Biological Monitoring
of the Upper Bulkley River
1993-94:
PE-0287

prepared for:

District of Houston

PO Box 370

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by

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January 1994

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1. Introduction

The District of Houston is required under Waste Management Permit No. PE-00287 to carry out receiving environment monitoring on the upper Bulkley River in the vicinity of the Houston Sewage Treatment Plant (STP). The objective of the monitoring program is to assess possible impacts of the STP discharge on aquatic life in the upper Bulkley River, with particular reference to juvenile salmonids. Water quality assessment and biological monitoring of the Bulkley September 1990 through December 1992 have been reported previously (Remington 1991, Remington et. al. 1993).

This report discusses biological monitoring of benthic algae (periphyton) and benthic invertebrates (benthos) conducted at one upstream and two downstream sites on the Bulkley August 22-23, 1994. There is also limited assessment of water quality during the period of March 1993 to August 1994. My thanks to Deb Portman, EPP, Skeena Region, who provided electronic water quality data and statistical analysis.

1.1 Upper Bulkley River

The upper Bulkley River is that portion of the Bulkley River above the confluence with the larger Morice River. The upper Bulkley has a drainage basin area of roughly 2400 km^2, which includes Bulkley Lake, Maxan Lake and Goosly Lake. At the municipality of Houston, about five kilometres upstream of the Morice confluence, the river has a low gradient with frequent meanders across a broad alluvial floodplain (Figure 1). The recreation potential of the river for walking, swimming, bird watching and fishing is high. Anadromous fish present in the upper Bulkley River include Coho and Chinook salmon and summer-run steelhead trout. Historical mean escapements of Coho spawners in the Upper Bulkley exceed 2000 fish, but numbers have declined markedly during most years in the past decade (Data on file, DFO Smithers). Chinook salmon escapement estimates are in the 500-600 range. Many of these fish spawn in the immediate vicinity of the STP. No reliable estimates are available for summer-run steelhead which tend to hold in the fall and winter in the mainstem Bulkley River and move up into the upper Bulkley with rising water levels and temperatures to spawn in May. A small number of sockeye and pink salmon are also reported on some years (Hancock et al. 1983).

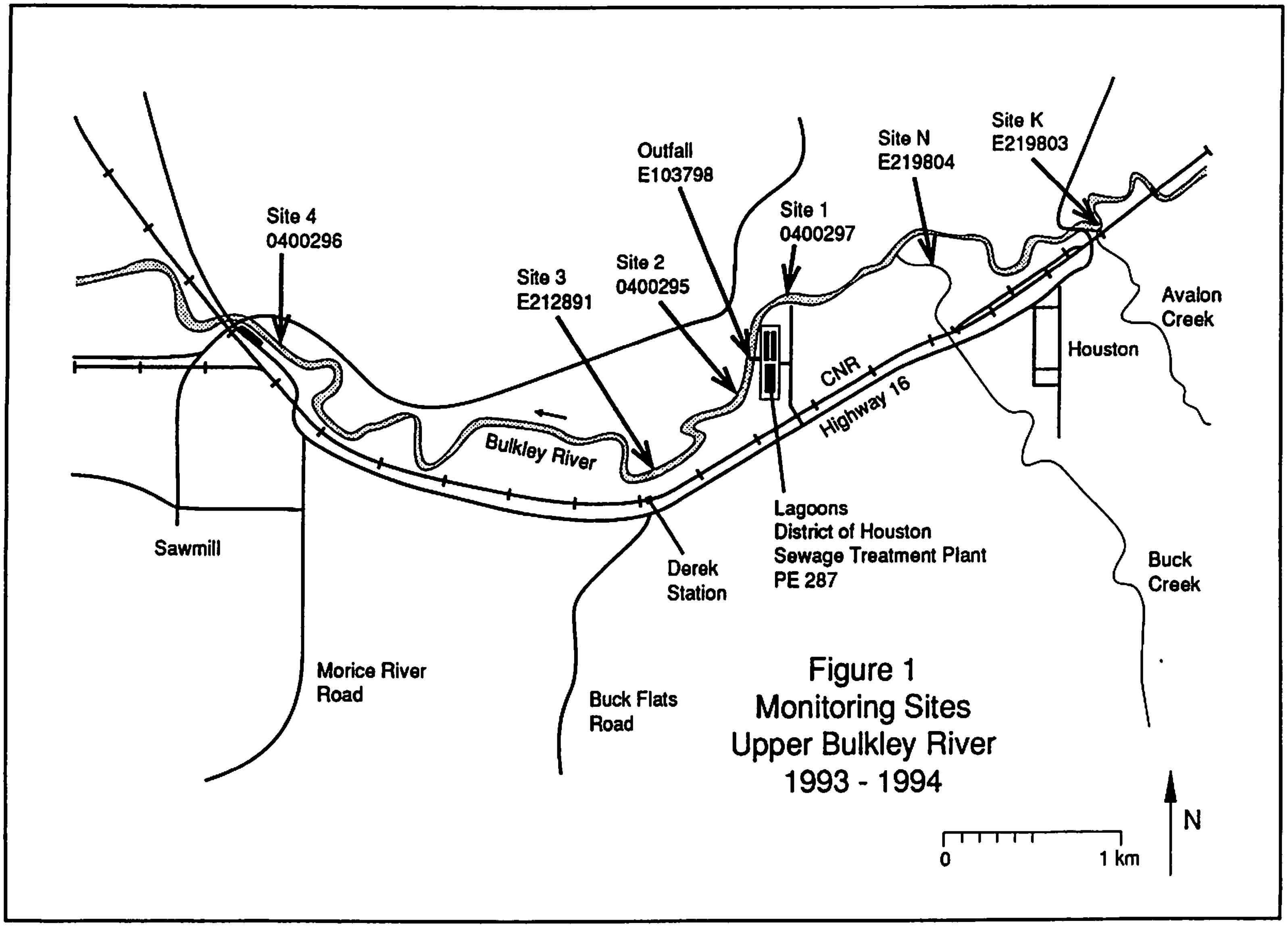


Figure 1
Monitoring Sites
Upper Bulkley River
1993 - 1994

1.2 District of Houston Sewage Treatment Plant - Background

1969 - 1989

The Houston STP is situated on the dyked south bank of the Upper Bulkley River about 1.2 km downstream of the confluence of Buck Creek and about 5 km upstream of its confluence with the Morice River. PE-0287 was issued on July 30, 1969, when the plant consisted of two aeration cells, chlorination plant and outfall to the center of the river. Biological studies by Maclean and Diemert (1987) and Remington (1991) reported increased periphyton biomass accumulation on artificial and natural substrates downstream of the STP. Taxonomic analysis also indicated a shift in periphyton community structure consistent with eutrophication. Subsequently a third storage cell was added to provide effluent storage during periods of extremely low flows.

1990 - 1991

A receiving environment monitoring program consisting of monthly water quality and annual biological monitoring was required by the WMB in November 1989. The District of Houston initiated monthly receiving water sampling and analysis September 17, 1990. and Remington Environmental was contracted to conduct receiving environment biological monitoring during summer low flows September 7-14, 1990. Four monthly monitoring sites were established by EPP as follows:

Site 1 (SEAM 0400297) 400 metres upstream of the outfall

Site 2 (SEAM E212484) 400 metres downstream of the outfall and downstream of the #3 Cell (The decision was made not to use the former EPP Site 0400295 located 100 m downstream of the outfall. Site 2 E212484 was established in order to assess the possibility of exfiltration from the #3 Cell. Cross-stream sampling was required at this site; Site 2E (east bank), 2C (centre) and 2W (west bank).

Site 3 (SEAM E212891) 850 metres downstream. This was the site of maximum periphyton accumulation reported in the 1966 study by Maclean and Deimert.

Site 4 (SEAM 0400296) 3.2 km downstream of the outfall.

Results of the 1990 biological monitoring (Remington, 1991) are summarized below:

- There was no ambient water quality data available for the river prior to the first season of biological monitoring. Water quality parameters for the following period of September, 1990 to June, 1991 did not exceed Bulkley River Objectives (Nijman, 1986), or the BC Environment Approved and Working Criteria for Water Quality (Pommen, 1989).

- Periphyton standing crop on the natural substrate equaled or exceeded the Bulkley River Objective for protection of aesthetics (50 mg/m2 chlorophyll-a) at all sites, and increased downstream of the STP. Periphyton standing crop was significantly greater at Site 3 as compared to Site 1 by t-Test ($p<0.0000007$). The Objective level for protection of aquatic life (<100 mg/m2 chlorophyll-a) was exceeded at Site 3 which had a standing crop of 320 mg/m2.

- Benthic invertebrate density was high at all sites and increased downstream of the STP. A t-Test indicated a significant difference in density between Site 1 and Sites 2 and 4. The average species density (number of taxa/m^2) was least at Site 1 and greatest at Site 3. Species richness (Margalef's diversity index) was least at Site 2 and greatest at Site 3.

- Fish enumeration was carried out at Sites 1 and 3. The predominant species were Longnose Dace (76.5%) and steelhead fry (18.8%). Juvenile Chinook and Coho each comprised 1.1% of the overall catch. Sample results suggested that juvenile salmonid densities (excluding one school of Mountain Whitefish) were slightly higher at the upstream site than the downstream site. However, habitat differences between sites, sampling difficulties, and small number of sample sites could have resulted in this slight variation. Juvenile salmonid densities were within ranges reported previously for the Upper Bulkley River (Tredger 1982).

A major upgrading of the sewage treatment plant was completed during the summer of 1991. These included a phosphorous removal facility (alum injection system and flocculation chamber), reconstruction of the chlorination/dechlorination system, upgrading of electrical power supply works, the installation of emergency overflow gate from Cell #3, and a new raker bar screen and flow meter. The phosphorous removal facility was not put into full time use until March, 1992.

1992 - 1993

The receiving environment monitoring program for PE-0287 was amended by letter (F. Rhebergen, July 25, 1992) to again include biological monitoring during summer low flows 1992.

Results of the 1992 biological monitoring (Remington et.al. 1993) are summarized below:

- A one way ANOVA was run on data for each water quality parameter to see if differences by site were apparent. Ammonia-N was the only parameter for which there was a significant difference indicated between sites. A series of *t*-Tests were then run to examine the differences in mean Ammonia concentrations between Site 1 (control) and each of the downstream sites. A significant ($P<0.05$) increase in mean ammonia concentrations was indicated for Sites 2E, 2C, and 3 downstream of the STP. A maximum ammonia concentration of 0.385 mg/L was recorded at Site 2E on September 2, 1992 during a period of extreme low flows. Although elevated, total ammonia concentrations were within objective levels for the protection of aquatic life.

The percentage of total ammonia which is present as un-ionized ammonia, which is toxic to fish and benthic invertebrates, increases with temperature and pH. A depression in dissolved oxygen concentrations during winter low flows, due to ammonia caused BOD, could have a negative impact of juvenile salmonid overwintering and egg survival, since inter-gravel oxygen levels are usually several mg/l lower than those in the water column. Improvement in the biological treatment of the effluent by improved aeration would be expected to reduce ammonia loading.

- Periphyton biomass as chlorophyll-a was near or below the 50 mg/m2 objective at Sites 1, 3 and 4, but equaled the objective level for the protection of aquatic life at Site 2E, with a biomass of 100 mg/m2. This increase in chlorophyll-a biomass at Site 2 was significant using the t-Test ($P= 0.0014$). Diatoms dominated the algal community at all sites and diversity and richness appeared unaffected by location. Two diatom taxa were found to decrease significantly at Site 2, with recovery at Sites 3 and/or 4. Other changes in periphyton community structure, although not statistically significant, were consistent with nutrient enrichment. A high degree of disturbance to the substrate was observed during the sampling period September 1992, and somewhat inconsistent biomass results were achieved. Therefore a repetition of the periphyton monitoring study in the following year was recommended.

- Calculation of growing season N:P ratios at Site 1 upstream of the STP indicated that the upper Bulkley River is either nitrogen limited or co-limited (that is, either biologically available nitrogen or phosphorus could contribute to excessive stream algal biomass). Nordin

(1985) lists the following as factors contributing to high risk of excessive algal biomass: (1) biologically available phosphorus greater than 0.003 mg/l or inorganic nitrogen greater than 0.025 mg/l. Thus it appears that the Bulkley River upstream of the STP with a mean ortho-phosphate concentration of 0.016 mg/l, and mean dissolved inorganic nitrogen concentration of 0.033 mg/l, is at high risk for excess algae biomass. The algal biomass at Site 1 upstream of the STP is already at or near the Objective level for protection of aesthetics and recreation of 50 mg/m^2 chlorophyll-a.

Comparison of the 1986 and 1992 data indicates that an increase in ortho-phosphate concentrations may have occurred at Site 1 upstream of the STP during this time period. Preliminary water quality data from two streams entering the Bulkley within the District of Houston boundaries (Avalon and Buck Creeks) indicated that these streams may be contributing to the phosphorus loading upstream of the STP. Two subdivisions which are not serviced by the District of Houston sewerage mains are of concern. One is along Avalon Creek, and the other is north of the railway tracks east of the confluence of Buck Creek. An investigation of non-point sources of nutrients to the Upper Bulkley River (e.g. from septic systems and agriculture) was suggested.

- There was no statistically significant spatial change found in benthic invertebrate density, diversity or richness in the September 1992 sampling, although invertebrate density was nearly doubled at sites 1 and 4 as compared to Site 2E. Only the density of one mayfly, *Serratella* sp., was found to significantly change by site, primarily due to a three fold increase in numbers at Site 4 relative to the highest density at Site 1 which was greater than at any of the other sites. Statistically insignificant trends were a decline in total abundance between sites 1 and 2 of chironomids and larvae of the empidid flies. The general recovery of the benthic community and in many cases an increase in densities suggests that changes which may have occurred at Site 2E were localized, with a general recovery at Sites 3 and 4.

- Fish species composition in the upper Bulkley is dominated by Longnose Dace and to a lesser extent Longnose Suckers (together accounting for about 90% of all fish in the study area). This pattern occurred upstream and downstream of the STP and probably reflects a combination of low stream velocities, warm temperatures, (and perhaps eutrophication) in this section of the upper Bulkley, providing Longnose Dace with a competitive feeding advantage over steelhead and salmon juveniles. Juvenile steelhead and salmon densities combined were in the 0.2 to 0.3 fish/m^2 range at all sites. This density is similar to that measured in 1990 and are relatively low densities compared to those found in Buck Creek and Foxy Creek, upstream in the Bulkley watershed. It should be emphasized that the sites selected for comparison were simple sections of stream and that complex debris sites with deeper pool habitat typically utilized by juvenile Coho were avoided. Generally the study sites were rated poor to moderate habitat for juvenile steelhead. (Typically the sites are limited by small bed material size and low water velocities.) Although overall fish biomass (g/m^2) was lower at the two downstream sites, the combined salmon and steelhead biomass was similar upstream and downstream of the STP. Steelhead fry lengths were significantly larger (3 mm fork length) upstream of the treatment plant than downstream. This occurred in the 1990 study also and may reflect more favourable growing conditions upstream of the treatment plant. Overall fry lengths at both locations were exceptionally large relative to other steelhead producing streams in the area.

1993

The 1992 receiving environment data was discussed and several changes in the monitoring program were agreed upon in a July 5, 1993 meeting between District of Houston and EPP. Receiving environment sampling should occur during positive discharge as much as possible. Cross-stream sampling was discontinued at Site 2, since entrainment of the effluent along the east shore at this site had been well documented. Monthly sampling will continue at Site 2E. Monitoring at Site 4 was reduced to occur during the summer and winter low flow periods only. Site "K" on the Bulkley River upstream of Avalon Creek will be sampled monthly as a background site. Site "N" on Buck Creek 50 metres downstream of 4th Street will be sampled monthly. Subsequently recommendations were made by EPP concerning improved aeration in the #1 and #2 Cells, and improvements to the #3 Cell to prevent short-circuiting and improve sludge removal operations. No biological monitoring was required in 1993.

1994

The District of Houston received a warning from EPP for non-compliance's with Permit PE-287 from January-April 1994. Under the permit Total Phosphorous cannot exceed 1.5 mg/L. The permit limit was exceeded on three sampling dates (maximum 2.3 mg/L). The exceedance occurred as the result of errors in the effluent testing procedures prior to discharge, which have been corrected. D. Remington recommended the wastewater operator should run blanks and standard solutions (available from Hach) on a regular basis to verify effluent testing results (By FAX, 29-Aug-94).

Proposed improvements to the aeration system and #3 Cell were discussed at a July 27, 1994 meeting between the District of Houston and EPP. The District has contracted Dayton & Knight Ltd. to upgrade the aeration system in Cells #1 and #2. Two blowers will be replaced as well. If possible a small berm will be constructed in the southeast corner of Cell #3 to contain alum sludge. Periphyton biomass and possibly benthic invertebrate monitoring will be required in 1994.

2. Site Descriptions

Several SEAM Site numbers relating to this permit were changed by EPP in 1993 in order to eliminate discrepancies between SEAM, WASTE and District of Houston reporting (D. Portman, memo 12-Sep-93). Revised SEAM Site Numbers are shown below. The District of Houston Site numbers are unchanged.

Site 1 (SEAM 0400297)

Site 1 is located approximately 400 metres upstream of the STP outfall at the end of Nadina Street on the left bank of the Bulkley River looking downstream. Biological monitoring was carried out at this site August 22, 1994. At the time of sampling the river was clear with moderately low flow conditions of 5.5 m^3/s (measured at Environment Canada Gauge Station No.08EE003 located at the Highway 16 Bridge near Site 4). The average velocity at this site during sampling was 0.24 m/s. Temperature was 14.5° C with a dissolved oxygen concentration of 10.2 mg/L. The river runs east to west in this reach with an estimated solar arc of 90% (about 10% shading from nearby cottonwoods). No Chinook spawners were observed at this site, which is quite different from previous sampling years, when much of this reach has been covered with redds.

Site 2 (SEAM 0400295)

This site was formerly referred to as Site 2E (SEAM Site E212484). Site 2 is located 200 metres downstream of the STP outfall and about 100 metres downstream of the #3 Cell on the left bank of the Bulkley River. Biological monitoring was carried out at this site August 22, 1994. Velocity was similar to Site 1, but could not be estimated because of extreme windiness. Temperature was

17° C and dissolved oxygen was 10.8 mg/l. The river runs north to south in this reach with an estimated solar arc of 100% (no shading). Again, no Chinook spawners or redds were present.

Site 3 (SEAM E212891)

Site 3 (SEAM Site E212891) is located approximately 900 metres downstream of the STP on the left bank of the Bulkley River. Biological monitoring was carried out at this site August 23, 1994. Average velocity was 0.38 m/s. Temperature was 15° C and dissolved oxygen was 11.8 mg/L. The flow is more or less east to west here with an estimated solar arc of 70%. One pair of Chinook spawners were active mid-stream at this site.

Site 4 (SEAM 0400296)

Site 4 (SEAM Site 0400296) is located roughly 3.5 km downstream of the STP, upstream of the highway and industrial bridges, on the left bank of the Bulkley River (near the Northwood Picnic Site). Water quality monitoring was conducted at this site during the months of December, January, February, July , August and September.

Site K (SEAM E219803)

Site K (SEAM E219803) is located approximately 1.6 km upstream of the STP just upstream of the Avalon Creek confluence with the Bulkley River on the right bank. This site is upstream of municipality and is considered a background site. Monthly water quality monitoring was carried out at this site.

Site N (SEAM E219804)

Site N (SEAM E219804) is located on the right bank of Buck Creek 50 m downstream of 4th Street. Monthly water quality monitoring was carried out at this site.

3. Sampling and Laboratory Methods

3.1 Water Quality

All water sampling was conducted by the Water/Wastewater Operator, District of Houston, usually Paul James. Monthly grab samples were collected according to the permitted monitoring program. Samples were immediately placed on ice and transported air freight to ASL Analytical Service Laboratories LTD. in Vancouver for analysis. Temperature and dissolved oxygen were recorded and the field notes were sent to EPP monthly. Samples were analyzed in accordance with Standard Methods for the Examination of Water and Wastewater (APHA, 1989).

3.2 Periphyton

Algal biomass as chlorophyll-a

Sampling was carried out according to MOE Methods of Aquatic Data Collection in B.C. (Shera and Clark, 1985). Care was taken to chose representative substrate (rocks) for sampling, at similar depth (15-20 cm) and water velocity at each site. Six replicate samples for biomass analysis were taken at each site. The periphyton was scraped and rinsed with DI water into a filter apparatus and collected on a 0.45 µm filter. The samples were immediately preserved by freezing in a darkened container with activated silica gel desiccant. The sample area was traced on paper in the field and later measured with a digital planimeter. The frozen desiccated samples were shipped to Xenon Environmental Inc. for chlorophyll-a analysis.

Periphyton identification and enumeration

One samples for periphyton identification and enumeration was taken at each site. The periphyton was scraped and rinsed into a sample container and preserved with Lugol's Solution. The sample area was traced on paper in the field and later measured with a digital planimeter. Taxonomic analysis and enumeration was conducted by LIMNOTEK Research and Development Inc. The taxonomic methods followed are outlined in Northcote et al. (1975).

Cell counts were made at 500x magnification after settlement in Utermohl chambers. An overall scan was made of the settled cells to ensure even distribution across the chamber area. Only cells containing cytoplasm were enumerated. A minimum of 100 individuals of the dominant species and a minimum of 300 cells in total were counted. Counts were completed across rectangular transects measuring 0.45 mm (eye piece diameter) x 40 mm (approximate width across the settling chamber). To achieve the minimum cell counts, one to twelve transects were counted. Where only one transect was required, at least one more was done to check and confirm the counts. Cells of filamentous algae were included in the counts. Biovolumes were determined by multiplying cell numbers by cell volume which was estimated from standard geometric formulae. At least 10 cells of each taxa were examined for volume estimates.

QAQC: To confirm cell counts and biovolume determinations, 10% of all samples are enumerated twice. Variation within 10% is regarded as acceptable between repeated counts. If the variation is greater than 10%, the count is repeated a third time and the final enumeration is the average of all three counts. Although rare, if a third count is required, all other samples will be resettled, and examined again.

3.3 Benthos

Triplicate benthic invertebrate samples were collected at each site using an enclosed cylindrical Hess-type sampler with 250 μm mesh. Care was taken to sample comparable riffle areas and depths (19 cm) at each site. The sampler was pressed into the substrate to 10 cm and the substrate disturbed with sufficient agitation to dislodge the invertebrates into the collecting net. Collected invertebrates were placed in sample containers and preserved with 10% formalin. Taxonomic analysis and enumeration were conducted by LIMNOTEK Research and Development, Inc.

Benthos identification and enumeration

In the laboratory, all benthos samples were washed through a series of sieves: 1000, 470, 250, and 100 μm. Fractions from the three largest pore sizes were examined in totality under a microscope at 40x magnification. All fauna were removed and placed in 70% ethanol for subsequent identification and enumeration. The 100 μm fraction was not enumerated but was placed in 70% alcohol for future reference. Since the sampling nets had a mesh size greater than 100 μm, this smallest size fraction was unlikely to contain many (if any) animals.

QA/QC: As a general rule, 10% of the samples are sorted twice by different people. With consecutive counts, an efficiency value for the first sort is determined. For this sample set, sorting efficiency was 95%. When new people are involved with picking insects, each sample is checked by an experienced technician until no errors are found.

Substrate particle size

One riverbed substrate sample was taken at each benthos site, to a depth of 10 cm. The oven dried samples were separated into particle size fractions outlined in Shera (1984) of cobble, gravel, sand, silt/clays and % by weight determined.

4. 1993-94 Receiving Environment Water Quality Monitoring

The 1993-94 receiving environment water quality data was screened and statistical analysis conducted by D. Portman, EPP. Data was entered into EXCEL spreadsheets and Single Factor ANOVA was used to examine water quality parameters of concern for site comparisons. The major findings are discussed below.

Ammonia-N

Ammonia-N (HN3) was the only parameter for which there was a significant difference indicated between Sites 1-4 upstream and downstream of the STP (Table 1). The average ammonia concentration at Site 2 is about 10 times greater than at the upstream sites. A significant increase in ammonia concentrations at Sites 2E, 2C and Site 3 was also noted in the previous report. The ammonia concentrations at upper Bulkley River sites are illustrated in Figure 2.

Studies have shown that the un-ionized ammonia molecule is the form of ammonia toxic to fish. The concentration of un-ionized ammonia increases with increasing temperature and pH. The B.C. Criteria values for protection of aquatic life from un-ionized ammonia have been calculated using total ammonia concentrations at varying temperature and pH (Pommen 1994). The maximum ammonia concentrations recorded at Site 2 occurred December-93 through February-94 (Table 2). The maximum ammonia concentration was 0.200 mg/l, 15-Dec-93. At temperatures ranging from

Table 1. Anova: Single-Factor for Ammonia-N March 1993- August 1994

Summary						
Groups	*Count*	*Sum*	*Average*	*Variance*		
			mg/l			
SITE #1	17	0.124	0.007	1.45E-05		
SITE #2	17	1.377	0.081	0.005002		
SITE #3	17	0.546	0.032	0.001079		
SITE #4	13	0.411	0.032	0.00135		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.048569	3	0.01619	8.54094	8.257E-05	2.758078
Within Groups	0.113732	60	0.001896			
Total	0.162301	63				

Table 2. Ammonia-N concentrations March 1993-August 1994

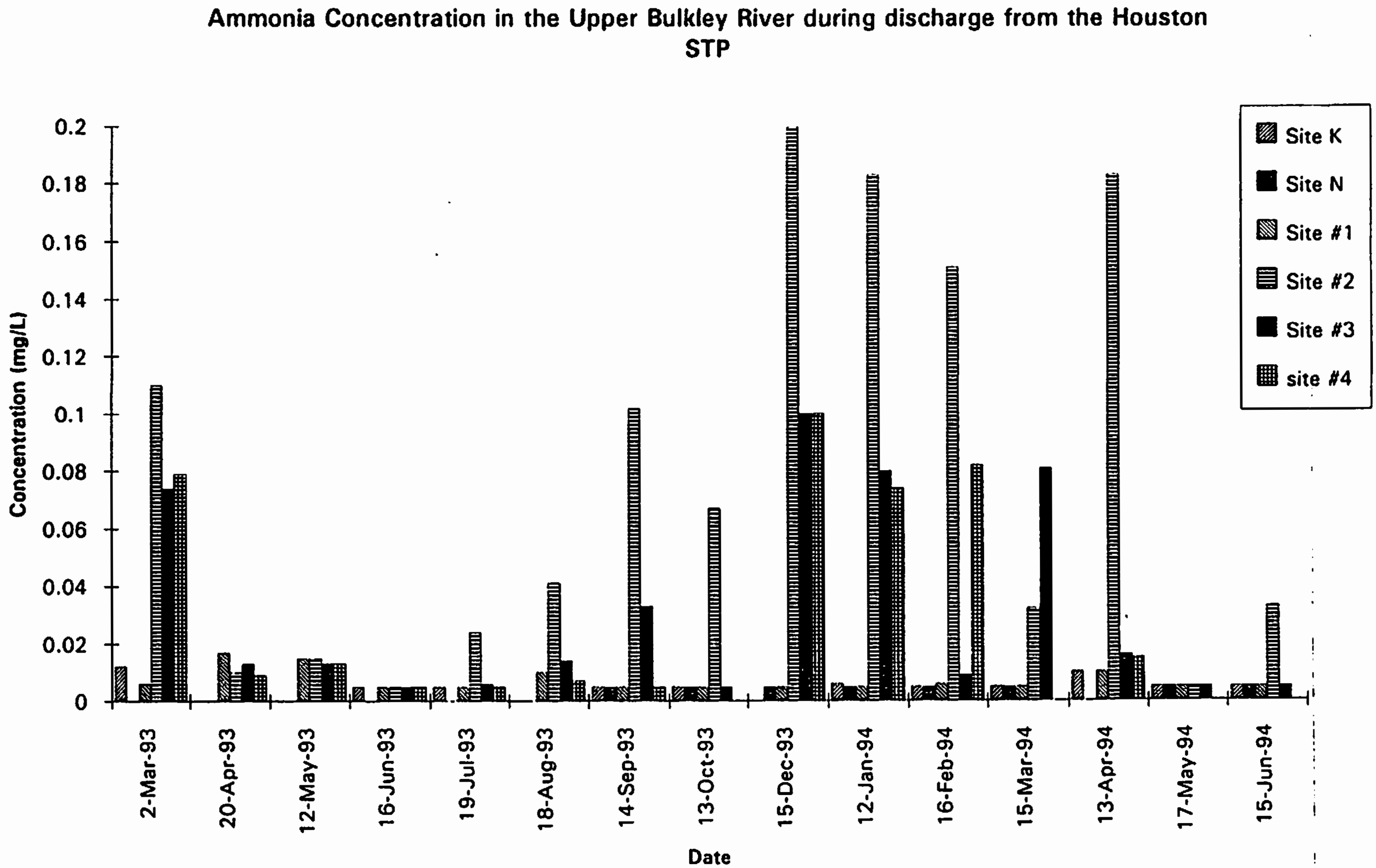
NH3 mg/l	Site K	Site N	SITE #1	Effluent	SITE #2	SITE #3	SITE #4
2-Mar-93	0.005		0.006	11.90	0.110	0.074	0.079
20-Apr-93			0.017		0.010	0.013	0.009
12-May-93	0.006		0.015	11.30	0.015	0.013	0.013
16-Jun-93	0.005		0.005	11.30	0.005	0.005	0.005
19-Jul-93	0.005		0.005	2.78	0.024	0.006	0.005
18-Aug-93	0.010		0.010	5.59	0.041	0.014	0.007
14-Sep-93	0.005	0.005	0.005	9.70	0.102	0.033	0.005
13-Oct-93	0.005	0.005	0.005	16.2*	0.067	0.005	
15-Dec-93	0.010	0.005	0.005	3.80 **	0.200	0.100	0.100
12-Jan-94	0.006	0.005	0.005	14.70 **	0.183	0.080	0.074
16-Feb-94	0.005	0.005	0.006	14.50 **	0.151	0.009	0.082
15-Mar-94	0.005	0.005	0.005	18.50 **	0.032	0.081	
13-Apr-94	0.010		0.010	13.70	0.183	0.016	0.015
17-May-94	0.005	0.005	0.005	9.05	0.005	0.005	
15-Jun-94	0.005	0.005	0.005	10.10	0.033	0.005	
13-Jul-94	0.010	0.009	0.010	8.90	0.050	0.028	0.011
23-Aug-94	0.005	0.005	0.005	9.14	0.166	0.059	0.006

* Measurement from #3 Cell

**Effluent LC50 < 100% (67-75 %)

0-1° C and pH ranging from 7.2-7.3 (at that date) the criteria for average 30-day concentration for total ammonia is 2.05-2.08 mg/l. An ammonia concentration of 0.166 mg/l was recorded in August-94. The Criteria value for the temperature and pH on that date is 1.54 mg/l.

Elevated ammonia concentrations were measured in the effluent during the winter of 93-94, and may be the cause of the less than 100% survival of rainbow trout in 96-hr LC50 toxicity tests of the effluent during this period (Table 2).


Ammonia Concentration in the Upper Bulkley River during discharge from the Houston STP
Concentration (mg/L)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
2-Mar-93
20-Apr-93
12-May-93
16-Jun-93
19-Jul-93
18-Aug-93
14-Sep-93
13-Oct-93
15-Dec-93
12-Jan-94
16-Feb-94
15-Mar-94
13-Apr-94
17-May-94
15-Jun-94
Date
Site K
Site N
Site #1
Site #2
Site #3
site #4

Nitrite

The provisional objective for nitrite in this section of the Bulkley is <0.020 mg/l average, and 0.060 mg/l maximum. (Nitrite is highly toxic to fish.) The average nitrite concentrations were 0.004 mg/l or less at all sites. The maximum nitrite concentration recorded was 0.019 mg/l at Site 2 on 13-Oct-93.

Nutrients

N:P ratio (ratio of nitrogen to phosphorus) in the water provides an indication of the relative availability of these major nutrients to algae. For streams, N:P ratios should be calculated from dissolved inorganic nitrogen or DIN (nitrate plus ammonia) and soluble reactive or ortho-phosphate (PO_4). Ratios of N:P (in available forms) of less than 5:1 are indicative of nitrogen limitation, ratios of 5:1 to 15:1 indicate no limitation or co-limitation and ratios of greater than 15:1 indicate phosphorus limitation (Nordin, 1985). N:P ratios for two growing seasons of water quality data (May to September, 1991-92) were reported previously (Remington et. al. 1993). The average N:P ratio at Site 1 upstream of the STP was 4:1, which would indicate a nitrogen limitation to algal growth rates. The N:P ratios at sites downstream of the STP ranged from 4:1 to 11:1, indicating nitrogen or co-limitation to algal growth rates. In other words, either nutrient can stimulate algal growth.

The algal biomass at Site upstream of the STP has consistently been at or near the Bulkley River Objective level for the protection of aesthetics and recreation of 50 mg/m^2 chlorophyll-*a* (Nijman 1986). In 1993 two additional sites (Sites K & N) were established in order to determine the upstream source(s) of the relatively high average ortho-phosphate concentrations at Site 1 of +/- 0.015 mg/l. A Single Factor ANOVA was run on water quality parameters of concern at the three upstream sites to see if differences by site were apparent. The only parameter which varied significantly between sites was ortho-phosphate (Table 3). The data set used in this analysis was fairly small, however the indication is that the source of phosphorus loading to the Bulkley upstream of the STP is Buck Creek.

Aluminum

Because aluminum is a byproduct of the alum phosphate removal treatment at the STP, dissolved aluminum was added to the monitoring program in 1993. Relatively few samples have been

Table 3. Anova: Single-Factor for ortho-Phosphate March 1993-August 1994

Summary						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Site K	11	0.118	0.011	5.04182E-05		
Site N	10	0.221	0.022	4.81E-05		
Site 1	11	0.166	0.015	3.64909E-05		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.000685	2	0.000343	7.634023113	0.00217	3.327656373
Within Groups	0.001302	29	4.49E-05			
Total	0.001987	31				

analyzed to date and Single-Factor ANOVA does not indicate a significant change in dissolved aluminum concentrations at sites downstream of the STP. However, with the exception of Site K, all sites had an average dissolved aluminum concentration in exceedance to the criteria for 30-day average dissolved aluminum. Site 3 had an average dissolved aluminum concentration of 0.1 mg/l which is equal to the criteria for maximum dissolved aluminum for the protection of aquatic life (Pommen 1994).

5. 1993-1994 Biological Monitoring

5.1 Periphyton

August 22-23 1994 periphyton biomass (chlorophyll-a) and average biomass at three sites is shown in Table 4. *A* *t*-Test was conducted to examine differences in mean chlorophyll-*a* between sites. A statistically significant difference in mean Chlorophyll-a biomass between Site 1 and Site 3 was indicated (P=0.014).

The Provisional Objective for the Bulkley River is 50 mg/m^2 chlorophyll-*a* to protect recreation (Nijman 1986). The B.C. Criteria call for a value of less than 50 mg/m2 chlorophyll-a for the protection of uses related to aesthetics and recreation and for a value of less than 100 mg/m2 chlorophyll-a to protect against undesirable changes in aquatic life (Nordin 1985). Biomass at all sites was less than the BC Criteria concentration for protection of aquatic life.

Table 4. Upper Bulkley River Periphyton Biomass
Chlorophyll-a (mg/m2)

Location	Date Sampled	Rep	Biomass/m2	Average/Site
Site 1	22-Aug-94	1	13.3	32.4
		2	44.1	
		3	31.3	
		4	23.9	
		5	29.5	
		6	52.0	
Site 2	22-Aug-94	1	71.4	54.5
		2	63.2	
		3	10.0	
		4	84.7	
		5	84.5	
		6	13.0	
Site 3	22-Aug-94	1	89.9	64.4
		2	44.6	
		3	37.6	
		4	74.2	
		5	87.7	
		6	52.5	

Taxonomic enumeration of periphyton is shown in Appendix 1. A similar increase in estimated biomass (total cell volume) is observed from Site 1 to Site 3. As in past studies Chrysophyta - Diatoms were the dominant algae, comprising 68% of cells at Site 1, 80% at Site 2 and 87% at Site 3. Chlorophyta (green algae) were the other dominant group. As in 1992, the blue-green algae *Lyngbya* was only present at Site 2.

5.2 Benthos

Particle size classification at each site is shown in Appendix 2, Table 1. There was less than 6% variation in particle size between the three sample sites. Gravels comprised 70-82% of the substrate at all sites.

Taxonomic enumeration of benthos is shown in Appendix 2, Table 2. Statistical analysis of the benthic data was prepared by LIMNOTEK. All enumeration data were entered onto an EXCEL worksheet and formatted for import into Systat files. For each taxa, summary statistics were determined with the purpose to examine the importance of taxonomic groups down to the genus level. Statistics were also determined for total numbers, number of taxa (richness), and the Margalef diversity index. It was clear from these statistics that 11 taxa were most abundant at all sites (cumulatively >90% of the community) despite the large number of taxa found. All other taxa were relatively rare or were found only incidentally. From these rare taxa, those which were found at one or more sites but not at others were identified as they may have been important indicators of site specific differences in community composition. A one way ANOVA was then run on data for each of the dominant taxa to determine if differences in abundance, by site, were apparent. The Bonferroni correction for multiple comparisons was applied to assign significant probability levels. The Bonferroni procedure corrects for the possibility of finding a significant effect by random chance and is simply the pre-assigned P level (0.05) divided by the 11 comparisons (0.005). If the P level was <0.005 then the outcome of the ANOVA was considered significant. Output was in the form of the probability tables shown in Table 5.

The mean density of organisms per sample increased from 578/sample at Site 1 to >2500/sample at Sites 2 & 3. Analysis of the data with one way ANOVA indicates a statistically significant site effect (P=0.009) probably caused by nutrient enrichment. An increase in number of taxa/sample and Margalef Diversity index were also significant to the P<0.05 level. A comparison of differences in abundance by site of the major taxa (making up 90% of the community), with application of the Bonferroni correction, did not indicate a significant difference in density of any individual organism. Chironomids (particularly Orthocladini) were the most abundant insect group with a large increase in density at Site 2. The most abundant Plecoptera (*Sweltza/Triznaka sp*) and the most abundant Ephemeroptera (*Rhithrogena sp*) also increased downstream of the STP. Given that diversity and numbers of sensitive animals did not decline, but rather increased, there was probably no toxic effect related to the effluent from the STP. The increase in densities looks like a response to nutrient enrichment.

6. STP Aeration System Upgrading

In late November 1994 the first of a series of upgrading projects on the aeration system to Cells #1 and 2 was completed. The leaking aeration distribution system was replaced and there is noticeably better aeration (K. Creed, pers. comm.). Scheduled for completion in 1995 is the relocation of exising aeration braanches from Cell #2 to Cell #1, repair of helixor aeration tubes, replacement of blower and motor, and check valve installation.

Table 5. Mean (± SE) density of all animals, species richness, Margalef's diversity index and counts of individual benthic invertebrates per sample by site (n = 3). Values without standard errors indicate that animals were only found in one of the samples and no variance could be determined. For most abundant taxa, the probability of a site effect (*P*) determined from independent ANOVA's is shown. With application of the Bonferroni correction for multiple comparisons the significant probability level was 0.005.

Taxa or Indicator	Site 1 (#/sample)	Site 2 (#/sample)	Site 3 (#/sample)	*P*
Total density (#/sample)	578.0 (103.9)	2523 (385)	2516 (813)	0.009
Total density (#/m²)	6,366	27,786	27,709	
Number of Taxa (richness)	26.3 (2.9)	37.3 (2.7)	40.0 (2.6)	0.029
Margalef Diversity	160.9 (20.9)	284.3 (25.1)	302.6 (34.0)	0.016
Phylum Nematoda		9.0 (3.0)	3.3 (2.3)	
Phylum Annelida				
Phylum Oligochaeta	5.5 (0.5)	45.7 (15.0)	49.0 (4.0)	
Phylum Coelentrata				
Hydra sp		79.0 (46.5)	2.5 (0.5)	
Phylum Arthropoda				
Class Hydrachnoidea				
Order Hydracarina		103.3 (35.5)	131.7 (67.8)	
Class Cladocera				
Daphnia sp		8.7 (3.3)		
Class Insecta				
Order Plecoptera				
Family Chloroperlidae				
Capnia/Bolshecapnia, Mesocapnia, Utacapnia sp	1.3 (0.3)	1.0	2.0	
Allocapnia sp			1.0	
Sweltza/Triznaka sp	49.0 (14.0)	151.7 (18.6)	115.0 (44.8)	0.082
Family Perlidae				
Hesperoperla sp		2.0		
Claassenia sp		1.0	1.5 (0.5)	
Family Perlodidae				
Megarcys sp	1.0			
Isoperla sp	8.3 (2.6)	23.7 (2.7)	31.7 (9.7)	0.027
Family Pteronarcyidae				
Pteronarcella sp	2.5 (0.5)		19.3 (6.2)	
Pteronarcys sp		3.5 (2.5)	7.0	

Taxa or Indicator	Site 1 (#/sample)	Site 2 (#/sample)	Site 3 (#/sample)	*P*
Family Neumoridae				
Zapada sp	2.0	2.0	10.3 (4.4)	
Order Ephemeroptera				
Family Baetidae				
Baetis sp	4.7 (3.2)	9.7 (2.0)	45.7 (24.8) ·	0.092
Pseudocloeon sp			6.7 (2.7)	
Family Heptageniidae				
Eporeus sp	1.0			
Rhithrogena sp	13.7 (5.9)	33.7 (18.0)	166.7 (38.9)	0.032
Family Ephemerellidae				
Drunella sp				
Ephemerella sp	1.0	8.3 (2.8)	31.0 (9.5)	
Serratella sp				
Family Leptophlebiidae				
Leptophlebia sp				
Paraleptophlebia sp	2.0 (0.58)	10.3 (3.5)	25.3 (15.9)	0.029
Family Siphlonuridae				
Ameletus sp		3.0		
Order Coleoptera				
Family Elmidae				
immature	1.0			
Optioservus sp	3.5 (2.5)	13.7 (3.5)	2.5 (0.5)	
Herterelmis sp		1.0	1.0	
Stenelmis sp			2.0	
Family Elmidae adults				
Order Trichoptera				
Family Brachycentridae				
Brachycentrus sp	1.0	1.0	1.0	
Eobrachycentrus sp	2.0			
Family Glossosomatiae				
Glossosoma sp	1.5 (0.5)	4.0	9.7 (4.3)	
Family Hydropsychidae				
Cheumatopsyche sp	1.0	12.3 (5.2)	36.0 (15.5)	

Order Coleoptera				
Hydropsyche sp	30.0 (15.7)	210.3 (94.1)	473.7 (214.6)	0.056
Arctopsyche sp		6.0	5.3 (2.6)	
Immature	9.0	31.0 (14.0)	153.3 (18.8)	
Family Polycentropodidae				
Polycentrupus sp	1.0	4.0 (2.0)	1.0	
Neureclipsis sp		1.0	2.0	
Nyctiophylax sp		1.0		
Family Hydroptilidae				
Hydroptila sp	11.7 (0.7)	22.3 (5.8)	32.0 (15.0)	0.757
Agraylea sp			1.0	
Pupae	2.0		2.0	
Family Lepidostomatidae				
Lepidostoma sp	7.0 (3.0)	1.0	5.0 (1.5)	
Family Rhyacophilidae				
Rhyacophila sp	1.0			
Order Diptera				
Family Athericidae				
Atherix sp	3.0	1.0	1.5 (0.5)	
Family Ceratopogonidae				
Bezzia, Probezzia, Palypomyia sp	9.0	3.5 (1.5)		
Family Chironomidae				
Tanypodini	12.3 (1.3)	88.3 (35.2)	53.7 (22.2)	0.022
Orthocladini	311.7 (50.3)	1318.7 (161.1)	820.7 (300.8)	0.039
Chironominae				
Chironomini				
Tanytarsini	45.7 (19.9)	140.7 (31.2)	104.3 (36.9)	0.16
pupae	31.7 (9.1)	67.0 (14.2)	54.7 (25.0)	0.506
Family Empididae				
Chelifera sp	2.0	2.5 (0.5)	2.3 (0.9)	
Hemerodromia sp	7.0	10.3 (2.7)	3.7 (1.8)	
Family Tipulidae				
Hexatoma sp	5.5 (1.5)	9.7 (0.9)	3.5 (2.5)	
Dicranota sp	1.5 (0.5)			
Antocha sp	1.0	2.3 (0.9)	1.5 (0.5)	

Order Coleoptera				
Family Simuliidae				
Pupae	1.0		1.5 (0.5)	
Simulium sp	4.0	4.0 (3.0)	32.0 (18.1)	
Prosimulium sp	2.0			
Family Psychodidae				
Pericoma sp	1.0	1.7 (0.7)	1.0	

7. References

APHA, 1985. Standard Methods for the Examination of Water and Wastewater (16th Edition). American Public Health Association, Washington, D.C.

Hancock, M.J., A.J. Leaney-East, and D.E. Marshall. 1983. Catalogue of salmon streams and spawning escapements of Statistical Area 4 (Upper Skeena River). Canadian Data Report of Fisheries and Aquatic Sciences No. 394.

Maclean, D.B. and K.A. Diemert. 1987. The Effects of the District of Houston Sewage Discharge on Downstream Water Quality and Periphyton (Algal) Biomass. Environmental Section Report 87-04, Northern Region, Skeena Zone, B.C. Ministry of Environment.

Nijman, R. 1986. Skeena-Nass Area: Bulkley River Basin Water Quality Assessment and Objectives. B.C. Ministry of Environment.

Nordin, R.N. 1985. Water Quality Criteria for Nutrients and Algae. Water Management Branch, B.C. Ministry of Environment.

Northcote, T.G., G.L. Ennis, and M.H. Anderson. 1975. Periphytic and planktonic algae of the lower Fraser River in relation to water quality conditions. Westwater Research Centre, Tech. Report No.8.

Pommen, L.W. 1989. Approved and Working Criteria for Water Quality. Water Management Branch, B.C. Ministry of Environment.

Remington, D. and Assoc. 1991. Environmental Assessment of the Upper Bulkley River in the Vicinity of the District of Houston Sewage Treatment Plant PE-0287. MS prepared for the District of Houston.

Remington, D., D. Bustard, C.J. Perrin, T. Lekstrum. 1993. Receiving Environment Monitoring of the Upper Bulkley River 1991-92: PE-0287. Prepared for the District of Houston.

Shera, W.P. (ed.). 1984. Methods of Aquatic Data Collection in British Columbia. Water Management Branch, Ministry of Environment Manual 7.

Tredger, C.D. 1982. Upper Bulkley River reconnaissance with reference to juvenile steelhead carrying capacity. Unpubl. MS. Fish and Wildlife Branch, Ministry of Environment, Victoria, B.C.

Appendix 1. Bulkley River Periphyton 1994

Species	Site 1 22-Aug-94		Site 2 22-Aug-94		Site 3 23-Aug-94	
	cells x 10-6/m2	u3x10-9/m2	cells x 10-6/m2	u3x10-9/m2	cells x 10-6/m2	u3x10-9/m2
CYANOPHYTA						
Lyngbya sp.			5.9 mm	35.4		
CHLOROPHYTA						
Ankistrodesmus falcatus	109.2	10.9	90.0	9.0	40.9	4.1
Cosmarium sp. A	11.3	17.0	22.9	34.4	4.0	6.0
Cosmarium sp. B	100.7	15.1	60.6	9.1	5.3	0.8
Scenedesmus sp.	5.7	0.6			5.3	0.5
CHRYSOPHYTA - DIATOMS						
Achnanthes sp.	404.0	24.2	455.0	27.3	141.3	8.5
Amphipleura pellucida	7.1	9.1				
Anomoeoneis vitreae			32.7	13.7	38.3	16.1
Cocconeis placentula					1.3	1.2
Cyclotella sp. B	8.5	5.1	13.1	7.9		
Cymbella prostrata					1.3	4.6
Cymbella ventricosa			60.6	29.7		
Epithemia sorex	22.7	27.2	45.8	55.0	64.7	77.6
Epithemia turgida	22.7	136.2	11.5	69.0	34.3	205.8
Fragilaria construens v. construens			6.6	1.2		
Fragilaria vaucheriae	7.1	2.4			42.3	14.4
Gomphonema herculeanum	4.3	17.2	1.6	6.4	1.3	5.2
Gomphonema olivaceum	4.3	2.1	24.6	11.8		
Melosira varians			54.0	138.2	59.4	152.1
Nitzschia acicularis	5.7	0.6				
Synedra ulna	2.8	8.3			2.6	7.8
TOTAL	716.1	276.0	879.0 5.9 mm	448.1	442.3	504.7

Site 1
Algal Clumps:
Spirogyra sp.
Ulothrix sp.
Stigeoclonium sp.

Site 2
Algal Clumps:
Cladophora sp.
Trace amounts
Cymbella sp. in tubes
Ulothrix sp.
Melosira varians

Site 3
Algal Clumps:
Melosira varians
Cymbella sp. in tubes
Stigeoclonium sp.

Appendix 2, Table 1

Particle Size Classification

Upper Bulkley River- Vicinity of Houston STP

	Site 1	Site 2	Site 3	Average deviation
Cobbles	20.24%	15.58%	13.24%	2.6%
Gravels	74.15%	82.08%	69.92%	4.5%
Sands	5.58%	2.33%	16.69%	5.7%
Silt/clays	0.02%	0.02%	0.14%	0.5%

Cobbles	<264mm	(70-85mm)
Gravels	<64mm	
Sands	<2mm	
Silt/clays	<0.062mm	

Appendix 2, Table 2. Bulkley River Benthos, 22-23 August 1994

INSECTS	S1 R1	S1 R2	S1 R3	S2 R1	S2 R2	S2 R3	S3 R1	S3 R2	S3 R3
Ephemeroptera									
Baetidae							16		7
Baetis	11	2	1	10	13	6	91	39	7
Pseudocloeon							12	3	5
Leptophlebiidae									
Paraleptophlebia	1	3	2	9	5	17	57	11	8
Ephemerellidae									
Ephemerella	1	1	1	5	6	14	35	45	13
Heptageniidae				1				15	2
Epeorus			1						
Rhithrogena	18	21	2	10	22	69	216	194	90
Siphlonuridae									
Ameletus						3			
Plecoptera									
Pteronarcyidae									
Pteronarcella	3	2		4	5	1	24	7	27
Pteronacys				1		6	7		
Perlodidae									
Isoperla	8	13	4	22	20	29	50	17	28
Megarcys		1							
Chloroperlidae									
Sweltsa/Triznaka	45	75	27	115	175	165	100	46	199
Capniidae								3	
C/B/M/U*	1	2	1	1		1			2
Allocapnia							1		
Neumoridae									
Zapada	2			2			19	5	7
Perlidae									
Hesperoperla				2					
Claassenia				1			2	1	
Trichoptera									
Pupae						3	2		1
Glossosomatidae									
Glossosoma	1	2			4	4	18	7	4
Polycentropodidae				1			1		
Neureclipsis				1					2
Polycentropus?	1				2	6		1	
Nyctiophylax					1?				
Hydropsychidae									
Damaged	1			9	8	17	39	4	12
Immature	9			16	59	18	191	135	134
Hydropsyche	61	19	10	327	24	280	882	155	384
Cheumatopstche	1		1	4	11	22	66	14	28
Arctopsyche				6		6	10	1	5
Lepidostomatidae									
Lepidostoma		10	4			1	6	2	7

Hydroptilidae									
Pupae	2						2		
Hydroptila	13	11	11	11	26	30	40	3	53
Agraylea							1		1
Rhyacophilidae									
Rhyacophila		1							
Brachycentridae									
Brachycentrus			1		1				1
Eobrachycentrus ?			2						
Diptera									
Chironomidae									
Pupa	18	49	28	57	49	95	95	9	60
Tanypodini	11	15	11	62	45	158	96	21	44
Orthocladini	285	409	241	1377	1015	1564	1298	265	899
Tanytarsini	11	80	46	107	112	203	134	31	148
damaged	13	29	14	70	56	95	100	20	47
Tipulidae						1			
Hexatoma	7	4		10	11	8	1		6
Dicranota		2 ?	1						
Antocha		1		4	2	1	2		1
Athericidae									
Atherix	3				1	1	1		2
Ceratopogonidae									
P/B/P**	9			2		5			
Simuliidae									
Pupae			1				1		2
Simulium	4			7	1		26	66	4
Prosimulium ?		2							
Empididae									
Chelifera	2			3		2	2	1	4
Hemerodromia	7			5	14	12	3	1	7
Psychodidae									
Pericoma		1		1	1	3	1	1	1
Coleoptera									
Elmidae				1					
Optioservus	1	6		20	13	8	3		2
Herterelmis				1				1	
Stenelmis							2		
immature	1						2	7	2
Hydracarina				41	105	164	254	20	121
Cladocera									
Daphnidae									
Daphnia				2	12	12			
Nematoda* **				6		12	8	1	1

Turbellaria		1							
Oligochaeta	5	6		40	74	23	45		53
Coelentrata									
Hydridae									
Hydra				45	21	171	3	2	
TOTAL	556	766	410	2419	1913	3236	3965	1154	2431

Specimen could not be identified further because it was an early instar or too damaged to identify further.

* Key does not distiguish Capnia, Bolshecapnia, Mesocapnia or Utacapnia

** Key does not distinguish Bezzia, Probezzia, or Palypomyia

*** Appear to be parasites of Chironomidae