MINISTRY OF ENVIRONMENT
PROVINCE OF BRITISH COLUMBIA

SKEENA-NASS AREA
BULKLEY RIVER BASIN
WATER QUALITY ASSESSMENT AND OBJECTIVES

TECHNICAL APPENDIX

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1. INTRODUCTION

The Bulkley River basin is in central British Columbia, east of Prince Rupert (see Figure 1). The Bulkley River is a major tributary of the Skeena River. It flows northwest from the headwaters at Bulkley Lake, through the interior plateau, to enter the Skeena River near Hazelton. The drainage area of the Bulkley River watershed is about 12 300 km^2, with the interior plateau contributing 85% of the watershed area, and the Nanika/Morice River watersheds contributing about 15%. The mean annual Bulkley River flow at Hazelton is about 201 m^3/s[6].

The purposes of this report are:

(i) to assess present water quality of the mainstem Bulkley and Morice Rivers using available information (up to April, 1984) on waste discharges, water quality, streamflows and water use;

(ii) to predict future water quality, considering future waste discharges and the effects of the Kemano-Completion Project on Bulkley and Morice River flows; and

(iii) to recommend water uses that should be protected in the Bulkley and Morice Rivers, and to recommend provisional water quality objectives to protect those uses.

The Kemano-Completion Project has been indefinitely postponed by Alcan, which is not proceeding with its application under the government review process at this time. However, the provincial government is completing its review of Alcan's proposal.

A similar report for the Nechako River basin, which would also be affected by the project, is being prepared. Both river systems are important salmon migration routes and salmon rearing areas.

2. HYDROLOGY

Low-flow estimates (November to April minimum seven-day averages) used in assessing the effect of waste discharges on water quality are presented in Table 1. The Morice River constitutes 99% of Lower Bulkley River flows at certain times under natural low flow conditions (without flow regulation).

A comparison of low winter flows at different points on the Bulkley River (Table 1) with licensed water withdrawals (Tables 2,3) shows that actual flows are an order of magnitude greater than licensed use. Water requirements are actually less during the winter when there are no irrigation withdrawals.

Flow envelopes for the Morice River at the Morice Lake outlet and at Peacock Creek (near the confluence with the Bulkley River), as well as the Bulkley River at Quick and Smithers are shown in Figures 2 to 5. Included in these figures are the predicted minimum monthly flows following the proposed Kemano-Completion Project. The project is predicted to increase winter low-flows slightly in the Morice and Bulkley Rivers(2). These are Alcan's projection, however, and it is not yet certain whether Alcan can or will provide this water during dry years. Reksten(65) has suggested that Alcan has been optimistic in its reservoir inflow projections, having used data collected only since 1950. He has suggested that the runoff estimates available for the period 1930-1949 should also be used in Alcan's analysis. These years include a period of lower than average runoff. The effect on flow projections of using the longer period of record (1930-1983) is not yet known.

3. WATER USE

3.1 WATER LICENSES

The water licenses and license applications on the Bulkley River are given in Table 4, with a license summary by reach in Table 5. The locations of all the licenses are shown in Figure 6.

Licenses for drinking water are restricted to the headwaters near Bulkley Lake (three licenses) and that reach of the Bulkley River between Telkwa and Smithers (six licenses). Industrial license CL-55785 (Teniers Enterprises) is for a commercial water hauling operation with the water used for a variety of purposes including domestic supply. Teniers takes water from locations on the Bulkley River in addition to their four licensed points (near Houston and downstream from Telkwa). Unlicensed water haulers also withdraw water from the Bulkley River(60). The Bulkley River is also the drinking water source for the Village of Telkwa, and indirectly for the Town of Smithers and the District of Houston, through water wells. The largest and continuously pumped of the three wells in each location is located on the banks of the Bulkley River. The quick recharge rate of these two wells together with their proximity to the Bulkley River suggest that the Bulkley River is the source of water through alluvial gravels.

The highest agricultural capability in the Skeena-Nass planning unit occurs on the Bulkley River floodplain(53). It is primarily hay production although vegetable farming appears to be increasing in importance. While the total vegetable crop area is small in comparison to that devoted to forage crops, the gross value of production could be similar(3). There are also beef and dairy cattle. The Bulkley River is used for irrigation water, with increased demands predicted for the future, in particular for hay production above Houston(54).

An undetermined number of irrigation and domestic licenses on the Bulkley River are also used for livestock watering.

As indicated in Table 5, there is no licensed water use between Smithers and Hazelton. There are several licenses on tributaries to the Bulkley River between Smithers and Hazelton, some of which service the Indian reserves along that corridor. There is likely to be some unlicensed water use on this reach of the Bulkley River for domestic purposes.

3.2 FISHERIES

There is year-round fisheries use in the Bulkley River. It is used as a migration route by steelhead and all salmon species except chum. Between 1970 and 1980, the Bulkley River supported an annual escapement of up to 930 chinook, 2 500 coho, 300 sockeye, and 2 500 pink salmon(52). There is adult holding throughout the winter. Although some spawning is known to occur in the Bulkley River by pink and chinook, it is more important as a juvenile rearing area. The Bulkley River also supports resident cutthroat trout, Dolly Varden, and rainbow trout, although mainstem spawning by these species is unlikely(51).

Total steelhead production for the Morice and Bulkley Rivers is between 6 000 and 9 000 adult fish with an annual escapement of 2 000-3 000 following commercial, native, and sport fisheries. Adult steelhead enter the Bulkley River from the Skeena River in mid-August through the fall, and then overwinter. Spawning occurs in May and June in the Bulkley River and its tributaries; however, most production of juvenile steelhead fry is attributed to tributary and mainstem habitats of the Morice River (between Gosnell and Lamprey Creeks). Parr tend to leave the tributaries and side channels in their first and second year. They rear and overwinter in the lower mainstem habitats, in particular the Bulkley River below Houston(1,4,5), prior to smolting.

There is a native food fishery for the Moricetown Indian Band, located downstream from Smithers. The Indians spear fish from the rocks on the banks of the Bulkley River.

3.3 WILDLIFE[53]

The Bulkley River Valley is a major wintering area for moose. Mule deer use the area throughout the year. Beaver, muskrat, river otter and mink have been observed on the Bulkley River, as well as birds including mergansers, belted kingfishers, bald eagles, and Canada geese.

3.4 RECREATION[53]

Sport fishing use (salmon, steelhead, cutthroat trout, Dolly Varden) of the Bulkley River is very high, especially below the Morice River. There is a salmon closure on the Upper Bulkley (above the Morice River) July 15 to October 31, and a general angling closure December 1 to June 30 on the Morice River to Barrett on the Bulkley River, and further downstream from the Suskwa River to Bulkley Canyon Station about 10 km east of Hazelton.

There are five licensed angling guides who work the Bulkley River between the Morice River and Moricetown, the latter located about 30 km downstream from Smithers. Two hotels, including the Bulkley Lodge and the Douglas Hotel, are located on the waterfront and cater to fishermen. The Trout Creek Emporium, downstream from Smithers, is a private campground with a tackle shop and store that also caters to fishermen. The Moricetown Indian Band has a tourist operation which is centered on the sport and native food-fishing attraction.

Boating is very popular on the Bulkley River, including use of canoes, kayaks, rafting and river boats. Commercial river raft trips used to operate from Moricetown Canyon, but are presently inactive. Boating difficulty is low between Houston and Smithers, moderately high between Smithers and Trout Creek, and very high between Trout Creek and Hazelton.

<u>Swimming</u> usually occurs only on the upper Bulkley River above the confluence with the Morice River because of the strong current downstream.

<u>Picnicking and camping</u> use of the Bulkley River is high, with picnic/campsites located at Houston, Telkwa, Smithers, the mouth of Trout Creek (private), and at Moricetown (operated by the Moricetown Indian Band). Other uses of the Bulkley River Valley during the summer include hiking, nature study, and photography.

4. WASTE DISCHARGES

The following waste discharges are summarized in Table 6, and their locations are denoted on Figure 6 by their name and permit number.

4.1 EQUITY SILVER MINE (PE 4475)

a) Description of the Discharges

Permit PE 4475 is for effluents from a copper-silver mine located about 32 km southeast of Houston, and at about 1 200 m elevation. It is located at the headwaters of Bessemer and Foxy Creeks. Bessemer Creek flows southward into Buck Creek, while Foxy Creek flows northward into Maxan Creek, both of which are major tributaries of the Upper Bulkley River. A dry concentrate of copper and silver is produced in an acid leach process. Future plans are to extract gold using cyanide, but this would require a permit amendment. The mill effluent is a slurry of crushed rock and process water which is discharged at a maximum permitted rate of 19 500 m^3/d to the tailings pond on the Foxy Creek side of the watershed (Figure 7). There is a seepage recovery pond below the tailings dam located about 50 m from Foxy Creek, with seepage pumped back to the tailings pond. Surface runoff, plant site water, and mine pit water result in another discharge which drains to Bessemer Creek.

Since 1980 a major system of perimeter ditches has been built to collect acid drainage before it flowed into Bessemer Creek. The drainage is treated with lime to pH 10 in a sump to neutralize the acids and remove metals. This treated drainage is stored near the main tailings pond and released to Foxy Creek at a maximum rate of 6 000 m^3/d when it reaches the effluent quality required by Permit PE 4475. A new silt-check dam and settling pond has been built lower down on Bessemer Creek to remove sediment and improve water quality. Overflows from this pond constitute a new discharge and a new permit compliance point.

All of the above changes are being amalgamated in an amendment to PE 4475. Present permit conditions are given in Table 8.

b) Present and Future Waste Loads

Permitted waste loadings are given in Table 8, and are calculated from the permitted concentration of variables and permitted effluent flow rates. Loadings are expected to remain the same in the future unless Equity installs a cyanide circuit to extract gold; this would require a permit amendment.

c) Impact of the Mine on Surface Water

Concerns have been raised over the impact of the Equity Mine on water quality of the Bessemer Creek-Buck Creek system in the southern mine drainage, and Foxy Creek in the northern drainage. These concerns include: 1) acid generation from the waste rock which is used to build containment dams and roads near the mine site, and 2) heavy metals (e.g. arsenic, selenium, copper, lead, zinc) associated with the mine process discharge water. A detailed assessment of receiving water data for the Equity mine will be made in a separate report, when data now being collected are available. This assessment will be important in indicating the likelihood of maintaining the existing water uses in Buck and Maxan Creeks in the future. There has been some indication of deterioration in water quality in Bessemer Creek; however, no direct impact on fisheries has been observed in either Bessemer or Foxy Creeks.

4.2 HOUSTON SEWAGE TREATMENT PLANT (PE 287)

a) Description of the Discharge

The District of Houston had a population of 3 921 in 1981. Population projections for 1993 range from no growth to 5 347 (growth rate of 2.5% per year). Permit PE 287 was issued to the District of Houston on July 30, 1969, and was last amended March 7, 1973. The permit is for the discharge of treated domestic sewage to the Bulkley River, about 1.2 km downstream from the mouth of Buck Creek, but about 5 km upstream from the confluence with the Morice River. Sewage is treated in an aerated lagoon, chlorinated, and stored when necessary in a pond with 20-day capacity so that the discharge does not exceed 10% of the Bulkley River flow at any time. This minimum dilution of about 10:1 is less than the usual acceptable minimum standard of 20:1 for municipal effluents(75). Treated effluent is discharged to the Bulkley River about 4 m from the bank, through an outfall pipe (no diffuser) lying on the river bottom(56). The permitted discharge rate is an average of 1 550 m^3/d.

The permit limits for the effluent are BOD_5 of ≦45 mg/L, suspended solids of ≦40 mg/L, total coliform bacteria <40 000/100 mL, and a chlorine residual of between 0.1 and 1.0 mg/L, but not to exceed 0.2 mg/L in the Bulkley River. The monitoring required of the permittee by Waste Management Branch includes a monthly grab sample analysed for BOD_5, total suspended solids, fecal and total coliforms, as well as a daily record of discharge volume, weight of chlorine added, residual chlorine concentration in the treated effluent, and a daily record of river flow at periods of low flow.

b) Present Waste Loads

The treated effluent flow has exceeded the 1 550 m^3/d permit limit for only 2.6% or 54 of 2 066 measurements taken over 10 years (see Table 9). The 10:1 required dilution cannot be checked as there are no daily river-flow records maintained by the permittee. The minimum Bulkley River flow yielding the minimum permitted 10:1 dilution with the maximum recorded effluent discharge (1 859 m^3/d) would be about 0.2 m^3/s. Although there are no flow records for the Upper Bulkley River, it has been predicted that the mean and the 1 in 10 year 7-day average low flows are 0.5 and 0.1 m^3/s, respectively (Table 1). Consequently, 0.2 m^3/s may occur once every four years(7). The storage lagoon would thus be required infrequently, or not at all if maximum effluent flows and minimum river flows do not coincide.

Suspended solids exceeded the permit limit (40 mg/L) in 11 of 71 samples, or in 15% of the samples between 1972 and 1983. Non-compliant levels occurred during freshet on about 50% of these occasions, suggesting infiltration into the sewage collection system as the cause.

Residual chlorine levels were less than the minimum permitted (0.1 mg/L) in 3 of 2 085 samples (1.4%) and greater than the maximum permitted (1.0 mg/L) in 3 of 2 085 samples (1.4 mg/L on August 29 and October 28, 1975; 1.5 mg/L on March 14, 1980).

BOD_5 in the treated effluent exceeded the 45 mg/L permit limit in 7.5% of the samples (5 of 67 samples) and total coliforms exceeded the permit limit of 40 000/100 mL only once in 48 samples.

Permitted and estimated actual waste loadings are presented in Table 10. The BOD_5, suspended solids, and residual chlorine loadings were within permit limits when average concentrations (from Table 9) were used, but were well above permitted limits under worse case conditions of maximum effluent concentration and flow. Phosphorus loadings cannot be calculated due to the absence of data, but nitrogen loadings (ammonia and nitrate/nitrite) are given in Table 10.

The theoretical effects of present waste loads (1981 data) on Bulkley River water quality are summarized in Table 11. The increases in concentration in the Bulkley River have been calculated, assuming complete mixing of the effluent and river water. The theoretical effect of discharges within permit levels is compared with theoretical worse case situations, using maximum recorded effluent characteristic-concentrations and assuming a minimum dilution of 10:1. Had there been records of Bulkley River low flows when this minimum dilution was not met, this worse case scenario would have been more accurate.

Table 11 shows that the maximum theoretical permitted residual chlorine level in the Bulkley River after complete mixing is 0.1 mg/L. This assumes the maximum permitted concentration of residual chlorine (1.0 mg/L), the maximum (average) permitted flow of 1 550 m^3/d, and river flows of at least 0.2 m^3/s to yield the required 10:1 dilution. The actual worse case residual chlorine in the effluent was 1.5 mg/L on May 14, 1980; had this occurred when flows in the Bulkley River were at their lowest, the theoretical concentration in the river would have been 0.15 mg/L, higher than the maximum theoretical 0.1 mg/L permitted based on permitted concentrations in the effluent together with the minimum 10:1 dilution. The permit, however, allows 0.2 mg/L in the Bulkley River at this point. Both the theoretical 0.1 mg/L calculated and the 0.2 mg/L residual chlorine limit stated in the permit are far in excess of the working fresh water aquatic life criterion (0.002 mg/L). As discussed in section 5.7, these data indicate that dechlorination may be required at the Houston sewage treatment facility.

The permit limit for the sewage effluent is 40 000 total coliforms/100 mL and a 10:1 minimum dilution. Theoretically these could all be fecal coliforms, yielding a maximum permitted level of 4 000 fecal coliforms/100 mL in the Bulkley River (Table 11). The historical data record for effluent fecal coliforms (Table 9) shows a mean of 83 MPN/100 mL but a maximum of 92 000 MPN/100 mL which is very high for a chlorinated effluent. This fecal coliform maximum occurred on November 18, 1980, during Bulkley River low flow, yielding a theoretical worse case incremental addition to the Bulkley River of 9 200/100 mL (Table 11). This greatly exceeds the 200-400 MPN/100 mL fecal coliform working primary-contact recreation criterion (section 5.7), albeit outside the main recreation period. Water quality monitoring is needed to confirm these theoretical high levels. A reduction in the fecal coliform levels in the effluent may be necessary during the recreation season to protect primary-contact recreation. A new chlorination pond constructed in 1984 (to replace the original pond built in 1970) may achieve this reduction. Chlorination would only be necessary during the recreation period to protect recreation use; dechlorination during this period (summer) would protect the fisheries.

Table 11 shows that ammonia-nitrogen levels in the Bulkley River after complete mixing could theoretically reach 1.7 mg/L under worse case conditions. Un-ionized ammonia under these conditions could exceed the working aquatic life criteria for the long term exposure of salmonids (see section 5.7). Similarly, the maximum nitrite-nitrogen level of 0.056 mg/L in Table 11 is greater than the 0.02 mg/L average criterion, but less than the 0.06 mg/L maximum criterion for salmonids.

The theoretical levels of the remaining characteristics in Table 11 in the Bulkley River after complete mixing are within working criteria for water uses.

In summary, there are possible problems with levels of residual chlorine, fecal coliforms, ammonia-nitrogen, and nitrite-nitrogen in the final sewage effluent at Houston. Should this be confirmed by water quality sampling of the Bulkley River, levels of these characteristics should either be reduced in the final effluent, or perhaps the minimum dilution in the Bulkley River should be increased to more than the required 10:1. This latter option might necessitate increasing the capacity of the storage lagoons at the treatment plant.

c) Future Waste Loads

Future waste loads from the Houston sewage treatment plant have not been predicted. We assume that the capacity of the storage lagoons will be expanded as effluent flow increases, so that the required 10:1 minimum dilution can be maintained in the Bulkley River. If this is the case, the waste loads and predicted effects on water quality should remain the same as at present.

4.3 SMITHERS SEWAGE TREATMENT PLANT (PE 373)

a) Description of the Discharge

The estimated maximum 1983 population and projected maximum 1993 population of the Town of Smithers are 4 820 and 6 230, respectively(58). These estimates are based on a 2.5% population increase each year, the rate of increase between 1971 and 1981.

The Town of Smithers holds permit PE 373 for the discharge of treated domestic sewage to the Bulkley River. In September of 1983, the treatment plant was changed from an activated sludge system designed for a population of 4 500 to an aerated lagoon system with a design capacity for 9 200 people. The average permitted discharge was increased from 2 850 m^3/d to 4 200 m^3/d with a maximum of 10 800 m^3/d. Because of the expected improvement in effluent quality, the permitted levels of BOD_5 and suspended solids were amended to 45 and 60 mg/L, respectively, from 75 and 100 mg/L. Chlorination is no longer required, although provisions were to be made in the site layout for chlorination/dechlorination if required in the future. Discharge of effluent which has bypassed the treatment works is prohibited. Effluent samples are to be taken monthly and analysed for BOD_5 and suspended solids. Daily discharges (24 hour) from the treatment plant are to be recorded.

The design of the sewage outfall maximizes initial dilution. Although the outfall pipe extends only about 10 m from the shore, it is buried in the bottom of the deep channel, with five equally spaced diffuser heads pointed downstream. Pressure restrictors on the diffusers assure that all are functioning in the dispersal of the effluent. This design promotes good mixing and should minimize water quality impacts in the initial dilution zone.

b) Present Waste Loads

Originally, the old sewage treatment plant, designed in 1972, functioned well. Flows were within the permit limit (2 850 m^3/d) during 1978-1980, but no data were collected since that date. High levels of suspended solids and BOD_5 occurred since 1979[12] as the Town of Smithers cut costs by only partially treating the wastes[13].

Few effluent data are available from the new sewage treatment plant since operation began in September of 1983. Data collected by Waste Management Branch and the permittee are summarized in Table 12. These data suggest that the new treatment facility is lightly loaded, and that good performance is to be expected. Effluent flow, BOD_5, and suspended solids were all within permit limits.

The ranges in concentrations for total nitrogen and total phosphorus have been extracted from the data record for both the old and new facility, and presented in Table 13. The data have been pooled because a significant change in effluent quality is not to be expected for these characteristics due to the new treatment plant design.

Present waste loading estimates are given in Table 14. These are calculated from the maximum characteristic level and maximum effluent flow on record (Tables 12, 13). The predicted effects of these maximum waste loads on Bulkley River water quality at Smithers are also summarized in Table 14. The increases in concentration above background levels are calculated at Bulkley River low flows, assuming complete mixing (for BOD_5 and suspended solids, the 1 in 10 year minimum 7-day average low flow of 15 m^3/s was used; for the nutrients nitrogen and phosphorus, the actual minimum average September flow of 80 m^3/s was used). The small increases in BOD_5, suspended solids, nitrogen and phosphorus, for the Bulkley River predicted in Table 14 are in agreement with water quality measurements presented in section 5.5. It concludes that the impact of the sewage discharge on these aspects of water quality is not presently significant. This is because dilution of the effluent (Table 7) is high, ranging from the theoretical worst case of 120:1 (low flow ÷ maximum permitted discharge; 15 m^3/s ÷ 10 800 m^3/d) to significantly higher dilutions such as that recorded by Waste Management Branch on November 30, 1983, of 2 150:1 (river flow of 37.83 m^3/s ÷ 1 523 m^3/d of treated effluent).

There is no fecal coliform permit limit for the unchlorinated sewage discharged at Smithers. There are only two effluent samples from the new treatment plant with fecal coliform analysis, taken by Waste Management Branch at Bulkley River low flows. Assuming complete mixing of effluent and river water, the theoretical incremental addition to the Bulkley River was 2 fecal coliforms/100 mL on November 30, 1983 (5 200/-100 mL in 1 523 m^3/d of effluent, diluted in 37.8 m^3/s of river water, or 2 149:1 dilution), and 3 fecal coliforms/100 mL on April 11, 1984 (9 000/100 mL in 1863 m^3/d of effluent, diluted in 69 m^3/s of river water, or 3 200:1 dilution). Although these data would appear to show that fecal coliform levels in the Bulkley River would be within drinking water criteria for water receiving only disinfection (<10 fecal coliforms/100 mL)[(18)], the data are too few to confirm this. Two of the following three predictions suggest that levels of fecal coliforms in the Bulkley River downstream from Smithers could exceed drinking water criteria but would be within primary-contact recreation criteria (200-400/100 mL[(55)]; see Section 5.7); the third prediction suggests fecal coliform levels would be within all of these criteria. These predictions include:

(i) from the data: worst case of 9 000 fecal coliforms/100 mL in the effluent (April 11, 1984) with the maximum recorded effluent discharge of 6 217 m^3/d (April 18, 1984), and the predicted 1 in 10 year 7-day average low flow in the Bulkley River of 15 m^3/s. This results in a theoretical dilution ratio of 208:1 or 43 fecal coliforms/100 mL added to the river.

(ii) from the fecal coliform: BOD_5 correlation derived for effluent from Dawson Creek by Butcher (1983)[57]: an effluent level of 54 000 fecal coliforms/100 mL is predicted, resulting in 450 fecal coliforms/100 mL after complete mixing in the Bulkley River during the low-flow November period. The concentration of fecal coliforms in the river would be lower during the summer recreation period because of the higher dilution; consequently the level of fecal coliforms would probably be within primary-contact recreation criteria (200-400/100 mL) without chlorination.

(iii) from two similar aerobic lagoon treatment plants in the United States (Pawnee, Illinois, and Bixby, Oklahoma): these showed effluent levels between 200 and 500 fecal coliforms/100 mL[10]. These levels are less than predicted by Butcher and would be within primary-contact recreation criteria and drinking water criteria after dilution in the Bulkley River during the low flows.

Further monitoring of the effluent and the Bulkley River will be needed to determine the effect of the effluent on fecal coliform levels and water uses in the river.

c) Future Waste Loads

A dairy plant has been proposed for Smithers with the following effluent characteristics: 22.7 m^3/d flow, fat content 156 mg/L, BOD_5 1 300 mg/L, and pH 6-13. Loadings of BOD_5 would be about 29.5 kg/d or 6% of the treatment plant design load. The impact of the proposed plant should be low, considering the total effluent flow of the sewage treatment plant.

Future (1993) waste loadings for the sewage treatment plant are presented in Table 14. They are based on two different predictions: (i) no population growth between 1983 and 1993; and (ii) a 2.5% per year growth in population, as occurred between 1971 and 1981, to give a 1993 population of 6 232. Projected flows and loadings for BOD_5 and suspended solids for the latter growth prediction are still within permit levels. The predicted future concentration increases in the Bulkley River of the characteristics shown in Table 14 are within water quality criteria and would not be expected to produce problems.

Sewage effluent dilution at Smithers after the proposed Kemano-Completion Project will be dependent on the regulated Bulkley River flow. The minimum flows in the Bulkley River are predicted by Alcan to increase slightly with the Kemano-Completion Project. The historical minimum mean monthly flow for 1962 to 1981 was 12.1 m^3/s, and the minimum mean monthly flow is predicted to be 13.9 m^3/s(2) with Kemano-Completion (Figure 5). Consequently, the unregulated 1 in 10 year, 7-day average low flow in the Bulkley River at Smithers (15 m^3/s) which would provide a minimum dilution of 120:1 to the maximum permitted effluent discharge (10 800 m^3/d) after complete mixing, is also expected to increase slightly. The lowest predicted post Kemano-Completion average mean monthly low flow (32 m^3/s)(2) would yield a dilution of 257:1 for the maximum effluent flow after complete mixing. Both of these post Kemano-Completion dilution predictions suggest that the future dilution of the effluent at low flow will still be high, resulting in minimal effects of regulated Bulkley River flow on water quality.

4.4 PROPOSED TELKWA COAL PROJECT

The proposed Telkwa Coal Project is located in the Goathorn Creek drainage of the Telkwa River (see Figure 6). It is currently in Stage II of the Mine Development Review Process.

Construction is currently planned for the late 1980's or early 1990's. The estimates of surface-mineable reserves are $50x10^6$ t, with plans to operate for a minimum of 20 years at a rate of $1.5x10^6$ t/y. Minimal blasting is predicted as most of the bedrock can be ripped. Cleaning of the coal will be required to remove ash and sulphur. About 250 people will be employed at full mine capacity. The population of neighboring Telkwa and Smithers will increase accordingly.

Site specific water quality objectives may be developed for surface waters adjacent to the mine (Goathorn Creek and the Telkwa River), based on the results of a baseline monitoring program submitted with the Stage II report. Objectives would be included late in Stage II or III when more information about the project is available, including the impact assessment and evaluation of water use.

Potential water quality problems from surface coal mining include: 1) suspended solids, turbidity, and sedimentation due to land disturbances; 2) nitrate, nitrite, ammonia, and algal growth due to use of explosives (blasting is predicted to be minimal so this impact may be minor); 3) acid mine drainage; and 4) abnormal groundwater quality.

The potential effects of the Telkwa Coal Project on downstream water quality are expected to be minimal, on both the Telkwa and Bulkley Rivers. The drainage area of Goathorn Creek, at the mine site, is 132 km^2. To put this area into perspective, this is only 11% of the drainage area of the Telkwa River at the mouth (1 210 km^2), and less than 2% of the drainage area of the Bulkley River before the confluence with the Telkwa River.

4.5 DIFFUSE SOURCES

4.5.1 LEACHATES FROM LANDFILLS

Landfills are described in Table 6 and the locations shown in Figure 6 by their permit numbers.

a) Perow (PR 3782)

This permit is held by the Regional District of Bulkley-Nechako for a landfill at Perow, about 20 km northeast of Houston. The site is located on a swampy plateau drained by Byman Creek which is about 1 km away. It is a single landfill site permitted to accept a maximum of

5.4 m^3/week of municipal and commercial refuse. It has a history of poor maintenance (scattered refuse, pit not regularly re-dug, occasional unpermitted burning, infrequent covering), although it has been compliant since July of 1982.

Byman Creek supports populations of Dolly Varden and cutthroat trout, and provides salmonid spawning habitat at its confluence with the Bulkley River. A monitoring program was implemented at four sites between 1976 and 1978 to ensure that no contamination of Byman Creek or its fishery was occurring due to leachates from the dump. These sites are shown in Figure 6, and include: 1) site 0400593, a culvert about 15 m north of the access road; 2) site 0400594, a culvert about 50 m south of the access road; 3) site 0400595, south corner of the refuse site; and 4) site 0400807, Byman Creek downstream from Perow loop (where Byman Creek flow direction changes from south to west). The data are summarized in Table 15. Only total copper and total iron exceeded working aquatic life criteria at site 0400807; 0.004 mg/L total copper, 3.2 mg/L total iron, compared to the criteria of 0.002 mg/L[20] and 0.3 to 1.0 mg/L[11], respectively. This occurred on April 25, 1978, when these metals could have been bound to suspended solids which were quite high (75 mg/L). No impact assessment is in the Waste Management Branch permit file PR 3782, nor have we attempted to draw any conclusions about the impact of this landfill on Byman Creek because of the paucity of data ($n \leq 2$) and lack of an upstream (control) site on Byman Creek.

b) Houston (PR 2687)

This permit is also held by the Regional District of Bulkley-Nechako. It is for a landfill site located south of Houston and about 1.6 km east of Buck Creek in an area of fine sands and gravels. It accepts up to 30 m^3/d of domestic and commercial refuse. A permit requirement is frequent covering and compaction, but no burning. Monitoring requires only periodic inspection by Waste Management Branch. No impact on the water quality of neighboring Buck Creek would be expected due to the distance from the landfill (1.6 km) and type of soils.

c) Telkwa (PR 2270)

Also held by the Regional District of Bulkley-Nechako, this permit is for domestic and commercial refuse from the Smithers and Telkwa region. It is located about 10 km south of Smithers. Up to 563 m^3/d of refuse is permitted in a single landfill, located in an area of silty gravel and clay about 200 m from the Bulkley River. Because this proximity gives the potential for leachates to affect water quality, a regular groundwater monitoring program with two wells was required by the Waste Management Branch in the 1983 permit. These wells have not yet been established.

4.5.2 OTHER DIFFUSE SOURCES

Other diffuse sources contributing nutrients and suspended sediments to the Bulkley River include:

a) Agricultural runoff, including livestock wastes, fertilizers and pesticides, and soils (suspended sediments) from erosion. There are extensive farmlands along the entire length of the Bulkley River upstream from Trout Creek, located about 20 km north of Smithers. The total area of cultivated land between Trout Creek and the junction with the Morice River is about 1 368 ha, with an additional 439 ha of cleared or built-up land(3). This is a total of 1 800 ha (18 km^2), and represents only 0.2-0.3% of the drainage area of the Bulkley River. Cultivated areas are mainly used for forage crops, vegetables, and to a lesser extent for grains. The amount of cultivated land on the Bulkley River upstream from the junction with the Morice River has not been determined; agricultural use in this area is primarily forage crops(54). An undetermined amount of agricultural runoff also occurs to lower Buck and Maxan Creeks.

b) Septic tank seepage from the Village of Telkwa.

The population of Telkwa was 840 in the 1981 census. Septic tanks and tile fields are used as the means of sewage treatment and disposal. The majority of the population is located in the Telkwa River drainage, well back from the Telkwa and Bulkley Rivers. The soils are poorly suited to this form of sewage treatment. Although the system appears adequate at present, some additional services may be recommended for the community plan by the Ministry of Municipal Affairs, particularly if the Telkwa Coal development proceeds (see section 4.4). At the present time, it is predicted that the effects of septic tanks on the Telkwa/-Bulkley River water quality are minimal, because of the small population and the large dilution available in the Telkwa and Bulkley Rivers.

c) Possible drainage from old abandoned mines on Bob and Dungate Creeks, tributaries to lower Buck Creek.

The possibility that there are leachates from these mines impacting Buck Creek water quality has not been investigated.

d) Erosion from logging and land clearing activities.

Logging has historically been active in the Bulkley River drainage, with a current allowable cut of 3 000 ha/year (30 km^2 or 0.25% of the Bulkley River drainage area)[14]. The effect of logging on water quality has not been determined.

Research elsewhere in North America has shown that changes in water quality from logging alone are relatively small, with the major exception being sediments[15]. One of the major causes of sediment in streams has been improper road construction to access the timber; poor construction techniques may cause surface erosion, mass soil-movement, and stream-channel erosion[16]. The major haul roads in the Bulkley River watershed that service the main logging areas near Houston and the Morice and Telkwa Rivers have been in place for years. One would expect the majority of erosion to be at new construction sites for new access roads in the Bulkley River drainage. The magnitude of sediment transport to streams from the logging harvest itself depends upon the site specific operation. The soil disturbance, the steep terrain, and wet weather make erosion and transport of sediments into streams probable[17].

The amount of broadcast-slash-burning following logging has not been quantified for the Bulkley River drainage. Changes in some water quality characteristics other than sediment might be expected following slash-burning. In particular, nitrogen and phosphorus could be released to surface water, becoming available for the growth of algae and aquatic plants in streams[15].

e) Forest Fires

There was an 1 800 ha (18 km^2) forest fire in the spring of 1983, in that area of the Bulkley River watershed bounded by Buck Creek, the Parrott Lakes, and the Morice River (Figure 6). This large area is currently being salvage logged. No attempt has been made to monitor the effect of this fire on the water quality of streams in the area.

Forest fires and slash burning can affect water quality. Besides an increase in suspended sediments and turbidity due to increased erosion, nutrient export can be increased. The impact on water quality of a spring fire, such as the 1 800 ha fire mentioned above, can be of short duration if vigorous regeneration of vegetation occurs which reduces sediment and nutrient losses to the aquatic environment. Fires occurring during the summer or early fall have the potential to burn more intensely, consequently exposing mineral soil to erosion and preventing the recycling of nutrients by vegetation[30].

Whereas losses of nitrate and other forms of nitrogen from undisturbed forest ecosystems appear to be negligible[31,33,34], nitrate-nitrogen in streamflow appears to increase during the first and second years following fires and slash burning[31,35]. Tiedemann and Helvey[32] reported a change from 0.015 mg/L maximum in a mountain stream before a fire to a maximum of 0.056 mg/L after a severe wildfire.

Fires also increase phosphorus export from a watershed, with concentrations elevated in the runoff for about two years. There appeared to be a negligible effect on a stream and a lake, however, for two fires that were studied [30,36]. This has been attributed to the transient and discontinuous nature of overland runoff, the adsorption of groundwater phosphorus to soils, and the usually quick revegetation following a spring fire[30]. Also, phosphorus from the fire in the Bulkley River watershed would be diluted quickly in the large flows of the Morice River, and rapidly incorporated into organic matter.

To put the area of this particular fire into perspective, it is only 3% of the drainage area of neighboring Buck Creek, 0.4% of the drainage area of the Morice River at the mouth, and only 0.3% of the drainage area of the Bulkley River immediately below the confluence with the Morice River. Although no water quality study was carried out to determine the impact of the fire, it is likely that small streams draining the fire (including Buck Creek) could have been affected, but not the larger Bulkley or Morice Rivers.

5. WATER QUALITY

The Ministry of Environment has begun to establish criteria for British Columbia which specify the Ministry policy respecting acceptable levels of water quality characteristics. Until approved criteria are established, working criteria have adopted from other jurisdictions for the purposes of assessing water quality and establishing provisional water quality objectives. The criteria eventually adopted as provincial policy may be different from the working criteria used here. Unless stated otherwise, criteria are expressed in this report as the concentrations of the characteristic in the total form rather than the dissolved.

The locations of sites discussed below are shown in Figure 6.

5.1 UPPER BULKLEY RIVER

5.1.1 OUTLET OF BULKLEY LAKE (SITE 0400200)

This site was sampled between 1972 and 1976, with the number of samples ranging from one to six, depending on the characteristic. The available data are summarized in Table 16.

The Bulkley River headwaters are soft, with hardness ranging from 25.9 to 37.0 mg/L (n=6). This is suitable for domestic use, although below the 80-100 mg/L hardness range considered acceptable by the British Columbia Ministry of Health[18]. Alkalinity was also low, ranging from 28.0 to 37.8 mg/L (n=4). This is within aquatic life criteria (>20 mg/L)[8] and irrigation criteria (<600 mg/L)[8]. Turbidity was within Canadian recreation criteria (<50 NTU)[55], but exceeded the maximum acceptable British Columbia drinking water standard of 5 NTU [18] on one occasion during freshet (9.2 NTU on June 14, 1974). All six of the turbidity measurements exceeded the objective level of 1 NTU for drinking water[18]. Additional sampling would be required to determine whether turbidity need be removed in water treatment to meet the Ministry of Health standard for drinking water.

Colour exceeded the British Columbia drinking water standard (15 TCU)[18] in all samples (maximum of 60 TCU; n=4). Similarly, tannin and lignin exceeded the detection threshold for taste and odour for drinking water (0.4 mg/L)[59] in the only sample analyzed (0.7 mg/L on September 11, 1972). Color and tannins and lignins reduce the aesthetic appeal of drinking water, but do not affect human health. The high level for these two characteristics could render the water aesthetically unappealing for the two domestic water licenses on the Upper Bulkley River in this area (see Figure 6).

Only one sample was analysed for fecal coliforms; 17 MPN/100 mL on September 11, 1972. The British Columbia drinking water standard suggests only disinfection when the 90th percentile of all samples is <10 fecal coliforms/100 mL[18]. There are too few data to determine what level of treatment is required prior to drinking, to protect the domestic users in the area.

Total iron equalled or exceeded the British Columbia drinking water standard (0.3 mg/L)[18] in all three samples, with a maximum of 0.6 mg/L. Dissolved iron was less than this standard in two different samples, indicating that some of the total iron may have been due to the iron content of soil particles, and thus not a problem. There are no samples with both analyses (total and dissolved iron) to assess the situation adequately. The drinking water standard for iron is based on aesthetic considerations rather than on human health.

One of five samples for total lead equalled the aquatic life criterion for soft water (0.005 mg/L)[19]. Analysis was not made of the dissolved fraction in these samples, which could have indicated the unavailable fraction of lead associated with suspended solids or particulate matter. Dissolved lead in two other samples was below the criterion.

Copper levels equalled or exceeded the aquatic life and wildlife criterion in soft water (0.002 mg/L)[20] in 3 of 5 samples, with a maximum of 0.015 mg/L dissolved copper on September 11, 1972. Such natural departures from aquatic life criteria are not unusual in B.C. waters because of widespread copper mineralization. It is unlikely that these copper levels are a problem for aquatic life in the Bulkley River. Copper levels were acceptable for other uses of the Upper Bulkley River, however, including drinking water, recreation, livestock watering, and irrigation.

Zinc levels also exceeded the aquatic life and wildlife criterion (0.05 mg/L for hardness 0-120 mg/L)[23], but only in 1 of 5 samples (0.09 mg/L dissolved zinc on September 11, 1972). These high copper and zinc levels should be investigated, in particular because of the possible synergism between the two[25,26]. Sampling would confirm whether or not relatively high levels are common. High levels of these two metals are noted elsewhere in the Bulkley River drainage (e.g., Morice River site 0400203 and Telkwa River site 0400187), suggesting copper/zinc mineralization in the watershed.

All other characteristics measured were within criteria for all water uses in this region of the Upper Bulkley River.

5.1.2 UPSTREAM FROM BUCK CREEK (SITE 0400201)

This site was also sampled between 1972 and 1976. The data are summarized in Table 17.

Compared to the outlet of Bulkley Lake (site 0400200), the water in the Bulkley River above Buck Creek increased in hardness, with values ranging from 34 to 92 mg/L (n=8), and increased in alkalinity, with values ranging from 36 to 97 mg/L (n=7). Turbidity was also higher, exceeding the maximum acceptable British Columbia drinking water standard (5 NTU)[18] during freshet (24 NTU June 14, 1974; 21 NTU June 2, 1975; 14 NTU July 5, 1976). All eight values exceeded the objective level of 1 NTU[18]. Turbidity would have to be removed to meet Ministry of Health drinking water standards for finished water (at the tap).

Color exceeded the British Columbia drinking water standard of 15 TCU[18] in 3 of 6 occasions, all during freshet. Although there are no domestic licenses in this area, there is a commercial water hauling operation (license CL-55785) that supplies water for domestic use. There may be aesthetic problems for users of this water during freshet.

There are too few fecal coliform data at site 0400201 (n=1; 13 MPN/100 mL on September 11, 1972) to determine whether disinfection is the only treatment required to meet the Ministry of Health drinking water standard (disinfection only is suggested if the 90th percentile is <10 fecal coliforms/100 mL)[18]. Further sampling should be done to protect the domestic users of the water provided by the water hauling license (CL-55785).

As at site 0400200 upstream, copper exceeded the aquatic life criterion (0.002 mg/L)[20] in 3 of 7 samples. Two of these were during freshet when the majority of copper could have been tied up with suspended sediments. The highest concentration recorded was 0.006 mg/L total copper on July 5, 1976. Unlike upstream site 0400200, zinc levels were below the aquatic life and wildlife criterion (0.05 mg/L)[23].

Iron levels exceeded the British Columbia drinking water standard (0.3 mg/L)[18] and aquatic life criteria (0.3-1.0 mg/L)[11] in 4 of 7 samples. The highest concentrations of total iron were 1.9 and 2.5 mg/L, during freshet when most of the iron could have been due to the iron content of suspended sediments which were also relatively high on the two dates (60 mg/L June 2, 1975; 28 mg/L July 5, 1976). Dissolved iron was less than or equal to the drinking water criterion, and thus iron may not be an aesthetic problem when the water is used for drinking.

Manganese exceeded the British Columbia drinking water standard (0.05 mg/L)[18] in 4 of 6 samples, with values ranging from <0.02 to 0.12 mg/L dissolved to 0.07 to 0.09 mg/L total manganese. Three of these four samples were taken during freshet. Manganese at these levels may cause aesthetic problems (e.g., laundry and fixture staining) if not removed prior to use for domestic purposes.

Only 1 of 7 samples had a total lead concentration equal to the 0.005 mg/L criterion for aquatic life[19]. All other concentrations were below detection limits for both the dissolved and total fractions. Some of this total lead may have been tied up with the suspended sediments of freshet (a relatively high 28 mg/L on July 5, 1976), which would leave the dissolved fraction that is available to aquatic life within the criterion.

All other characteristics measured met criteria for all other water uses.

5.1.3 HOUSTON AREA, SEWAGE TREATMENT PLANT (PE 287) INFLUENCE

Site 0400297, upstream from the sewage treatment plant discharge.

The available data from this site, sampled between 1974 and 1975, are summarized in Table 18.

In general, water chemistry was similar to that at site 0400201 upstream (section 5.1.2) from the confluence with Buck Creek. Turbidity was higher than the maximum acceptable drinking water standard (5 NTU)[18] in 1 of 2 samples (21 NTU on May 20, 1975). Copper exceeded the minimum aquatic life and wildlife criterion (0.002 mg/L)[20] also on that date (0.003 mg/L dissolved copper). Fecal coliform levels were higher than at upstream sites (although not necessarily significantly higher due to the wide confidence limits on MPN coliform values), varying from 8 to 70 MPN/100 mL. This result indicates that a partial level of treatment (filtration, or equivalent), followed by disinfection <u>may</u> be necessary to meet British Columbia Ministry of Health requirements[18] prior to drinking water use, but levels were within primary-contact recreation criteria (200-400 MPN/100 mL)[55].

Levels of other characteristics in Table 18 were suitable for all other water uses, during the period sampled.

<u>Site 0400295</u>, 100 m downstream from the sewage treatment plant discharge.

The available data for this site, sampled from 1974 to 1975, are also summarized in Table 18.

Turbidity exceeded the maximum acceptable British Columbia drinking water standard (5 NTU)[18] in 1 of 2 samples (23 NTU on May 20, 1975). This could not be attributed to the upstream discharge, however, but reflects freshet conditions.

Total ammonia-nitrogen was greater at downstream site 0400295 than at the upstream site 0400297 in 2 of 4 samples, and is attributed to the sewage discharge. Un-ionized ammonia-nitrogen concentrations (calculated) were still below criteria for aquatic life (0.007-0.030 mg/L as N)[27]. The maximum total ammonia value was 0.068 mg/L ammonia-N on June 25, 1975, compared to 0.038 mg/L at upstream site 0400297. This is much less than the theoretical maximum of 1.7 mg/L calculated in Section 4.2.

Nitrite-nitrogen was predicted to be a maximum of 0.056 mg/L in the Bulkley River under worst case conditions (Section 4.2). Limited data from this site (n=4) showed only one sample with nitrite-nitrogen concentration above the detection limit (0.005 mg/L); this was 0.007 mg/L. Further monitoring is required to determine whether levels of nitrite-nitrogen conflict with water use.

There was a slight increase in fecal coliforms downstream from the discharge in 2 of 3 samples (8 and 49 MPN/100 mL at upstream site 0400297, compared to 27 and 110 MPN/100 mL at downstream site 0400295). Again, these differences are probably not too significant due to the wide confidence limits on MPN coliform values. Nevertheless, increases in fecal coliforms downstream from the sewage discharge were not dramatic during the sampled period. Partial water treatment followed by disinfection would probably be required before drinking use to meet Ministry of Health requirements[18]. Fecal coliform levels were suitable for primary-contact recreation (200-400 MPN/100 mL criteria)[55]. Further monitoring of fecal coliforms is needed to confirm these conclusions as the theoretical maximum levels calculated in Section 4.2 suggested potential conflicts with water use.

Phosphorus concentrations were greater downstream from the discharge in all four samples taken in 1974 and 1975. Phosphorus concentration was quite high on one date (0.153 mg/L total phosphorus on September 24, 1974) in terms of algal growth requirements, although no analysis was done of the dissolved fraction. In the two samples for which analyses of both fractions are available, the majority of phosphorus was tied up as particulate, thus largely unavailable for algal growth (0.061 and 0.123 mg/L total phosphorus, compared to 0.02 and 0.014 mg/L orthophosphorus). Low ammonia-N and nitrate-N on those dates (0.68 mg/L and 0.01 mg/L ammonia-N; <0.02 mg/L Nitrate-N both dates) suggest that nitrogen was limiting, and also suggest that algae were not likely a problem. No sampling of algal biomass downstream from the Houston sewage discharge has been done to determine whether algae are in fact stimulated by the discharge.

As at upstream sites, dissolved copper continued to exceed the aquatic life and wildlife criterion (0.002 mg/L)[20] in the one sample taken May 20, 1975. The downstream concentration was greater than at the upstream (control) site 0400297 (0.005 compared with 0.003 mg/L). Although this would appear to be due to the sewage discharge, the dilution available in the Bulkley River in May (freshet) would make this unlikely. The difference is probably due to the variability in background river concentrations.

Site 0400296, 3.2 km downstream from the sewage treatment plant discharge.

The data collected for this site between 1974 and 1975, which can be compared with data from upstream sites 0400295 and 0400297 collected during the same period, are summarized in Table 18. The entire data record from 1974 to 1984 for site 0400296 is summarized in Table 19. Monthly sampling began in August of 1983 by the Waste Management Branch.

Turbidity exceeded the maximum acceptable British Columbia drinking water standard (5 NTU)[18] on the same date as the upstream sites previously mentioned (23 NTU at this site and 0400295 on May 20, 1975; 21 NTU at site 0400297).

As at site 0400295, fecal coliform levels were somewhat higher than at site 0400297 upstream from the Houston sewage discharge, meaning that water probably would require partial water treatment to meet Ministry of Health requirements[18]. The range in levels in the Bulkley River at this point (2-79 MPN/100 mL) shows suitability for primary-contact recreation (200-400 MPN/100 mL)[55] during the sampled period.

Dissolved ammonia-nitrogen concentrations were relatively high for the last 3 of 9 samples. These occurred on December 5, 1983 (0.15 mg/L), January 10, 1984 (0.203 mg/L), and February 6, 1984 (0.201 mg/L).

The concentration of un-ionized ammonia-nitrogen, the toxic form, is low at winter temperatures and Bulkley River pH[28] (temperatures <5°C, pH about 7.4) and below fresh water aquatic life criteria (0.007-0.030 mg/L)[27].

Phosphorus levels for site 0400296 as indicated in Tables 18 and 19 were quite high. Orthophosphorus ranged from 0.008-0.049 mg/L, and total dissolved phosphorus from 0.014-0.056 mg/L. Most of these high concentrations were during the no-growth winter period for algae, however. The only data from summer sampling are old: May 20 and June 25, 1975 (0.014 and 0.02 mg/L orthophosphorus, respectively). Nitrogen at these times was low, and probably limiting (0.013 and 0.052 mg/L ammonia-N; undetectable concentrations of nitrate-N). These historical data suggest that no algal problems were likely at that time. Future water samples at this site, and others on the Bulkley River, should be analyzed for all nitrogen and phosphorus species (nitrate is currently not always done), and a qualitative on-site assessment of the algal biomass should be made. These more complete nutrient and algal data could be of predictive value for the Bulkley River.

Aluminum exceeded the aquatic life criterion for fingerling trout (0.050 mg/L)[32] on December 5, 1983 (0.06 mg/L total aluminum), and both dissolved and total aluminum equalled the criterion on January 10, 1984. Natural aluminum levels in excess of the 0.05 mg/L criterion are quite common in the Bulkley River basin.

Copper exceeded the aquatic life criterion (0.002 mg/L)[23] on May 20, 1975, and October 6, 1983, with concentrations on both dates of 0.004 mg/L dissolved copper. These relatively high levels are similar to those reported for other upstream sites, reflecting copper mineralization which is common in British Columbia.

Iron equalled or exceeded the British Columbia drinking water standard (0.3 mg/L)[18] in 3 of 4 samples for total iron (maximum of 0.46 mg/L on January 10, 1984), but in only 1 of 4 samples for dissolved iron (0.32 mg/L, also on January 10, 1984). As levels of suspended solids were low for all occasions (3 mg/L) when iron exceeded the criterion, it was likely that iron was present in the water both in the dissolved form and as iron precipitates. It is also possible that some of the dissolved iron precipitated on the filter paper during the filtration step of the analysis, resulting in lower than actual concentrations for this fraction. Therefore iron may be an aesthetic problem in untreated water used for domestic purposes.

As at upstream site 0400201, manganese equalled or exceeded the British Columbia drinking water standard (0.05 mg/L)[18] in all four samples for total manganese and 3 of 5 samples for dissolved manganese (maximum of 0.09 mg/L on January 10, 1984, for both dissolved and total manganese). These levels may cause aesthetic problems (e.g., staining) if not removed from raw water prior to domestic use.

All other characteristics measured were suitable for all water uses.

<u>Site 0920089</u>, 4.5 km downstream from the sewage treatment plant discharge.

The data for site 0920089 are summarized in Table 19. These data were collected from 1972-1973 by the federal government, and in 1983 by the British Columbia Ministry of Environment (Waste Management Branch).

Turbidity continued to exceed the maximum acceptable drinking water standard (5 NTU)[18] during freshet (74 NTU on April 22, 33 NTU on May 18, and 7.7 NTU on June 29, 1971). There was also one relatively high value of 23 NTU on January 30, 1972.

Metals continued to exceed criteria for some uses of the Upper Bulkley River. Aluminum concentrations equalled or exceeded the aquatic life criterion (0.05 mg/L)[9] in two samples: 0.05 mg/L total aluminum on November 14, 1983, and 0.85 mg/L total aluminum on June 28, 1983. The latter high value includes 0.04 mg/L of the dissolved fraction, and at least part of the remaining aluminum would have been tied up with suspended solids characteristic of freshet, although there are no supporting data. Aluminum concentrations exceeding the aquatic life criterion were also noted at site 0400296, 1.3 km upstream.

Cadmium exceeded the aquatic life criterion for soft water (0.0002 mg/L)[21] for both dissolved and total cadmium on the first date this analysis was performed; 0.012 mg/L total cadmium, 0.0018 mg/L dissolved cadmium on June 28, 1983. High detection limits on November 14, 1983 (0.0005 mg/L) may have masked concentrations that on that date also exceeded this criterion. The minimum detection limit for cadmium should be at least as low as the criterion level, 0.0002 mg/L. The British Columbia drinking water standard (0.005 mg/L)[18] was exceeded in 1 of 4 samples (0.012 mg/L on June 28, 1983).

Copper exceeded the aquatic life criterion (0.002 mg/L)[20] in 1 of 7 samples; 0.004 mg/L total copper was measured on June 28, 1983. This higher level may have been associated with high levels of suspended solids during freshet.

Similarly, the single high value for iron (1.7 mg/L total iron) in excess of the drinking water and aquatic life criteria (0.3-1.0 mg/L)[11,18] was for the same date during freshet, June 28, 1983, and was probably due to the iron content of suspended solids. All seven dissolved iron values were low ($\leq$0.19 mg/L).

Only 1 of 6 lead samples had detectable levels (0.005 mg/L total lead), on June 28, 1983, during freshet. This level equalled the criterion for aquatic life[19].

Manganese levels equalled or exceeded the British Columbia drinking water standard (0.050 mg/L)[18] on December 1, 1970 (0.050 mg/L), and February 23, 1971 (0.070 mg/L), but was suitable for all water uses in the remaining samples.

Zinc levels were less than the criterion for aquatic life and wildlife (0.050 mg/L)[23] for all six samples from 1970-1972 and 1983. There are no samples between 1972 and 1976, however, when site 0400200 upstream had relatively high levels.

Levels of other characteristics met criteria for all uses of the Bulkley River.

5.2 MORICE RIVER SITE 0400203, Upstream from the Bulkley River.

This site was sampled infrequently between 1972 and 1976 ($n \leq 7$, depending on the characteristic), but has been sampled monthly since March of 1983 by the Waste Management Branch. Available data are summarized in Table 20.

Morice River flows at site 0400203 are much greater than Upper Bulkley River flows. The Morice:Upper Bulkley ratio of predicted low flows is about 22:1 to 75:1 (see Table 1). The drainage area of the Morice River at the mouth is 4 270 km^2, compared to 1 740 km^2 for the Upper Bulkey River.

Water at site 0400203 was soft (see Table 20), generally ranging from 18 to 24 mg/L hardness (n=17). One exception was 98 mg/L total hardness on June 1, 1983; this high value could have been attributed to high suspended solids during freshet (105 mg/L on that date). The water is softer than Upper Bulkley River water and similarly was below the 80-100 mg/L hardness range considered acceptable for domestic purposes[18]. Alkalinity was also lower than that of Upper Bulkley River water, ranging from 18.5 to 31.2 mg/L (n=18), but generally met the aquatic life criterion (>20 mg/L)[8] and the irrigation criterion (<600 mg/L)[8].

Turbidity exceeded the maximum acceptable British Columbia drinking water standard (5 NTU)[18] in 5 of 15 samples during freshet between 1974 and 1983, ranging from 7.4 to 44 NTU, indicating that treatment to remove turbidity would be necessary prior to drinking during freshet.

Ammonia and nitrate nitrogen and dissolved phosphorus concentrations in the Morice River at site 0400203 were low, approaching the limits of detection. Maximum concentrations were as follows: 0.013 mg/L ammonia-N on June 2, 1975 (n=15); 0.06 mg/L nitrate/nitrite-N on March 20, 1974 (n=17); undetectable orthophosphorus for all samples (n=9); 0.008 mg/L total dissolved phosphorus on March 4, 1983 (n=11).

Several metals in the Morice River at site 0400203 sometimes equalled or exceeded water use criteria. Frequently it was the total metal concentration (not the dissolved fraction) that exceeded criteria, and usually during freshet (April to July) when the majority of metal could be bound to the suspended solids which were relatively high during that period (10-105 mg/L). These metals and the relevant criteria are:

(i) Aluminum, aquatic life criterion of 0.05 mg/L[9]. The criterion was exceeded in 3 of 10 samples for dissolved aluminum, with a maximum of 0.17 mg/L on May 4, 1983. Six of 11 samples for total aluminum exceeded this criterion, with a maximum of 3.06 mg/L on June 1, 1983.

(ii) Copper, aquatic life criterion of 0.002 mg/L[20]. This criterion was equalled in 2 of 14 samples for dissolved copper, and exceeded in 10 of 13 samples for total copper with a maximum of 0.011 mg/L on July 5, 1976.

(iii) Iron, British Columbia drinking water standard of 0.3 mg/L[18], aquatic life criterion of 1.0 mg/L[11]. All samples were less than these two criteria for the dissolved iron fraction. Total iron exceeded the drinking water standard in 7 of

13 samples, and exceeded the aquatic life criterion in 3 of 13 samples, with the maximum concentration of 3.53 mg/L on June 1, 1983.

(iv) Lead, aquatic life criterion of 0.005 mg/L(19). This criterion was equalled or exceeded only infrequently; 1 of 14 samples for dissolved lead, 2 of 13 samples for total lead, both dissolved and total lead with the same maximum concentration of 0.007 mg/L on January 10, 1984.

(v) Manganese, British Columbia drinking water standard of 0.05 mg/L(18), aquatic life criteria of 0.1-1.0 mg/L(11). Dissolved manganese was undetectable in all samples (<0.2 mg/L; n=14). Total manganese exceeded the drinking water standard in 3 of 13 samples, and exceeded the lower limit of the aquatic life criteria on one occasion with a concentration of 0.15 mg/L on June 1, 1983.

(vi) Total zinc equalled the aquatic life criterion (0.05 mg/L)(23) in 1 of 17 samples, on November 14, 1983. All results for dissolved zinc were below the criterion (n=14).

Other characteristics sampled were within criteria for all water uses of the Morice and Bulkley Rivers.

5.3 BULKLEY RIVER AT QUICK, SITE 0920088

Sampling has occurred regularly at this site since 1966. It is the most intensively sampled site on the Bulkley River ($n \leq 99$). The available data are summarized in Table 21.

Bulkley River water at Quick continued to be soft, with hardness ranging from 18.7 to 46.9 mg/L (n=95). There was one anomalously low concentration of 4.2 mg/L on March 22, 1973. All values were less than the 80-100 mg/L range considered acceptable for drinking water[18], but the water is still suitable for this use. Alkalinity ranged from 3.3 to 47.6 mg/L (n=99), but was usually within the aquatic life criterion (>20 mg/L)[8] and the irrigation criterion (<600 mg/L)[8]. Turbidity ranged from 0.1 to 85 NTU (n=96), consistently exceeding the maximum acceptable drinking water standard (5 NTU)[18] during the April to June freshet period, indicating that treatment to remove turbidity prior to drinking would be necessary during freshet. Similarly, the highest levels of suspended solids were during freshet: 141 mg/L on April 27, 1971; and 178 mg/L on June 18, 1976. The remaining suspended solids data ranged from 19 to 57 mg/L, levels which provide good to moderate protection for aquatic life[29].

Nitrogen and phosphorus were at low levels. There is no evidence in the data that upstream nutrient sources (such as the sewage treatment plant discharge at Houston) are compromising water use, probably due to the high dilution in the Bulkley River at this point.

Levels of some metals were relatively high on occasion, with the potential for conflict with some water uses. Copper exceeded the aquatic life criterion (0.002 mg/L)[20] in 8 of 27 samples for the dissolved fraction (maximum measured concentration of 0.012 mg/L) and in 8 of 22 samples for total copper (maximum also of 0.012 mg/L). Although copper levels were high on some dates in the Upper Bulkley River, none of these dates correspond to high copper levels at Quick. Dilution of Upper Bulkley River water with the much higher flows of the Morice River would reduce copper levels to those below the aquatic use criterion (0.002 mg/L) at Quick. The Morice River, however, could be identified as the source of at least part of the copper in water samples at Quick on May 4, June 1, and October 6, 1983. Levels of copper in the Morice River were similar to those in the Upper Bulkley and both at times exceeded the criterion.

Dissolved iron approached the maximum allowed by the British Columbia drinking water standards (0.3 mg/L)[18] and aquatic life criteria (0.3-1.0 mg/L)[8,11] only once (maximum of 0.22 mg/L on May 4, 1983). Total iron exceeded the drinking water standard and the lower aquatic life criterion in 6 of 17 samples (maximum of 3.42 mg/L), all during freshet when the majority of iron would be due to the iron content of the suspended solids, and thus be of no significance to drinking water or aquatic life.

The majority of samples had undetectable levels for lead. The fresh water aquatic life criterion (0.005 mg/L)[19] was equalled or exceeded in only four samples: June 8, 1972 (0.01 mg/L dissolved lead); March 22, 1973 (0.009 mg/L total lead); October 8, 1975 (0.008 mg/L total lead); and June 28, 1983 (0.005 mg/L total lead). There are lead data both from the Morice River (maximum concentration of 0.005 mg/L) and Upper Bulkley River (0.007 mg/L maximum) which were very similar to the concentrations found at Quick.

Cadmium was undetectable for both the dissolved and total fractions in all samples except in the sample taken June 28, 1983, for which levels were 0.0018 mg/L and 0.012 mg/L, respectively. The concentration of total cadmium on that date exceeded the British Columbia drinking water standard (0.005 mg/L)[18], the aquatic life criterion (0.0002 mg/L)[21], and the recreation and irrigation criterion (0.010 mg/L)[21]. This anomalously high concentration corresponded with a high lead concentration (0.005 mg/L) on the same date, although levels of suspended solids were low (9 mg/L).

Dissolved aluminum levels exceeded the aquatic life criterion (0.05 mg/L)[29] and the primary-contact recreation criterion (0.1 mg/L)[29] in 2 of 11 samples: levels were 0.11 mg/L on July 24, 1967, and 0.26 mg/L on May 4, 1983. Total aluminum exceeded this criterion in 4 of 9 samples (maximum of 2.9 mg/L), mainly during freshet.

Total cobalt exceeded the aquatic life and irrigation criteria (0.050 mg/L)[29] in one sample, with a concentration of 0.15 mg/L on December 5, 1983. Detection limits were too high (0.1 mg/L) for the six other samples taken in 1983, and consequently may have masked other results exceeding these criteria. The minimum detectable concentration for cobalt analyses should be 0.005 mg/L so as to be consistent with these criteria.

Total manganese exceeded the British Columbia drinking water standard (0.05 mg/L)[18] in 5 of 37 samples, with a maximum of 0.15 mg/L on April 25, 1983. The lower limit of the aquatic life criteria (0.1-1.0 mg/L)[11] was also exceeded in 3 of 35 samples, with the same maximum as above. All these samples were during freshet when the manganese content of the suspended sediments could have been high.

Total nickel exceeded the aquatic life criterion for soft water (0.025 mg/L)[22] in only 1 of 4 samples, with a concentration of 0.06 mg/L on December 5, 1983. High detection limits in the remaining seven samples in 1983 may have masked other results exceeding this criterion. The minimum detectable concentration for nickel analyses should be changed to 0.010 mg/L to be consistent with the aquatic life criterion.

Total zinc exceeded the aquatic life criterion (0.050 mg/L)[23] in 1 of 28 samples, with a level of 0.13 mg/L on March 22, 1973.

Analyses were also made for polychlorinated biphenyls and several pesticides in 1974 (one or two samples, depending on the characteristic). All results were below limits of detection, and therefore were not included in Table 21.

All other characteristics measured at Quick met criteria for known uses of the Bulkley River.

5.4 TELKWA RIVER, SITE 0400187

The Telkwa River flows into the Bulkley River at Telkwa. The drainage area of the Telkwa River at the mouth is 1 210 km^2, or 13% of the drainage area of the Bulkley River at Smithers. Comparison of low flows from Table 1 shows the Telkwa River to be about 22% of the Bulkley River at Quick.

The available water quality data for the Telkwa River at the mouth at site 0400187 (see Figure 6) are summarized in Table 22. These data show Telkwa River water to be soft, ranging from 20.6 to 63.2 mg/L hardness, which is similar to Bulkley River water, and consequently less than the 80-100 mg/L considered acceptable for domestic purposes[18]. The alkalinity is higher, however, ranging from 22.1 to 64.5 mg/L and consequently suitable for aquatic life (>20 mg/L criterion)[8]. Turbidity ranged from 1.1 to 180 NTU with the high levels occurring during freshet. Some turbidity would have to be removed to meet the maximum acceptable British Columbia drinking water standard (5 NTU)[18]. Suspended solids ranged from 1 to 424 mg/L, the maximum value corresponding with the highest turbidity of 180 NTU on June 2, 1975, during freshet. Color frequently exceeded the British Columbia drinking water standard (15 TCU)[18] during freshet, with the maximum of 60 TCU occurring June 2, 1975.

Nitrogen and phosphorus concentrations at site 0400187 were low, generally not detectable. The levels of some metals, however, were relatively high. Levels of dissolved copper equalled or marginally exceeded the aquatic life criterion (0.002 mg/L)[20] in 4 of 13 samples, with a maximum of 0.003 mg/L on May 4 and October 6, 1983. Total copper levels were higher, with 6 of 14 values exceeding the criterion, and a maximum of 0.02 mg/L. Similar levels of copper in excess of the aquatic life criterion occurred elsewhere in the Bulkley and Morice Rivers, and as mentioned previously, are found frequently in British Columbia due to widespread copper mineralization.

Aluminum frequently exceeded aquatic life criteria (0.050-0.1 mg/L)[30] for the dissolved fraction (0.22 mg/L maximum on May 4, 1983) as well as total aluminum (5.4 mg/L maximum on June 1, 1983). The highest concentrations of total aluminum were during freshet, apparently due to the aluminum content of the suspended sediments (the maximum suspended solids of 424 mg/L was on June 2, 1975). The primary-contact recreation criterion of 0.1 mg/L[76] was also exceeded on several occasions.

Total chromium equalled the lower limit of the aquatic life criteria (0.020-0.040 mg/L)[24] in 1 of 14 samples; that sample was taken November 14, 1983.

Cobalt exceeded the aquatic life as well as the irrigation criterion (both 0.050 mg/L)[29] in 1 of 11 samples with a level of 0.13 mg/L total cobalt on November 14, 1983. The minimum detectable concentration of 0.1 mg/L is too high, and could be masking other occasions when the criterion is exceeded. It has been suggested earlier in this report that the minimum detectable concentration should be reduced to 0.005 mg/L to be consistent with these criteria.

One of 13 dissolved iron values (0.94 mg/L) exceeded the drinking water and aquatic life criteria of 0.3 mg/L[8,11,18] during freshet on June 28, 1983. Total iron values were much higher with 9 of 14 exceeding these criteria, and a maximum of 18.4 mg/L recorded during freshet on June 2, 1975. Paired dissolved iron, total iron, and suspended solids or turbidity values show that with the one exception mentioned above, the iron is present mainly in the particulate form, and is associated with elevated levels of suspended sediment. The iron bound in sediment particles is not significant to drinking water or aquatic life.

Lead levels exceeded the aquatic life criterion for soft water (0.005 mg/L)[19] in 1 of 14 samples, with a level of 0.006 mg/L total lead on June 1, 1983. This high level was associated with high suspended solids on that date.

Total manganese exceeded the British Columbia drinking water standard (0.050 mg/L)[18] in 4 of 13 samples with a maximum of 0.5 mg/L on June 2, 1975. These high levels were associated with high levels of suspended solids during those four days during freshet.

Molybdenum equalled the continuous use irrigation criterion (0.01 mg/L)[29] in two samples during the irrigation season, and exceeded the criterion in 1 of 12 samples, with a level of 0.03 mg/L on November 14, 1983, during the non-irrigation season.

All the recent sample analyses for nickel used an 0.05 mg/L detection limit. The aquatic life criterion for nickel, however, is 0.025 mg/L[26]. As suggested previously in this report, the detection limit should be changed to 0.010 mg/L to be consistent with the aquatic life criterion.

All other characteristics measured were below criteria for all known uses of the Telkwa and Bulkley Rivers.

5.5 BULKLEY RIVER AT SMITHERS

There are four water quality sites near Smithers. These include: site 0400204, about 8 km upstream from the sewage treatment plant discharge (PE 373); site 0400434, the control site just upstream from the discharge; site 0400435, 100 m downstream; and site 0400436, 1.2 km downstream (see Figure 6). The historical data for upstream site 0400204 (1966-1976; n=23) are summarized in Table 23. The few historical data from the three sites 0400434, 0400435, and 0400436, used to monitor the old sewage treatment plant, are summarized in Table 24. Two of these sites, 0400434 and 0400435, were sampled during 1983 and 1984 to monitor the performance of the new treatment facility; these data are summarized in Table 25.

Historical data from these four sites are similar to those from upstream sites, showing Bulkley River water to be soft (<50 mg/L hardness; except 81.1 mg/L on March 20, 1974 at site 0400204), low in alkalinity (<40 mg/L; except 82 mg/L on March 20, 1974, also at site 0400204), and with turbidity exceeding the maximum acceptable drinking water standard (5 NTU)[18] during freshet, indicating that turbidity removal prior to drinking would be necessary during freshet. Color continued to exceed the drinking water standard (15 TCU)[18] during freshet at all four sites.

Several characteristics are noteworthy at site 0400204 (Table 23), the site most intensively sampled of the four. These include:

(i) Suspended solids, which were very high during freshet, with a maximum of 327 mg/L on June 2, 1975. Turbidity was correspondingly higher than the 5 NTU maximum acceptable drinking water standard[18], indicating that some of the suspended solids/turbidity would have to be removed before drinking to meet Ministry of Health guidelines.

(ii) Copper, which frequently equalled or exceeded the aquatic life and wildlife criteria (0.002 mg/L)[20], as did the three other downstream sites: the maximum concentration of dissolved copper was at site 0400204, with a concentration of 0.004 mg/L on November 25, 1971.

(iii) Iron, with concentrations exceeding the British Columbia drinking water standard and the aquatic life criterion (0.3 mg/L)[18,77] in 3 of 5 samples for total iron, with a maximum of 11.3 mg/L on June 2, 1975. The majority of the iron would have been due to the iron content of suspended sediment and thus not important.

(iv) Lead, in excess of the aquatic life criterion (0.005mg/L)[19], was found in 1 of 8 samples; 0.017 mg/L dissolved lead on August 17, 1971.

(v) Manganese, which exceeded the British Columbia drinking water standard (0.05 mg/L)[18] and the lower limit of the aquatic life criteria (0.1-1.0 mg/L)[11] in 2 of 5 samples for total manganese, with a maximum of 0.34 mg/L on June 2, 1975. These high levels may not be important due to their association with high levels of suspended sediment during freshet.

The new sewage treatment plant at Smithers was designed to replace the old facility because of its poor performance. There are not enough receiving environment data to determine if there was environmental degradation due to the old sewage treatment plant. Biannual concurrent sampling at Bulkley River low flows by Waste Management Branch at sites 0400434 (control) and 0400435, together with the sewage treatment plant discharge, should provide the data required to evaluate the new facility.

Analysis of the first sample taken November 30, 1983, (see Table 25) showed an elevation in total ammonia at the end of the initial dilution zone (site 0400435), but only along the left bank (Zone 1 in Table 25). There were four sample points across the width of the river and the left bank showed 0.038 mg/L compared with undetectable levels at the control site 0400434. This level of total ammonia represents an un-ionized ammonia level of <0.001 mg/L which is within the aquatic life criteria for un-ionized NH_3-N of 0.007-0.030 mg/L[27]. Kjeldahl-N and total phosphorus were also slightly elevated on the left bank at upstream site 0400434, although levels were still low. On April 11, 1984, levels of total phosphorus and suspended solids were greater at site 0400435 than at upstream control site 0400434, but again only along the left bank. From these limited data (n=2) it would appear that the sewage discharge is not always completely mixed at the end of the 100 m initial dilution zone (site 0400435). Apparently there is strong mixing at the river shallows about 50 m below site 0400435, so that no significant elevations would be expected in the characteristics measured beyond about 150 m downstream from the discharge. These small increases would be as predicted in section 4.3, with no water use conflicts expected.

Although total coliforms were elevated at Zone 1 of site 0400435 on November 30, 1983 (230 MPN/100 mL compared to 9 MPN/100 mL at upstream site 0400434), there was no significant elevation in fecal coliforms downstream from the sewage discharge either on that date or April 11, 1984 (see Table 25). This is in agreement with section 4.3 that predicted minimal increases in fecal coliforms downstream from the discharge (2-3/100 mL). Levels of fecal coliforms at both sites 0400434 and 0400435 were within guidelines for primary-contact recreation (200-400 fecal coliforms/100 mL)[55] on the dates sampled.

5.6 BULKLEY RIVER WATER QUALITY, POST KEMANO-COMPLETION

The proposed Kemano-Completion Project, with the damming of the Nanika River and consequent reduction in Bulkley River flows, will not significantly change water quality in the Bulkley River. Most of the water stored behind the Nanika dam would be withdrawn from peak streamflow in late spring and early summer (see Figure 2). Remaining flows and subsequent dilution of downstream effluents at that time of year will still be high. The main impact of effluents on water quality is usually expected at low river flows when the resulting dilution is lowest. The minimum monthly post Kemano-Completion data from Alcan[2] predict that the quantity of water released at the Nanika dam will be slightly higher than normal during the period of low flow (February to April). This would result in slightly higher dilution of effluents than under unregulated flow conditions. For example, the predicted dilution of the treated sewage from the plant at Smithers, using the predicted minimum mean monthly post Kemano-Completion Bulkley River flow (13.9 m^3/s)[2], is between 111:1 and 286:1 (depending on the flow of treated sewage discharged; see Table 7). The natural mean monthly low flow is 12.1 $m^3/s^{(2)}$, which results in a lesser dilution of between 97:1 and 249:1, under the same effluent discharge conditions.

It is difficult to predict the effect of reduced peak flows (late spring to early summer) in the Morice River on downstream Bulkley River water quality. Whereas the Morice River contributes about 70% of the total drainage area above the confluence with the Upper Bulkley River (6 010 km^2 total), it contributes about 92% to the total Bulkley River flow below the confluence under natural conditions (natural mean June flow of the Morice River at the mouth ÷ the total flow including that of the Upper Bulkley River mean flow x 100; or 329.3 $m^3/s^{(2)}$/329.3 m^3/s + 28.1 $m^3/s^{(6)}$ x 100). This contribution is reduced to about 90% of the total flow downstream from the confluence with the Upper Bulkley River following Kemano-Completion (predicted mean June flow of the Morice River at the mouth ÷ the total flow including the Upper Bulkley River natural mean June flow x 100; or 253.2 $m^3/s^{(2)}$/253.2 m^3/s + 28.1 m^3/s x 100). Because the water quality of the two rivers is similar (generally nutrient poor, but with some metals exceeding water quality criteria, primarily during freshet due to the high levels of suspended solids), this slight reduction from 92% to 90% in contribution of peak flows from the Morice River is not expected to lower water quality downstream from the confluence with the Upper Bulkley River.

It is likely that the concentration of some metals associated with high concentrations of suspended solids during freshet will be increased with the flow reductions proposed by Alcan after the Kemano-Completion project. Although data for suspended solids at the outlet of Bulkley Lake (site 0400200) are few (n=2), suspended solids loadings to the Morice and Bulkley Rivers from the lake are expected to be low. The majority of suspended solids in the Morice River just upstream from the confluence with the Bulkley River (site 0400203; maximum of 105 mg/L suspended solids on June 1, 1983) is due to inflowing tributaries.

Reduced flows from Morice Lake would provide less dilution of inflowing tributary water; thus Kemano-Completion could increase the concentration of heavy metals in the Morice and Bulkley Rivers, some of which already tend to exceed use criteria during freshet.

Temporarily elevated mercury levels are expected in the Morice and Bulkley Rivers with Kemano-Completion, due to the formation of the new Nanika-Kidprice Reservoir in the headwaters. A dam will be constructed at the outlet of Kidprice Lake, diverting about 62% of the mean annual flow from the Nanika River to the Nechako Reservoir, with the remaining 38% released at the dam(66). Elevated mercury levels, in particular the postimpoundment mercury levels in predatory fish, are expected, and would appear to be related to the size of the increase in lake area (amount of flooding) compared to the preimpoundment lake area(67,68). Mercury levels in resident fish are expected to increase in the new reservoir within two to three years, in particular in the Kidprice basin where there will be a 209% increase in surface area of the former Kidprice Lake(66). Envirocon(66) stated that the potential for mercury contamination within the new (Nanika-Kidprice) reservoir will be increased due to the high mercury level in its soils which are within the North American mercuriferous belt (detailed in Sherbin(70)). Envirocon predicts that fishing in the new reservoir will have to be prohibited until mercury levels in sport-fish are below the limit for human consumption (0.5 mg/ kg)(69). The effect of these postimpoundment mercury levels on downstream water quality of the Morice and Bulkley Rivers is unknown. Dilution would reduce the effect of the contaminant. However, dilutions will be about 5:1 at the outlet of Morice Lake, 9:1 at the mouth (junction with the Bulkley River), and 11:1 at Quick, all based on predicted yearly average flows from Alcan with Kemano-Completion(2).

A temporary upsurge in the level of phosphorus is usually expected in new reservoirs(72), including the Nanika-Kidprice Reservoir proposed with Kemano-Completion. The increase can be as much as an order of magnitude in the first two or three years followed by decline to a stabilized trophic state. It is due to direct leaching as well as biological release from flooded vegetation and soils [73]. Although phytoplankton typically increase two to threefold[74] with the increase of nutrients, Envirocon[66] predicts an order of magnitude increase within the first two years followed by decline to current levels within five to six years. The impact on downstream water quality is not known, although the dilutions discussed above would similarly reduce these impacts.

5.7 WATER QUALITY OBJECTIVES FOR THE BULKLEY RIVER

In general, water in the Bulkley and Morice Rivers was shown to be soft, low in alkalinity and nutrients, and with turbidity and color exceeding drinking water standards during freshet. Several metals equalled or exceeded aquatic use criteria, usually during freshet (April to July) when the majority of metal would be bound to suspended solids. These metals included aluminum, cobalt, cadmium, chromium, copper, iron, manganese, nickel, lead, and zinc. These results suggest that the capacity of the Bulkley and Morice Rivers to accept further inputs of metals from future developments may be limited during freshet unless it is shown that the binding of these metals to suspended solids renders them harmless to the designated uses.

The proposed designated water uses for the Bulkley and Morice Rivers include aquatic life (fisheries) and wildlife, irrigation, livestock watering, industrial use, and primary-contact recreation throughout the rivers, from the headwaters at Bulkley and Morice Lakes to the junction with the Skeena River at Hazelton.

Irrigation is proposed as a designated use throughout the Bulkley and Morice Rivers to protect future options. Although there are no irrigation licenses between the confluence with the Morice River and Bulkley Lake, there is increasing demand for irrigation water to increase hay production. Neither are there irrigation licenses downstream from Smithers, as licensed use of inflowing creeks is more practical than pumping water uphill from the Bulkley River. Drinking water is a proposed designated use for certain reaches of the Morice and Bulkley Rivers, including: (1) Upper Bulkley River from Buck Creek upstream to Bulkley Lake, and (2) the Morice River from the outlet of Morice Lake, past the junction with the Upper Bulkley River, downstream to Smithers. Excluded are two reaches, which are: (1) the Bulkley River downstream from Buck Creek and the Houston sewage discharge to the mouth of the Morice River. Although there are no domestic (drinking) water licenses on this reach, industrial license CL55785 is used for hauling water to domestic-use customers; (2) the Bulkely River downstream from the Smithers sewage discharge to the Skeena River. There is probably some unlicensed drinking water use in this area by the Indians on the reserves at Moricetown.

Provisional water quality objectives are proposed for the Morice and Bulkley Rivers. The objectives are based on Ministry criteria as well as preliminary working criteria for water quality and on available data on ambient water quality, waste discharges, water uses and river flows. The objectives will remain provisional until receiving water monitoring programs provide adequate data, and the Ministry has established approved water quality criteria for all the characteristics of concern.

The objectives can be considered as policy guidelines for resource managers to protect water uses in the specified water bodies. For example, they can be used to draw up waste management permits and plans, regulate water use or plan fisheries management. They can also provide a reference against which the state of water quality in a particular water body can be checked.

Water quality objectives have no legal standing and their direct enforcement would not be practical. This would be due to the difficulty of accurately measuring contaminants in receiving water and attributing the contamination exceeding the objective to particular sources for legal purposes, and thus of proving violations and their causes. Hence, although water quality objectives should be used when determining effluent permit limits, they should not be incorporated as part of the conditions in a waste management permit.

Depending on the circumstances, water quality objectives may already be met in a water body, or may describe water quality conditions which can be met in the future. To limit the scope of the work, objectives are only being prepared for waterbodies and for water quality characteristics which may be affected by man's activity, now and in the foreseeable future.

Characteristics of Concern:

The provisional water quality objectives proposed apply everywhere in reaches where designated uses apply, except in the defined initial dilution zones of waste discharges. These zones can extend up to 100 m downstream from any effluent discharge, but are not to exceed more than 25% of the width of the river.

a) Fecal contamination, primarily from the sewage treatment plants at Houston and Smithers.

This is indicated by fecal coliforms. The British Columbia drinking water standard infers a 90th percentile <10 fecal coliforms/ 100 mL[18] to protect drinking water use with disinfection only. Primary-contact recreation criteria are 200 (geometric mean) to 400 (90th percentile) fecal coliforms/100 mL[40]. Secondary-contact recreation criteria are 1 000 fecal coliforms/100 mL (90th percentile) in not less than five samples in any consecutive 30-day period[41]. Irrigation and livestock watering criteria are 1 000 (geometric mean) to 4 000 or 5 000 (maximum) fecal coliforms/100 mL[61].

The recommended provisional objective is a 90th percentile of <10 fecal coliforms/100 mL in any 30-day period to protect drinking water use in those reaches of the Bulkley and Morice Rivers from Bulkley Lake to Houston and downstream from Morice Lake to Smithers, designated for drinking water use. This objective would allow disinfection as the only water treatment required before drinking. A provisional objective of 200 (geometric mean for 30 days) to 400 (90th percentile in a 30-day period) fecal coliform/100 mL is proposed for the remaining two reaches of the Bulkley River, downstream from Houston to the Morice River, and from Smithers to the Skeena River, to protect primary-contact recreation. Although the data are few, it appears that these objectives have been met in the past. More data are required for a complete assessment, however, and to confirm the objectives. It is improbable that the drinking water objective could be met either: 1) immediately downstream from the sewage discharge at Houston because of the low dilution at certain times of the year, or 2) downstream from the Smithers sewage discharge unless chlorination was added to the treatment facility. These provisional objectives will be reconsidered when more data are available, or if it is decided that drinking water is to be a protected use in either of the two reaches where the objective is in place to protect recreation but not drinking water.

As stated in section 3.1, water license CL-55785 is for commercial water hauling primarily to domestic customers. One of the four licensed points of withdrawal is downstream from the Houston sewage discharge, where the provisional fecal coliform objective to protect recreation is proposed. As this objective does not protect drinking water, and water for this use could require more complete treatment (not just disinfection), the licensee (Teniers Enterprises Ltd.) should be informed that water from this particular reach of the Bulkley River may need more than disinfection before drinking water use.

b) Periphyton Standing Crop

The periphyton criteria for British Columbia streams are that the standing crop from natural substrates be less than 50 mg/m² chlorophyll *a* to protect recreation, and less than 100 mg/m² chlorophyll *a* to protect aquatic life from excessive standing crops[38]. The recommended provisional objective for periphyton in the Morice and Bulkley Rivers is 50 mg/m² chlorophyll *a* to protect recreation. There are no data to determine whether this provisional objective has been met historically in either the Morice or Bulkley Rivers.

c) Particulate Matter

The criteria for protecting aquatic life in British Columbia from excessive particulate matter due to anthropogenic sources are expressed in terms of turbidity and suspended solids by Singleton[39]. Induced turbidity should not exceed 5 NTU when background turbidity is ≦50 NTU, nor should induced turbidity be more than 10% of background when background is >50 NTU; induced suspended solids should not exceed 10 mg/L when background levels are ≦100 mg/L nor should induced suspended solids be more than 10% of background when background is >100 mg/L.

The recommended provisional objectives for turbidity and suspended solids are the above criteria, to protect aquatic life throughout the Morice and Bulkley Rivers. Data are too few from the Bulkley River at the Smithers and Houston sewage discharges to determine whether these objectives have been met historically (the new facility at Smithers began operation in November of 1983). The objectives will be confirmed or reconsidered when new data are available.

d) Dissolved Oxygen

Criteria for dissolved oxygen have been set by other jurisdictions. Variables considered often include the following: 1) the different sensitivities of fish species and life stages to low oxygen concentration, 2) the increase in sensitivity by stress factors (e.g. high temperature, toxicants), 3) the level of risk that is considered acceptable, 4) the choice of units (percent saturation versus milligrams per liter), and 5) the choice of mean versus instantaneous minimum concentration. Although a single guideline criterion expressed as milligrams per liter may be simplistic and restrictive it is the preference of some agencies, including: 1) The State of Alaska[40], which has established an aquatic life and wildlife criterion at >7 mg/L dissolved oxygen for freshwater used by anadromous fish, 2) the State of Idaho[41] which has set a criterion for salmonid spawning and incubation periods of >6 mg/L dissolved oxygen or 90% saturation, whichever is greater.

In contrast, the criteria of Davis[62] are quite detailed and differentiate between fish populations (Canadian species), temperature, and level of risk. The criteria are in units of percent saturation. At low temperature, the criterion is that percent saturation that provides the partial pressure of oxyen essential for maintaining the necessary oxygen tension gradient in the gills for proper gas exchange (oxygen partial pressure of 120 mm Hg at sea level). At high temperature the criterion is that percent saturation that provides sufficient oxygen to meet the requirements of respiration as defined by the incipient oxygen response level; this is the concentration where reduced oxygen effects first become apparent (high degree of protection for salmonids: 7.75 mg/L). Sigma[78] reviewed these criteria for application to fish hatchery operations and determined that, for a given level of protection, a single minimum concentration criterion (mg/L) could be specified for all temperataures. The rationale included the following: (1) the decrease in rate of diffusion of oxygen at the gills at low temperatures is more than offset by the decrease in rate of oxygen consumption for metabolism at low temperatures; (2) the affinity of hemoglobin for oxygen increases at low temperatures, and the oxygen transport system within the fish is facilitated; and (3) the oxygen reponse threshold is not clearly related to temperature.

The proposed provisional objectives for the Bulkley and Morice Rivers is a minimum of 7.8 mg/L to protect fisheries, which is that concentration of oxygen from Davis[62] which provides a high level of protection for salmonids at high temperature (7.75 mg/L rounded off to 7.8 mg/L for field use). Although data are few (n=3), this objective has been met downstream from both the sewage treatment plants at Houston and Smithers; the minimum dissolved oxygen concentrations were 9.45 mg/L at Houston site 0400295, and 10.7 mg/L at Smithers site 0400435, both sampled July 10, 1974. Although the solubility of oxygen increases at low temperature, it is possible that dissolved oxygen concentrations in the Bulkley River at certain times are lower during the winter than those reported, due to low flows and possible ice cover conditions.

e) Un-ionized Ammonia

Studies have shown that the un-ionized ammonia molecule and not the ammonium ion is the form of ammonia toxic to fish[63,64]. The proposed provisional objectives for un-ionized ammonia in the Morice and Bulkley Rivers are based on the criteria developed by Pommen[27] from a study in British Columbia: an average of 0.007 mg/L or less over a period of 30 days and a maximum of 0.030 mg/L at any one time. Historical data are too few to determine whether these objectives have been met downstream from the sewage discharges at Houston and Smithers. These objectives will be confirmed or reconsidered when new data are available.

f) Nitrite

The British Columbia drinking water standard for nitrite nitrogen is 1.0 mg/L[18]. The standard was developed to protect infants from methemoglobinemia which occurs when nitrite combines with haemoglobin, reducing the oxygen carrying capacity of the blood[8]. Aquatic life criteria reflect the high toxicity of nitrite to fish. The mechanism of toxicity is the same as for humans. Nitrite is very toxic to cutthroat and rainbow trout[42,43], both found in the Bulkley River. B.C. Research[44] recommended 0.020 mg/L nitrite-nitrogen as the maximum level acceptable for salmonids for prolonged periods. The U.S. Environmental Protection Agency[8] found 0.060 mg/L as the maximum level to avoid mortality to fish after 10 days.

Provisional objectives for nitrite are proposed for the Bulkley and Morice Rivers of 0.020 mg/L nitrite-nitrogen (averaged over 30 days) and a maximum of 0.060 mg/L to protect fisheries. The limited historical data from sites downstream from the treated sewage discharges at Houston and Smithers indicate that these objectives have been met. The maximum recorded concentration was 0.007 mg/L nitrite-nitrogen at site 0400295 downstream from the Houston sewage discharge.

g) Residual Chlorine

Total residual chlorine is equal to the sum of the free residual chlorine (HOCl, -OCl, Cl_2) and the combined residual chlorine (inorganic and some organic chloramines). This measurement has been considered sufficient to define chlorine toxicity to aquatic organisms[45].

An aquatic life criterion of 0.002 mg/L maximum total residual chlorine to protect trout and salmonid species has been recommended by various jurisdictions[8,45,46,47,48]. This criterion (0.002 mg/L) is proposed as the provisional objective for total residual chlorine for the Bulkley River.

Since the objective is less than the minimum detectable concentration, it will be necessary to estimate the receiving water concentration using effluent loading and stream flow downstream from sewage treatment plants that discharge chlorinated effluent; currently this applies only to Houston. The maximum total residual chlorine concentration in the final effluent at Houston which would be allowable to meet this objective at the mimimum 10:1 dilution (specified by permit PE 287) is 0.02 mg/L. The permit presently allows 0.1 to 1.0 mg/L in the final effluent which at minimum Bulkley River flows (10:1 dilution) could theoretically result in 0.01 to 0.10 mg/L total residual chlorine in the river, levels which exceed the objective. A dechlorination facility should be considered for the Houston sewage treatment plant to protect the fishery during winter low flows. Chlorination is necessary to protect recreation and drinking water use (downstream from Morice River) from fecal contamination.

A 1.0 mg/L total chlorine residual in the effluent at Houston would require a 500:1 dilution to reduce it to the objective of 0.002 mg/L in the Bulkley River. Given an effluent flow of about 0.02 m^3/s (section 4.2), dechlorination would be necessary to meet the objective at combined river and effluent flows of less than about 10 m^3/s (0.02 m^3/s x 500). Combined flows of greater than 10 m^3/s occur only in May and June, and thus dechlorination would be needed for the rest of the year.

Total residual chlorine must be measured in the field as soon as samples are collected because of its unstable nature. Measurements in the final effluent at the plant can be made to 0.05 mg/L with a precision of ±48% (i.e., 0.03 to 0.07 mg/L), if the modification to the Fischer and Porter amperometric titration technique as recommended by Cook(49) is used. The analysis would be sensitive enough to monitor total residual chlorine levels at the treatment plant and, together with effluent flows and flows in the Bulkley River, allow theoretical estimates of concentrations in the receiving environment to check the objective (0.002 mg/L).

Sampling of the Bulkley River to monitor for the total residual chlorine objective in addition to what is proposed above is not recommended. Although Walker(50) has stated that field measurements can be read to 0.04 mg/L with <u>careful</u> use of the Hach kit colorimetric technique, field measurements are usually too crude.

h) Mercury

No water quality objective is proposed for mercury because elevated levels will be due to uncontrollable circumstances if Kemano-Completion proceeds. It is recommended that the guidelines reported by Environment Canada(71) be used as alert levels for possible water use restrictions in the Morice and Bulkley Rivers. These levels for total mercury are maxima of: 0.5 µg/g wet weight in fish tissue and 0.0001 mg/L in water to protect consumers of fish; 0.001 mg/L for drinking water and recreation; and 0.003 mg/L to protect livestock and wildlife.

5.8 MONITORING RECOMMENDATIONS

The recommended effluent and water quality monitoring for the Bulkley River is outlined in Table 26. Recommendations are made from a technical perspective and the extent of the monitoring will be determined by the overall priorities and monitoring resources available. This monitoring is recommended primarily to support the provisional objectives and to determine whether the objectives are being met at monitored sites in the Bulkley River. The recommended monitoring program will also provide data for future objectives.

Coordinated sampling of waste discharges and the receiving environment is currently carried out by Waste Management Branch. It is recommended that any sampling agencies continue this practice so that cause and effect relationships can be determined.

The recommended sampling for fecal coliforms at Houston and Smithers (at least 1 sample per week for 5 weeks in a period no longer than 30 days) should occur during the summer low flow period (August-September) when both recreational use and drinking water use are significant. Although this will not show whether the drinking water objective is being met during the winter lowest flow period (February), sampling of the required frequency in winter is impractical above Houston (total ice conditions; water only from wells) and extremely hazardous at Smithers (ice cover). Sampling upstream from the sewage treatment plants at Houston and Smithers during summer low flow would show whether the drinking water objective was met in those 2 reaches of the Bulkley and Morice Rivers protected for that use, including from Bulkley Lake downstream to Houston, and from Morice Lake downstream to Smithers. Sampling downstream from the two sewage treatment plants would show whether the recreation objective was met in the two remaining reaches, including from Houston downstream to the Morice River, and from Smithers downstream to the Skeena River.

To determine whether the periphyton objective is being met, it is recommended that the monitoring sites for the two sewage treatment plants (Houston and Smithers) be checked once a year during low flow, but still within the algal-growth period, probably September. Subsamples should be taken randomly from a stream section, and the mean biomass of the composite sample compared to the objective.

Monthly sampling frequency for suspended solids, turbidity, and metals is recommended to investigate their relationship, and to provide a data base for setting future water quality objectives for metals. Elevated levels for some metals (aluminum, cobalt, cadmium, chromium, copper, iron, manganese, nickel, lead, zinc) with respect to criteria have been noted in the data (sections 5.1 to 5.5). A summary of minimum detection limits for certain metals is given in Table 27.

The Waste Management Branch is monitoring some of these sites monthly as part of their regional network. These sites included in Table 26 are: 0400296 (Houston), 0400203 (Morice River), 0920088 (Quick) and 0400187 (Telkwa River). The performance of the new Smithers sewage treatment plant is also being monitored twice per year (PE 373, sites 0400434 and 0400435) during low Bulkley River flow.

Should Alcan again proceed with Kemano-Completion, a detailed evaluation of mercury in the Morice-Bulkley system should be considered as there are no background data. This study should include an evaluation of mercury levels in water and fish, as well as the potential for mobilization of mercury in the soils to be flooded in the Nanika-Kidprice Reservoir. These data would contribute to the evaluation of post- Kemano-Completion mercury levels.

An evaluation of agricultural fertilizers and pesticides used in the Bulkley River watershed should be conducted, including an assessment of their impacts on water quality. Historically, only at Quick (site 0920088) during 1974 were there analyses for several pesticides, all of which were below limits of detection at that time.

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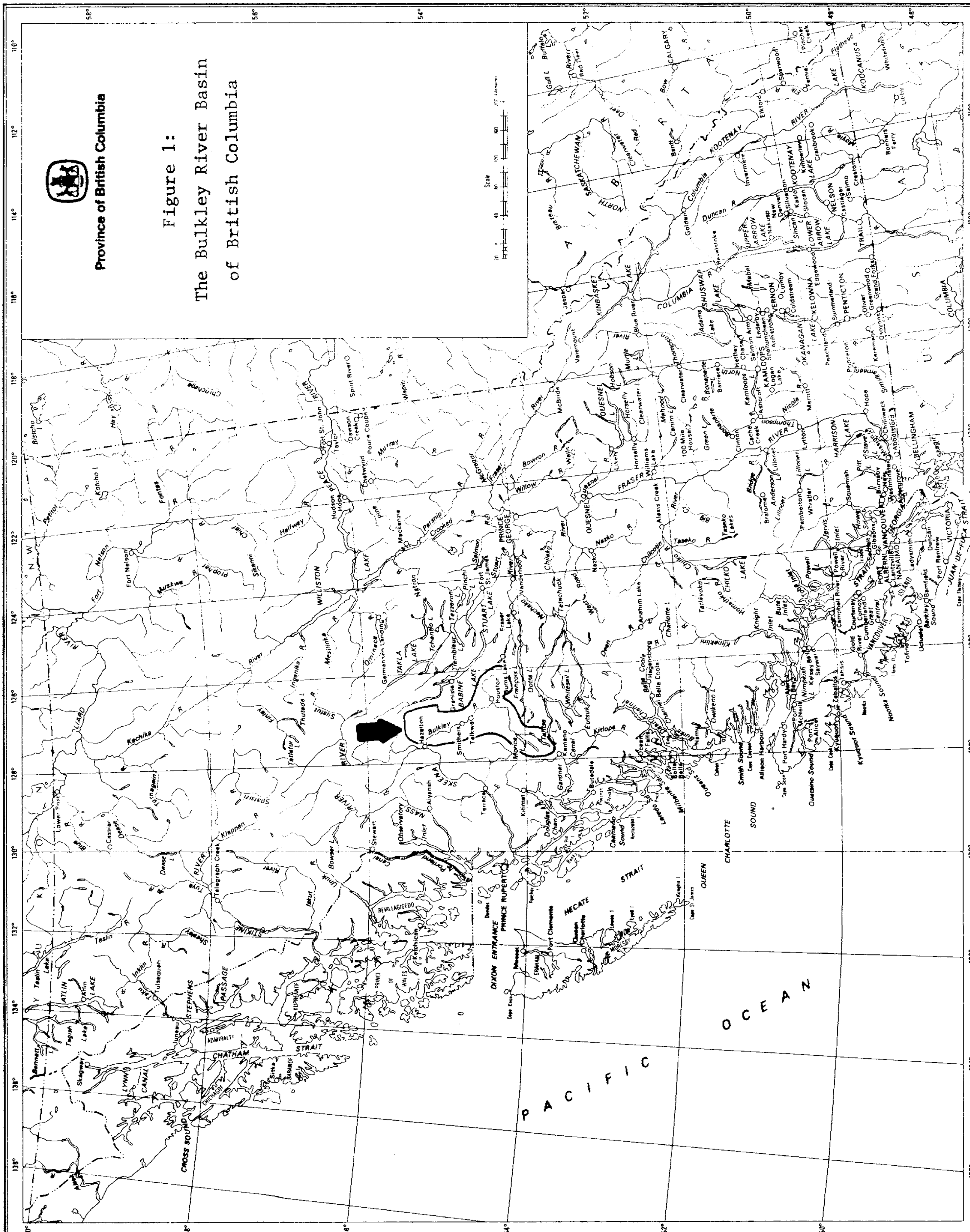


Figure 1: The Bulkley River Basin of British Columbia

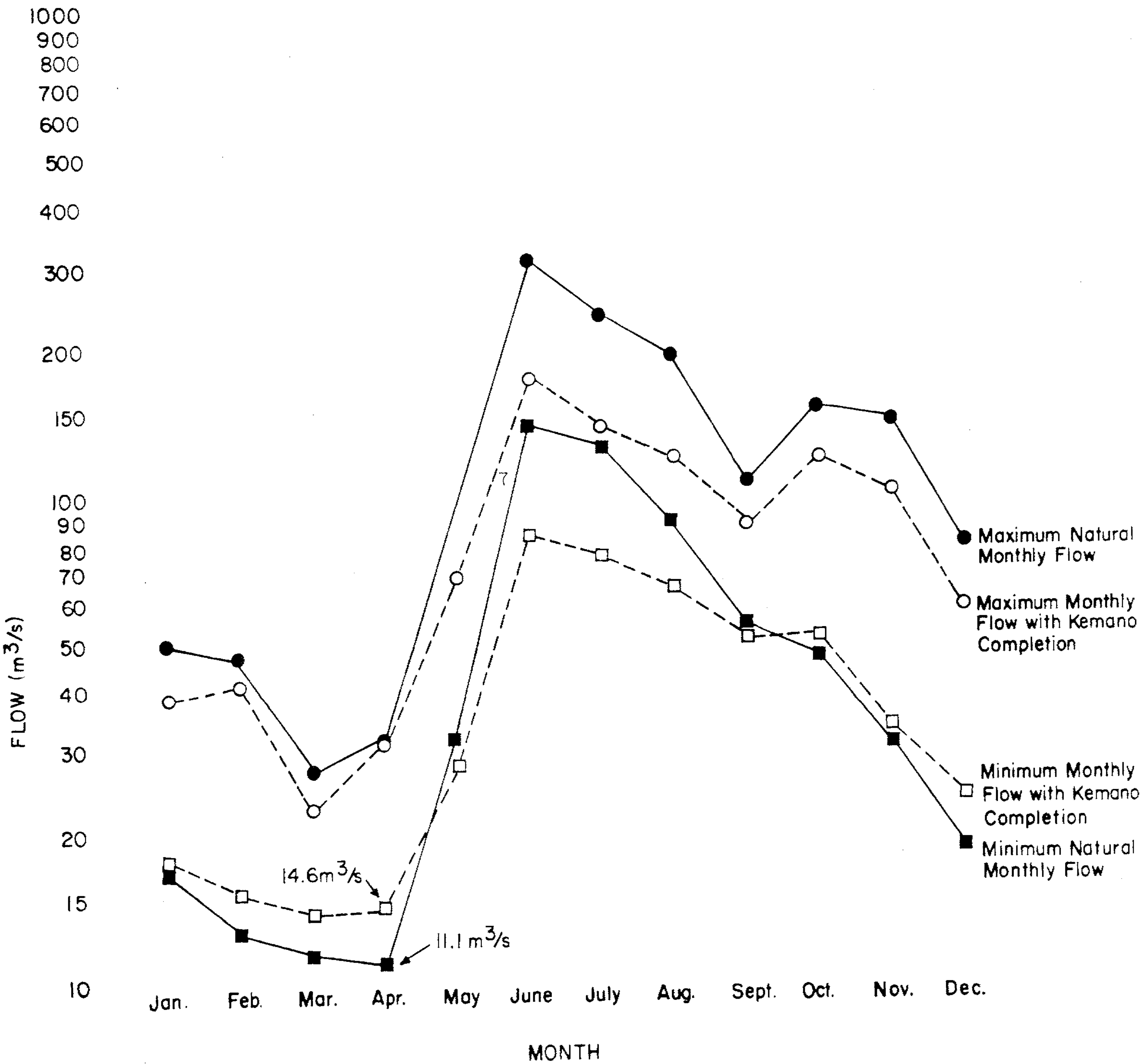


Figure 2 . Monthly Flows, Morice River at Morice Lake Outlet, Gauge Station 08ED002, 1962-1981 (data from Envirocon, 1983).

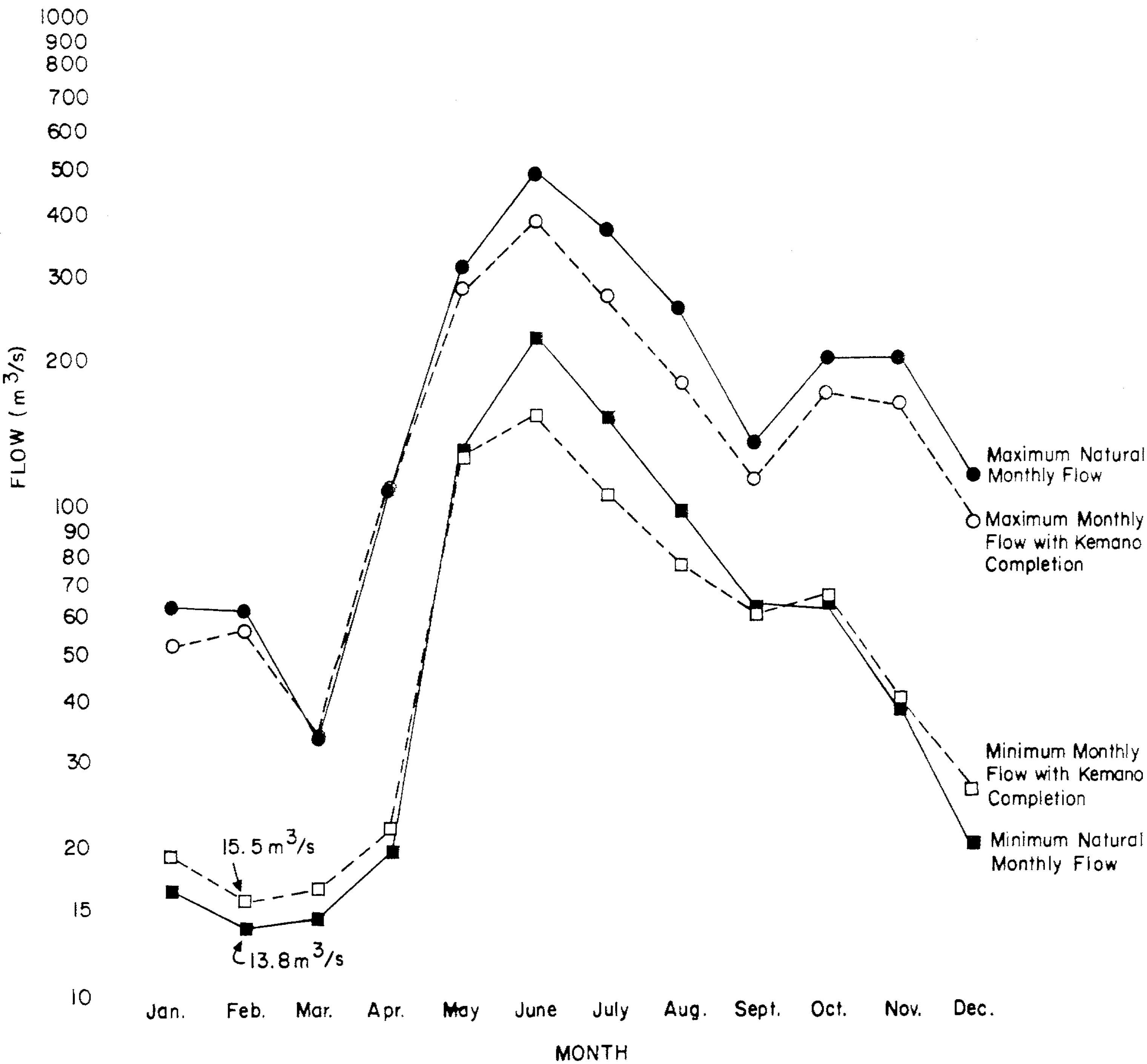


Figure 3. Monthly Flows, Morice River Upstream from Confluence with the Bulkley River (at Peacock Creek), 1962–1981 (data from Envirocon, 1983).

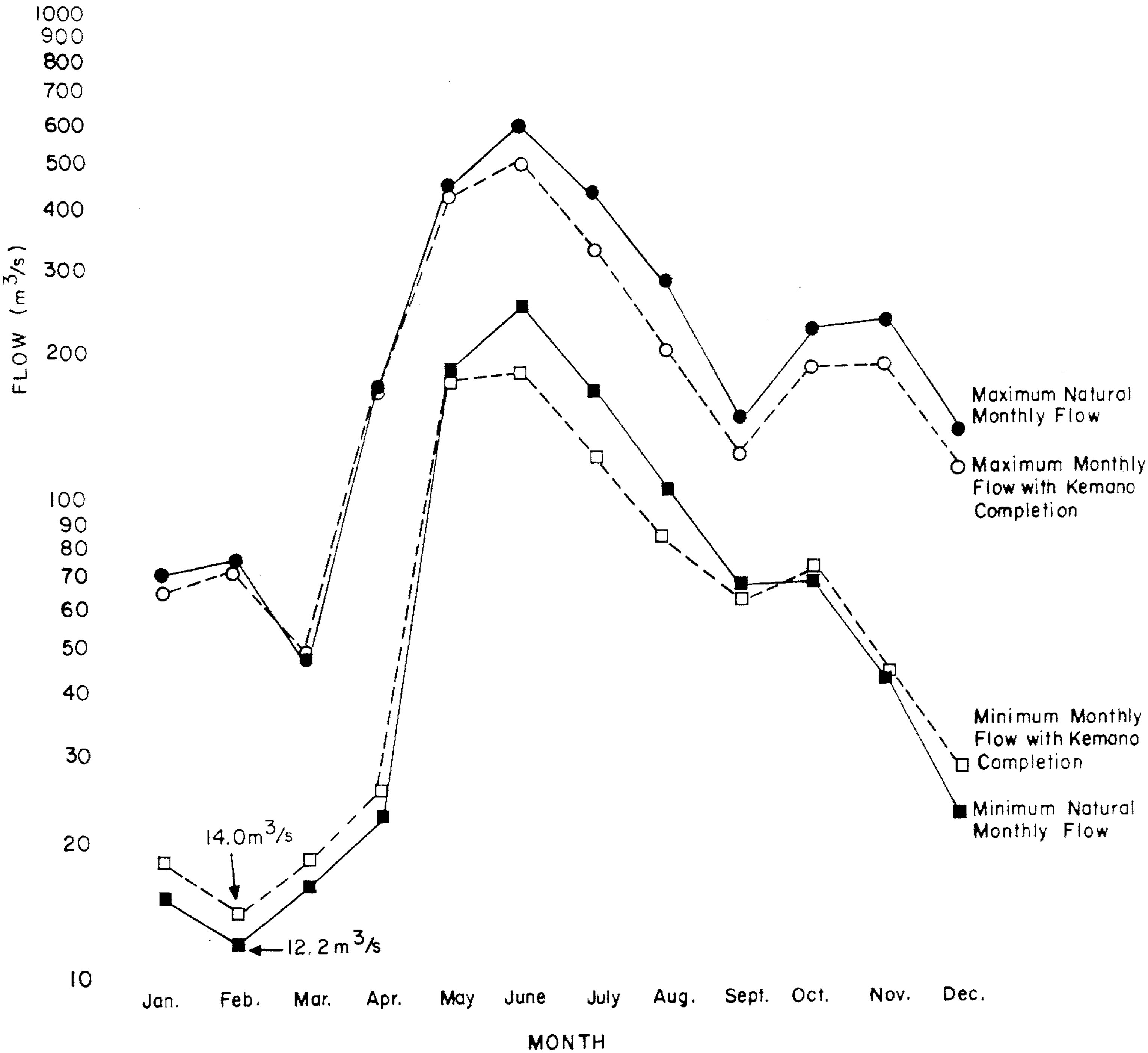


Figure 4. Mean Monthly Flows, Bulkley River at Quick, Gauge Station 08EE004, 1962 – 1981 (data from Envirocon, 1983).

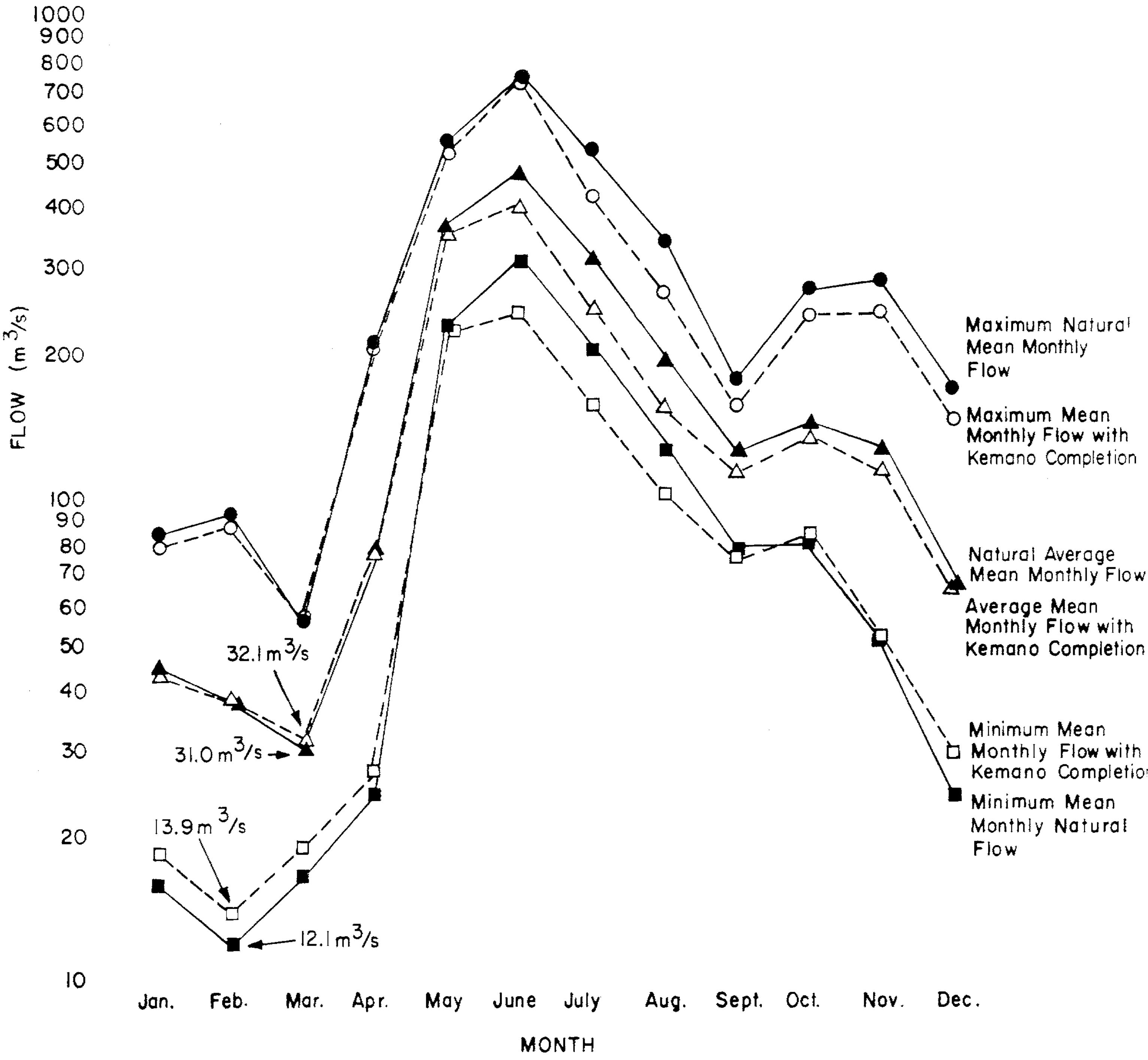
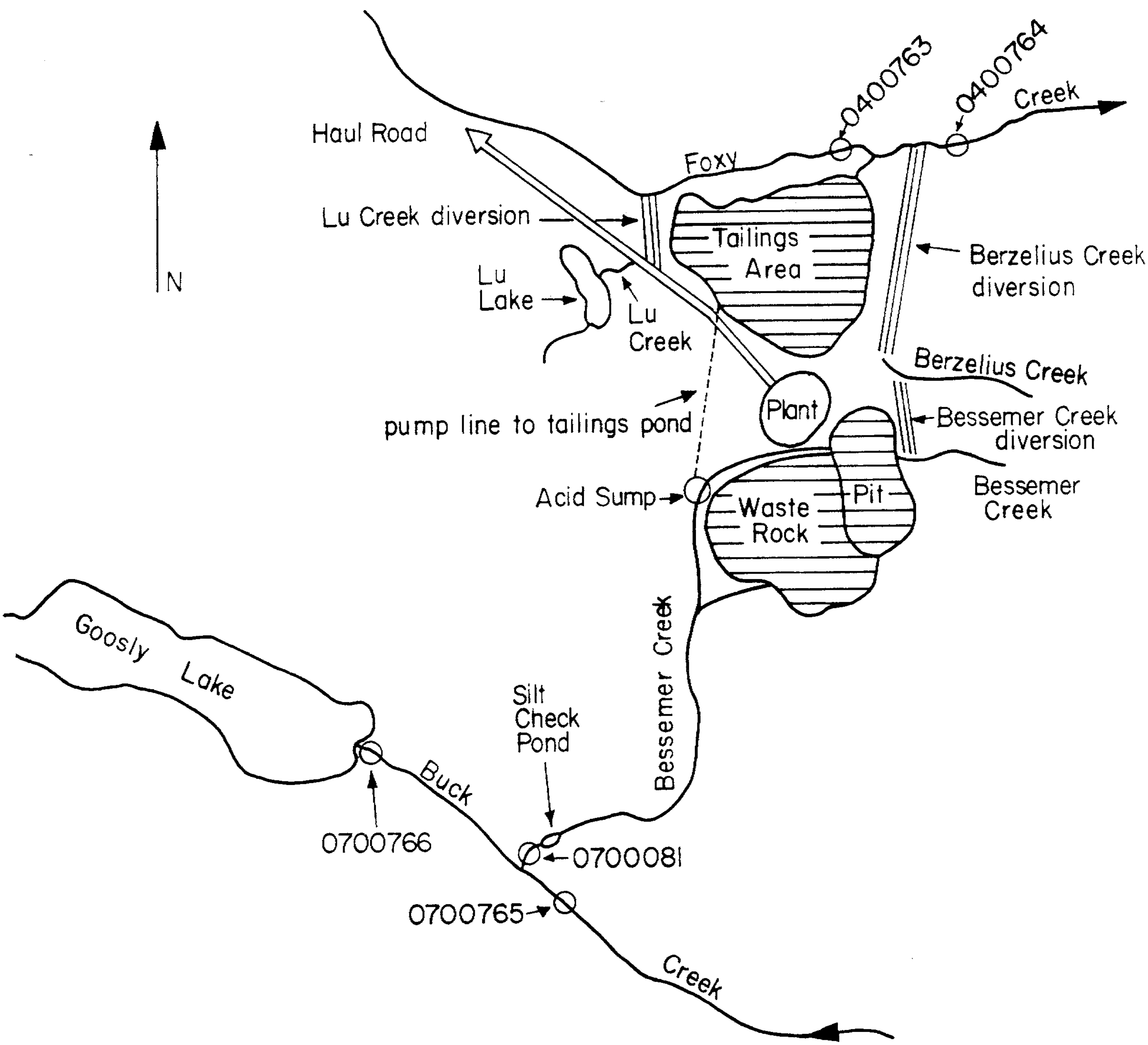


Figure 5. Monthly Flows, Bulkley River at Smithers, 1962 — 1981 (data from Envirocon, 1983).

Figure 6

Figure 6.



$\ominus$ Sampling Site

Scale – 1 : 25 000

Figure 7. Map of Equity Mine (PE 4475) Site.

TABLE 1

LOW FLOW ESTIMATES, BULKLEY RIVER BASIN, NOVEMBER TO APRIL MINIMUM 7-DAY AVERAGE DAILY DISCHARGE

Stream Site	Drainage Area (km^2)	Recurrence Interval Mean Year (m^3/s)	10-Year (m^3/s)
Bulkley R. above Morice R. near Houston (gauged station 08EE003)	1 740	0.5	0.1
Morice R. at mouth	4 270	11.0	7.4
Bulkley R. immediately downstream of the junction with the Morice R.	6 010	11.5	7.5
Bulkely R. near Quick (gauged station 08EE004)	7 360	22.8	13.7
Bulkley R. at Smithers	9 000	24	15
Goathorn Cr. at mouth (gauged station 08EE008)	132	--	0.53
Telkwa R. below Goathorn Cr. (at mouth)	1 210	5.0	3.2

from Obedkoff[7]

TABLE 2
LICENSED WATER WITHDRAWALS FROM THE BULKLEY RIVER: A SUMMARY BY REACH

Reach	Licensed Withdrawals		
	m^3/s	m^3/d	m^3/y
Source to Morice R.	0.00061	52.36	19 084
Morice R. to gauge at Quick	0.07213	3 117.00	187 680
Quick gauge to Telkwa R.	0.02602	1 128.10	80 572
Telkwa R. to Canyon Cr.	0.12012	5 649.63	634 250
Canyon Cr. to Skeena R.	0.0	0.0	0.0

TABLE 3
LICENSED WATER WITHDRAWALS FROM THE BULKLEY RIVER, CUMULATIVE TOTALS PROCEEDING DOWNSTREAM

Reach	Licensed Withdrawals		
	m^3/s	m^3/d	m^3/y
Source to Morice R.	0.00061	52.36	19 084
(+) Morice R. to gauge at Quick	0.07274	3 169.36	206 764
(+) Quick gauge to Telkwa R.	0.09876	4 297.46	277 336
(+) Telkwa R. to Canyon Cr.	0.21888	9 947.09	911 592
(+) Canyon Cr. to Skeena R.	0.21888	9 947.09	911 592

TABLE 4
LICENSED WATER USE ON THE BULKLEY RIVER

License	Quantity	Use	Licensee and Location
FL 42594	$3x10^{-5} m^3/s$ 2.3 m^3/d 830 m^3/y	Domestic water supply	L.& J. Matson. L3530, north bank of the Bulkley R. at Rose Lake
CL 39659	$3x10^{-5} m^3/s$ 2.3 m^3/d 830 m^3/y	Domestic water supply	A. Strimbold. L3389, south bank of the Bulkley River at Forestdale
CL 39089	$3x10^{-5} m^3/s$ 2.3 m^3/d 830 m^3/y	Domestic water supply	J.P.R. Johnson, L3509, south bank of the Bulkley R. at Forestdale
CL 55785 (1),(2), (3),(4)	$1.05x10^{-3} m^3/s$ 90.9 m^3/d 33 186 m^3/y	Industrial	Teniers Enterprises Ltd. Industrial Water Hauling. Draws water from 4 loctions: (1) upstream Houston, (2) upstream of Morice junction, (3) downstream of Telkwa junction, (4) downstream of Smithers Bridge.

..continued

TABLE 4 (Continued)

License	Quantity	Use	Licensee and Location
6000004 (application)	7.1×10^{-2} m^3/s 3084.5 m^3/d 185 000 m^3/y	Irrigation*	E.R. and W. Jaarsma. Section 712, north bank of Bulkley R. at Barrett
CL50318	7.3×10^{-4} m^3/s 32.5 m^3/d 2680 m^3/y	Irrigation* and domestic water supply	D.& B. Gillespie. L2125, south bank of the Bulkley R. at Puick
0368534 (application)	1.4×10^{-2} m^3/s 617.8 m^3/d 37020 m^3/y	Irrigation*	K.& H. Hodson et al. Section 3. north bank of the Bulkley R. at Quick
CL38578	9.5×10^{-3} m^3/s 410.4 m^3/d 24 680 m^3/y	Irrigation*	E.S. Ellis. Section 19, north bank of the Bulkley R. at Hubert
0367477 (application)	3.5×10^{-5} m^3/s 2.3 m^3/d 880 m^3/y	Domestic water supply	R. & S. Bavalis Lot 9 (Section 26, north bank of the Bulkley R. S.E. of Telkwa)
CL 38315	1.4×10^{-3} m^3/s 60.5 m^3/d 3702 m^3/yr	Irrigation*	L.E. Wakefield Lot 10
CL 52518	3×10^{-5} m^3/s 2.3 m^3/d 830 m^3/y	Domestic water supply	B. & W. Paisley Lot 7
CL 51771	7.3×10^{-4} m^3/s 32.5 m^3/d 2680 m^3/y	Irrigation* and domestic water	W. Stubbs Lot 6
CL 54985	3×10^{-5} m^3/s 2.3 m^3/d 830 m^3/y	Domestic water supply	P.F. Ezinga Lot 5
CL 43264	1.05×10^{-2} m^3/s 909 m^3/d 3.32×10^{5} m^3/y	Community waterworks	Corporation of the Village of Telkwa. Bulkley R. at the mouth of the Telkwa R.
CL 39560	7.14×10^{-2} m^3/s 3085 m^3/d 1.85×10^{5} m^3/y	Irrigation*	J. Grieder. Section F, east bank of the Bulkley R. between Telkwa and Smithers
CL 36881	1×10^{-4} m^3/s 9.1 m^3/d 3322 m^3/y	Domestic water supply	Pika Trailer Court. Section 17 east bank of the Bulkley R., 2 km upstream of the bridge at Smithers
CL 50316	1.2×10^{-2} m^3/s 514 m^3/d 3.1×10^{4} m^3/y	Irrigation*	J. Zust. Section 29, east bank the Bulkley R. downstream of the bridge at Smithers
FL38715	2.4×10^{-2} m^3/s 1028 m^3/d 6.2×10^{4} m^3/y	Irrigation*	Bob's Welding and Machine Works Ltd. 3 sites all on the west bank of the Bulkley R.
6000001 (application)	1.9×10^{-3} m^3/s 82.1 m^3/d 4936 m^3/y	Irrigation*	H. & T. Zandberg. Lot 74, Section 31 on the north bank of the Bulkley R. opposite the Riverside Park in Smithers

*Irrigation licenses are issued in acre-feet and converted to m^3/s by assuming 2 months of operation, 12 hours a day in the summer months.

TABLE 5

BULKLEY RIVER, SUMMARY OF LICENSED WATER USE BY REACH

Reach	Licensed Use (including applications)
Headwaters to the Morice River	domestic (3 licenses), industrial (1 license with 2 withdrawals)
Morice River to the Telkwa River	irrigation (6 licenses), domestic (3 licenses)
Telkwa River to Smithers	waterworks (1 license), domestic (1 license), irrigation (4 licenses), industrial (1 license with 2 withdrawals)
Smithers to Hazelton	- none -

TABLE 6

SUMMARY OF PERMITTED EFFLUENT DISCHARGES
BULKLEY RIVER DRAINAGE BASIN

Permit Holder	Permit Number	Discharges To	Discharge Rate	Type of Discharge
Equity Silver Mine Ltd.	PE 4477	Foxy Cr. and Bessemer Cr.	19 500 m^3/d to tailings pond	waste from a silver mine/mill complex
District of Houston	PE 287	Bulkley R.	1 550 m^3/d average	treated sewage effluent
Town of Smithers	PE 373	Bulkley R.	4 200 m^3/d average 10 800 m^3/d maximum	treated sewage effluent
Diffuse Sources: Regional Dist. of Bulkley Nechako	PR 3782	ground, at Perow	5.4 m^3/week	refuse, landfill
	PR 2270	ground, at Telkwa	563 m^3/d	refuse, landfill
	PR 2687	ground, at Houston	30 m^3/d	refuse, landfill

TABLE 7

MINIMUM DILUTION RATIOS FOR THE SEWAGE EFFLUENT DISCHARGES IN THE BULKLEY RIVER BASIN

Permit Holder	Permit Number	Discharges To	Permitted Discharge m^3/d	Maximum Actual Discharge m^3/d	River Low Flow Estimate m^3/s	Minimum Dilution Ratio
District of Houston	PE 287	Bulkley R.	1550 or <10% of river flow	1859	0.1[1]	10:1[2] 5.6:1[3] 4.6:1[4]
Town of Smithers	PE 373	Bulkley R.	a) Pre-Kemano Completion			
			4200 average	NA, assume compliance	12.1 or 1.0×10^6 m^3/d[5]	249:1
			10800 max.	NA, assume compliance	12.1 or 1.0×10^6 m^3/d[5]	97:1
			b) Post-Kemano Completion			
			4200 average		13.9 or 1.2×10^6 m^3/d[6]	286:1
			10800 max.		13.9 or 1.2×10^6 m^3/d[6]	111:1
			4200 average		32.1 or 2.8×10^6 m^3/d[7]	667:1
			10800 max.		32.1 or 2.8×10^6 m^3/d[7]	259:1

(1) November to April minimum 7-day average daily discharge, 10 year return period.
(2) Assumes permit compliance; 10:1 is the minimum dilution allowed.
(3) Assume maximum permitted discharge to Bulkley R. low flow, without using treatment plant storage capacity to avoid exceeding the minimum dilution (10:1) required by permit.
(4) Assume maximum actual discharge to Bulkley River low flow, without using treatment plant storage capacity to avoid exceeding the minimum dilution (10:1) required by permit.
(5) Natural minimum mean monthly low flow, pre-Kemano-Completion.
(6) Predicted minimum Bulkley River low flow (February, Alcan's data), post-Kemano-Completion.
(7) Predicted average Bulkley River low flow (March, Alcan's data), post-Kemano-Completion.

TABLE 8

SUMMARY OF PERMITTED LEVELS OF CHARACTERISTICS AND LOADINGS FOR THE EQUITY MINE (PE 4475)

Characteristic	Permit Conditions			
	Level or Concentration	Present and Future Loadings (kg/d), to: Bessemer Cr. Minimum	Bessemer Cr. Maximum	Foxy Cr. Maximum
Discharge Flow Rate (m^3/d)				
- to Bessemer Cr.	17 000 average	-	-	-
	170 000 maximum	-	-	-
- to Foxy Cr.	6 000 maximum (1:5 minimum dilution)	-	-	-
Aluminum, Dissolved	0.5 mg/L	8.5	85	3
Antimony, Dissolved	0.05 mg/L	0.85	8.5	0.3
Arsenic , Dissolved	0.05 mg/L	0.85	8.5	0.3
Copper , Dissolved	0.05 mg/L	0.85	8.5	0.3
Iron , Dissolved	0.3 mg/L	5.1	51	1.8
Lead , Dissolved	0.05 mg/L	0.85	8.5	0.3
Zinc , Dissolved	0.5 mg/L	8.5	85	3
Methylene Blue Active Substances	1.0 mg/L	17	170	6
NO_2/NO_3 Nitrogen	20.0 mg/L	340	3 400	120
Oil and Grease	15.0 mg/L	255	2 550	90
pH	6.5-8.5	-	-	-
Suspended Solids	50.0 mg/L	850	8 500	300

TABLE 9

EFFLUENT MONITORING RESULTS, HOUSTON SEWAGE TREATMENT PLANT, JANUARY 1972 TO DECEMBER 1983

Site Number		Houston Sewage Treatment Plant PE 287				
Characteristic	Units	Max.	Min.	Mean	N	Permit Limits
BOD_5	mg/L	88	5	22	67	≦45
Chloride , Total	mg/L	10	0	3.5	705	
Chlorine , Residual	mg/L	1.5	0	0.2	2085	0.1-1.0
Conductivity, Specific	µS/cm	907	587	741	26	
Coliforms, Fecal	MPN/100 mL	92 000	0	83	48	- -
, Total	MPN/100 mL	-	-	-	-	40 000
Flow	m^3/d	1 859	9	885	2066	1 550 or 10% of river flow
Nitrogen-Ammonia, Total	mg/L	16.8	11.1	13.3	4	
-Nitrate, Diss.	mg/L	0.64	0.24	0.43	5	
-Nitrite, Diss.	mg/L	0.561	0.039	0.250	5	
Phosphorus-Ortho, Diss.	mg/L	3.48	2.95	3.22	3	
- Total	mg/L	6.88	3.42	4.41	4	
pH		8.7	6.5	7.5	993	
Solids, , Suspended	mg/L	75	2	25.4	71	≦40
, Dissolved	mg/L	362	330	350.7	3	
, Total	mg/L	514	324	423	28	

* Geometric mean
** Expressed as total coliforms
Data from Ministry of Environment's data bank, EQUIS

TABLE 10

SUMMARY OF PERMITTED AND PRESENT WASTE LOADINGS FOR THE SEWAGE TREATMENT PLANT AT HOUSTON (PE 287)

	Permit Conditions		Present Conditions		
Characteristic	Level or Concentration	Loading (kg/d)	Maximum Level or Concentration	Maximum Present Daily Loadings[1] (kg/d)	Average Present Daily Loadings[2] (kg/d)
Flow	1 550 m^3/d	-	1 859 m^3/d	-	-
BOD_5	45 mg/L	70	88 mg/L	164	34
Chlorine, Residual	0.1-1.0 mg/L	0.2-1.6	1.5 mg/L	2.8	0.3
Nitrogen, Ammonia	NS	-	16.8 mg/L	31.2	20.6
Nitrate	NS	-	0.64 mg/L	1.2	0.7
Nitrite	NS	-	0.561 mg/L	1.0	0.4
Solids, Suspended	40	62	75 mg/L	140	39.4

NS - not specified

[1] Maximum concentration times maximum flow; a maximum estimate of loadings

[2] Average concentration times permitted flow

Note: No phosphorus loadings have been calculated as the data are few (n=3-4) and old (1974-1976)

TABLE 11

THE EFFECT OF THE SEWAGE TREATMENT PLANT AT HOUSTON ON BULKLEY RIVER WATER QUALITY

Characteristic	Incremental Effect on Bulkley River Water Quality at Low Flows: Theoretical Permitted Maximum	Worst Case (Estimate)
Effluent Dilution	10:1[1]	–[2]
Chlorine, Residual	0.1 mg/L	0.15 mg/L[3]
Coliforms, Fecal	4000/100 mL (Total)	9 200/100 mL[3]
Nitrogen, Ammonia, Total	NS	1.7 mg/L[3]
, Nitrate, Dissolved	NS	0.064 mg/L[3]
, Nitrite, Dissolved	NS	0.056 mg/L[3]
Solids, Suspended	4 mg/L	7.5 mg/L[3]

NS - not specified

1 Assume permit compliance, with storage of effluent in lagoons when a minimum dilution of 10:1 in the Bulkley River cannot be met.

2 There is no complete record of Bulkley River low flows, therefore the worse case dilution of effluent cannot be calculated.

3 Maximum recorded effluent concentration ÷ the minimum permitted effluent dilution.

TABLE 12

EFFLUENT MONITORING RESULTS, SMITHERS SEWAGE TREATMENT PLANT (PE 373), THE NEW FACILITY, NOVEMBER 1983 TO MAY 1984

Characteristic	Units	Smithers Sewage Treatment Plant (PE 373)							Permit Limit
		Nov. 28/83	Nov. 30/83	Jan. 3/84	Feb. 28/84	April 3/84	April 11/84	May 8/84	
BOD_5	mg/L	<10	12	<10	18.0	12.0	12	22.0	≤45
Carbon, Total Organic	mg/L	--	15	--	--	--	24	--	NS
, Total Inorganic	mg/L	--	62	--	--	--	74	--	NS
COD	mg/L	--	54	--	--	--	72	--	NS
Coliforms, Fecal	MPN/100 mL	--	5200	--	--	--	9000	--	NS
, Total	MPN/100 mL	--	52000	--	--	--	56000	--	NS
Flow	m^3/d	--	1523	1814[1]	1534	2023	1863	--	4200 avg.
		(Nov. avg. = 1724 max. = 1943)		(Jan. avg. = 1686 max. = 2432)	(Feb. avg. = 1782 max. = 2349)	(April avg. = 2147 max. = 6217)			10800 max.
Nitrogen, NH_3/NH_4	mg/L	--	14.6	--	--	--	16.7	--	NS
, NO_2/NO_3	mg/L	--	0.81	--	--	--	0.02	--	NS
, Kjeldahl	mg/L	--	17.6	--	--	--	21.2	--	NS
pH		7.3	7.9	7.1	7.1	7.5	7.7	7.6	NS
Phosphorus, Total	mg/L	--	3.36	--	--	--	3.86	--	NS
Solids, Total Suspended	mg/L	14.0	16	9.5	20.0	10.0	13	38.5	≤60
, Total Dissolved	mg/L	--	328	--	--	--	421	--	NS
Specific Conductance	µS/cm	--	629	--	--	--	775	--	NS

[1] average of 3 consecutive days
NS not specified
Data from Ministry of Environment and the permittee

TABLE 13

EFFLUENT MONITORING RESULTS, SMITHERS SEWAGE TREATMENT PLANT, DATA FROM BOTH THE OLD AND NEW FACILITIES JANUARY 1975 TO NOVEMBER 1983

Site Number		Smithers Sewage Treatment Plant PE 373			
Characteristic	Units	Max.	Min.	Mean	N
Nitrogen - total (Kjel + NO_2/NO_3)	mg/L	21.2	16.1	17.7	6
Phosphorus - total	mg/L	4.2	3.4	3.6	5

TABLE 14

SUMMARY OF WASTE LOADINGS AND THEORETICAL EFFECT ON BULKLEY RIVER WATER QUALITY FROM THE SEWAGE TREATMENT PLANT AT SMITHERS (PE 373)

Characteristic	Permit Conditions		Present Conditions		Projected Loadings for 1993 (kg/d)[2]	Incremental Effect on Bulkley River Water Quality At Low Flow[4]; Based On...		
	Level or Concentration	Loading kg/d	Maximum Level or Concentration[1]	Maximum Present Daily Loading (kg/d)		1983 Loadings	Projected 1993 Loadings	Permitted Variable Concentration and Effluent Flow
Flow	4 200 m^3/d average 10 800 m^3/d maximum	-	6 217 m^3/d (April 11/84)	-	6 217 to 8 038 m^3/d	-	-	-
BOD_5	≤45 mg/L	189 average 486 maximum	22 mg/L (May 8/84)	137[3]	137 to 177	0.106 mg/L	0.106 to 0.137 mg/L	0.146 (from average permitted effluent flow) to 0.375 mg/L (from maximum permitted effluent flow)
Suspended Solids	≤60 mg/L	252 average 648 maximum	38.5 mg/L (May 8/84)	239[3]	239 to 309	0.184 mg/L	0.184 to 0.238 mg/L	0.194 (from average permitted effluent flow) to 0.50 mg/L from maximum permitted effluent flow)
Nitrogen, Total	-NS-	-	21.2 mg/L (April 11/84)	132[3]	132 to 171	0.019 mg/L	0.019 to 0.025 mg/L	0.013 (from average permitted effluent flow) to 0.033 mg/L (from maximum permitted effluent flow)
Phosphorus, Total	-NS-	-	4.2 mg/L (July 6/78)	10[3]	10 to 13	0.001 mg/L	0.001 to 0.002 mg/L	0.003 (from average permitted effluent flow) to 0.007 mg/L from maximum permitted effluent flow)
Coliforms, Fecal	-NS-	-	9000/100 mL	-	-	43/100 mL	-	-

[1]Flow, BOD_5, suspended solids, and fecal coliform data from new sewage treatment facility (November of 1983 to the present); data for other variables taken from complete historical record (1975-1984).
[2]Assume population growth between 0-2 1/2% per year from the 1981 (census) population of 4 570; maximum 1983 population of 4 820, 1993 population of 6 232.
[3]Based on maximum recorded concentration and maximum recorded effluent flow.
[4]Low flow, for (i) BOD_5 and suspended solids, used 1 in 10 year, minimum (November) low flow of 15 m^3/s.
(ii) nutrients (nitrogen and phosphorus), used minimum average September flow of 80 m^3/s.
NS - Not specified.

TABLE 15

DATA FROM SAMPLING SITES NEAR PEROW REFUSE DUMP, (PR 3782), 1976-1978

Site 0400593: North Culvert (about 15 m north of access road)

Characteristic	Units	Max.	Min.	Mean	N
Chloride , Dissolved	mg/L	2.2	1.8	2.0	2
Coliforms , Total	MPN/100 mL	540	130	265*	2
Copper , Total	mg/L	<0.001	<0.001	<0.001	2
Iron , Total	mg/L	0.2	<0.1	<0.15	2
Lead , Total	mg/L	<0.001	<0.001	<0.001	2
Nitrogen ,Ammonia, Total	mg/L	<0.005	<0.005	<0.005	1
Nitrate/Nitrite, Diss.	mg/L	<0.02	<0.02	<0.02	2
Kjeldahl , Total	mg/L	0.76	0.49	0.63	2
Total	mg/L	0.76	0.49	0.63	2
Phosphorus, Ortho Diss.	mg/L	0.042	0.042	0.042	1
, Total Diss.	mg/L	0.049	0.049	0.049	1
, Total	mg/L	0.05	0.039	0.045	2
pH		7.7	7.4	7.5	2
Solids , Dissolved	mg/L	161	161	161	1
, Suspended	mg/L	1	1	1	1
Zinc , Total	mg/L	<0.005	<0.005	<0.005	2

Site 0400594: South Culvert (about 50 m south of access road)

Characteristic	Units	Max.	Min.	Mean	N
Chloride , Dissolved	mg/L	2.3	1.3	1.8	2
Coliforms , Total	MPN/100 mL	220	41	95*	2
, Fecal	MPN/100 mL	27	22	24*	2
Copper , Total	mg/L	0.002	<0.001	<0.0015	2
Hardness , Total	mg/L	115	115	115	1
Iron , Total	mg/L	0.1	0.1	0.1	1
Lead , Total	mg/L	<0.001	<0.001	<0.001	2
Nitrogen , Ammonia,Total	mg/L	0.019	0.019	0.019	1
Nitrate/Nitrite, Diss.	mg/L	<0.02	<0.02	<0.02	2
Kjeldahl, Total	mg/L	0.95	0.68	0.82	2
Total	mg/L	0.95	0.68	0.82	2
Phosphorus, Ortho, Diss.	mg/L	0.104	0.104	0.104	1
Total, Dissolved	mg/L	0.115	0.115	0.115	1
Total	mg/L	0.233	0.049	0.135	3
pH		7.7	7.3	7.5	2
Solids , Dissolved	mg/L	169	145	157	2
, Suspended	mg/L	37	1	19	2
Zinc , Total	mg/L	0.014	<0.005	<0.009	2

..continued

TABLE 15 (Continued)

Site 0400595: Refuse Site South

Characteristic	Units	Max.	Min.	Mean	N
Calcium , Dissolved	mg/L	37.7	37.7	37.7	1
Hardness , Total	mg/L	124	124	124	1
Magnesium , Dissolved	mg/L	7.2	7.2	7.2	1
Phosphorus, Total	mg/L	0.093	0.093	0.093	1
Solids , Dissolved	mg/L	199	199	199	1
, Suspended	mg/L	1	1	1	1

Site 0400807: Byman Creek, Downstream at Perow Loop

Characteristic	Units	Max.	Min.	Mean	N
Chloride , Dissolved	mg/L	0.7	0.6	0.65	2
Coliforms , Total	MPN/100 mL	110	<2	15*	2
Copper , Total	mg/L	0.004	0.001	0.003	2
Iron , Total	mg/L	3.2	0.2	1.7	2
Lead , Total	mg/L	<0.001	<0.001	<0.001	2
Nitrogen , Ammonia,Total	mg/L	0.18	0.18	0.18	1
Nitrate/Nitrite, Diss.	mg/L	0.02	<0.02	<0.02	2
Kjeldahl , Total	mg/L	0.56	0.2	0.38	2
Total	mg/L	0.58	0.2	0.39	2
Phosphorus, Ortho, Diss.	mg/L	0.014	0.014	0.014	1
Total Dissolved	mg/L	0.021	0.021	0.021	1
Total	mg/L	0.106	0.006	0.056	2
Solids , Dissolved	mg/L	91	91	91	1
, Suspended	mg/L	75	75	75	1
Zinc , Total	mg/L	<0.005	<0.005	<0.005	1

* Geometric mean
Data from Ministry of Environment's data bank, EQUIS

TABLE 16

Bulkley River Water Quality, Site 0400200, Downstream Bulkley Lake 1972-1976

Characteristic	Units	N	Max.	Min.	Mean
Alkalinity, Total	mg/L	4	37.8	28	34
Cadmium , Total	mg/L	1	<0.005	<0.005	<0.005
Calcium , Dissolved	mg/L	6	9.1	6.6	8.0
Carbon , Total	mg/L	3	9	5	6.7
, Total Organic	mg/L	4	15	9	12
Chromium , Dissolved	mg/L	2	<0.005	<0.005	<0.005
, Total	mg/L	3	<0.005	<0.005	<0.005
Chloride , Dissolved	mg/L	4	2.1	0.7	1.1
Coliforms , Fecal	MPN/100 mL	1	17	17	17
, Total	MPN/100 mL	1	140	140	140
Color , True	TCU	4	60	30	43
, TAC	TAC	5	50	22	34
Copper , Dissolved	mg/L	2	0.015	0.002	0.009
, Total	mg/L	3	0.005	0.001	0.003
Hardness , Dissolved	mg/L	6	37	25.9	32.3
Iron , Dissolved	mg/L	2	0.22	<0.1	<0.16
, Total	mg/L	3	0.6	0.3	0.5
Lead , Dissolved	mg/L	2	<0.003	<0.001	*
, Total	mg/L	3	0.005	<0.001	<0.003
Magnesium , Dissolved	mg/L	5	3.3	2.3	2.9
, Total	mg/L	3	3.3	2.4	2.9
Manganese , Dissolved	mg/L	2	0.02	<0.02	<0.02
, Total	mg/L	2	0.04	0.03	0.035
Mercury , Dissolved	mg/L	2	0.00005	<0.00005	<0.00005
, Total	mg/L	2	0.00005	<0.00005	<0.00005
Molybdenum, Total	mg/L	2	<0.0005	<0.0005	<0.0005
Nickel , Total	mg/L	2	<0.01	<0.01	<0.01
Nitrogen , Ammonia, Total	mg/L	3	0.084	0.011	0.036
Nitrate/Nitrite, Diss.	mg/L	3	0.04	<0.02	0.03
Organic , Total	mg/L	3	0.43	0.26	0.34
Kjeldahl , Total	mg/L	4	0.53	0.27	0.42
Total	mg/L	3	0.45	0.27	0.39
Oxygen , Dissolved	mg/L	3	8.7	6.8	8.1
pH		5	7.5	6.9	7.2
Phosphorus, Ortho, Diss.	mg/L	2	0.015	0.015	0.015
, Total	mg/L	6	0.06	0.024	0.037
Potassium , Dissolved	mg/L	3	1.1	1	1.07
Silica , Dissolved	mg/L	3	12.8	9.6	10.9
Sodium , Dissolved	mg/L	4	2.6	2.1	2.3
Solids , Dissolved	mg/L	4	74	70	72
, Suspended	mg/L	5	13	4	6.4
Specific Conductivity	µS/cm	9	165	60	88
Sulphate , Dissolved	mg/L	3	<5	<5	<5
Surfactant, Total	mg/L	1	<0.03	<0.03	<0.03
Tannin & Lignin, Total	mg/L	1	0.7	0.7	0.7
Turbidity	NTU	6	9.2	1.7	4.3
Zinc , Dissolved	mg/L	2	0.09	<0.005	0.048
, Total	mg/L	3	0.013	<0.005	<0.009

Data from Ministry of Environment's data bank, EQUIS
* No detectable concentrations were measured for this characteristic

TABLE 17

Bulkley River Water Quality, Site 0400201, Upstream From Buck Creek (Houston) 1972-1976

Characteristic	Units	N	Max.	Min.	Mean
Alkalinity, Total	mg/L	7	96.5	35.9	64.5
Cadmium , Total	mg/L	1	<0.0005	<0.0005	<0.005
Calcium , Dissolved	mg/L	8	24.2	8.8	15.7
Carbon , Total	mg/L	5	21	8	14
Chromium , Dissolved	mg/L	3	<0.0005	<0.0005	<0.0005
, Total	mg/L	4	0.017	<0.005	<0.008
Chloride , Dissolved	mg/L	7	1.1	<0.5	<0.9
Coliforms , Fecal	MPN/100 mL	1	13	13	13
, Total	MPN/100 mL	1	350	350	350
Color , True	TCU	6	60	5	27
, TAC	TAC	7	56	2	24
Copper , Dissolved	mg/L	3	0.003	0.001	0.002
, Total	mg/L	4	0.006	0.001	0.003
Hardness , Dissolved	mg/L	8	92	34	58
Iron , Dissolved	mg/L	3	0.33	<0.1	<0.21
, Total	mg/L	4	2.5	0.3	1.3
Lead , Dissolved	mg/L	3	<0.003	<0.001	*
, Total	mg/L	4	0.005	<0.001	<0.002
Magnesium , Dissolved	mg/L	7	6.4	2.0	4.0
, Total	mg/L	3	5.8	3.3	4.8
Manganese , Dissolved	mg/L	3	0.12	<0.02	<0.07
, Total	mg/L	3	0.09	0.07	0.08
Mercury , Dissolved	mg/L	3	0.00014	0.00005	0.00008
, Total	mg/L	3	<0.00005	<0.00005	<0.00005
Molybdenum, Total	mg/L	2	0.0007	<0.0005	<0.0006
Nickel , Total	mg/L	2	<0.01	<0.01	<0.01
Nitrogen , Ammonia, Total	mg/L	6	0.014	0.006	0.012
Nitrate/Nitrite, Diss.	mg/L	6	0.07	<0.02	<0.03
Organic , Total	mg/L	6	0.34	0.09	0.23
Kjeldahl , Total	mg/L	6	0.35	0.20	0.28
Total	mg/L	6	0.35	0.18	0.25
Oxygen , Dissolved	mg/L	4	9.1	7	8.4
pH		6	7.7	7.5	7.6
Phosphorus, Ortho Diss.	mg/L	4	0.009	<0.003	<0.0045
, Total	mg/L	8	0.11	0.007	0.042
Potassium , Dissolved	mg/L	5	1.2	0.4	0.9
Silica , Dissolved	mg/L	5	11.9	5.9	8.9
Sodium , Dissolved	mg/L	6	5.2	2	3.4
Solids , Dissolved	mg/L	6	112	50	87
, Suspended	mg/L	6	60	2.3	26.4
Specific Conductivity	µS/cm	10	215	70	133
Sulphate , Dissolved	mg/L	5	<5	<5	<5
Tannin and Lignin, Total	mg/L	2	0.2	<0.1	<0.15
Temperature	°C	4	14	6	11.8
Turbidity	NTU	8	24	1.5	8.9
Zinc , Dissolved	mg/L	3	0.008	<0.005	<0.006
, Total	mg/L	4	0.009	<0.005	<0.006

*No detectable values were measured for this characteristic
Data from Ministry of Environment's data bank, EQUIS

TABLE 18

Bulkley River Water Quality Monitoring of the Sewage Treatment Plant at Houston (PE 287): Data from Sites 0400297 (Upstream), 0400295 (100 m Downstream), and 0400296 (3.2 km Downstream) 1974-1975

Characteristic	Units	N	U/S 0400297 Max.	U/S 0400297 Min.	U/S 0400297 Mean	N	D/S 0400295 Max.	D/S 0400295 Min.	D/S 0400295 Mean	N	D/S 0400296 Max.	D/S 0400296 Min.	D/S 0400296 Mean
Alkalinity, Total	mg/L	2	47	33.5	40.3	2	44.3	33.2	38.8	2	44.3	33.5	38.9
Cadmium, Dissolved	mg/L	1	<0.0005	<0.0005	<0.0005	1	<0.0005	<0.005	<0.005	1	<0.005	<0.005	<0.005
Calcium, Dissolved	mg/L	2	11.6	8.4	10.0	2	10.8	8.3	9.6	2	11	8.4	9.7
Carbon, Total Organic	mg/L	-	-	-	-	-	-	-	-	1	12	12	12
Chlorine, Residual	mg/L	3	0	0	0	3	0	0	0	3	0	0	0
Chromium, Dissolved	mg/L	2	<0.005	<0.005	<0.005	1	<0.005	<0.005	<0.005	1	<0.005	<0.005	<0.005
Coliforms, Fecal	MPN/100 mL	4	70	8	27*	3	110	<20	<39*	4	79	2	20*
, Total	MPN/100 mL	4	350	33	80*	3	240	50	127*	4	240	23	89*
Color, True	TCU	2	50	40	45	2	50	40	45	2	50	40	45
, TAC	TAC	2	44	31	38	2	42	29	36	2	40	27	33.5
Copper, Dissolved	mg/L	2	0.003	0.003	0.003	1	0.005	0.005	0.005	1	0.004	0.004	0.004
Hardness, Dissolved	mg/L	2	44.2	32.5	38.4	2	41	31.8	36.4	2	41.5	32.1	36.8
Iron, Dissolved	mg/L	2	0.2	0.2	0.2	1	0.2	0.2	0.2	1	0.2	0.2	0.2
Lead, Dissolved	mg/L	1	<0.001	<0.001	<0.001	1	<0.001	<0.001	<0.001	1	<0.001	<0.001	<0.001
Magnesium, Dissolved	mg/L	2	3.7	2.8	3.25	2	3.4	2.7	3.1	2	3.4	2.7	3.1
Manganese, Dissolved	mg/L	1	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02
Nickel, Dissolved	mg/L	1	<0.1	<0.1	<0.1	1	0.01	0.01	0.01	1	<0.01	<0.01	<0.01
Nitrogen, Ammonia, Total	mg/L	4	0.038	0.007	0.017	4	0.068	0.01	0.03	4	0.052	0.007	0.023
, Nitrate, Diss.	mg/L	4	<0.02	<0.02	<0.02	4	0.3	<0.02	<0.09	4	<0.02	<0.02	<0.02
, Nitrite, Diss.	mg/L	4	<0.005	<0.005	<0.005	4	0.007	<0.005	<0.006	4	<0.005	<0.005	<0.005
, Organic, Total	mg/L	4	0.44	0.15	0.25	4	0.64	0.06	0.31	4	0.44	0.17	0.21
, Kjeldahl, Tot.	mg/L	4	0.45	0.16	0.26	4	0.65	0.13	0.34	4	0.45	0.19	0.26
, Total	mg/L	3	0.25	0.16	0.2	3	0.6	0.13	0.34	3	0.25	0.19	0.22
Oxygen, Dissolved	mg/L	3	10.5	9.7	10.0	3	10.4	9.5	10.1	3	10.5	9.5	10.1
pH		2	7.5	7.4	7.45	2	7.5	7.4	7.45	2	7.5	7.4	7.45
Phosphorus, Ortho Diss.	mg/L	2	0.015	0.012	0.014	2	0.02	0.014	0.017	2	0.02	0.014	0.017
, Total	mg/L	4	0.112	0.011	0.055	4	0.153	0.052	0.097	4	0.13	0.011	0.062
Sodium, Dissolved	mg/L	1	2.6	2.6	2.6	1	2.4	2.4	2.4	1	2.4	2.4	2.4
Solids, Dissolved	mg/L	2	104	72	88	2	82	72	77	2	71	12	41.5
, Suspended	mg/L	3	30	9	19	3	65	14	33	3	64	13	32.3
, Sus. Inorganic	mg/L	1	12	12	12		-	-	-	1	11	11	11
, Sus. Organic	mg/L	1	2	2	2		-	-	-	1	2	2	2
Specific Conductance	μS/cm	4	200	80	118	4	210	75	116	4	210	75	117.5
Sulphate, Dissolved	mg/L	1	<5	<5	<5	1	<5	<5	<5	1	<5	<5	<5
Temperature	°C	4	12	8	10.8	4	12	7.5	10.6	4	11.5	7.5	10.1
Turbidity	NTU	2	21	4	12.5	2	23	4.3	13.7	2	23	3.7	13.3
Zinc, Dissolved	mg/L	1	0.02	0.02	0.02	1	<0.005	<0.005	<0.005	1	<0.005	<0.005	<0.005

* Geometric Mean
Data from Ministry of Environment's data bank, EQUIS

TAB__ 9

Bulkley River Water Quality Downstream from the Sewage Treatment Plant at Houston (PE 287): Sites 0400296 (3.2 km Downstream) and 0920089 (4.5 km Downstream) 1970-1984

Characteristic	Units	SITE NUMBER 0400296 N	Max.	Min.	Mean	0920089 N	Max.	Min.	Mean
Alkalinity, Total	mg/L	7	88.3	33.5	69.9	17	83.9	25.2	57.1
Aluminum , Dissolved	mg/L	4	0.05	<0.02	<0.04	12	0.04	0.03	0.035
, Total	mg/L	4	0.06	0.01	0.04	2	0.85	0.05	0.32
Arsenic , Dissolved	mg/L	4	<0.001	<0.001	<0.001	2	<0.001	<0.001	<0.001
, Total	mg/L	4	<0.001	<0.001	<0.001	2	<0.001	<0.001	<0.001
Barium , Dissolved	mg/L	4	0.03	0.02	0.028	2	0.02	0.02	0.02
Boron , Dissolved	mg/L	4	<0.01	<0.01	<0.01	2	<0.01	<0.01	<0.01
Cadmium , Dissolved	mg/L	5	<0.0005	<0.0005	<0.0005	2	0.0018	<0.0005	<0.0012
, Total	mg/L	4	<0.005	<0.0005	*	2	0.012	<0.0005	<0.006
Calcium , Dissolved	mg/L	6	20.1	8.4	15.1	12	20.9	7.6	16.5
, Total	mg/L	4	21.2	15.4	19.1	1	8.23	8.23	8.23
Carbon , Total Organic	mg/L	6	12	2	5	17	17	1	9.2
, Total	mg/L	5	25	17	21.6	16	20	5	11.1
Chloride , Dissolved	mg/L	5	2.5	1.4	2.1	13	1	0.3	0.6
Chlorine , Residual	mg/L	3	0	0	0	-	-	-	-
Chromium , Dissolved	mg/L	5	<0.01	<0.005	*	1	<0.1	<0.1	<0.1
, Total	mg/L	4	<0.01	<0.01	<0.01	1	<0.1	<0.1	<0.1
Cobalt , Dissolved	mg/L	4	<0.1	<0.1	<0.1	2	<0.1	<0.1	<0.1
, Total	mg/L	4	<0.1	<0.1	<0.1	2	0.12	<0.1	<0.1
Coliforms , Fecal	MPN/100 mL	4	79	2	20**	-	-	-	-
, Total	MPN/100 mL	4	240	23	136**	-	-	-	-
Color , Apparent	ACU	-	-	-	-	15	77	<5	<29
, True	TCU	2	50	40	45	-	-	-	-
, T.A.C.	TAC	2	40	27	34	-	-	-	-
Copper , Dissolved	mg/L	5	0.004	<0.001	<0.002	8	0.002	<0.001	<0.0015
, Total	mg/L	4	0.004	0.001	0.003	2	0.004	0.002	0.003
Fluoride , Total	mg/L		-	-	-	5	0.08	<0.05	<0.064
Hardness , Dissolved	mg/L	6	76.4	32.1	58.5	15	79	33.3	60.3
Iron , Dissolved	mg/L	5	0.32	0.03	0.21	8	0.19	0.05	0.13
, Total	mg/L	4	0.46	0.17	0.34	2	1.7	0.13	0.92
Lead , Dissolved	mg/L	5	<0.001	<0.001	<0.001	8	0.001	<0.001	<0.001
, Total	mg/L	4	<0.001	<0.001	<0.001	2	0.005	<0.001	<0.003
Magnesium , Dissolved	mg/L	6	6.4	2.7	5.0	2	1.28	0.99	1.14
, Total	mg/L	4	6.5	5.2	6.1	2	1.92	1.35	1.64
Manganese , Dissolved	mg/L	5	0.09	<0.01	<0.04	5	0.07	<0.01	<0.03
, Total	mg/L	4	0.09	0.05	0.06	2	0.06	0.01	0.035
Molybdenum, Dissolved	mg/L	4	<0.01	<0.01	<0.01	2	<0.01	<0.01	<0.01
, Total	mg/L	4	<0.01	<0.01	<0.01	2	0.02	<0.01	<0.015
Nickel , Dissolved	mg/L	5	<0.05	<0.01	*	2	<0.05	<0.05	<0.05
, Total	mg/L	4	<0.05	<0.05	<0.05	2	<0.05	<0.05	<0.05

..continued

TABLE 19 (Continued)

		SITE NUMBER							
		0400296				0920089			
Characteristic	Units	N	Max.	Min.	Mean	N	Max.	Min.	Mean
Nitrogen , Ammonia, Total	mg/L	9	0.203	<0.005	<0.078	2	0.014	0.006	0.010
Nitrate/Nitrite, Diss.	mg/L	9	0.12	<0.02	<0.048	17	0.09	<0.005	<0.038
, Nitrate, Diss.	mg/L	4	<0.02	<0.02	<0.02	-	-	-	-
, Nitrite, Diss.	mg/L	4	<0.005	<0.005	<0.005	-	-	-	-
, Organic, Total	mg/L	5	0.44	<0.01	0.21	-	-	-	-
, Kjeldahl, Total	mg/L	9	0.45	0.02	0.26	2	0.13	0.07	0.10
, Total	mg/L	7	0.51	0.19	0.28	2	0.15	0.13	0.14
Oxygen , Dissolved	mg/L	3	10.5	9.5	10.1	4	11.7	8.2	10.0
pH		7	8.1	7.4	7.6	17	8.3	6.9	7.6
Phosphorus, Ortho, Diss.	mg/L	7	0.049	0.008	0.030	16	<0.07	<0.002	*
, Total Diss.	mg/L	5	0.056	0.014	0.042	17	0.033	<0.001	<0.014
, Total	mg/L	9	0.13	0.011	0.058	13	0.297	0.007	0.051
Potassium , Dissolved	mg/L	5	1.2	0.9	1.06	2	0.3	0.3	0.3
, Total	mg/L	-	-	-	-	11	1.2	0.3	0.85
Silica , Dissolved	mg/L	5	13.6	11.5	12.9	17	15.3	4.2	10.9
Sodium , Dissolved	mg/L	6	6.2	2.4	5.1	17	5.3	1.2	3.4
Solids , Dissolved	mg/L	7	122	76	102	2	45	41	43
, Suspended	mg/L	7	64	3	15.6	4	81	4	24
Specific Conductivity	µS/cm	7	182	71	145	17	168	55	118
Sulphate , Dissolved	mg/L	6	<5	3	<4.1	13	4	<1	<2.8
Temperature	°C	4	11.5	7.5	10.1	-	-	-	-
Turbidity	NTU	7	23	1.1	5.2	16	74	1	10.6
Vanadium , Dissolved	mg/L	4	<0.01	<0.01	<0.01	2	<0.01	<0.01	<0.01
, Total	mg/L	4	<0.01	<0.01	<0.01	2	<0.01	<0.01	<0.01
Zinc , Dissolved	mg/L	5	0.007	<0.005	<0.005	8	<0.022	<0.001	*
, Total	mg/L	4	0.028	<0.005	<0.012	2	0.03	0.02	0.025

* No detectable concentrations were measured for these characteristics
** Geometric Mean
Data from Ministry of Environment's data bank, EQUIS

TABLE 20

Morice River Water Quality, Site 0400203, Upstream from the Confluence with the Bulkley River, 1971-1984

Characteristic	Units	N	Max.	Min.	Mean
Alkalinity, Total	mg/L	18	31.2	18.5	22.1
Aluminum , Dissolved	mg/L	10	0.17	<0.02	0.05
, Total	mg/L	9	3.06	0.03	0.48
Arsenic , Dissolved	mg/L	11	<0.25	<0.001	*
, Total	mg/L	11	<0.25	<0.001	*
Barium , Dissolved	mg/L	10	0.02	0.01	0.012
Boron , Dissolved	mg/L	10	<0.01	<0.01	<0.01
Cadmium , Dissolved	mg/L	10	<0.01	<0.0005	*
, Total	mg/L	11	<0.0021	<0.0005	*
Calcium , Dissolved	mg/L	17	9.69	5.59	7.03
, Total	mg/L	11	10	6.5	7.4
Carbon , Total	mg/L	16	8	2	4.9
, Total Organic	mg/L	17	8	<1	<2.5
Chromium , Dissolved	mg/L	14	<0.01	<0.005	*
, Total	mg/L	13	0.01	<0.005	<0.009
Chloride , Dissolved	mg/L	17	0.7	<0.5	<0.53
Cobalt , Dissolved	mg/L	10	<0.1	<0.1	<0.1
, Total	mg/L	10	<0.1	<0.1	<0.1
Coliforms , Fecal	MPN/100 mL	1	<2	<2	<2
, Total	MPN/100 mL	1	23	23	23
Color , True	TCU	7	40	<5	<11
, TAC	TAC	5	31	<1	<11
Copper , Dissolved	mg/L	14	0.002	<0.001	<0.001
, Total	mg/L	13	0.011	0.001	0.004
Hardness , Dissolved	mg/L	13	23.9	17.9	20.8
, Total	mg/L	4	98.1	18.9	40.7
Iron , Dissolved	mg/L	14	0.14	0.01	0.071
, Total	mg/L	13	3.53	0.02	0.95
Lead , Dissolved	mg/L	13	0.007	<0.001	<0.002
, total	mg/L	14	0.007	<0.001	<0.002
Magnesium , Dissolved	mg/L	16	1.14	0.57	0.80
, Total	mg/L	12	19.6	0.6	2.4
Manganese , Dissolved	mg/L	14	<0.02	<0.01	*
, Total	mg/L	13	0.15	<0.01	<0.04
Mercury , Dissolved	mg/L	4	0.00005	<0.00005	<0.00005
, Total	mg/L	2	<0.00005	<0.00005	<0.00005
Molybdenum, Dissolved	mg/L	10	<0.01	<0.01	<0.01
, Total	mg/L	12	<0.01	<0.005	*
Nickel , Dissolved	mg/L	10	<0.05	<0.05	<0.05
, Total	mg/L	12	<0.05	<0.01	*

..continued

TABLE 20 (Continued)

Characteristic	Units	N	Max.	Min.	Mean
Nitrogen , Ammonia Total	mg/L	15	0.013	<0.005	<0.006
Nitrate/Nitrite, Diss.	mg/L	17	0.06	<0.02	<0.03
, Organic, Total	mg/L	7	0.14	<0.01	<0.07
, Kjeldahl,Total	mg/L	16	0.22	<0.01	<0.09
, Total	mg/L	16	0.27	0.03	0.10
Oxygen , Dissolved	mg/L	3	10.1	9.5	9.7
pH		17	7.5	6.8	7.3
Phosphorus, Ortho, Diss.	mg/L	9	<0.003	<0.003	<0.003
, Total Diss.	mg/L	11	0.008	<0.003	<0.004
, Total	mg/L	18	0.092	0.004	0.020
Potassium , Dissolved	mg/L	15	0.4	0.2	0.3
Silica , Dissolved	mg/L	15	6	3	3.9
Sodium , Dissolved	mg/L	16	1.6	0.8	1.1
Solids , Dissolved	mg/L	18	51	25	35.6
, Suspended	mg/L	19	105	1	18.9
Specific Conductivity	µS/cm	17	69	42	49.2
Sulphate , Dissolved	mg/L	15	<5	2.2	<3.4
Temperature	°C	3	14	7	11.7
Turbidity	NTU	15	44	0.6	8.9
Vanadium , Dissolved	mg/L	10	<0.01	<0.01	<0.01
, Total	mg/L	10	0.01	<0.01	<0.01
Zinc , Dissolved	mg/L	14	0.01	<0.005	<0.005
, Total	mg/L	13	0.05	<0.005	<0.011

*No detectable concentrations were measured for these characteristics
Data from Ministry of Environment's data bank, EQUIS

TABLE 21

Bulkley River Water Quality Site 0920088 at Quick
1966-1984

Characteristic	Units	N	Max.	Min.	Mean
Alkalinity, Total	mg/L	99	47.6	3.3	25.4
Aluminum , Dissolved	mg/L	13	0.26	<0.01	<0.05
, Total	mg/L	11	2.9	<0.01	<0.75
Arsenic , Dissolved	mg/L	12	<0.005	<0.001	*
, Total	mg/L	12	0.0025	<0.0002	<0.0017
Barium , Dissolved	mg/L	7	0.02	0.01	0.02
, Total	mg/L	5	0.1	0.09	0.098
Boron , Dissolved	mg/L	8	<0.01	<0.005	*
Cadmium , Dissolved	mg/L	10	0.0018	<0.0005	<0.0017
, Total	mg/L	17	0.012	<0.0002	<0.0002
Calcium , Dissolved	mg/L	96	14.7	1.5	8.7
, Total	mg/L	8	10.6	7.3	8.5
Carbon , Total	mg/L	23	10.6	2.0	6.0
, Total Organic	mg/L	23	16	<1	4.5
Chromium , Dissolved	mg/L	9	<0.01	<0.01	<0.01
, Total	mg/L	12	0.01	0.001	0.008
Chloride , Dissolved	mg/L	100	2.1	<0.1	0.4
Cobalt , Dissolved	mg/L	7	<0.1	<0.1	<0.1
, Total	mg/L	16	0.15	<0.001	<0.061
Color , Apparent	ACU	90	100	<5	<15
, True	TCU	1	75	75	75
Copper , Dissolved	mg/L	29	<0.012	<0.001	<0.006
, Total	mg/L	24	0.012	<0.001	<0.004
Fluoride , Total	mg/L	48	0.14	<0.02	<0.07
Hardness , Dissolved	mg/L	96	46.9	4.2	26.6
Iron , Dissolved	mg/L	41	0.22	<0.001	<0.039
, Total	mg/L	19	3.42	0.04	0.69
Lead , Dissolved	mg/L	26	0.01	<0.001	<0.033
, Total	mg/L	24	<0.01	<0.001	<0.004
Magnesium , Dissolved	mg/L	7	1.56	0.81	1.11
, Total	mg/L	9	2.94	0.88	1.47
Manganese , Dissolved	mg/L	20	<0.01	<0.001	<0.01
, Total	mg/L	37	0.15	<0.01	<0.03
Mercury , Total	mg/L	5	<0.00005	<0.00005	<0.00005
Molybdenum, Dissolved	mg/L	9	<0.01	<0.01	<0.01
, Total	mg/L	16	0.02	<0.0002	<0.01
Nickel , Dissolved	mg/L	9	<0.05	<0.05	<0.05
, Total	mg/L	16	0.06	<0.001	<0.03
Nitrogen , Ammonia, Total	mg/L	35	0.2	0.002	0.07
Nitrate/Nitrite, Diss.	mg/L	90	0.09	<0.001	<0.027
, Organic, Total	mg/L	2	0.44	0.33	0.39
, Kjeldahl,Total	mg/L	15	0.52	0.04	0.25
, Total	mg/L	12	0.61	0.04	0.22

..continued

TABLE 21 (Continued)

Characteristic	Units	N	Max.	Min.	Mean
Oxygen , Dissolved	mg/L	5	13	9.4	11.9
pH		99	7.9	6.3	7.4
Phosphorus, Ortho, Diss.	mg/L	25	0.03	<0.002	<0.004
, Total, Diss.	mg/L	26	0.02	<0.001	<0.006
, Total	mg/L	29	0.309	<0.002	<0.033
Potassium , Dissolved	mg/L	9	0.5	0.3	0.3
, Total	mg/L	90	1.0	<0.1	<0.4
Selenium , Total	mg/L	3	0.0001	<0.0001	<0.0001
Silica , Dissolved	mg/L	91	9.2	0.5	4.7
Silver , Total	mg/L	3	<0.01	<0.01	<0.01
Sodium , Dissolved	mg/L	99	4.1	0.5	1.3
Solids , Dissolved	mg/L	17	108	32	50.1
, Suspended	mg/L	17	178	1	40.2
, Sus. Inorganic	mg/L	1	87	87	87
, Tot. Inorganic	mg/L	13	166	3	44.4
Specific Conductivity	µS/cm	100	107	11.4	58.8
Sulphate , Dissolved	mg/L	95	10.5	<1	<3.3
Temperature	°C	44	20	0	6.6
Turbidity	NTU	96	85	0.1	9.9
Vanadium , Dissolved	mg/L	9	<0.01	<0.01	<0.01
, Total	mg/L	10	<0.01	<0.01	<0.01
Zinc , Dissolved	mg/L	30	0.026	<0.001	<0.007
, Total	mg/L	35	0.13	<0.001	<0.011

Note: Analyses were made for polychlorinated biphenyls and several pesticides in 1974 (1-2 samples); however, all levels were below detection limits

*No detectable concentrations were measured for these characteristics

Data from Ministry of Environment's data bank, EQUIS

TABLE 22

Telkwa River Water Quality, Site 0400187 at Telkwa
1974-1984

Characteristic	Units	N	Max.	Min.	Mean
Alkalinity, Total	mg/L	16	64.5	22.1	38.8
Aluminum , Dissolved	mg/L	11	0.22	<0.02	<0.09
, Total	mg/L	10	5.4	<0.02	<0.91
Arsenic , Dissolved	mg/L	11	<0.005	<0.001	*
, Total	mg/L	11	<0.005	<0.001	*
Barium , Dissolved	mg/L	11	0.06	0.02	0.03
Boron , Dissolved	mg/L	11	<0.01	<0.01	<0.01
Cadmium , Dissolved	mg/L	11	<0.01	<0.0005	*
, Total	mg/L	12	<0.0005	<0.0005	<0.0005
Calcium , Dissolved	mg/L	17	19.7	6.7	11.6
, Total	mg/L	13	18.8	8.4	12.7
Carbon , Total Organic	mg/L	16	9	<1	<2.3
, Total	mg/L	16	16	4	9.6
Chromium , Dissolved	mg/L	13	<0.01	<0.005	*
, Total	mg/L	14	0.02	<0.005	<0.01
Chloride , Dissolved	mg/L	16	0.7	<0.5	<0.52
Cobalt , Dissolved	mg/L	11	<0.1	<0.1	<0.1
, Total	mg/L	11	0.13	<0.1	<0.10
Color , True	TCU	5	60	5	21
, TAC	TAC	6	32	1	11
Copper , Dissolved	mg/L	13	0.003	<0.001	0.0015
, Total	mg/L	14	0.02	<0.001	<0.004
Hardness , Dissolved	mg/L	14	63.2	20.6	36.7
Iron , Dissolved	mg/L	13	0.94	0.03	0.18
, Total	mg/L	14	18.4	0.11	2.26
Lead , Dissolved	mg/L	13	0.001	<0.001	<0.001
, Total	mg/L	14	0.006	<0.001	<0.002
Magnesium , Dissolved	mg/L	17	3.4	0.9	1.6
, Total	mg/L	13	3.09	0.92	2.16
Manganese , Dissolved	mg/L	13	0.02	<0.01	<0.09
, Total	mg/L	13	0.5	0.01	0.09
Mercury , Dissolved	mg/L	2	<0.00005	<0.00005	<0.00005
, Total	mg/L	2	<0.00005	<0.00005	<0.00005
Molybdenum, Dissolved	mg/L	11	0.01	<0.01	<0.01
, Total	mg/L	12	0.03	<0.0005	<0.011
Nickel , Dissolved	mg/L	11	<0.05	<0.05	<0.05
, Total	mg/L	12	<0.05	<0.01	*
Nitrogen , Ammonia, Total	mg/L	15	0.01	<0.005	<0.006
Nitrate/Nitrite, Diss.	mg/L	16	0.11	0.02	0.049
, Organic, Total	mg/L	5	0.28	0.03	0.10
, Kjeldahl,Total	mg/L	15	0.29	0.03	0.11
, Total	mg/L	16	0.32	0.04	0.15

..continued

TABLE 22 (Continued)

Characteristic	Units	N	Max.	Min.	Mean
Oxygen , Dissolved	mg/L	2	10.2	7.2	8.7
pH		16	7.9	7.1	7.5
Phosphorus, Ortho, Diss.	mg/L	9	<0.003	<0.003	<0.003
, Total, Diss.	mg/L	11	0.007	0.003	0.005
, Total	mg/L	17	0.34	0.006	0.048
Potassium , Dissolved	mg/L	15	0.4	0.2	0.3
Silica , Dissolved	mg/L	15	8.1	3.1	5.7
Sodium , Dissolved	mg/L	15	2.9	0.9	1.8
Solids , Dissolved	mg/L	16	86	33	52
, Suspended	mg/L	17	424	1	45.4
Specific Conductivity	µS/cm	17	139	48	83.7
Sulphate , Dissolved	mg/L	15	6.2	2.2	4.7
Tannin and Lignin, Total	mg/L	1	<0.1	<0.1	<0.1
Turbidity	NTU	14	180	1.1	24.7
Vanadium , Dissolved	mg/L	11	<0.01	<0.01	<0.01
, Total	mg/L	11	<0.01	<0.01	<0.01
Zinc , Dissolved	mg/L	12	<0.005	<0.005	<0.005
, Total	mg/L	14	0.023	<0.005	<0.008

*No detectable concentrations were measured for these characteristics
Data from Ministry of Environment's data bank, EQUIS

TABLE 23

Bulkley River Water Quality, Site 0400204, 8 km Upstream from the Sewage Treatment Plant at Smithers 1966-1976

Characteristic	Units	N	Max.	Min.	Mean
Alkalinity, Total	mg/L	22	82	20.7	30.0
Aluminum , Dissolved	mg/L	1	0.03	0.03	0.03
Cadmium , Total	mg/L	2	<0.0005	<0.0005	<0.005
Calcium , Dissolved	mg/L	20	21.1	6.9	10.0
, Total	mg/L	2	10.2	9.7	10.0
Carbon , Total Organic	mg/L	19	23	<1	<5.2
, Total	mg/L	17	23	3	6.9
Chromium , Dissolved	mg/L	3	<0.005	<0.005	<0.005
, Total	mg/L	3	0.008	<0.005	<0.006
Chloride , Dissolved	mg/L	19	6.8	0.1	0.8
Coliforms , Fecal	MPN/100 mL	1	<2	<2	<2
, Total	MPN/100 mL	1	49	49	49
Color , Apparent	ACU	15	55	<5	<14
, True	TCU	6	40	5	18
, TAC	TAC	7	31	<1	<12
Copper , Dissolved	mg/L	8	0.004	<0.001	<0.002
, Total	mg/L	5	0.014	<0.001	<0.007
Flow	m^3/s	20	555.0	21.8	169.8
Fluoride	mg/L	6	<0.1	<0.05	*
Hardness , Dissolved	mg/L	22	81.1	21.3	30.8
Iron , Dissolved	mg/L	10	0.1	<0.001	<0.065
, Total	mg/L	5	11.3	0.2	3.3
Lead , Dissolved	mg/L	8	0.017	<0.001	<0.003
, Total	mg/L	5	<0.01	<0.001	*
Magnesium , Dissolved	mg/L	7	6.9	0.74	1.97
, Total	mg/L	4	1.6	0.9	1.2
Manganese , Dissolved	mg/L	6	0.02	<0.01	<0.013
, Total	mg/L	5	0.34	<0.01	<0.09
Mercury , Dissolved	mg/L	3	<0.00005	<0.00005	<0.00005
, Total	mg/L	3	<0.00005	<0.00005	<0.00005
Molybdenum, Total	mg/L	2	0.0007	<0.0005	<0.0006
Nickel , Total	mg/L	2	<0.01	<0.01	<0.01
Nitrogen , Ammonia, Total	mg/L	7	<0.1	<0.005	*
Nitrate/Nitrite, Diss.	mg/L	21	0.14	<0.005	<0.045
, Organic, Total	mg/L	6	0.24	0.03	0.085
, Kjeldahl, Total	mg/L	6	0.25	0.03	0.10
, Total	mg/L	6	0.27	0.03	0.12
Oxygen , Dissolved	mg/L	7	12.7	7.5	11.0
pH		21	7.9	7.3	7.5
Phosphorus, Ortho, Diss.	mg/L	18	0.04	<0.002	<0.006
, Total, Diss.	mg/L	14	0.02	<0.001	<0.004
, Total	mg/L	19	0.25	<0.003	<0.036

..continued

TABLE 23 (Continued)

Characteristic	Units	N	Max.	Min.	Mean
Potassium , Dissolved	mg/L	5	1.0	0.2	0.4
, Total	mg/L	12	0.9	0.2	0.3
Silica , Dissolved	mg/L	20	12.8	3.1	5.3
Sodium , Dissolved	mg/L	21	6.1	0.7	1.6
Solids , Dissolved	mg/L	7	120	30	51.4
, Suspended	mg/L	9	327	2.4	58.6
, Susp. Inorganic	mg/L	3	33	<1	<16.7
Specific Conductivity	µS/cm	23	188	47	66.9
Sulphate , Dissolved	mg/L	17	5.2	<1	3.9
Tannin and Lignin, Total	mg/L	2	0.1	<0.1	<0.1
Temperature	°C	6	11	0	6.4
Turbidity	NTU	23	96	0.9	13.0
Zinc , Dissolved	mg/L	8	0.016	<0.001	<0.005
, Total	mg/L	4	0.018	<0.005	<0.010

*No detectable concentrations were measured for these characteristics
Data from Ministry of Environment's data bank, EQUIS

TABLE 24
Bulkley River Water Quality Monitoring at the Sewage Treatment Plant at Smithers (PE 373): Data from Sites 0400434 (Upstream Control), 0400435 (100 m Downstream), and 0400436 (1.2 km Downstream)
1974-1975

Characteristic	Units	U/S 0400434 N	U/S 0400434 Max.	U/S 0400434 Min.	U/S 0400434 Mean	D/S 0400435 N	D/S 0400435 Max.	D/S 0400435 Min.	D/S 0400435 Mean	D/S 0400436 N	D/S 0400436 Max.	D/S 0400436 Min.	D/S 0400436 Mean
Alkalinity, Total	mg/L	2	28	22.5	25.3	2	27.8	22	24.9	2	28	21.8	24.9
Cadmium, Dissolved	mg/L	1	<0.0005	<0.0005	<0.0005	1	<0.0005	<0.0005	<0.0005	1	<0.0005	<0.0005	<0.0005
Calcium, Dissolved	mg/L	2	19	8.8	13.9	2	8.9	7.5	8.2	2	8.8	7.5	8.2
Carbon, Total Organic	mg/L	1	2	2	2	1	2	2	2	1	2	2	2
Chlorine, Residual	mg/L	4	0	0	0	1	0	0	0	4	0	0	0
Chromium, Dissolved	mg/L	1	<0.005	<0.005	<0.005	1	<0.005	<0.005	<0.005	1	<0.005	<0.005	<0.005
Coliforms, Fecal	MPN/100 mL	2	20	20	20*	2	20	<20	<20*	2	20	<20	<20*
, Total	MPN/100 mL	2	80	40	57*	2	50	<20	<32*	2	40	20	28*
Color, True	TCU	2	30	15	23	2	30	20	25	2	30	15	22.5
, TAC	TAC	2	33	12	23	2	32	14	23	2	23	13	18
Copper, Dissolved	mg/L	1	0.002	0.002	0.002	1	0.003	0.003	0.003	1	0.004	0.004	0.004
Hardness, Dissolved	mg/L	2	28.6	23.1	25.9	2	28.8	22.6	25.7	2	28.6	22.6	25.6
Iron, Dissolved	mg/L	1	0.1	0.1	0.1	1	<0.1	<0.1	<0.1	1	<0.1	<0.1	<0.1
Lead, Dissolved	mg/L	1	<0.001	<0.001	<0.001	1	<0.001	<0.001	<0.001	1	<0.002	<0.002	<0.002
Magnesium, Dissolved	mg/L	2	7.6	1.6	4.6	2	1.6	0.95	1.28	2	1.6	0.95	1.28
Manganese, Dissolved	mg/L	1	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	1	<0.2	<0.2	<0.2
Nickel, Dissolved	mg/L	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01
Nitrogen, Ammonia, Total	mg/L	2	0.016	0.014	0.015	2	0.011	0.01	0.01	2	0.011	0.011	0.011
Nitrate/Nitrite, Diss.	mg/L	2	0.03	0.03	0.03	2	0.02	0.02	0.02	2	0.03	0.02	0.025
Nitrate, Diss.	mg/L	2	0.03	0.03	0.03	2	0.02	0.02	0.02	2	0.03	0.02	0.025
Nitrite, Diss.	mg/L	2	<0.005	<0.005	<0.005	2	<0.005	<0.005	<0.005	2	<0.005	<0.005	<0.005
, Organic, Total	mg/L	2	0.24	<0.01	<0.13	2	0.07	0.01	0.04	2	0.12	0.01	0.065
, Kjeldahl, Total	mg/L	2	0.25	0.02	0.14	2	0.08	0.02	0.05	2	0.13	0.02	0.075
, Total	mg/L	1	0.05	0.05	0.05	1	0.04	0.04	0.04	1	0.04	0.04	0.04
Oxygen, Dissolved	mg/L	3	11.5	10.6	11.0	3	11.7	10.7	11.2	3	11.7	10.8	11.3
pH		2	7.5	7.5	7.5	2	7.4	7.4	7.4	2	7.5	7.4	7.45
Phosphorus, Ortho, Diss.	mg/L	2	0.004	0.004	0.004	2	0.004	0.003	0.0035	2	0.003	<0.003	<0.003
, Total	mg/L	2	0.05	0.046	0.048	2	0.048	0.048	0.048	2	0.049	0.046	0.048
Sodium, Dissolved	mg/L	1	1.6	1.6	1.6	1	1.5	1.5	1.5	1	2	2	2
Solids, Dissolved	mg/L	2	58	42	50	2	56	38	47	2	58	38	48
, Suspended	mg/L	5	38	2	28.6	5	48	2	31	5	48	3	33
Specific Conductivity	µS/cm	3	63	49	54	5	62	49	52	7	250	49	83
Sulphate, Dissolved	mg/L	1	<5	<5	<5	1	<5	<5	<5	1	<5	<5	<5
Temperature	°C	5	10	6	8.2	5	10	6	8.4	5	10	6	8
Turbidity	NTU	2	21	17	19	2	19	16	17.5	2	21	17	19
Zinc, Dissolved	mg/L	1	<0.005	<0.005	<0.005	1	<0.005	<0.005	<0.005	1	0.01	0.01	0.01

*Geometric Mean
Data from Ministry of Environment data bank, EQUIS

TABLE 25

Bulkley River Water Quality Monitoring of the Sewage Treatment Plant at Smithers (PE 373): Data from Sites 0400434 (Upstream) and 0400435 (100 m Downstream), 1983-1984

NOVEMBER 30, 1983

Characteristic	Units	U/S 0400434				D/S 0400435			
		Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4
BOD_5	mg/L	<10	<10	<10	<10	<10	<10	<10	<10
Carbon, Total Organic	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
, Total Inorganic	mg/L	8	8	8	8	8	8	8	8
COD	mg/L	<10	13	-	-	<10	15	13	<10
Coliforms, Fecal	MPN/100 mL	8	9	14	11	16	14	15	14
Total	MPN/100 mL	9	43	32	27	230	28	54	36
Nitrogen, NH_3/NH_4, Diss.	mg/L	<0.005	<0.005	<0.005	<0.005	0.038	<0.005	<0.005	<0.005
, NO_2/NO_3, Diss.	mg/L	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
, Kjeldahl, Total	mg/L	0.03	0.02	0.02	0.02	0.06	0.02	0.02	0.02
pH		7.7	7.6	7.6	7.6	7.6	7.6	7.6	7.6
Phosphorus, Total	mg/L	0.007	0.007	0.01	0.007	0.016	0.008	0.007	0.007
Solids, Dissolved	mg/L	45	42	40	45	47	46	50	45
, Suspended	mg/L	1	1	1	1	1	1	1	1
Specific Conductivity	µS/cm	70	69	70	70	72	70	70	68
Temperature	°C	0	0	0	0	0	0	0	0

APRIL 1, 1984

Characteristic	Units	U/S 0400434				D/S 0400435			
		Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4
BOD_5	mg/L	<10	<10	<10	<10	<10	<10	<10	<10
Carbon, Total Organic	mg/L	4	4	4	4	4	4	4	4
, Total Inorganic	mg/L	10	10	10	10	10	10	10	10
COD	mg/L	18	17	18	20	21	18	17	12
Coliforms, Fecal	MPN/100 mL	4	1	3	2	0	1	2	4
Total	MPN/100 mL	105	65	85	55	55	72	53	50
Nitrogen, NH_3/NH_4, Diss.	mg/L	0.005	<0.005	<0.008	0.005	<0.008	0.008	0.008	0.005
, NO_2/NO_3, Diss.	mg/L	0.03	0.02	0.02	0.02	0.03	0.02	0.02	0.02
, Kjeldahl, Total	mg/L	0.20	0.18	0.19	0.20	0.22	0.20	0.20	0.17
pH		7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8
Phosphorus, Total	mg/L	0.019	0.018	0.019	0.020	0.034	0.018	0.016	0.020
Solids, Dissolved	mg/L	76	72	75	74	76	75	72	75
, Suspended	mg/L	3	4	3	4	22	3	4	3
Specific Conductivity	µS/cm	88	86	85	86	87	86	86	88
Temperature	°C	5.5	5.5	5.5	5.5	6	6	6	6

Note: Zone 1 is the side of the river with the sewage treatment plant discharge; Zone 4 is the opposite side.

TABLE 26

RECOMMENDED EFFLUENT AND WATER QUALITY MONITORING FOR THE BULKLEY RIVER

Characteristic	SITE									
	Houston STP				Morice River	Quick	Telkwa River	Smithers STP		
	U/S 0400297	PE 287	D/S 0400295	D/S 0400296	0400203	0920088	0400187	U/S 0400434	PE 373	D/S 0400435
Fecal Coliforms[1]	5(30)	5(30)	5(30)	-	-	-	-	5(30)	5(30)	5(30)
Periphyton Standing Crop	LF(1)	-	LF(1)	-	-	-	-	LF(1)	-	LF(1)
Suspended Solids	LF(2)	LF(2)	LF(2)	M	M	M	M	LF(2)	LF(2)	LF(2)
Turbidity	LF(2)	LF(2)	LF(2)	M	M	M	M	LF(2)	LF(2)	LF(2)
Oxygen, Dissolved	LF(2)	LF(2)	LF(2)	-	-	-	-	LF(2)	LF(2)	LF(2)
N: Ammonia, Total Diss.	LF(2)	LF(2)	LF(2)	-	-	-	-	LF(2)	LF(2)	LF(2)
Nitrite	LF(2)	LF(2)	LF(2)	-	-	-	-	LF(2)	LF(2)	LF(2)
Nitrate/Nitrite	LF(2)	LF(2)	LF(2)	-	-	-	-	LF(2)	LF(2)	LF(2)
Kjeldahl, Total	LF(2)	LF(2)	LF(2)	-	-	-	-	LF(2)	LF(2)	LF(2)
Total (calculated)	LF(2)	LF(2)	LF(2)	-	-	-	-	LF(2)	LF(2)	LF(2)
P: Ortho, Dissolved	LF(2)	LF(2)	LF(2)	-	-	-	-	LF(2)	LF(2)	LF(2)
Total, Dissolved	LF(2)	LF(2)	LF(2)	-	-	-	-	LF(2)	LF(2)	LF(2)
Total	LF(2)	LF(2)	LF(2)	-	-	-	-	LF(2)	LF(2)	LF(2)
Temperature	LF(2)	LF(2)	LF(2)	M	M	M	M	LF(2)	LF(2)	LF(2)
pH	LF(2)	LF(2)	LF(2)	M	M	M	M	LF(2)	LF(2)	LF(2)
Hardness	LF(2)	-	LF(2)	M	M	M	M	LF(2)	-	LF(2)
Specific Conductivity	LF(2)	-	LF(2)	M	M	M	M	LF(2)	-	LF(2)
Metals (Total and Diss): Al, Co, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn	-	-	-	M	M	M	M	-	-	-

[1] 1 sample per week for 5 weeks in a period no longer than 30 days, during late summer (August to September) when water used for both recreation and drinking.

U/S - upstream from
D/S - downstream from
M - monthly
LF(1)-at low flow, once per year
LF(2)-at low flow, twice per year

Note: sampling may need to be increased or decreased to check objectives, depending on circumstances.

TABLE 27
SUMMARY OF DETECTION LIMITS FOR CERTAIN METALS

Metal	"Package" Detection Limit	Most Sensitive Detection Limit	Most Restrictive Water Quality Criterion	Package+ Identification Where Analysis Available	Comments
Aluminum	0.02	0.02	0.05	F,G	Use Package Analysis
Cadmium	0.01	0.0001	0.0002	F,G	Use More Sensitive Analysis
Chromium	0.01	0.005	0.02	F,G	Use More Sensitive Analysis**
Cobalt	0.10	0.005	0.05	F,G	Use More Sensitive Analysis
Copper	0.01	0.001	0.002	F,G	Use More Sensitive Analysis
Iron	0.01	0.005	0.3	F,G	Use Package Analysis
Manganese	0.01	0.001	0.05	F,G	Use Package Analysis
Nickel	0.05	0.01	0.013	F,G	Use More Sensitive Analysis
Lead	0.10	0.001	0.00075-0.03	F,G	Use More Sensitive Analysis
Zinc	0.01	0.005	0.05	F,G	Use Package Analysis

* From EQUIS Test Code Dictionary
** More Sensitive Analysis recommended so that uncertainty of values for detection limits is eliminated
\+ Package "F" provides analyses as total; package "G" as dissolved