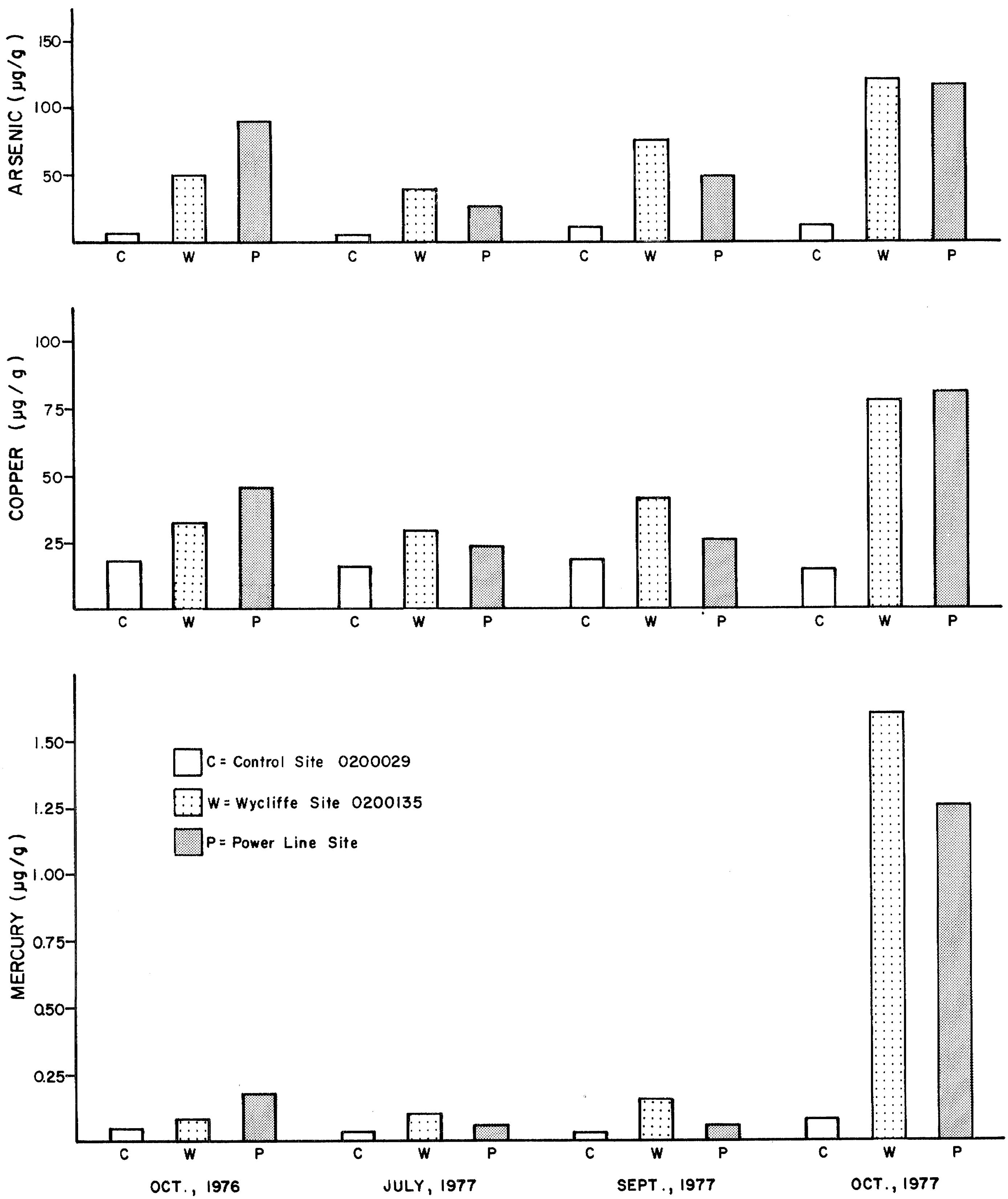

FIGURE 40

MEAN MONTHLY FLOW OF THE KOOTENAY RIVER AT FORT STEELE

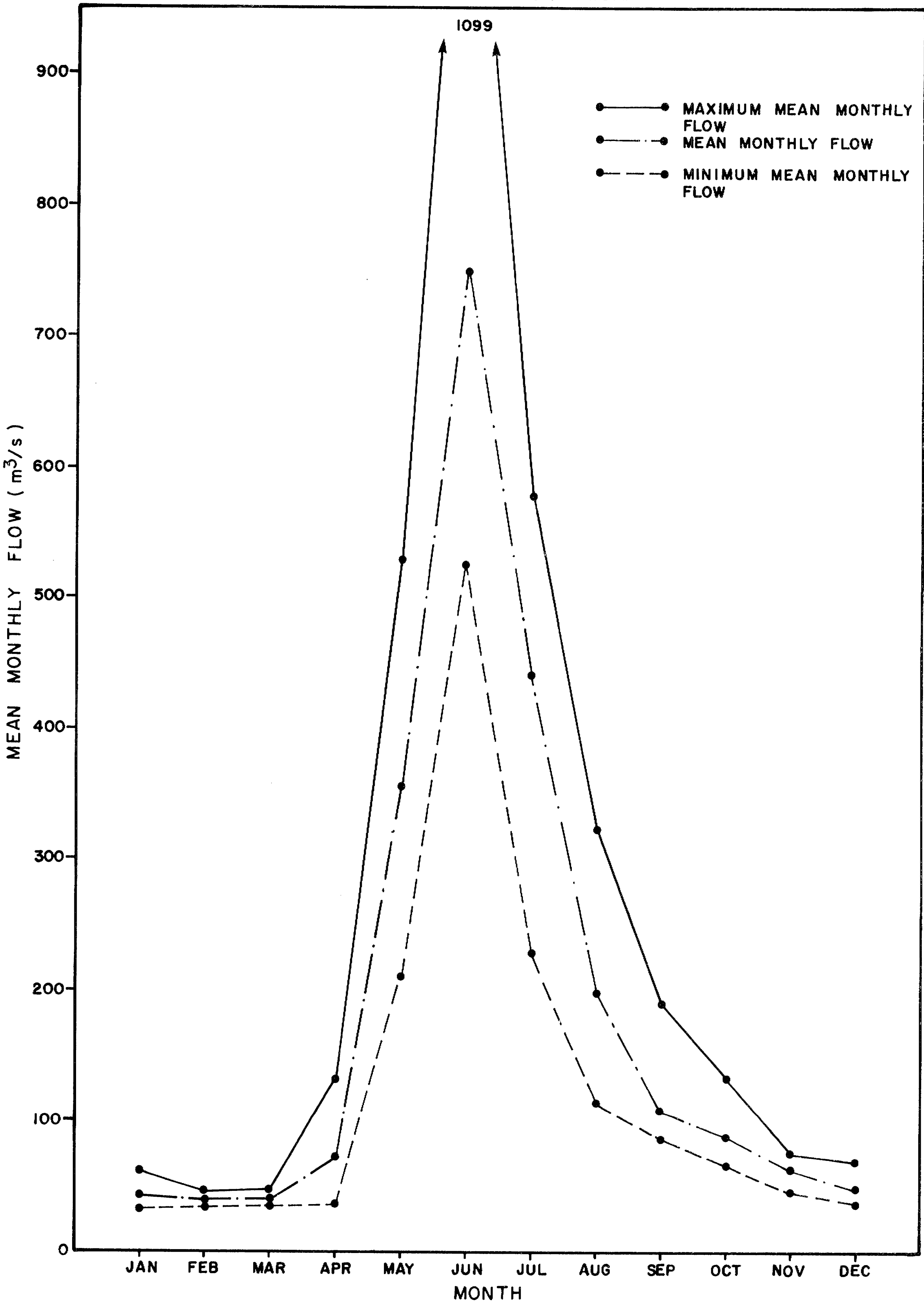

FIGURE 41

SODIUM AND SULPHATE IN THE KOOTENAY RIVER, SITE 0200038 DOWNSTREAM FROM THE ST. MARY RIVER

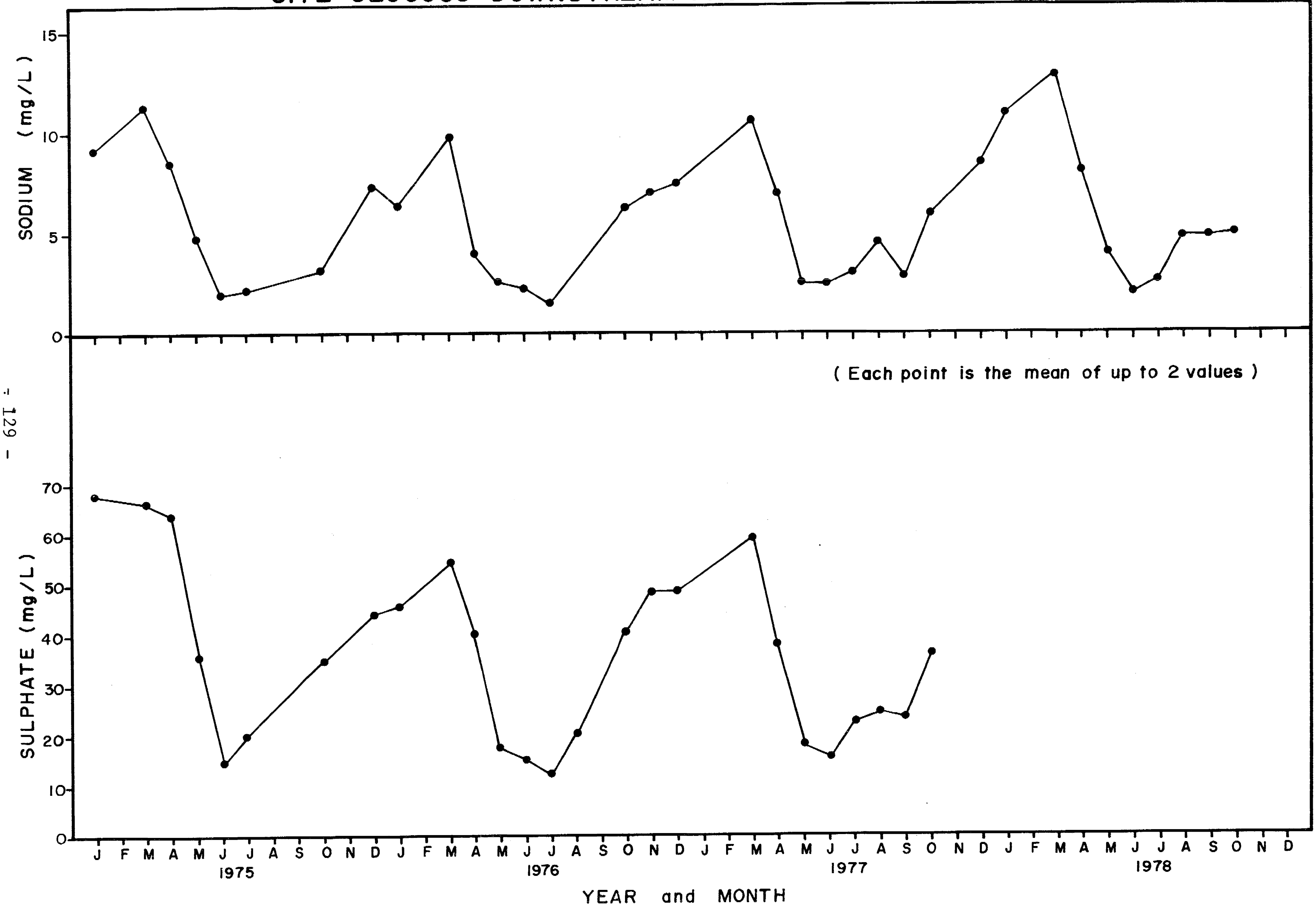

FIGURE 42

IRON AND FLUORIDE IN THE KOOTENAY RIVER, SITE 0200038 DOWNSTREAM FROM THE ST. MARY RIVER

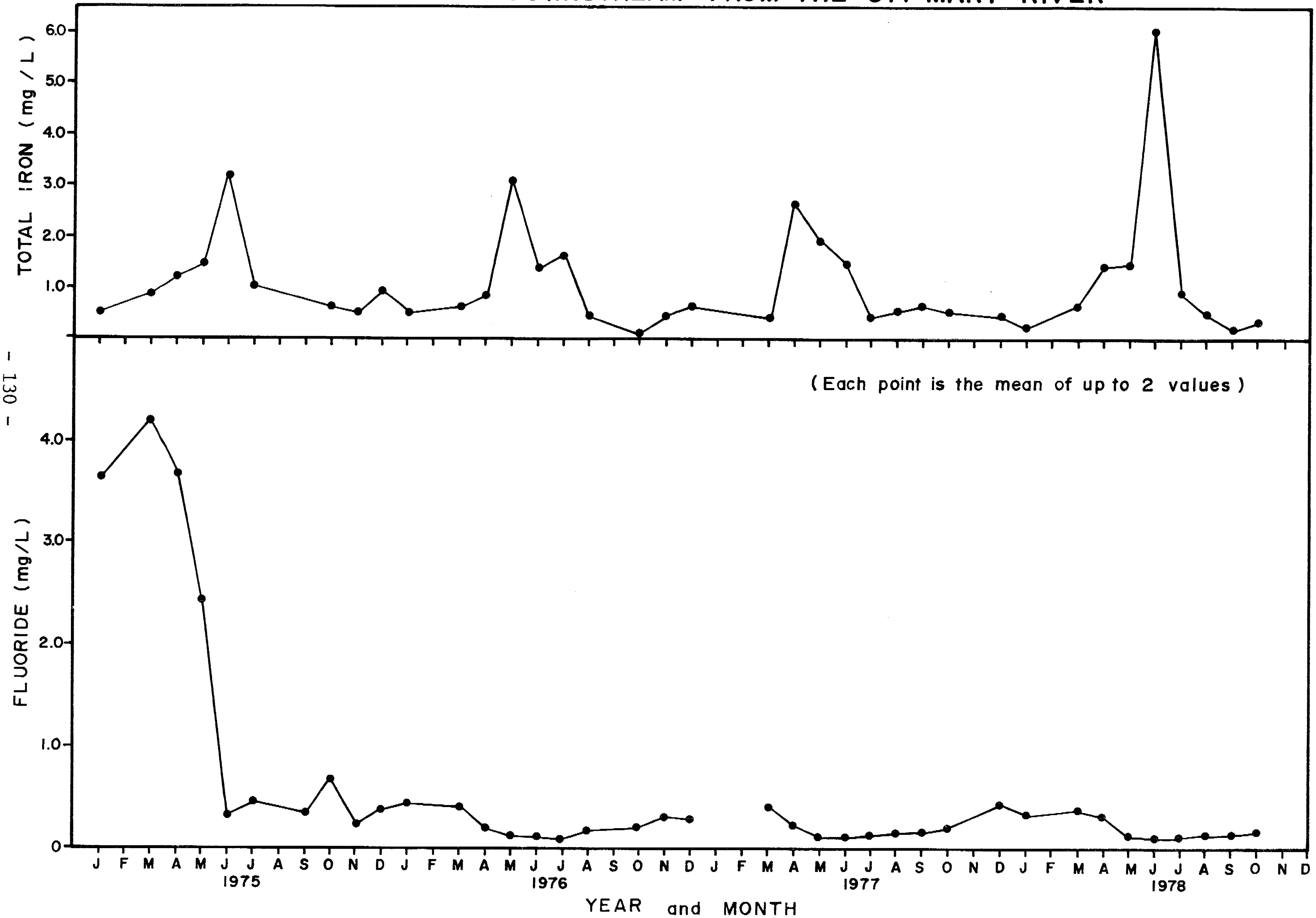

FIGURE 43
PHENOLS AND COLOUR IN THE KOOTENAY RIVER, SITE 0200038 DOWNSTREAM FROM THE ST. MARY RIVER

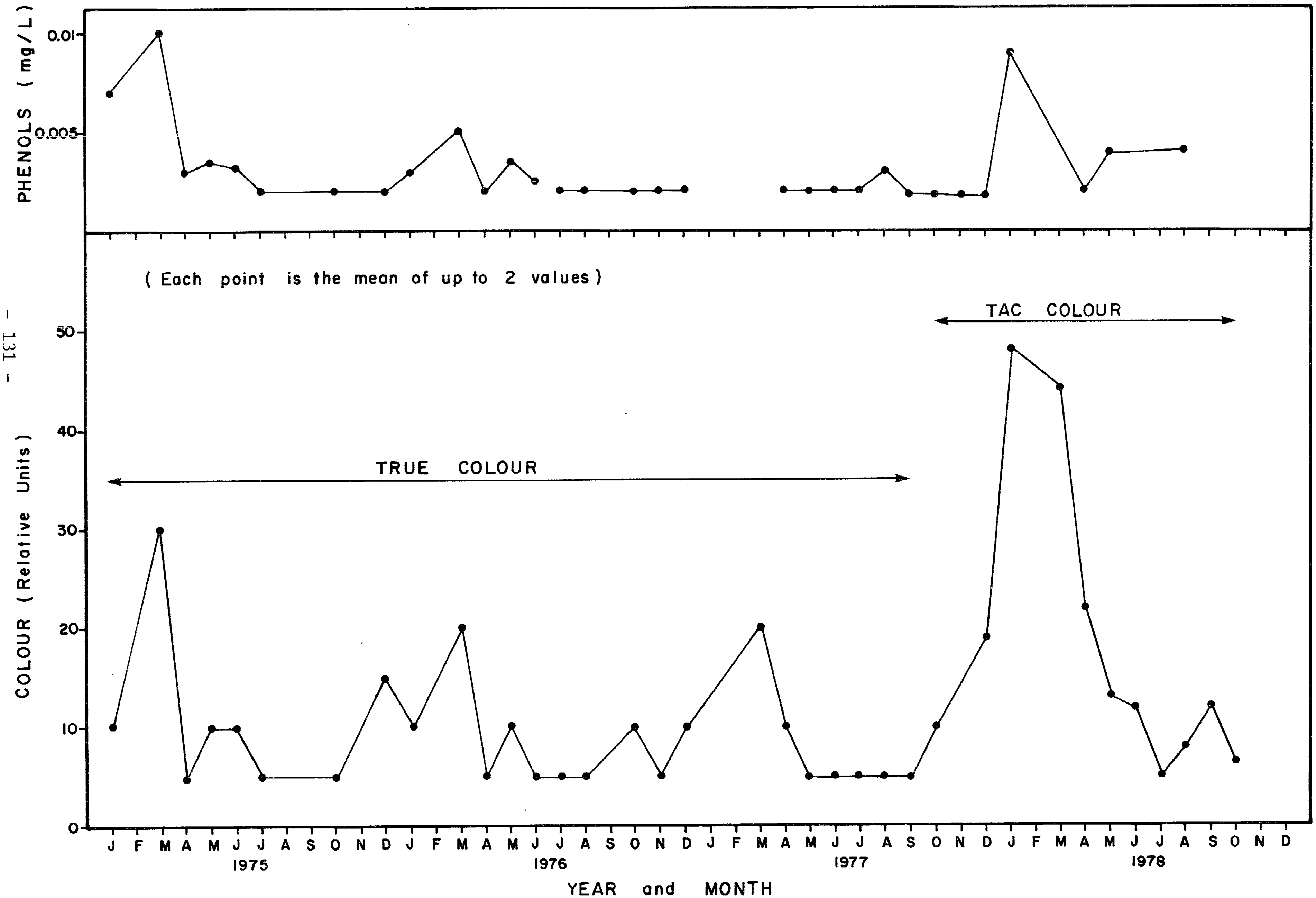

FIGURE 44

ISOTHERMS VERSUS SITE AND DEPTH IN THE KOOCANUSA RESERVOIR

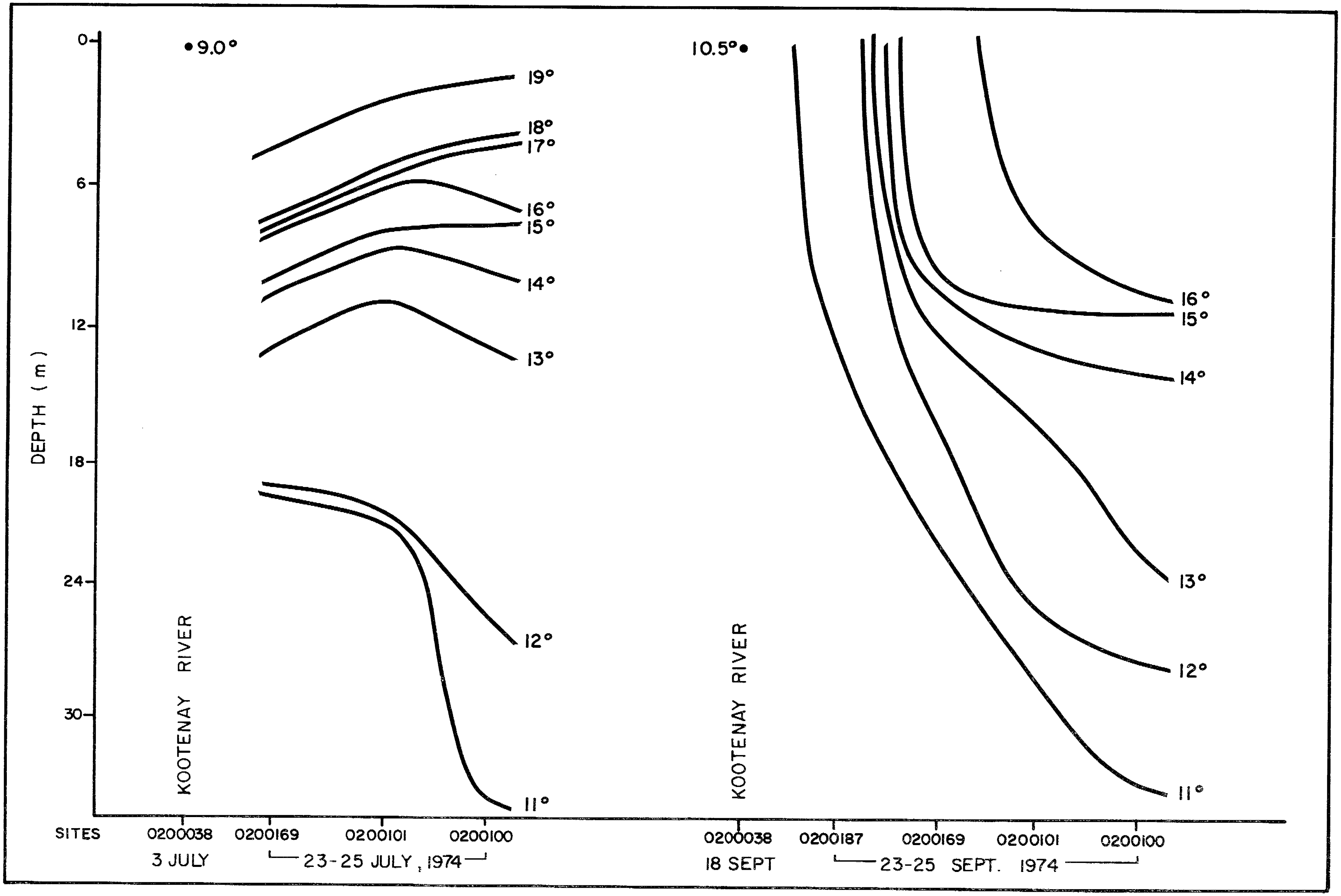

FIGURE 45

MEAN MONTHLY FLUORIDE LEVELS IN THE KOOCANUSA RESERVOIR
SITE 0200100 AT THE INTERNATIONAL BORDER

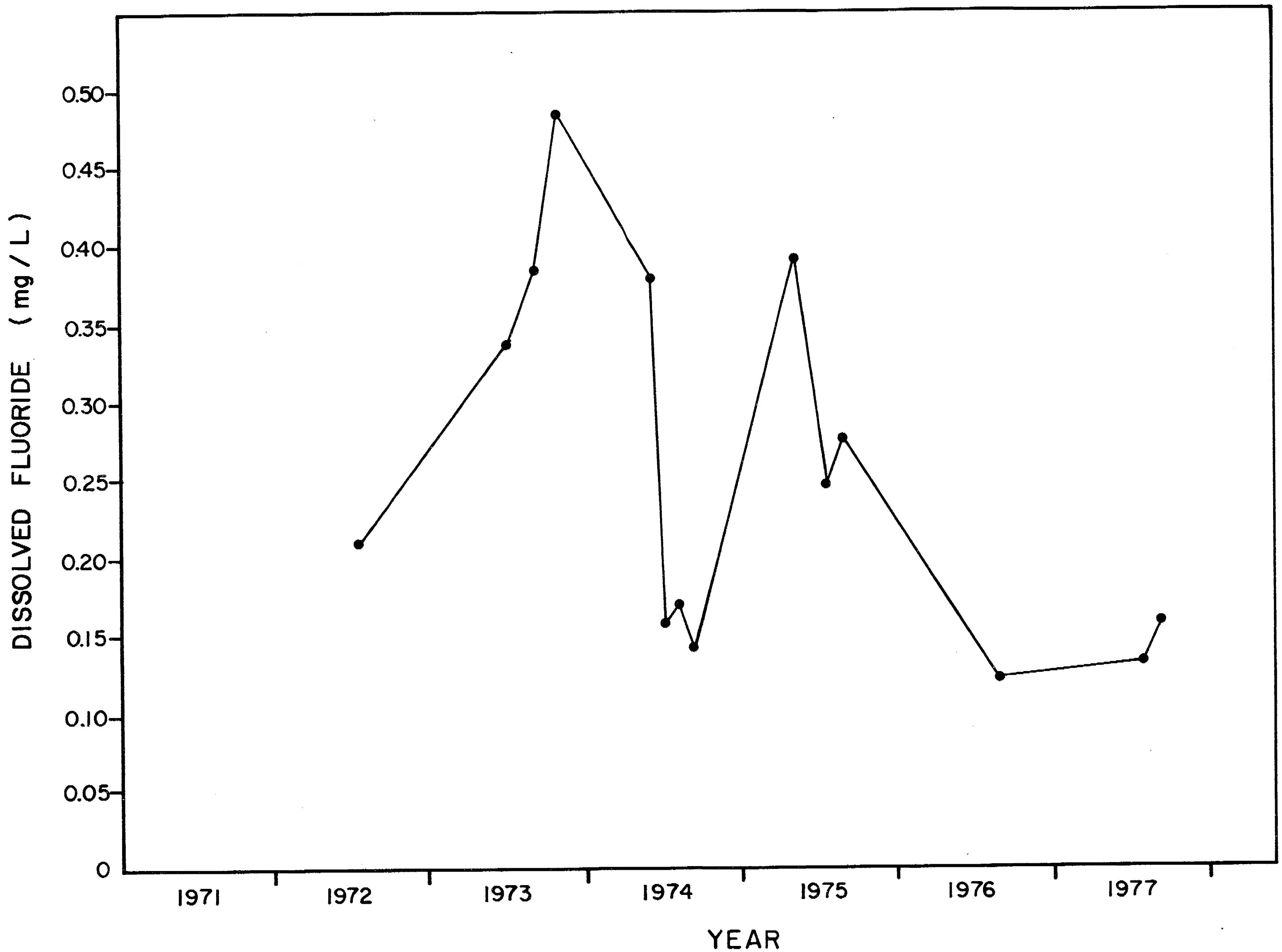

FIGURE 46

WATER SOURCES IN THE KOOTENAY RIVER BASIN BETWEEN CANAL FLATS AND THE ST. MARY RIVER WITH LIMITED WATER AVAILABILITY

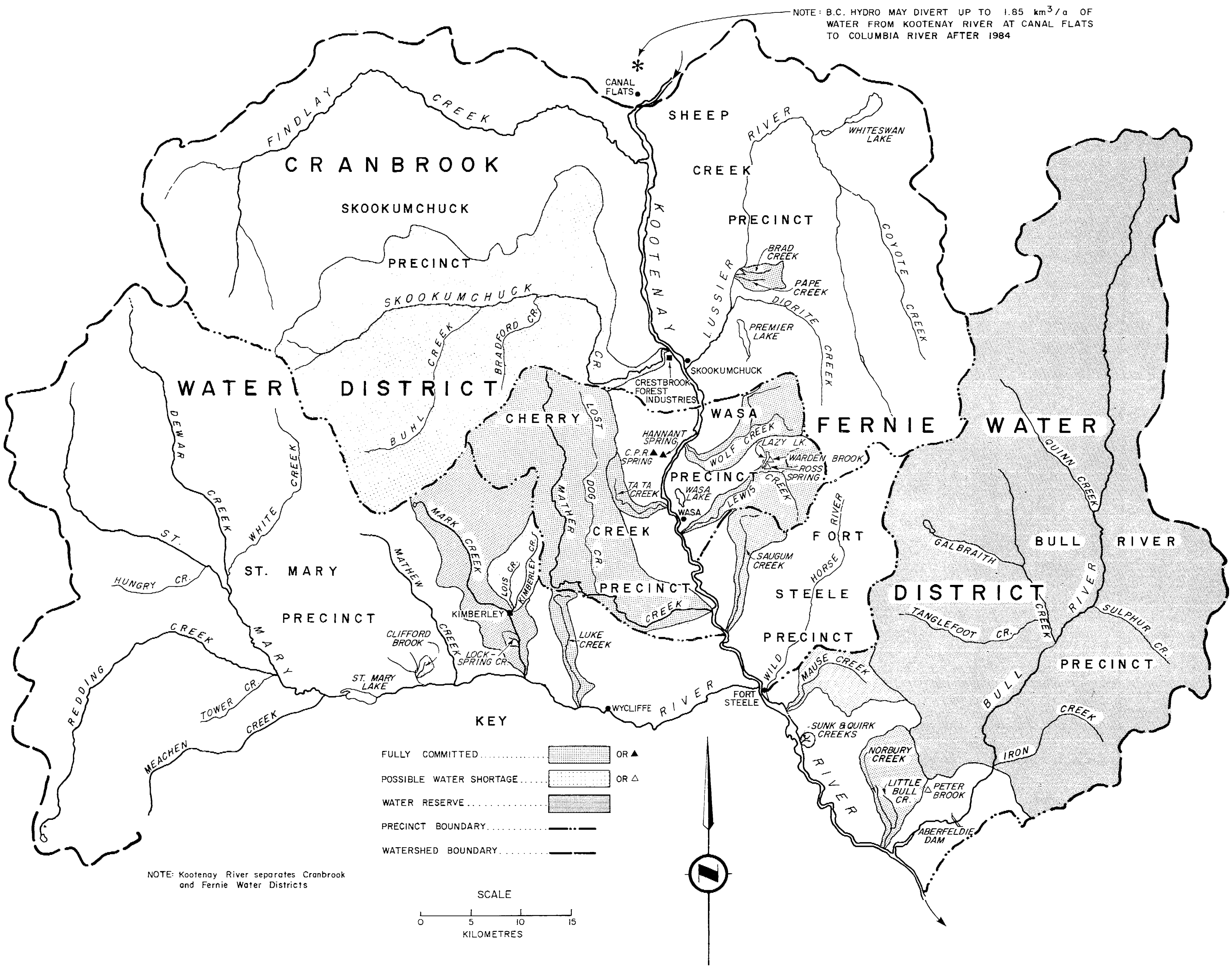

FIGURE 47

WATER SOURCES IN THE KOOTENAY RIVER BASIN
BETWEEN ST. MARY RIVER AND THE INTERNATIONAL BORDER
WITH LIMITED WATER AVAILABILITY

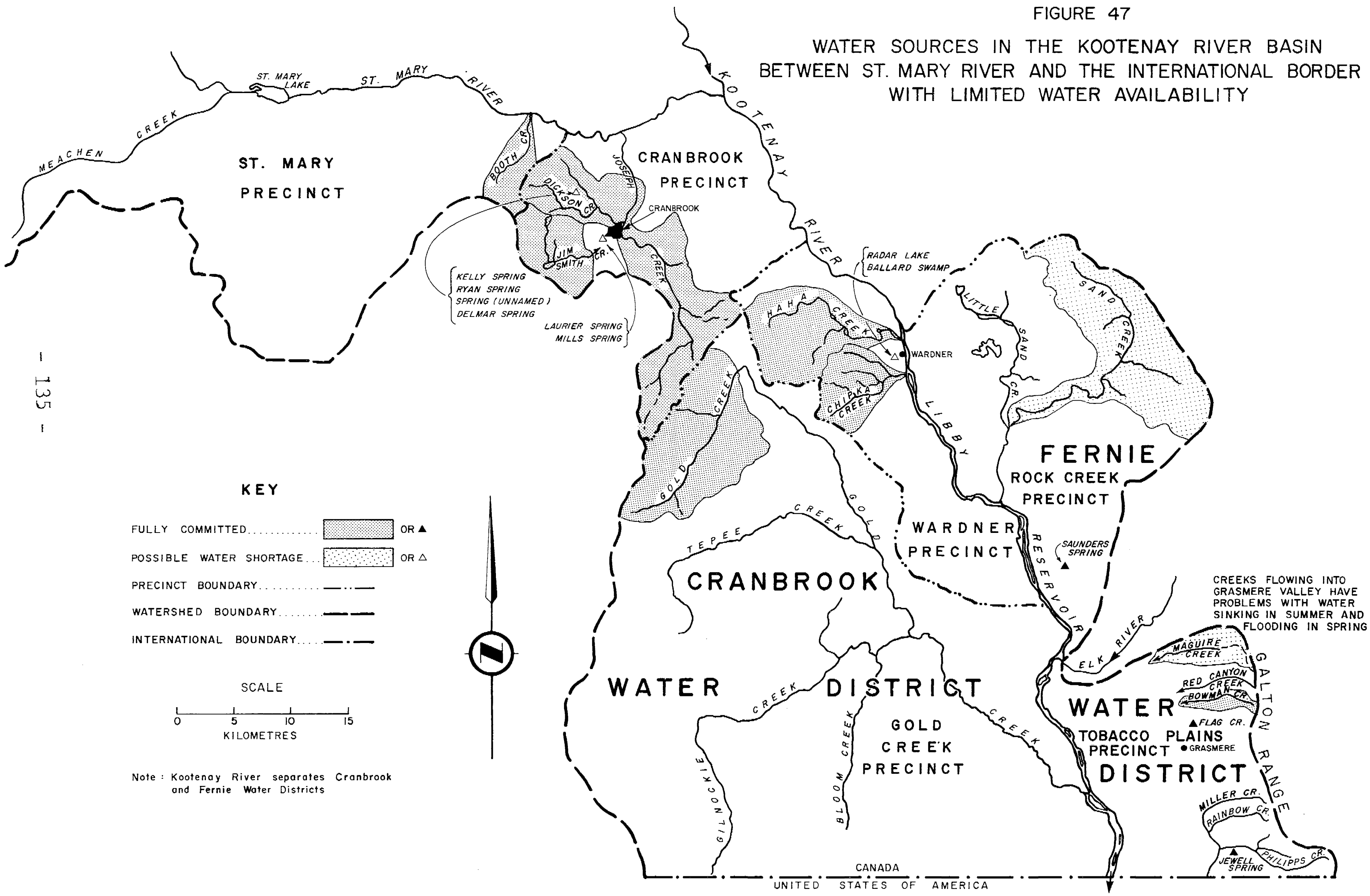

TABLE 1

DESCRIPTION OF WATER QUALITY SAMPLING SITES IN THE UPPER KOOTENAY RIVER BASIN

Site Number	Description
1190023	Kootenay River in Kootenay National Park, where Highway 93 first approaches the river from the south (30 m upstream from picnic area).
0200231	Kootenay River downstream from Cross River, at bridge crossing in Lot 11860.
0200020	Kootenay River at Canal Flats, at Highway 93/95 bridge crossing.
0200226	Mitchell River upstream from Assiniboine Creek at proposed Baymag Mines Ltd. minesite.
0200227	Assiniboine Creek upstream from Mitchell River at proposed Baymag Mines Ltd. minesite.
0200228	Mitchell River downstream from Assiniboine Creek and proposed Baymag Mines Ltd. minesite.
0200229	Mitchell River just upstream from the Cross River.
0200230	Cross River just upstream from the Kootenay River in Lot 12059.

TABLE 2

MITCHELL RIVER AND ASSINIBOINE CREEK WATER QUALITY DATA TO MAY 1978

Sampling Site		Mitchell River Upstream Assiniboine Creek 0200226				Assiniboine Creek Upstream Mitchell River 0200227				Mitchell River Downstream Assiniboine Creek 0200228				Mitchell River Upstream Cross River 0200229			
Parameter	Type of Value	N	Max.	Min.	Mean.	N	Max.	Min.	Mean.	N	Max.	Min.	Mean.	N	Max.	Min.	Mean.
Alkalinity-Total	mg/L	1			106	1			78	1			94	1			96
Arsenic-Total	µg/L	1			<5	1			5	3	<5	<5	<5	3	<5	<5	<5
Calcium-Dissolved	mg/L	1			31	1			20.5	3	26.7	22.9	25.2	3	26.7	22.9	25.4
Total	mg/L	1			32	1			20.9	3	28.8	25.3	27.2	3	28.3	25.5	27.3
Copper-Total	µg/L	1			<1	1			<1	3	1	<1	1	3	1	<1	1
Fluoride-Dissolved	mg/L	1			<0.1	1			<0.1	3	<0.1	<0.1	<0.1	3	<0.1	<0.1	<0.1
Hardness-Total	mg/L	1			124	1			92	3	111	89	100	3	112	90	102
Iron-Total	mg/L	1			<0.1	1			<0.1	3	0.2	<0.1	0.2	3	0.2	<0.1	0.2
Lead-Total	µg/L	1			<1	1			<1	3	2	<1	2	3	1	<1	1
Magnesium-Dissolved	mg/L	1			11.3	1			10.0	3	10.7	7.7	9.1	3	11.0	8.0	9.4
Total	mg/L	1			11.4	1			10.1	3	10.9	8.6	9.5	3	11.4	8.9	9.8
Manganese-Total	mg/L	1			<0.02	1			<0.02	3	<0.02	<0.02	<0.02	3	0.02	<0.02	0.02
Mercury-Total	µg/L	1			<0.05	1			<0.05	3	<0.05	<0.05	<0.05	3	<0.05	<0.05	<0.05
Molybdenum-Total	µg/L	1			<0.5	1			<0.5	3	0.6	<0.5	0.5	3	0.7	<0.5	0.6
Nitrogen-Ammonia	µg/L	1			<5	1			<5	2	<5	<5	<5	2	<5	<5	<5
Nitrite/Nitrate	mg/L	1			0.1	1			0.09	2	0.11	0.10	0.10	2	0.11	0.10	0.10
Organic	mg/L	1			<0.1	1			<0.1	2	0.02	0.01	0.015	2	0.21	0.04	0.12
Total	mg/L	1			0.1	1			0.09	2	0.13	0.12	0.12	2	0.26	0.15	0.2
pH		1			8.2	1			8.2	2	8.2	8.1	8.2	2	8.1	8.1	8.1
Phosphorus-Dissolved	µg/L	1			<3	1			<3	2	<3	<3	<3	2	<3	<3	<3
Total	µg/L	1			<3	1			<3	3	6	<3	5	3	5	<3	4
Sodium-Dissolved	mg/L	1			0.5	1			0.2	3	0.5	0.4	0.4	3	1.4	0.4	0.8
Solids-Dissolved	mg/L	1			132	1			100	3	118	104	113	3	120	112	117
Total	mg/L	1			2	1			2	3	16	2	8	3	20	2	9
Sulphate-Dissolved	mg/L	1			14.9	1			10.0	3	13.9	7.6	10.1	3	13.4	7.6	10.2
Turbidity	J.T.U.	1			0.5	1			0.5	3	5.7	0.6	3.4	3	5.3	0.6	3.3
Zinc-Total	µg/L	1			<5	1			<5	3	<5	<5	<5	3	<5	<5	<5

N = Number of Values
All data are from the Ministry of Environment's Data Bank, EQUIS.

TABLE 3

KOOTENAY AND CROSS RIVER WATER QUALITY DATA TO MAY 1978

Sampling Site		Kootenay River in Kootenay National Park 1190023				Cross River at the Mouth 0200230				Kootenay River Downstream Cross River 0200231			
Parameter	Type of Value	N	Max.	Min.	Mean	N	Max.	Min.	Mean	N	Max.	Min.	Mean
Alkalinity-Total	mg/L	1			102	1			103	1			112
Arsenic-Total	µg/L	3	<5	<5	<5	2	<5	<5	<5	3	<5	<5	<5
Calcium-Dissolved	mg/L	2	31.7	30.5	31.1	2	28.3	24.2	26.2	3	32.2	27.3	30.3
Total	mg/L					2	30.2	29.0	29.6	3	41.0	34.2	37.4
Coliforms-Fecal	MPN/100 mL	1			2								
Color, T.A.C.	T.A.C. color units	2	1	<1	1								
Copper-Total	µg/L					2	<1	<1	<1	3	3	<1	2
Fluoride-Dissolved	mg/L	2	<0.1	<0.1	<0.1	2	<0.1	<0.1	<0.1	3	<0.1	<0.1	<0.1
Hardness-Total	mg/L	2	108	104	106	2	116	94	105	3	125	101	114
Iron-Dissolved	mg/L	3	<0.1	<0.1	<0.1								
Total	mg/L	1			1.0	2	0.4	<0.1	0.2	3	1.3	<0.1	0.9
Lead-Dissolved	µg/L	2	1	<1	1								
Total	µg/L					2	<1	<1	<1	3	3	<1	2
Magnesium-Dissolved	mg/L	2	7.0	6.7	6.9	2	1.0	8.1	9.6	3	10.9	7.9	9.3
Total	mg/L					2	11.7	9.7	10.7	3	11.2	9.8	10.4
Manganese-Dissolved	mg/L	2	<0.02	<0.02	<0.02								
Total	mg/L					2	<0.02	<0.02	<0.02	3	0.04	<0.02	0.03
Mercury-Total	µg/L					2	<0.05	<0.05	<0.05	3	<0.05	<0.05	<0.05
Molybdenum-Total	µg/L					2	<0.5	<0.5	<0.5	3	0.5	<0.5	0.5
Nitrogen-Ammonia	µg/L	1			<5	2	<5	<5	<5	2	<5	<5	<5
Nitrite/Nitrate	mg/L	1			0.14	2	0.11	0.10	0.10	2	0.11	0.11	0.11
Organic	mg/L	1			<0.01	2	<0.01	<0.01	<0.01	2	0.2	0.08	0.14
Total	mg/L	1			0.14	2	0.11	0.10	0.10	2	0.31	0.19	0.25
pH		4	8.3	8.1	8.2	2	8.2	8.2	8.2	2	8.2	8.2	8.2
Phosphorus-Dissolved	µg/L	3	<3	<3	<3	2	<3	<3	<3	2	<3	<3	<3
Total	µg/L	3	23	6	12	2	10	<3	6	3	33	4	21
Sodium-Dissolved	mg/L					2	0.5	0.5	0.5	3	0.8	0.7	0.7

TABLE 3 (CONTINUED)

KOOTENAY AND CROSS RIVER WATER QUALITY DATA TO MAY 1978

Sampling Site		Kootenay River in Kootenay National Park 1190023				Cross River at the Mouth 0200230				Kootenay River Downstream Cross River 0200231			
Parameter	Type of Value	N	Max.	Min.	Mean	N	Max.	Min.	Mean	N	Max.	Min.	Mean
Solids-Dissolved	mg/L	1			126	2	126	110	118	3	130	118	124
Suspended	mg/L	1			28	2	24	4	14	3	78	8	49
Sulphate-Dissolved	mg/L					2	11.5	7.6	9.6	3	11.5	7.6	9.6
Tannin and Lignin	mg/L	3	0.1	<0.1	0.1								
Temperature	°C	2	10.0	7.0	8.5								
Turbidity	J.T.U.	3	17.0	4.2	8.6	2	10	0.9	5.4	3	36.0	2.7	24.9
Zinc-Total	µg/L	2	<5	<5	<5	2	13	<5	9	3	9	<5	6

N = Number of Values
All data are from the Ministry of Environment's Data Bank, EQUIS.

TABLE 4

WATER QUALITY OF KOOTENAY RIVER AT CANAL FLATS (SITE 0200020), SEPTEMBER 1975 to MAY 1978

Parameter	Type of Value	N	Max.	Min.	Mean
Alkalinity-Total	mg/L	47	205.	65.	129.
Arsenic-Dissolved	µg/L	23	<5	<5	<5
Cadmium-Dissolved	µg/L	24	<0.5	<0.5	<0.5
Calcium-Dissolved	mg/L	33	57.5	29.7	43.0
Carbon-Total Organic	mg/L	30	6.0	<1	1.8
Chloride-Dissolved	mg/L	27	10.9	1.9	5.6
Chromium-Dissolved	µg/L	20	<5	<5	<5
Coliforms-Fecal	MPN/100 mL	16	<200	<2	8*
Color-T.A.C.	T.A.C. color units	6	5.0	<1	1.7
Color-True	true color units	26	10	<5	5.2
Copper-Dissolved	µg/L	25	4.0	<1	1
Fluoride-Dissolved	mg/L	29	0.25	<0.1	0.11
Hardness-Total	mg/L	33	210	107	158
Iron-Dissolved	mg/L	25	0.1	<0.1	<0.1
Total	mg/L	28	18.2	<0.1	0.3*
Lead-Dissolved	µg/L	25	1	<1	<1
Magnesium-Dissolved	mg/L	33	16.4	7.7	12.4
Manganese-Dissolved	µg/L	25	<20	<20	<20

Parameter	Type of Value	N	Max.	Min.	Mean
Nitrogen-Ammonia	µg/L	33	37	<5	7
Nitrite/Nitrate	mg/L	32	0.25	0.08	0.14
Organic	mg/L	33	0.3	<0.01	0.065
Total	mg/L	32	0.59	0.11	0.21
Oxygen-Dissolved	mg/L	24	13.6	8.3	11.0
% Saturation		20	116	81	94
pH		56	8.5	7.6	8.2
Phosphorus-Dissolved	µg/L	31	<3	<3	<3
Total	µg/L	32	372.	<3	8*
Potassium-Dissolved	mg/L	26	0.5	0.2	0.35
Silica-Dissolved	mg/L	25	5.0	2.9	4.0
Sodium-Dissolved	mg/L	29	6.7	1.7	4.4
Solids-Dissolved	mg/L	32	244	124	191
Suspended	mg/L	32	692	2	48
Sulphate-Dissolved	mg L	26	57.2	12.1	32.4
Tannin and Lignin	mg/L	30	0.6	<0.1	0.12
Temperature	°C	29	11.0	0.0	5.1
Turbidity	J.T.U.	30	140.0	0.3	18.3
Zinc-Dissolved	µg/L	25	<5	<5	<5

N = Number of Values
* = Geometric Mean
Data are from the Ministry of Environment's Data Bank, EQUIS.

TABLE 5

CRESTBROOK FOREST INDUSTRIES LTD., SKOOKUMCHUCK PULP MILL

SUMMARY OF EFFLUENT DATA, JANUARY 1975 TO APRIL 1978

Sampling Site		0225035 Settling Pond Influent				0225036 Settling Pond Effluent				PE0024001 Final Effluent				Pollution Control Objectives (19)	
Parameter	Type of Value	N	Max.	Min.	Mean	N	Max.	Min.	Mean	N	Max.	Min.	Mean	Level A	Level B
BOD_5	mg/L	1	41	41	41					41	139.0	<10	50		
	kg/t	146	72	2	29.5	148	61	4.5	27.5	148	18	2	7.5	7.5	30
Carbon-Total Organic	mg/L									40	360	25	208		
Chloride-Dissolved	mg/L									40	622	85.6	441		
Chlorine-Residual	mg/L	404	0	0	0					400	0	0	0		
Chromium-Dissolved	mg/L									25	0.05	<0.005	0.013		
Coliforms-Fecal	MPN/100 mL									23	>240 000	<2	*398		
Total										6	24 000	2 000	*5 595		
Color-True	rel. units	1 042	9 000	10	1 808	1 036	6 117	133	1 841	1 050	4 183	265	1 886		
Flow	m^3/s									1 051	0.80	0.13	0.56		
Mercaptans	mg/L	93	<0.01	<0.01	<0.01					93	<0.01	<0.01	<0.01		
Nitrate	mg/L									150	0.85	0	0.09		
Oil and Grease	mg/L	4	31.7	9	22.4	4	19.0	5.6	14.4	38	40.9	1.8	12.0		
Oxygen-Dissolved	mg/L									1 010	8.9	1.7	3.9	2.0	
pH		1 045	11.4	2.4	6.4	1 037	11.3	2.7	6.9	1 109	9.0	6.2	7.2	6.5-8.0	6.5-8.0
Phenol	mg/L									39	0.768	0.004	0.26		
Phosphorus-Total	mg/L	151	2.7	0.003	0.2					190	0.802	0.003	0.17		
Resin Acid	mg/L	148	49.0	1.0	8.9					1 562	11.4	1.2	4.4		
Specific Conductivity	μmho/cm	1 044	4 950	187	1 699					1 106	2 700	542	1 775		
Solids-Total	mg/L									41	2 144	402	1 604		
	kg/t	148	1 535.5	49.0	287.5	149	609	455	228.5	148	332	83	218		
Solids-Suspended	mg/L	2	174	123	148					40	145	27	85		
	kg/t	147	715.5	2	78.5	149	318	1.5	20.5	148	34.5	1	9.5	10	17.5
Solids-Volatile	kg/t	147	309	0.035	33.5					148	18.0	0.1	6.5		
Sodium-Dissolved	mg/L									26	452	155	321		
Sulphide	mg/L	149	6.5	0.004	0.49					169	0.72	0.0	0.18		
Surfactants	mg/L									5	0.64	<0.03	0.19		
Tannin and Lignin	mg/L									41	240	11	102		
Temperature	°C	399	35	14	27					1 054	32	9	20.7	35	35

N = Number of Values
* = Geometric Mean

TABLE 6

CRESTBROOK FOREST INDUSTRIES LTD, SKOOKUMCHUCK PULP MILL EFFLUENT BIOASSAY RESULTS FROM JANUARY 1976 TO SEPTEMBER 1978

1976			1977			1978		
Date	Pass/Fail[a]	96h LC_{50}[b]	Date	Pass/Fail	96h LC_{50}[b]	Date	Pass/Fail	96hLC_{50}[b]
January 4	P		January 3	P		January 9	F	
February 1	P		February 6	P		January 23	F	63%
March 1	P		March 6	P		February 5	F	30-65%
March 28	P		July 27	P		February 19	F	30-65%
July 5	P		August 10	F		March 5	F	44%
September 13	P		August 23	F		March 19	F	44%
September 25	P		August 24	F	76%	April 2	F	44%
October 4	P		September	P	mill shut	April 19	F	
November 2	P				down	May 14	F	22-30%
December 5	P		October 10	F		May 28	F	20-30%
			October 25	P		June 18	P	
			November 7	P		July 16	F	
			December 5	P		July 30	F	44%
						August 20	F	27%
						September 17	P	

a - Pass indicates a 96h LC_{50} of greater than 90 percent under 1971 objectives and 100 percent under 1977 objectives.
b - Percent effluent which causes 50 percent mortality in 96 hours.

TABLE 7

CRESTBROOK FOREST INDUSTRIES LTD., SKOOKUMCHUCK PULP MILL
PERCENT COLOUR REDUCTION IN EFFLUENT TO ACHIEVE CERTAIN
RIVER COLOUR LEVELS DURING THE YEAR

		Calculated Mean Monthly Percent Colour Reduction (±Standard Error) Required To Obtain Certain River Colour Levels		
Month	N \ River Colour	10 CPPA Units	15 CPPA Units	20 CPPA Units
January	20	67.5 ± 2.3	51.4 ± 2.8	33.8 ± 4.3
February	18	76.5 ± 1.7	64.9 ± 2.6	53.1 ± 3.4
March	21	78.8 ± 1.6	68.1 ± 2.3	56.6 ± 3.2
April	15	63.3 ± 6.6	49 ± 7.3	36.5 ± 6.3
May	17	35.6 ± 6.4	17.9 ± 5.7	9.7 ± 4.6
June	16	28.8 ± 7.5	16.2 ± 6.1	9.8 ± 4.8
July	13	16.8 ± 7.1	9.0 ± 4.9	4.3 ± 3.0
August	10	6.6 ± 3.8	0	0
September	7	0	0	0
October	12	38.5 ± 6.7	21.9 ± 7.2	11.4 ± 6.5
November	13	44.5 ± 5.5	39.1 ± 6.9	23.4 ± 7.7
December	15	64.4 ± 3.2	44.5 ± 5.4	30.6 ± 4.9

N - Number of values.

TABLE 8

KOOTENAY RIVER WATER QUALITY, BETWEEN CANAL FLATS AND WASA, FOR PARAMETERS INFLUENCED BY THE DISCHARGE FROM THE SKOOKUMCHUCK PULP MILL (JANUARY 1975–JUNE 1978)

Parameter \ Site		Site 0200020 Kootenay River, at Canal Flats				Site 0200175 Kootenay River, 0.5 km Upstream From Pulp Mill				Site 0200048 Kootenay River, 2.5 km Downstream From Pulp Mill				Site 0200019 Kootenay River, 18 km Downstream From Pulp Mill			
		N	Max.	Min.	Mean	N	Max.	Min.	Mean	N	Max.	Min.	Mean	N	Max.	Min.	Mean
Coliforms-Fecal	MPN/100 mL	22	<200	<2	54*	3	<2	<2	<2*	27	>24 000	<2	68*				
Total	MPN/100 mL	4	>2 400	<2	14*	1	<2	<2	<2*	8	>24 000	700	2 432*				
Colour-True	true colour units	35	10	<5	5.1	151	24	0.5	6.9	180	82	3	28	29	50	<5	16
Nitrogen-Ammonia	mg/L	43	0.037	<0.005	0.007	4	0.008	<0.005	0.006	37	0.03	<0.005	0.008	36	0.02	<0.005	0.008
Nitrite	mg/L	35	<0.005	<0.005	<0.005	4	<0.005	<0.005	<0.005	21	0.006	<0.005	<0.005	21	0.007	<0.005	0.005
Nitrate/Nitrite	mg/L	21	0.23	0.09	0.14					20	0.17	0.06	0.11	19	0.2	0.09	0.12
Kjeldhal	mg/L	43	0.34	<0.01	0.07	4	0.08	0.01	0.04	38	0.38	<0.01	0.1	37	0.36	<0.01	0.11
Oil and Grease	mg/L									24	21.5	<1.0	3.6				
Oxygen-Dissolved	mg/L	33	13.6	8.3	10.7	150	14	9.5	11.8	183	13.7	9.2	11.4	26	13	8.7	10.6
pH		37	8.8	7.6	8.2	157	8.6	5.3	7.7	157	8.6	5.8	7.9	74	8.6	7.9	8.2
Phosphorus-Dissolved	mg/L	42	<0.003	<0.003	<0.003	4	<0.003	<0.003	<0.003	38	0.007	<0.003	0.003	37	0.004	<0.003	0.003
Total	mg/L	46	0.372	<0.003	0.021	4	0.008	<0.003	0.004	49	0.22	<0.003	0.018	48	0.256	<0.003	0.02
Phenols	mg/L	1	<0.002	<0.002	<0.002	4	0.003	<0.002	<0.002	37	0.029	<0.002	0.007	36	0.024	<0.002	0.006
Solids-Suspended	mg/L	2	38	34	36	3	7	1	5	22	430	1.5	41.8				
Total	mg/L	43	842	148	236	5	236	160	204	43	570	126	222	41	714	168	240
Tannin and Lignin	mg/L	41	0.6	<0.1	0.12	5	0.1	<0.1	0.1	43	5	<0.1	1.3	42	6.0	0.1	1.1
Turbidity	J.T.U.	40	140	0.3	17	131	85	0	5.5	160	90	1	9.2	31	130	1.1	16

N - Number of values.
* - Geometric mean.

TABLE 9

KOOTENAY RIVER WATER QUALITY, BETWEEN CANAL FLATS AND WASA, FOR PARAMETERS UNAFFECTED BY THE DISCHARGE FROM THE SKOOKUMCHUCK PULP MILL (JANUARY 1975-JUNE 1978)

Site / Parameter		Site 0200020 Kootenay River, at Canal Flats				Site 0200175 Kootenay River, 0.5 km Upstream From Pulp Mill				Site 0200048 Kootenay River, 2.5 km Downstream From Pulp Mill				Site 0200019 Kootenay River, 18 km Downstream From Pulp Mill			
		N	Max.	Min.	Mean	N	Max.	Min.	Mean	N	Max.	Min.	Mean	N	Max.	Min.	Mean
Alkalinity-Total	mg/L	61	205	65	130	7		126	131	37	251	63	118	54	146	79	119
Arsenic-Dissolved	mg/L	32	0.006	<0.005	<0.005	4	<0.005	<0.005	<0.005	1	0.008	0.008	0.008	6	0.007	<0.005	<0.005
Cadmium-Dissolved	mg/L	32	0.005	<0.0005	<0.0005	4	<0.0005	<0.0005	<0.0005					7	<0.0005	<0.0005	<0.0005
Calcium-Dissolved	mg/L	43	57.5	29.7	43.1	5	49.3	34.9	42.5	5	49	36	46	1	49	49	49
Carbon-Total Organic	mg/L	40	6.0	<1	1.6	3	1	<1	<1	38	10	<1	3.3	7	7	<1	<2
Chromium-Total	mg/L	3	0.005	<0.005	<0.005	4	<0.005	<0.005	<0.005	24	0.026	<0.005	0.006	6	0.007	<0.005	<0.005
Copper-Total	mg/L	5	0.003	<0.001	0.002	4	<0.001	<0.001	<0.001					22	0.007	<0.001	0.002
Cyanide	mg/L													6	<0.01	<0.01	<0.01
Fluoride-Dissolved	mg/L	39	0.25	<0.1	0.11	5	0.15	0.11	0.12	5	0.12	<0.1	0.11	12	0.13	<0.1	0.11
Iron-Dissolved	mg/L	34	0.1	<0.1	<0.1	5	<0.1	<0.1	<0.1	5	0.1	<0.1	<0.1	20	<0.1	<0.1	<0.1
Total	mg/L	37	18.2	<0.1	1.1	4	0.2	<0.1	0.15					37	12.3	<0.1	0.94
Hardness-Total	mg/L	43	214	107	158	5	190	134	163	5	187	134	174	42	195	96	153
Lead-Total	mg/L	5	0.004	<0.001	<0.002	5	<0.001	<0.001	<0.001	1	<0.001	<0.001	<0.001	37	0.017	<0.001	0.002
Magnesium-Dissolved	mg/L	43	17.9	7.7	12.3	5	16.2	11.4	13.7	5	15.6	10.7	14.3	42	16	6.6	12.3
Manganese-Total	mg/L	34	0.05	<0.02	0.03	4	<0.02	<0.02	<0.02	1	0.02	0.02	0.02	38	0.2	<0.02	0.03
Mercury-Total	µg/L													6	<0.05	<0.05	<0.05
Molybdenum-Total	mg/L					4	0.0008	<0.0005	0.0006					31	0.0017	<0.0005	<0.0008
Nickel-Total	mg/L					4	<0.01	<0.01	<0.01					31	0.05	<0.01	0.01
Potassium-Dissolved	mg/L	35	0.5	0.2	0.35	4	0.7	0.5	0.6					31	0.7	0.2	0.49
Silica	mg/L	34	5.1	2.9	4.0	4	6.6	5.3	5.8					32	6.1	3.3	4.7
Specific Conductance	µhmo/cm	68	470	162	319	156	650	40	251	218	319	140	270	64	460	123	326
Sulphate	mg/L	34	62.5	12.1	34.5	4	68.9	35.6	41.4								
Surfactants	mg/L					3	<0.03	<0.03	<0.03	6	<0.03	<0.03	<0.03	5	<0.03	<0.03	<0.03
Zinc-Total	mg/L	7	0.014	<0.005	0.007	4	<0.005	<0.005	<0.005	5	0.03	<0.005	0.01	42	0.007	<0.005	0.006

N - Number of values.

TABLE 10

NUMBER OF ANALYSES CARRIED OUT BY CRESTBROOK FOREST INDUSTRIES LTD. (CFI) AND THE PROVINCE, FROM 1975 TO 1978

Year	No. of Effluent Analyses			No. of River-Water Analyses		
	CFI	Province	Total	CFI	Province	Total
1975	4 526	221	4 747	480	1 551	2 031
1976	5 643	259	5 902	635	1 391	2 026
1977	4 907	267	5 174	568	1 179	1 747
1978	5 273	269	5 542	428	815	1 243
Mean for '75-'78	5 341			1 762		
Recommended-1979[a]	1 930[b]			390		
Percent Reduction	64%			78%		

a - The recommended program does not include analyses of the settling pond influent and effluent.

b - This number will be modified if the rapid infiltration method is used.

TABLE 11

CITY OF KIMBERLEY SEWAGE TREATMENT PLANT
SUMMARY OF AMENDED POLLUTION CONTROL PERMIT PE-148

Date of Last Amendment	January 17, 1979
Date of Implementation	December 31, 1979
Effluent Flow Rate	Mean annual: 6 273 m^3/d Maximum daily: 14 550 m^3/d
Effluent Characteristics	BOD_5: 45 mg/L Suspended Solids: 60 mg/L Residual Chlorine: Oct.-March <0.05 mg/L April-Sept. <0.5 mg/L
Treatment	Grit removal, comminution, activated sludge, secondary effluent sedimentation, chlorination, dechlorination, aerobic sludge digestion, sludge drying
Receiving Water	St. Mary River

TABLE 12

KIMBERLEY SEWAGE TREATMENT PLANT

SUMMARY OF EFFLUENT DATA, 1975-1978

		Number Of Values	Max.	Min.	Mean	Percent Of Values Exceeding Permit Levels	Remarks
BOD_5	mg/L	30	131	19	57	53	
Carbon-Organic	mg/L	6	59	14	37		
Chlorine-Residual	mg/L	112	1.0	0.03	0.56	98	October To March
		105	1.11	0	0.42	36	April To September
Coliforms-Fecal	MPN/100 mL	10	540 000	<2 000	46 243		Geometric Mean
Total	MPN/100 mL	2			>240 000		
Flow	m^3/s	308	0.104	0.048	0.057		
Nitrogen-Ammonia	mg/L	1			16.5		
Kjeldahl	mg/L	1			23		
NO_2/NO_3	mg/L	1			0.53		
Organic	mg/L	1			6.5		
Oxygen-Dissolved	mg/L	5	10.8	6.4	8.3		
pH		39	7.5	6.5	7.3		
Phosphorus-Ortho	mg/L	7	3.24	0.889	1.96		
Total	mg/L	11	4.74	1.38	3.4		
Solids-Total	mg/L	6	1 096	796	950		
Suspended	mg/L	32	97	18	46	22	
Suspended Volatile	mg/L	19	45.5	20	31		
Specific Conductivity	µmho/cm	13	1 280	618	1 025		

TABLE 13

COMINCO LTD., KIMBERLEY, SUMMARY OF AMENDED POLLUTION CONTROL PERMIT PE-189, ISSUED OCTOBER, 1975, FOR THE SULLIVAN MINE, CONCENTRATOR AND FERTILIZER OPERATIONS

	Sewer 32 Wastes from phosphate plant, recycle tank overflows, iron sluicing pond overflow.	Siliceous Tailing Pond overflow.	Iron Tailing Pond overflow.	Mine drainage 3900 Foot Portal, surface streams, mine domestic wastes, change-room effluents.	Mine drainage 3700 Foot Portal	Roaster and Sulphuric Acid Plant effluents	Gypsum from Phosphoric Acid Plant
Permit Appendix No.	01	02	03	04	05	06	07
Discharge Point	Mark Creek	James Creek	James Creek	Mark Creek	Kimberley Creek	calcine and north ponds-no positive discharge.	gypsum pond no positive discharge.
Operation Date	December 31, 1979	December 31, 1979	December 31, 1979	December 31, 1979	December 31, 1977	August 31, 1976	
Compliance Date	December 31, 1980	December 31, 1980	December 31, 1980	December 31, 1980	December 31, 1977	No effluent discharge.	No effluent discharge.
Effluent Characteristics	SS, 50 mg/L pH, 6.5-8.5 NH_3, diss. 0.5 mg/L As, diss. 0.05 mg/L CN, tot. 0.10 mg/L F, diss. 2.50 mg/L Fe, diss. 0.30 mg/L Pb, diss. 0.05 mg/L PO_4, tot. 2.00 mg/L Zn, diss. 0.50 mg/L oil & grease, 15 mg/L	SS, 150 mg/L pH, 6.5-9.5 Al, 1.00 mg/L NH_3, diss. 0.50 mg/L As, diss. 0.25 mg/L Cu, diss. 0.30 mg/L CN, tot. 0.50 mg/L F, diss. 5.00 mg/L Fe, diss. 1.00 mg/L Pb, diss. 0.10 mg/L Mn, diss. 0.50 mg/L PO_4, tot. 2.00 mg/L Zn, diss. 2.00 mg/L	SS, 150 mg/L pH, 6.5-9.5 As, diss. 0.25 mg/L Cu, diss. 0.30 mg/L CN, tot. 0.50 mg/L F, diss. 5.00 mg/L Fe, diss. 1.00 mg/L Pb, diss. 0.10 mg/L Mn, diss. 0.50 mg/L PO_4, tot. 2.00 mg/L Zn, diss. 2.00 mg/L	SS, 150 mg/L pH, 6.5-9.5 Al, diss. 1.00 mg/L NH_3, diss. 1.00 mg/L As, diss. 0.25 mg/L Cu, diss. 0.30 mg/L F, Diss. 5.00 mg/L Fe, diss. 1.00 mg/L Pb, diss. 0.10 mg/L Mn, diss. 0.50 mg/L Zn, diss. 2.00 mg/L	SS, 150 mg/L pH, 6.5-9.5 Fe, diss. 1.00 mg/L Pb, diss. 0.10 mg/L Zn, diss. 2.00 mg/L	to be monitored	typical gypsum and process water from a phosphoric acid plant
Effluent Quantity	daily max. 0.32 m^3/s	daily max. 0.32 m^3/s annual mean 0.06 m^3/s	daily max. 0.32 m^3/s annual mean 0.16 m^3/s	daily max. 0.16 m^3/s annual mean 0.08 m^3/s	daily max. 0.02 m^3/s	daily max. 0.05 m^3/s	daily max. 0.13 m^3/s

TABLE 14

COMINCO LTD., KIMBERLEY

SUMMARY OF THE CHARACTERISTICS OF THE DISCHARGES TO MARK CREEK, 1975-1978

Parameter (Site)		3900 Foot Portal Site 0225040				3700 Foot Portal Site PE0018905				Sewer 32 Site PE0018901			
		N	Max.	Min.	Mean	N	Max.	Min.	Mean	N	Max.	Min.	Mean
Aluminum-Dissolved	mg/L	55*	222	11	87.8	49	0.37	<0.01	0.033	29	0.38	0.01	0.14
Arsenic-Dissolved	mg/L	55*	0.11	0.005	0.019	50	0.178	0.001	0.008	58*	0.6	<0.005	0.076
Total	mg/L	13	1.2	0.1	0.40					9	0.23	0.005	0.073
Boron-Dissolved	mg/L	5	0.1	<0.1	0.1					5	0.1	<0.1	0.1
Cadmium-Dissolved	mg/L	51	0.65	0.016	0.126	48	<0.0005	<0.0005	<0.0005	51	0.03	<0.0005	<0.007
Calcium	mg/L	20	288	90.5	219					26	78	9.6	39.2
Copper-Dissolved	mg/L	64*	1.15	0.013	0.214	49	0.065	<0.001	0.011	53	0.35	0.002	0.039
Total	mg/L	8	1.2	0.1	0.3					2	0.04	0.01	0.025
Chromium-Total	mg/L	4	0.08	0.08	0.08					5	0.046	0.013	0.023
Cyanide	mg/L	54	0.07	0.01	0.018					58*	0.12	<0.01	0.017
Flow	m^3/s	145	0.123	0.028	0.047	144	0.0006	0.0002	0.0004	932	0.53	0.042	0.41
Fluoride	mg/L	38*	13.1	0.4	4.97					176*	185	0.2	12.2
Hardness	mg/L	20	2 950	983	2 184					25	231	33.4	116
Iron-Dissolved	mg/L	176*	1 150	30	257	53*	14	0.01	0.404	60*	17	0.075	1.15
Total	mg/L	60	2 280	155	345	3	0.3	0.3	0.3	10	32.7	0.6	8.4
Lead-Dissolved	mg/L	176*	10.2	0.7	3.03	53*	0.11	<0.001	0.04	61*	1.6	<0.001	0.15
Total	mg/L	12	12.2	2.5	6.75	3	0.017	0.01	0.014	9	1.1	0.007	0.40
Magnesium-Dissolved	mg/L	20	610	177	398					26	8.8	1.8	3.9
Manganese-Dissolved	mg/L	66*	81	15.5	34					55	0.9	0.01	0.26
Mercury-Total	µg/L	52	3.65	<0.05	0.63					51	5.2	<0.05	0.25
Molybdenum-Total	mg/L	4	0.018	0.002	0.012					3	0.025	<0.0005	0.009
Nickel-Dissolved	mg/L	5	0.6	0.4	0.48					4	0.01	<0.01	<0.01
Nitrogen-Ammonia	mg/L	55*	19.1	<0.01	5.9					168*	51.5	0.09	3.5
NO_2/NO_3	mg/L	7	11.7	4	5.8					5	0.28	0.05	0.13
Kjeldhal	mg/L	7	12	5	6.7					4	8	3	4.7
Oil and Grease	mg/L	3	5.4	1.9	3.6					55*	5	<1	3.5
pH		197*	4.9	2.4	3.2	65*	8.6	6.3	8.0	411*	9.6	2.9	4.8
Phosphorus-Ortho	mg/L									163	56.7	0.2	7.7
Total	mg/L	13	0.123	0.009	0.055					42	32.5	1.15	6.6
Solids-Total	mg/L	4	7 466	7 188	7 266	13	670	598	615	14	1 380	96	363
Suspended	mg/L	152*	8 190	10	434	41*	66	<1	6	144*	105	1	23
Sulphate	mg/L	55	6 440	522	1 987	50	311	53	142	59	262	2.2	71.6
Zinc-Dissolved	mg/L	173*	550	0.97	95.3	53*	0.52	0.01	0.063	66*	11.2	<0.005	1.34
Total	mg/L	59	560	41.6	101.7	3	0.06	0.05	0.055	8	3.18	0.04	0.89

N - Number of values.
* - Parameters under permit.

TABLE 15

SUMMARY OF WATER QUALITY DATA FOR MARK CREEK, 1975-1978

Parameter / Site		Mark Creek Control Site 0200037				Mark Cr. D/S From Sullivan Mine Site 0200212				Mark Creek, D/S From Sewer 32 Site 0200036			
		N	Max.	Min.	Mean	N	Max.	Min.	Mean	N	Max.	Min.	Mean
Aluminum-Dissolved	mg/L	44	1.16	0.01	0.09	44	30	0.04	6.8				
Arsenic-Dissolved	mg/L	68	0.01	<0.001	0.004	52	0.933	0.001	0.023	34	0.16	<0.005	0.018
Total	mg/L	34	<0.005	<0.005	<0.005	26	0.38	<0.005	0.036	33	0.225	0.009	0.047
Cadmium-Dissolved	mg/L	78	0.005	<0.0005	0.003	52	0.105	0.002	0.018	33	0.03	0.001	0.007
Total	mg/L	33	0.0016	<0.0005	0.0007	26	0.05	0.002	0.019	32	0.03	0.0019	0.009
Calcium	mg/L	34	15.1	1.6	6.3	27	102	5.9	39.5	34	106	13	62
Colour	rel. units	26	30	<5	8.8	17	30	<5	6.7	26	15	<5	6.5
Copper-Dissolved	mg/L	76	0.04	<0.001	0.008	51	0.17	0.004	0.036	32	0.05	<0.001	0.012
Total	mg/L	34	0.01	<0.001	0.002	26	0.26	0.004	0.045	34	0.16	0.008	0.03
Chromium-Total	mg/L	7	<0.005	<0.005	<0.005					7	0.044	<0.005	0.018
Cyanide	mg/L	7	<0.01	<0.01	<0.01	13	<0.01	<0.01	<0.01	7	<0.01	<0.01	<0.01
Fluoride	mg/L	79	0.13	0.025	0.074	48	1.71	0.08	0.56	34	176	0.85	19
Hardness	mg/L	34	57.9	6.3	23.5	27	852	40	289	34	420	62	253
Iron-Dissolved	mg/L	79	2.0	0.012	0.27	58	79.2	0.03	19.2	34	15	0.1	4.9
Total	mg/L	34	4.6	0.1	0.78	26	183	3	35.8	34	71.6	3.3	14.6
Lead-Dissolved	mg/L	77	0.14	<0.001	0.03	58	1.6	0.013	0.36	34	0.4	<0.001	0.06
Total	mg/L	33	0.1	<0.001	0.01	26	6.6	0.036	0.82	34	2.6	0.076	0.45
Magnesium	mg/L	34	4.9	0.57	1.9	27	145	6.2	46	34	43.9	6.6	24
Manganese-Dissolved	mg/L	79	0.59	<0.01	0.058	51	10.2	0.03	3.7	34	2.82	0.43	1.19
Total	mg/L	34	0.18	<0.02	0.05	26	10.2	0.43	3.7	34	2.82	0.43	1.23
Mercury-Total	µg/L	55	0.25	<0.05	0.05	40	0.95	0.01	0.11	10	0.35	<0.05	0.10
Molybdenum-Total	mg/L	18	0.0012	<0.0005	0.0006	9	0.0005	0.0005	0.0005	29	0.009	<0.0005	0.002
Nickel-Total	mg/L	17	0.02	<0.01	0.011	19	0.2	<0.01	0.04	28	0.03	<0.01	0.016
Nitrogen-Ammonia	mg/L	34	0.024	<0.005	0.012	25	3.64	0.038	0.81	34	28.6	0.078	2.35
Nitrate	mg L	28	0.11	<0.02	0.04	19	2.4	0.07	0.80	28	1.17	0.14	0.73
Nitrite	mg/L	28	<0.005	<0.005	<0.005	19	0.043	<0.005	0.014	28	0.038	<0.005	0.01
Kjeldhal	mg/L	34	0.24	0.01	0.077	25	5.0	0.08	1.09	34	35	0.17	2.8
pH		111	8.4	5.8	7.3	84	7.5	3.6	4.8	67	7.9	3	5.7
Phosphorus-ortho	mg/L	34	0.008	<0.003	0.003	25	0.005	<0.003	0.0032	34	27.2	<0.003	2.2
Total	mg/L	38	0.058	0.004	0.009	27	0.184	0.009	0.048	36	29.3	0.003	3.5
Solids-Total	mg/L	33	180	24	55	20	1 310	108	588	30	810	138	512
Suspended	mg/L	45	178	0.5	14	31	420	10	81	29	302	14	59
Sulphate	mg/L	79	23.9	0.1	6.25	59	1 450	4.3	271	34	433	67	251
Zinc-Dissolved	mg/L	78	0.7	<0.005	0.11	57	35.4	0.69	10.9	34	8.6	0.29	3.3
Total	mg/L	34	0.44	<0.005	0.16	27	35.7	1.52	11.6	34	9.5	1.12	4.0

N - Number of values.

TABLE 16

COMINCO LTD., KIMBERLEY

SUMMARY OF THE CHARACTERISTICS OF THE POND OVERFLOWS AND THE RECEIVING CREEKS, 1975-1978

Parameter / Site		Iron Tailing Pond Overflow PE0018903				Siliceous Tailing Pond Overflow PE0018902				James Creek At Highway 95 0200213				Cow Creek At Highway 95 0200214			
		N	Max	Min.	Mean	N	Max.	Min.	Mean	N	Max.	Min.	Mean	N	Max.	Min.	Mean
Aluminum-Dissolved	mg/L	51	165	<0.01	8.7	44*	0.8	<0.01	0.13								
Arsenic-Dissolved	mg/L	54*	0.272	0.001	0.02	57*	0.033	0.001	0.006	7	0.042	<0.005	0.018	68	1.49	0.002	0.095
Total	mg/L	6	9.2	<0.005	1.54	6	0.011	<0.005	0.006	8	1.2	0.017	0.26				
Cadmium-Dissolved	mg/L	50	0.27	0.0044	0.043	50	0.1	<0.0005	0.015								
Calcium	mg/L									22	720	446	614	19	560	430	506
Copper-Dissolved	mg/L	57*	1.0	<0.001	0.14	57*	0.11	<0.001	0.029	7	1.11	0.02	0.30				
Total	mg/L	6	5.86	0.03	1.07	7	0.02	<0.001	0.016	7	1.15	0.02	0.36				
Cyanide	mg/L	161*	0.24	<0.01	0.028	176*	1.8	<0.01	0.17								
Flow	m^3/s	1 008	0.335	0	0.082	980	0.358	0	0.055	118	0.585	0.03	0.182	137	0.007	<0.0001	0.001
Fluoride	mg/L	51*	3.19	0.24	0.85	50*	7.74	0.26	1.44	60	5.1	1.01	2.15	66	31.7	0.23	2.3
Hardness	mg/L									22	2 530	1 540	2 034	19	2 440	1 920	2 278
Iron-Dissolved	mg/L	170*	2 750	18.8	502	183*	585	0.03	49	63	665	59.4	227	68	1 736	4.5	322
Total	mg/L	56	2 750	114	528	54	263	2.55	41.8	8	650	160	359				
Lead-Dissolved	mg/L	171*	7.5	0.03	1.76	177*	0.34	<0.001	0.11	8	2.3	<0.001	0.675				
Total	mg/L	6	7.1	1.8	4.03	6	0.3	0.1	0.17	7	5.8	0.9	2.37				
Manganese-Dissolved	mg/L	64*	55	3	14.4	64*	19.6	2	8.6	23	17.7	4.4	10.0	19	13.5	7.7	9.7
Total	mg/L	6	55.5	8.9	23.5	7	20.3	5.1	10.7	7	17.8	10.5	13.5				
Mercury-Total	µg/L	49	0.48	<0.05	0.13	45	0.7	<0.05	0.11	1	0.05	0.05	0.05				
Nitrogen-Ammonia	mg/L	17	3.2	0.11	0.92	23*	4.8	0.04	1.22	5	7	0.02	1.57				
NO /NO	mg/L									6	1.39	0.67	1.04				
Kjeldahl	mg/L									8	8	2	4				
pH		196*	7.3	1.6	4.6	209*	7.7	2.2	6.3	25	7.4	2.4	5.0	88	6.5	2	3.9
Phosphorus-Ortho	mg/L	52*	2.8	0.006	0.216	48*	4.22	<0.003	0.455	59	4.8	0.005	0.54	65	4.65	0.005	0.21
Total	mg/L	15	1.17	0.015	0.241	21	11.5	0.184	2.13	7	11.7	1.01	4.29				
Solids-Total	mg/L	12	5 796	3 144	4 595	15	3 264	2 622	2 954	1	3 570	3 570	3 570	1	4 186	4 186	4 186
Suspended	mg/L	147*	1 173	2	67.2	162*	123	1	30	1	72	72	72				
Sulphate	mg/L	56	4 005	673	1 681	54	2 066	411	1 158	62	2 835	604	1 499	68	5 299	708	1 682
Zinc-Dissolved	mg/L	171*	351	0.13	10.7	177*	24.3	0.01	0.92	62	33.7	0.56	5.6	18	30.8	2.15	8.05
Total	mg/L	56	351	0.32	16.7	54	3.2	0.02	0.72	8	33.7	1.93	12.8				

N - Number of values.
* - Parameters under permit.

TABLE 17

COMINCO LTD., KIMBERLEY

LOADINGS OF CERTAIN CONTAMINANTS AND THE EFFECT ON WATER QUALITY IN THE ST. MARY RIVER

(Mean ± Standard Error)

Contaminant \ Discharge	3900 Ft. Portal Site 0225040	3700 Ft. Portal Site PE0018905	Sewer 32 Site PE0018901	Iron Tailing Pond Overflow Site PE001890	Siliceous Tailing Pond Overflow Site PE001890	Total	Calculated Increase in St. Mary River During Low Flow ($8.9 m^3/s$)
Ammonia:							
Loading kg/d	26.3 ± 0.2	N.D.*	103.9 ± 14.6	0.6 ± 0.1	8.2 ± 1.8	139	0.18 mg/L
%	18.9 ± 0.14		74.7 ± 10.5	0.4 ± 0.07	5.9 ± 1.3	99.9	
Ortho-Phosphate							
Loading kg/d	N.D.*	N.D.*	251.5 ± 29.7	1.5 ± 0.55	1.4 ± 0.45	254.4	0.33 mg/L
%			98.9 ± 11.7	0.56 ± 0.22	0.55 ± 0.18	100	
Fluoride							
Loading kg/d	21.8 ± 3.4	N.D.*	340 ± 28	5.4 ± 0.7	6.1 ± 0.68	373.3	0.49 mg/L
%	5.8 ± 0.9		91.1 ± 7.5	1.4 ± 0.2	1.6 ± 0.2	99.9	
Dissolved Iron							
Loading kg/d	1 047 ± 110	0.08 ± 0.01	27.9 ± 4.5	3 264 ± 440	1 706 ± 34	6 045	7.86 mg/L
%	17.3 ± 1.8	0.001 ± 0.0002	0.46 ± 0.07	54.0 ± 7.3	28.2 ± 0.6	99.96	
Dissolved Zinc							
Loading kg/d	390.8 ± 43.2	0.04 ± 0.003	45.7 ± 7.8	70.9 ± 1.6	4.7 ± 1.2	512.1	0.67 mg/L
%	76.3 ± 8.4	0.008 ± 0.0006	8.9 ± 1.7	13.8 ± 2.7	0.9 ± 0.2	99.9	
Dissolved Manganese							
Loading kg/d	138.9 ± 11.2	N.D.*	9.9 ± 1.3	99.6 ± 10.0	35.1 ± 2.2	283.5	0.37 mg/L
%	49.0 ± 3.9		3.5 ± 0.5	35.1 ± 3.5	12.4 ± 0.8	100	
Dissolved Lead							
Loading kg/d	12.1 ± 0.83	0.034 ± 0.003	5.15 ± 1.03	13.4 ± 2.7	0.61 ± 0.09	31.3	0.04 mg/L
%	38.7 ± 2.7	0.11 ± 0.009	16.5 ± 3.3	42.8 ± 8.6	1.9 ± 0.29	100	

N.D.* - No data, contribution considered negligible.

TABLE 18

COMINCO LTD., KIMBERLEY

IRON, ZINC AND pH IN EFFLUENTS AND RECEIVING WATERS

	Iron Percent Dissolved		Zinc Percent Dissolved		pH	
	N	Mean ± S.E.	N	Mean ± S.E.	N	Mean ± S.E.
St. Mary R., u/s Cominco Site 0200029	33	<74.1		<100	104	7.4 ± 0.34
St. Mary R., 6.5km u/s Cominco Site 0200135	4[a] 30[b]	79 ± 7 34 ± 3.1	4[a] 30[b]	94.3 ± 2.7 76.3 ± 2.9	8[a] 89[b]	4.0 ± 0.1 7.0 ± 0.08
Mark Ck, u/s Cominco Site 0200037	33	55.7 ± 4.8	33	93.2 ± 2.2	105	7.3 ± 0.04
3900 Foot Portal Site 0225040	55	81.0 ± 2.5	46	92.7 ± 1.6	197	3.2 ± 0.02
Mark Ck, d/s 3900 Foot Portal	23	80.7 ± 0.23	23	98.3 ± 0.46	76	4.9 ± 0.79
Sewer 32 Site 020018901	6	14.7 ± 10.5	5	67.8 ± 10.6	411	4.8 ± 0.07
Mark Ck, d/s Sewer 32	33	39.6 ± 3.0	33	85 ± 2.0	65	5.7 ± 0.19
Iron Pond Overflow Site PE0018903	44	89.7 ± 1.9	42	91.4 ± 2.2	183	4.6 ± 0.07
Siliceous Pond Overflow Site PE0018902	41	72.3 ± 3.9	45	76.0 ± 3.1	193	6.3 ± 0.06
James Ck., d/s Iron and Siliceous Ponds Site 0200213	7	84 ± 7.3	6	86.5 ± 10.3	85	5.0 ± 0.14

N - Number of values.
a - January, 1975 to April 1975 (See Figure 31 for pH and 35 for iron and zinc).
b - May, 1975 to December, 1978 (See Figure 31 for pH and 35 for iron and zinc).
S.E. - Standard error.

TABLE 19

SUMMARY OF FISH BIOASSAYS BY B.C. RESEARCH[37,38] WITH COMINCO EFFLUENTS

Date	96 hour LC_{50} (% v/v) and in parentheses 95% confidence intervals			
	Sewer 32 no pH adjustment	Sewer 32 neutralized	Siliceous Tailing Pond Supernatant	St. Mary River at Wycliffe
July 27, 1976	0.64 (0.56-0.72)		8.5 (7.0-10.3)	> 100
October 25, 1976	3.1 (2.5-4.1)		6.8 (4.8-9.5)	> 100
December 16, 1976	> 100		>100(31.9-> 100)	> 100
February 2, 1977	12.2 (11.0-13.7)		> 100	> 100
July 5 & 6, 1977	19.5 (13.9-27.2)	56.0 (47.5-65.9)	20.0 (15.0-25.0)	100
October 14, 1977	17.3 (14.7-20.4)	15.1 (12.5-18.1)	93.0 (91.0-95.0)	> 100
December 12, 1977	52.8 (40.2-69.2)	> 100	2.82 (2.09-3.80)	> 100
February 28, 1978	> 100	> 100	> 100	> 100

TABLE 20

WATER QUALITY OF THE ST. MARY RIVER FOR PARAMETERS AFFECTED MOSTLY BY COMINCO'S DISCHARGES

Parameter / Site		St. Mary River, upstream from Cominco and Kimberley STP Site 0200029				St. Mary River, just downstream from Kimberley STP Site 0200132				St. Mary River, 6.5 km downstream from Cominco's discharges Site 0200135			
		N	Max.	Min.	Mean	N	Max.	Min.	Mean	N	Max.	Min.	Mean
Fluoride	mg/L	72	0.7	0.06	0.11					71	33	<0.1	1.82
Iron-Dissolved	mg/L	70	0.11	<0.05	0.08					70	20	0.04	0.93
Total	mg/L	36	0.7	<0.1	0.175					35	30	0.3	3.47
Lead-Dissolved	mg/L	68	0.01	<0.001	0.005					70	0.022	<0.001	0.007
Total	mg/L	36	0.001	<0.001	<0.001					34	0.1	0.001	0.027
Manganese-Dissolved	mg/L	48	0.2	<0.01	0.045					70	0.57	0.01	0.14
Total	mg/L	36	0.03	<0.02	0.02					35	0.57	0.02	0.17
Nitrogen-Ammonia	mg/L	73	0.1	<0.005	0.057					69	1.4	0.006	0.16
Nitrate	mg/L	31	0.19	0.03	0.12					28	0.39	0.04	0.184
Nitrite	mg/L	31	<0.005	<0.005	<0.005					28	0.008	<0.005	0.005
Organic	mg/L	36	0.14	<0.01	0.05					34	0.22	<0.01	0.079
Kjeldahl	mg/L	36	0.15	<0.01	0.06					35	1.0	0.03	0.27
pH		63	8.3	6.0	7.4	37	8.4	6.6	7.3	52	7.9	3.7	6.9
Phosphorus-Ortho	mg/L	72	<0.1	<0.003	<0.016	9	1.62	<0.003	0.413	70	6.32	<0.003	0.31
Total	mg/L	40	0.012	<0.003	0.005	13	2.8	0.003	0.86	41	6.67	0.015	0.74
Solids-Suspended	mg/L	35	102	<1	7.2	2	266	146	206	36	43	1	7.9
Dissolved	mg/L	37	58	26	45	11	586	26	204	35	336	32	119
Total	mg/L	53	300	10	55	28	616	36	170	35	380	34	130
Sulphate	mg/L	71	9.6	1.2	6.1					71	189	5	48
Zinc-Dissolved	mg/L	68	0.07	<0.005	0.011					70	1.5	0.02	0.23
Total	mg/L	36	<0.02	<0.005	<0.006					35	1.59	0.024	0.38

N - Number of values.

TABLE 21

WATER QUALITY OF THE ST. MARY RIVER FOR PARAMETERS AFFECTED LITTLE BY COMINCO'S DISCHARGES

Parameter \ Site		St. Mary River, upstream from Cominco and Kimberley STP Site 0200029				St. Mary River, just downstream from Kimberley STP Site 0200132				St. Mary River, 6.5 km downstream from Cominco's discharges Site 0200135			
		N	Max.	Min.	Mean	N	Max.	Min.	Mean	N	Max.	Min.	Mean
Alkalinity-Total	mg/L	64	62	13	27.4	7	114	4	40.6	59	37	0	21.7
Aluminum-Dissolved	mg/L	34	0.2	0.02	0.10					34	0.2	0.02	0.10
Arsenic-Dissolved	mg/L	47	0.022	0.002	0.006					66	0.021	0.003	0.006
Total	mg/L	36	0.01	<0.005	0.005					36	0.026	<0.005	0.008
Cadmium-Dissolved	mg/L	72	0.01	<0.0005	0.003					70	0.01	<0.0005	0.003
Total	mg/L	23	<0.0005	<0.0005	<0.0005					35	0.0044	<0.0005	0.0009
Calcium-Dissolved	mg/L	37	11.1	4.6	8.4					35	46.3	6	20.2
Carbon-Organic	mg/L	15	3	<1	1.3	11	38	<1	13				
Chromium-Dissolved	mg/L	8	<0.005	<0.005	<0.005					7	0.005	<0.005	<0.005
Colour-True	rel. units	28	10	<5	5.5					27	27	15	7.8
Copper-Dissolved	mg/L	68	0.01	<0.001	0.003					67	0.03	<0.001	0.004
Total	mg/L	36	0.004	<0.001	0.001					35	0.05	<0.001	0.005
Cyanide	mg/L	28	0.01	<0.01	<0.01					42	0.09	<0.01	0.01
Hardness	mg/L	37	39	15.6	29.8					35	158	20.3	72.7
Magnesium-Dissolved	mg/L	37	2.8	1.0	2.1					35	11.1	1.3	5.4
Mercury-Total	µg/L	47	0.6	<0.05	0.079					44	0.5	<0.05	0.06
Molybdenum-Total	mg/L	36	0.0013	<0.0005	0.0006					28	0.001	<0.0005	0.0006
Nickel-Total	mg/L	16	<0.01	<0.01	<0.01					18	0.02	<0.01	0.011
Phenol	mg/L	17	0.004	<0.002	0.002					27	0.013	<0.002	0.005
Turbidity	J.T.U.	28	6.2	0.29	1.02					28	46	1.6	11.1

N - Number of values.

TABLE 22

SUMMARY OF FISH CAGING EXPERIMENTS BY
B.C. RESEARCH[37,38] IN THE ST. MARY RIVER

	No. of Fish Dead (of 25 fish)[a] After 4 Days	
	St. Mary River at Pumphouse (0200029)	St. Mary River at Wycliffe (0200135)
July, 1976	0	0
October, 1976	0	1
December, 1976	1	5[b]
March, 1977	0	4
July, 1977	2	1
October, 1977	0	0
December, 1977	0	0
February, 1978	0	3

a Only 10 fish per cage in December, 1976.
b Two of five surviving fish in weakened condition.

TABLE 23

SUMMARY OF METAL LEVELS IN FOUR TROPHIC LEVELS OF AQUATIC INVERTEBRATES FROM THE ST. MARY RIVER, IN 1977[38]

(Values in PPM Dry Weight)

Parameter	Site	Baetidae (algivore) Pumphouse 0200029	Baetidae (algivore) Wycliffe 0200135	Baetidae (algivore) Power Line	Hydropsychidae (filter-feeder) Pumphouse 0200029	Hydropsychidae (filter-feeder) Wycliffe 0200135	Hydropsychidae (filter-feeder) Power Line	Ephemerella (detritivore) Pumphouse 0200029	Ephemerella (detritivore) Wycliffe 0200135	Ephemerella (detritivore) Power Line	Plecoptera (carnivore) Pumphouse 0200029	Plecoptera (carnivore) Wycliffe 0200135	Plecoptera (carnivore) Power Line
Arsenic	July				<32	<51	16.6	<68	17.5	19.5	<8.4	<16.7	<8.4
	Oct.	5.4	<56	<58	4.4	10.0	10.0	<10.8	47.8	47.5	<2.5	6.2	11.8
Cadmium	July				39.1	<61.3	<7.96	82	<11.7	<11.1	<10.1	<20.1	<10.0
	Oct.	16.9	<35.5	<37.0	<2.11	1.8	1.9	<6.5	11.6	10.8	<1.6	1.1	2.1
Copper	July				85.9	122	36.6	148	49.1	66.7	58.5	80.4	30.1
	Oct.	39.0	<88.6	<92.6	205.4	44.2	46.8	409.3	182.7	174.2	96.2	54.0	71.9
Iron	July												
	Oct.	6 266.9	29 255.3	6 111.1	1 768.8	9 970.2	5 981.3	5 039.5	39 202.7	33 535.3	827.5	5 744.3	7 934.8
Lead	July				<195	306	382	<411	454	534	<50.4	100	80.3
	Oct.	<33.9	<354.6	<370.4	<20.5	132.1	129.6	<64.8	930.2	676.1	<15.8	102.2	185.1
Mercury	July												
	Oct.				0.38	0.17	0.16		0.10	1.52	0.14	0.03	0.34
Zinc	July				125	1 495	1 608	724	2 128	3 825	412	382	1 054
	Oct.	237.1	3 297.9	8 333.3	196.5	606.6	1 050.7	279.4	4 750.8	5 949.9	598.9	758.6	1 206.1

TABLE 24

SUMMARY OF METAL LEVELS IN MUSCLE OF FISH FROM ST. MARY RIVER, COLLECTED UPSTREAM AND DOWNSTREAM FROM MARK CREEK IN JULY AND OCTOBER, 1977[38]

(Values in PPM Dry Weight)

	Iron				Zinc				Copper				Mercury			
	N	Max.	Min.	Mean	N	Max.	Min.	Mean	N	Max.	Min.	Mean	N	Max.	Min.	Mean
Brook Trout-U/S	1			30.91	2	29.4	19.8	24.6	2	3.8	1.4	2.6	1			0.01
-D/S	5	39.3	20	24.2	6	49.1	13.8	24.6	6	4.8	1.9	3.2	4	0.03	0.01	0.02
Burbot-U/S	2	65.5	46.4	55.9	4	38.3	20.8	27.5	4	257.6	3.7	69	2	0.04	0.03	0.035
-D/S	2	164.1	40	102.1	3	68.1	35.3	52.7	3	93	4.1	34.6	2	0.02	0.01	0.015
Cutthroat Trout-U/S	6	50.6	16.1	28.7	6	42.5	14.4	22.6	6	8.2	1.7	3.3	2	0.03	0.01	0.02
-D/S	19	64.5	10	19.7	20	54.9	13.3	22.9	20	44.6	1.3	5.3	11	0.17	0.01	0.06
Dolly Varden-U/S	5	44.2	10	18.9	5	31.6	16.5	21.8	5	3.8	1.3	2.3	1			0.04
-D/S	2	30	20	25	2	21.8	19.2	20.5	2	3.6	2.1	2.8	2	0.11	0.06	0.085
Sculpin-U/S	2	106.5	20	63.3	3	48.9	41.3	43.9	3	19.9	7.7	12.1	2	0.05	0.03	0.04
-D/S	3	60	23.9	36.0	3	187.6	82.1	133.6	3	15.7	<4.7	<11.7	1			0.02

N - Number of values.
U/S - Upstream.
D/S - Downstream.

TABLE 25

SUMMARY OF METAL LEVELS IN LIVER OF FISH FROM ST. MARY RIVER, COLLECTED UPSTREAM AND DOWNSTREAM FROM MARK CREEK IN JULY AND OCTOBER, 1977[38]

(Values in PPM Dry Weight)

	Iron				Zinc				Copper				Mercury			
	N	Max.	Min.	Mean	N	Max.	Min.	Mean	N	Max.	Min.	Mean	N	Max.	Min.	Mean
Brook Trout-U/S	2	520	234	377	2	146	47.2	96.6	2	103	12.5	57.7	1			0.06
-D/S	6	1 510	72.1	689	6	264	20.4	143.7	6	104	10	61.1				
Burbot-U/S	4	490	120	243	4	269.6	56.1	148.5	4	183.8	24.8	88.1				
-D/S	1			60	1			26.4	1			95				
Cutthroat Trout-U/S	5	850	304	446	5	124.3	70.8	101.9	5	76.1	16.2	40.7				
-D/S	17	3 045	365	1 035	17	446.6	63.4	149.5	17	80.1	8.7	36.7	2	0.14	0.14	0.14
Dolly Varden-U/S	5	1 611	670	1 016	5	183.3	112.3	144.2	5	92.7	15.4	50.7				
-D/S	1			2 240	1			256	1			63.3				

N - Number of values.
U/S - Upstream.
D/S - Downstream.

TABLE 26

PARTICLE SIZE DISTRIBUTION OF SEDIMENTS FROM THE ST. MARY RIVER[37,38]

Size Range mm	Percent of Particles in Size Range (Mean ± Standard Deviation)					
	St. Mary River At Pumphouse (0200029)		St. Mary River At Wycliffe (0200138)		St. Mary River At Power Line	
	October, 1976	October, 1977	October, 1976	October, 1977	October, 1976	October, 1977
	N=4	N=10	N=4	N=10	N=4	N=10
>4	82 ± 9.5	93.0 ± 4.2	68 ± 9.4	89.3 ± 4.9	90 ± 2.3	97.1 ± 2.8
2 to 4	5.5 ± 4.3	2.4 ± 1.6	8.5 ± 0.84	3.4 ± 1.6	2.5 ± 0.69	0.15 ± 0.19
1 to 2	5.3 ± 3.9	1.5 ± 1.0	6.2 ± 2.4	1.3 ± 1.0	1.1 ± 0.29	0.12 ± 0.16
0.5 to 1	3.2 ± 1.2	1.9 ± 1.0	6.4 ± 3.6	2.1 ± 1.2	1.6 ± 0.71	0.45 ± 0.60
0.25 to 0.5	1.9 ± 0.77	0.8 ± 0.4	4.9 ± 1.9	2.3 ± 0.9	2.9 ± 1.0	1.20 ± 1.35
0.125 to 0.25	0.80 ± 0.39	0.2 ± 0.1	2.3 ± 0.80	0.7 ± 0.3	1.3 ± 0.42	0.46 ± 0.37
0.063 to 0.125	0.43 ± 0.27	0.1 ± 0.05	1.1 ± 0.50	0.3 ± 0.2	0.43 ± 0.17	0.15 ± 0.13
<0.063	0.70 ± 0.33	0.2 ± 0.1	2.0 ± 1.0	0.5 ± 0.3	0.45 ± 0.19	0.46 ± 0.60

N - Number of values.

TABLE 27

SUMMARY OF PERIPHYTON DATA FROM ST. MARY RIVER[37,38]

(All Values Mean of 4 Replicates, Range in Brackets)

	Chlorophyll *a* $\mu g/cm^2$		Phaeopigment $\mu g/cm^2$		Biomass ash-free wt. mg/cm^2	
	Pumphouse 0200029	Wycliffe 0200135	Pumphouse 0200029	Wycliffe 0200135	Pumphouse 0200029	Wycliffe 0200135
May 3, 1976		0.028 (0.022-0.036)		0.002 (nil-0.009)		0.406 (0.319-0.522)
September 2, 1976	0.027 (0.012-0.044)	1.17 (1.03-1.34)	0.011 (nil-0.033)	0.048 (0.037-0.064)	0.016 (n=1)	0.397 (0.403-0.446)
October 1, 1976		8.81 (6.78-11.1)		3.88 (3.04-5.91)		1.44 (1.13-1.62)
October 25-27, 1976	0.0006 (nil-0.0013)	1.28 (0.989-1.84)	0.007 (nil-0.018)	0.590 (0.279-1.19)	(<0.001-0.003)	0.417 (0.354-0.525)
July 26, 1977	0.071 (0.042-0.103)	0.239 (0.187-0.382)	0.099 (0.062-0.176)	0.262 (0.197-0.420)	0.128 (0.078-0.157)	0.188 (0.159-0.231)
September 19, 1977	0.295 (0.260-0.336)	4.32 (3.91-5.80)	0.336 (0.289-0.379)	4.60 (4.26-6.00)	0.179 (0.162-0.203)	0.574 (0.458-0.786)
October 18, 1977	0.027 (0.011-0.036)	8.22 (6.72-11.4)	0.044 (0.019-0.330)	8.45 (7.07-11.4)	0.103 (0.043-0.168)	0.974 (0.910-1.08)

TABLE 28

PERIPHYTIC ALGAE PRESENT AT THE ST. MARY RIVER SAMPLING SITES, 1976[37]

Species \ Site	Wycliffe 0200135				Pumphouse 0200029			
	July 27	Sept. 2	Oct. 1	Oct. 27	May 3	Sept. 2	Oct. 1	Oct. 25
Bacillariophyceae								
Achnanthes sp.	*	*	**	*	*			
Achnanthes minutissima			*					
Cocconeis sp.		*	*					
Cymbella sp. 1	*		*	*	*			
Cymbella sp. 2				*				
Cymbella sp. 3				*				
Cymbella parva					*			
Cymbella parvula		***	**					
Fragilaria sp.	*							
Fragilaria capucina		*					*	
Fragilaria crotonesis			*					
Fragilaria vaucheriae			*					
Gomphonema sp.	*	**	**	*	*	*		
Hannaea arcus	*	*	*	*	*	*		
Melosira sp.				*				
Navicula sp. 1	*		*	*	*	*		
Navicula sp. 2			*					
Synedra sp. 1		*		*	*			*
Synedra sp. 2								*
Synedra acus								*
Synedra mazamaensis			*					
Synedra tabulata		***	**	*		*		
Synedra tenera					*		*	
Synedra ulna	*	*	*				*	
Tabellaria fenestrata							*	
Tabellaria flocculosa	*			*		*	*	*
Chlorophyceae								
Closterium sp.			*					
Spirogyra sp.	*			*				
Ulothrix sp.				*				
Zygnema sp.							***	
Cyanophyceae								
Oscillatoria sp.				*				

* Present ** Abundant *** Very Abundant

TABLE 29

PERIPHYTIC ALGAE PRESENT AT THE ST. MARY RIVER SAMPLING SITES, 1977[37]

Species \ Site	Wycliffe 0200135			Pumphouse 0200029		
	July 26	Sept. 19	Oct. 18	July 26	Sept. 19	Oct. 18
Bacillariophyceae						
Achnanthes sp.	*	*	*			
Achnanthes minutissima					*	*
Cocconeis placentula	*					
Cymbella turgida	*	*	*	*	*	*
Diatoma elongatum				**	*	**
Fragilaria capucina		*	*			
Fragilaria crotonesis				*		
Gomphonema sp.		*				
Hannaea arcus	*			**		
Melosira sp.				*		
Navicula cryptocephala				*	*	*
Navicula pupula	*	*				
Navicula radiosa			*			*
Nitzschia dissipata	**	**	***			
Nitzchia sigmoidea		*	*			
Surirella ovata			*			
Synedra acus	*	*	*	*	*	
Synedra radians	*	*	*	*		*
Synedra ulna	**	*	**	**	***	***
Tabellaria fenestrata	**	*	*	**	**	***
Chlorophyceae						
Closterium sp.		*		*		
Oedegonium sp.	*					
Spirogyra sp.	*	***	**			
Stigeoclonium sp.	*	**	**			
Ulothrix subtilissima		*				
Ulothrix tennuissima		**	***			
Cyanophyceae						
Oscillatoria angustissima	**	*	*			
Oscillatoria tenuis	*		*			

* Present   ** Abundant   *** Very Abundant

TABLE 30

SUMMARY OF BENTHIC INVERTEBRATE FAMILIES FROM ST. MARY RIVER, 1976[37]

(Values are Number/m², Mean of 4 Replicates)

	May 3, 1976		September 2, 1976		October 1, 1976		October 25, 1976	
Species \ Site	Pumphouse 0200029	Wycliffe 0200135	Pumphouse 0200029	Wycliffe 0200135	Pumphouse 0200029	Wycliffe 0200135	Pumphouse 0200029	Wycliffe 0200135
Ephemeroptera								
Ephemerellidae	19.8		21.8	396.2	11.4	130	32.2	145.5
Heptageniidae	24.0		113.3	18.7	140.4	15.6	1 153.4	2.1
Baetidae	31.0		133.1	378.6	1 145.0	5 662.8	1 825.2	573.6
Plecoptera								
Nemouridae				293.3	20.8	452.4	11.4	232.9
Taeniopterygidae	1.0		109.2	133.1	201.8	1 560.0	131.0	2 409.2
Lauctridae					2.1	93.6		257.6
Capniidae			1.0	4.2		208.0	7.3	180.7
Perlidae			2.1		2.1	5.2	2.1	10.4
Perlodidae	3.1						1.0	
Chloroperlidae				9.4				8.3
Trichoptera								
Hydroptilidae					1.0		2.1	
Rhyacophilidae	1.0		4.1	6.2	7.3	31.2	3.1	6.2
Hydropsychidae	4.2		80.1	418.1	98.8	842.4	62.4	203.6
Brachycentridae	2.1			55.1	1.0	31.2		4.2
Limnephilidae		12.5		1.0	28.1	46.8	67.6	141.4
Glossosometidae							1.0	12.5
Lepidostomatidae		2.1				140.4	1.0	
Diptera								
Chironomidae	188.5	237.5	328.6	2 381.6	745.7	6 557.2	657.3	29 983.8
Simuliidae	1 551.0	2.1	4 373.2		295.4		224.6	
Empididae			1.0	9.4		36.4	2.1	8.3
Blepharoceridae								
Tipulidae		2.1						
Other	8.3		12.4	11.5	32.1	41.6	9.4	81.1
Biomass (mg/m²)	35.98	5.62	557.80	796.17	237.33	2 689.18	87.67	2 185.57
Diversity (Shannon-Weaver)	1.01	0.69	1.12	2.26	2.42	2.16	2.42	0.82

TABLE 31

SUMMARY OF BENTHIC INVERTEBRATE FAMILIES FROM ST. MARY RIVER, 1977(38)

(Values are Number/m², Mean of 4 Replicates)

	July 26, 1977		September 19, 1977		October 18, 1977	
Species / Site	Pumphouse 0200029	Wycliffe 0200135	Pumphouse 0200029	Wycliffe 0200135	Pumphouse 0200029	Wycliffe 0200135
Ephemeroptera						
Ephemerellidae	539	736	582	1 970	730	1 272
Heptageniidae	160	35	394	168	974	772
Baetidae	1 060	1 686	1 424	12 756	2 684	11 001
Plecoptera						
Pteronaraidae	2	2				
Nemouridae	54	147	17	292	20	84
Taeniopterygidae	37	3	843	4 032	814	2 167
Lauctridae			12	188		94
Capniidae	30	3		110	94	3 240
Perlidae	24	3	71		14	
Perlodidae	44	5	8		9	43
Chloroperlidae			2			
Trichoptera						
Hydroptilidae	15	2	58		36	
Rhyacophilidae	15	29	14	53	9	
Hydropsychidae	513	124	249	444	20	63
Brachycentridae	49	33	359	3 754	177	1 022
Limnephilidae	2					
Glossosometidae	5		143		89	
Diptera						
Chironomidae	2 423	11 613	3 612	44 532	6 533	65 146
Simuliidae	872	413	28	42	129	
Empididae		28	14	375	21	220
Tipulidae			2			
Ragionidae					6	
Other	22	33	7	221	51	315
Biomass (mg/m²)	108.7	230.85	130.17	1 647.50	82.82	310.00
Diversity (Shannon-Weaver)	1.25	2.6	1.7	2.6	1.3	2.2

TABLE 32

WATER QUALITY OF THE KOOTENAY RIVER, BELOW THE ST. MARY RIVER FOR PARAMETERS AFFECTED MOSTLY BY DISCHARGES, 1975-1978

		Site 0200038, Kootenay River at Picture Valley				
		N	Max.	Min.	Mean	Major Contributing Sources
Coliforms-Fecal	MPN/100 mL	29	<20 000	<2	49[a]	Crestbrook, Misc.
Total	MPN/100 mL	13	<20 000	49	807[a]	Crestbrook, Misc.
Colour-True	rel. units[b]	34	40	<5	9.4	Crestbrook
TAC	rel. units[c]	20	48	1	14.5	Crestbrook
Fluoride	mg/L	53	4.4	<0.1	0.59	Cominco
Iron-Dissolved	mg/L	37	0.4	<0.1	0.11	Cominco
Total	mg/L	51	10	0.1	1.26	Cominco
Lead-Dissolved	mg/L	41	0.006	<0.001	0.001	Cominco
Total	mg/L	46	0.017	<0.001	0.005	Cominco
Nitrogen-Ammonia	mg/L	46	0.104	<0.005	0.023	Cominco
Nitrate	mg/L	34	0.22	0.06	0.129	
Nitrite	mg/L	34	0.005	<0.005	<0.005	
Kjeldhal	mg/L	45	0.28	<0.1	0.122	
Organic	mg/L	45	0.27	<0.1	0.10	
pH		89	9.1	7.3	8.0	Cominco
Phenol	mg/L	38	0.014	<0.002	0.003	Crestbrook
Phosphorus-Ortho	mg/L	46	0.486	<0.003	0.053	Cominco
Total	mg/L	72	0.767	0.003	0.105	Cominco
Solids-Total	mg/L	53	468	130	204	Crestbrook, Cominco
Dissolved	mg/L	45	262	90	159	
Suspended	mg/L	2	49	9	29	
Sodium	mg/L	46	12.9	1.5	5.1	Crestbrook
Sulphate	mg/L	34	68	11.5	33.2	Crestbrook
Turbidity	J.T.U.	41	144	2.6	20.7	Crestbrook
Tannin & Lignin	mg/L	8	1.2	<0.1	0.6	Crestbrook
Zinc-Dissolved	mg/L	33	0.1	<0.005	0.033	Cominco
Total	mg/L	52	0.22	0.007	0.061	Cominco

N - Number of values.
a - Geometric mean.
b - Jan/75 to Nov/77
c - Dec/77 to Dec/78

TABLE 33

WATER QUALITY OF THE KOOTENAY RIVER, BELOW THE ST. MARY RIVER FOR PARAMETERS AFFECTED LITTLE BY DISCHARGES

		Site 0200038 Kootenay River at Picture Valley			
		N	Max.	Min.	Mean
Alkalinity-Total	mg/L	59	124	61	93
Arsenic-Dissolved	mg/L	35	0.013	<0.005	0.005
Total	mg/L	36	0.013	<0.005	0.005
Cadmium-Dissolved	mg/L	34	<0.0005	<0.0005	<0.0005
Total	mg/L	34	0.0008	<0.0005	<0.0005
Carbon-Organic	mg/L	45	7	<1	2.5
Chromium-Dissolved	mg/L	20	<0.005	<0.005	<0.005
Total	mg/L	34	0.023	<0.005	0.006
Copper-Dissolved	mg/L	30	0.007	<0.001	0.0015
Total	mg/L	51	0.01	<0.001	0.002
Hardness	mg/L	52	194	73	123
Magnesium-Dissolved	mg/L	52	15.5	5.3	9.9
Total	mg/L	23	15.6	5.8	10.3
Manganese-Dissolved	mg/L	40	0.1	<0.02	0.037
Total	mg/L	47	0.16	<0.02	0.052
Mercury-Total	µg/L	14	<0.05	<0.05	<0.05
Molybdenum-Total	mg/L	32	0.0022	<0.0005	0.0008
Nickel-Dissolved	mg/L	34	<0.01	<0.01	<0.01
Total	mg/L	34	0.01	<0.01	<0.01

N - Number of values.

TABLE 34

ANALYSES OF SEDIMENTS FROM THE KOOTENAY RIVER AND THE ST. MARY RIVER, OCTOBER 1975, JULY AND AUGUST 1976 (Values In PPM Dry Weight Except Mercury PPM Wet Weight)

	Kootenay River D/S St. Mary River, At Site 0200038				St. Mary River U/S Cominco Ltd.		
	N	Max.	Min.	Mean	N	Max.	Min.
Arsenic	3	8	5	6	3	12.8	5.2
Chromium	3	17.2	13.5	16.0	3	N.D.	N.D.
Copper	2	20.2	15.8	18	3	18.6	15.0
Fluoride	3	220	200	210	3	N.D.	N.D.
Iron	3	19 500	17 800	18 400	3	23 750	18 715
Lead	3	44.1	28.2	36.8	3	42.8	32.2
Manganese	3	345	311	328	3	N.D.	N.D.
Mercury	1	<0.05	<0.05	<0.05	3	0.08	0.03
Nickel	2	29.6	25.3	27.5	3	N.D.	N.D.
Phosphorus	3	610	550	587	3	N.D.	N.D.
Zinc	3	121	72.9	91.5	3	73.8	61.1

N - Number of values.
N.D. - Not detectable.

TABLE 35

TURBIDITY AND CHLOROPHYLL a IN THE KOOCANUSA RESERVOIR
AT SITE 0200100 IN 1975

Date	Extinction Depth m	Turbidity at Various Depths J.T.U.					Chlorophylla a mean 0 to 20 metres mg/m^3
		1 m	5 m	10 m	15 m	20 m	
May 28	0.5	6.6	11				0.7
June 24	0.9	9		15		18	1.9
July 21	4.9	1.2	1.4	2.2	6.2	12	1.7
August 26	5.2	11	12	12		25	1.2
September 23	6.4	0.7		1.5			2.0
November 25	4.6	1.1			1.1		3.0

TABLE 36

LOADING OF SUSPENDED SEDIMENTS TO THE KOOCANUSA RESERVOIR

	Tonnes/Year			
	Kootenay	Elk	Bull	Total
1972	419 953	86 573	12 827	519 353
1973	56 201	43 798	35 794	135 793
1974	368 589	119 050	35 233	522 872
1975	390 262	590 228*	45 431	1 025 921
1976	474 180	176 701	41 686	692 567
1977	232 897	92 770	24 882	350 549
1978	498 897	249 644	46 191	792 732

* - June sample = 486 mg/L accounts for 528 671 tonnes.

TABLE 37

CONCENTRATIONS OF TOTAL PHOSPHORUS AT OVERTURN IN THE KOOCANUSA RESERVOIR, AT SITE 0200100

Year	Date	Depth m	Total Phosphorus Concentration μg/L
1973	Oct. 3	3	50
		12	46
		20	58
1974	Oct. 4	0	60
		16	70
1975	May 28	1	116
		5	123
	Nov. 25	1	48
		15	48
		30	53
1976	June 1	1	22
		8	20
		16	22
	Nov. 2	1	6
		16	7
		32	9
1977	June 2	1	9
		10	10
		20	17
	Nov. 1	1	6
		14	6
		25	13
1978	June 6	1	16
		26	20
	Nov. 15	1	6
		18	7
		36	8

TABLE 38

SEDIMENT AND WATER CHEMISTRY ALONG THE LENGTH OF KOOCANUSA RESERVOIR

Sediments (Aug. 6, 1976)		Sites		
		0200169	0200101	0200100
Fluoride	ppm	250	270	140
Phosphorus	ppm	580	640	400
Arsenic	ppm	6	6	2
Chromium	ppm	18.1	21	10.1
Copper	ppm	19.9	40	12.6
Iron	ppm	18.5	198	12.7
Lead	ppm	48.0	50.8	20.0
Manganese	ppm	40.0	51.5	0.309
Nickel	ppm	25.4	29.6	16.4
Zinc	ppm	163.5	17.3	43.3
Water				
Fluoride	ppm	0.307 (N=9)	0.83 (N=14)	0.201 (N=15)
Phosphorus	ppm	47 (N=27)	32 (N=39)	30 (N=62)

N - Number of values.

TABLE 39

SUMMARY OF PHYTOPLANKTON DATA FROM THE KOOCANUSA RESERVOIR

Site Number	1973				1974				1975					
	June 25	July 23	Aug. 27	Oct. 3	July 23	Aug. 19	Sept. 24	Oct. 22	June 24	July 21	Aug. 26	Sept. 23	Oct. 28	Nov. 25
0200100														
density-cells/mL	6	68	81	228	237	117	346	254	1	17	25	19	2	9
biomass-mg/m^3	2	27	26	61	9	24	101	118	1	8	87	37	1	4
0200101														
density-cells/mL		85	78		23	225	247	1 090		43	275	15		
biomass-mg/m^3		34	69		5	82	76	475		26	514	6		
0200169														
density-cells/mL			104		24	259	23	2 090			1 348	952	10	
biomass-mg/m^3			36		9	107	8	1 090			5 683	195	9	

Site Number	1976				1977					
	Aug. 9	Sept. 1	Oct. 4	Nov. 2	June 2	July 5	Aug. 26	Aug. 30	Sept. 27	Nov. 1
0200100										
density-cells/mL	2	5	4	12	77	433	26	144	133	177
biomass-mg/m^3	1	2	1	6	38	215	213	73	63	92
0200101										
density-cells/mL	5	67	5	38		108	311	16	936	728
biomass-mg/m^3	0	34	1	19		40		14		
0200169										
density-cells/mL	10	439	10	31						
biomass-mg/m^3	4	278	2	14						

TABLE 40

SUMMARY OF CHLOROPHYLL a, DATA FROM THE KOOCANUSA RESERVOIR
(Values In mg/m^3)

Site Number		May	June	July	Aug.	Sept.	Oct.	Nov.
Data Averaged From 1, 5, 10, 15 and 20 m Depths								
0200100	1974			1.2	1.1	0.4	1.4	
0200101				1.1	1.4	0.6	1.6	
0200169				1.5	0.8	0.6	2.5	
0200100	1975		1.9	1.7	1.2	2.0	1.4	3.0
0200101								
0200169					6.2	22.4	7.8	2.3
0200100	1976		2.0	7.4	0.8		1.3	1.3
0200101				1.7	3.4	2.1		
0200169				2.8	1.2	2.8	1.2	1.5
0200100	1977		1.4	2.2	2.0	1.4	1.2	2.1
0200101				4.2	1.9	10.6	1.5	
0200100	1978		2.6	0.7	0.9	1.4	2.7	2.3
0200101				0.8	0.7	1.2	1.9	
Data At 1 m Depth								
Site Number		May	June	July	Aug.	Sept.	Oct.	Nov.
0200100	1974	0.8	3.1	1.9	0.6	0.4	1.1	
0200101					1.3	0.3	1.4	
0200169				1.7	0.6	0.4	2.7	
0200100	1975	0.7	5.3	2.8	1.6	3.3	1.5	3.1
0200101								
0200169					8.1	57.0	12.3	2.6
0200100	1976		2.8	5.5	1.1		1.3	1.2
0200101				2.2	4.5	3.2		
0200169				5.3	1.3	3.7	1.2	1.7
0200100	1977		1.6	2.4	1.8	1.5	1.2	2.2
0200101			7.3	4.9	2.1	23.0	1.4	
0200100	1978		7.3	1.1	1.4	1.6	3.0	3.1
0200101				1.5	0.9	1.8	2.6	

TABLE 41

SUMMARY OF ZOOPLANKTON DATA FROM THE KOOCANUSA RESERVOIR

(Values In Organisms/cm^2 Lake Surface)

Site No.	1973 June 25	1973 July 23	1973 Aug. 16	1973 Aug. 27	1973 Oct. 3	1974 May 22	1974 June 26	1974 July 23	1974 Aug. 19	1974 Sept. 24	1974 Oct. 23
0200100	17.5	53.7	21.7	12.4	17.9	0	5.1	39.1	13.3		
0200101		0.9		2.2				17.6	15.1		

Site No.	1975 May 28	1975 June 24	1975 July 21	1975 Aug. 26	1975 Sept. 23	1975 Oct. 28	1976 June 1	1976 July 6	1976 Aug. 9	1976 Sept. 1	1976 Oct. 4	1976 Nov. 2
0200100	0	0.2	33.4	15.3	18.2	7.11	5.7	0.4	35.9	15.6	18.6	3.4
0200101				11.6	16.2			13.5	39.3	28.3	32.2	12.4

Site No.	1977 June 2	1977 July 5	1977 July 26	1977 Aug. 30	1977 Sept. 27	1977 Nov. 1
0200100	53.0	72.9	9.3	13.0	51.5	19.1
0200101		0.6	0.4	0	0.3	0.1

TABLE 42

WATER SOURCES WITH LIMITED WATER AVAILABILITY IN THE LOWER KOOTENAY RIVER BASIN

Locality	Water Source	Number Of Licences	Quantity*	Purpose	Comments
South Section (Figure 47)					
Grasmere Valley	Jewell Spring	1	0.8 2.5	Domestic Irrigation	Fully Committed.
	Flag Creek	8	2.5 359.0	Domestic Irrigation	Fully Committed.
	Maguire Creek	5	5.8 957.0	Domestic Irrigation	Possible Water Shortage In Low Flow Year
	Bowman Creek	2	247.0	Irrigation	Fully Committed.
					Creeks Flowing Down Into Grasmere Valley Have Problems With Water Losses To Groundwater Storage In Summer And Flooding In Spring. See Text For Discussion of Water Availability In The Grasmere Valley.
Baynes Lake	Saunders Spring	1	0.8	Domestic	Fully Committed, 1 Refusal Of Water.
Jaffray-Galloway	Sand Creek	13	912.0	Irrigation	Possible Water Shortage For Irrigation In Late August And September During Low Flow Years Upstream From Little Sand Creek.
Wardner	Chipka Creek	7	2.5 365.0	Domestic Irrigation	Fully Committed.
	Ha Ha Creek	11	12.4 832.0	Domestic Irrigation	Fully Committed, 1 Refusal Of Water.
	Gold Creek	5	13 400.0 1 110.0	Domestic Irrigation	Fully Committed Above City Of Cranbrook Diversion To Joesph Creek, 3 Refusals Of Water.
	Radar Lake and Ballard Swamp	1	123.0	Irrigation	Possible Water Shortage.

* - Values are in dam^3/a ($1\ dam^3/a = 1000\ m^3/a$).
\+ - Water sources are located in the Fernie Water District Tobacco Plains, Rock Creek Bull River, Fort Steele, Wasa, and Sheep Creek precincts and Cranbrook Water District, Gold Creek, Wardner, Cranbrook, St. Mary, Cherry Creek and Skookumchuck precincts.

TABLE 42 (CONTINUED)

WATER SOURCES WITH LIMITED WATER AVAILABILITY IN THE LOWER KOOTENAY RIVER BASIN

Locality	Water Source	Number Of Licences	Quantity*	& Purpose	Comments
Cranbrook	Joesph Creek	18	16 000.0	Domestic	Fully Committed, 6 Refusals Of Water.
			980.0	Irrigation	
	Jim Smith Creek and Lake	5	12.4	Domestic	Fully Committed, 3 Refusals Of Water.
			617.0	Conservation	
			30.0	Irrigation	
	Dickson Dreek	1	0.8	Domestic	Fully Committed.
			1.2	Irrigation	
	Booth Creek	4	2.5	Domestic	Fully Committed, 1 Refusal Of Water.
			50.0	Irrigation	
			44.0	Industrial	
	Kelly, Ryan and Delmar Springs	2	0.8	Domestic	Fully Committed.
			31.0	Irrigation	
	Laurier and Mills Springs	4	2.5	Domestic	Fully Committed.
			0.7	Irrigation	
<u>North Section (Figure 46)</u>					
Bull River	Bull River	4	315 400.0	Power	Water Down To A Point 3 Miles North Of The Aberfeldie Dam Reserved For Power Purposes, Water May Be Obtained Under Interim Licences With Consent Of Minister Of The Environment.
			416.0	Industrial	
			38.0	Irrigation	
	Little Bull Creek	4	8.4	Domestic	Fully Committed Except For Freshet Period.
			2 320.0	Irrigation	
	Norbury Creek	13	5.8	Domestic	Fully Committed Except For Freshet Period, Supplies Water For Fish Hatchery.
			1 670.0	Irrigation	
			18 900.0	Fish Culture	

TABLE 42 (CONTINUED)

WATER SOURCES WITH LIMITED WATER AVAILABILITY IN THE LOWER KOOTENAY RIVER BASIN

Locality	Water Source	Number Of Licences	Quantity*	Purpose	Comments
Bull Creek	Peter Brook	1	0.84	Domestic	Possible Water Shortage, Refusal Of 62 dam^3/a For Irrigation In 1969.
			60.0	Irrigation	
Fort Steele	Mause Creek	9	7.3	Domestic	Fully Committed.
			812.0	Irrigation	
	Sunk and Quirk Creeks	5	1.7	Domestic	Possible Water Shortage.
			365.0	Irrigation	
	Saugum Creek	7	0.8	Domestic	Fully Committed, Supplies Water For Wildfowl Conservation Projects.
			1 306.0	Conservation	
			409.0	Irrigation	
Wasa	Lewis Creek	9	1.7	Domestic	Fully Committed, 2 Refusals Of Water, Land Improvement Licence Is For Diversion To Lazy Lake To Maintain Water Levels.
			964.0	Irrigation	
			4 463.0	Land Improvment	
	Wolf Creek	12	6.6	Domestic	Fully Committed During Low Flow (September).
			57.0	Conservation	
			1 530.0	Irrigation	
	Ross Spring	1	0.4	Domestic	Possible Water Shortage For Existing Licence At Low Flow.
	Lazy Lake and Warden Brook	2	1.7	Domestic	Possible Water Shortage, Water Only Available For Domestic Purposes, Irrigation Water Refused.
Lussier River	Brad Creek	1	92.0	Irrigation	Fully Committed.
	Pape Creek	1	11.0	Irrigation	Fully Committed.

TABLE 42 (CONTINUED)

WATER SOURCES WITH LIMITED WATER AVAILABILITY
IN THE LOWER KOOTENAY RIVER BASIN

Locality	Water Source	Number Of Licences	Quantity*	Purpose	Comments
Ta Ta Creek	Ta Ta Creek	11	5.1	Domestic	Fully Committed, 1 Refusal Of Water.
			420.0	Irrigation	
	Hannant and C.P.R. Springs	1	1.7	Domestic	Fully Committed.
			41.0	Irrigation	
Skookumchuck	Skookumchuck Creek	5	58 000.0	Industiral	Possible Water Shortage, Licenced Water Usage Exceeds Creek Flow During Low Flow. Provides Water Supply For Crestbrook Forest Industries Ltd. Pulp Mill.
			2.5	Domestic	
			680.0	Irrigation	
Kimberley	Mather Creek	24	24.0	Domestic	Fully Committed, 0.23 m^3/s Reserved For Fisheries Interests.
			2350.0	Irrigation	
	Luke Creek	3	5.8	Domestic	Fully Committed, 2 Refusals Of Water.
			409.0	Irrigation	
	Lockspring Creek	2	1 060.0	Domestic	Fully Committed.
	Mark Creek	7	2 420.0	Domestic	Fully Committed, 1 Refusal Of Water, Supplies Water For Cominco Ltd. And Kimberley.
			9 960.0	Industrial	
			22 400.0	Power	
	Lois and Kimberley Creeks	2	83.0	Domestic	Possible Water Shortage, 1 Refusal Of Water, Supplies Water For Cominco Ltd. At Kimberley.
			332.0	Industrial	
	Clifford Brook	1	1.7	Domestic	Possible Water Shortage.
			4.6	Irrigation	