MINISTRY OF ENVIRONMENT, LANDS, AND PARKS

Water Quality Assessment and Objectives for the Fraser River From Moose Lake to Hope

Prepared pursuant to:

Section 2 (e)
Environment Management Act, 1981

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Approved:

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SUMMARY

THIS DOCUMENT is one in a series that describes ambient Water Quality Objectives for British Columbia. It has two parts: the following overview and a technical appendix which is available as a separate document. The overview provides general information about water quality in the main stem of the Fraser River from Moose Lake to Hope in three main River reaches. These reaches are from Moose Lake to Tete Jaune Cache, from Tete Jaune Cache to the Nechako River confluence, and from the Nechako River confluence to Hope. The technical appendix presents details of a recent water quality assessment for these reaches and forms the basis for recommendations and objectives presented in the overview. The overview is intended for both technical readers and others who may not be familiar with the process of setting water quality objectives. Separate tables listing water quality objectives and monitoring recommendations are included for those readers requiring data about these waterbodies. A separate report will be published on water quality objectives for the Fraser River from Hope to Sturgeon and Roberts Banks.

The Fraser River is home to both resident and anadromous species of fish. There are 26 species of resident fish documented as being in the Fraser River above Hope, with most species being in the river as far north as the Chilcotin River. Salmonid species are present in large numbers and make the Fraser River a world-class system for these fish species. Runs have increased during the 1980s for all species of salmon in the River. This same decade had the largest average runs for chinook, chum, and sockeye salmon. Consistent achievement of water quality objectives in the Fraser River is critical for the continued success and sustainability of the Fraser's salmon resource.

Most water contamination in the River above Hope is related to treated wastewater discharges from pulp and paper mills located at Prince George and Quesnel as well as treated municipal sewage discharges from Prince George, Williams Lake, Quesnel, Lytton, and Lillooet. Flows from the Thompson River, a tributary to the Fraser, carry the treated wastewater from a pulp mill and a municipal sewage discharge from the City of Kamloops.

This report describes the specific Water Quality Objectives recommended to protect aquatic life, wildlife, livestock watering, irrigation, and drinking water supplies in all three reaches of the Fraser River Basin from Moose Lake to Hope. The objectives have been prepared for Environment Managers for use in determining the effectiveness of different pollution prevention controls which are being used.

PREFACE

Purpose of Water Quality Objectives

WATER QUALITY OBJECTIVES are tools for the effective management of water resources. They describe conditions that water managers have agreed should be met in order to protect the most sensitive designated uses of fresh, estuarine, and coastal marine waters. They are used in conjunction with other management tools such as effluent controls and pollution prevention planning to achieve high standards of water quality.

Water Quality Objectives are being prepared for specific bodies of fresh, estuarine, and coastal marine surface waters of British Columbia by the Ministry of Environment, Lands, and Parks as part of their mandate to responsible water resource management. Objectives are prepared only for those waterbodies and water quality characteristics that may be affected by human activity now or in the future.

How Objectives Are Determined

WATER QUALITY OBJECTIVES are based on water quality criteria (now called guidelines for consistency with similar terms used for other media within BC) which are numerical concentrations for chemical, physical, radiological, biological characteristics of water, biota (plant and animal life) or sediment to their effects on water use necessary to protect and enhance designated uses of water. Water Quality Objectives are numerical concentrations established to support and protect the most sensitive designated use of water at a specified site. They are derived from the guidelines by considering local water quality, water uses, water movement, waste discharges, and socio-economic factors.

Water Quality Objectives are based on the best scientific information available at the time the Objectives are developed. When insufficient information exists, provisional Water Quality Objectives may be applied until the data required to develop formal Water Quality

Objectives are available. Provisional objectives are deliberately conservative, and a monitoring or study program is required that will lead to the establishment of permanent objectives.

Water Quality Objectives are set to protect the most sensitive designated water use at a specific location. Designated uses of water include the following:

- raw drinking water, public water supply, and food processing
- fish, other aquatic life, and wildlife
- agriculture (livestock watering and irrigation)
- recreation and aesthetics
- industrial water supplies

Each objective for a location may be based on the protection of a different water use, depending on the uses that are most sensitive to the physical, chemical, or biological characteristics affecting that waterbody.

How Objectives Are Used

WATER QUALITY OBJECTIVES have no legal standing at this time and therefore, can not be directly enforced. Water management in BC is enforced through permits issued for effluent discharges with controls placed on, and enforcement actions for volumes and concentrations of contaminants discharged. The limits set are based upon best available technology for treatment.

Water Quality Objectives do provide policy direction for resource managers for the protection of water uses in specific waterbodies. Objectives provide a reference for the evaluation of water quality, the issuing of discharge permits, water withdrawal licenses and orders, and the management of fisheries and the province's land base. They also provide a reference against which the state of water quality in a particular waterbody can be checked, and help to determine whether basin-wide water quality studies should be initiated. Water Quality Objectives are also a standard for assessing the Ministry's performance in protecting water uses.

Objectives and Monitoring

Water Quality Objectives are established to protect all the uses which may take place in a water body. Monitoring is undertaken to determine compliance with the stated Water Quality Objectives and whether the designated water uses are being protected. Monitoring usually takes place at a critical time when a water quality specialist has determined that the Water Quality Objectives may not be met. It is assumed that if all designated water uses are protected at the critical time, then they also will be protected at other times when the threat is less. The monitoring usually takes place during a five-week period, which allows the specialists to measure the worst, as well as the average condition in the water. For some water bodies, the monitoring period and frequency may vary, depending upon the nature of the problem, severity of threats to designated water uses, and the way the objectives are expressed (i.e., mean value, maximum value).

INTRODUCTION

The Fraser River drains about one-quarter of the Province of British Columbia, and extends from the Alberta-British Columbia border in the north and east, to the estuary and the River confluence with the Strait of Georgia, in the south and west of the Province (see Figure 1). The purpose of this report was to develop Water Quality Objectives in the Fraser River from Hope to Moose Lake to provide policy direction to resource and environment managers for the protection of designated uses of waterbodies within the stretch of the waterbody defined by this report. Others that may find the information useful include environmental scientists and other agency staff including regulators, habitat biologists, and water quality specialists. The public will also find the Water Quality Objectives useful for assessing the health of their environment, articulating concerns about existing uses of resources in their environment, and monitoring the performance of various government agencies cooperating to maintain acceptable high levels of water quality in the Fraser River Basin.

The Fraser River from Moose Lake to Hope Profile

Hydrology

The Fraser River exhibits a classic perpetual annual snow melt hydrograph pattern due to its extensive snow pack and massive basin storage. High flows take place from May to August, with 64% of the annual volume runoff taking place during this time. Low flow months are consistently between November and April. The extreme lowest mean monthly discharges (ten year, seven-day low flows in parentheses) have ranged from 4.06 (4.10) m^3/s at Red Pass, to 20.6 (21.0) m^3/s at McBride, to 97 (110) m^3/s at Shelley (just upstream from Prince George), to 218 (232) m^3/s at Marguerite (downstream from Quesnel), to 482 (563) m^3/s at Hope. These compare to extreme high flows at the same stations of 235 m^3/s, 918 m^3/s, 3470 m^3/s, 5390 m^3/s, and 10800 m^3/s, respectively.

Water Uses

Water uses in each of the three reaches of the Fraser River designated in this document are similar. Consumptive water uses include domestic water supply (including livestock watering) withdrawals in all three reaches, and irrigation water supplies below Prince George. Fisheries values are considered to be high, with 26 resident species using the river upstream from Hope, and five salmon species migrating to and spawning in tributaries upstream from Hope. The returns of these five species increased during the 1980's, with the largest average runs for the decade being recorded in the 1980's for chinook, chum, and sockeye salmon.

Recreational water use along the Fraser River is generally limited, since the precipitous geography of the upper and middle Fraser reaches allows for only a low to moderate recreational use. Primary-contact recreation does not normally occur along the Fraser River itself, since the tributaries are generally warmer and less turbid. River rafting (secondary-contact) is popular, with over 60 companies using the Fraser River or 36 of its tributaries.

Waste Water Discharges

There are no significant direct discharges of wastewater to the Fraser River between Moose Lake and Tete Jaune Cache. The most significant discharges to the Fraser River between Tete Jaune Cache and the Nechako River confluence are from the Northwood Pulp Mill and the Prince George Pulp and Intercontinental Mills at Prince George. Significant improvements to effluent quality have been made at all pulp mills since 1991. Downstream from the Nechako River confluence are municipal-type discharges from the Prince George area, treated sewage discharges from Williams Lake, Lytton, and Lillooet, as well as discharges from the two pulp mills (and the municipal-type discharge) at Quesnel.

Non-point sources are also impacting water quality, especially forestry operations, in every major tributary entering the mainstem Fraser. Studies performed on the impacts of forestry on fish habitat or water quality indicate that historically, there has been severe sedimentation of stream gravel used for salmonid spawning and greatly increased sediment and nutrient loadings which have reduced light penetration. This type of dgradation should be improved significantly when future forest practices are undertaken in compliance with the new Forest Practices Code of BC Act.

Agricultural inputs to the Fraser River are likely greatest downstream from Hope. In this reach of the river, considerably more land is in agricultural use, more fertilizers are used, and more livestock are housed. These activities lead to increased ammonia, nutrient, oxygen-demanding and bacteriological loadings to the river. In the urbanized areas of the watershed, stormwater runoff increases concentrations of metals, nutrients, and suspended solids.

Water Quality Assessment and Objectives

Water Quality Assessment

The data examined in the present assessment indicate that the water quality of the Fraser River was generally fair to good in all reaches. Information on water and sediment quality, contaminants in fish tissues, and the abundance and diversity of benthic invertebrate populations near the major effluent discharges were evaluated. The River was generally well-buffered to acidic inputs, with moderate water hardness. Metal concentrations generally met guidelines to protect aquatic life. Dissolved oxygen concentrations were occasionally below the guidelines for minimum concentrations to protect aquatic life. Colour was generally below guidelines for drinking water supplies but turbidity and suspended solids concentrations were such that water would require filtration for drinking water supplies. Bacteriological concentrations were generally below guidelines for drinking water supplies.

The highest concentrations of organochlorine compounds in sediments were found at sites downstream from Hope, likely due to slower river velocities in this area. Reduced flow allows finer sediment particles, which adsorb higher concentrations of organics, to settle out.

Resident fish from Moose Lake had the highest lead and molybdenum concentrations in muscle along the length of the river. Fish from McBride had the highest concentrations in muscle of cadmium, copper, chromium, and nickel. Fish collected near Lillooet had the highest concentrations of arsenic, cadmium, copper, and zinc in livers. Dioxins and furans in fish collected upstream from Prince George and upstream from the Nechako River confluence were low compared to fish collected from below the pulp mills at Prince George and Quesnel. Mountain whitefish collected downstream from Quesnel had the highest dioxin and furan concentrations. It is important to note that levels of dioxins and furans have declined dramatically over the past few years. None of these levels were sufficiently high to be of concern from the perspective of human consumption, and no fisheries closures took place as a result.

Water Quality Objectives

Water Quality Objectives proposed for the three reaches of the Fraser River from Moose Lake to Hope are summarized in Table 1. The objectives are based on B.C. approved and working criteria, the Canadian Water Quality Guidelines developed by the Canadian Council of Ministers of the Environment for water quality, and on available data on ambient water quality, waste discharges, water uses, and stream flows.

Where insufficient information exists, provisional Water Quality Objectives may be applied until the data required to develop formal, definitive Water Quality Objectives are available. Provisional objectives are deliberately conservative, and a monitoring or study program is specified that will lead to the establishment of permanent objectives. Permanent objectives are established when the information available about the local conditions and water quality guidelines is complete.

Depending on the circumstances, Water Quality Objectives may already be met in a waterbody, 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 human activity now and in the foreseeable future.

Designated water uses for all three reaches of the Fraser River from Moose Lake to Hope are for the protection of aquatic life, wildlife, recreation, livestock watering, and drinking water supplies. Irrigation water is to be protected downstream from Prince George.

Water Quality Objectives which are based on approved or draft B.C. water quality guidelines include those for dioxins and furans, chlorophenols, microbiological indicators, ammonia, nitrite, nitrate, and pH. The objectives are required to ensure that inputs from non-point source discharges, pulp and paper mills, and the sewage treatment plants do not impair water uses. An objective is proposed for pH as a range of values. The upper value will control the formation of toxic quantities of ammonia. Different dissolved oxygen levels, based on the Ministry's modification of the CCREM (now known as the CCME) guidelines in the Technical Appendix, are proposed for the waterbodies.

Monitoring Recommendations

Monitoring programs should be designed and coordinated to determine the degree to which Water Quality Objectives are being met. Monitoring of ecosystem responses will provide a means of identifying situations where more restrictive effluent standards may be required or where Water Quality Objectives need to be adjusted to meet water management goals.

The long-term purpose of monitoring is to detect a pre-determined degree of change at a significant frequency when monitoring is performed at a level of effort to confer reliable information. If a parameter is consistently within one order of magnitude of the Water Quality Objective, monitoring should be continued at the same frequency. If the objective is exceeded, the monitoring effort should be increased to determine the extent the objective is exceeded. The actual monitoring undertaken will depend upon regional resources.

A recommended monitoring design is included as Table 6. Should the objectives be exceeded, some water uses may be threatened at some time in the future.

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LOCATION AND MONITORING SITES MAPS

WATER QUALITY OBJECTIVES AND MONITORING TABLES

THE FOLLOWING TABLES provide a summary of the objectives data and monitoring recommendations.

To protect water uses in a waterbody, objectives specify a range of values for characteristics (variables) that may affect these uses. These values are maximum and/or minimum values that are not to be exceeded.

Some readers may be unfamiliar with terms such as: maximum concentration, 30-day average concentration, 90th percentile, and not applicable (NA). Maximum concentration means that a value for a specific variable should not be exceeded; 30-day average concentration means that a value should not be exceeded during a period of 30 days, when five or more samples are collected at approximately equal time intervals. The term 90th percentile indicates that 9 out of 10 values should be less than a particular value. Not applicable (NA) means that water uses are not threatened for that particular variable.

TABLE 1
WATER QUALITY OBJECTIVES FOR THE FRASER RIVER FROM MOOSE LAKE TO HOPE

Waterbodies	Fraser R., Moose L. to Tete Jaune Cache	Fraser R., Tete Jaune Cache to Nechako R.	Fraser R. from Nechako R. to Hope
Designated Water Uses	aquatic life, wildlife, drinking water (partial treatment), livestock, irrigation, secondary-contact recreation		
Characteristics			
Fecal coliforms[1]	not applicable	≤ 100/cL 90th percentile	
Enterococci[1]	not applicable	≤ 25/cL 90th percentile	
Total Chlorine Residual	not applicable	Average ≤ 2 µg/L	
Suspended solids[2]	10 mg/L maximum increase (upstream < 100 mg/L) 10% maximum increase (upstream > 100 mg/L)		
Turbidity[2]	5 NTU maximum	1 NTU maximum increase (upstream <5 NTU) 5 NTU maximum increase (upstream < 50 NTU) 10% maximum increase (upstream > 50 NTU)	
Colour - true	15 TCU maximum	15 TCU maximum (June-September) 75 TCU maximum (October-May) 10% maximum increase (upstream > 15 or 75 TCU, respectively)	
Temperature (°C)	not applicable	Maximum change 1 °C	
Total ammonia-N	not applicable	See Tables 2 and 3	
Nitrite-N	not applicable	See Table 4	
Nitrate-N + Nitrite-N	not applicable	10 mg/L maximum	
Periphyton chlorophyll-a[3]	not applicable	50 mg/m^2 maximum	
pH[4]	6.5-8.5		
Dissolved oxygen	not applicable	Higher of 80% saturation or 8.0 mg/L minimum 11.0 mg/L when salmonid embryos and larvae present (November–April)	
Lead, total	0.8 µg/g maximum in edible fish muscle		
PCBs, total	2.0 µg/g maximum in edible fish muscle 0.1 µg/g maximum in whole fish		
Chlorophenols	not applicable	See Table 5	
AOX	not applicable	No increase at 95% confidence level	
Dehydroabietic Acid	not applicable	Maximum 8 µg/L at pH 7.0 Maximum 12 µg/L at pH 7.5	
Total Resin Acids	not applicable	Maximum 25 µg/L at pH 7.0 Maximum 45 µg/L at pH 7.5	

TABLE 1
WATER QUALITY OBJECTIVES FOR THE FRASER RIVER FROM MOOSE LAKE TO HOPE (CONTINUED)

Waterbodies	Fraser R., Moose L. to Tete Jaune Cache	Fraser R., Tete Jaune Cache to Nechako R.	Fraser R. from Nechako R. to Hope
Designated Water Uses	aquatic life, wildlife, drinking water (partial treatment), livestock, irrigation		
Characteristics			
Dioxins and Furans 2,3,7,8-T_4CDD equivalents	not applicable	Maximum (dissolved) 0.06 pg/L in water Maximum 0.25 pg/g (normalized to 1% organic carbon) in sediments Maximum 50 pg/g (wet-weight) in lipids of fish muscle or fish eggs	

Note: While Water Quality Objectives do not apply in initial dilution zones where acutely toxic conditions are not permitted, they do apply to discrete samples of water and sediment from all other parts of the Fraser River from Moose Lake to Hope. In practise, the extent of initial dilution zones is defined on a site-specific basis, with due regard to water uses, aquatic life, including migratory fish, and other waste discharges. However, where sufficient site-specific data is not available for defining initial dilution zones for the objectives established, provisional initial dilution zones will be defined as extending up to 100 metres downstream from a discharge, and occupying no more than 25% of the stream width around the discharge point, from the bed of the stream to the surface. It is also important to note that objectives for fish apply to all parts of the river, including fish in the initial dilution zone.

[1]The average and the 90th percentiles are calculated from at least five weekly samples collected in a period of thirty days. For values recorded as less than the detection limit, the detection limit itself should be used in calculating the statistic. The 90th percentile can be extrapolated by graphical methods when fewer than ten samples are collected.

[2]The increase (in mg/L or NTU) is over levels measured at a site upstream from a discharge or series of discharges and as close to them as possible, and applies to downstream values.

[3]The maximum is based on an average calculated from at least five randomly located samples from natural substrates at each site on any sampling date.

[4]Measurements may be made in-situ, but must be confirmed in the laboratory if the objective is not achieved.

TABLE 2
MAXIMUM CONCENTRATION OF TOTAL AMMONIA NITROGEN FOR PROTECTION OF AQUATIC LIFE (mg/L-N)

	Temperature										
pH	0°C	1°C	2°C	3°C	4°C	5°C	6°C	7°C	8°C	9°C	10°C
6.5	27.7	28.3	27.9	27.5	27.2	26.8	26.5	26.2	26	25.7	25.5
6.6	27.9	27.5	27.2	26.8	26.4	26.1	25.8	25.5	25.2	25	24.7
6.7	26.9	26.5	26.2	25.9	25.5	25.2	24.9	24.6	24.4	24.1	23.9
6.8	25.8	25.5	25.1	24.8	24.5	24.2	23.9	23.6	23.4	23.1	22.9
6.9	24.6	24.2	23.9	23.6	23.3	23	22.7	22.5	22.2	22	21.8
7	23.2	22.8	22.5	22.2	21.9	21.6	21.4	21.1	20.9	20.7	20.5
7.1	21.6	21.3	20.9	20.7	20.4	20.2	19.9	19.7	19.5	19.3	19.1
7.2	19.9	19.6	19.3	19	18.8	18.6	18.3	18.1	17.9	17.8	17.6
7.3	18.1	17.8	17.5	17.3	17.1	16.9	16.7	16.5	16.3	16.2	16
7.4	16.2	16	15.7	15.5	15.3	15.2	15	14.8	14.7	14.5	14.4
7.5	14.4	14.1	14	13.8	13.6	13.4	13.3	13.1	13	12.9	12.7
7.6	12.6	12.4	12.2	12	11.9	11.7	11.6	11.5	11.4	11.3	11.2
7.7	10.8	10.7	10.5	10.4	10.3	10.1	10	9.92	9.83	9.73	9.65
7.8	9.26	9.12	8.98	8.88	8.77	8.67	8.57	8.48	8.4	8.32	8.25
7.9	7.82	7.71	7.6	7.51	7.42	7.33	7.25	7.17	7.1	7.04	6.98
8	6.55	6.46	6.37	6.29	6.22	6.14	6.08	6.02	5.96	5.91	5.86
8.1	5.21	5.14	5.07	5.01	4.95	4.9	4.84	4.8	4.75	4.71	4.67
8.2	4.15	4.09	4.04	3.99	3.95	3.9	3.86	3.83	3.8	3.76	3.74
8.3	3.31	3.27	3.22	3.19	3.15	3.12	3.09	3.06	3.03	3.01	2.99
8.4	2.64	2.61	2.57	2.54	2.52	2.49	2.47	2.45	2.43	2.41	2.4
8.5	2.11	2.08	2.06	2.03	2.01	1.99	1.98	1.96	1.95	1.94	1.93
8.6	1.69	1.67	1.65	1.63	1.61	1.6	1.59	1.58	1.57	1.56	1.55
8.7	1.35	1.33	1.32	1.31	1.3	1.29	1.28	1.27	1.26	1.26	1.25
8.8	1.08	1.07	1.06	1.05	1.04	1.04	1.03	1.03	1.02	1.02	1.02
8.9	0.871	0.863	0.856	0.849	0.844	0.839	0.836	0.833	0.832	0.831	0.83
9	0.703	0.697	0.692	0.688	0.685	0.682	0.681	0.681	0.68	0.681	0.68

	Temperature									
pH	11°C	12°C	13°C	14°C	15°C	16°C	17°C	18°C	19°C	20°C
6.5	25.2	25	24.8	24.6	24.5	24.3	24.2	24	23.9	23.8
6.6	24.5	24.3	24.1	23.9	23.8	24.6	23.5	23.3	23.3	23.2
6.7	23.7	23.5	23.3	23.1	23	22.8	22.7	22.6	22.5	22.4
6.8	22.7	22.5	22.3	22.2	22	21.9	21.8	21.7	21.6	21.5
6.9	21.6	21.4	21.3	21.1	21	20.8	20.7	20.6	20.5	20.4
7	20.3	20.2	20	19.9	19.7	19.6	19.5	19.4	19.3	19.2
7.1	18.9	18.8	18.7	18.5	18.4	18.3	18.2	18.1	18	17.9
7.2	17.4	17.3	17.2	17.1	16.9	16.8	16.8	16.7	16.6	16.5
7.3	15.9	15.7	15.6	15.5	15.4	15.3	15.2	15.2	15.1	15.1
7.4	14.2	14.1	14	13.9	13.9	13.8	13.7	13.6	13.6	13.5
7.5	12.6	12.5	12.4	12.4	12.3	12.2	12.2	12.1	12.1	12
7.6	11.1	11	10.9	10.8	10.8	10.7	10.7	10.6	10.6	10.5
7.7	9.57	9.5	9.43	9.37	9.31	9.26	9.22	9.81	9.15	9.12
7.8	8.18	8.12	8.07	8.02	7.97	7.93	7.9	7.87	7.84	7.82
7.9	6.92	6.88	6.83	6.79	6.75	6.72	6.69	6.67	6.65	6.64
8	5.81	5.78	5.74	5.71	5.68	5.66	5.64	5.62	5.61	5.6
8.1	4.64	4.61	4.59	4.56	4.54	4.53	4.51	4.5	4.49	4.49
8.2	3.71	3.69	3.67	3.65	3.64	3.63	3.62	3.61	3.61	3.61
8.3	2.97	2.96	2.94	2.93	2.92	2.92	2.91	2.91	2.91	2.91
8.4	2.38	2.37	2.36	2.36	2.35	2.35	2.35	2.35	2.35	2.36
8.5	1.92	1.91	1.91	1.9	1.9	1.9	1.9	1.9	1.91	1.92
8.6	1.55	1.54	1.54	1.54	1.54	1.54	1.55	1.55	1.56	1.57
8.7	1.25	1.25	1.25	1.25	1.25	1.26	1.26	1.27	1.28	1.29
8.8	1.02	1.02	1.02	1.02	1.03	1.03	1.04	1.05	1.06	1.07
8.9	0.832	0.834	0.838	0.842	0.847	0.853	0.861	0.87	0.88	0.891
9	0.684	0.688	0.692	0.698	0.704	0.711	0.72	0.729	0.74	0.752

TABLE 3
AVERAGE 30-DAY CONCENTRATION OF TOTAL AMMONIA NITROGEN FOR PROTECTION OF AQUATIC LIFE (mg/L-N)

pH	Temperature										
	0°C	1°C	2°C	3°C	4°C	5°C	6°C	7°C	8°C	9°C	10°C
6.5-7.1	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.9	1.88	1.86	1.84
7.2	2.08	2.05	2.02	1.99	1.96	1.95	1.92	1.9	1.88	1.86	1.85
7.3	2.08	2.05	2.02	1.99	1.97	1.95	1.92	1.9	1.88	1.86	1.85
7.4	2.08	2.05	2.02	2	1.97	1.95	1.92	1.9	1.88	1.87	1.85
7.5	2.08	2.05	2.02	2	1.97	1.95	1.93	1.91	1.88	1.87	1.85
7.6	2.09	2.05	2.03	2	1.97	1.95	1.93	1.91	1.89	1.87	1.85
7.7	2.09	2.05	2.03	2	1.98	1.95	1.93	1.91	1.89	1.87	1.86
7.8	1.78	1.75	1.73	1.71	1.69	1.67	1.65	1.63	1.62	1.6	1.59
7.9	1.5	1.48	1.46	1.44	1.43	1.41	1.39	1.38	1.36	1.35	1.34
8	1.26	1.24	1.23	1.21	1.2	1.18	1.17	1.16	1.15	1.14	1.13
8.1	1	0.989	0.976	0.963	0.952	0.942	0.932	0.922	0.914	0.906	0.899
8.2	0.799	0.788	0.777	0.768	0.759	0.751	0.743	0.736	0.73	0.724	0.718
8.3	0.636	0.628	0.62	0.613	0.606	0.599	0.594	0.588	0.583	0.579	0.575
8.4	0.508	0.501	0.495	0.489	0.484	0.479	0.475	0.471	0.467	0.464	0.461
8.5	0.405	0.4	0.396	0.381	0.387	0.384	0.38	0.377	0.375	0.372	0.37
8.6	0.324	0.32	0.317	0.313	0.31	0.308	0.305	0.303	0.301	0.3	0.298
8.7	0.26	0.257	0.254	0.251	0.249	0.247	0.246	0.244	0.243	0.242	0.241
8.8	0.208	0.206	0.204	0.202	0.201	0.2	0.198	0.197	0.197	0.196	0.196
8.9	0.168	0.166	0.165	0.163	0.162	0.161	0.131	0.131	0.131	0.131	0.131

pH	Temperature									
	11°C	12°C	13°C	14°C	15°C	16°C	17°C	18°C	19°C	20°C
7.8	1.57	1.56	1.55	1.54	1.53	1.42	1.32	1.23	1.14	1.07
7.9	1.33	1.32	1.31	1.31	1.3	1.21	1.12	1.04	0.97	0.904
8	1.12	1.11	1.1	1.1	1.09	1.02	0.944	0.878	0.818	0.762
8.1	0.893	0.887	0.882	0.878	0.874	0.812	0.756	0.704	0.655	0.611
8.2	0.714	0.709	0.706	0.703	0.7	0.651	0.606	0.565	0.527	0.491
8.3	0.571	0.568	0.566	0.564	0.562	0.523	0.487	0.455	0.424	0.396
8.4	0.458	0.456	0.455	0.453	0.452	0.421	0.393	0.367	0.343	0.321
8.5	0.369	0.367	0.366	0.366	0.365	0.341	0.318	0.298	0.278	0.261
8.6	0.297	0.297	0.296	0.296	0.296	0.277	0.259	0.242	0.227	0.213
8.7	0.241	0.24	0.24	0.241	0.241	0.226	0.212	0.198	0.186	0.175
8.8	0.196	0.196	0.196	0.197	0.198	0.185	0.174	0.164	0.154	0.145
8.9	0.16	0.161	0.161	0.162	0.163	0.153	0.144	0.136	0.128	0.121
9	0.132	0.132	0.133	0.134	0.135	0.128	0.121	0.114	0.108	0.102

- the average of the measured values must be less than the average of the corresponding individual values in Table 3.
- each measured value is compared to the corresponding individual values in Table 3. No more than one in five of the measured values can be greater than one-and-a-half times the corresponding objective values in Table 3.

TABLE 4
MAXIMUM AND 30-DAY AVERAGE NITRITE (N) CONCENTRATIONS TO PROTECT AQUATIC LIFE

Chloride Concentration (mg/L)	Maximum Nitrite–N Concentration (mg/L)	30-Day Average Nitrite–N Concentration* (mg/L)
<2	0.06	0.02
2-4	0.12	0.04
4-6	0.18	0.06
6-8	0.24	0.08
8-10	0.30	0.10
>10	0.60	0.20

*The 30-day average chloride concentration should be used to determine the appropriate 30-day average nitrite objective.

TABLE 5
MAXIMUM CONCENTRATIONS OF CHLOROPHENOLS TO PROTECT AQUATIC LIFE

Chlorophenol Objective (μg/L)			Chlorophenol Objective (μg/L)		
2-MCP	any pH	0.90	2,3,6-TCP	≥ pH 7.3	0.32
3-MCP	any pH	0.50	2,4,5-TCP	< pH 7.9	0.08
4-MCP	any pH	0.70	2,4,5-TCP	≥ pH 7.9	0.24
2,3-DCP	any pH	0.20	2,4,6-TCP	< pH 7.5	0.12
2,4-DCP	any pH	0.30	2,4,6-TCP	≥ pH 7.5	0.50
2,5-DCP	any pH	0.30	3,4,5-TCP	any pH	0.06
2,6-DCP	< pH 7.9	0.30	2,3,4,5-TTCP	< pH 7.5	0.04
2,6-DCP	≥ pH 7.9	0.90	2,3,4,5-TTCP	≥ pH 7.5	0.20
3,4-DCP	any pH	0.20	2,3,4,6-TTCP	< pH 7.1	0.04
3,5-DCP	< pH 8.1	0.12	2,3,4,6-TTCP	≥ pH 7.1	0.30
3,5-DCP	≥ pH 8.1	0.35	2,3,5,6-TTCP	< pH 7.1	0.02
2,3,4-TCP	< pH 7.9	0.10	2,3,5,6-TTCP	pH 7.1-pH 8.1	0.10
2,3,4-TCP	≥ pH 7.9	0.30	2,3,5,6-TTCP	> pH 8.1	0.25
2,3,5-TCP	< pH 7.9	0.08	2,3,4,5,6-PCP	< pH 6.9	0.02
2,3,5-TCP	≥ pH 7.9	0.25	2,3,4,5,6-PCP	pH 6.9-pH 7.9	0.10
2,3,6-TCP	< pH 7.3	0.06	2,3,4,5,6-PCP	> pH 7.9	0.30

TABLE 6
RECOMMENDED WATER QUALITY MONITORING FOR THE FRASER RIVER FROM MOOSE LAKE TO HOPE

Site Number	Location	Frequency	Date	Variables
New Site New Site	Fraser River at outlet from Moose Lake Fraser River at Red Pass	5 times weekly in 30 days	May - June	Suspended solids Turbidity
E206580 New Site New Site 0600011 E206581	Fraser River @ Hansard Fraser River above Nechako R confluence and below mills outfalls Fraser River above Quesnel Fraser River below Quesnel (Marguerite) Fraser River at Hope	5 times weekly in 30 days once - 3 replicates per site	January - March	Dissolved oxygen pH Temperature MF fecal Enterococci Escherichia coli Residual chlorine NH3–N NO3–N NO2–N Colour - true Turbidity Suspended solids AOX Dehydroabietic acid Total resin acids Dioxins and furans (H2O) Dioxins and furans (sed)
   E206580 E206182 New Site 0600011 E206581	Site with suitable natural substrate near the following: Fraser River at Hansard Fraser River at Stoner Fraser River above Quesnel Fraser River at Marguerite Fraser River at Hope		July–Sept	Periphyton chlorophyll-a Lead, PCBs, Dioxins & furans (fish) (Minimum of 3 species with 5 individuals per species at each site)

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1. INTRODUCTION

1.1 BACKGROUND

The British Columbia Ministry of Environment, Lands, and Parks is preparing water quality assessments and objectives in priority water basins in British Columbia. This report describes the water quality within the Fraser River from its headwaters near Moose Lake to its entry at Hope into the lower Fraser valley. Presented in this report are data collected generally in the period from 1985 to December 1991, although we have updated the information for the pulp and paper mills to about the end of 1993. The reasons for this are so that the assessment will focus on recent information and therefore impacts related to present operations, and take into account an intensive water quality sampling program on a number of Fraser River sites has been operational in about the same period of time. The objectives are being prepared for use by resource managers.

Water Quality Objectives have been prepared, or are being prepared for several other areas of the Fraser River system. For example, Swain and Holms prepared objectives for the lower Fraser River from Hope to Kanaka Creek (1.1) and from Kanaka Creek to the mouth (1.2), while Swain prepared water quality objectives for the remaining tributaries to the lower Fraser River along the north shore (1.3). Other water quality objectives were prepared for the Nechako River system (1.4), the Thompson River system (1.5) including the Bonaparte River (1.6), Tabor Lake (1.7), and the San Jose River (1.8). Water quality objectives are required for the upper Fraser River so that those objectives in place for the Fraser River Estuary (1.2) can be updated in the near future.

In order to focus this assessment and to reduce the scope of the task, only those discharges which affect the main stem of the Fraser River will be considered. The effects of other discharges which are likely to affect a Fraser River tributary will not be considered as such, but simply in terms of the impact of that particular tributary on Fraser River water quality.

1.2 WATER QUALITY OBJECTIVES - BASIC PHILOSOPHY

Water quality objectives are established in British Columbia for water bodies on a site-specific basis(1.9). The objective can be a physical, chemical or biological characteristic of water, biota or sediment, which will protect the most sensitive designated water use at a specific location with an adequate degree of safety[1,9]. The objectives are aimed at protecting the most sensitive designated water use with due regard to ambient water quality, aquatic life, waste discharges and socio-economic factors[1,9].

Water quality objectives are based upon approved or working water quality criteria which are characteristics of water, biota, or sediment [1,9] that must not be exceeded to prevent specified detrimental effects from occurring to a water use[1,9]. The working criteria upon which many of the proposed objectives are based come from the literature, and are referenced in the following chapters. The B.C. Ministry of Environment, Lands, and Parks is in the process of developing approved criteria for water quality characteristics of particular importance to British Columbia.

As a general rule, objectives are only set in water bodies where man-made influences threaten a designated water use, either now or in the future. The objectives proposed in this report are to be reviewed as additional monitoring information becomes available and as the Ministry of Environment, Lands, and Parks establishes more approved water quality criteria.

Point sources of waste water are controlled through the issuance of Waste Management permits, which specify quantities of waste water which can be discharged to the environment, and quantities and types of contaminants which can be discharged. The water quality objectives are designed to help the Ministry determine whether the permits are effective in protecting the environment. The objectives take into account the use of the water to be protected and the existing water quality. They allow for changes from background which can be tolerated, or for upgrading which may be required. Any difference between background levels and the stated water quality objective indicates that some waste assimilative capacity can be used while still maintaining a good margin of safety to protect designated water uses. In cases of water quality degradation, objectives will set a goal for corrective measures.

The objectives, except those for fish, do not apply within the initial dilution zones of effluents. These zones in rivers are defined as extending up to 100 m downstream from a discharge, and occupying no more than 50% of the width of the river, from its bed to the surface. In lakes, initial dilution zones are defined as extending up to 100 m horizontally in all directions from the discharge, but not to exceed 25% of the width of the water body.

The actual extent of the initial dilution zones may be reduced in the future based on site-specific studies related to individual effluent discharges.

In cases where there are many effluents discharged, there could be some concern about the additive effect of dilution zones in which water quality objectives may be exceeded. Permits issued pursuant to the Waste Management Act control effluent quality which in turn determine the extent of initial dilution zones and the severity of conditions within them. In practice, small-volume discharges or discharges with low levels of contaminants require mixing zones much smaller than the maximum dilution zone allowed. The concentrations of contaminants permitted in effluents are such that levels in the dilution zones will not be acutely toxic to aquatic life or create objectionable or nuisance conditions. Processes such as chemical changes, precipitation, adsorption and microbiological action, as well as dilution, take place in these zones to ensure that water quality objectives will be met at their border.

1.3 DESCRIPTION OF THE WATERSHED

The Fraser River rises in the Rocky Mountains, drains an area of about 230 000 km^2, and flows 1 400 km to its outlet in the Strait of Georgia near Vancouver, British Columbia (Figure 1.1). It flows through almost all the types of terrain found in British Columbia. From Mount Robson Park, the Fraser flows west skirting the Cariboo Range, then south along the Interior Plateau lying between the Coast Mountains on the west and the Cariboo and Monashee Mountain ranges to the east, and finally south and west through the Coast Mountains to the sea. Since the drainage is so large (approximately 25% of the Province), the conditions throughout the basin influence water quality.

The climate of British Columbia is influenced largely by the north-south orientation of the mountain ranges and the position of the Province immediately east from the Pacific Ocean. Moist, eastward-flowing air masses from the Pacific are forced over the mountain barriers, resulting in relatively heavy precipitation on west-facing slopes and drier conditions on east-facing slopes. This is particularly apparent during the winter months when large amounts of rain and snow fall with the frequent passage of Pacific storms. In winter, the Province is occasionally affected by much colder, drier air from northern arctic climes. When this occurs, periods of very cold and dry weather persist until the return of the milder Pacific air. During the summer, a weakening in the west to east upper-air movement, in combination with the development of a persistent high-pressure area off the coast, results in fewer frontal systems moving through British Columbia. As a result, summers tend to be dry through most of the Province.

The Fraser River flows through three of the five physiographic regions of the Province. The **Coastal Area** near Vancouver has moderate amounts of precipitation in the autumn and winter, with mild winters, cool summers, and long periods free from freezing temperatures. The mountains in this area receive large volumes of precipitation which often results in heavy snow packs. The **Interior Plateau** in the Kamloops to Prince George area experiences a much drier continental climate, with diurnal and seasonal differences in temperature which are much greater than along the coast. Summers tend to be hot and dry, while winters are cooler with less precipitation than found along the coast, with Prince George being colder and wetter than Kamloops. The **Columbia Mountains** and **Southern Rockies** near Valemount have marked contrasts in climate, but generally experience warm summers and cool winters.

Historic salmon runs on the Fraser River are among the largest in the world. Stocks support a major commercial fishery for all six Pacific species, important native food fisheries, and a significant recreational sport fishery.

For the purpose of this water quality assessment, the Fraser River has been divided into three main reaches. These are the Fraser River from Moose Lake (headwaters) to Tete Jaune Cache (Reach 1), the Fraser River from Tete Jaune Cache to Prince George at the confluence of the Nechako River (Reach 2), and the Fraser River from Prince George to Hope (Reach 3). These reaches are depicted in Figure 1.2, and are based upon the recommendations of Whitfield [1.10].

2. HYDROLOGY

The Fraser River exhibits a classical perpetual annual snow melt hydrograph pattern due to its large alpine snowpack and its massive basin storage. All the hydrometric stations analyzed along its length (see below) showed high flow months from May to August. For the Fraser River at Hope, 64% of its annual volume runoff was recorded during this period. The low-flow months range consistently between November and April. The range of flows based on monthly mean discharges for stations shown on Figure 2.1 is shown below:

Hydrometric Station	Station Number	Highest Mean Monthly Discharge (m^3/s)	Lowest Mean Monthly Discharge (m^3/s)
Moose R. near Red Pass	08KA008	113	0.329
Fraser R. at Red Pass	08KA007	235	4.06
Fraser R. at McBride	08KA005	918	20.6
Fraser R. at Hansard	08KA004	2100	60.4
Fraser R. at Shelley	08KB001	3470	97
Fraser R. near Marguerite	08MC018	5390	218
Fraser R. at Big Bar Cr.	08MD013	6240	300*
Fraser R. above Texas Cr.	08MF040	6500	316
Fraser R. at Hope	08MF005	10800	482

*Estimate based on regional average trend of minimum discharges

Low-flow estimates for the Fraser River were based directly on the results of frequency analyses of the main stem hydrometric data. Seven-day average low-flows were based on a water year from July 1st to June 30th. A calendar year would produce underestimated low flows since low flows would be extracted from the same (lowest) trough of two successive annual hydrographs. Years with missing low-flow data were excluded from the analyses. Hydrometric records downstream from Shelley were excluded prior to October 8, 1952, when the Nechako Reservoir began to be filled.

Low-flow estimates for the Fraser River going from upstream to downstream direction are shown below:

Hydrometric Station	Drainage Area km^2	Period of Record (years)	7-day low-flow $L/s/km^2$	7-day low-flow m^3/s	10 yr,7-day low-flow m^3/s
Moose R. near Red Pass	458	34	2.36	1.08	0.76
Fraser R. at Red Pass	1 700	35	2.91	4.95	4.10
Fraser R. at McBride	6 890	33	3.87	26.7	21.0
Fraser R. at Hansard	18 000	37	4.42	79.6	60.6
Fraser R. at Shelley	32 400	40	4.51	146	110
Fraser R. near Marguerite	99 700	33	3.11	310	232
Fraser R. at Big Bar Cr.	131 000	10	2.93	384	291
Fraser R. above Texas Cr.	138 000	38	2.98*	411*	315*
Fraser R. at Hope	203 000	38	3.44	698	563

All the estimates are based on the frequency results of hydrometric station data except for the Fraser River flows above Texas Creek (*) which are based on a regional average trend of the unit low flows along the Fraser River.

The seven-day unit low-flow estimates ($L/s/km^2$) for the Fraser River increase from its source until Shelley, reflecting the gradual runoff increase from east to west of the Columbia Mountains. The gradual decrease in unit low-flow below Shelley reflects the influence of the dry Fraser Plateau. Below Texas Creek, the wetter eastern Coast Mountains with winter rainfall increase the unit low-flow.

The Nechako Reservoir operation plans call for a minimum release of 12 m^3/s during the December to March period. The low-flow estimates for sites at Marguerite and downstream should be reduced to reflect future operation.

3. WATER USES

The Fraser River above Hope is used for several competing interests, including use for hydroelectric power generation in the Nechako River system, industrial water withdrawals, aquatic life, irrigation water supplies and livestock watering, drinking water supplies, wildlife, as well as recreation.

3.1 Fisheries Use

3.1.1 Salmon

Fraser River stocks of salmon were devastated by rock slides at Hell's Gate in 1913 and 1914, caused by railway construction (3.4). Fishways to improve the upstream passage of fish at Hell's Gate became operational in 1945.

The following are the average annual escapements of salmon to the Fraser River upstream from Hope for the past four decades (3.1,3.2). Chinook salmon spawn along the entire length of the Fraser River and in its tributaries, coho salmon as far upstream as the Thompson River, while very few chum salmon are found upstream from Hope.

YEARS	CHINOOK	CHUM	COHO	PINK	SOCKEYE
1951-1960	56 170	NR	22 673	233 210	1 228 270
1961-1970	47 409	25	21 269	421 476	1 129 501
1971-1980	66 207	NR	16 011	990 102	1 029 210
1981-1989	101 301	1 923	21 426	726 444	1 922 611

NR = no returns measured

These data suggest that during the past four decades, the stocks of coho salmon spawning upstream from Hope have remained constant, while sockeye, pink, chum, and chinook returns have improved. The escapements to the different reaches of the Fraser River above Hope are shown in Table 3.1.

Sockeye is the salmon species which uses the Fraser River above Hope in greatest numbers to reach spawning areas. This species spawns in greatest numbers in the South Thompson River, in tributaries of the Fraser River from Lillooet to Prince George, and in the Nechako River and its tributaries (Table 3.1). For the last four decades, salmon stocks for the seven river reaches were generally high in the 1950's, showed declines in the 1960's, some improvement in the 1970's, and were generally the highest of the four decades in the 1980's. Exceptions to this were in the Fraser River north from Prince George, where populations fluctuated and may be on the decline.

The second most plentiful species in the Fraser River upstream from Hope is pink salmon. This species spawns in two main areas; the Fraser River tributaries from Hope to Lillooet and in the Lower Thompson River and its tributaries. Relatively small populations are also found in the North and South Thompson rivers, and in tributaries to the Fraser River from Lillooet to Prince George. Pink salmon were found in greatest numbers in that reach from Hope to Lillooet in the 1980's, although prior to that period, this species was encountered in highest numbers in the Lower Thompson River. Pink salmon stocks have shown a steady increase in the last four decades in the Fraser River from Hope to Lillooet; however, the stocks in the Lower Thompson River, after showing steady increases in the period 1951 to 1980, have had a significant decline in numbers returning in the last 1981 - 1989 period.

Chinook salmon are found throughout the Fraser River and its tributaries in relatively equal numbers except for the reach from Hope to Lillooet. Numbers of returning chinook have been increasing in most areas during the last four decades. There are some minor exceptions to this general statement, most notably in the Lower Thompson River where numbers in the 1960's were only about two-thirds that number found in the 1950's; however, numbers have been slowly increasing in the last two decades.

Coho salmon are not generally found above Lillooet, and the largest numbers are found in the Lower, North, and South Thompson river systems. Coho salmon stocks do not appear to have improved during the last four decades, and are generally about the same as during the 1950's. Chum salmon do not generally utilize the Fraser River or its tributaries above Hope, although a small number are found between Hope and Lillooet.

The yearly escapements are presented in Figure 3.1 for the period 1950 to 1990. These data indicate that a statistically significant increase has occurred during that period (P=0.05).

3.1.2 Other Species

The distribution of resident Fraser River fish is presented (3.3) according to four regions: the lower Fraser below Hope, the middle Fraser from Hope to the Chilcotin River mouth, the Thompson River, and the Upper Fraser from the Chilcotin River to the headwaters. Below are those species found in the Middle and Upper Fraser (3.3).

Species	Common Name	Middle	Upper
Coregonus clupeaformis	Lake whitefish	?i	√
Prosopium coulteri	Pygmy whitefish	-	√
P. williamsoni	Mountain whitefish	√	√
Salvelinus confluentus	Bull trout	√	√
S. fontinalis	Brook trout	√i	√i
S. namaycush	Lake trout	-	√
Oncorhynchus clarki	Cutthroat trout	√	-
O. mykiss	Rainbow trout	√	√
O. nerka	Kokanee	√	√
Acrocheilus alutaceus	Chiselmouth	-	√
Couesius plumbeus	Lake Chub	√	√
Cyprinus carpio	Common carp	√i	-
Hybognathus hankinsoni	Brassy minnow	-	√
Mylocheilus caurinus	Peamouth	√	√
Ptycocheilus oregonensis	Northern Squawfish	√	√
Rhinichthys cataractae	Longnose dace	√	√
R. falcatus	Leopard dace	√	√
Richardsonius balteatus	Redside shiner	√	√
Catostomus catostomus	Longnose sucker	√	√
C. columbianus	Bridgelip sucker	√	√
C. commersoni	White sucker	-	√
C. macrocheilus	Largescale sucker	√	√
Lota lota	Burbot	√	√
Cottus aleuticus	Coastrange Sculpin	√	-
C. asper	Prickly sculpin	√	√
C. cognatus	Slimy sculpin	-	√

√ Present - Absent i Introduced

From these data, it is evident that there are a large number of resident fish species in the Fraser River above Hope, although population sizes are not available. Of the four reaches, the Middle Reach has the lowest species representation, probably due to difficulty in re-colonizing the area after deglaciation (3.3). With respect to introduced species, it was speculated that species such as the common carp and brown bullhead have likely had negative impacts on native species present (3.3).

It has also been documented that "at least 16 of the Fraser's 47 truly freshwater fishes spend part of their life in the ocean but migrate up its arms and mainstem to spawn" (3.3). Other than the species discussed earlier, these include lamprey (*Lampetra ayresi* and *L. tridentata*), white sturgeon (*Acipenser transmontanus*), American shad (*Alosa sapidissima*), cutthroat trout (*Oncorhynchus clarki*), and rainbow trout (*O. mykiss*). These species are generally restricted to the middle Fraser River, although a few rainbow trout do go to the upper Fraser River reach (3.3). The larvae of the lamprey are dominant members of the benthic community (food item for white sturgeon), and as adults are serious predators of salmon (3.3). The white sturgeon (*Acipenser transmontanus*) is the largest fish in the system, commonly exceeding several hundred kilograms, and is an important component of the native food fishery (3.3). Little is known about the abundance of the American shad (*Alosa sapidissima*) (3.3).

3.2 Consumptive Water Uses

Locations of consumptive water uses are shown on Figure 3.2.

Consumptive water uses upstream from Tete Jaune Cache to Moose Lake are minimal. There are five permitted water withdrawals, for a total of 6.8 m^3/d for domestic use, 11.4 m^3/d for a C.N.R. work camp, and 91 m^3/d the Mount Robson camp site.

Between Tete Jaune Cache and Prince George there are two licensees. These are for 45.5 m^3/d for a private campground and 342 510 m^3/d for the Northwood pulp mill, just north from Prince George

The final reach of the river is between Prince George and Hope. Between Prince George and Quesnel there are 14 water licenses which permit the withdrawal of 18 200 m^3/d for Prince George water supply, 13.7 m^3/d for private domestic water supplies, 91

m^3/d for dust suppression, 122 325 m^3/d for a private power generator, and 539 dam^3/a for irrigation water supplies.

From Quesnel to Hope, there are 40 water licenses, for the withdrawal of 6.8 m^3/d for private domestic withdrawals, 67.9 m^3/d for dust control, 0.7 m^3/d for a forest industry operation, 13 454 m^3/d for mining, 11 012 dam^3/a for irrigation, and 296 dam^3/a for a nursery operation.

3.3 Recreational Water Uses

Primary-contact recreational water use of the Fraser River waters is minimal. The attitude of many individuals contacted was that primary-contact recreation would not normally occur along most of the Fraser River, since bathing would likely take place in tributaries which were generally less turbid, and warmer.

This does not take into account the activities such as river rafting and kayaking at locations such as Hell's Gate. Although not considered primary-contact recreation, per se, the probability of coming into contact with water-borne diseases would likely be as great, or greater, than through swimming. The "Fraser River and some 36 of its tributaries are used by over 60 rafting companies" [3.5].

The precipitous geography (steep-cut banks) of the upper and middle Fraser reaches results in much of the area being classified as having moderate to low capability to support recreational use. Included in these areas are 9 200 ha in the upper Fraser reach and 8 500 ha in the middle Fraser reach [3.5]. Only about 100 ha in each of the two reaches would be classified as having a very high or high capability to attract and support outdoor land-based recreation [3.5].

4. PERMITTED WASTE DISCHARGES

Permitted waste discharges can be located on Figure 4.1.1 by their permit number. A summary of each permit and the associated discharge volume allowed by the permit is included as Table 4.1. The permitted waste discharges will be discussed according to the river reach into which they discharge effluent. In order to limit the scope of this assessment, only those discharges which impact the main stem of the Fraser River will be considered. The effects of other discharges which are likely to affect a Fraser River tributary will be considered only in terms of the impact of that particular tributary on Fraser River water quality.

4.1 Fraser River from Moose Lake to Tete Jaune Cache

There are no direct discharges of waste water to the Fraser River under permit in this river reach.

4.2 Fraser River from Tete Jaune Cache to Nechako River Confluence

4.2.1 The Corporation of the Village of McBride (PE 402)

The Village of McBride (population 700) is located about 100 km south-east from Prince George. The waste water is domestic sanitary sewage, which is treated in a facultative lagoon. The lagoon capacity is 30 300 m^3, and with a surface area of about two hectares. The average daily flow is about 430 m^3/d, so that the average retention time is about 70 days, although this decreases to about 40 days at the maximum permitted discharge. The effluent is discharged from a submerged outfall at a distance of about 10 m from the shore at the low water level. The effluent is not disinfected.

Permit PE 402 allows a maximum effluent discharge of 750 m^3/d, with maximum concentrations of 100 mg/L suspended solids and 100 mg/L BOD_5. At a ten-year, seven-day low-flow of 21 m^3/s at McBride (Chapter 2), the minimum dilution available for the highest allowable discharge rate is 2419:1, assuming complete mixing of the treated effluent with the Fraser River.

Effluent data are summarized in Table 4.2.1. The data indicate that only one of 13 flow values exceeded the permit level, while all BOD_5 and suspended solids concentrations met the limits. The maximum concentrations of the following characteristics in the effluent would result in these calculated increases at the minimum dilution rate and with complete mixing:

Calculated Maximum Increase with complete mixing			
fecal coliforms	537 /100 mL	BOD_5	0.024 mg/L
ammonia	0.003 mg/L	Susp. solids	0.03 mg/L
nitrite	0.00009 mg/L		

There are no licensed water users downstream until Prince George. It should be noted that these increases are based upon mixing of the river with the effluent, which will not occur completely at the edge of the initial dilution zone where only a portion of the river flow (say 25% or less) would be used for mixing. As well, maximum increases are expected under ice cover when some water uses such as recreation are not a concern. Thus, it is not anticipated that this discharge will influence water quality, except possibly for fecal coliform concentrations under ice cover which would not impact recreational use of the river.

4.2.2 **Northwood Pulp and Paper - Upper Fraser** (PE 2655)

Northwood Pulp and Paper has a permit for the discharge of treated domestic waste water from the Village of Upper Fraser (population 550), located approximately 60 km north-east from Prince George. The municipal sewage is treated in an extended aeration-type secondary treatment plant, chlorinated, and discharged through a submerged outfall into the Fraser River. The outfall extends about 20 m into the river. Permit PE 2655 allows the discharge of a maximum of 273 m^3/d, with maximum concentrations of 60 mg/L suspended solids, and 45 mg/L BOD_5.

Using the flow data for the Fraser River at Hansard, assuming a ten-year low-flow of 60.6 m^3/s, using the permitted maximum flow of 273 m^3/d, and assuming complete mixing of the effluent and river flow, the minimum dilution will be in excess of 19 000:1. The effluent is not anticipated to be a concern in the river, even if only 25% or less of the flow is available for dilution at the edge of the initial dilution zone.

The company provides daily pH, chlorine residual, and flow data for this discharge. Residual chlorine in the period from 1989 to 1991 has ranged from zero at times when the chlorine line was broken, to a maximum of 1.0 mg/L. All but three of about 1000 readings have been in the range of 0.1 to 0.5 mg/L, with the remaining three values at 1.0 mg/L. Flows (n=1050) during the same period have been reported as being from about 19 to 68 m^3/d, with all but twelve of the readings less than or equal to about 50 m^3/d. The pH values reported ranged from 7.0 to 10.0; however, the quality of the data is questionable, since it is reported in units which differ by 0.5 (i.e., 7.0, 7.5), and one value reported as 9.0 was later tested and found to be 7.4 by another laboratory.

We conclude that there will be no effect from this operation given the effluent quality data and the large available dilution.

4.2.3 **Northwood Pulp and Paper-Prince George Paper Plant** (PE 157, PR 5000)

This pulp and paper mill is situated the furthest upstream on the Fraser River of all the pulp and paper mills (Figure 4.1.2), and is located at Prince George, about nine kilometres upstream from the Intercontinental and Prince George Pulp and Paper (Figure 4.1.2). It started production in 1966, and expanded its production in mid-1982.

4.2.3.1 Process Description

Northwood Pulp and Paper operates a bleached kraft pulp mill with a production capacity of 1 650 ADt/d (air dried tonnes per day). As this assessment generally will deal with data since 1985, only those process modifications after that time will be reported. Dwernychuk [4.2] reported that in 1989, the plant processed an average of about 1 300 ADt/d of bleached kraft pulp. The wood furnish consisted of 50% spruce, 35% pine, and 15% fir. The bleaching sequence consisted of chlorine dioxide substitution, oxidative alkaline extraction, chlorine dioxide, alkaline extraction, and chlorine dioxide. "Recent modifications in the mill and present ClO_2 capacity allows for 100% ClO_2 substitution in each bleach plant."[4.16]

Within the plant, there is a fibre and chemical spill collection and recovery system. As well, white water is reused as much as possible, as is contaminated condensate, in the brownstock washers, with return of the knotter rejects to the digesters. Unbleached pulp decker filtrate is used in the two diffusion washers and for dilution; "jump stage" washing is used to reduce freshwater requirements; while unbleached pulp screen rejects are recycled to the digester.

Waste water from the operation goes from the plant in one of four lines: "clear", acid with pH control, caustic, and "general". The "clear" effluent bypasses much of the treatment system, and joins the remainder of the flow at the flow splitter. The remainder of the effluent goes to a mechanical clarifier (with underflow going to vacuum drum filters, and the subsequent solids going to landfill), then through the flow splitter to one of two aerated stabilization basins (545 098 m^3 and 757 080 m^3 capacity). Retention time in the aerated stabilization basins is from 7.5 to about 9 days, depending on the rate of production. About 40% of the waste water is treated in a biobasin with about 18 hours retention, before going to the outfall stilling basin, and then to the Fraser River through a submerged outfall with three risers, each with two 50-cm diameter nozzles.

Permit PE 157 allows the discharge of a maximum 190 000 m^3/d of effluent with the following effluent characteristics: maximum temperature of 35 ^oC (under amendment to 38 ^oC), pH range from 6.5 to 8.5, BOD_5 loading of 12 400 kg/d, suspended solids loading of 16 500 kg/d, and an effluent toxicity of between 75% and $\geq$ 100% as a 96-h LC50, depending upon the flow.

Northwood Pulp also has an industrial landfill located just north from the pulp mill, to which it can discharge an average of 16 612 tonnes per year of refuse (consisting of 4 260 tonnes primary clarifier sludge, 750 tonnes oversize hog fuel and knots, 11 700 tonnes power boiler ash and lime grits, and 22 tonnes wood ash from fire fighting training). The site is subject to seasonally high water table intrusions, and is below the 200 year river flood plain level. Thus there can be times when this refuse site and its leachate may be a possible concern in the river, although the available dilution during such times (periods of flooding) would be quite large.

4.2.3.2 Effluent Quality

A data summary for the Northwood Pulp final process effluent quality is contained as Tables 4.2.3 to 4.2.5, with Ministry data on general effluent conditions in Table 4.2.3, dioxin and furan data for two effluent samples in Table 4.2.4, and a summary of data reported to the Ministry by the company to the end of 1993 in Table 4.2.5.

In terms of the variables cited in Waste Management permit PE 157 (Table 4.2.5), the average daily effluent flows were always less than the permit level, suspended solids loadings were often higher than permitted, while BOD_5 loadings also were higher than permitted but less frequently than those of suspended solids. The minimum dilution available to the effluent based upon the maximum permitted flow of 190 000 m^3/d, and the seven-day low-flow (10-year return period) of 110 m^3/s at Shelley, would be about 50:1 assuming complete mixing of the effluent and the river. At the edge of the initial dilution zone, the minimum dilution available for the effluent would be about 25% of this (assuming the dilution zone occupies one-quarter of the river), or about 13:1.

The highest loadings of suspended solids and BOD_5 varied on a monthly basis. The highest actual loadings to the river took place in June 1988 for suspended solids and November 1988 for BOD_5; however, the highest loadings with coincident low-flow periods were December 1988 for suspended solids and November 1988 for BOD_5. Potential increases in the river concentrations during these times would have been about 3.59 mg/L and 3.07 mg/L, respectively, assuming complete mixing or about 14.4 mg/L and 12.3 mg/L, respectively, at the edge of the initial dilution zone.

Dissolved oxygen concentrations in the effluent usually have exceeded 2.0 mg/L on a monthly basis since 1987. Dissolved oxygen has usually been higher in the winter months, with the lowest concentrations occurring during July and August. The mean monthly pH of the effluent has usually been between 7.0 and 8.0, although a value of 6.9 was reported for August 1987.

Toxicity data for the effluent are not presented in the tables; however, most of the tests during the period 1985 to 1991 have shown that the mill effluent is non-acutely toxic to rainbow trout over a four-day test exposure. In comparison, tests using the Microtox-bioluminescence test procedure showed some toxicity (impairment of light generation :

Table 4.2.3), although the mean value for the 5-minute Microtox test was 84.2% (V/V), indicating very little impairment.

Measurable mean effluent chlorophenol concentrations have been 13.5 µg/L pentachlorophenol, 2 µg/L tetrachlorophenol, and 6 µg/L trichlorophenol. Given the available minimum dilution of 50:1 available to the effluent, resulting calculated average concentrations in the river with complete mixing would be 0.27 µg/L pentachlorophenol, 0.04 µg/L tetrachlorophenol, and 0.12 µg/L trichlorophenol, or about 1.08 µg/L, 0.16 µg/L, and 0.48 µg/L, respectively, at the edge of the initial dilution zone.

Ministry of Environment, Lands, and Parks chlorophenol criteria to protect aquatic life are expressed as isomers for each congener(4.4). For example, the most stringent criteria for trichlorophenols (TCP) ia a maximum of 0.06 µg/L of either 2,3,6-TCP at pH <7.3, or 3,4,5-TCP at any pH. This is calculated to be exceeded by the mean concentration in the effluent under these calculated fully-mixed conditions. For tetrachlorophenol (TTCP), the most restrictive criterion is 0.04 µg/L 2,3,4,5-TTCP at pH < 7.5, equal to the calculated average concentration. For pentachlorophenol (PCP), the criterion to protect aquatic life in the pH range from 6.9 to 7.9 is 0.10 µg/L, which was easily exceeded by the calculated average concentration. It is not known if any of the chlorophenols were present as the most toxic isomer; however, this is one underlying assumption in these calculations. Only with measurement of the actual isomers will a proper calculation be possible, although there will likely be a strong likelihood of chlorophenol toxicity under certain low flow conditions.

Resin acids measured in the effluent are in Table 4.2.3. Mean concentrations and calculated river concentrations are:

Resin Acid	Mean Effluent Concentration(µg/L)	Calculated River Concentration(µg/L)	Calculated Concentration at edge of dilution zone (µg/L)
Abietic	122	2.44	9.76
Dehydroabietic	410	8.2	32.8
Isopimaric	280	5.6	22.4
Levo pimaric	17	0.34	1.36
Neoabietic	52	1.04	4.16
Pimaric	194	3.88	15.5
Sandaraco pimaric	23	0.46	1.84
Sum (Resin Acids)	-	22	87.8

Criteria to protect freshwater aquatic life (4.5) from resin acids are as follows: 8 µg/L dehydroabietic acid at pH 7.0 or 25 µg/L total resin acids, and 12 µg/L dehydroabietic acid at pH 7.5 or 45 µg/L total resin acids. The data indicate that the total resin acid concentration of about 22 µg/L can approach criteria levels at lower pH values in the river with complete mixing and would exceed them at the edge of the initial dilution zone. In this case, the criteria for dehydroabietic acid is exceeded slightly. Duncan (6.26) has provided data for July 12, 1993 indicating that the concentrations 20 m and 100 m downstream from the outfall were 8 and 2 µg/L for total resin acids and 4 and 2 µg/L dehydroabietic acid, respectively.

Only one colour measurement was reported, that being 1 200 TAC units. This concentration could increase the colour in the Fraser River by 24 TAC units under low-flow conditions.

Two samples were collected in November and December 1991, and were analyzed for dioxins and furans. The data are listed in Table 4.2.4. The TEQ (Toxic equivalents) values for these samples were calculated to be 9.7 and 7.3 pg/L. Given the dilution of 50:1 at low-flow conditions, if the effluent was representative of typical discharge conditions, TEQ concentrations in the river could increase by about 0.5 pg/L during extreme low-flow conditions. At the edge of the initial dilution zone, this increase would be about 2.0 pg/L. The discharge could increase the TEQ values considerably in the river at low-flows. The cumulative effect of the other bleached kraft pulp mill discharges also must be taken into account. As well, dioxins and furans quickly partition from the water column to the sediments and biota, and these environmental compartments must also be considered in future sections.

AOX (measure of the concentration of total organic chlorine or other halogens and often used as an indicator of the level of contamination by organic chemicals) values have been measured in the effluent since 1989. The data are summarized in Table 4.2.5. The mean monthly loadings were about 3 kg/ADt to the end of 1991, thereafter decreasing to about 1.0 kg/ADt in 1992 and 0.7 kg/ADt in 1993. As well, the absolute loadings to the river during the same time period have shown the same decrease, with the mean annual loadings decreasing each year. These AOX loadings can increase AOX concentrations in the river. Based on the seven-day low-flow (10-year return period) at Shelley of 110 m^3/s, the highest monthly AOX discharge of 6628 kg/d could potentially cause an increase of

0.69 mg/L in the river after complete mixing. There are no environmental criteria for AOX since it is just a gross indicator of chlorinated organics and is poorly correlated with their toxicity.

Dwernychuk (4.3) et al. reported data for one composite sample which had been collected May 15, 1990 when the discharge rate was 150,000 m^3/d. The data for that sample and two subsequent samples in July 1991 and March 1993 were as follows:

Compound	May 15, '90	July 1991	March 1993
AOX	27 000 µg/L	-	-
2,4,6-trichlorophenol	1.5 µg/L	5.8 µg/L	0.48 µg/L
2,3,4,6-tetrachlorophenol	0.9 µg/L	1.64 µg/L	ND
pentachlorophenol	0.6 µg/L	ND	ND
3,4,5-trichloroguaiacol	17 µg/L	25.3 µg/L	1.9 µg/L
tetrachloroguaiacol	23 µg/L	11.7 µg/L	0.32 µg/L
3,4,5-trichlorocatechol	20 µg/L	ND	1.37 µg/L
tetrachlorocatechol	42 µg/L	0.24 µg/L	0.05 µg/L
2,3,7,8-tetrachlorodibenzofuran	250 pg/L	-	-
total tetrachlorodibenzofuran	420 pg/L	-	-

The flow in the Fraser River at Shelley on May 15, 1990 was 1370 m^3/s, which would have resulted in a dilution rate of 789:1. Thus, the only measurable increase in concentration on that particular day would occur for AOX, where the increase in the Fraser River with complete mixing is calculated to be 34.2 µg/L. If the low-flow dilution of only 50:1 were available, measurable increases would have been 540 µg/L AOX, 0.46 µg/L tetrachloroguaiacol, 0.4 µg/L 3,4,5-trichlorocatechol, 0.84 µg/L tetrachlorocatechol, 5 pg/L 2,3,7,8-TTCF, and 8.4 pg/L tetrachlorodibenzofuran. Increases under the low-flow conditions would be about four times higher at the edge of the initial dilution zone. Significant decreases are apparent for the 1991 (and some increases as well) and 1993 samples.

4.2.3.3 Impact of Effluent on the Fraser River

4.2.3.3(a) Dioxins and Furans

Mah et al. (4.1) collected sediments and fish in the spring of 1988 upstream and downstream from pulp mill effluent discharges in the interior of British Columbia. Dioxin and furan concentrations in sediments collected upstream from the Prince George pulp mills could not be detected above varying levels of detection (4.1). Downstream from the Northwood Pulp and Timber operation, the three sediment samples had non-detectable concentrations of 2,3,7,8-T_4CDD (<15 pg/g dry-weight), but measurable concentrations of 2,3,7,8-T_4CDF (274, 69.9, and 44.6 pg/g dry-weight). These concentrations represent TEQ values of 27.4 pg/g, 7 pg/g, and 4.5 pg/g, respectively. Similarly, downstream from the Canfor Prince George Pulp and Inter-Continental Pulp mill (discussed in Section 4.2.6), the three sediment samples had non-detectable concentrations of 2,3,7,8-T_4CDD (<15 pg/g dry-weight), but measurable concentrations of 2,3,7,8-T_4CDF in two of the three samples (50.7, 63.7, and <10 pg/g dry-weight) (4.1). These represent TEQ values of 5.1 pg/g, 6.4 pg/g, and 0.5 pg/g, respectively.

Singleton (6.22) has proposed a sediment quality criterion that the maximum TEQ concentration in sediments should not exceed 0.25 pg/g (dry-weight) normalized to 1% organic carbon. Thus, the three samples collected downstream from the Northwood operation exceed the objective.

Mah et al. (4.1) concluded that "the degree of contamination of bed sediments, at least for this relatively small set of samples, was primarily determined by sample location relative to sources of contamination and was not greatly affected by organic carbon content or particle size of sediments".

Fish collected downstream from the Northwood Pulp and Timber operation at Prince George (4.1) had higher dioxin and furan concentrations in muscle tissue than those collected downstream from the Canfor Prince George Pulp and Inter-Continental Pulp mill (Section 4.2.6). In fact, a composite muscle sample of seven largescale suckers (Catostomus macrocheilus) had 156 pg/g (wet-weight) of 2,3,7,8 tetrachlorodibenzofuran (2,3,7,8-T_4CDF) and 11.7 pg/g of 2,3,7,8-T_4CDD, or 27.3 pg/g as the TEQ. This compares to non-detectable concentrations (<2 pg/g wet-weight) in muscle of largescale suckers collected upstream from the Prince George mills, and concentrations of 40.8 pg/g

2,3,7,8-T_4CDF and 2 pg/g 2,3,7,8-T_4CDD (6.1 pg/g TEQ) in largescale suckers collected downstream from the Canfor Prince George Pulp and Inter-Continental Pulp mill(4.1).

The highest concentrations in fish muscle collected downstream from the Prince George pulp mills were in mountain whitefish (Prosopium williamsoni), with concentrations of 290 pg/g 2,3,7,8-T_4CDF and 19.5 pg/g 2,3,7,8-T_4CDD. The TEQ value for this fish would be 48.5 pg/g, compared to the fish health criterion proposed by Singleton (6.22) of 50 pg/g based on 1% lipid content in edible tissue of aquatic organisms. Health and Welfare Canada have established a food tolerance limit of 20 pg/g TEQ for fish(4.6).

Dwernychuk et al. (4.3), in an extensive survey of pulp mill effluents, drinking water supplies, sediments, and fish from the headwaters of the Fraser River to the Strait of Georgia, found that "all measured parameters were below the detection limit for sediments collected at S1 (near Hansard, upstream of Prince George) indicating that anthropogenic inputs (predominantly pulp mill effluent) from Prince George/Quesnel and other communities/industries downstream of Prince George are probably the primary sources of organochlorines." In fact, concentrations of tetrachlorophenol, pentachlorophenol, tri- and tetra- catechol, and 2,3,7,8-tetrachlorodibenzofuran "were higher in sediments collected from the lower reaches of the Fraser compared to sediments collected in the vicinity of Prince George."(4.3) Concentrations of tri- and tetra- chloroguaiacol in sediments were similar along the length of the Fraser (other than at Hansard which was lower) (4.3).

Dwernychuk et al. (4.3) noted that "tissue concentrations of organochlorines appeared to have declined between 1989 and 1990 sampling events, although more data sets need to be acquired before any trends can be confirmed." "Concentration gradients were not well defined (i.e., did not decrease linearly with increasing distance from mill effluent diffusers); however, organochlorines were detected in fish at reaches along the entire length of the Fraser system." (4.3)

Hatfield (4.14) has reported that in comparing data from an October 1992 survey with those from the 1988 and 1990/1991 surveys, it was reported that "dioxin and furan levels were markedly lower in mountain whitefish and rainbow trout muscle samples". The 1992 survey reflects conditions "after significant process and bleaching modifications were undertaken by the pulp mills to reduce emissions of dioxins, furans, and other organochlorines" (4.14). This decrease was "attributed to the reduced organochlorine loading by the pulpmills" (4.14). There were no samples collected from the vicinity of the two Prince George pulp mills in 1992, with the closest sample site being at Stoner.

4.2.3.3(b) Benthic Invertebrates - Methods

Benthic invertebrate communities were sampled upstream and downstream from Prince George Pulp and Paper Limited, Intercontinental Pulp Company Limited and Northwood Pulp and Timber Limited mill discharges (Figure 4.1.2 - Sites -1.0, 0.0, 4.7, 4.9, and 5.6). Sampling began with a pre-operational review, in which eight surveys were performed between July 1963 and April 1966, prior to the openings of the Northwood and Prince George mills in mid-1966 and Intercontinental in 1968. The sampling sites were changed in 1966 and sampling continued on a yearly basis to 1970. In 1972 the locations of the five sampling sites changed again and sampling continued yearly until 1981. Sampling was repeated in 1984, 1986, and again in 1989.

Invertebrates were chosen as the biological indicators of pollution in this study for many reasons: good taxonomic keys exist to aid in identification, invertebrates have been studied often world-wide in the past, invertebrates are relatively stationary and are therefore continually exposed to potential stresses, and changes in the heterogeneous communities that invertebrates form can be analyzed (4.9).

Sampling methodologies and river conditions have not always been consistent. This is not unexpected since the study spans 18 years.

From 1963 through 1970 tray and grab samples were both collected. Tray or "artificial substrate" samplers were used on rocky substrates and consisted of a tray anchored to the river bottom. Peterson grab samples were taken from softer mud/silt substrates. This methodology changed periodically when loss due to vandalism or high-water made the use of trays impossible (1972, 1976 and 1981); in these cases Surber samplers were used instead. Samples taken in 1984 and 1986 were collected using trays only. These differences in sampling techniques make interpretation of the data difficult if not impossible.

Once the samples were collected they were screened through fixed-mesh sieves and the invertebrates sorted and identified (see Tables 4.2.11 and 4.3.14 for species lists). In the period from 1963 to 1981, 595 µm mesh sieves were used. In 1984, screens with 180 µm openings were used. Concerned that opening size may have produced the unusually high population densities of the 1984 survey, samples from the 1986 study were re-screened through the larger-sized opening (595 µm), and two sites were re-sampled with 180 µm screens. When the replicates were compared at each of the two sample sites, the 180 µm screen retained a statistically significantly higher number of invertebrates than the 595µm screen at one site. At the other site, the 595 µm screen retained more invertebrates, but not at a statistically significant level.

Many approaches have been used to interpret the data collected upstream and downstream from the mill effluent diffusers. Tolerance indices show how a given factor such as effluent affects the invertebrates at a taxonomic level. Because different invertebrate species exhibit varying degrees of sensitivity to water quality conditions, when water quality deteriorates the more sensitive species are replaced by tolerant species, which are better able to cope with the degraded conditions [4.11].

4.2.3.3(c) Benthic Invertebrates - Indices

Benthic invertebrates may be classified as sensitive, facultative or tolerant. The proportion of invertebrates from each category in a given sample can indicate water quality relative to other sites in an area, or can show how the same site has changed over time [4.9]. The presence or absence of sensitive organisms is the most important factor; a presence of sensitive invertebrates indicates that the sample has come from relatively clean conditions, even if tolerant species also are present [4.9].

Mayflies (Ephemeroptera), stoneflies (Plecoptera) and caddisflies (Trichoptera) are benthic invertebrates that are often classed as sensitive; they comprise a large portion of a clean water association [4.12]. Aquatic Diptera inhabit both clean and polluted zones (facultative), while species of Tubificid worms and some Dipterans can tolerate highly polluted environments.

The 1963-1970 data show that the invertebrate communities in the Prince George area (both upstream and downstream) had low numbers of sensitive, facultative and tolerant species and that the relative proportions of each type were related to substrate composition. The 1972-1981 data show sensitive organisms dominated and no deleterious effects of mill effluent were found.

The Jaccard index compares stations on the basis of presence/absence of taxa. The 1963-1970 data revealed low levels of similarity between stations. When clusters did appear, control stations were often associated with experimental stations, indicating similar invertebrate communities in each (4.9).

The cluster analyses performed on the 1972-1981 data were calculated using Czeckanowski's coefficient rather than the Jaccard index. Both indices involve the formation of clusters on the basis of site similarity, however, Czeckanowski's coefficient considers relative abundance of each taxa rather than simply just the presence or absence of taxa, as in the Jaccard index (4.11). Czeckanowski's coefficient showed few close cluster associations between 1972 and 1981. Similarities often existed among sites that used the same methods (i.e., tray or grab), emphasizing the earlier concern about the validity of results in which sites of differing sampling methods are compared.

In 1984, tolerance indices showed that facultative invertebrates dominated all stations, including those upstream from the Northwood mill. Because the sampling station immediately downstream from the Northwood diffuser contained the highest concentration of sensitive invertebrates, the dominance of facultative invertebrates was probably not due to effluent (4.9). The Fraser River flowed at an exceptionally high level that year, possibly causing the unnaturally high invertebrate population densities that were recorded in 1984.

The 1984 samples (tray sampling was used only) showed two significant associations using Czeckanowski's coefficient. The first was between sites -1.0 and 4.7, the controls. The coefficient of similarity between them was 0.70, again indicating similar communities and indicating some form of organic enrichment (4.8).

The second important association occurred between sites 0.0 and 4.9, which are both directly downstream from discharges. The coefficient of similarity between these two sites was 0.73, indicating a high level of community similarity, most likely due to mill discharges (4.9).

Analysis of the 1986 samples using tolerance indices showed that sensitive invertebrates had regained dominance at all sample sites except one, located downstream from the Intercontinental and Prince George mill outfall. It was speculated that facultative organisms stayed dominant at that station because their community was firmly established or possibly due to the effects of sublethal stress on the sensitive invertebrates (4.8). Even though the potential for sublethal stress exists, its occurrence is very unlikely; low river flows and an increased effluent toxicity would be necessary (4.8).

Czeckanowski's coefficient showed that invertebrate communities were quite similar among stations in the 1986 samples, regardless of their position relative to the effluent diffusers; two clusters occur, each consisting of a control site and an impact site (4.8).

Tolerance data for the 1989 sampling period show very high numbers of sensitive fauna at all stations except 5.6. Because station 5.6 normally experiences the lowest current velocities, sediment tends to build up, encouraging colonization by oligochaetes (4.2). Oligochaetes are facultative and therefore the large numbers of them found at station 5.6 could influence the tolerance index significantly. Among sensitive invertebrates found at all stations, Ephemoptera, Trichoptera and Plecoptera were common.

Cluster analyses from the 1989 data (using Czeckanowski's coefficient) showed a high degree of similarity (approximately 0.82) between stations 0.0 and 4.9, both immediately downstream from effluent diffusers. However, both stations were linked to the control station, -1.0, at a level of approximately 0.70, indicating that mill effluent is probably not the main cause of the association (4.2).

In 1989 there was high equitability between all stations except 5.6 (due to the high oligochaete population), and richness fluctuated with no clear pattern of change. The Shannon-Weaver index indicated that no signs of environmental stress exist; in many cases the experimental stations had higher diversity than the controls (4.2).

Between 1963 and 1989, the mill effluents appear to have had little or no effect on the tolerance indices and community composition of the Fraser River downstream from the mills. Fluctuations in community composition occurred periodically, but not necessarily due to the mill effluent.

4.2.3.3(d) Benthic Invertebrates - Population Density/Organic Enrichment

The possibility of organic enrichment affecting the benthic invertebrate communities around Prince George has been suggested numerous times by Dwernychuk (4.8, 4.9, 4.11). Certain invertebrate species have been shown, in the past, to prefer organic-rich sediments. When an increase is seen in the number of these species or the population size of one of these species, it is assumed that organic components in the water have become more abundant.

Between 1963 and 1970 organic enrichment is thought to have caused an increased invertebrate population density below the City of Prince George and similarities between communities inhabiting areas immediately downstream from effluent diffusers. However, organic enrichment is not considered detrimental in this case because the proportion of sensitive invertebrates increased as well as the tolerant ones (4.11).

The results for the number of invertebrates in the river are summarized in the following Table. Complete species lists are in Table 4.2.12.

	Number of Invertebrates (per m^2) in the Fraser River Near Prince George				
	Sample Site refers to distance upstream (-) or downstream from Northwood Pulp and Paper outfall (see Figure 4.1.2) in km				
Year	**-1.0**	**0.0**	**4.7**	**4.9**	**5.6**
1989	1763	1709	1481	1706	26242
1986	1293	961	3472	2340	3491
1984	2881	3854	917	7961	6114
1981	-	162	-	1259	1342
1980	440	1533	638	909	508
1979	917	435	38	1308	720
1978	1493	379	712	1193	942
1977	1364	1879	292	398	373
1976	382	482	138	369	-
1975	312	-	21	71	32
1974	6	-	-	55	-
1973	35	-	-	360	-
1972	316	-	-	-	-

The 1972-1981 data indicate that the Prince George Pulp and Paper effluent diffuser significantly increased the overall population density at sampling stations downstream. Samples taken in 1984 had higher population densities than any other year, but they may have been be due to low river flows and/or the change in sample screen size, not organic enrichment.

In 1986, the lowest invertebrate population was found at station 0.0, directly downstream from the Northwood effluent outflow, while the highest population was found at station 4.7, directly upstream from the Prince George Pulp and Paper mill effluent outflow. When sampler contents, current velocities and tolerance categories were reviewed, however, it was found that the low density at station 0.0 could not be explained solely on effects from the Northwood effluent (4.8).

Population densities between stations in 1989 showed no marked differences except that station 5.6 had significantly higher invertebrate populations than the rest. Again, this was due to the low current velocities and sediment accumulation that encouraged a huge increase in oligochaete numbers (4.2).

Although organic enrichment of habitat, caused by Northwood, Prince George and Intercontinental pulp mill effluent, has altered the population density of the invertebrate communities studied, it has not significantly altered the species composition of these communities. However, organic enrichment and population density increases cannot go on indefinitely; habitat degradation could occur at downstream locations if enrichment increases to too high a level (4.11).

Monitoring of invertebrate populations should only be considered if more reliable indices are developed to overcome the variable, ambiguous results. Any new studies should be undertaken under ice cover, during the winter low-flow period when effluent quality is poorest due to the cold weather inhibiting treatment efficiency.

In a review of the data collection techniques used with benthic invertebrates, Environmental Management Associates have recently recommended (4.13) that in order to reliably attribute differences in community structure to effluent effects:

1. physical and chemical habitat variables along with benthic invertebrate sampling should be measured simultaneously,
2. statistically-rare species should be deleted from the analysis,
3. there should be increased replication but smaller samples, and
4. the data should be corrected for habitat variation unrelated to effluents.

In addition, it was recommended that measurements should be made of morphological deformities and contaminant levels in tissues of benthic insects (4.13).

4.2.4 **Northwood Pulp - Prince George Spiragester** (PE 112)

Northwood Pulp has a permit for the discharge of treated domestic waste water. The sewage is treated in a spiragester-type secondary treatment process prior to discharge to a slough of the Fraser River (Figure 4.1.2). The spiragester is a huge Imhoff cone that acts to separate solids and aerate the sewage. Treatment is largely anaerobic. The maximum retention time is 11 hours, prior to discharge through a 20-cm diameter pipe which empties over an embankment into a slough tributary to the Fraser River.

Permit PE 112 allows the discharge of a maximum 145 m^3/d of treated effluent, with maximum concentrations of 60 mg/L suspended solids, and 45 mg/L BOD_5. The data for the discharge are summarized in Table 4.2.2. All maximum reported values were well below those permitted.

It is likely that with minimal flushing of the slough, the small volume, and high quality of the discharge, there is no problem with the discharge. However, some monitoring for dissolved oxygen concentrations should be undertaken in the slough area to ensure that the discharge is not causing a problem.

4.2.5 **City of Prince George** (PE 3868)

This sewage treatment facility is used to treat municipal-type waste water generated from the Prince George Airport, two schools, a mobile home park, and a number of scattered residences. The facility is located about three kilometres upstream from the Nechako River confluence on the east side of the river (Figure 4.1.2).

Treatment of the waste water is provided by a two-cell mechanically aerated lagoon system. The first cell has a five-day design retention period, while the second cell has a 15-day design retention period. Chlorination facilities and a chlorine contact tank are not used. Discharge to the Fraser River is through a submerged outfall located at a depth of about three metres below the low water level, and at a distance of about 25 m from the shore.

Waste Management permit PE 3868 allows the discharge of 1 375 m^3/d of treated effluent, with maximum concentrations of 60 mg/L suspended solids, and 45 mg/L BOD_5. The effluent data for the lagoon system are summarized as Table 4.2.6. The data indicate that the permit limits have been met consistently.

Based on the 7-day, 10-year low-flow at Shelley of 110 m^3/s, and the maximum permitted discharge rate of 1 375 m^3/d, the effluent would have a 6 900:1 dilution rate, assuming complete mixing. Due to the high quality of the effluent, and the large dilution available, it is not expected that this discharge will be of significant concern to water quality in the Fraser River. This is also the case at the edge of the initial dilution zone where the available dilution may only be 25% of that calculated for the case of complete mixing.

4.2.6 **Prince George Pulp and Intercontinental Pulp and Paper** (PE 3900, PE 76)

Prince George Pulp and Intercontinental Pulp operate a bleached kraft pulp mill and a bleached kraft pulp and paper mill in Prince George, adjacent to one another (Figure 4.1.2). They have utilized a common waste water treatment system and outfall to discharge effluent to the Fraser River since about 1977. As well, effluent from an oil refinery waste treatment system is discharged through the same system.

4.2.6.1 Process Description

CANFOR operates the bleached kraft pulp mills with a production capacity of about 1 500 air dried tonnes per day (ADt/d). Dwernychuk [(4.2)] reported that in 1989, the plant processed an average of about 1 300 (ADt/d) of bleached kraft pulp. The wood furnish consisted of 45% spruce, 45% pine, and 10% balsam fir. The bleaching sequence consisted of chlorine dioxide substitution, oxidative alkaline extraction, chlorine dioxide, alkaline extraction, and chlorine dioxide. A 5% to 10% chlorine dioxide substitution rate was used until July 1991 when the minimum substitution rate increased to 70% (usually is 100%) [(4.16)].

Waste water from the operations is treated separately at each mill for fibre removal in two mechanical clarifiers (each 55 m in diameter), one clarifier at each mill. At the Intercontinental mill, the fibrous stream consists mainly of waste water from the machine room. At the Prince George Pulp and Paper mill, the fibrous stream consists mainly of waste water from the machine room and the screen room. The sludge from each clarifier is dewatered in a filter press with the decant returned to the clarifier.

The non-fibrous toxic wastes at each plant consist mainly of contaminated evaporator condensate, turpentine decanter underflow, power boiler sluicing water, causticizing and kiln area effluent, and contaminated digester and washer effluent. These are sent to the toxic spill ponds (68 000 m^3 capacity at the Intercontinental mill and 53 000 m^3 capacity at the Prince George mill). The toxic spill pond at the Prince George mill is preceded by two parallel 3 785 m^3 capacity settling ponds, operated on an alternating basis. The effluents from the toxic spill ponds are treated in separate aerated biobasins, with capacities of 101 000 m^3 (with an associated 9 085 m^3 stilling zone) at Intercontinental and 74 200 m^3 (with an associated 13 625 m^3 stilling zone) at Prince George Pulp and Paper. The effluents from the biobasins are sent to the common 30 280 m^3 settling pond and then to the 927 420 m^3 aeration lagoon with a retention time of about four days.

Treated waste water from an oil refinery (Husky Oil) located just north from the pulp mills is sent to the Intercontinental toxic spill pond for subsequent treatment. The discharge to the river is through a 120-cm diameter header pipe which is supported by three piers and extends about one-half the width of the river. At each pier a 35-cm diameter pipe goes down into the river, where there are two nozzles per pipe from which the effluent is discharged.

When the toxic spill ponds are dredged, the sludges are dewatered, with the decant being returned to the toxic spill ponds, and the solids being landfilled on-site. Sludge dewatering takes place in shallow lagoons located adjacent to the toxic spill ponds.

Waste Management permit PE 3900 allows the discharge of a maximum 240 000 m^3/d (215 000 m^3/d monthly average), with pH in the range from 6.5 to 8.0, and a maximum temperature of 38 ^oC. The 96-hour LC50 is to be $\geq$ 100% on both a daily and monthly average basis. The maximum daily and monthly average BOD_5 and suspended solids are to be less than the following:

(F) * (PRODUCTION {ADt}/EFF) * (1 000) mg/L

where: F = 11.25 for the monthly SS

= 18.75 for maximum SS

= 7.5 for maximum BOD_5

=7.5 for average BOD_5

EFF = 90th %ile discharge rate for average values

The maximum daily and average monthly AOX values are to be less than the following:

(F) * (kg AOX/ADt) * (CBPROD/EFF) * (1 000) mg/L

Where: F = 2.5 for monthly average

F = 3.8 for maximum daily

CBPROD = 90 th %ile of daily production using chlorine or chlorine compound

Domestic sewage is treated in two lagoons. Waste Management permit PE 76 allows the discharge of 432 m^3/d, with maximum concentrations of 100 mg/L suspended solids, and 100 mg/L BOD_5. Semi-annual samples collected by the company (n=13) since 1985 have had the following values:

Variable	Maximum	Minimum	Mean L	Standard Deviation
BOD_5 (mg/L)	24	5	12	5
Suspended Solids (mg/L)	32	2	15.8	8.7
Fecal Coliforms (#/100 mL)	23 000	8	240 (median)	-

The data indicate that the lagoons are providing a high level of treatment. Based on a seven-day, 10-year low-flow of 110 m^3/s at Shelley, the effluent at the maximum discharge rate would be diluted by a factor of 22 000:1, assuming complete mixing of the effluent with the river water. Thus, with this good quality effluent receiving such large dilution, even at low flows (and at the edge of the initial dilution zone where the available dilution may only be 25% of that calculated here), impacts would not be expected in the river due to this discharge of treated domestic waste water.

4.2.6.2 Effluent Quality

A summary of the effluent data for PE 3900 is included as Tables 4.2.7 to 4.2.9. The pH of the effluent is about neutral, with a mean value of about 6.9 (Table 4.2.7).

Average monthly flows for the operation from 1985 to 1993 are summarized in Table 4.2.9. There does not appear to be a trend on a monthly basis or through the years. In recent years, the loading of suspended solids in the effluent has been from 5470 kg/d (March 1993) to 15 269 kg/d (March 1992) (Table 4.2.9). With a ten-year, seven-day low-flow of 110 m^3/s at Stoner and the range of recent loadings, the increase in suspended solids could potentially be from 0.6 to 1.6 mg/L after complete mixing. This assumes that the loading rates apply at a time of extreme low-flow. If this were the case, it may be expected that the increase at the edge of the initial dilution zone where only about 25% of the river flow was available for dilution, would be in the order of 6.4 mg/L. If the maximum recorded mean daily suspended solids loading of 16 890 kg/d (March 1987) is taken into account (Table 4.2.9), the maximum possible increase with complete mixing in suspended solids is calculated to be 1.8 mg/L, or 7.2 mg/L at the edge of the initial dilution zone. There does not appear to be a trend of suspended solids loadings either on a monthly basis or through the years. The Ministry of Environment has established water quality criteria [(6.13)] which allow the incremental suspended solids concentration to be increased by 10 mg/L, a value which potentially does not appear to be exceeded.

The BOD_5 ranged from 12 to 133 mg/L in the effluent (Table 4.2.7). The potential increase in BOD_5 for seven-day low-flows with a 10-year return period would be from 0.3 to 3.4 mg/L. Using the maximum recorded mean monthly BOD_5 loading (Table 4.2.9), the maximum calculated increase could be 1.9 mg/L, or 7.6 mg/L at the edge of the initial dilution zone. There does not appear to be a trend in BOD_5 loadings on a monthly basis since 1988.

Dissolved oxygen concentrations in the effluent are also summarized in Table 4.2.9. Dissolved oxygen concentrations on a mean monthly basis have been as high as 7.4 mg/L (September 1990) and as low as 3.3 mg/L (June and July, 1985). The year with the highest mean monthly dissolved oxygen concentration was 1990; however, 1990 also had the lowest mean monthly discharge rate, which would result in a longer retention time in the treatment facility and more effective treatment. Conversely, the years with the highest discharges (1985, 1987-1989) had the lowest retention time and had the lowest dissolved oxygen concentrations (4.7 - 5.0 mg/L).

Toxicity of the effluent has been reduced so that all 96 hour LC50 values since 1989 have been >100%, considered to be non-toxic (4.16).

Data for a number of resin acids in effluent were collected on occasion. The maximum concentrations (Table 4.2.7) of the seven resin acids were as follows: abietic, 0.21 mg/L; dehydroabietic, 0.57 mg/L; isopimaric, 0.29 mg/L; levo pimaric, 0.16 mg/L; neoabietic, 0.081 mg/L; pimaric, 0.19 mg/L; and sandaraco pimaric, 0.026 mg/L. Using the 40:1 dilution ratio, the maximum increase would be 15 µg/L of dehydroabietic acid. If all the maximum concentrations occurred on the same day, the total resin acid concentration would increase by 39 µg/L. These could be in the order of 58 µg/L dehydroabietic acid and 155 µg/L total resin acids at the edge of the initial dilution zone.

Ministry data for resin acids in the effluent have been collected since 1989. Concentrations appear to have decreased from 1989 levels to about 2.0 mg/L since 1989, although the data base is too short to determine any firm conclusions in that regard. Information on loadings of resin acids for the period 1990 to 1993 show that the mean loadings were 255 kg/d, 190 kg/d, 251 kg/d, and 271 kg/d, respectively, according to data provided through the Fraser River Action Plan (4.15).

Nevertheless, if the maximum resin acid concentration in effluent (8.57 mg/L in February 1989) were to be discharged to the river under one-in-10-year low-flow conditions, the resin acid concentration in the river would be calculated to increase by 165 µg/L. Criteria to protect freshwater aquatic life (4.5) from resin acids are as follows: 8 µg/L dehydroabietic acid at pH 7.0 or 25 µg/L total resin acids, and 12 µg/L dehydroabietic acid at pH 7.5 or 45 µg/L total resin acids. The calculated resin acid concentration in the river can exceed these criteria under some one-in-10-year low-flow conditions. The criterion of 45 µg/L would almost be exceeded (calculated value of 43 µg/L in the river) if the maximum concentration of 2.25 mg/L in the effluent in December 1991 were used in the calculation. It was calculated that the Northwood effluent could increase the resin acid concentration in the river by about 22 µg/L under one-in-10-year low-flow conditions. Duncan (6.26) has measured total resin acids at 15 µg/L and dehydroabietic acid at 5 µg/L 20 m downstream from the outfall and at 8 and 5 µg/L 100 m downstream from the outfall on July 12, 1993.

The data indicate that resin acids can approach criteria levels at lower pH values in the river. When the "worst-case" loadings for the Northwood Pulp and Paper plant are taken into account, there could be times when resin acid concentrations might be of concern. It must be recognized that the likelihood that all of these factors (maximum effluent concentrations at both mills, on the same day as the maximum discharge rate took place, to coincide with extreme low flows in the river) would occur at the same time is very small; however, the possibility of chronic effects being present should be investigated.

Data for only two chlorophenols were reported for this effluent on one occasion. The concentrations of 0.07 mg/L pentachlorophenol and 0.0051 mg/L tetrachlorophenol (Table 4.2.7), could increase river concentrations by 1.3 µg/L pentachlorophenol and 0.1 µg/L tetrachlorophenol. Data reported for a composite sample of the effluent collected November 22, 1993 showed most chlorophenolic congeners to be below detection (<0.00005 mg/L) except for 2,4-Dichlorophenol which had a concentration of 0.00012 mg/L, according to data provided through the Fraser River Action Plan (4.15).

Draft criteria of the Ministry of Environment, Lands, and Parks for chlorophenols to protect aquatic life are expressed as isomers for each congener(4.4). For example, the most sensitive criterion for tetrachlorophenol (TTCP) is 0.04 µg/L 2,3,4,5-TTCP at pH < 7.5. This was exceeded by the calculated maximum concentration for TTCP. For pentachlorophenol (PCP), the criterion to protect aquatic life in the pH range from 6.9 to 7.9 is 0.10 µg/L, which was easily exceeded by the calculated maximum concentration. It should be stressed that it is not known if any of the chlorophenols were present as the most toxic isomer; however, this is one underlying assumption in these calculations. Only with the measurement of the actual isomers in the effluent will a proper calculation be possible.

Values for AOX (Table 4.2.9) appear to be decreasing considerably since August 1991, while yearly loadings have decreased yearly at both mills since 1989 (Table 4.2.10). This decreasing trend in loadings continued in 1992 and 1993, when loadings were 1080 kg/d and 984 kg/d, respectively, according to data provided through the Fraser River Action Plan (4.15). It was estimated earlier that the Northwood effluent could increase the AOX concentrations by 0.69 mg/L under one-in-10-year low-flow conditions. The CANFOR effluent, based on the maximum monthly AOX concentration during 1990 and 1991, and the one-in-10-year low-flow conditions, could potentially increase the river concentrations by an additional 0.74 mg/L, for a total possible increase of 1.43 mg/L.

Data for dioxins and furans in the effluent are summarized as Table 4.2.8. The TEQ values in the effluent have been as high 204.5 pg/L, and as low as 15 pg/L. Based on the minimum dilution 40:1, the calculated increase in the TEQ in the Fraser River due to this discharge would be 5.1 pg/L. TEQ concentrations in the river were determined to potentially increase by about 0.5 pg/L during extreme low-flow (about 2 pg/L at the edge of the initial dilution zone) conditions from discharges from the Northwood operation. Singleton has proposed a water quality criterion of 0.15 pg/L of TEQ in ambient water (6.22). Thus, the two discharges may increase the TEQ values above the proposed criterion and could be a concern for aquatic life in the river. The data base for dioxins and furans is small, and may not be truly representative of the potential impact of the discharges over time. The 1993 sample reported through the Fraser River Action Plan had a TEQ of 7.45 pg/L as calculated by B.C. Environment, or 2.043 pg/L as calculated by Environment Canada(4.15).

Dwernychuk (4.3) <u>et al.</u> reported data for one composite sample collected June 11, 1990, as follows:

Compound	Concentration
AOX	25 000 µg/L
2,4,6-trichlorophenol	4.3 µg/L
2,3,4,6-tetrachlorophenol	1.7 µg/L
pentachlorophenol	0.9 µg/L
tetrachloroguaiacol	0.5 µg/L
3,4,5-trichlorocatecol	19 µg/L
tetrachlorocatecol	35 µg/L
2,3,7,8-tetrachlorodibenzofuran	270 pg/L
total tetrachlorodibenzofuran	500 pg/L
2,3,7,8-tetrachlorodibenzodioxin	110 pg/L
total octachlorodibenzodioxin	1400 pg/L

The coincident flow in the Fraser River at Shelley on that day was 2710 m^3/s. Using the average flow rate of 145 107 m^3/d (Table 4.2.9), the available dilution to the effluent was about 1 600:1. Therefore, increases in river concentrations which might be measurable under these flow conditions are calculated to be 15.6 µg/L AOX (62.4 µg/L at the edge of the initial dilution zone), 0.17 pg/L 2,3,7,8-TCDF (0.68 pg/L at the edge of the initial dilution zone), 0.07 pg/L 2,3,7,8-TCDD (0.28 pg/L at the edge of the initial dilution zone), and 0.88 pg/L total octachlorodibenzodioxin (3.52 pg/L at the edge of the initial dilution zone). Thus the increase in concentration of 2,3,7,8-TCDD at the edge of the initial dilution zone would increase above the criterion of 0.15 pg/L for filtered water samples [6.22]. Obviously, if these concentrations were released at times when flows were lower, the potential impact would be greater.

4.2.6.3 Impact of Effluent on the Fraser River

The impacts of this discharge on Fraser River sediments, fish, and benthic invertebrates has been discussed in Section 4.2.3.3.

4.2.7 **B.C. Chemicals Limited** (PE 190)

B.C. Chemicals operates a sodium chlorate plant, and a crude tall oil acidulation and depitching plant adjacent to the Prince George and Intercontinental pulp mill complex at Prince George, just upstream from the Nechako River confluence (Figure 4.1.2). Waste water discharges from the plant consist of uncontaminated cooling water from the sodium chlorate plant. The once-through water is used to cool the electrolytic cells.

Waste Management permit PE 190 allows the discharge of a maximum of 6 500 m^3/d of effluent, at a maximum temperature of 35 ^oC, and with a 96-h LC10 of $\geq$ 100%, considered to be non-acutely toxic.

4.2.8 **FMC of Canada Limited** (PE 9033)

FMC began to operate a hydrogen peroxide manufacturing plant adjacent to the Intercontinental Pulp mill in 1990 (Figure 4.1.2). The plant has a production capacity of up to 88 000 kg/d of hydrogen peroxide. Steam and water for the process are provided by the Intercontinental plant, while hydrogen is provided by B.C. Chemicals. Hydroquinone is formed in the presence of hydrogen, palladium, and spent work solution. This new solution is filtered to remove the palladium, and then piped to an oxidation tower where atmospheric oxygen reacts with hydrogen in the hydroquinone to form hydrogen peroxide. The hydroquinone is converted to quinone which remains in the recycled solvents. Work solution loaded with peroxide is piped to the bottom of an extractor, to which deionized water is added at the top. The peroxide passes into the aqueous phase at this point, and is then concentrated with distillation. Peroxide solution is cooled and stabilized using elements such as tin.

Waste water is generated from four sources: once-through cooling water, cooling tower blowdown, process waste water which is pre-treated in an oil separator and pond, and safety water used to flush the peroxide sewer system and prevent the build-up of peroxide. The waste water is treated in two parallel 9 460 m^3 equalization ponds, with discharge through a submerged outfall into the Fraser River.

Waste Management permit PE 9033 allows for the discharge of a maximum 7 700 m^3/d of plant effluent (including once-through cooling water), with pH in the range from 6.5 to 8.5, and maximum concentrations as follows: suspended solids of 20 mg/L, residual chlorine of 0.1 mg/L, hydrogen peroxide of 50 mg/L, total organic carbon of 35 mg/L, and temperature of 30 ^{o}C. In addition, the 96 h-LC50 is to be $\geq$ 100%.

The data for the operation are summarized in Table 4.2.11. All values were below the permit limits, except for hydrogen peroxide in June and July 1990, just after plant start-up. All hydrogen peroxide values during 1991 were within the permit limits. At the maximum permitted discharge rate of 7 700 m^3/d, and at the 10-year, 7-day low-flow as reported at Shelley, the effluent would be diluted a minimum of 1 234:1 with complete mixing.

Through the Fraser River Action Plan, a preliminary assessment of the FMC operation took place at the end of 1993 (4.15). Samples were collected on November 3, 1993 and February 14, 1994. Loadings (kg/d) to the river were also summarized (4.15), and those for hydrogen peroxide are presented below:

Variable	Year	Number of Values	Maximum (kg/d	Minimum (kg/d	Mean (kg/d	Standard Deviation
H_2O_2	1990	174	325	3.7	98.5	68.0
	1991	343	345	0.0	66.9	67.6
	1992	362	217	0.0	25.0	36.0
	1993	241	101	0.0	17.1	21.3

These data illustrate that there has been a significant reduction in the loading to the river since the plant began operating, while mean yearly flow rates have increased from 2400 m^3/d in 1990 to 3515 m^3/d in 1991 to 4375 m^3/d in 1992 to 4765 m^3/d in 1993 (4.15). The minimum dilution available to the discharge in 1993 was about 2000:1. Thus, with this good quality effluent and high dilution rate, this effluent should not be a concern in the river.

4.3 Fraser River from Nechako River Confluence to Hope

4.3.1 **B. C. Buildings Corporation** (PE 1763)

B. C. Buildings Corporation operates the Prince George Regional Correctional Centre on the east side of the Fraser River and south from the Prince George city centre (Figure 4.1.2). Sewage is generated in the kitchen, bath, toilet, and laundry facilities at the Centre. The sewage from this facility was diverted to the City of Prince George Lansdowne STP (PE 146).

The waste water is treated in an extended aeration package plant with two aeration tanks which can be operated in parallel. However, since flows are well below design, one tank is used for sludge digestion. The treated waste water is discharged after chlorination to the Fraser River through a submerged outfall at a depth of 0.5 m below low water.

Waste Management permit PE 1763 allows for the discharge of a maximum of 31.5 m^3/d, with maximum concentrations of 45 mg/L BOD_5 and 60 mg/L suspended solids. Data for this operation are summarized in Table 4.3.1. The data indicate that the effluent quality has exceeded permit conditions. However, at maximum permitted flows and the 10-year 7-day low-flow, the dilution available for this discharge is over 330 000:1 with complete mixing. Therefore, there should not be any noticeable impact from this discharge, even at the edge of the initial dilution zone.

4.3.2 **City of Prince George-BCR Industrial Park** (PE 5132)

The City of Prince George operates a sewage treatment plant located on the south and east sides of the Fraser River in the BCR Industrial area of Prince George (Figure 4.1.2).

The plant receives waste water generated by the numerous businesses in the 50-ha area. Waste water is treated in two mechanically aerated stabilization lagoons operated in series, with a design capacity of 936 m^3/d. At the design flow rate, the retention times in each cell are 5 and 15 days, respectively. The treated waste water is discharged to the Fraser River through a submerged outfall.

Waste Management permit PE 5132 allows for the discharge of a maximum of 1 400 m^3/d, with maximum concentrations of 100 mg/L for each of suspended solids and BOD_5. Effluent data are summarized in Table 4.3.2. The data indicate that the recorded average monthly flows and the concentrations of suspended solids, and BOD_5 were always well below the permit levels. This is based on a very limited data base; however, the majority of the data are for 1989 to 1991. The average monthly flows are slightly misleading as presented in Table 4.3.2, inasmuch as the maximum daily flow between 1989 and 1991 was 701 m^3/d, while the minimum flow was 42 m^3/d, still well within the permit limit.

Using the seven-day low-flow (ten-year return period) of 122 m^3/s for the Fraser River as an estimate for this site, as well as the maximum permitted discharge rate, the minimum available dilution to the effluent would be about 7 500:1, assuming complete mixing and the maximum permitted discharge and the ten-year, 7-day low-flow for the river. This large amount of dilution, in combination with the high quality effluent, will ensure that there is not an appreciable impact on the Fraser River water quality, even at the edge of the initial dilution zone.

4.3.3 **City of Prince George** (PE 146)

The City of Prince George operates this secondary treatment plant which handles the majority of the municipal-type waste water generated within the City. It is located in the southern area of the City, and on the west side of the Fraser River (Figure 4.1.2).

The treatment plant consists of two primary clarifiers, a secondary treatment module, and a submerged diffuser in the Fraser River. The plant is to be operated in such a manner that all sewage receives at least primary treatment, but when flows begin to threaten the efficient operation of the secondary treatment facilities, excess primary-treated flows bypass the secondary treatment module, and are combined with the secondary-treated waste water prior to discharge to the Fraser River.

4.3.3.1 Effluent Quality

Waste Management permit PE 146 allows the discharge of a maximum of 45 000 m^3/d, with maximum concentrations of 65 mg/L BOD_5 and 50 mg/L suspended solids. A data summary for the effluent is in Table 4.3.3. The data indicate that suspended solids, BOD_5, and flows have been within the permit limits.

Some very high fecal coliform concentrations have been reported for the effluent; as high as 1 685 000 CFU/cL (Table 4.3.3). Using the seven-day low-flow (ten-year return period) of 122 m^3/s for the Fraser River as an estimate for this site, as well as the maximum permitted discharge rate, the minimum available dilution to the effluent would be 235:1. With this dilution, the calculated potential increase in fecal coliforms in the Fraser River would be 7 171 CFU/cL, or as high as 28 000 CFU/cL at the edge of the initial dilution zone. This could be a concern to downstream water users. The median fecal coliform value of 240 000 CFU/cL would increase concentrations by over 1 000 CFU/cL with complete mixing or by over 4 000 CFU/cL at the edge of the initial dilution zone, assuming the heterogeneous coliforms are mixed evenly, also a potential concern for downstream water users.

The maximum concentrations of ammonia and nitrite reported for the effluent were 31.4 mg/L and 7.78 mg/L (Table 4.3.3). Under the minimal dilution calculated above, the calculated maximum increases in concentrations would be 0.07 mg/L of ammonia and 0.017 mg/L nitrite, or 0.28 mg/L and 0.068 mg/L, respectively, at the edge of the initial dilution zone. These calculated potential increases with complete mixing represent, in the case of ammonia nitrogen, about one-eighth the criterion for the 30-day average concentration listed in Table 4.3.5 at high pH (8.3) and temperatures of about 17 ^{o} C. For nitrite, the calculated potential increase is nearly the allowable 30-day average concentration (Table 4.3.5) when chloride concentrations are <2 mg/L. (In later sections of this report, it will be shown that Fraser River chloride concentrations of chloride can reach 11 mg/L at times, and the pH as high as 8.3.) The maximum chloride concentration in the effluent of 121 mg/L is calculated to increase the river concentration by only 0.51 mg/L under these low-flow conditions.

4.3.3.2 Impact of the Discharge

The City of Prince George has conducted three studies, two during 1987 and one during 1991, following the installation of a 20-port diffuser. The results are reported below for fecal coliforms for the surveys of April 22, 1987, September 16, 1987, and November 13, 1991, respectively:

Sample	400 m u/s PE 146		200 m u/s PE 146		400 m d/s PE 146		1.6 km d/s PE 146		8 km d/s PE 146		16 km d/s PE 146		20 km d/s PE 146	
Date	E	W	E	W	E	W	E	W	E	W	E	W	E	W
Ap. 22/87	10	<2	20	2	100	Grtr 2400	8	Grtr 2400	14	1500	20	60	-	-
Sept 16/87	130	5	13	5	540	49	540	11	540	130	920	79	350	540
Nov 13/91 (Diffuser)	6	12	17	18	7	250	16	390	12	45	120	49	250	120

Grtr= greater than

The data indicate that prior to the installation of the diffuser, the effects of the discharge could be seen as far downstream as twenty kilometres. Predicted increases of up to 1 000 CFU/cL at median effluent concentrations and low flows were fairly good, when it is appreciated that the samples were collected long past the time of low flows. The resulting concentrations exceed water quality criteria for drinking water supplies of 100 CFU/cL (6.16). After the installation of the diffuser, high fecal coliforms levels still were measurable although mixing was more rapid.

Ammonia results for the same surveys were as follows:

Sample	100 m u/s Hwy. 97		200 m u/s PE 146		400 m d/s PE 146		1.6 km d/s PE 146		8 km d/s PE 146		16 km d/s PE 146		20 km d/s PE 146	
Date	E	W	E	W	E	W	E	W	E	W	E	W	E	W
Ap. 22/87	-	-	<0.02	<0.02	<0.02	0.29	<0.02	0.25	<0.02	0.06	-	-	-	-
Sept 16/87	0.04	0.04	-	-	0.04	0.19	<0.02	0.04	<0.02	0.05	0.04	<0.02	<0.02	<0.02
Sample	100 m u/s Hwy. 97		200 m u/s PE 146		400 m d/s PE 146		1.6 km d/s PE 146		8 km d/s PE 146		16 km d/s PE 146		20 km d/s PE 146	

Date	E	W	E	W	E	W	E	W	E	W	E	W	E	W
Nov 13/91 (Diffuser)	<005	<005	<005	<005	0.02	0.028	0.006	0.01	0.01	0.007	<005	<005	0.008	<005

<005=<0.005

The ammonia concentrations were elevated considerably in both the 1987 surveys, with concentrations above those upstream measured as far downstream as 8 km. Compared to a pH of 8.3 and a river temperature of $6^{o}C$ in April, the 0.29 mg/L concentration is about one-half the average criterion (Table 4.3.5). However, with the installation of the diffuser, the data for 1991 indicate that ammonia concentrations are considerably lower, although still elevated above background.

Dissolved oxygen results for the same surveys were as follows:

Sample	100 m u/s Hwy. 97		200 m u/s PE 146		400 m d/s PE 146		1.6 km d/s PE 146		8 km d/s PE 146		16 km d/s PE 146		20 km d/s PE 146	
Date	E	W	E	W	E	W	E	W	E	W	E	W	E	W
Ap. 22/87	11.7	11.7	11.8	11.7	11.8	11.7	11.4	11.6	11.7	11.6	12.2	11.6	-	-
Sept 16/87	10.0	10.2	10.4	10.2	10.0	10.0	10.1	9.9	10.0	10.1	10.2	10.3	10.1	10.2
Nov 13/91 (Diffuser)	13.3	13.5	13.7	13.4	13.5	13.5	13.3	13.4	13.6	13.6	13.3	13.7	13.6	13.7

The data for dissolved oxygen show that even prior to the installation of the diffuser, dissolved oxygen concentrations were not being affected by the discharge.

4.3.4 **Northwood Pulp and Timber Limited** (PR 4824)

Northwood Pulp and Timber Limited operates a veneer/plywood/stud mill within the BCR Industrial site in the south of Prince George, and to the east of the Fraser River (Figure 4.1.2). The mill's log yard parallels the Fraser River, at distances from 100 to 350 m, and about 14 m higher in elevation than the river. The only waste under permit and associated with this operation is refuse consisting of broken logs, burner ash, bark, and dirt, and miscellaneous wood. It is disposed of in a 1.5 ha refuse site.

Waste Management permit PR 4824 allows the discharge of 2600 m^3/a (50 m^3/week) of material to the landfill. Due to the nature and small volume of material, and the distance of the landfill to the Fraser River, it is not expected that there will be an impact on the river.

4.3.5 **Netherlands Overseas Mills** (PR 5002)

This company operates a log yard, sawmill, and planer mill about 4.5 km south from Prince George, on the east side of the Fraser River (Figure 4.1.2). Waste from the operation consists of broken logs, bark, chips, and inorganic material.

Waste Management permit PR 5002 allows the discharge of 15.3 m^3/d of refuse to a landfill (3.8 ha), which is located about 225 m from the Fraser River. Due to the nature and small volume of material, and the distance of the landfill to the Fraser River, it is not expected that there will be an impact on the river.

4.3.6 **Woodland Lumber Ltd.** (PR 7915)

This company operates a log yard and sawmill which supplies the Woodland Window operation. It is located just south from the Netherlands operation (Section 4.3.5), on the east side of the Fraser River (Figure 4.1.2), about 500 m from the river. Waste from the operation consists of broken logs, bark, chips, and inorganic material.

Waste Management permit PR 7915 allows the disposal of 3 120 m^3/a (60 m^3/week) to the landfill. Due to the nature and small volume of material, and the distance of the landfill to the Fraser River, it is not expected that there will be an impact on the river.

4.3.7 **City of Prince George**-Danson Lagoons (PE 4905)

The City of Prince George operates a lagoon system located south from the City and to the east from the Fraser River (Figure 4.1.2). The lagoons treat municipal waste water generated from the Danson Industrial Park, located south from the BCR Industrial Park, as well as waste from a trailer park.

Treatment of the municipal waste water is provided by two facultative lagoons, operated in series. The lagoon system is calculated to provide an 89-day retention period at a flow of 178 m^3/d. The influent from the trailer park is pre-treated to secondary treatment levels in a multi-lagoon system. The treated waste water is discharged through a submerged outfall located 1.1 m below the lowest low water mark, to the Fraser River. The effluent is not disinfected.

Waste Management permit PE 4905 allows the discharge of a maximum 1 000 m^3/d of effluent, with maximum concentrations of 100 mg/L each of suspended solids and BOD_5. The permit allows for the eventual addition of aerators to the lagoon system.

The data for the discharge are summarized as Table 4.3.7. The reported data for all regulated variables indicate that the permit limits have consistently been achieved. Of possible concern are the high concentrations of bacteria in the effluent. Using the seven-day low-flow (ten-year return period) of 122 m^3/s for the Fraser River as an estimate for this site, together with the maximum permitted discharge rate, the minimum available dilution to the effluent would be over 10 000:1. With the maximum fecal coliform of 2 280 000 CFU/cL, the calculated maximum increase in the river would be 228 CFU/cL. At the edge of the initial dilution zone, this could be in the order of 900 CFU/cL. Considering that the highest reported flow is about one-tenth of that allowed by permit, the actual maximum increase would only be about 23 CFU/cL, or about 100 CFU/cL at the edge of the initial dilution zone. Therefore, the discharge of this effluent is unlikely to be noticeable in the Fraser River at most times.

4.3.8 **Prince George Wood Preserving Ltd.** (PR 7093)

Prince George Wood Preserving operates a log storage area and sawmill south from Prince George, and east from the Fraser River (Figure 4.1.2). Waste generated is limited to industrial refuse, consisting of broken logs, bark, dirt, burner ash, and miscellaneous wood. The waste is put in a landfill (about 1.0 ha) which is located about 400 m from the Fraser River.

Waste Management permit PR 7093 allows the discharge of 3600 m^3/a (69 m^3/wk) of refuse to the site. Due to the nature of the refuse and the distance to the Fraser River, it is not anticipated that there will be an impact on the river.

4.3.9 **Rustad Brothers and Co. Ltd** (PR 4718)

Rustad Brothers and Company operated a refuse site on the east side of the Fraser River to which log yard wastes (dirt, wood, cinders) were discharged (Figure 4.1.2). The refuse site was immediately adjacent to the Fraser River. Although the permit (PR 4718) has been cancelled, concern regarding leachates from the site have been expressed by Regional Ministry of Environment personnel, who are monitoring the site.

4.3.10 **Carrier Lumber Ltd.** (PR 7092)

Carrier Lumber operates a sawmill and planer mill complex south from Prince George, and on the east side of the Fraser River (Figure 4.1.1). Waste from the site consists of burner ash (50%), soil (30%), and wood waste (20%). The waste is discharged to a landfill located about 60 m from the Fraser River, and about 50 m above the highest recorded water table.

Waste Management permit PR 7092 allows the discharge of 2300 m^3/a (44 m^3/wk) to the landfill. Due to the nature of the material being landfilled, its volume, and the distance to the river, an impact on the Fraser River is unlikely.

4.3.11 **Rustad Brothers and Co. Ltd-World Wide Storage Ltd.**(PR 4850)

Rustad Brothers and Company operates a sawmill which is located south from Prince George, and on the east side of the Fraser River (Figure 4.1.1). Waste from the site consists of burner ash, soil, sawdust, and wood waste. The waste is discharged to a landfill located about 100 m from the Fraser River.

Waste Management permit PR 4850 allows the disposal of 95 ^{3}/d to the refuse site. It is unlikely that this operation would have an impact on the Fraser River, due to its distance from the river, and the volume of waste products.

4.3.12 **Quesnel River Pulp Company** (PE 5803)

Quesnel River Pulp operates a bleached thermomechanical-chemithermomechanical pulp mill (TMP/CTMP) in Quesnel. The mill began operations in 1981 as a TMP mill, with the CTMP production coming on-line in 1982. The mill produces TMP and CTMP alternately on about two-week cycles. The design production rate is 950 ADt/d.

4.3.12.1 Process Description

Incoming wood chips are washed, steamed, and impregnated with sodium sulphite cooking liquor. The sodium sulphite is manufactured at the plant using caustic and SO_2. The chips are then processed through three lines of primary and secondary refiners. After refining, the pulp is washed and screened, and any rejects are processed in a rejects refiner. TMP is bleached using sodium hydrosulphite, while CTMP is bleached using purchased hydrogen peroxide.

Domestic sewage from the mill itself is mixed with the pulp mill effluent. This comprises a very small percentage of the total flow. Mill waste water is treated in a system which utilizes primary clarification, and anaerobic digestion, followed by aerobic polishing of the effluent. Waste water is divided into two streams. The chip washing effluent, pressates, and cleaner rejects are directed to an 18.3-m diameter gravity clarifier and then to a two-cell 53 000 m^3 lagoon. The remainder of the fibre-bearing streams, including white water and disc filter effluent, is treated in air flotation clarifiers (capacity of 666 m^3 each), followed by pH adjustment in a pre-acidification tank, then treatment in two upflow anaerobic sludge blanket reactors. Finally, this stream also enters the two-cell activated sludge lagoon which has a retention time of 2.9 days. Following treatment in the lagoon, most of the effluent is clarified in another air flotation clarifier and then discharged to the Fraser River through a submerged two-port bottom outfall diffuser. The full scale anaerobic/aerobic treatment plant was brought into operation in October 1988. The post-clarifier came on-line in December 1991 to meet permit requirements for suspended solids discharge to the river. Prior to that time, suspended solids permit limits were applicable following primary treatment.

Waste Management permit PE 5803 allows the discharge of a maximum 28 000 m^3/d at a maximum temperature of 38 ^oC, with pH in the range from 6.5 to 8.5, a toxicity requirement for the 96-hour LC 50 $\geq$ 100%, a maximum BOD_5 loading of 7 125 kg/d, and a maximum suspended solids loading of 8 075 kg/d after primary treatment. After December 1992, the maximum allowable daily and average monthly suspended solids and BOD_5 loadings are to be determined from the following equations:

(F) * (PRODUCTION {ADt}/EFF) * (1 000) mg/L

where: F = 11.25 for the average monthly SS

= 18.75 for maximum SS

= 7.5 for maximum and average BOD_5

EFF = 90th %ile discharge rate of effluent

4.3.12.2 Effluent Quality

To estimate dilution available to effluents in the Quesnel area, the average annual flow of 1 090 m^3/s in the Fraser River at Quesnel for the year 1930, the only year data were available for a complete year, was compared to the average annual flow at Marguerite (1 410 m^3/s). The ratio of these (1 090/1 410) to the seven-day low-flow at Marguerite was determined to be 179 m^3/s.

Data for the effluent are summarized as Table 4.3.8, with more detailed data summaries in Table 4.3.9. The highest recorded daily effluent flow with coincident low river flow was in February 1991, when an effluent flow of 24 429 m^3/d was reported. If this flow was released during low-flow conditions, the available dilution (assuming a river flow of 179 m^3/s and complete mixing) would be 633:1. However, it should be noted that within 100 metres downstream from the outfall, the effluent from the mill does not become well mixed, and there is evidence that it remains near the eastern shore of the Fraser River (see Section 4.3.12.3).

The coincident suspended solids loading of 10 701 kg/d would have resulted in an increase of 0.7 mg/L, assuming complete mixing of the effluent with the river water. Actual increases downstream from the diffuser could even be greater if the effluent is not well mixed. The allowable suspended solids loading to the river for the period from

October 1988 to December 1992 was 8 075 kg/d, this was exceeded during six months of 1990, five months of 1990, eight months of 1989, and in all but one of the ten reported months in 1988. Suspended solids loadings fluctuate on a yearly basis (Table 4.3.9), with 1992 and 1993 mean daily loadings of 9763 kg/d and 7828 kg/d, respectively, according to data provided through the Fraser River Action Plan (4.15).

The effluent containing 1.4 mg/L of dissolved oxygen would have resulted in a decrease in dissolved oxygen concentration in the river of only 0.01 mg/L, assuming complete mixing of the effluent and the river water. No dissolved oxygen sags have been reported. The allowable BOD_5 loading of 7 125 kg/d was exceeded during six of the months in 1991, one of the months in 1990, and in four of the months in 1989. The discharge BOD_5 loading was reduced by about 50% in 1988 with the completion and bringing into operation of the anaerobic/aerobic treatment system. Mean daily loadings in 1992 and 1993 were the lowest on record, with mean daily loadings of 3494 kg/d and 2697 kg/d, respectively, according to data provided through the Fraser River Action Plan (4.15).

The pH values in the effluent have usually been within the permitted range from 6.5 to 8.5, and effluent temperatures have usually been at or below the maximum permitted $38^{o}C$.

The variability in the effluent toxicity is reflected in the data in Table 4.3.9. Improved effluent toxicity has been apparent, with considerably better toxicity results since 1988. Again, this coincides with the anaerobic/aerobic treatment system becoming operational in October 1988. Toxicity results have improved dramatically with only one failure in 1992 and with all LC50 values being greater than 100% in 1993 and to June 1994.

True colour ranged from 440 to 1500 units in the effluent. Given the low-flow dilution of 633:1, the effluent would increase the colour in the river by 0.7 to 2.8 true colour units.

It is calculated that the maximum ammonia concentration of 1.54 mg/L could increase ammonia concentrations in the river by 2.3 µg/L. The maximum recorded total phosphorus concentration in the effluent could increase total phosphorus concentrations in the river by 0.27 mg/L, assuming complete mixing of the effluent with the river.

The effluent loading of resin acids in 1990, 1991, and 1992 were 38.7 kg/d, 76.9 kg/d, and 21.7 kg/d, respectively, according to data provided through the Fraser River Action Plan (4.15). Values measured in three effluent grab samples (4.15) collected on November 1, 1993 were as follows:

Resin Acid (mg/L)	**Sample 1 (0:00)**	**Sample 2 (8:00)**	**Sample 3 (16:00)**
Abietic	0.069	0.1	0.11
Arachidic	0.01	0.025	0.021
Behenic	0.046	0.13	0.096
Chlorodehydroabietic	<0.001	<0.001	<0.001
Dehydroabietic	0.13	0.16	0.16
Dichlorodehydroabietic	<0.001	<0.001	<0.001
9,10-dichlorostearic	<0.001	<0.001	<0.001
Isopimaric	0.018	0.025	0.027
Lauric	0.003	0.004	0.003
Levo Pimaric	0.027	0.038	0.037
Lignoceric	0.083	0.22	0.16
Linoleic	0.21	0.75	0.78
Linolenic	<0.001	0.025	0.023
Myristic	0.024	0.039	0.034
Neoabietic	0.008	0.01	0.012
Oleic	0.21	0.51	0.51
Palmitric	0.42	0.69	0.56
Palustric	<0.001	<0.001	<0.001
Pimaric	0.028	0.044	0.05
Sandaraco Pimaric	0.002	0.004	0.005
Stearic	0.044	0.12	0.0093
Total	0.28	0.38	0.40

Criteria to protect freshwater aquatic life (4.5) from resin acids are as follows: 8 µg/L dehydroabietic acid at pH 7.0 or 25 µg/L total resin acids, and 12 µg/L dehydroabietic acid at pH 7.5 or 45 µg/L total resin acids. With a dilution of about 600:1 at the edge of the initial dilution zone, resulting ambient concentrations, assuming these measured values are representative, (4.15) would increase by about 0.27 µg/L dehydroabietic acid and 0.67 µg/L total resin acids. This should not be a concern in the river.

There are limited data on chlorinated organic contaminants in this effluent, as the process is totally chlorine-free. One pentachlorophenol value was 1.1 µg/L, while one tetrachlorophenol value was 3.6 µg/L. If these data are representative of concentrations in this effluent, no noticeable increase would be evident in the Fraser River.

Dwernychuk (4.3) reported data for one composite effluent sample collected May 3, 1990 when the discharge rate was 18 720 m^3/d, contained 18 µg/L AOX and 140 pg/L total octachlorodibenzodioxin. The river flow on the same day was 1 300 m^3/s at Shelley, 2390 m^3/s at Marguerite, and estimated to be about 1 850 m^3/s at Quesnel. These flows would have provided a dilution factor to the effluent of about 8 538:1 at Quesnel. The maximum increase was calculated to be 0.02 pg/L in the water column for total octachlorodibenzodioxin with complete mixing. This is equivalent to 0.17 pg/L, or TEQ of 0.00017 pg/L at the edge of the initial dilution zone. Singleton (6.22) has proposed a water quality objective of a maximum of 0.06 pg TEQ/L in filtered water samples. Thus, the concentration of dioxins at the edge of the initial dilution zone would not have been a concern when sampled.

4.3.12.3 Impact of Effluent on the Fraser River

Dwernychuk (4.7) reported that water quality data collected downstream from the Quesnel River Pulp (QRP) mill diffuser "indicated that there existed a high probability of river channeling along the eastern shore of the Fraser River immediately downstream of the QRP diffuser." At that time, it was not certain that the low volume effluent impinged on this region of the shoreline downstream of the discharge. In order to clarify effluent movement downstream of the QRP diffuser, limited receiving water quality and sodium tracer studies were performed during the 1985 program in conjunction with the invertebrate program. Sodium tracer studies in 1985 did not produce a reliable definition of effluent position in the horizontal/vertical planes of the Fraser system subsequent to effluent discharge from the QRP diffuser. There was a suggestion, however, of effluent near the bank about 600 metres downstream from the outfall (4.7,4.16).

Dwernychuk (4.7) then reported on the impacts of this discharge on the Fraser River during a study in September and October 1987. The discharge from the Quesnel River Pulp mill did not alter surface water temperatures, had no impact on river colour, virtually no effect on river pH, specific conductivity, turbidity, suspended solids, dissolved oxygen percent saturation, sulphate, or chloride. Effects were noted for dissolved sodium and total Kjeldahl nitrogen.

Dwernychuk [4.7] also noted that population densities of benthic invertebrates increased considerably between 1985 and 1987, especially downstream from the Quesnel River Pulp mill diffuser. This may be related to improved effluent quality and river flow velocity changes during this time. With respect to tolerance categories, it was noted that since 1984, these have been relatively stable except for a site about 500 m downstream from the Quesnel River Pulp mill diffuser, which had a decline in sensitive fauna and a slight increase in facultative organisms [4.7].

The slight increase in the number of invertebrate taxa downstream from the diffuser between 1985 and 1987 was attributed to lower river flows between the years [4.7]. "Generally, tolerant fauna comprised an insignificant portion of the populations sampled"[4.7]. The richness of the species in the community was similar from upstream to downstream from the diffuser, although the upstream control site was not as rich in 1987 as in 1985 [4.7]. "No marked variation in equitability/dominance was noted over the study area" in 1987 [4.7]. "There is no indication from the data base suggesting stress in the environment based on community composition and structure"[4.7]. Further discussion of receiving water impacts has been provided in Section 4.2.3.3.

4.3.13 **Cariboo Pulp and Paper** (PE 1152)

Cariboo Pulp and Paper has operated a bleached kraft pulp and paper mill in Quesnel since 1972 (Figures 4.1.1 and 4.1.3). The effluent treatment system for the mill also is used by the City of Quesnel and the Red Bluff area of the Cariboo Regional District for the treatment of their municipal-type waste water. The volume of the municipal-type waste water is about 4 000 m^3/d.

4.3.13.1 Process Description

Cariboo Pulp and Paper operates a bleached kraft pulp mill with a design production capacity of 950 ADt/d. Dwernychuk [4.2] reported that the wood furnish consisted of 45% white spruce, 45% lodgepole pine, and 10% white (balsam) fir. The bleaching sequence consists of chlorine dioxide substitution, oxidative alkaline extraction, hypochlorite (now discontinued), chlorine dioxide, alkaline extraction, and chlorine dioxide. A minimum 45% chlorine dioxide substitution rate is now used.

Within the plant, there is a fibre and chemical spill collection and recovery system. The spill basin is aerated and has a capacity of 65 000 m^3, with a retention time of about sixteen hours at average flow rate. The company added a pressure diffuser washer immediately downstream from the digester in 1989 in an attempt to reduce the soda losses to the sewer. As well, an oxygen delignification system was added to the bleaching stage in 1991 to reduce the amount of chlorine used. This has resulted in an 80% reduction in the amount of elemental chlorine used.

General sewer waste waters are treated in a mechanical clarifier (56 m diameter), which at typical flows of 31 000 m^3/d has an hydraulic loading of 12.6 $m^3/m^2/d$, followed by solids removal on a vacuum filter. Bleach plant waste waters from the bleach plant acid and caustic seal tanks are combined with the general sewer wastes and these are sent to the settling area (30 000 m^3) of a pre-treatment aerated lagoon prior to discharge to the surface aeration area of the lagoon (65 000 m^3 capacity and one day retention). The municipal sewage from the City of Quesnel and the Cariboo Regional District are also treated in the lagoon. Fibres and solids are removed for use as hog fuel.

The flow from the pre-treatment lagoon then goes to a second lagoon with subsurface aeration and a capacity of 416 000 m^3 and a retention time of four days, prior to treatment in a final 370 000 m^3 aeration (surface aerators) lagoon, which provides a nominal retention time of about four days. The treated effluent flows a distance of over two kilometres and discharges through a two-port bottom diffuser into the Fraser River, about one kilometre upstream from the confluence of the Quesnel River. The effluent treatment system was expanded to these capacities in October 1991.

Waste Management permit PE 1152 allows for the discharge of a maximum of 118 200 m^3/d, with pH in the range from 6.5 to 8.5, a maximum temperature of 38 ^oC, a minimum dissolved oxygen of 2.0 mg/L, a 96-h LC50 $\geq$ 100%, and the following for suspended solids, and BOD_5:

(F) * (PRODUCTION {ADt}/EFF) * (1 000) mg/L

where: F = 11.25 for the monthly average SS

= 18.75 for maximum SS

= 7.5 for maximum BOD_5
=7.5 for average BOD_5
EFF = 90th %ile discharge rate for effluent

The maximum daily and average monthly AOX values are to be less than the following:

(F) * (kg AOX/ADt) * (CBPROD/EFF) * (1 000) mg/L
Where: F = 2.5 for monthly average
F = 3.8 for maximum daily
CBPROD = 90 th %ile of daily production using chlorine or chlorine compounds

As well, the permit requires that AOX be reduced to 1.5 kg/ADt by December 31, 1995 and totally eliminated by December 31, 2002. A second chlorine dioxide generator was installed in 1992 to reduce the AOX levels to $\leq$ 1.5 kg/t.

Discharges from a water treatment system to provide fresh water to the pulp mill are to the Quesnel River, and will not be discussed further in this report.

4.3.13.2 Effluent Quality

The effluent data summaries are found in Tables 4.3.10, 4.3.11, and 4.3.12. Effluent discharge rates have increased in each of the years in the period from 1990 to 1992 and then were reduced slightly in 1993 (Table 4.3.12), with a maximum flow of 123 573 m^3/d in July 1992, which is in excess of the maximum permitted flow of 118 200 m^3/d. The minimum dilution available to the effluent with complete mixing and using the seven-day low-flow with a ten-year return period would be 78:1 for river flows measured at Shelley, 165:1 for river flows measured at Marguerite, or an estimated 127:1 based on the ratio of flow between Quesnel and Marguerite. With the immediate input of the Quesnel River just downstream from the Cariboo Pulp discharge, the latter dilution ratio is likely more appropriate for use in calculating potential impacts.

In the two years prior to upgrading the treatment facility, the maximum suspended solids loading to the river was 16 209 kg/d in May 1991, when low-flows would not be present in the river. The highest loadings during low river flows was 15 912 kg/d in March 1991. Based on the dilution ratio of 127:1 available for complete mixing and a loading of about 16 000 kg/d, it is calculated that the suspended solids would have increased by only 1.3 mg/L. At the edge of the initial dilution zone, this increase is likely more in the order of about 5.2 mg/L. This would not be a concern to downstream water users. With improved treatment, loadings have decreased, which would result in even a smaller increase in suspended solids concentrations at low flows as a result of this discharge.

In the two years prior to upgrading the treatment facility, the maximum BOD_5 loading (Table 4.3.12) to the river was 4 165 kg/d in in May 1991 and 4 161 kg/d in January 1990. The minimum dissolved oxygen concentration in the effluent was 0.1 mg/L during eleven months in 1990 and seven months in 1991; however, the treatment system improvements in October 1991 were immediately effective in raising the minimum dissolved oxygen concentration to 3.1 mg/L in November and 2.3 mg/L in December 1991.

The pH of the effluent appears to be becoming more acidic, according to the data in Table 4.3.12. The lowest pH data in the period 1988 to 1993 were found in 1991, with pH values less than 7.0 being recorded each month. Prior to 1991, values less than 7.0 were recorded in four months in 1990. After 1991, the pH appears to be controlled better, with only three months of 1992 with pH less than 7.0, and one month in 1993.

The data summaries in Table 4.3.12 also indicate that the maximum allowable temperature of 38 ^{o}C has been achieved consistently in the period 1988 to 1993, with the maximum recorded temperature being 36 ^{o}C in August 1991.

The variability in the effluent toxicity prior to 1992 is reflected in the data in Table 4.3.12. With the effluent treatment expansion which was completed in October 1991, the acute toxicity was eliminated. If sublethal toxicity is prevented at concentrations of 0.05 of the LC_{50} value, then the lowest toxicity reported of 2% would require a dilution of about 1000:1. This dilution would only be available between May and August when complete mixing of effluent and the river has occurred. At low flows, sub-lethal toxicity may not be prevented in the plume.

Fecal coliforms in the effluent have been as high as 460 000 CFU/cL (Table 4.3.11). The test for fecal coliforms also measures the presence of Klebsiella, which is not of fecal origin but can be present at high levels in pulp mill effluents. This can lead to an unrealistic expectation of fecal contamination hazard. If this level of fecal contamination were discharged under low-flow conditions, it is calculated that river concentrations could increase by 3 538 CFU/cL when fully mixed. This would be a concern to downstream water users. However, the median value of 320 CFU/cL would increase the river concentration by only 3 CFU/cL, which would not be a concern to downstream water users. Increases at the edge of the initial dilution zone would likely be about four times higher.

True colour concentrations in the effluent have been as high as 2 520 units (Table 4.3.10), but this was measured prior to 1991 when the treatment system was expanded. Colour concentrations have decreased on average from about 2 000 units before 1991 to about 1 000 units after 1991 [4.16]. Under conditions of maximum effluent flow and minimum river flow, it is calculated that colour concentrations could increase by as much as 19 units downstream from the discharge with complete mixing before 1991, or about 10 units after 1991. This could be a concern to downstream water users at certain flow regimes.

Ammonia nitrogen concentrations have been as high as 2.18 mg/L in the effluent (Table 4.3.10). With complete mixing of the effluent and the river water under low-flow conditions, it is calculated that an increase of 0.017 mg/L (about 0.068 mg/L at the edge of the initial dilution zone) would be possible. Similarly, the maximum recorded nitrite concentration of 0.048 mg/L could cause an increase in river concentrations of nitrite of only 0.0004 mg/L with complete mixing, or 0.0016 mg/L at the edge of the initial dilution zone. Neither of these possible increases are considered a concern in the river for aquatic life.

Adsorbable organic halides (AOX) measured in the effluent have been as high as 31 mg/L, before 1991. After 1991, AOX has been reduced from about 5 kg/d to about 1 kg/d[4.16]. Under low-flow conditions, it is calculated that concentrations in the river could have increased by 0.24 mg/L with complete mixing before 1991, or by about 0.05 mg/L after 1991. Single penta- and tetrachlorophenol measurements were quite low in the effluent; 0.2 µg/L and 0.5 µg/L, respectively. When mixed with the river water, the resulting concentrations would not be measurable and would meet water quality criteria in the river. None of these increases are likely of concern.

Dioxin and furan data collected during 1991 are summarized in Table 4.3.11. The maximum concentration of 2,3,7,8-T_4CDD was from a composite effluent sample collected January 20, 1991. This sample had the highest TEQ of all the nine samples collected, with 91.4 pg/L. Under low-flow conditions and with complete mixing of the effluent and the river water, the calculated increase in the river concentration would be 0.70 pg/L. This would rise to 2.8 pg/L at the edge of the initial dilution zone. Singleton has proposed a water quality criterion of 0.06 pg TEQ/L (6.22) for filtered water samples, which could mean that there is a concern.

Dwernychuk (4.3) reported data for one composite sample collected May 15, 1990 when the discharge rate was 94 000 m^3/d, as follows:

Compound	Concentration
AOX	29 000 µg/L
2,4,6-trichlorophenol	8.5 µg/L
pentachlorophenol	2.0 µg/L
3,4,5-trichloroguaiacol	38 µg/L
tetrachloroguaiacol	32 µg/L
3,4,5-trichlorocatechol	13 µg/L
tetrachlorocatechol	29 µg/L

There were no dioxins or furans detected in the sample.

The river flow rate on May 15, 1990 at Marguerite was 2 390 m^3/s. Thus, the effluent was discharged into a river flow of about 1 848 m^3/s, which would provide a dilution of 1699:1 with complete mixing. Under these conditions, the aforementioned concentrations would be calculated to increase river concentrations with complete mixing of the effluent and the river (those applicable to the edge of the initial dilution zone are in parenthesis) by 17.1 µg/L (68 µg/L) AOX, 0.022 µg/L (0.088 µg/L) trichloroguaiacol, 0.019 µg/L (0.076 µg/L) trichlorocatechol, 0.018 µg/L (0.072 µg/L) tetrachlorocatechol, 0.005 µg/L (0.02 µg/L) trichlorophenol, and 0.002 µg/L (0.008 µg/L) pentachlorophenol. Only the increase in AOX would have been a concern with complete mixing on May 15, 1990.

4.3.13.3 Impact of Effluent on the Fraser River

Dwernychuk (4.7) provided aerial photographs which illustrated that a definite colour plume existed for the Cariboo mill effluent, and that the plume was not well mixed with the river until the first major bend in the river about 2 500 m downstream from the mill. Colour increased in the river by about 30 units at a distance of about 100 m from the diffuser (4.7).

"In terms of Cariboo effluent, sub-lethality could occur within the plume up to" the Quesnel River confluence, a distance downstream of about 500 metres (4.7). "This region of the river is not considered prime habitat and can be avoided by actively mobile species such as fish"(4.7).

Dwernychuk (4.7) reported that in surveys near the mill in the Fraser River in September and October 1987, there was an increase in water temperature of about 0.5 °C at a distance of about 100 m downstream from the outfall, but that temperatures returned to background further downstream. Other variables for which similar patterns existed included specific conductivity, dissolved sodium, percent dissolved oxygen (which had decreases), ammonia, total Kjeldahl nitrogen, sulphate, and chloride.

Mah et al. (4.1) collected sediments and fish in the spring of 1988 upstream and downstream from pulp mill effluent discharges in the interior of British Columbia. Two of these were the Quesnel River Pulp Company and the Cariboo Pulp and Paper Company which discharge treated effluent to the Fraser River just upstream from the confluence of the Quesnel River.

Dioxins were not detectable (<15 pg/g dry-weight) in any of the three sediment samples collected either upstream or downstream from the Quesnel pulp and paper mills (4.1). There were measurable concentrations of 2,3,7,8-T_4CDF both upstream (50.7, 63.7, and <10 pg/g) and downstream from the Quesnel River Pulp Company discharge (238, 36.6, and 213 pg/g dry-weight) and the Cariboo Pulp and Paper discharge (281, 232, and 176 pg/g dry-weight). Mah et al. (4.1) concluded that "the degree of contamination of bed sediments, at least for this relatively small set of samples, was primarily determined by sample location relative to sources of contamination and was not greatly affected by organic carbon content or particle size of sediments". With respect to the water quality criterion for sediments proposed by Singleton (6.22) of 0.25 pg/g (dry-weight) normalized to 1% organic carbon content, the TEQ values for all these sediments would exceed the criterion.

Fish collected upstream and downstream the Quesnel pulp and paper mills had similar concentrations in muscle when the same species were compared [4.1]. Concentrations of 2,3,7,8-T_4CDD were 25.3 pg/g (wet-weight) in a composite sample composed of seven largescale suckers (Catostomus macrocheilus) collected upstream, compared to a concentration of 20.8 pg/g in a composite sample of seven largescale suckers collected downstream. The 2,3,7,8-T_4CDF concentrations were 392 pg/g and 321 pg/g, respectively [4.1]. As was the case for the Prince George mills, the highest concentrations were in muscle from mountain whitefish (Prosopium williamsoni), with concentrations of 137 pg/g 2,3,7,8-T_4CDD and 1185 pg/g 2,3,7,8-T_4CDF. All of these concentrations except for Mountain Whitefish would meet Singleton's proposed criterion of 50 pg/g (TEQ wet-weight) [6.22].

Dwernychuk et al. [4.3] in an extensive survey of pulp mill effluents, drinking water supplies, sediments, and fish from the headwaters to the Strait of Georgia found that the highest concentrations of organochlorine compounds in sediments tended to be found between Hope and Barnston Island.

Hatfield [4.14] has reported that in comparing data from an October 1992 survey of fish with those from the 1988 and 1990/1991 surveys, "dioxin and furan levels were markedly lower in mountain whitefish and rainbow trout muscle samples". The 1992 survey reflects conditions "after significant process and bleaching modifications were undertaken by the pulpmills to reduce emissions of dioxins, furans, and other organochlorines" [4.14]. This decrease was "attributed to the reduced organochlorine loading by the pulpmills" [4.14].

In 1982, 1984, 1985, 1987, and 1989, benthic invertebrate samples were taken from various sites around the Quesnel River Pulp Company and Cariboo Pulp and Paper Company effluent diffusers on the Fraser River near the City of Quesnel (see Figure 4.1.4). Six tray samplers were set at each of the seven sites. Samples were screened through 180 μm filters and the invertebrates sorted and counted. One site location (QB2A) was moved 20 m upstream in 1984 after exceptionally low invertebrate densities, blamed on high current velocities, were collected there in 1982. In addition, some stations were abandoned in 1989. The results are summarized in the following table.

	Percent Sensitive and Tolerant (in Parentheses) Invertebrates at Sites in the Fraser River Near Quesnel (see Figure 4.1.4)								
Year	**Sample Site**								
	QB1	**QB1A**	**QB2**	**QB2A**	**QB3**	**1**	**3A**	**3B**	**4**
1989	8(92)	2(97)	-	6(93)	5(93)	-	-	5(94)	6(92)
1987	4(95)	15(84)	5(94)	33(66)	4(95)	4(94)	6(93)	11(88)	3(96)
1985	6(93)	7(92)	23(76)	30(70)	6(92)	-	-	-	-
1984	9(91)	-	83(17)	-	4(96)	11(89)	13(87)	61(39)	17(83)
1982	82(18)	-	84(16)	-	40(59)	53(47)	79(21)	50(49)	67(33)
1981	-	-	-	-	-	31(69)	-	66(33)	37(63)
1980	-	-	-	-	-	97(3)	97(3)	98(2)	97(3)
1979	-	-	-	-	-	28(72)	9(88)	16(82)	40(60)
1978	-	-	-	-	-	71(25)	64(24)	-	87(12)
1977	-	-	-	-	-	92(8)	79(7)	-	73(24)
1976	-	-	-	-	-	98(2)	91(9)	-	78(21)
1975	-	-	-	-	-	76(24)	59(33)	-	44(56)
1974	-	-	-	-	-	92(8)	33(64)	-	78(2)
1973	-	-	-	-	-	88(10)	91(3)	-	88(11)
1972	-	-	-	-	-	52(45)	38(5)	-	2(21)

Tolerance indices from the 1982 and 1984 data were compared, showing a major decrease in sensitive fauna at sites QB1 and QB3. Because sensitive invertebrates at the control station (QB1) decreased as well as those at the downstream station (QB3), the decrease is not likely due to this mill effluent (4.10).

When a cluster analysis using Czeckanowski's coefficient was performed on the 1984 data, the station directly downstream from the Quesnel River Pulp Company diffuser had little in common with the other stations; it was joined to the other stations with a coefficient of approximately 0.48. However, station QB1, a control, and station 4, the furthest station downstream, were very closely linked (coefficient of 0.80). This indicates that mill effluent may have been influencing the benthic community composition (4.10).

Samples from 1982 and 1984 showed major population declines between the control station, QB1, and the first station downstream from the Quesnel River Pulp Co. effluent outflow, QB2. In 1982, this decline was blamed on strong water currents at QB2. In 1984, after QB2 was relocated to a more stable spot, the same trend occurred, but this time was blamed on the effluent. Invertebrate populations immediately upstream and downstream from the Cariboo Pulp and Paper Co. are consistent; both sites showing an increase in population between 1982 and 1984.

Species diversity, richness and equitability were all very low at QB2, which means the invertebrate community at this station is very vulnerable to disruption (4.10).

When different aspects of invertebrate community and taxonomy are analyzed and reviewed together, it appears that effluent from the Quesnel River Pulp has adversely affected benthic invertebrates immediately downstream from the diffuser (4.10). However, water chemistry data (pH, color, dissolved oxygen, etc.) from the same time frame show no significant decrease in water chemistry directly caused by the Quesnel River Pulp (4.10). Therefore, negative changes in invertebrate communities near the mill are probably due to a combination of mill effluent, natural variation and/or some other undetermined cause.

Dwernychuk (4.7) summarized information on benthic invertebrates collected in 1987. The station locations are in Figure 4.14. "Cariboo stations (control and experimental) in 1987 have experienced a decline in sensitive and an increase in facultative organisms relative to 1984. In general, the higher facultative percentage was related to the higher Dipteran populations. Relative distribution of tolerance categories since 1972 have fluctuated with no defined trend. Studies in 1987 yielded the lowest composition of sensitive fauna. The transition is not indicative of negative environmental conditions since the control station exhibited a comparable trend." (4.7).

With respect to the number of taxa/species composition, Dwernychuk (4.7) reported that the "Cariboo network of stations have exhibited a general increase in the numbers of taxa since 1984". "Generally, tolerant fauna comprised an insignificant portion of the populations sampled." (4.7) The richness of species in the community near the Cariboo discharge increased between 1984 and 1987, and "was indicative of a variety of taxa being collected from river substrates relative to numbers of individuals actually captured".(4.7) There was no marked variation in equitability/dominance over the study area, and community diversity was relatively constant (4.7).

Data from 1987 indicate that tolerance indices of all stations in the Quesnel area remained relatively stable, except station QB2 which showed a dramatic decrease in sensitive fauna. Percentages of sensitive fauna at QB2 decreased from 83% in 1984 to 23% in 1985 and finally to a low of 5% in 1987. Most stations have experienced a slight decrease in sensitive fauna since 1972, but since the control stations exhibited the same trend it is not necessarily indicative of environmental effects due to the two Quesnel-area mills. However, the drastic decrease of sensitive species at station QB2 cannot go unnoticed.

Using Czeckanowski's coefficient to analyze the 1987 data, two main clusters occurred including stations QB2, QB3, and QB2A (0.7980 level of similarity), and QB1 and QB1A (0.7620). The grouping of the first three stations, which are all immediately downstream from the Quesnel River Pulp diffuser, suggests one or more factors in this area have influenced the structure and dynamics of the invertebrate communities. The stations in the second grouping are both located upstream from the Quesnel River Pulp diffuser. Although mill effluent is suspected to have affected benthic communities downstream from the diffuser, its impacts are not large enough to cause major alterations in the natural community dynamics (4.7).

Population densities at all Quesnel stations in 1987 were relatively high. Stations QB2 and QB2A, which showed significant population decreases in 1984, underwent substantial population increases in 1987. These increases may be due to the low river flows that year; perhaps reduced current velocities and less scouring caused the settling out of a greater proportion of the organic load, thus providing better invertebrate habitats. Another explanation lies with the decreased toxicity of TMP effluent between 1985 and 1987; the improved habitat may have caused increased invertebrate populations [4.7].

Richness, equitability and diversity indices were generally consistent throughout the study area and varied little from other years.

While collecting samples in Quesnel in 1989, large amounts of algae (including diatoms, green algae, bluegreen algae and red algae) were found in dense layers on the tray samplers. No algae were found on the samplers at the Prince George sample sites. In 1989 sensitive invertebrate species decreased in number and facultative ones thrived. This trend may be due to reduced current velocities or due to nutrient loading from upstream, in the form of Prince George's sewage and mill effluent, or runoff from farming and grazing lands [4.2]. Cluster analysis of the 1989 data using Czechanowski's coefficient showed that the highest degree of similarity was found among those stations with close to the same current velocities. Invertebrate population densities at Quesnel in 1989 varied greatly from site to site; for example, the high and low populations were both found at the control stations. Generally, stations with the lowest current velocities had the largest numbers of fauna.

Overall, there is not conclusive evidence that the benthic invertebrate communities around Quesnel are affected by the effluent released by the Quesnel River Pulp Company and the Cariboo Pulp and Paper Company. Station QB2, downstream from the Quesnel River Pulp Co., underwent a rapid decrease in sensitive invertebrate species between 1982 and 1987, low diversity, richness and equitability in 1984, and a population decline between 1982 and 1984. Together, these changes indicate that the benthic invertebrate communities at QB2 are under stress, likely due to mill effluent. However, given the facts that the same trends occurred, to a lesser degree, at other stations including the controls, and also that some of these trends were reduced or eliminated in recent years, no definite conclusions can be drawn at this time. Mill effluent, natural variation or some unknown factor may be affecting invertebrate populations downstream from effluent diffusers, but none can be blamed wholly. Any future benthic studies should be done during the winter when flows are minimal in the river, when treatment efficiencies at the mills are reduced, and when the potential impact on benthic communities will be greatest.

In a review of the data collection techniques used with benthic invertebrates, Environmental Management Associates have recently recommended (4.13) that in order to reliably attribute differences in community structure to effluent effects:

1. physical and chemical habitat variables along with benthic invertebrate sampling should be measured simultaneously,
2. statistically-rare species should be deleted from the analysis,
3. there should be increased replication but smaller samples, and
4. the data should be corrected for habitat variation unrelated to effluents.

In addition, it was recommended that measurements should be made of morphological deformities and contaminant levels in tissues of benthic insects (4.13).

4.3.14 **City of Williams Lake** (PE 255)

The City of Williams Lake operates a sewage lagoon system for the treatment of municipal-type wastewater. The system is located to the north from the City. Treated wastewater is discharged through a pipeline located in the Williams Lake Creek Valley into the Fraser River.

The lagoon system consists of two anaerobic ponds (each with a capacity of 18 000 m^3 and an operating depth of 4.6 m) operated either in parallel or in series, followed by an aerated lagoon (74 500 m^3 capacity and operating depth of 4.6 m) and a final polishing pond (36 300 m^3 capacity and an operating depth of 4.6 m). The detention time at a flow of 3 409 m^3/d in the anaerobic cells is 10.6 days if both cells are used in either series or parallel mode. At the same flow rate, the detention period in the aerated lagoon is 29.3 days, followed by ten days in the polishing cell.

Consideration is presently being given to expand the lagoon system so that wastewater from a proposed fibreboard project could be handled through the same treatment works. The volume of wastewater anticipated is 250 m^3/d.

Waste Management permit PE 255 allows the discharge of 6 820 m^3/d of treated waste water to the Fraser River, with maximum concentrations of 60 mg/L suspended solids and 45 mg/L BOD_5. The effluent is not required to be disinfected.

A summary of the data for the discharge is included as Table 4.3.13. The data indicate that the permit levels for suspended solids were always achieved, and that those for BOD_5 and flow usually were achieved.

Using the seven-day low-flow (with a 10 year return period) for the Fraser River at Marguerite of 232 m^3/s and the maximum effluent flow of 9 722 m^3/d, the minimum dilution available to the effluent would be about 2 060:1. This assumes complete mixing of the effluent and the river water. Thus, it is calculated that if the maximum recorded fecal coliform concentration of 560 000 CFU/cL were discharged during extreme low flows and at maximum discharge rates, the increase in the river due to this discharge would be 272 CFU/cL. At the edge of the initial dilution zone, this could be as high as 1 100 CFU/cL. In either case, this could impact on downstream water users who may use the river water. It should be noted that if the median effluent concentration were discharged under the same scenario, that the increase in the river concentration would be 14 CFU/cL (56 CFU/cL at the edge of the initial dilution zone), which would be considerably less of an impact.

5. NON-POINT SOURCE DISCHARGES

Non-point source discharges are considered to originate from an undefined or diffuse source as opposed to a point source discharge where the waste water is discharged through a pipe directly to the river. Within the Fraser River basin, these include sources such as agricultural runoff which carries nutrients and pesticides, forestry operations which can carry suspended solids, and urban stormwater runoff which can carry metals, solids, and oils and greases. Each of these is discussed in the following sections.

5.1 Forestry

"Sizable portions of virtually every major tributary entering the mainstem Fraser have been subject to clear-cut logging. Except for two localities, one in the middle reaches and the other in the upper reaches, no detailed studies have been made relevant to effects of such logging practices on fish habitat. Construction of logging roads through post glacial lake terraces in the Upper Fraser Sub-basin have resulted in severe sedimentation of stream gravels suitable for salmonid spawning." (3.3)

The timber resource statistics for the Fraser basin were included in Reference 3.3. For the areas directly adjacent to the Fraser River but not within its tributaries (e.g., Nechako River), the following was reported:

	Upper Fraser (N. from Prince George)	Middle Fraser (to Hope)
Total Forest Area (ha)	2 563 950	2 988 150
Operable Forest Area (ha)	1 042 722	1 302 253
Operable Volume (m^3)	222 285 000	221 740 000
Un-salvaged Losses (m^3/a)	120 600	111 500
Allowable Annual Cut (m^3/a)	2 884 200	3 352 000

The impacts of forestry operations on water quality have not been studied in British Columbia on a wide-scale. Slaney *et al.* (5.1) and Parkinson *et al.* (5.2) reported on the effects of logging in the Slim-Tumuch watershed in the early 1980's. This watershed is located 80 km east from Prince George and is a tributary to the Fraser River. Sediment and nutrient loadings were found to be greater where logging took place (Tumuch Lake) relative to an unlogged area (Shandy Lake) even when stream protection measures were undertaken in that time period(5.2). It was also found that average lake "light penetration during spring to early summer was greatly reduced as deforestation increased from 1.6% of the Tumuch Lake watershed in 1972 to 7.3% in 1974; Secchi disc readings in the inlet basin were frequently less than two metres throughout May and June. Both primary production and algal biomass (chlorophyll-a) were less in Tumuch Lake than in Shandy Lake, particularly in the Tumuch inlet basin." "Growth rates of most salmonid fish, back-calculated for pre-logging years, were similar in Shandy and Tumuch Lakes both before and after logging, but small shifts occurred in length at age of rainbow trout (age 5-decrease) and mountain whitefish (age 4, 5, 6 - increase) in Tumuch Lake after logging."(5.2).

Further impacts on water quality were noted by Slaney *et al.* (5.1). In comparing two streams in the same watershed which were logged (Centennial Creek) and unlogged (Rosanne Creek), the following effects of logging were noted. "In Centennial Creek transport of sediment through reserve strips (from disturbed sloping deposits of fine textured soils) reduced the quality of salmonid rearing habitat because concentrations of suspended sediment reached levels (mean, 75 mg/L) where benthic insects decreased markedly. Interstices of rubble in pools and runs were also filled with sediment in lower Centennial Creek, reducing potential over-winter habitat of salmonids."(5.1)

Slaney *et al.* (5.1) continued by noting that in "a small tributary that was clear-cut, but where soils were coarse and stabilized rapidly, assessments of rearing capability of trout habitat suggested (a) little effect on invertebrate drift and on survival of planted trout in an upper reach, logged by falling and skidding away from the stream, (b) reduced density of drifting invertebrates and decreased survival of trout fry in a lower reach that was associated with extensive in-stream falling and skidding one year earlier. Growth of under yearlings during summer to autumn, however, was significantly greater in both logged reaches; populations apparently benefited in growth rate from moderate increases in water temperature which were not associated with chronic sedimentation or low dissolved oxygen "(5.1).

In conclusion, since the Fraser River itself has a high natural sediment load, forestry impacts are most important on tributaries, but of minor concern on the main stem of the Fraser River.

5.2 Agriculture

The amount of farmland in the Fraser Basin has been reported (3.3) as follows for the main Fraser River reach:

	Upper Fraser	Middle Fraser
% of area in Farmland	1.2	6.5
Farmland (ha)	33 008	194 665
% Improved *	36	27
% Crops	20	15
% Pasture	45	65
Area fertilized(ha)	4 843	20 591
Application rate (t/ha)	0.16	0.13
Number of grazing animals	10 821	94 915
Number of chickens	2 200	83 706
Number of pigs	181	1 196
Pesticide use (ha sprayed)	1 291	730

* Some amount of money invested to improve the agricultural capability of the land.

As can be seen from these data, there is considerably more agricultural activity in the middle than the upper Fraser reach. As well, in comparison to the data for forestry in Section 5.1, the land area devoted to agriculture relative to forestry is small. This is likely due to the mountainous geography of the area. Regardless, as can be seen from the data, "cattle dominated as the main product throughout the Basin" (3.3).

Nutrient coefficients proposed by Bangay(5.3) were used to determine potential loadings. These estimates were 7.92 kg P and 68 kg N per animal per year for cows. Using the data for grazing animals, and assuming all were cattle, the potential yearly loading to the basin could be 85 700 kg P and 736 700 kg N in the upper Fraser reach, and 751 700 kg P and 6 454 220 kg N for the middle Fraser reach. For the purpose of this assessment, the following assumptions will be made:

(1) all of the phosphorus and nitrogen generated reaches the Fraser River (an extreme which actually will never happen) and

(2) the nutrients build-up during the winter months (October to April) and are transported to the river with runoff during a release period from one to four weeks of the year.

Using a flow of 246 m^3/s for the upper Fraser (mean April flow for Hansard) and 1 120 m^3/s for the middle Fraser (mean April flow for Marguerite), the following maximum increases (mg/L) in phosphorus and total nitrogen concentrations, respectively, in the Fraser River from cattle are predicted:

Release Period	One week		Two weeks		Four weeks	
	P	N	P	N	P	N
River Reach						
Upper Fraser R.	0.58	4.95	0.29	2.48	0.15	1.24
Middle Fraser R.	1.11	9.5	0.55	4.8	0.28	2.4

These calculated values indicate that nutrients from cattle could increase concentrations in the river; however, the assumptions are extreme and overly simplistic. Also, when the majority of the nutrients would reach the Fraser River, suspended solids concentrations in the river would be very high due to the large runoff. This would result in poor light penetration into the water column, which in turn would result in the nutrients not being the limiting factor as far as algal growth is concerned. The implications on water quality of these possible increases are discussed more fully in Chapter 6.

The data for pesticide use in the Table at the beginning of Section 5.2 indicate that pesticides were used on only 3.9% of the farmland in the upper Fraser reach, and 0.4% of the farmland in the middle Fraser reach. Depending upon the distance of the treated areas from the river, the application rate for the pesticide, and the types of pesticides, these may reach the river. However, with the large dilution available, it is doubtful whether these will be in measurable quantities in the river water column, although there may be areas where these could reside in the sediments.

5.3 Urban Stormwater Runoff

Locations of stormwater pipes discharging directly to the Fraser River are shown in Figure 4.1.2 for the Prince George area, and in Figure 4.1.3 for the Quesnel area. As well in the Prince George area, Hudson's Bay Slough (Figure 4.1.2) is a major settling area for stormwater and snow dumps. In the Prince George area, there are seventeen direct discharges to the Fraser River ranging in diameter from 250 mm to 2 400 mm, while at Quesnel there are sixteen discharges to the river which range in diameter from 200 mm to 750 mm.

To estimate the potential loading of contaminants to the Fraser River, data from Swain (5.4) may be used. The monitoring results on contaminant levels in stormwater runoff were based on a one-year study of stormwater from a 12.95 ha residential catchment area in Vancouver where the discharge occurred through a 610-mm diameter pipe. The combined cross-sectional areas of the storm sewer pipes associated with the City of Prince George are approximately 38 times larger than at the Vancouver site, while those for Quesnel are about 7 times larger. If it is assumed that the slope of the pipes in Quesnel and Prince George average the 0.6% slope in Vancouver, then the discharge volume into the Fraser River would be 38 times greater at Prince George and 7 times greater at Quesnel than flow from the one Vancouver catchment.

Significant differences exist in precipitation quantities between Quesnel, Prince George, and Vancouver. Prince George, on average, receives 651.5 mm of precipitation, with almost 410 mm as rainfall, while Quesnel receives 531.4 mm (365 mm as rainfall), and Vancouver near the study site 1 350 mm (1 282 mm as rainfall). Thus, Vancouver receives 2.07 times more precipitation volume on a yearly basis than Prince George and 2.54 times more precipitation than Quesnel. During the period that Swain's data(5.4) were collected, the volume of precipitation was 37% higher than normal, so that to relate the two data to sets, the ratios will be increased to 2.84 (=2.07 x 1.37) times for Prince George and 3.48 times for Quesnel. Thus, the loadings from Prince George storm sewers will actually be only 13 times greater (=38÷2.84) than from the 12.95 ha Vancouver catchment, while those from Quesnel will be twice (=7÷3.48) those from the Vancouver catchment. This results in the following net loadings (and increases in concentrations) from stormwater to the Fraser River based on a ten-year, seven-day low-flow and complete mixing:

	Estimated Loadings (kg/d) to the Fraser River		Estimated Increases (mg/L) in the Fraser River	
	Prince George	Quesnel	Prince George	Quesnel
Aluminum	15.7	2.4	0.0017	0.0003
Cadmium	2.13	0.32	0.0002	0.0001
Copper	0.92	0.14	<0.0001	<0.0001
Zinc	3.38	0.52	0.0004	0.0001
Suspended Solids	578.1	88.9	0.06	0.009
Total Nitrogen	40.95	6.30	0.004	0.0007
Total Phosphorus	5.15	0.79	0.0005	0.0001

These estimated increases are quite small compared to the present river concentrations. It is possible that there may be some localized zones of impact in the mixing zones of the storm sewer discharges, including contamination of bottom sediments. However, stormwater discharges are not likely a concern to water users.

6. AMBIENT WATER QUALITY AND PROPOSED WATER QUALITY OBJECTIVES

6.1 Fraser River from Moose Lake to Tete Jaune Cache

Water chemistry data have been collected by Environment Canada at Red Pass (Site 00BC08KA0007) as part of the federal-provincial trend monitoring network, while data on a number of species of fish were collected in a 1980 survey by Singleton at Moose Lake [6.1]. The 1980 survey was part of a major survey of Fraser River fish, which examined metals and organics concentrations in fish at four sites upstream from Hope, and three sites in the lower Fraser River. A survey of PCB and organochlorine pesticides in fish tissue from male lake trout, undertaken in 1991 and 1992 and which included fish from Moose Lake, looked at fish from 14 Rocky Mountain lakes.[6.24]

Designated water uses in this reach of the Fraser River are the protection of wildlife and aquatic life, secondary-water contact recreation, and protection of domestic water supplies, including livestock watering.

6.1.1 Water Chemistry

The Red Pass monitoring site is located near the outlet from Moose Lake, and is considered to be representative of the Fraser River at its headwaters. There is limited anthropogenic activity near this reach of the Fraser River, so data from this monitoring site should be as close to background concentrations as one might find for the entire Fraser River basin. Data reported in Table 6.1.1 were collected by Environment Canada between 1985 and July 1991.

The water chemistry data for the Red Pass site are to be examined for trend detection by Environment Canada (A. El-Shaarawi).

6.1.1.1 pH and Alkalinity

The pH in the Fraser River varied between 6.9 and 8.2, with a median pH of 7.9 and a mean of 7.8. Several of the earliest reported pH data were deemed to be questionable (i.e., were "flagged"), and it is of interest that these data often were also the lowest in the data set. The pH is in a range which is satisfactory for drinking water supplies (6.5 to 8.5) and for the protection of aquatic life (6.5 to 9.0) [6.2]. There are no point or non-point sources of wastes to this area of the river which would alter the natural pH significantly. Therefore, no water quality objective is proposed for pH in this stretch of the Fraser River.

The total alkalinity of the Fraser River at Red Pass varied from 40.7 to 64 mg/L (Table 6.1.1). These levels indicate that the river is well buffered to acidic inputs [6.3].

6.1.1.2 Hardness and Metals

The river hardness varied from 45.7 to 79.8 mg/L (Table 6.1.1). Values of this magnitude indicate that the river is of moderate hardness, but slightly below the 80 mg/L level considered optimum for drinking water supplies. Water hardness is known to modify the toxicity of several metals.

The total aluminum concentration was as high as 0.392 mg/L (Table 6.1.1). This is considerably in excess of the B.C. criterion to protect aquatic life of a maximum dissolved aluminum concentration of 0.1 mg/L when the pH exceeds 6.5 [6.4]. In fact, 12 of the 34 values reported were in excess of this criteria level for the maximum, although 8 of these had been "flagged" as being questionable. Regardless, there are times when the criteria for dissolved aluminum may be exceeded at the headwaters. <u>However, there are no point or non-point sources of wastes to this area of the river which would alter the natural aluminum concentrations significantly. Therefore, no water quality objective is proposed for aluminum for this stretch of the Fraser River.</u>

Four of 104 total cadmium measurements exceeded the working water quality criteria for aquatic life of a maximum 0.2 µg/L total cadmium for water hardness in the range from 0 to 60 mg/L, and a maximum of 0.8 µg/L total cadmium for hardness from 60 to 120 mg/L [6.5]. Cadmium concentrations in the headwaters therefore appear to be satisfactory for aquatic life almost all the time.

The working water quality criteria to protect aquatic life from total chromium are a maximum of 0.002 mg/L to protect phytoplankton and zooplankton, and 0.02 mg/L maximum to protect fish populations [6.5]. The data for total chromium (Table 6.1.1) show that eight of the 68 measurements at Red Pass exceeded the 0.002 mg/L criterion, although none exceeded the 0.02 mg/L criterion. Thus, total chromium concentrations in the headwaters appear to be satisfactory for aquatic life almost all the time. It is believed that some of the earlier chromium values may reflect the fact that sample bottles were washed for a time with chromic acid.

The B.C. criteria for total copper to protect aquatic life are related to water hardness, and can be determined from the following formulae (6.6):

Maximum (µg/L) Total Copper = [0.094(hardness)+2] ....(1)
Average* (µg/L) Total Copper ≤ [0.04 (average hardness)] ....(2)

Where hardness is reported as mg/L $CaCO_3$

*For hardness values ≤50 mg/L, the 30-day average total copper should not exceed 2 µg/L.

The criteria for the data presented in Table 6.1.1 would be an average total copper concentration of 0.003 mg/L, and maximum total copper concentrations of 0.006 mg/L for a hardness of 45.7 mg/L and 0.010 mg/L for a hardness of 79.8 mg/L. It was found that 22 of the 104 total copper concentrations were in excess of 0.010 mg/L, while an additional six total copper values were between 0.006 and 0.010 mg/L. About one in three background copper concentrations in the Fraser River exceed the B.C. criteria to protect aquatic life. However, contamination in the late 1980's until the start of 1991 was apparent in the Environment Canada data and was attributed to poor bottle washing and preservative vial failure. <u>There are no point or non-point sources of wastes to this area of the river which would alter the natural copper concentrations significantly. Therefore, no water quality objective is proposed for copper in this stretch of the Fraser River at this time.</u>

The criteria to protect aquatic life and drinking water supplies (aesthetics) from excess iron are a maximum concentration of 0.3 mg/L (6.5,6.7). Seven of 86 total iron concentrations were in excess of the criteria at the Red Pass site. Background iron concentrations in the Fraser River are therefore usually below working water quality criteria to protect aquatic life and aesthetics of drinking water supplies.

B.C. criteria for total lead to protect aquatic life are determined from the following formulae(6.10):

Maximum (µg/L) total lead ≤ exp (1.273 ln(hardness)-1.460) ...(3)

$$\text{Average } (\mu g/L) \text{ total lead} \leq 3.31 + \exp(1.273 \ln(\text{average hardness}) - 4.705) \quad \ldots(4)$$

For the Fraser River at Red Pass, all total lead concentrations were less than the criterion of a maximum of 0.030 mg/L which is based on the minimum hardness of 45.7 mg/L. Background lead concentrations in the Fraser River are therefore below the B.C. criteria for maximum concentrations. In addition, the mean concentration reported in Table 6.1.1 of 0.002 mg/L, is about one-half the criterion for the average concentration (0.005 mg/L). The same problems with contamination have existed for lead as were reported for copper.

All total manganese concentrations (Table 6.1.1) were below criteria to protect drinking water and aquatic life. The B.C. criterion for total mercury to protect aquatic life are a maximum of 0.1 µg/L [6.8], and all but one value (suspected to reflect contamination of the sample) was less than this criterion. All the molybdenum concentrations were well below the most stringent B.C. criterion of 0.01 mg/L to protect irrigation water supplies [6.9]. All nickel values were below the most stringent working criterion of 0.025 mg/L to protect aquatic life when water hardness is in the range from 0 to 60 mg/L [6.5]. All zinc values were below the most stringent working criterion of 0.03 mg/L to protect aquatic life, although phytoplankton may be affected at concentrations as low as 0.014 mg/L [6.5], and 8 of 104 values exceeded 0.014 mg/L. Zinc also would have been subject to contamination as were copper and lead.

6.1.1.3 Dissolved Oxygen and Oxygen-Consuming Materials

There were no data reported for dissolved oxygen concentrations in the Fraser River at Red Pass (Table 6.1.1). Dissolved oxygen is a crucial indicator of the health of the aquatic environment, and concentrations may be affected through the inputs of wastewater. There are no direct wastewater discharges to the Fraser River in this reach. Therefore, no water quality objectives for dissolved oxygen are proposed at this time.

6.1.1.4 Solids, Turbidity, and Colour

Dissolved solids have been as high as 191 mg/L (Table 6.1.1). These concentrations are typical of this area and below working criteria to protect drinking and irrigation water supplies [6.5]. Specific dissolved solids, such as chloride (maximum 0.7 mg/L), sodium (maximum 1.2 mg/L), and potassium (maximum 0.5 mg/L), were all well below the working criteria of 100 mg/L chloride for irrigation (6.5), about 27 mg/L sodium for irrigation (6.5), and 20 mg/L potassium for livestock watering (6.5).

Suspended solids concentrations in the Fraser River at Red Pass have been measured as high as 21 mg/L (Table 6.1.1). With a median concentration of <10 mg/L, these concentrations are considered to be quite low. In Chapter 5, it was determined that forestry practices could increase concentrations of suspended solids and turbidity in the river. The Ministry criteria for induced suspended solids concentrations to protect aquatic life are that for background concentrations of < 100 mg/L, suspended solids could increase by as much as 10 mg/L, while for background concentrations greater than 100 mg/L, suspended solids concentrations could increase by up to 10%(6.13). These are the proposed water quality objectives for suspended solids. These apply along the Fraser River, from Moose Lake to Tete Jaune, except in initial dilution zones of effluents. Future studies should be undertaken to develop objectives in the future which are more site-specific.

These initial dilution zones of effluents are to extend no further than 25% across the river width, from the bed to the surface, and extend no further than 100 m downstream from a discharge or a series of discharges.

Turbidity has been measured as high as 9 NTU (Table 6.1.1), although only one of the 110 values exceeded 5 NTU. Ministry criteria for turbidity relate to induced levels at different concentrations, and not to absolute concentrations. However, the concentrations measured in this reach of the river would be considered low, with a mean concentration of only 1.5 NTU. In Chapter 5, it was determined that forestry practices could increase concentrations of suspended solids and turbidity in the river. In order to protect this high quality water for drinking water users, it is proposed that the maximum turbidity should not exceed 5 NTU. This is the proposed water quality objective for turbidity. This applies along the Fraser River, from Moose Lake to Tete Jaune Cache, except in initial dilution zones of effluents described above. As well, the more restrictive of the proposed objectives for suspended solids and turbidity applies.

Colour has been measured as high as 10 colour (apparent) units (Table 6.1.1). The drinking water criterion for true colour is 15 colour units maximum to protect drinking water supplies (6.7). Since there are domestic water supplies from the river in this area, and forestry operations can contribute colour to the system, a water quality objective is proposed for colour in the Fraser River. The proposed objective is that the maximum colour concentration should not exceed 15 true colour units. The objective applies in the Fraser River, between Moose Lake and Tete Jaune Cache, except in initial dilution zones of effluents, described in Section 6.1.1.4.

6.1.1.5 Nutrients

Nitrate/nitrite had a maximum concentration of 0.161 mg/L, well below the criterion of 10 mg/L maximum for nitrate (6.15) to protect drinking water supplies. Non-point sources of discharges such as forestry and agricultural operations can increase nitrogen concentrations, but not to nearly the degree that water uses in this reach may be threatened. Therefore, no water quality objective is proposed for nitrogen compounds at this time.

The maximum phosphorus concentration was 0.019 mg/L (Table 6.1.1). Non-point source's of discharges such as forestry and agricultural operations can increase phosphorus concentrations, but it is not believed that water uses in this reach are threatened. Therefore, no water quality objective is proposed for phosphorus or periphyton chlorophyll-a at this time.

6.1.2 Sediment Chemistry

There are no data on sediments from this reach of the river.

6.1.3 Analyses of Fish

Singleton reported (6.1) in 1983 that the fish from Moose Lake had the highest of all concentrations of lead (0.39 µg/g) and molybdenum (1.39 µg/g) in muscle tissue of a longnose sucker compared to fish collected at other sites between Moose Lake and the Estuary. There are no criteria for molybdenum concentrations in fish tissues. The lead concentration is still below the 0.8 µg/g alert level for human consumption(6.10). Since it has been shown in Section 6.1.1.2 that the lead concentrations measured in the Fraser River water column were below criteria for maximum and average lead concentrations, finding a high lead concentration in the fish may be an anomaly, or may be related to the fact that a highway is located along one shore of the lake, thereby possibly allowing for the introduction of lead from vehicle emissions. Recent data reported by Swain and Walton for lead concentrations in the sediments from the Fraser River Estuary have shown a dramatic decrease (approximately two-thirds of earlier concentrations) in concentrations since the mid-1980's due to the ban of leaded gasoline (6.15) . Therefore, lead concentrations in fish should also be lower than found during the early 1980's.

The B.C. criteria to protect aquatic life from excess lead in fish flesh is an alert level of 0.8 µg/g (wet-weight) in edible portions of fish (6.10). In order to ensure that fish in Moose Lake and the upper Fraser River are protected, this is the water quality objective which is proposed for lead. The objective applies in all reaches of the Fraser River, from Moose Lake to Tete Jaune Cache.

Donald et al. (6.24) reported that lake trout from Moose Lake had high mean PCB concentrations (0.119 µg/g) compared to lake trout from 13 other Rocky Mountain lakes. "The high PCB levels in Moose Lake are probably due to direct contamination. Moose Lake is the only lake we studied that has a major highway, railway, and electric-power line in its basin, and these follow the inlet river and shoreline of the lake for many kilometres. Perhaps a spill of PCB along the railway or highway was responsible for the high PCB levels in Moose Lake." (6.24) This mean value is below the B.C. criteria for PCBs in fish flesh of 2.0 µg/g in edible portions of fish, but slightly exceeds the criterion of 0.1 µg/g for whole fish to protect wildlife (6.25).

Also at measurable concentrations in the same fish from Moose Lake were endrin in one of ten fish (0.019 µg/g), hexachlorobenzene in five fish up to 0.004 µg/g, O,P'-DDT in five fish at up to 0.012 µg/g, P,P'-DDT in three fish at up to 0.038 µg/g, and P,P'-DDD in three of ten fish at up to 0.021 µg/g (6.24). There are no criteria for these substances in fish flesh.

The B.C. criteria to protect aquatic life from excess PCBs in fish flesh is a maximum of 2.0 µg/g (wet-weight) in edible portions of fish for human consumption and 0.1 µg/g (wet-weight) in whole fish to protect wildlife (6.25). In order to ensure that fish in Moose Lake and the upper Fraser River are protected, these are the water quality objectives which are proposed for PCBs. The objectives apply in all reaches of the Fraser River, from Moose Lake to Tete Jaune Cache.

6.2 Fraser River from Tete Jaune Cache to Nechako River Confluence

Water chemistry data have been collected by the B.C. Ministry of Environment, Lands, and Parks at Hansard (SEAM Site E206580, NAQUADAT Site 00BC08KA0001), upstream from Prince George, as part of a Federal/Provincial ambient water quality trend monitoring program which began in 1985. The variability of water chemistry at Hansard was assessed by Carmichael and McNeil [6.18] prior to the commencement of sampling. It was determined that there was minimal cross-section variability at the 0.05 confidence level, and that a "single mid-stream site should, therefore, adequately represent the Fraser River cross-section at Hansard."[6.18]

The water chemistry data for the Hansard site are to be examined for trend detection by Environment Canada (A. El-Shaarawi).

Designated water uses in this reach of the Fraser River include protection of aquatic life and wildlife, domestic water supplies including livestock watering, and secondary-contact recreation.

6.2.1 Water Chemistry

Water chemistry data for Hansard are summarized in Tables 6.2.1 and 6.2.2, while those for the Nechako River are in Table 6.2.3. The Fraser River at Shelley (just upstream from the Nechako) has a drainage area of 32 400 km^2 compared to only 1 700 km^2 at Red Pass and the Nechako River just upstream from Prince George at Isle Pierre has a drainage area of 42 500 km^2. Thus the Nechako can have considerable influence on Fraser River water quality at and downstream from Prince George.

6.2.1.1. pH and Alkalinity

The pH of the Fraser River at Hansard, upstream from Prince George and the Nechako River confluence, has ranged from 7.6 to 8.3, with a median value of 7.9 (B.C. MoELP data) and from 6.7 to 8.3. with a mean of 7.73 (Environment Canada data) (Table 6.2.1). These compare to a median value of 7.9 measured upstream at Red Pass. Therefore, the tributaries to the river and anthropogenic activities have not, on average, affected the pH in the river between Red Pass and Hansard.

The pH was in a range which is satisfactory for drinking water supplies (6.5 to 8.5) and for the protection of aquatic life (6.5 to 9.0) (6.2). A water quality objective is required for pH since ammonia may be a concern. The objective is that the pH of the Fraser River outside initial dilution zones of effluents should be maintained in the range from 6.5 to 8.5.

The total alkalinity of the river, as represented by only two B.C. MoELP values, ranged from 57.8 to 94.8 mg/L. The Environment Canada data (n=173) indicated a range of alkalinity values from 43 to 105 mg/L, with a mean of 67.9 mg/L (Table 6.2.1)). These data indicate that the river is well buffered to acidic inputs (6.3).

The influence of the Nechako River as it enters the Fraser River at Prince George is summarized in Table 6.2.3. The data indicate that although the Nechako River can be more acidic in nature (to a pH as low as 7.3 according to B.C. MoELP data or 6.7 by Environment Canada data) than the Fraser River at Hansard, the median pH for the same time period was equal according to B.C. MoELP data. The difference in pH was also reflected in lower minimum alkalinity in the Nechako River (mean concentration of 56 mg/L and 49.5 mg/L, according to B.C. MoELP and Environment Canada, respectively) and hardness concentrations (about 51 mg/L according to both data sets) in the Nechako River than in the Fraser River. Thus the Nechako River will have only a minimal impact on the pH and alkalinity of the Fraser River by lowering the pH slightly.

6.2.1.2 Hardness and Metals

The mean total hardness of the Fraser River at Hansard, upstream from Prince George was 76.7 mg/L. The minimum hardness was 56.2 mg/L according to B.C. MoELP data, while Environment Canada data indicated a mean of 78.5 mg/L and a minimum value of 50.1 mg/L (Table 6.2.1). The optimal hardness for drinking water is 80 mg/L. The Fraser River at this point would be considered to have moderate hardness. Since the mean hardness at Red Pass was 64.3 mg/L, it appears that input from tributaries and anthropogenic activities between Red Pass and Hansard (Chapters 4 and 5) have increased the mean river hardness. The Nechako River had lower hardness values (about 51 mg/L mean) than found in the Fraser River. It would therefore be expected that there could be a slight decrease in hardness downstream from Prince George, and the confluence with the Nechako River at the point of complete mixing.

The B.C. criterion for the protection of aquatic life from excess aluminum is that the dissolved aluminum concentration should not exceed a maximum concentration of 0.1 mg/L when the pH exceeds 6.5 (6.4). Since all the B.C. MoELP and the Environment Canada data for aluminum are reported as total aluminum, it is not possible to evaluate the frequency of this criterion being exceeded. However, 15 of 106 total B.C. MoELP values and 7 of 69 total Environment Canada values were at or below this criterion, usually during periods of low-flow in the river when suspended solids concentrations were low. These concentrations likely were representative of dissolved concentrations.

Concentrations of total aluminum as measured by B.C. MoELP (mean of 0.91 mg/L) and Environment Canada (mean 0.41 mg/L) in the Nechako River usually were slightly lower than in the Fraser River at Hansard. It would therefore be anticipated that aluminum concentrations downstream from Prince George should be the same or slightly lower than at Hansard. Although there are a number of stormwater inputs to the Fraser River near Prince George (Section 5.3), the calculated potential increase in concentration from these was determined to be minimal under low-flow conditions (1.7 µg/L). Therefore, no water quality objective is proposed for aluminum in this reach of the Fraser River.

The criteria to protect aquatic life from total chromium are a maximum of 0.002 mg/L for phytoplankton and zooplankton, and 0.02 mg/L to protect fish (6.5). The B.C. MoELP detection limit of 0.005 mg/L was too high to determine the frequency at which the criterion to protect zooplankton and phtyoplankton was exceeded, although all Environment Canada data were below these criteria. With respect to the criterion to protect fish, only 1 of 67 B.C. MoELP and no Environment Canada values exceeded 0.02 mg/L, while most of the measurements were less than 0.01 mg/L. In the Nechako River (Table 6.2.3), total chromium concentrations were similar (median of <0.01 mg/L and mean of 0.0032 mg/L, according to B.C. MoELP and Environment Canada, respectively) to those in the Fraser River at Hansard, so that there should be no change in concentrations measured between Prince George from and Hansard. Chromium was not determined to be a metal which might increase with anthropogenic activity; therefore, no water quality objective is proposed at this time.

The toxicity to aquatic life of several metals is related to the water hardness. For copper, the B.C. criteria to protect aquatic life are determined from the formulae (1 and 2) presented in Section 6.1.1.2.

For the minimum reported B.C. MoELP hardness concentration of 56.2 mg/L, the associated copper criteria would be a maximum of 0.007 mg/L and an average of 0.002 mg/L. The reported B.C. MoELP minimum copper concentration was 0.007 mg/L (Table 6.2.1); however, the detection limit frequently was 0.010 mg/L, and most of the 44 measurements were reported as <0.010 mg/L. Environment Canada data for total copper for the same site ranged from 0.0004 to 0.4 mg/L (mean value of 0.017 mg/L), with 49 of 168 values exceeding the 0.007 mg/L criterion, but during a period when sample contamination was occurring. Therefore, it is difficult to draw any firm conclusions regarding the criteria being exceeded because of these factors. However, four B.C. MoELP total copper values were in excess of the criteria, the maximum being 0.25 mg/L in November 1989. The other three copper values were all 0.02 mg/L (September 1987, April 1988, and October 1988).

It is difficult to predict the influence that copper concentrations in the Nechako River would have on the Fraser River downstream from Prince George, since only five total measurements were made by B.C. MoELP, compared to 43 in the Fraser River at Hansard. The B.C. MoELP values in the Nechako River ranged from 0.002 mg/L to 0.02 mg/L (Table 6.2.3), and thus were similar to values reported for the Fraser River at Hansard. Environment Canada values for total copper concentrations were from 0.0004 to 0.729 mg/L, with a mean value of 0.0195 mg/L. Thus the mean total concentrations at each site were similar, so that we would not anticipate an influence on copper concentrations from the Nechako River. Although there are a number of stormwater inputs to the Fraser River near Prince George (Section 5.3), the calculated potential increase in copper concentration from these was determined to be minimal under low-flow conditions. Therefore, no water quality objective is proposed for copper at this time.

The criterion to protect aquatic life from excess total iron is the same as to protect aesthetics of drinking water supplies; 0.30 mg/L [6.4,6.6]. Eight of the 44 B.C. MoELP and 38 of 166 Environment Canada measurements of iron met these criteria. Iron concentrations in the Nechako River were lower than in the Fraser River at Hansard (mean total concentrations of 0.63 (B.C. MoELP and 0.47 mg/L (Environment Canada) in the Nechako River respectively, compared to 2.38 and 2.57 mg/L in the Fraser River at Hansard). Thus, it is likely that the Nechako River inputs should lower iron concentrations in the Fraser River downstream from Prince George. The high iron concentrations were likely due to the high suspended solids concentrations in the river. Iron was not identified as a metal which might increase from anthropogenic activity; therefore, no water quality objective is proposed at this time.

The one B.C. MoELP total mercury measurement in the Fraser River at Hansard, and the two in the Nechako River, were all <0.05 µg/L. Environment Canada mercury concentrations (n=162) ranged from 0.005 µg/L to 0.08 µg/L (mean of 0.017 µg/L) in the Fraser River at Hansard and from 0.005 µg/L to 0.53 µg/L (mean value of 0.024 µg/L) in the Nechako River. These mean values were less than the criterion for the maximum concentration of 0.10 µg/L to protect aquatic life, but the detection limit was too high to determine if the criterion of 0.02 µg/L as a 30-day average was met (6.8). Mercury was not indicated as a metal which might increase from current anthropogenic activity; in fact, there is a natural geological fault area in the Pinchi Lake area of the Nechako River watershed (6.28) which might contribute natural mercury to the system. Therefore, no water quality objective is proposed for mercury at this time.

The most restrictive criterion related to manganese relates to the protection of the aesthetics of drinking water supplies, where a maximum of 0.05 mg/L is recommended(6.7). This compares to a range of 0.1 to 1.0 mg/L to protect aquatic life (6.5). The mean concentration of 0.048 mg/L (B.C. MoELP) in the Fraser River at Hansard (Table 6.2.1) is similar to that found by the Environment Canada (0.052 mg/L), and met the most restrictive criterion. Thirteen of the 44 B.C. MoELP and 53 of 169 Environment Canada total values at Hansard exceeded the criterion. The 0.1 mg/L criterion to protect aquatic life was exceeded by only 3 of the 44 B.C. MoELP measurements and 13 of 169 Environment Canada measurements in the Fraser River at Hansard, likely due to the high suspended solids concentration at that location.

Manganese concentrations in the Nechako River (Table 6.2.3) appear to be lower than in the Fraser River at Hansard (a mean B.C. MoELP concentration of 0.027 mg/L in the Nechako compared to 0.048 mg/L in the Fraser River at Hansard, and a mean Environment Canada concentration of 0.025 mg/L compared to 0.052 mg/L), so that manganese concentrations in the Fraser River downstream from Prince George may decrease slightly in concentration from those measured at Hansard. Manganese was not identified as a metal which might increase from anthropogenic activity; therefore, no water quality objective is proposed at this time.

The mean B.C. MoELP total molybdenum concentration was the same in both the Fraser River at Hansard and in the Nechako River, 0.012 mg/L (Tables 6.2.1 and 6.2.3), while Environment Canada total measurements were only as high as 0.0004 mg/L in the Fraser River and 0.0031 mg/L in the Nechako. These values are very close to the criterion of 0.01 mg/L as an average concentration to protect irrigation water supplies [6.9]. Only four of 44 total values in the Fraser River at Hansard exceeded the criterion, while only three of 38 total values in the Nechako River exceeded the criterion. These higher values are likely associated with natural fluctuations in the river. Therefore, it is unlikely that molybdenum concentrations will be modified in the Fraser River downstream from Prince George from the input of Nechako River waters. As well, the water would be of good quality for most water users. Molybdenum was not identified as a metal which might increase from anthropogenic activity; therefore, no water quality objective is proposed at this time.

Very few B.C. MoELP total lead values were measured in the Fraser or in the Nechako rivers. The two concentrations in the Fraser River were 0.001 and 0.004 mg/L (Table 6.2.1), while the maximum concentration in the Nechako River of the three measurements was 0.006 mg/L (Table 6.2.3). Environment Canada total concentrations ranged from 0.0001 mg/L to 0.0233 mg/L, with a mean concentration of 0.0024 mg/L (Table 6.2.1) in the Fraser River and from 0.0002 to 0.0188 mg/L (mean value of 0.0013 mg/L) in the Nechako River. The maximum total lead concentration in any sample using the corresponding hardness concentration (mg/L $CaCO_3$) should not exceed[6.10]:

$$\text{Maximum } (\mu g/L) \text{ total lead} \le \exp\,(1.273 \ln(\text{hardness}) - 1.460) \ldots\ldots\ldots\ldots(3)$$

This formula and the minimum hardness concentration in the Fraser River would result in a criterion for lead of a maximum of 0.039 mg/L, while in the Nechako River, this criterion value would be 0.022 mg/L. In addition to the criterion for the maximum concentration, 80% of the values should be less than or equal to the 30-day average concentration [6.10]. The 30-day average total lead concentration in any sample using the corresponding average hardness concentration (mg/L $CaCO_3$) should not exceed:

$$\text{Average } (\mu g/L) \text{ total lead} \le 3.31 + \exp(1.273 \ln (\text{average hardness}) - 4.705) \ldots\ldots(4)$$

For the Fraser River at Hansard, the average criterion based upon the mean hardness concentration would be 0.006 mg/L, while in the Nechako River, this would be

0.005 mg/L. The measured values met both the criteria for the maximum total concentrations, while all but one B.C. MoELP value and all but 9 of 168 Environment Canada values met the criterion for the average concentration. The effect of the Nechako River on the Fraser River downstream from Prince George is that lead concentrations might decrease slightly. Although there are a number of stormwater inputs to the Fraser River near Prince George (Section 5.3), the calculated potential increase in lead concentration from these (0.2 μg/L) was determined to be minimal under low-flow conditions. Therefore, no water quality objective is proposed for lead at this time.

The maximum nickel concentration allowed by the working water quality criteria is for the protection of aquatic life, at 0.065 mg/L for hardness concentrations from 60 to 120 mg/L [6.5]. All B.C. MoELP and Environment Canada nickel concentrations in the Fraser River at Hansard (Table 6.2.1) were <0.05 mg/L. Only 2 of 38 B.C. MoELP (0.07 and 0.09 mg/L) but no Environment Canada total nickel measurements in the Nechako River (Table 6.2.3) exceeded the detection limit. Thus, the Nechako River is not expected to have an effect on nickel concentrations in the Fraser River downstream from Prince George. Nickel was not identified as a metal which might increase from anthropogenic activity; therefore, no water quality objective is proposed at this time.

Criteria to protect aquatic life from excess zinc concentrations are a maximum of 0.03 mg/L for most aquatic life [6.5], but as low as 0.014 mg/L to protect certain species of phytoplankton [6.11]. Eight of 44 B.C. MoELP total zinc measurements in the Fraser River at Hansard exceeded the 0.03 mg/L criterion for the maximum concentration, while 14 of 44 values exceeded the 0.014 mg/L criterion. For the Environment Canada total zinc data, 20 of the 165 total values exceeded the 0.03 mg/L criterion, and 35 of the 165 values exceeded the 0.014 mg/L criterion. Three of 38 total values in the Nechako River exceeded the 0.03 mg/L criterion, while 10 of 38 total values exceeded the 0.014 mg/L criterion. Zinc is a frequent contaminant in analytical laboratories and sampling procedures, which would account for the high values recorded here. Therefore, based upon the frequency that the two criteria were exceeded in each river, the effect of the Nechako River may be decrease slightly the zinc concentrations in the Fraser River downstream from Prince George. Although there are a number of stormwater inputs to the Fraser River near Prince George (Section 5.3), the calculated potential increase in total zinc concentration from these (0.4 μg/L) was determined to be minimal under low-flow conditions. Therefore, no water quality objective is proposed for zinc at this time.

6.2.1.3 Dissolved Oxygen and Oxygen-Consuming Materials

There were no data reported for dissolved oxygen concentrations in either the Fraser River at Hansard or in the Nechako River at Prince George (Tables 6.2.1 and 6.2.3). Dissolved oxygen is a crucial indicator of the health of the aquatic environment, and concentrations may be affected through the inputs of wastewaters from the McBride lagoons, the Prince George S.T.P., and the wastewater discharges from the two pulp and paper mills. Duncan has provided dissolved oxygen data for the Fraser River at Shelley from January 18, 1991. Readings were taken at 10 m intervals across the river at the surface just under ice, and ranged from about 13 to 14 mg/L [6.26].

There are no approved British Columbia criteria for dissolved oxygen. The following is the rationale to derive working water quality criteria for dissolved oxygen to be used in this document.

The CCREM[6.5] has developed criteria for dissolved oxygen, based on EPA criteria[6.12]. The criteria are based on warm-water and cold-water biota being present in a system. Cold-water systems were defined as any with at least one salmonid present. In British Columbia, this definition covers virtually the entire Province.

The EPA[6.12] had based its criteria, and discussed its findings, on the basis of salmonids and non-salmonids. Table 3-7 in CCREM (page 3-14) is from EPA[6.12]. The EPA[6.12] indicated that there was no impairment at 11.0 mg/L when embryo larvae were present or 8.0 mg/L for other life stages, and slight impairment at 9.0 mg/L and 6.0 mg/L, respectively. The EPA[6.12] based its criteria (accepted by CCREM) on the slight impairment levels, and then added 0.5 mg/L to arrive at the criteria. In British Columbia, we are fortunate enough to generally have high quality waters, and there is no need to accept the slight impairment level. Therefore, the criteria which will be used for dissolved oxygen in this document will be based on salmonids and should provide for no impairment (i.e., 8.0 mg/L and 11.0 mg/L minima). There are also concerns about the percent saturation of dissolved oxygen being adequate to protect aquatic life.

Dissolved oxygen modeling [4.11]has shown that no significant past, present, or future dissolved oxygen depletions should occur as a result of the discharges near Prince George. However, due to the fact that dissolved oxygen is such an important water quality constituent, and since there are discharges of oxygen-consuming wastewaters to this reach of the Fraser River, a water quality objective is proposed for dissolved oxygen. The objective is that the higher value of either a minimum of 80% of the maximum percent saturation at the corresponding temperature or, the minimum dissolved oxygen concentration should not be less than 8.0 mg/L for all life stages except when embryo and larvae are present, at which time the minimum concentration should be 11.0 mg/L. The objective applies along the Fraser River, except in the initial dilution zones of effluents, described in Section 6.1.1.4.

6.2.1.4 Solids, Turbidity, and Colour

Dissolved solids concentrations in the Fraser River at Hansard have ranged from 62 to 138 mg/L according to B.C. MoELP data and from 10 to 272 mg/L according to Environment Canada data, with mean concentrations of almost 99 and 114 mg/L, respectively (Table 6.2.1). These are all well below the most restrictive criteria of 500 mg/L to protect drinking water aesthetics [(6.7)]. Therefore, no Objective is proposed. The mean concentration at the Red Pass site was 90 mg/L, so that it appears that inputs from other tributaries between Red Pass and Hansard increased dissolved solids concentrations slightly at the Hansard station. Dissolved solids concentrations in the Nechako River have been lower, from 48 to 106 mg/L and from 29 to 229 mg/L, respectively (mean concentrations: 75 and 119 mg/L - Table 6.2.3). Dissolved solids in the Fraser River downstream from Prince George should be about the same concentration (mean 90 mg/L) due to the input of the Nechako River.

Suspended solids concentrations in the Fraser River at Hansard have ranged from <1 to 334 mg/L, with a mean concentration of 48 mg/L (B.C. MoELP data - Table 6.2.1), while Environment Canada data ranged from 10 to 342 mg/L (mean value of 71.2 mg/L). This is considerably higher than the <10 mg/L median concentration recorded for the Red Pass site. Thus, the tributaries (most likely the McGregor River input) and anthropogenic activities between Hansard and the Red Pass site are increasing suspended solids concentrations in the river.

The B.C. criteria for suspended solids are related to increases in concentrations which are permissible from upstream to downstream of a discharge or series of discharges. There are a number of wastewater discharges in this river reach which potentially could increase concentrations of suspended solids, including the pulp mill discharges, although it has been calculated that this should not be a concern for stormwater. As well, forestry activities can potentially increase suspended solids concentrations. Water quality objectives are proposed for suspended solids, based upon the B.C. criteria [6.13]. The objective to protect aquatic life are a maximum induced increase over background concentrations of 10 mg/L for upstream concentrations <100 mg/L, and a maximum of 10% increase for upstream concentrations >100 mg/L. These objectives apply to the Fraser River from Red Pass to the Nechako River confluence, except in initial dilution zones of effluents, described in Section 6.1.1.4.

The suspended solids concentrations in the Nechako River have ranged from <1 to 88 mg/L, with a mean concentration of about 10 mg/L (B.C. MoELP data) and from 10 to 89 mg/L (mean value of about 27 mg/L) according to Environment Canada data (Table 6.2.3). Based on these concentrations, it is likely that the input of the Nechako River to the Fraser River should decrease suspended solids concentrations slightly downstream from Prince George.

Suspended solids measurements indicate concentrations of materials which can damage membranes of fish gills or cause siltation of spawning beds. Turbidity measures the transmission of light through water.

Very few turbidity measurements by the B.C. MoELP (2) were made in the Fraser River at Hansard (Table 6.2.1) although Environment Canada made 173 measurements. The two B.C. MoELP values were 1.6 and 18 NTU, while the Environment Canada values ranged from 0.3 to 250 NTU (mean 15.8 NTU). The maximum acceptable concentration for turbidity in drinking water is 1 NTU, although 5 NTU may be permitted if it can be demonstrated that disinfection is not compromised[6.7]. The aesthetic objective for drinking water is 5 NTU[6.7]. Turbidity values at Red Pass were always less than 10 NTU, and the mean value was 1 NTU. As with suspended solids, it appears and is logical that the tributaries and anthropogenic activities between Red Pass and Hansard are increasing turbidity in the Fraser River.

B.C. criteria for turbidity are related to increases which are permissible from upstream to downstream of a discharge or series of discharges. Since there are a number of wastewater discharges (including non-point sources) in this river reach which potentially can increase turbidity, a water quality objective is proposed for turbidity, based upon the B.C. criteria [6.13]. The objectives to protect drinking water supplies are a maximum induced increase over background concentrations of 5 NTU for upstream concentrations <50 NTU, and a maximum of 10% increase for upstream concentrations >50 NTU. Where upstream values are <5 NTU, the maximum permitted increase is 1 NTU. The objectives apply along the Fraser River, from Tete Jaune Cache to the Nechako River confluence, except in the initial dilution zones of effluents, described in Section 6.1.1.4.

Turbidity in the Nechako River has been as high as 100 NTU, with a mean of 36.1 NTU (Table 6.2.3)according to B.C. MoELP data and from 0.1 to 30 NTU (mean value of 3.5 NTU) according to Environment Canada data. Thus the input of the Nechako River should decrease Fraser River turbidity values.

Temperature readings at Hansard have ranged as high as 21°C (Environment Canada data - Table 6.2.1), while the maximum in the Nechako was 25.7°C (Table 6.2.3). It was noted in the discussion of the Quesnel pulp mills (Section 4.3.13.3) that there was an increase in temperature of about 0.5 °C about 100 m downstream from the outfall. Similar temperature changes might be expected in the Fraser River near the Prince George mills. The water quality criterion to protect aquatic life from extremes of temperature is that the maximum change in temperature from upstream or background should not exceed 1 °C (6.23). This is the proposed water quality objective for temperature from Tete Jaune Cache to the Nechako River confluence, except in the initial dilution zones of effluents, described in Section 6.1.1.4.

Colour is an important water quality characteristic in the Fraser River due to the wastewater discharges from the pulp and paper mills. Measurements of colour have been frequent in the Fraser River at Hansard (Table 6.2.1), with B.C. MoELP values ranging from <1 to 33 TAC units, with a mean of 6.5 units (Table 6.2.1), and apparent colour (Environment Canada) values from 5 to 120 units (mean value of 20.4). Water quality criteria for colour are related to aesthetics for drinking water supplies and recreation. The criteria are a maximum of 15 true colour units for drinking water supplies where colour removal is not used, or 75 units where colour removal is used (6.7). The 15 unit criterion is indicated as a desirable level for recreation, although a value of 100 units is deemed the maximum permissible for recreation (6.14).

Only 9 of 106 total absorbance colour measurements (Table 6.2.1) have exceeded the 15 true colour unit criteria, and usually only in the February to April period. For the apparent colour values, 71 of 173 values exceeded the 15 unit criterion, and 6 of 173 exceeded the 75 unit criterion. (It is important to remember that the apparent colour values are obtained without filtration of the samples, while true colour is measured on a filtered sample.) Since less than 10% of the TAC values were in excess of 15 true colour units, it is quite likely that about the same number of true colour measurements would exceed the criterion. A water quality objective is proposed for true colour. The objective is that the maximum true colour should be 15 units during the recreation season from June through September, while the maximum true colour should not exceed 75 units for the remainder of the year. When upstream true colour values exceed either the 15 or 75 units objective (depending on the time of year), the maximum allowable increase from upstream to downstream from a discharge or series of discharges is 10%. This increase is deemed to be actually no increase, since analytical precision is likely no better than 10%. The objectives apply along the Fraser River, from Tete Jaune Cache to the Nechako River confluence, except in the initial dilution zones of effluents, described in Section 6.1.1.4.

The mean apparent colour concentration measured at the Red Pass site was 5.2 units, lower than the mean 20.2 units measured at Hansard, and the 15.4 units measured in the Nechako River. It is therefore possible that tributaries and anthropogenic activities between Hansard and the Red Pass site are causing slight increases in colour, while the Nechako River might actually decrease colour concentrations.

6.2.1.5 Nutrients

Total phosphorus concentrations in the Fraser River at Hansard as measured by B.C. MoELP (n=2) were 0.006 mg/L and 0.056 mg/L, while dissolved phosphorus concentrations ranged from <0.003 to 0.007 mg/L, and dissolved ortho phosphorus concentrations from <0.003 to 0.004 mg/L (Table 6.2.1). Environment Canada total phosphorus values (n=173) ranged from 0.002 mg/L to 0.65 mg/L (mean value of 0.056 mg/L). Only total phosphorus was measured at the Red Pass site, with a mean recorded concentration of 0.005 mg/L. Considering the increase in suspended solids between Red Pass and Hansard, it is likely that total phosphorus would increase in the river between the two sites.

Comparable B.C. MoELP ranges for the Nechako River were: total phosphorus, 0.01 to 0.128 mg/L (n=3), dissolved phosphorus: <0.003 to 0.029 mg/L (n=88), and dissolved ortho-phosphorus: <0.003 to 0.007 mg/L (n=6), while the Environment Canada data for total phosphorus (n=174) ranged from 0.002 to 0.175 mg/L (mean concentration of 0.030 mg/L). The mean concentrations in the Nechako River appear about the same as in the Fraser River at Hansard, so that no change in Fraser River concentrations below the Nechako would be expected. It is doubtful that the concentrations in the Fraser River are a concern regarding algal growth since it is likely that other factors, such as turbidity, stream velocity, or substrate availability are more important considerations.

In Chapter 5, it was indicated that forestry operations could increase nutrient loadings to the river. As well, agricultural inputs were estimated to increase both phosphorus and nitrogen concentrations. In flowing streams, the effects of excess nutrients are reflected in increased periphyton growth. The B.C. criteria (6.21) apply to recreational uses, with a maximum periphyton chlorophyll-a concentration of 50 mg/m^2. Since nutrients can be increased in the Fraser River between Tete Jaune Cache and Prince George, a water quality objective is proposed for periphyton chlorophyll-a. The objective is that the maximum periphyton chlorophyll-a concentration (which is actually the mean of six samples collected from natural substrate) should not exceed 50 mg/m^2. The objective applies outside initial dilution zones, described in Section 6.1.1.4.

The maximum ammonia nitorgen concentration of 0.165 mg/L in the Fraser River at Hansard was below all criteria for maximum concentrations at all temperatures and for pH values as indicated by Nordin and Pommen (6.15) and shown in Table 4.3.3. For the average concentrations listed in Table 4.3.4, there would not be a problem below a pH of 8.7. Thus, ammonia is not a problem in the Fraser River. Ammonia has not been measured at the Red Pass site. Since there are a number of wastewater discharges to this reach of the Fraser River which contain high concentrations of ammonia, a water quality objective is proposed for total ammonia concentrations in the Fraser River between Tete Jaune Cache and the Nechako River confluence. The objective is that the maximum ammonia nitrogen concentration should not exceed concentrations listed in Table 4.3.3, and average concentrations should not exceed concentrations shown in Table 4.3.4. The objectives apply to discrete samples collected outside the initial dilution zone of effluents, described in Section 6.1.1.4. It is recommended that monitoring for ammonia should be focused at sites near the discharges within the Prince George area.

The highest ammonia nitrogen concentration in the Nechako River was 0.02 mg/L (Table 6.2.3). Therefore, based on maximum recorded ammonia concentrations, the effect of the Nechako River could be to reduce ammonia concentrations in the Fraser River downstream from Prince George. Mean and median ammonia concentrations at the two sites were similar, so that there may normally not be any change due to the Nechako River inputs.

Nitrite concentrations were not measured in either the Fraser River or the Nechako River. Since the incomplete oxidation of ammonia to nitrate would result in nitrite being formed, and since there are periods of the year when the river would be covered with ice, reducing oxygen exchange and possibly preventing complete oxidation of the ammonia to nitrate, a provisional water quality is proposed for nitrite. The objective is that the maximum and average nitrite nitrogen concentrations should not exceed those values listed in Table 4.3.6. The objective applies in the Fraser River between Tete Jaune Cache and the Nechako River confluence, and outside the initial dilution zones of effluents, described in Section 6.1.1.4. It is recommended that monitoring for nitrite should be focused at sites near the discharges within the Prince George area.

The maximum MoELP nitrate or nitrate/nitrite nitrogen concentration (n=2) was 0.13 mg/L in the Fraser River at Hansard (Table 6.2.1), below the maximum concentration of 10 mg/L to protect drinking water supplies [6.15]. Environment Canada concentrations (n=172) ranged from 0.002 mg/L to 0.335 mg/L, with a mean concentration of 0.110 mg/L, still well below the maximum concentration of 10 mg/L to protect drinking water supplies [6.15]. The maximum nitrate/nitrite nitrogen concentration at Red Pass was 0.161 mg/L while the maximum in the Nechako was 23.2 mg/L (Mean value of 0.17 mg/L). Thus, nitrate concentrations appear to approximately double from Red Pass to Hansard, but remain unchanged from Hansard and downstream from the Nechako River confluence.

Since ammonia which is discharged can be converted to nitrate and there is a small data base related to nitrate concentrations, a water quality objective is proposed for nitrate in the Fraser River. The objective is that the maximum nitrate nitrogen concentration should not exceed 10.0 mg/L. The objective applies to discrete samples collected in the Fraser River between Tete Jaune Cache and the Nechako River confluence, and outside the initial dilution zones of effluents, described in Section 6.1.1.4. It is recommended that monitoring for nitrate should be focused at sites near the discharges within the Prince George area.

6.2.1.6 Bacteriological Quality and Chlorine

Fecal coliform concentrations (MoELP) ranged from <1 to 55 CFU/cL in the Fraser River at Hansard (Table 6.2.1). The B.C. criteria(6.16) to protect drinking water supplies which are provided partial treatment, a level necessary given the high suspended solids concentrations in the Fraser River, are that 90th percentile values should not exceed 100/100 mL *Escherichia coli*, nor 100/100 mL fecal coliforms. The 90th percentile values are based on a minimum of 5 weekly samples in 30 days. There were no coliform data collected at the Red Pass site, but coliform levels would most likely be quite low at that site, given the lack of anthropogenic inputs so far upstream.

Discharges from the sewage treatment facilities in McBride and Prince George can contain high concentrations of microbiological indicators. For this reason, a water quality objective is proposed. The objective is that 90th percentile values should not exceed 100/100 mL *Escherichia coli*, nor 100/100 mL fecal coliforms. The objectives apply in the Fraser River from Red Pass to the Nechako River confluence, except in the initial dilution zones of effluents described in Section 6.1.1.4. These objectives are restrictive enough to ensure that recreation users are protected.

Fecal coliforms measured in the Nechako River at Prince George (Table 6.2.3) have been higher than measured at Hansard, although the median values of 6 CFU/cL at Hansard and 4 CFU/cL in the Nechako were similar. Therefore, it seems unlikely that the inputs from the Nechako River will cause fecal contamination in the Fraser River to be increased.

If chlorination is being used as a disinfectant in effluent discharges, there is a concern that the chlorine residual be sufficiently low to protect aquatic life by the time the effluent is discharged to the river. Dechlorination should be used as a standard practice prior to discharging the effluents to the river. The B.C. criteria for continuous exposure to residual chlorine in freshwater is that the average chlorine residual should not exceed 2 µg/L (6.22). This is the proposed water quality objective for total residual chlorine in the Fraser River between Tete Jaune Cache and the Nechako River confluence, except in the initial dilution zones of effluents described in Section 6.1.1.4.

6.2.1.7 Organics

A number of organic compounds associated with pulp and paper mill discharges were measured in the Fraser River at Hansard during 1991/92 (Table 6.2.2). These compounds included chlorophenols, guaiacols, catechols, veratrols, vanillins, trichlorosyringol, and adsorbable organohalides (AOX). All values for all compounds except AOX were less than the detection limits of 0.1 and 0.05 µg/L. AOX was measured at or above the detection limit of 10 µg/L for 9 of the 29 analyses (maximum 20 µg/L). The remaining 20 analyses were all <10 µg/L. AOX is an inexpensive, reproducible method by which it is possible to determine a general measure of the total amount of chlorinated constituents present. As such, it is not a direct measure of aquatic health. The Ministry of Environment has a policy that AOX should be eliminated from discharges in the long-term. Without meaning to detract from this principle, a water quality objective is proposed for AOX in the Fraser River, from Tete Jaune Cache to the Nechako River confluence, except in the initial dilution zones of effluents, described in Section 6.1.1.4. The long-term objective is that the AOX concentration should not increase significantly at the 95% confidence level from upstream to downstream from a discharge, or series of discharges.

In Section 4.2.3.2 where impacts from the Northwood Pulp operation were discussed, and Section 4.2.6.2 where impacts from the Prince George Pulp and Paper operation were discussed, it was noted that these two operations could increase the concentrations of a number of organic contaminants under certain flow conditions. In particular, the two operations together may increase pentachlorophenol concentrations by 1.57 µg/L, tetrachlorophenol by 0.14 µg/L, and trichlorophenol by 0.12 µg/L. Draft B.C. criteria for these compounds, listed in Table 6.2.4, are the proposed water quality objectives for the chlorophenols in the water column [4.4]. The objectives apply in the Fraser River, from Tete Jaune Cache to the Nechako River confluence, except in the initial dilution zones of effluents, described in Section 6.1.1.4.

In Section 4.2.3.2, concern was noted for the possible increases in resin acid concentrations which might arise in the river under certain flow conditions. The water quality criteria cited were as follows: 8 µg/L dehydroabietic acid at pH 7.0 or 25 µg/L total resin acids, and 12 µg/L dehydroabietic acid at pH 7.5 or 45 µg/L total resin acids. These are the proposed water quality objectives, applicable to the Fraser River between Tete Jaune

Cache and the Nechako River confluence, except in the initial dilution zones of effluents, described in Section 6.1.1.4.

Possible increases were calculated in dioxin and furan concentrations in the Fraser River due to the two pulp mills which discharge to this reach of the Fraser River. The draft B.C. criteria (6.22) for dioxins and furans in water to protect aquatic life is that the maximum concentration of 2,3,7,8-T_4CDD TEQs in filtered water (i.e., dissolved) should not exceed 0.06 pg/L. This is the proposed water quality objective for dioxins and furans in the Fraser River, between Tete Jaune Cache and the Nechako River confluence, except in initial dilution zones of effluents, described in Section 6.1.1.4.

6.2.2 Sediment Chemistry

Dwernychuk (4.3) reported on sediments collected in 1990 upstream and downstream from the pulp mills in the Fraser River. Measurements of organochlorine compounds just upstream from Hansard and at a site between the two pulp mill discharges in Prince George were both below the detection limits of 1 ng/g for all organochlorines except pentachlorophenol, which had a detection limit of 2 ng/g.

Dioxins and furans were all non-detectable (below varying detection limits) at both sites except for octachlorodibenzodioxin, which was measured at concentrations of 16 pg/g upstream from the pulp mills and 32 pg/g downstream from the pulp mills. In terms of toxicity equivalents to 2,3,7,8-tetrachlorodibenzodioxin (TEQ), these were calculated to be 2.34 and 3.93 pg/g, respectively, as calculated by B.C. Environment, or 0.02 and 0.03 pg/g, respectively, as calculated by Environment Canada.

In Section 4.2.3.3(a), we reported that Mah et al. (4.1) collected sediments in the spring of 1988 upstream and downstream from pulp mill effluent discharges, and that dioxin and furan concentrations in sediments collected upstream from the Prince George pulp mills could not be detected above varying levels of detection (4.1). Downstream from the Northwood Pulp and Timber operation, the three sediment samples had non-detectable concentrations of 2,3,7,8-T_4CDD (<15 pg/g dry-weight), but measurable concentrations of 2,3,7,8-T_4CDF (274, 69.9, and 44.6 pg/g dry-weight). These concentrations represent TEQ values of 27.4 pg/g, 7 pg/g, and 4.5 pg/g, respectively. Similarly, downstream from the Canfor Prince George Pulp and Inter-Continental Pulp mill (discussed in Section

4.2.6), the three sediment samples had non-detectable concentrations of 2,3,7,8-T_4CDD (<15 pg/g dry-weight), but measurable concentrations of 2,3,7,8-T_4CDF in two of the three samples (50.7, 63.7, and <10 pg/g dry-weight) [4.1]. These represent TEQ values of 5.1 pg/g, 6.4 pg/g, and 0.5 pg/g, respectively.

Mah et al. [4.1] concluded that "the degree of contamination of bed sediments, at least for this relatively small set of samples, was primarily determined by sample location relative to sources of contamination and was not greatly affected by organic carbon content or particle size of sediments".

The two pulp mills which discharge to this reach of the Fraser River contribute dioxins and furans which may settle out in backwater, slow moving areas.. The draft B.C. criteria [6.22] for dioxins and furans in sediment is that the maximum concentration of 2,3,7,8-T_4CDD TEQs in bottom sediments should not exceed 0.25 pg/g (normalized to 1% organic carbon). This value should be adjusted on a site-specific basis by multiplying the % organic carbon of the sample by 0.25. This is the proposed water quality objective for dioxins and furans in sediments in the Fraser River, between Tete Jaune Cache and the Nechako River confluence, except in initial dilution zones of effluents, described in Section 6.1.1.4.

6.2.3 Analyses of Fish

Data on a number of species of fish were collected in a 1980 survey by Singleton at a site just downstream from McBride [6.1]. The 1980 survey was part of a major survey of Fraser River fish, which examined metals and organics concentrations in fish at four sites upstream from Hope, and three sites in the lower Fraser River.

Singleton reported [6.1] that the fish from McBride had the highest concentrations of cadmium (0.22 µg/g wet-weight), chromium (0.65 µg/g), copper (3.46 µg/g), and nickel (1.30 µg/g) in muscle tissue from a northern squawfish.

In Section 4.2.3.3(a) we reported that fish collected in 1988 downstream from the Northwood Pulp and Timber operation at Prince George [4.1] had higher dioxin and furan concentrations in muscle tissue than those collected downstream from the Canfor Prince George Pulp and Inter-Continental Pulp mill (Section 4.2.6). In fact, a composite muscle sample of seven largescale suckers (*Catostomus macrocheilus*) had 156 pg/g (wet-weight) of 2,3,7,8 tetrachlorodibenzofuran (2,3,7,8-T_4CDF) and 11.7 pg/g of 2,3,7,8-T_4CDD, or 27.3 pg/g as the TEQ. This compares to non-detectable concentrations (<2 pg/g wet-weight) in muscle of largescale suckers collected upstream from the Prince George mills, and concentrations of 40.8 pg/g 2,3,7,8-T_4CDF and 2 pg/g 2,3,7,8-T_4CDD (6.1 pg/g TEQ) in largescale suckers collected downstream from the Canfor Prince George Pulp and Inter-Continental Pulp mill(4.1).

The highest concentrations in fish muscle collected in 1989 downstream from the Prince George pulp mills were in mountain whitefish (Prosopium williamsoni), with concentrations of 290 pg/g 2,3,7,8-T_4CDF and 19.5 pg/g 2,3,7,8-T_4CDD. The TEQ value for this fish would be 48.5 pg/g, compared to the Health Canada food tolerance limit of 20 pg/g TCDD for fish(4.6).

Many of the conclusions on organic compounds in fish species applicable to this reach, collected mostly in 1990, and reported by Dwernychuk et al. (4.3), are summarized in Section 6.3.3. However, data on fish collected upstream from Prince George and in the Nechako River near the confluence with the Fraser are as follows. Dioxin and furan data were available for livers from rainbow trout, largescale sucker, and Dolly Varden char from only the Fraser River at TEQ concentrations of 1.4 pg/g, 3.3 pg/g, and 3.2 pg/g, respectively. In fish from the Nechako, TEQ values were 2.4 pg/g for largescale suckers, 4.0 pg/g for Mountain Whitefish, and 0.9 pg/g for rainbow trout. These values are low in comparison to what was found below the pulp mills at Prince George and Quesnel, reported in Section 6.3.3.

The few data for organochlorine compounds in both muscle and livers from fish collected upstream from Prince George in the Fraser River and in the Nechako River near its confluence with the Fraser were all at or very near the detection limit of 1.0 ng/g for all of the chlorinated phenols, catechols, and guaiacols tested. (4.3)

The Lheit-Lit'en Nation have recently reported on the contaminant concentrations measured in 1993 in four white sturgeon captured in the vicinity of the Northwood Pulp and Paper operation (6.27). The conclusions of this work were that mercury, lead, and dioxins and furans in liver, white epaxial muscle, and red epaxial muscle "represent significant hazards to aboriginal consumers of fish and fishery products" (6.27). The concentrations of these were as follows:

Flesh	Mercury	Lead	Dioxins & Furans
White Epaxial	0.18-1.42 µg/g ww	0.06-0.10 µg/g ww	2.1-6.4 ng/kg ww
Red Epaxial	no data	no data	17.1-93.3 ng/kg ww
Livers	0.16-1.44 µg/g ww	0.06-0.28 µg/g ww	18.9-34.0 ng/kg ww

The two pulp mills which discharge to this reach of the Fraser River release dioxins and furans which potentially can be accumulated by fish. The draft B.C. criteria [6.22] for dioxins and furans in fish to protect aquatic life is that the maximum concentration of 2,3,7,8-T_4CDD TEQs in lipids of fish tissue or fish eggs should not exceed 50 pg/g (wet-weight). This is the proposed water quality objective for dioxins and furans in fish in the Fraser River, between Tete Jaune Cache and the Nechako River confluence, except in initial dilution zones of effluents. This proposed objective is more stringent than the Health and Welfare food tolerance level and is designed to protect fish against long-term chronic effects.

6.3 Fraser River from Nechako River Confluence to Hope

Water chemistry data have been collected by the B.C. MoELP and Environment Canada at Marguerite and Hope (SEAM Sites 0600011 and E206581, respectively) as part of a Federal/Provincial ambient water quality trend monitoring program which began in 1985, while B.C. MoELP have collected data at Stoner (SEAM Site E206182). Water chemistry data collected by Environment Canada at the Marguerite and Hope sites are also summarized in Tables 6.3.2 and 6.3.5, respectively. The water chemistry data for the three sites are to be examined for trend detection by Environment Canada (A. El-Shaarawi). Information from a draft report (March 1992) has been included for the station at Marguerite [6.17].

Chinchilla and Beyer [6.19] analyzed water chemistry data collected at Hansard and Stoner between 1985 and 1988. Conclusions related to changes in water chemistry for that period have been included.

Designated water uses include protection of wildlife and aquatic life, as well as secondary-contact recreation, domestic water supplies including livestock watering, and irrigation.

6.3.1 Water Chemistry

Water chemistry data have been collected at three sites in the Fraser River, and at the mouth of the Thompson River. These data are summarized in Table 6.3.1 to 6.3.5.

6.3.1.1 pH and Alkalinity

There was virtually no change (based on median values) in pH going in a downstream direction along the Fraser River, between Stoner and Hope, according to B.C. MoELP data. The median pH was 7.8 at Stoner (Table 6.3.1), 8.0 at Marguerite (Table 6.3.2), and 7.9 at Hope (Table 6.3.5). The pH at all the sites generally was in a range which is satisfactory for drinking water supplies (6.5 to 8.5) and for the protection of aquatic life (6.5 to 9.0) [(6.2)]. Pulp and paper mills can have plant upsets or spills, so that a water quality objective is required for pH. The proposed objective is that the pH should be maintained in the range from 6.5 to 8.5.

The median pH of the Thompson River according to B.C. MoELP data was about the same as in the Fraser, at 7.8 (Table 6.3.3). Mean pH values (7.7 at Marguerite, 7.4 in the Thompson River, and 7.6 at Hope) measured by Environment Canada were slightly lower than the B.C. MoELP median values. The input from the Thompson River is not expected to change Fraser River pH.

The alkalinity of the river, as represented by only two to fourteen B.C. MoELP values, ranged from a mean concentration of 61.9 mg/L at Hope, to 64.9 at Stoner. On average, these data indicate that the river is well buffered to acidic inputs [(6.3)]. Environment Canada data were 51.2 mg/L at Hope and 65.4 mg/L at Marguerite. The mean alkalinity of the Thompson River was 42.1 (MoELP) and 37.6 mg/L (Environment Canada) (Table 6.3.4). Thus, the Thompson may reduce the alkalinity of the Fraser River slightly, as has been seen for the decreasing mean alkalinity concentration in a downstream direction.

El-Shaarawi [(6.17)] determined that there was not a well-defined seasonal cycle for pH in the years 1985 to 1991 at Marguerite. For alkalinity, there was determined to be significant seasonality, with high values in winter which decreased to a minimum in the summer (6.17). The higher concentrations in winter likely reflect the greater influence of groundwater in forming a larger percentage of the base flow.

6.3.1.2 Hardness and Metals

As was the case with alkalinity, the mean river hardness decreased in a downstream direction. The mean hardness concentration as measured by B.C. MoELP was 79.3 mg/L at Stoner (Table 6.3.1), 78.1 mg/L at Marguerite (Table 6.3.2), and 63.6 mg/L at Hope (Table 6.3.5). Environment Canada reported mean concentrations of 72.4 mg/L at Marguerite and 57.7 mg/L at Hope. It would appear from both data sets that the tributaries have decreased the mean river hardness, but only to about the same level as was measured at the furthest upstream site at Red Pass. The mean hardness concentrations of the Thompson River as reported by B.C. MoELP and Environment Canada were 48.2 and 43.3 mg/L (Table 6.3.4).

El-Shaarawi (6.17) determined that for hardness concentrations at Marguerite, there was a significant seasonal cycle with high values during the winter and low values during the summer. Calcium and magnesium displayed the same cycle (6.17). The highest values occurring in winter likely reflect the increasing percentage of groundwater at this time of year contributing to the base flow (i.e., less surface runoff in the river).

The B.C. criterion for the protection of aquatic life from excess aluminum is that the dissolved aluminum concentration should not exceed a maximum concentration of 0.1 mg/L when the pH exceeds 6.5 (6.4). Since most of the data for aluminum are reported as total aluminum, it is not possible to evaluate the frequency of this criterion being exceeded except at the Stoner site. For dissolved aluminum, the maximum reported concentration was 0.29 mg/L (Table 6.3.1), which is higher than the criterion to protect aquatic life. Only 7 of 27 values exceeded the criterion with all but one being 0.11 or 0.12 mg/L.

Several very high total aluminum concentrations have been reported (to 20 mg/L) at Marguerite (Table 6.3.3). At Stoner, 22 of 25 total aluminum values exceeded the criterion for dissolved aluminum, while 112 of 115 total aluminum values at Marguerite exceeded the criterion for dissolved aluminum. There seems to be little difference in the mean total aluminum concentrations between Hansard and Hope, with high concentrations being present, apparently representing a natural situation. Since it was estimated in Chapter 5 that total aluminum concentrations from stormwater would increase by only 0.002 mg/L when the impacts of Prince George and Quesnel were combined under low-flow conditions, a water quality objective is not required for aluminum at this time.

Chinchilla and Beyer (6.19) reported that dissolved barium concentrations increased between Hansard and Stoner in the period 1985 to 1988 only during the winter period.

The criteria to protect aquatic life from total chromium are a maximum of 0.002 mg/L for phytoplankton and zooplankton, and 0.02 mg/L to protect fish (6.5). The B.C. MoELP detection limit of 0.005 mg/L was too high to determine the frequency at which the criterion to protect zooplankton and phtyoplankton was exceeded. With respect to the criterion to protect fish, all dissolved chromium concentrations at Stoner were below the criterion, as were all Environment Canada total chromium values at Hope, although 1 of 47 values at Marguerite exceeded 0.02 mg/L. There were only four B.C. MoELP total chromium values for the Thompson River; all were <0.01 mg/L (Table 6.3.3). For the Environment Canada total values, they were as high as 0.0096 mg/L, with a mean value of 0.002 mg/L. The 0.002 mg/L criterion was exceeded by only 16 of 169 Environment Canada values. Chromium was not classified as a metal which might increase from anthropogenic activity; therefore, no water quality objective is proposed at this time.

Water hardness is used to determine the toxicity of certain metals to aquatic life. For copper, the B.C. criteria to protect aquatic life are determined from the formulae presented in Section 6.1.1.2.

For the minimum reported B.C. MoELP hardness concentration of 58.1 mg/L at Stoner, 44.5 mg/L at Marguerite, and 32.6 mg/L at Hope, the associated copper criteria would be a maximum value of 0.0074, 0.0062, and 0.0051 mg/L, respectively, and an average value of 0.0023, 0.002, and 0.002 mg/L, respectively. At Stoner, 5 of 35 dissolved copper values were at concentrations of 0.001 or 0.02 mg/L, while the remainder were below the detection limit of 0.001 mg/L. At Marguerite, 3 of 32 total copper values exceeded the criterion for the maximum copper concentration, although there were also 26 values recorded as <0.01 mg/L in concentration. At Hope, 6 of 44 total copper values exceeded the criterion for the maximum copper concentration, although there were 36 values reported as <0.010 mg/L. It must be remembered that high copper (or other metals) concentrations can be due to sampling/laboratory error and may not be a reflection of environmental risk.

Total copper concentrations measured by Environment Canada were as high as 0.135 mg/L at Marguerite and 0.159 mg/L at Hope, with mean concentrations of 0.012 mg/L and 0.009 mg/L, respectively. Concentrations in the Thompson River were a maximum of 0.771 mg/L and a mean value of 0.015 mg/L. Based upon the mean Environment Canada total copper data, copper concentrations appear to decrease along the length of the river (0.041 mg/L at Red Pass, 0.017 mg/L at Hansard, 0.012 mg/L at Marguerite, and 0.009 mg/L at Hope). Copper was not classified as a metal which increases significantly from anthropogenic activity; therefore, no water quality objective is proposed at this time.

The criteria to protect aquatic life from excess total iron is the same as to protect aesthetics of drinking water supplies: 0.30 mg/L (6.4,6.6). At Stoner where dissolved and total iron were measured, all 35 dissolved concentrations were below the criterion, but 33 of 36 total iron values exceeded the criterion. This shows that the high iron is associated with particulate matter, is not available to aquatic life and would be removed prior to drinking. At Marguerite, 27 of 32 total iron values exceeded the criterion, while at Hope, 40 of 44 total iron values exceeded the criterion. Mean concentrations of total iron decreased in a downstream direction, with values falling from 2.38 mg/L at Stoner, to 2.18 mg/L at Marguerite, and 1.8 mg/L at Hope (Tables 6.3.1, 6.3.2, and 6.3.5). Mean concentrations of total iron (Environment Canada) decreased from 3.5 mg/L at Marguerite to 2.6 mg/L at Hope. There were only four total iron MoELP measurements but 186 Environment Canada total measurements in the Thompson River; however, the mean concentrations of 0.085 and 0.29 mg/L, respectively, implies that the tributaries to the Fraser River may be reducing the iron concentrations. Iron was not indicated as a metal which might increase from anthropogenic activity; therefore, no water quality objective is proposed at this time.

The criteria for total mercury are that the maximum concentration should not exceed 0.10 µg/L to protect aquatic life, and the average concentration should not exceed 0.02 µg/L as a 30-day average (6.8). The analytical detection limit at the Provincial Laboratory of 0.05 µg/L does not allow us to determine whether the criteria for the average value is met. However, all values at Hope and Marguerite were reported as being less than the detection limit. At Stoner, three of 14 values were at the detection limit, and one additional value was at 0.07 µg/L. Thus the criteria for the maximum concentration were met at all three sites. Mercury (Environment Canada) ranged from 0.005 to 0.41 µg/L (mean of 0.026 µg/L) at Marguerite and from 0.005 to 0.080 µg/L (mean of 0.021 µg/L) at Hope, while Thompson River concentrations ranged from 0.0002 to 0.052 µg/L (mean of

0.012 μg/L). Mercury was not classified as a metal which might increase from anthropogenic activity; therefore, no water quality objective is proposed at this time.

The most restrictive criterion related to manganese relates to the protection of the aesthetics of drinking water supplies, where a maximum of 0.05 mg/L is recommended (6.7). This compares to a range of 0.1 to 1.0 mg/L to protect aquatic life (6.5). The mean B.C. MoELP total manganese concentration at the three sites was generally in excess of the most restrictive criterion, although the mean concentration decreased in a downstream direction. At Stoner, 12 of 36 values exceeded the criteria, while at Marguerite 10 of 32 manganese values exceeded the criteria, and 11 of 44 values at Hope exceeded the criteria. Environment Canada total manganese concentrations ranged from 0.53 mg/L (mean of 0.08 mg/L) at Marguerite to 0.4 mg/L (mean of 0.1 mg/L) at Hope, while Thompson River concentrations were as high as 0.139 mg/L (mean of 0.01 mg/L). Manganese was not classified as a metal which might increase from anthropogenic activity; therefore, no water quality objective is proposed at this time.

For molybdenum, the most restrictive criterion is 0.01 mg/L (average concentration to protect irrigation water supplies) (6.9). The median concentration at all three sites was less than the criterion, with the maximum reported values at the three MoELP sites being 0.02 mg/L. Environment Canada total molybdenum concentrations ranged as high as 0.0010 mg/L (mean of 0.0004 mg/L) at Marguerite to 0.0009 mg/L (mean of 0.0006 mg/L) at Hope, while Thompson River concentrations were as high as 0.001 mg/L (mean of 0.0006 mg/L). Molybdenum was not classified as a metal which might increase from anthropogenic activity; therefore, no water quality objective is proposed at this time.

The maximum total lead concentration in any sample using the corresponding hardness concentration (mg/L $CaCO_3$) should not exceed (6.10):

$$\text{Maximum } (\mu g/L) \text{ total lead} \leq \exp\,(1.273\ \ln(\text{hardness})-1.460) \quad \text{..........(3)}$$

This formula and the minimum hardness concentration in the Fraser River would result in a criterion of a maximum of 0.041 mg/L at Stoner, 0.030 mg/L at Marguerite, and 0.020 mg/L at Hope. Based on very limited B.C. MoELP data, these maxima were obtained for dissolved concentrations at Stoner, and total concentrations at Marguerite and at Hope.

Based on the Environment Canada total lead concentrations, the maximum concentrations of 0.009 mg/L at each site easily were below the criteria for maximum concentrations.

In addition to the criterion for the maximum concentration, 80% of the lead values should be less than or equal to the 30-day average concentration (6.10). The 30-day average total lead concentration in any sample using the corresponding average hardness concentration (mg/L $CaCO_3$) should not exceed:

$$\text{Average } (\mu g/L) \text{ total lead} \leq 3.31 + \exp(1.273 \ln (\text{average hardness}) - 4.705) \quad ......(4)$$

For the Fraser River, this is an average of 0.005 mg/L at Stoner, 0.004 mg/L at Marguerite, and 0.004 mg/L at Hope. Generally, the very few B.C. MoELP data for total lead, and the numerous Environment Canada data for total lead, met these criteria for average concentrations. It was estimated in Chapter 5 that the lead concentrations in the Fraser River could be increased by stormwater by up to 0.3 µg/L, when the stormwater flows from both Quesnel and Prince George were combined. This small potential increase, combined with the fact that the criteria to protect aquatic life are generally achieved, suggests that a water quality objective is not warranted for lead at this time.

The maximum nickel concentration allowed by the working water quality criteria is for the protection of aquatic life, at 0.025 mg/L for hardness concentrations from 0 to 60 mg/L, and at 0.065 mg/L for hardness concentrations from 60 to 120 mg/L (6.5). All the B.C. MoELP total nickel concentrations at both Stoner and Marguerite were reported as <0.05 mg/L, which means that we cannot determine if the criteria for the lower hardness range was met, but we can report that the criteria for the higher range was met. At Hope, only 1 of 44 total nickel concentrations was above the detection limit of 0.05 mg/L, and on that occasion, the value was 0.08 mg/L, a value which exceeded the criteria for both ranges of hardness. Environment Canada total nickel data were similar at both Marguerite, and Hope, with mean concentrations of 0.006 mg/L at Marguerite and 0.0046 mg/L at Hope. The four B.C. MoELP total nickel concentrations reported for the Thompson River were <0.05 mg/L (Table 6.3.4), while the Environment Canada total nickel data were as high as 0.04 mg/L, with a mean concentration of 0.0013 mg/L. Nickel was not classified as a metal which might increase from anthropogenic activity; therefore, no water quality objective is proposed at this time.

The criterion to protect aquatic life from excess zinc concentrations is a maximum of 0.03 mg/L for most aquatic life (6.5), but is as low as 0.014 mg/L to protect certain species of phytoplankton (6.11). The B.C. MoELP median total zinc concentrations at Stoner and Marguerite (Tables 6.3.1 and 6.3.2) were <0.01 mg/L, while at Hope, the mean total zinc concentration was 0.024 mg/L (Table 6.3.5). Thus, the criteria to protect all aquatic life were met at the two upstream stations for all but the maximum recorded values, but at the downstream Hope station, 3 of 44 values exceeded the 0.03 mg/L criterion (maximum of 0.39 mg/L). Environment Canada mean total concentrations were 0.026 mg/L at Marguerite and 0.01 mg/L at Hope. The three B.C. MoELP zinc measurements in the Thompson River were all <0.005 mg/L (Table 6.3.4), while the Environment Canada total zinc was as high as 2.07 mg/L (mean value of 0.017 mg/L).

In Chapter 5, it was estimated that stormwater contributions would increase zinc in the Fraser River by only 0.5 µg/L at low-flow when the stormwater inputs from Quesnel and Prince George were combined. This small potential increase, combined with the fact that the criteria to protect aquatic life are generally achieved, suggests that a water quality objective is not warranted for zinc at this time.

6.3.1.3 Dissolved Oxygen and Oxygen-Consuming Materials

Chinchilla and Beyer (6.19) determined that chemical oxygen demand increased in concentration between Hansard and Stoner during the period 1985 to 1988 only during the winter period. This could result in decreases in dissolved oxygen concentrations during the same period.

There were no data reported for dissolved oxygen concentrations for the sites at the Fraser River at Stoner (Table 6.3.1), Marguerite (Table 6.3.2), or Hope (Table 6.3.5). Dissolved oxygen is a crucial indicator of the health of the aquatic environment, and concentrations may be affected through the inputs of wastewaters from the Prince George S.T.P. and pulp mills, and the wastewater discharges from the two Quesnel pulp and paper mills, one of which contains the treated municipal Quesnel wastewater. Duncan (6.26) provided dissolved oxygen data for the Fraser River at Stoner for January 22, 1991. The data, collected under ice at 5 m intervals, ranged from about 11 to 14 mg/L.

There are no approved British Columbia criteria for dissolved oxygen. The rationale to derive working water quality criteria for dissolved oxygen in this document was presented in Section 6.2.1.3. Therefore, a water quality objective is proposed for dissolved oxygen. The objective is that the higher value of either a minimum of 80% of the maximum percent saturation at the corresponding temperature or, the minimum dissolved oxygen concentration should not be less than 8.0 mg/L for all life stages except when embryo and larvae are present, at which time the minimum concentration should be 11.0 mg/L. The objective applies along the Fraser River, except in the initial dilution zones of effluents, described in Section 6.1.1.4.

6.3.1.4 Solids, Turbidity, Temperature, and Colour

Mean B.C. MoELP dissolved solids concentrations increased between Red Pass (90 mg/L), Hansard (99 mg/L), Stoner (99 mg/L) and Marguerite (107 mg/L), but decreased again to the lowest concentrations at Hope (86 mg/L). (A similar trend is apparent for the Environment Canada values.) These lower concentrations at Hope likely reflect the impact of tributaries, such as the Thompson River, with maximum and mean concentrations of 90 and 67 mg/L, respectively (Table 6.3.4). All the dissolved solids values were well below the most restrictive criteria of 500 mg/L to protect drinking water aesthetics (6.7). Dissolved solids concentrations are reflected in specific conductivity values.

El-Shaarawi (6.17) determined that, for specific conductivity measurements at Marguerite, there was strong seasonality ($P<0.0001$) and also significant year-to-year differences, although most of the latter trend was caused by the very few data collected in 1985. He indicated that specific conductivity (as well as dissolved solids) was high during the winter and low during the summer (6.17). These same variations were also reported for potassium, sodium, sulphate, and chloride. This seasonal trend likely reflects the greater influence the ground water component has on water quality.

Specific dissolved solids (B.C. MoELP data), such as chloride (maximum 11 mg/L at Stoner and Marguerite, decreasing to 6.8 mg/L at Hope), sodium (maximum 9.8 mg/L at Stoner, 8.1 mg/L at Marguerite, and 6 mg/L at Hope), and potassium (maximum 0.9 mg/L at Marguerite and 0.8 mg/L at Hope), were all well below the working criteria of 100 mg/L chloride for irrigation (6.5), about 26 mg/L sodium for irrigation (6.5), and 20 mg/L potassium for livestock watering (6.5).

Chinchilla and Beyer (6.19) reported that for the 1985 to 1988 period, there were significant increases between concentrations at Hansard and Stoner for dissolved chloride and sodium. Derksen has determined that a correlation exists between chloride concentrations and AOX discharge from pulp mills. Therefore, this trend may reflect increasing wastewater discharges from the pulp and paper mills.

Suspended solids concentrations in the Fraser River downstream from Prince George appear to decrease in a downstream direction, based on mean B.C. MoELP concentrations. Mean values were 70 mg/L at Stoner (Table 6.3.1), 74 mg/L at Marguerite (Table 6.3.2) and 46 mg/L at Hope (Table 6.3.5), compared to 48 mg/L at Hansard and <10 mg/L at Red Pass. (A similar trend is apparent for the Environment Canada values.) This is likely due to the inputs from the tributaries, such as the Thompson and Nechako rivers, where the mean suspended solids concentration were about 6 and 10 mg/L, respectively (Table 6.3.4).

The B.C. criteria for suspended solids are related to increases in concentrations which are permissible from upstream to downstream of a discharge or series of discharges. There are a number of wastewater discharges in this river reach which potentially could increase concentrations of suspended solids, including the pulp mill discharges, although it has been calculated that this should not be a concern for urban stormwater discharges. As well, forestry activities can potentially increase suspended solids concentrations. A water quality objective is proposed for suspended solids, based upon the B.C. criteria (6.13). The objective to protect aquatic life is a maximum induced increase over background concentrations of 10 mg/L for upstream concentrations <100 mg/L, and a maximum 10% increase for upstream concentrations >100 mg/L. The objective applies to the Fraser River from the Nechako River confluence to Hope, except in initial dilution zones of effluents, described in Section 6.1.1.4.

Turbidity was not measured at the Stoner site. There were only three B.C. MoELP turbidity measurements at the Hope and Marguerite sites. At both sites (Table 6.3.2 and 6.3.5), the values were virtually the same, resulting in mean values of 10.5 NTU at Marguerite and 10.4 NTU at Hope. Nearly identical mean values were also reported for the Environment Canada data, with means of 21.6 and 21 NTU, respectively. The three B.C. MoELP turbidity measurements in the Thompson River were all 0.8 NTU (Table 6.3.4), which is lower than has been measured at either of the two Fraser River sites. The Environment Canada values ranged up to 19 NTU, with a mean of 1.4 NTU.

B.C. criteria for turbidity are related to increases which are permissible from upstream to downstream of a discharge or series of discharges. Since there are a number of wastewater discharges (including non-point sources) in this river reach which potentially can increase turbidity, a water quality objective is proposed for turbidity, based upon the B.C. criteria [6.13]. The objective to protect drinking water supplies is a maximum induced increase over background concentrations of 1 NTU for upstream concentrations <5 NTU, 5 NTU for upstream concentrations <50 NTU, and a maximum of 10% increase for upstream concentrations >50 NTU. The objective applies along the Fraser River, from the Nechako River confluence to Hope, except in the initial dilution zones of effluents, described in Section 6.1.1.4.

Temperature readings from Environment Canada data indicate that values as high as 20°C at Marguerite and 30°C (questionable) at Hope. It was noted in the discussion of the Quesnel pulp mills (Section 4.3.13.3) that there was an increase in temperature of about 0.5°C at a distance of about 100 m downstream from the outfall. The water quality criterion to protect aquatic life from extremes of temperature is that the maximum change in temperature should not exceed 1°C [6.23]. This is the proposed water quality objective for temperature from the Nechako River confluence to Hope, except in the initial dilution zones of effluents, described in Section 6.1.1.4.

The B.C. MoELP mean total absorbance colour concentrations were virtually unchanged from Stoner (18.2 TAC, n=37) to Marguerite (19.9 TAC, n=78) to Hope (17.3 TAC, n=3). Environment Canada mean apparent colour values were 41.2 units (n=178) at Marguerite and 27.8 units (n=239) at Hope. The criteria for colour are a maximum of 15 true colour units for drinking water supplies where colour removal is not used, or 75 units where colour removal is used [6.7]. The 15 unit criterion is indicated as a desirable level for recreation, although a value of 100 units is deemed the maximum permissible for recreation [6.14]. True colour is the colour measured on a filtered or centrifuged sample, compared to apparent colour which is the colour measured on an unfiltered sample.

The 15 true colour unit criterion was exceeded by total absorbance colour measurements on 20 of 37 occasions at Stoner, 38 of 78 occasions at Marguerite, and 2 of 3 occasions at Hope. Since the pulp and paper mills in Prince George and Quesnel can add colour to the Fraser River, a water quality objective is proposed for true colour. The objective is that the maximum true colour should be 15 units during the recreation season from June through September, while the maximum true colour should not exceed 75 units for the remainder of the year. When upstream true colour values exceed either the 15 or 75 units objective (depending on the time of year), the maximum increase from upstream to downstream from a discharge or series of discharges is 10%. This increase is deemed to be actually no increase, since analytical precision is likely no better than 10%. The objectives apply along the Fraser River, from the Nechako River confluence to Hope, except in the initial dilution zones of effluents, described in Section 6.1.1.4.

El-Shaarawi (6.17) found that for apparent colour at Marguerite, there were significant seasonal effects and increasing year-to-year trends. Values were found to be higher in 1991 than in previous years, while values were also found to be high in the spring and low during the summer. Since apparent colour is a measurement of colour for an unfiltered sample, increased turbidity and suspended solids from runoff during the Spring period would be evident for colour (apparent) measurements at this same time period.

Chinchilla and Beyer (6.19) found that colour increased in concentration between Hansard and Stoner during the winter months (i.e., low-flow). This may reflect a more pronounced impact of the pulp and paper mill discharges during low-flow periods.

6.3.1.5 Nutrients

The B.C. MoELP mean total phosphorus concentration decreased in a downstream direction, from 0.053 mg/L at Stoner (Table 6.3.1), to 0.040 mg/L at Marguerite (Table 6.3.2), to 0.033 mg/L at Hope (Table 6.3.5). This same apparent trend was also evident for mean concentrations of ortho dissolved and dissolved phosphorus at the same sites. A slight decrease in mean concentrations was apparent in the Environment Canada data, with values of 0.11 mg/L at Marguerite and 0.09 mg/L at Hope. This reduction may be due to inputs from sources such as the Thompson River, where the B.C. MoELP mean total phosphorus concentration was 0.007 mg/L (Table 6.3.4) and the Environment Canada mean was 0.018 mg/L.

Chinchilla and Beyer (6.19) found that dissolved phosphorus concentrations increased in the period 1985 to 1988 between Hansard and Stoner, but only during the winter period. El-Shaarawi (6.17) determined that total phosphorus had significant seasonality at Marguerite, being high only during the spring, but there were no long-term year-to-year trends in any form of phosphorus.

In Chapter 5, it was indicated that forestry operations could release nutrients to the river. As well, agricultural inputs were estimated to increase both phosphorus and nitrogen concentrations. In flowing streams, the effects of excess nutrients are reflected in increased periphyton growth. The B.C. criteria (6.21) apply to recreational uses, with a maximum periphyton chlorophyll-a concentration of 50 mg/m^2. Since nutrients can be increased in the Fraser River between Prince George and Hope, a water quality objective is proposed for periphyton chlorophyll-a. The objective is that the maximum periphyton chlorophyll-a concentration (which is actually the mean of six samples collected from natural substrate) should not exceed 50 mg/m^2. The objective applies outside initial dilution zones, described in Section 6.1.1.4.

Mean ammonia nitrogen concentrations may have been decreasing in a downstream direction, from 0.016 mg/L at Stoner (Table 6.3.1), to 0.014 mg/L at Marguerite (Table 6.3.2), to a median value of <0.005 mg/L at Hope (Table 6.3.5). The maximum ammonia nitrogen concentration of 0.07 mg/L in the Fraser River was at Marguerite, and was below all criteria for maximum concentrations at all temperatures and for pH values as indicated by Nordin and Pommen (6.15) and shown in Table 4.3.3. Thus, ammonia is not a problem in the Fraser River. Since there are a number of wastewater discharges to this reach of the Fraser River which contain high concentrations of ammonia, a water quality objective is proposed for total ammonia concentrations in the Fraser River between the Nechako River confluence and Hope. The objective is that the maximum ammonia concentration should not exceed concentrations listed in Table 4.3.3, and average concentrations should not exceed concentrations shown in Table 4.3.4. The objectives apply to discrete samples collected outside the initial dilution zone of effluents, described in Section 6.1.1.4. It is recommended that monitoring be undertaken at those times when discharges are taking place which would alter ammonia values significantly.

Chinchilla and Beyer (6.19) found that ammonia concentrations increased in the period 1985 to 1988 between Hansard and Stoner, but only during the winter period. The highest ammonia nitrogen concentration in the Thompson River was 0.024 mg/L (Table 6.3.4). The mean ammonia concentration was 0.006 mg/L. Based on maximum and mean recorded ammonia concentrations, the effect of the Thompson River could be to reduce ammonia concentrations in the Fraser River.

Nitrite concentrations were not measured in the Fraser River at any of the sites. Since the incomplete oxidation of ammonia to nitrate would result in nitrite being formed, and since there are periods of the year when the river would be covered with ice, reducing oxygen exchange and possibly preventing complete oxidation of the ammonia to nitrate, a provisional water quality objective is proposed for nitrite. The objective is that the maximum and average nitrite concentrations should not exceed those values listed in Table 4.3.5. The objective applies in the Fraser River between the Nechako River confluence and Hope, outside the initial dilution zones of effluents, described in Section 6.1.1.4. It is recommended that monitoring be undertaken at those times when discharges are taking place which would alter nitrite values significantly (i.e., also under ice conditions).

El-Shaarawi [6.17] determined that dissolved nitrogen, and nitrate plus nitrite had significant seasonality at Marguerite, with high nitrogen concentrations in winter and early spring, and low concentrations during the summer.

Nitrate (or nitrate/nitrite) -nitrogen concentrations were low, with B.C. MoELP mean values of 0.07 mg/L at Stoner (Table 6.3.1) and Marguerite (Table 6.3.2), and 0.11 mg/L at Hope (Table 6.3.5). Environment Canada values were as high as 0.38 mg/L at Marguerite and 0.61 mg/L at Hope. The most stringent B.C. criteria for nitrate- nitrogen is a maximum concentration of 10 mg/L to protect drinking water supplies [6.15], well above the highest recorded values.

Since ammonia which is discharged can be converted to nitrate, especially under ice cover conditions, and there is a small data base related to nitrate concentrations, a water quality objective is proposed for nitrate in the Fraser River. The objective is that the maximum nitrate- nitrogen concentration should not exceed 10.0 mg/L. The objective applies to discrete samples collected in the Fraser River between the Nechako River confluence and Hope, outside the initial dilution zones of effluents, described in Section 6.1.1.4. It is recommended that monitoring be undertaken at those times when discharges are taking place which would alter nitrate values significantly.

6.3.1.6 Bacteriological Quality and Chlorine

Fecal coliform concentrations seemed to decrease in a downstream direction, with median values of 6 CFU/cL at Hansard (Table 6.2.1), 120 CFU/cL at Stoner (Table

6.3.1), 83 CFU/cL at Marguerite (Table 6.3.2), and 49 CFU/cL at Hope (Table 6.3.5). The B.C. criteria(6.16) to protect drinking water supplies which are provided partial treatment, a level needed given the high turbidity in the Fraser River, are that 90th percentile values should not exceed 100/100 mL (100 mL = cL) *Escherichia coli*, 25/100 mL *enterococci*, nor 100/100 mL fecal coliforms. The 90th percentile values are based on a minimum of five weekly samples in 30 days.

Discharges from the sewage treatment facilities in Prince George and Quesnel can contain high concentrations of microbiological indicators. For this reason, a water quality objective is proposed. The objective is that 90th percentile values should not exceed 100/100 mL *Escherichia coli*, nor 100/100 mL fecal coliforms. The objectives apply in the Fraser River from the Nechako River confluence to Hope, except in the initial dilution zones of effluents described in Section 6.1.1.4. Due to the fact that Klebsiella are discharged from pulp mills, fecal coliforms may not prove to be the best measure of the safety of the water. When the fecal coliform objective is exceeded, action should only result if the *Escherichia coli* is also exceeded.

Fecal coliforms in the Thompson River (Table 6.3.4) have been measured only once, at <2 CFU/cL.

If chlorination is being used as a disinfectant in effluent discharges, there is a need for the chlorine to be low to protect aquatic life by the time the effluent is discharged to the river. The B.C. criteria for continuous exposure to residual chlorine in freshwater is that the average chlorine residual should not exceed 2 µg/L (6.22). This is the proposed water quality objective for total residual chlorine in the Fraser River between the Nechako River confluence and Hope, except in the initial dilution zones of effluents described in Section 6.1.1.4.

6.3.1.7 Organics

A number of organic compounds associated with pulp and paper mill discharges were measured in the Fraser River at Marguerite and Hope during 1991 (Tables 6.3.3 and 6.3.6, respectively). These compounds included chlorophenols, guaiacols, catechols, veratrols, vanillins, trichlorosyringol, and adsorbable organohalides (AOX). Data collected in 1992 and early 1993 are summarized in the second portion of these same tables. Data were collected in the Thompson River at Spences Bridge in 1992 and 1993 (Table 6.3.4); however, all values were below detection for all the variables except AOX.

At Marguerite, trichloroguaiacol was always detected (<0.05 to 0.85 µg/L), while tetrachlorophenol and pentachlorophenol were detected only in 1991 and early 1992. At Hope in 1992 and 1993, tetrachlorophenol and pentachlorophenol were detected.

Of significance is that chlorophenols were in detectable concentrations at Marguerite, as tri-, tetra-, and penta- chlorophenol, with maximum concentrations of 0.17 µg/L, 0.16 µg/L, and 0.22 µg/L, respectively (Table 6.3.3). Draft B.C. criteria for these and other chlorophenolic compounds, <u>listed in Table 6.2.4, are the proposed water quality objectives for the chlorophenols in the water column</u> (4.4). The objectives apply in the Fraser River, from the Nechako River confluence to Hope, except in the initial dilution zones of effluents, described in Section 6.1.1.4.

Chlorocatechols were not detected (<0.1 µg/L) at either site except once for tetrachlorocatechol at 0.29 µg/L at Hope before 1992 (Table 6.3.6). Chloroguaiacols were detected at Marguerite during both time periods, but at lower concentrations since 1992. This was also the case at Hope, although these compounds were not detected after 1992. There are no water quality criteria for these compounds.

Veratrols and vanillins were usually below detection limits of 0.1 µg/L (Tables 6.3.3 and 6.3.6) at both sites, although vanillin was detected at Marguerite.

AOX is a cheaper, reproducible measure of the total amount of chlorinated constituents present. As such, it is not a direct measure of aquatic health. AOX concentrations appear to have decreased considerably at Marguerite, with maximum values of 310 and 140 µg/L, and mean concentrations of 121 and 55.3 µg/L, respectively, both before 1992 and in 1992/1993 (Table 6.3.3). Similar declines (140 µg/L maximum and 50 µg/L mean in 1991) were measured at Hope, with a 1992/93 maximum of 80 µg/L and a mean of 35 µg/L (Table 6.3.6).

Derksen (6.23) has shown that there is a relationship between chloride and AOX concentrations. Although we didn't have coincident chloride and AOX concentrations, we did perform correlations between specific conductivity and AOX. These are presented in Figures 6.1 and 6.2, for Marguerite and Hope, respectively. Using the resulting equations, it might be possible in a very cursory manner to estimate historic AOX concentrations.

Since the Ministry of Environment has a policy that AOX should be eliminated from discharges in the long-term, a water quality objective is proposed for AOX in the Fraser River, from the Nechako River confluence to Hope, except in the initial dilution zones of effluents, described in Section 6.1.1.4. The objective is that the AOX concentration should not increase significantly at the 95% confidence level from upstream to downstream from a discharge, or series of discharges.

Resin acids are wood components which may be associated with many of the pulp and paper discharges. No data have been collected in the Fraser River; although, as reported in Section 4.2.3.2, these can be present in discharges. The water quality criteria for resin acids are as follows: 8 μg/L dehydroabietic acid at pH 7.0 or 25 μg/L total resin acids, and 12 μg/L dehydroabietic acid at pH 7.5 or 45 μg/L total resin acids. These are the proposed water quality objectives, applicable to the Fraser River between the Nechako River confluence and Hope, except in the initial dilution zones of effluents, described in Section 6.1.1.4.

Possible increases were calculated in dioxin and furan concentrations in the Fraser River due to the two pulp mills which discharge to this reach of the Fraser River. The draft B.C. criteria (6.22) for dioxins and furans in water to protect aquatic life is that the maximum concentration of 2,3,7,8-T_4CDD TEQs in filtered water (i.e., dissolved) should not exceed 0.06 pg/L. This is the proposed water quality objective for dioxins and furans in the Fraser River, between Tete Jaune Cache and the Nechako River confluence, except in initial dilution zones of effluents, described in Section 6.1.1.4.

6.3.2 Sediment Chemistry

Dwernychuk et al. (4.3) reported that for twelve sites along the Fraser River between Hansard and the Strait of Georgia, the highest concentrations of organochlorine compounds in sediments were found between Hope and Barnston Island. Detectable concentrations of tetra- and penta- chlorophenol, tri- and tetra- chloroguaiacol and chlorocatecol were measured at the three sites, compared to non-detectable concentrations of these same compounds at the other Fraser River sites(4.3). The highest concentrations measured were 6.8 ng/g (dry-weight) of 2,3,4,6-tetrachlorophenol at Mission, 7.9 ng/g of pentachlorophenol at Barnston Island, 2.5 ng/g 3,4,5-trichloroguaiacol and 2.1 ng/g tetrachloroguaiacol, 16 ng/g 3,4,5-trichlorocatechol, and 39 ng/g tetrachlorocatechol at Hope (4.3).

"No correlation was noted between either the amount of clay or silt in sediments and concentrations of trichlorocatechol, tetrachlorophenol, and tetrachlorodibenzofuran"(4.3). "Trichloroguaiacol and tetrachloroguaiacol concentrations in sediments were similar along the entire length of the Fraser; no obvious concentration gradient was discernible. No apparent correlation existed between particle size distribution and organochlorine concentration for the samples collected"(4.3).

In terms of dioxins and furans in the sediment samples, the highest TEQ values were less than 7 pg/g as calculated by B.C. Environment, and less than 2 pg/g as calculated by Environment Canada (4.3). These TEQ values are higher than the draft criteria (6.22) of 0.25 pg/g (dry-weight) normalized to 1% organic carbon. The actual detectable concentrations (pg/g dry-weight) were as follows:

Compound	d/s Prince George	Stoner	Quesnel	d/s Quesnel	Dog Cr.	Hope
H_6CDD						6.0
Total H_7CDD		27				7.2
1,2,3,4,6,7,8 H_7CDD		12				7.2
O_8CDD	35	78	43	79	75	64
2,3,7,8 T_4CDF					2	4.4

Of interest is the fact that the highest concentrations of O_8CDD were found at virtually identical concentrations downstream from the pulp mills at Quesnel and Prince George (at Stoner). However, the highest concentration of O_8CDD was found in the lower Fraser River in the Main Arm in Ewen Slough, at a concentration of 160 pg/g (dry-weight), or with a TEQ of 0.16 pg/g, less than the draft criterion of 0.25 pg/g.

The pulp mill which discharges to this reach of the Fraser River at Quesnel contributes dioxins and furans which settle out in backwater, slow moving areas.. The draft B.C. criteria (6.22) for dioxins and furans in sediment is that the maximum concentration of 2,3,7,8-T_4CDD TEQs in bottom sediments should not exceed 0.25 pg/g (normalized to 1% organic carbon). This value should be adjusted on a site-specific basis by multiplying the % organic carbon of the sample by 0.25. This is the proposed water quality objective for dioxins and furans in sediments in the Fraser River, between the Nechako River confluence and Hope, except in initial dilution zones of effluents, described in Section 6.1.1.4.

6.3.3 Analyses of Fish

Data on a number of species of fish were collected in a 1980 survey by Singleton at two sites in this reach; at a site just upstream from Quesnel, and a site between Lytton and Lillooet(6.1). The 1980 survey was part of a major survey of Fraser River fish, which examined metals and organics concentrations in fish at four sites upstream from Hope, and three sites in the lower Fraser River.

Singleton (6.1) reported that the fish from the site located downstream from Lillooet had the highest concentrations of arsenic (1.04 µg/g, wet-weight), cadmium (2.61 µg/g), copper (399 µg/g), and zinc (49.6 µg/g) in livers from two mature salmon. As well, detectable concentrations of PCBs were reported for muscle tissue from one white sturgeon (0.5 µg/g) collected downstream from Lillooet. Approved B.C. criteria are that the maximum PCBs in edible tissue should not exceed 2.0 µg/g (wet-weight).

Dwernychuk et al. (4.3) reported organochlorine compounds were detected in some fish from upstream control sites (1.8 ng/g wet-weight of 2,3,4,6-tetrachlorophenol in the composite liver sample (n=6) of Mountain whitefish from the Nechako River site), "indicating that fish containing these compounds were migrating into organochlorine-free sections or tributaries of the Fraser".

"In general, concentration gradients were not well defined (i.e., did not decrease linearly with increasing distance from mill effluent diffusers), however organochlorines were detected in fish at reaches along the entire length of the Fraser" (4.3). Generally, concentrations in the muscle were near the detection limit of 1.0 ng/g wet-weight (4.3). Livers had considerably higher concentrations, although these compounds were not detected in all the liver samples. The highest detectable values in livers for those compounds detected were as follows:

Organochlorine Compound	Concentration (ng/g)	Species	Site
2,4,6-Trichlorophenol	86	1 Dolly Varden	R8-d/s Marguerite
2,3,4,6-Tetrachlorophenol	20	Dolly Varden	R8-d/s Marguerite
Pentachlorophenol	18.7	Rainbow trout	R17-between Mission & Chilliwack
3,4,5-Trichloroguaiacol	428	Dolly Varden	R9-@ Dog Creek
Tetrachloroguaiacol	285	Dolly Varden	R9-@ Dog Creek
3,4,5-Trichlorocatechol	8.4	Dolly Varden	R8-d/s Marguerite
Tetrachlorocatechol	13.8	Largescale Sucker	R3-just d/s Prince George

"For fish captured in the Fraser system, Mountain Whitefish livers accumulated the highest concentrations of dioxins and furans of all the species examined, and the lowest average concentrations of chlorinated phenols, catechols, and guaiacols." (4.3) The highest liver concentrations in terms of toxicity equivalents to 2,3,7,8-tetrachlorodibenzodioxin (TEQ) was for Mountain Whitefish captured downstream from Quesnel, with a concentration of 540 pg/g. In fact, the mean value for all the livers from Mountain Whitefish in this reach (6 samples composed of only 1 liver each) was 323.9 pg/g (SD=130 pg/g). This compares to values for livers from Mountain Whitefish of 69.1 pg/g for a composite of three from near Stoner, 61.7 pg/g for a composite of four from upstream from Quesnel, 36.8 pg/g for a composite of nine collected near Lillooet, and 8.6 pg/g for a composite of four from near Hope. The draft B.C. criteria (6.22) for dioxins and furans to protect fish health is 50 pg/g in the fish lipids, or 1 pg/g tissue assuming 2% lipids in fish.

Largescale suckers exhibited low levels of dioxins and furans in tissues, and tended to exhibit a decrease in concentrations relative to data reported in 1989 (4.3). "Rainbow trout in the Fraser River exhibited non-detectable levels of dioxins in tissues from all stations, with the exception of reaches R8 (south of Marguerite) and R17 (near Mission). Furans were detected in low levels in all tissue samples of Rainbow trout between Prince George (R3) and Mission (R17), with the exception of a liver composite from Lillooet

(R10). Data indicate low levels of organochlorines in Rainbow trout throughout the Fraser system." (4.3)

Dwernychuk et al.(4.3) reported that based on average liver concentrations in each of Dolly Varden char, Rainbow trout, Mountain whitefish, and largescale suckers, dioxins and furans accumulated most in whitefish and least in rainbow trout, while the converse was true for chlorinated phenols, catechols, and guaiacols. These latter compounds were also high in Dolly Varden livers.

The October 1992 survey of dioxin and furan concentrations in fish from the Fraser River showed considerable decreases in concentrations from those measured in 1988 and 1990/1991 (4.14). "Whitefish collected downstream of Quesnel in 1988 exhibited the highest muscle dioxin (137 pg/g) and furan (1185 pg/g) levels of all specimens analyzed by Mah et al. (1989). In the study documented herein, dioxin and furan levels in muscle tissues collected in a similar area (R7; "Below Quesnel") were both 3.2 pg/g, a reduction of more than 40-fold in dioxin levels and 350-fold for furan."(4.14) In terms of TEQs, the data for the three surveys were as follows:

2,3,7,8-T_4CDD-TEQ values in Mountain whitefish muscle and (liver) samples between 1988 and 1992

	1988	**1990/1991**	**1992**
(R4)Stoner	no data	51.9 (65.0)	4.9 (18.8)
(R5) Above Quesnel	no data	24.5 (61.2)	1.5 (4.3)
(R7) Below Quesnel	256 (no data)	90.0 (321.6)	0.0 (20.9)
(R8) 20 km South of Marguerite	no data	no fish captured	11.1 (36.8)
(R10) Lillooet	no data	6.3 (35.5)	0.7 (1.9)
(R16) Hope	no data	2.7 (6.2)	1.6 (0.6)

The pulp mill which discharges to this reach of the Fraser River release dioxins and furans which potentially can be accumulated by fish. The draft B.C. criteria (6.22) for dioxins and furans in fish to protect aquatic life is that the maximum concentration of 2,3,7,8-T_4CDD TEQs in lipids of fish tissue or fish eggs should not exceed 50 pg/g (wet-weight).. This is the proposed water quality objectives for dioxins and furans in fish in the Fraser River, between the Nechako River confluence and Hope.

7. AMBIENT WATER QUALITY MONITORING TO CHECK WATER QUALITY OBJECTIVES

A monitoring program is outlined in Table 7.0 for the Fraser River from Hope to Moose Lake. The B.C. Ministry of Environment, Lands, and Parks normally samples five times in a thirty-day period to check the attainment of water quality objectives. This should be continued for at least three years for the variables for which water quality objectives have been established.

At the same time, it must be recognized that there is some monitoring taking place under the Federal/Provincial monitoring agreement, and that there may be additional monitoring undertaken through the Environment Canada Green Plan. A monitoring scheme under the latter has recently been published [7.1]. The monitoring to check objectives should be coordinated with all such programs, to prevent duplication of effort.

There are some variables which are quite expensive to monitor, such as dioxins and furans in fish tissue. The utility of collecting a small number of fish each year as is often suggested for monitoring water quality objectives is questionable in this river. It would be preferable to collect three or four species every two to three years, with at least five individuals of about the same size (and assumed age) per species, and check the attainment of the objectives for fish in that manner. This would reduce the effort required to collect the fish, and yield a better data base in the long term.

The exact monitoring program undertaken will depend upon available resources.

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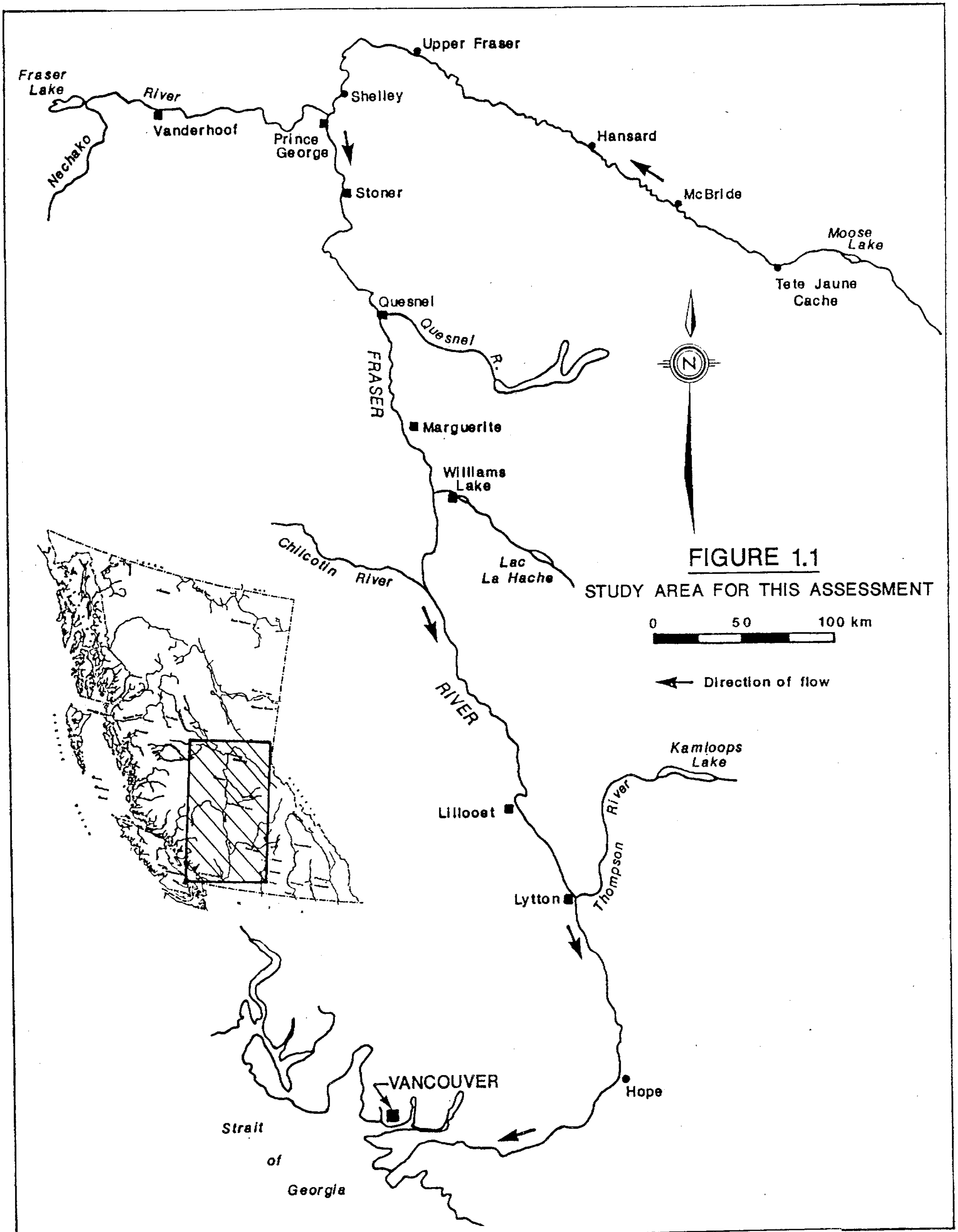


FIGURE 1.1
STUDY AREA FOR THIS ASSESSMENT

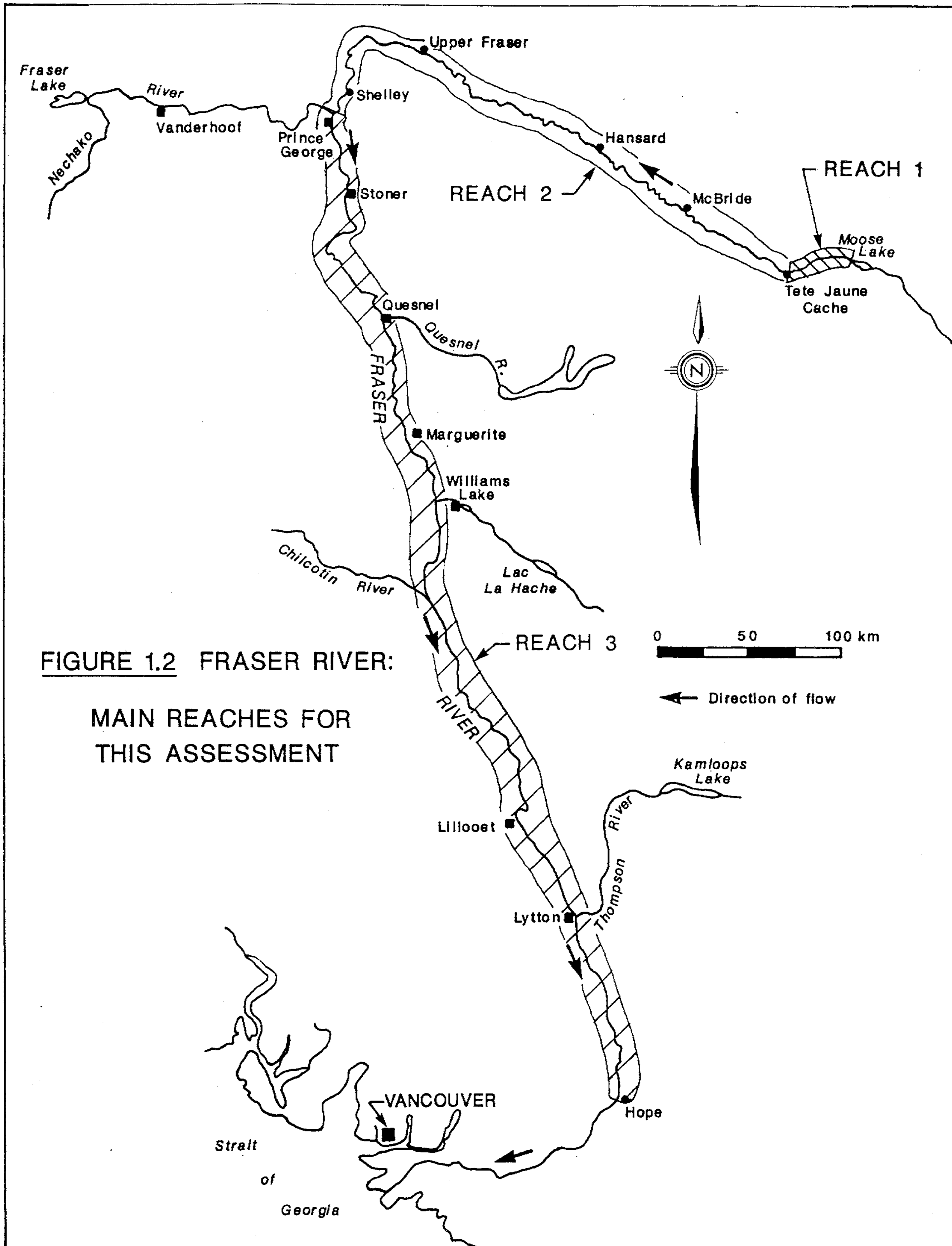
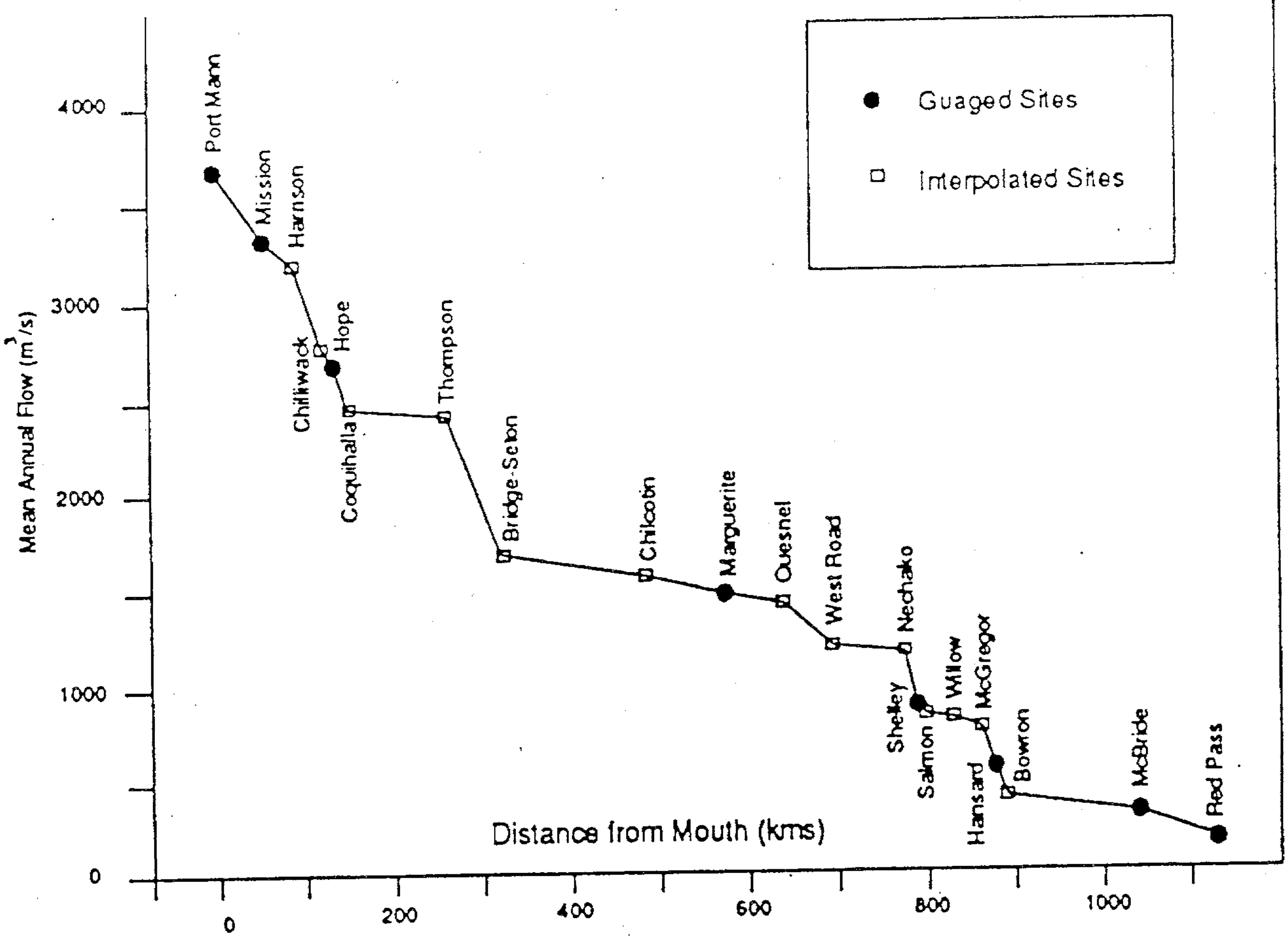


FIGURE 1.2 FRASER RIVER:

MAIN REACHES FOR THIS ASSESSMENT



Mean Annual Mainstem Flow from Headwaters to Mouth of the Fraser River.

FIGURE 1.3: FROM NORTHCOTE AND BURWASH

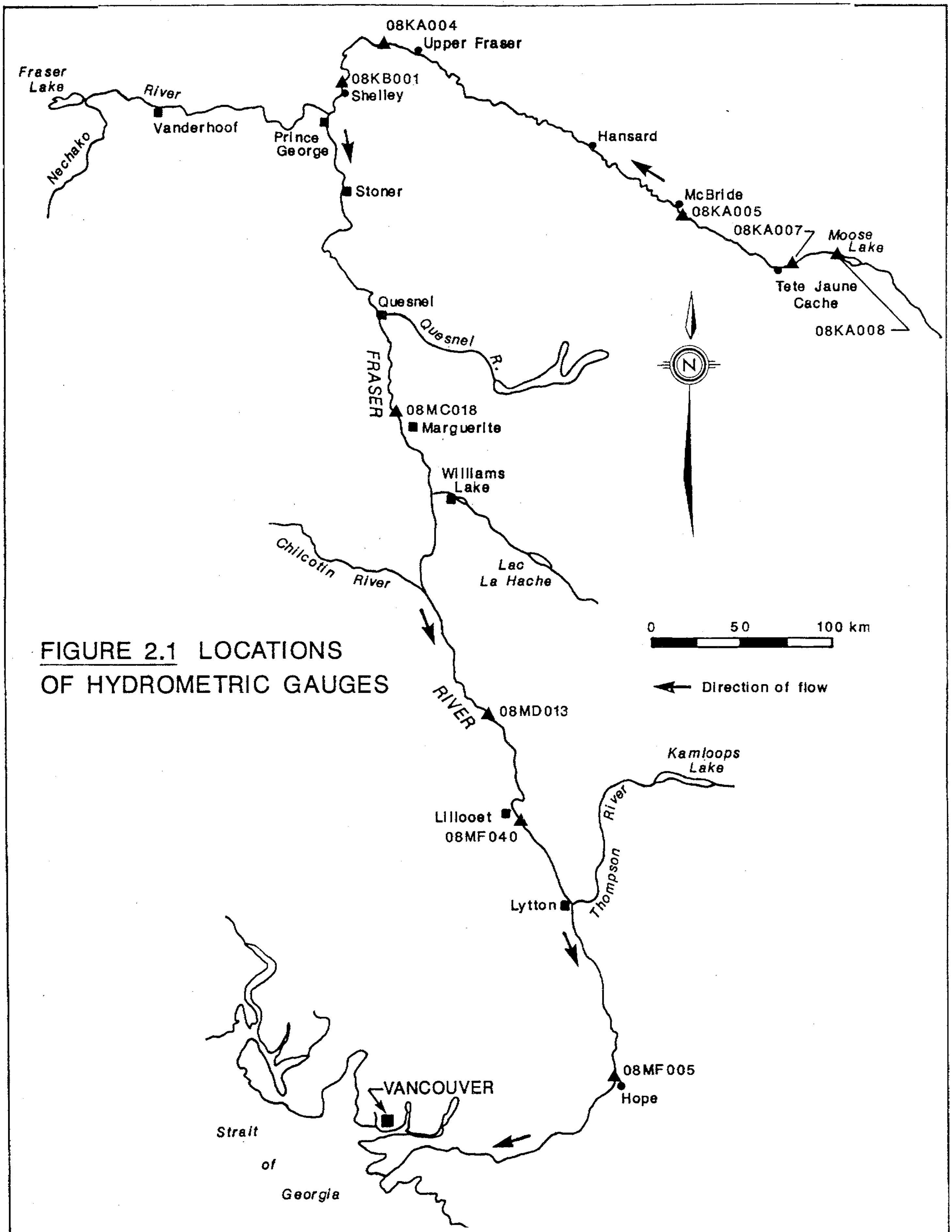
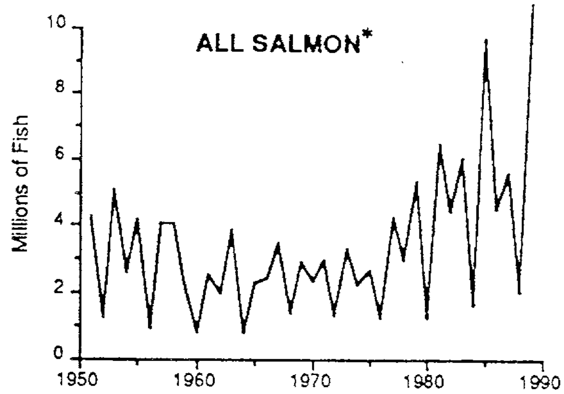


FIGURE 2.1 LOCATIONS OF HYDROMETRIC GAUGES



Average Annual Pacific Salmon Escapement to the Fraser River Basin, 1951 to 1989. Total Escapement (all salmon) includes interpolated values for pink salmon on even numbered years;

- * trend statistically significant at p = or less than 0.05;
- ** trend almost significant at p = 0.05;
- *** trend statistically significant at p = or less than 0.01 (calculated Z = 1.94, tabled Z at p = 0.05 = 1.96).

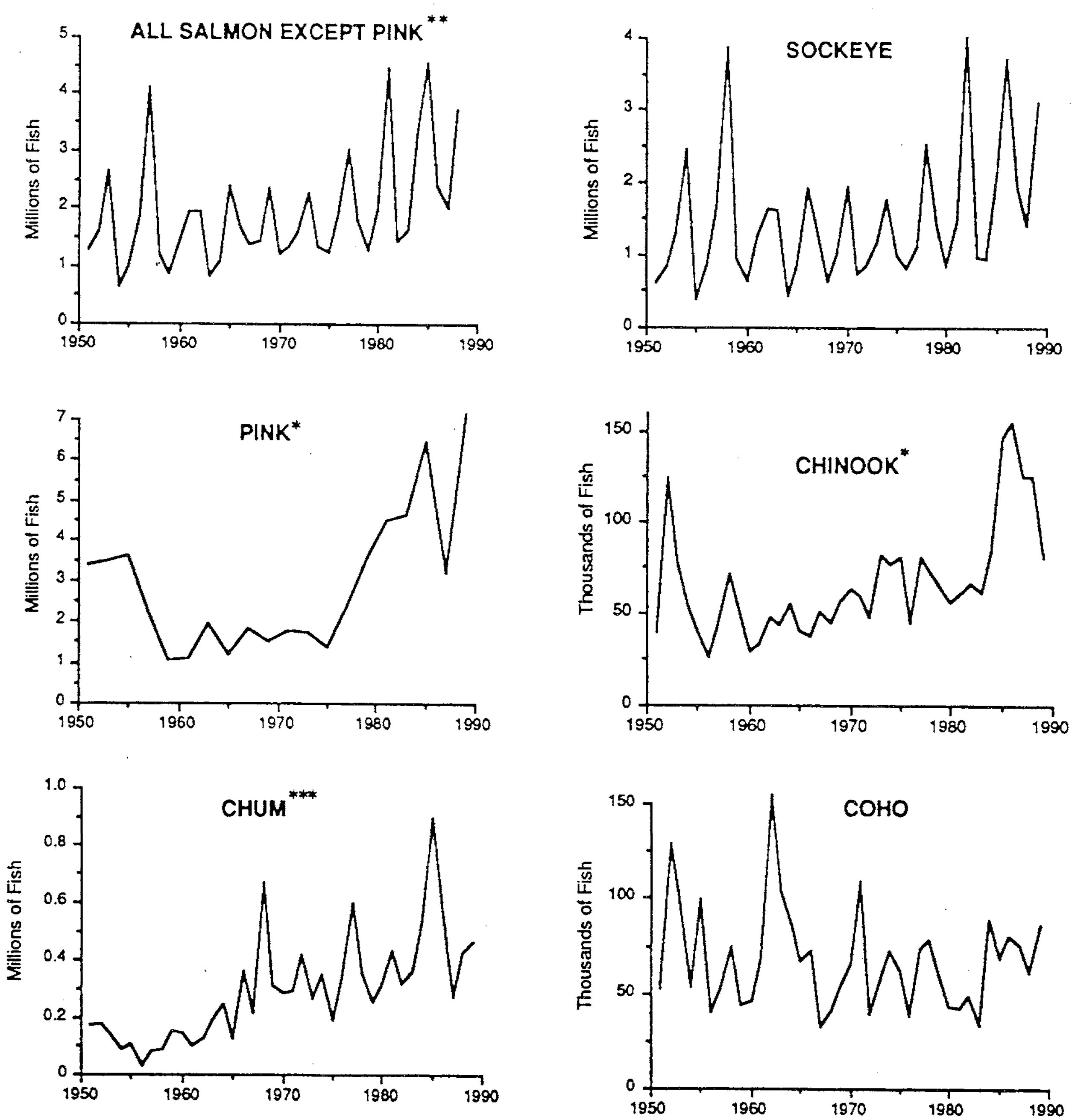


FIGURE 3.1: FROM NORTHCOTE AND BURWASH

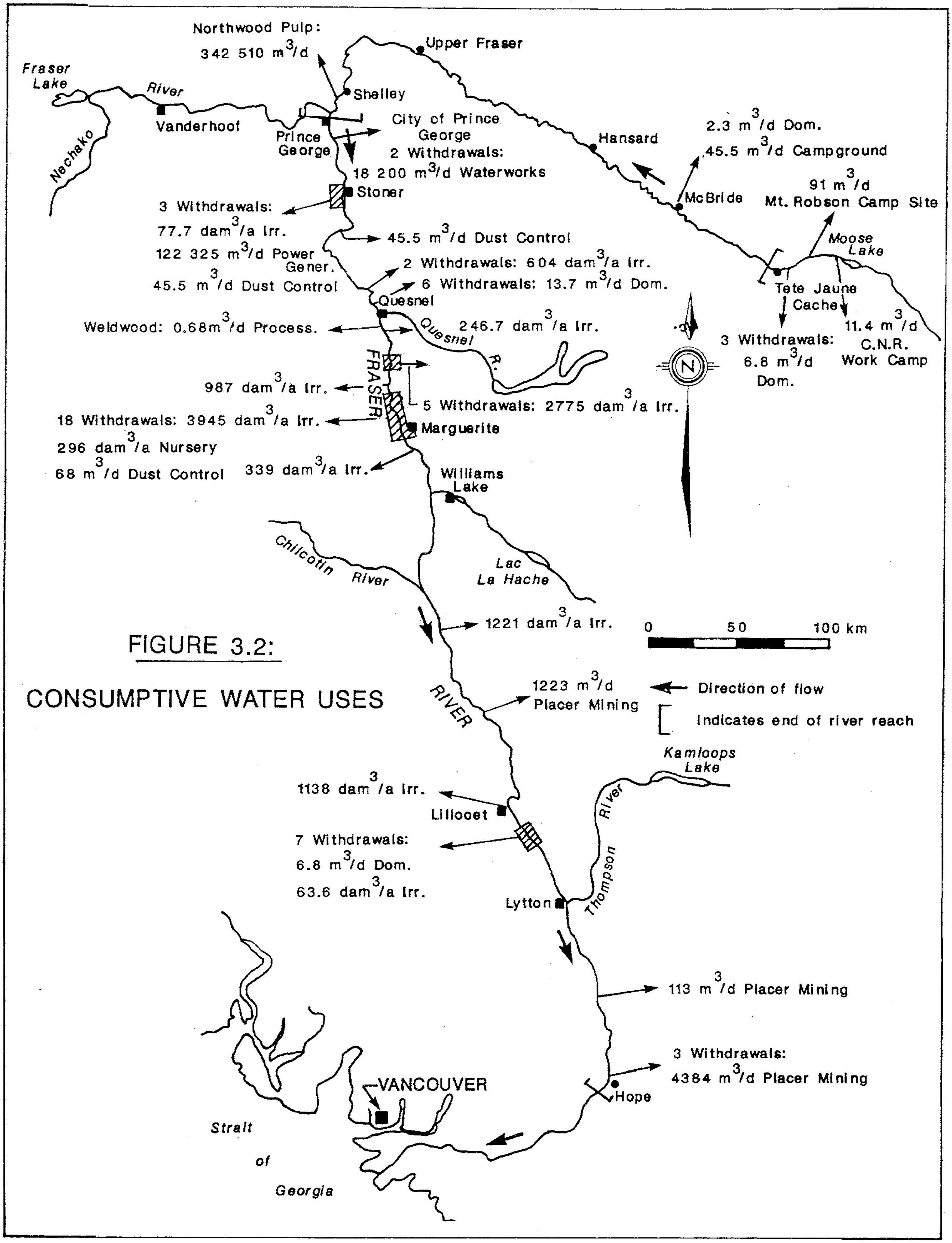


FIGURE 3.2:

CONSUMPTIVE WATER USES

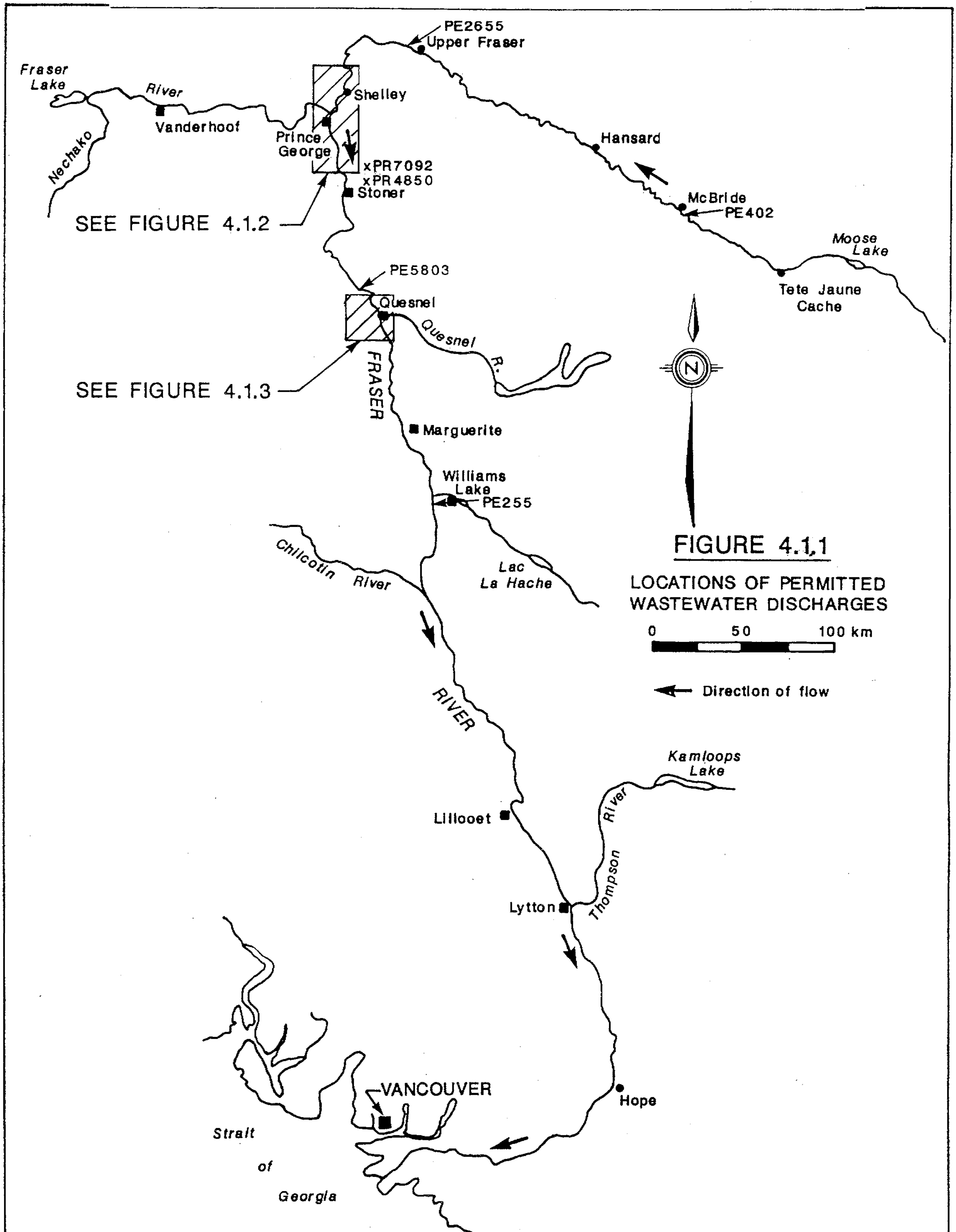


FIGURE 4.1.1

LOCATIONS OF PERMITTED WASTEWATER DISCHARGES

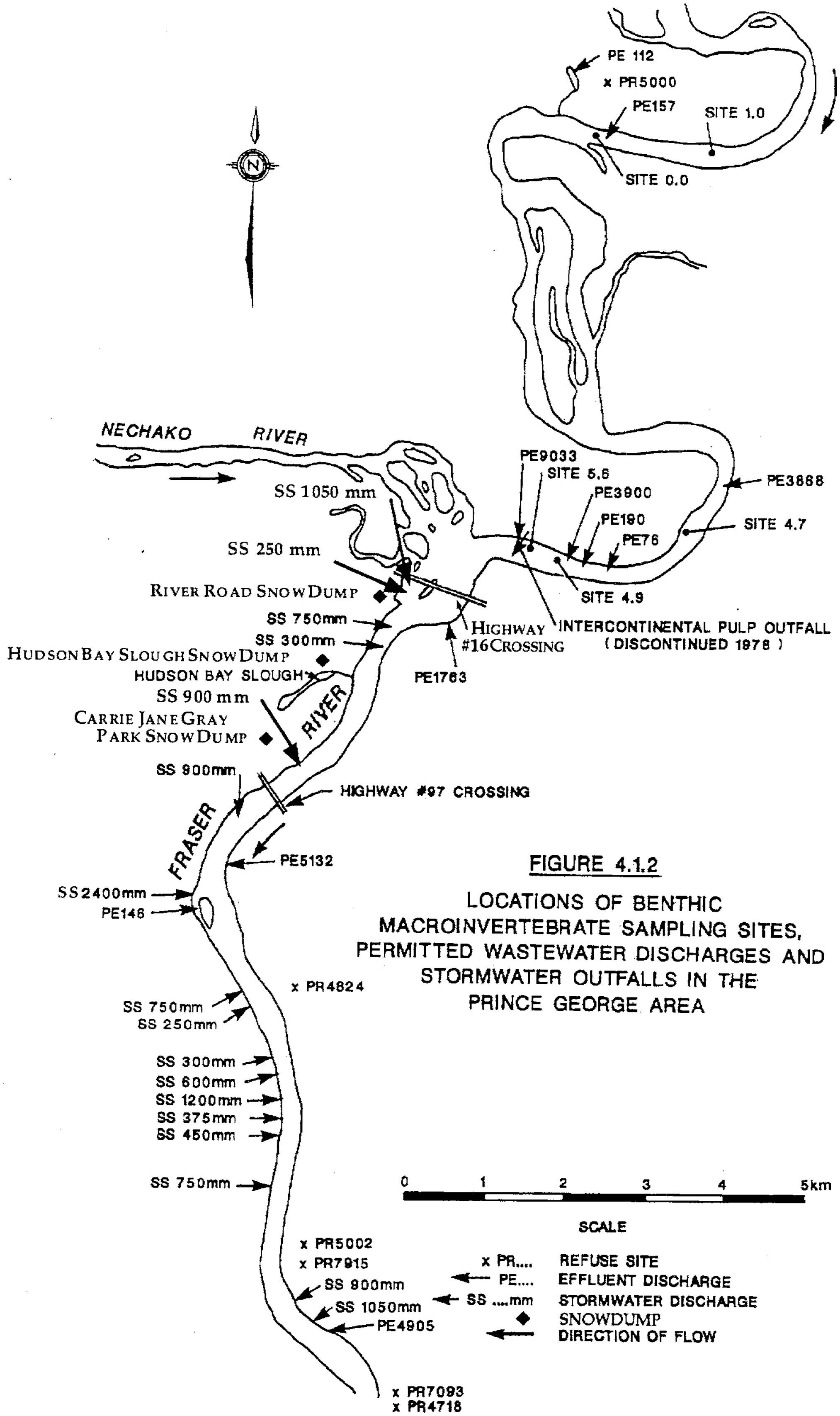


FIGURE 4.1.2

LOCATIONS OF BENTHIC MACROINVERTEBRATE SAMPLING SITES, PERMITTED WASTEWATER DISCHARGES AND STORMWATER OUTFALLS IN THE PRINCE GEORGE AREA

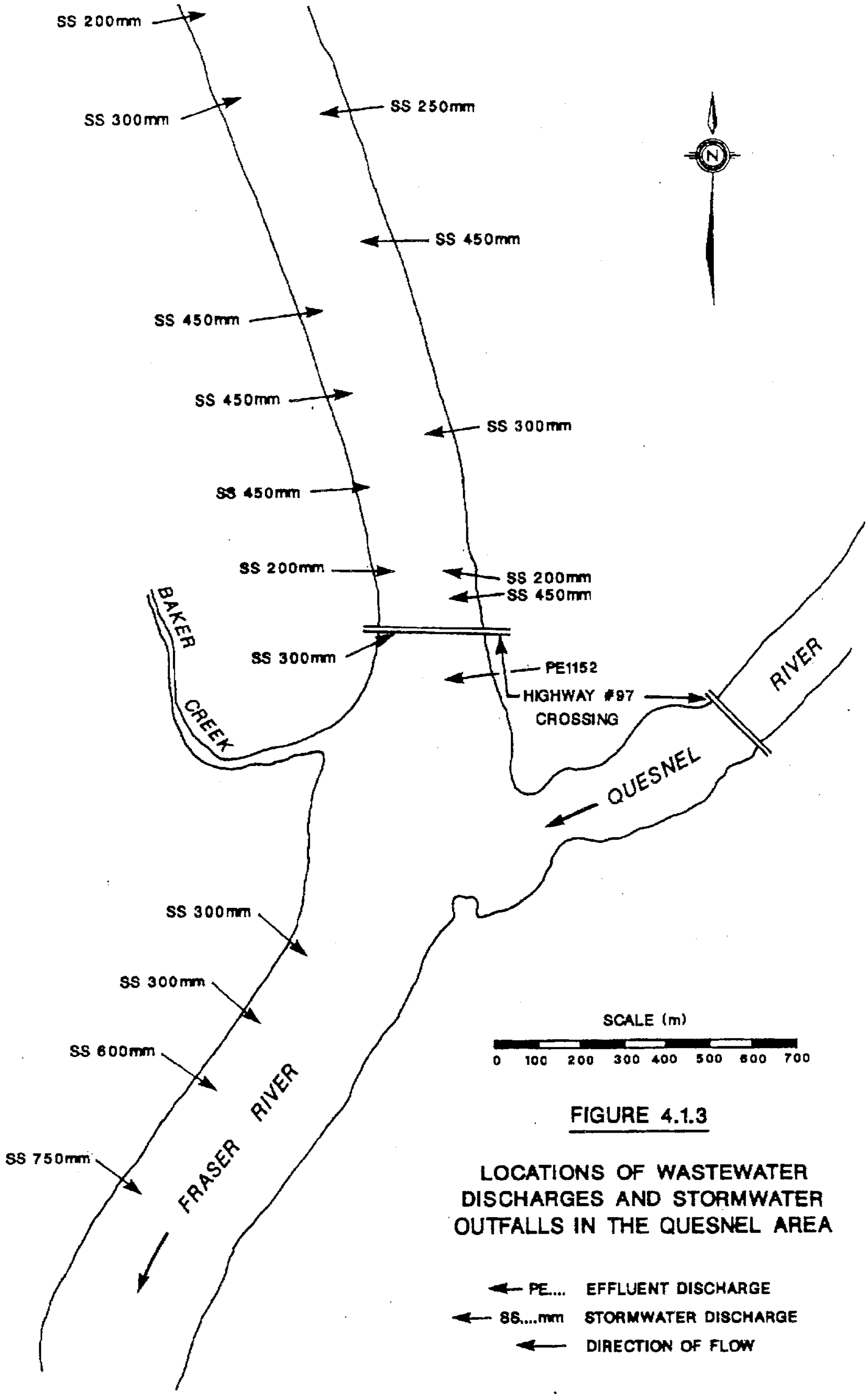


FIGURE 4.1.3

LOCATIONS OF WASTEWATER DISCHARGES AND STORMWATER OUTFALLS IN THE QUESNEL AREA

← PE.... EFFLUENT DISCHARGE
← SS....mm STORMWATER DISCHARGE
← DIRECTION OF FLOW

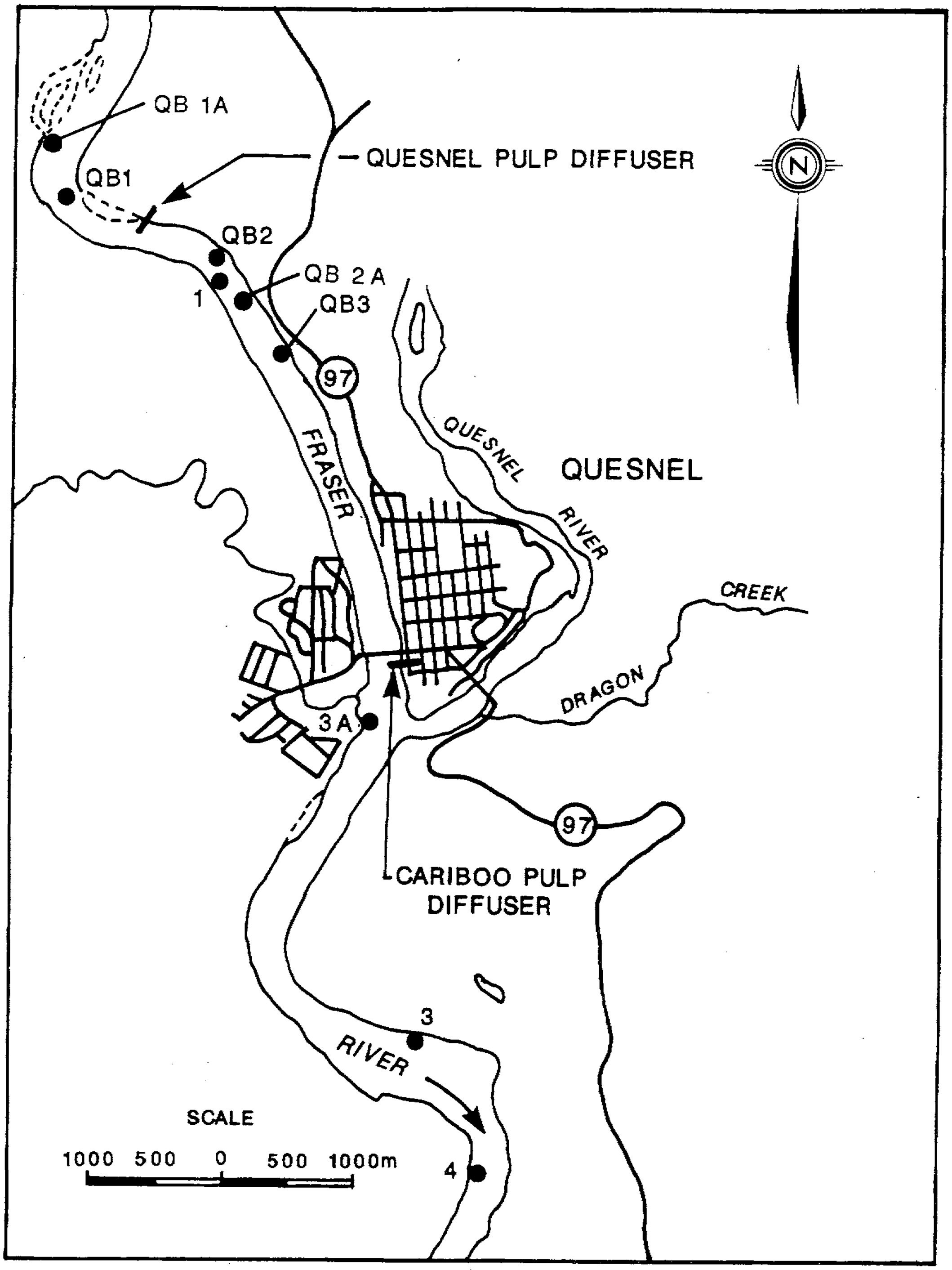


FIGURE 4.1.4 LOCATION FOR BENTHIC INVERTEBRATE STUDIES

FIGURE 6.1

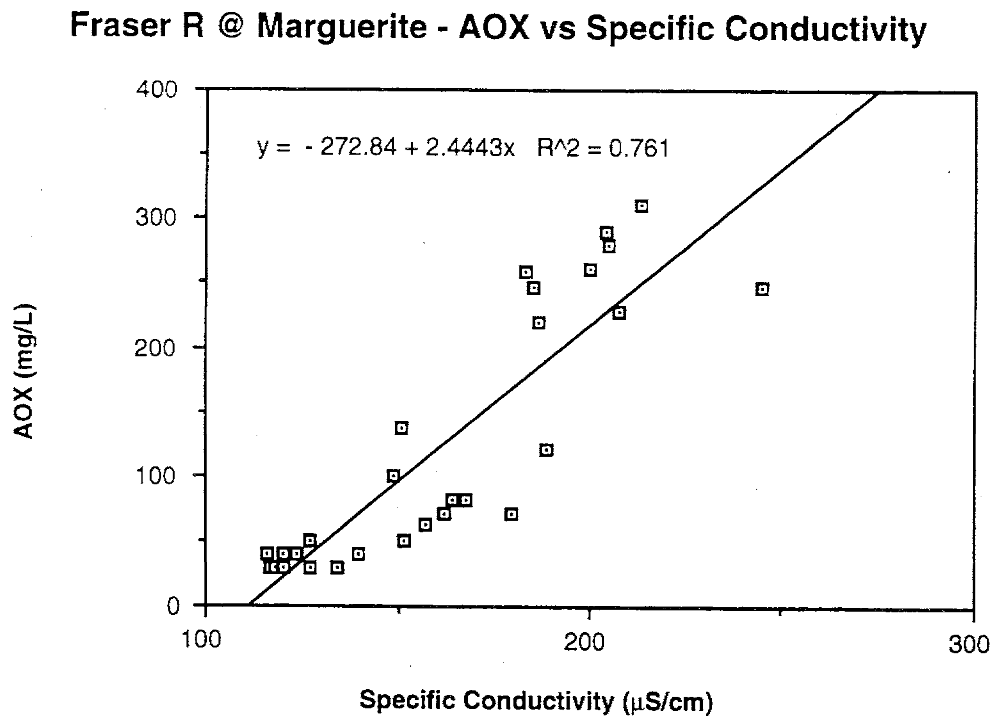


FIGURE 6.2

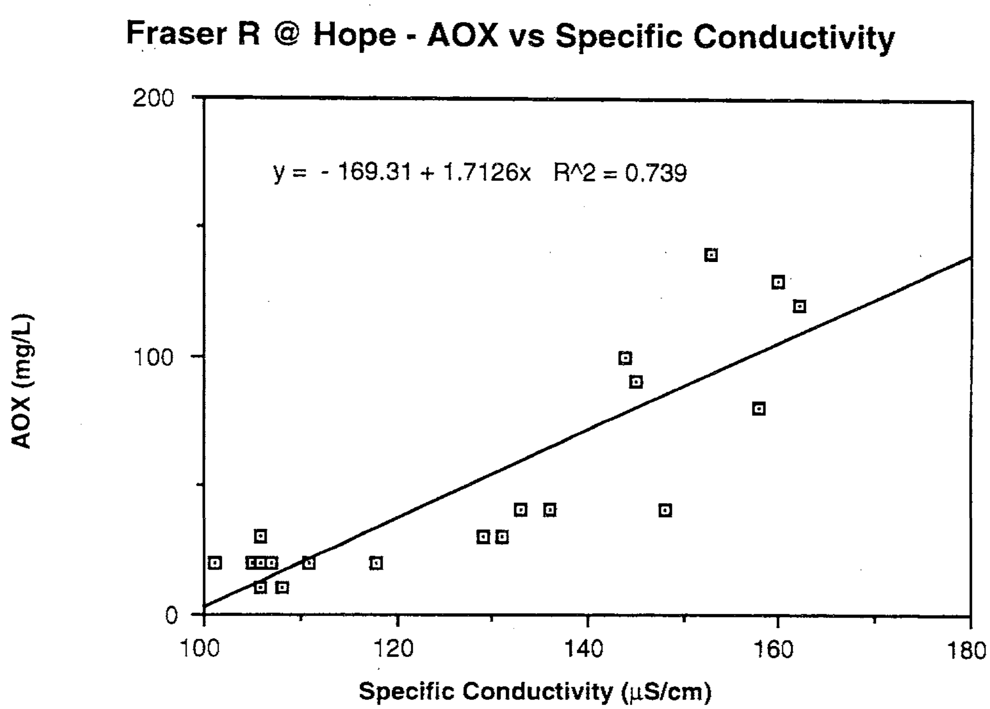


Table 3.1

Mean Annual Salmon Escapements To The Different Reaches of the Fraser River Since 1951

Year	Chinook	Chum	Coho	Pink	Sockeye
Reach 1 : Hope to Lillooet					
1951-1960	238	N/R	983	54 934	18 496
1961-1970	286	25	2 997	164 397	10 013
1971-1980	542	N/R	2 278	412 321	13 556
1981-1989	877	1 923	2 199	531 233	30 211
Reach 2 : Lillooet to Prince George					
1951-1960	2 630	N/R	N/R	N/R	320 119
1961-1970	7 015	N/R	N/R	N/R	346 361
1971-1980	9 403	N/R	N/R	N/R	342 927
1981-1989	17 291	N/R	166	797	718 686
Reach 3 : Nechako River System					
1951-1960	1 901	N/R	N/R	N/R	235 869
1961-1970	1 168	N/R	N/R	N/R	213 932
1971-1980	2 431	N/R	N/R	N/R	231 682
1981-1989	1 981	N/R	N/R	N/R	395 796
Reach 4 : Lower Thompson River					
1951-1960	8 952	N/R	4 455	178 557	N/O
1961-1970	5 347	N/R	3 162	257 552	N/O
1971-1980	5 552	N/R	1 345	575 488	N/O
1981-1989	5 958	N/R	2 041	192 862	2 334
Reach 5 : South Thompson River					
1951-1960	11 683	N/R	10 885	N/O	645 432
1961-1970	14 630	N/R	7 640	N/O	544 046
1971-1980	15 771	N/R	5 543	3 742	423 399
1981-1989	19 653	N/R	10 234	1 533	754 319
Reach 6 : North Thompson River					
1951-1960	4 650	N/R	6 350	N/O	9 077
1961-1970	4 650	N/R	7 470	N/O	6 543
1971-1980	4 353	N/R	6 846	493	8 122
1981-1989	7 869	N/R	6 786	19	15 044
Reach 7 : Fraser River and tributaries above Prince George					
1951-1960	6 478	N/R	N/R	N/R	14 541
1961-1970	4 507	N/R	N/R	N/R	8 608
1971-1980	7 275	N/R	N/R	N/R	11 168
1981-1989	20 041	N/R	N/R	N/R	6 221

N/R = NO RETURN

N/O = NO ENUMERATION

TABLE 4.1

SUMMARY OF EFFLUENT DISCHARGES TO THE FRASER RIVER

Reach : Tete Jaune Cache to Nechako R				
Name of Discharger	**Permit Number**	**Report Section**	**Discharge Type**	**Permitted Volume m^3/d**
Village of McBride	PE 402	4.2.1	Municipal	750
Northwood Upper Fraser	PE 2655	4.2.2	Municipal	273
Northwood Pulp & Paper	PE 157 PR 5000	4.2.3	Industrial	190,000 eff. 153 refuse
Northwood Prince George Spiragester	PE 112	4.2.4	Municipal	145
City of Prince George (P.G.)	PE 3868	4.2.5	Municipal	1250
CanFor P.G. Pulp &	PE 3900	4.2.6	Industrial	240,000 max
Intercontinental Pulp & Paper	PE 76		Municipal	432
B.C. Chemicals Limited	PE 190	4.2.7	Industrial	6500
FMC of Canada Limited	PE 9033	4.2.8	Industrial	7700

Reach : Nechako River Confluence to Hope				
Name of Discharger	**Permit Number**	**Report Section**	**Discharge Type**	**Permitted Volume m^3/d**
B.C. Buildings Corporation	PE 1763	4.3.1	Municipal	31.5
City of Prince George -BCR Industrial Park	PE 5132	4.3.2	Municipal	1400
City of Prince George	PE 146	4.3.3	Municipal	45,000
Northwood Pulp & Timber Ltd	PR 4824	4.3.4	Industrial	2600 m^3/a
Netherlands Overseas Mills	PR 5002	4.3.5	Industrial	15.3
Woodland Lumber Limited	PR 7915	4.3.6	Industrial	3120 m^3/a
City of Prince George Danson Lagoons	PE 4905	4.3.7	Municipal	1000
Prince George Wood Preserving Limited	PR 7093	4.3.8	Industrial	3600 m^3/a
Rustad Brothers & Co Ltd	PR 4718 cancelled	4.3.9	Industrial	cancelled
Carrier Lumber Ltd	PR 7092	4.3.10	Industrial	2300 m^3/a
Rustad Brothers & Co Ltd- World Wide Storage Ltd	PR 4850	4.3.11	Industrial	95
Quesnel River Pulp Company	PE 5803	4.3.12	Industrial	28,000
Cariboo Pulp and Paper	PE 1152	4.3.13	Industrial	118,200
City of Williams Lake	PE 255	4.3.14	Municipal	6820

eff = effluent
PE = effluent permit
PR = refuse permit

TABLE 4.2.1

EFFLUENT QUALITY DATA SUMMARY FOR McBRIDE (PE 402)

Characteristic	Number of Values	Maximum	Minimum	Mean	Std.Dev
Coliforms-fecal	14	1300000	240	37000+	-
Flow	13	882	196	430	190
Nitrogen-ammonia	3	7.19	0.366	4.05	3.44
Nitrogen-nitrate/nitrite	3	0.23	<0.02	0.11	0.11
Nitrogen-nitrite	3	0.22	0.012	0.093	0.112
Oxygen-dissolved	8	18.1	4	9.2	5.1
Oxygen-BOD5	17	58	<10	29.5	14
pH	16	9.8	5.6	7.35+	-
Solids-suspended	16	73	4	36.4	19.8
Specific Conductivity	12	540	388	445	44

PERIOD OF RECORD : 1985 - 1991

Values are as mg/L except:

1) Coliforms as MPN/100 mL

2.) Flow as m^3/d

3.)pH

4.)Specific Conductivity as µS/cm

Table 4.2.2

Effluent Data Summary - Northwood Pulp and Timber Spiragester Discharge (PE 112)

Characteristic	Number of Values	Maximum	Minimum	Mean	Std.Dev
Coliforms-fecal	27	79000	8	2400+	-
Flow	319	102.3	30	53.8	3.7
Oxygen-BOD5	34	28	3	14.2	6.6
Solids-suspended	34	38	3	16.4	7.9

PERIOD OF RECORD : 1985 - 1991

Values are as mg/L except:
1) Coliforms as MPN/100 mL
2.) Flow as m^3/d

SOURCE OF DATA: NORTHWOOD PULP AND PAPER SUBMISSIONS TO ENVIRONMENTAL PROTECTION, PRINCE GEORGE, PURSUANT TO PERMIT PE 112

Table 4.2.3

Effluent Data Summary - Northwood Pulp (PE 157)

Characteristic	Number of Values	Maximum	Minimum	Mean	Std.Dev
Abietic Acid	14	0.95	<0.001	0.122	0.275
Aluminum	2	0.64	0.55	0.60	-
B.O.D.5	19	122	15	51.3	23.7
Bromodichloromethane	8	<0.001	<0.001	<0.001	-
Bromoform	8	<0.001	<0.001	<0.001	-
Chloroform	8	0.083	<0.001	0.014	0.028
Chlorodibromomethane	8	<0.001	<0.001	<0.001	-
Colour - TAC	1	1200	1200	1200	-
Dehydroabietic Acid	14	3.1	<0.001	0.41	0.85
Isopimaric Acid	14	1.8	<0.001	0.28	0.55
Levo Pimaric Acid	14	0.16	<0.001	0.017	0.04
Microtox EC50 5 min	10	>100	22.7	84.2	26.1
Microtox EC50 15 min	1	>100	>100	>100	-
Neoabietic Acid	14	0.45	<0.001	0.052	0.124
Nitrogen - ammonia	6	0.202	0.063	0.051	0.021
Oil & Grease	1	15	15	15	-
Pentachlorophenol	8	0.058	0.0003	0.0135	0.024
pH	20	7.5	7.1	7.3+	-
Pimaric Acid	14	1.3	<0.001	0.194	0.383
Sandaraco Pimaric Acid	14	0.21	<0.001	0.023	0.059
Specific Conductivity	20	3900	2400	2944	391
Suspended Solids	20	658	59	173	123
Tetrachlorophenol	8	0.0048	0.0007	0.0020	0.0014
Trichlorophenol	6	0.011	<0.0001	0.006	0.005
Zinc	2	0.35	0.09	0.22	-

PERIOD OF RECORD: 1985 - 1991

All values are as mg/L except:

1.) Coliforms and Streptococcus as CFU/cL
2.) Microtox EC50 as %(V/V)
3.) pH
4.) Specific Conductivity as µS/cm

DATA SOURCE: MOE "SEAM" RETRIEVAL SYSTEM

TABLE 4.2.4
DIOXINS AND FURANS IN NORTHWOOD PULP AND PAPER EFFLUENT

(pg/L)	92.11.26	91.12.16
T4CDD - TOTAL	<1.5	<1.8
2,3,7,8,	NDR(5.0)	NDR(5.9)
P5CDD - TOTAL	<1.8	<1.3
1,2,3,7,8,	<1.8	NDR(3.0)
H6CDD - TOTAL	11	25
1,2,3,4,7,8	<3.4	<3.5
1.2.3.6.7.8	NDR(4.8)	8.2
1.2.3.7.8.9	<3.4	4.6
H7CDD - TOTAL	46	44
1.2.3.4.6.7.8	46	26
O8CDD	NDR(460)	210
T4CDF - TOTAL	68	53
2,3,7,8	19	18
P5CDF - TOTAL	6.6	7.4
1,2,3,7,8	2.4	2.4
2,3,4,7,8	<1.8	<2.0
H6CDF - TOTAL	13	6.7
1,2,3,4,7,8	7.5	NDR(4.2)
1,2,3,6,7,8	5.3	3.6
2,3,4,6,7,8	<3.3	<2.2
1,2,3,7,8,9	<3.3	<2.2
H7CDF - TOTAL	39	8
1,2,3,4,6,7,8	12	8
1,2,3,4,7,8,9	<5.5	<2.2
O8CDF	64	21
Total TEQ	9.654	7.326

SURROGATE STANDARD RECOVERY

13C-T4CDD	70	85
13C-T4CDF	67	77
13C-P5CDD	73	80
13C-H6CDD	68	73
13C-H7CDD	74	76
13C-O8CDD	67	52

NDR means the peak was detected but did not meet quantification criteria

Table 4.2.5
Summary of Permit Data For Northwood Pulp and Paper

Monthly Flow - m^3/d

Month	1993	1992	1991	1990	1989	1988	1987	1986	1985
January	168800	146700	135700	146000	144300	145548	136200	144938	150830
February	172400	142300	153800	138980	149800	145300	148200	144389	155464
March	153000	148200	151500	146150	134000	139949	146420	141063	142387
April	158100	143900	129900	121107	138800	128150	136107	119107	138159
May	176900	159700	149800	153800	155300	157084	141430	148623	151065
June	170900	76200	143600	159900	164070	152500	152783	149020	160310
July	180200	67600	165200	159989	161950	155600	160406	155013	143333
August	150500	173400	162100	151482	165900	158800	155545	132320	157890
September	125800	153900	123300	123400	161100	153800	155040	154790	151217
October	155100	134100	134200	116800	139780	130700	109100	135180	91535
November	153100	140100	126400	94450	151000	142500	137790	121400	143930
December	143200	167100	127800	126600	150400	139500	139300	124230	110420
Mean	159000	137765	141966	134211	151354	145807	143128	139164	141186

Total Suspended Solids - kg/d

Month	1993	1992	1991	1990	1989	1988	1987	1986	1985
January	11527	8514	12077	16367	15584	18333	13187	16317	20411
February	10452	8823	11381	10145	19427	18368	17060	19480	30642
March	10171	9395	9999	11760	23943	23927	18975	19706	22059
April	10241	11080	9743	19579	16323	16112	16084	15463	25201
May	9257	11367	8008	19458	10816	17794	13772	17119	11078
June	9018	4653	8329	15530	14062	27371	10653	17676	8895
July	11572	3618	8764	16176	21918	24052	15543	24197	8267.5
August	8633	10351	8899	18510	17746	14073	18151	15884	11686
September	5237	10818	7992	7951	21828	15698	15683	18515	10120
October	8539	10744	9667	3419	17262	13488	8897	16631	6153
November	9137	9917	6320	4490	16235	21011	13608	9779	16604
December	7678	11245	7190	12220	16576	22947	17543	9920	15318

Table 4.2.5 (Continued)

BOD5-kg/d Month	1993	1992	1991	1990	1989	1988	1987	1986	1985
January	7609	4841	13434	8510	9050	7015	10127	13899	10457
February	6703	5254	4768	6172	8863	9414	13631	10766	13752
March	7056	5872	5909	6147	11088	10262	14145	11380	12941
April	5722	5468	5846	11019	7573	7166	8007	8687	12418
May	4882	5290	4231	6130	6341	8722	7215	9982	6024
June	3993	1477	4021	5915	7290	14255	5867	11135	5346
July	6139	1289	5681	5433	10347	11417	6162	15878	6080
August	4267	6387	4530	8469	7935	7107	7350	9207	5555
September	3419	6304	3848	6791	11298	7130	5887	11583	5308
October	6364	4950	4419	8284	11529	6865	4971	8696	6985
November	5542	5855	7331	7089	17749	21900	7318	7915	8907
December	5518	6998	4260	5355	8692	14901	8368	7005	8537

AOX-kg/ADt MONTH	1993	1992	1991	1990	1989
January	0.84	1.23	3.74	4.41	-
February	0.82	1.46	4.01	4.70	-
March	2.2	1.15	12.2	4.37	-
April	0.55	1.17	4.26	2.15	-
May	1.1	1.35	2.64	3.24	-
June	0.82	0.50	2.38	3.21	-
July	0.24	0.23	1.78	3.87	2.85
August	0.13	1.27	0.86	2.56	3.00
September	0.41	1.03	1.21	2.27	3.45
October	0.42	1.14	1.95	3.40	3.05
November	0.45	0.43	1.35	2.60	4.15
December	0.44	1.17	1.35	3.20	3.40
Mean	0.70	1.01	3.14	3.28	3.32

AOX kg/d Month	1993	1992	1991	1990	1989
January	1148	1848	3243	3442	-
February	1327	2177	5597	6495	-
March	1375	1675	5026	1921	-
April	775	1425	3454	1634	-
May	1150	1996	3430	4180	-
June	1008	442	3046	3667	-
July	324	230	2652	6628	4133
August	135	1925	1058	3247	3849
September	352	1570	1391	2127	4457
October	620	858	1190	3040	3532
November	597	616	1770	3000	3366
December	530	919	1689	4646	4019
Mean	778	1307	2777	3590	3892

Table 4.2.5 (Continued)

Mean Monthly Dissolved Oxygen (mg/L)

Month	1993	1992	1991	1990	1989	1988	1987	1986	1985
January	4.6	3.2	5.0	3.0	3.9	3.9	2.9	4.5	5.0
February	3.2	3.2	3.7	4.4	3.5	3.3	3.6	2.7	2.3
March	3.3	2.8	3.5	3.4	3.1	2.7	3.7	2.6	4.0
April	3.3	3.4	3.4	3.8	3.4	3.4	4.4	4.2	4.5
May	2.3	1.7	3.1	3.3	3.4	2.6	3.0	1.9	2.9
June	3.1	2.9	3.4	3.7	3.1	2.3	3.1	2.1	2.9
July	1.9	6.0	3	3.4	2.6	2.4	2.7	1.5	3.4
August	1.9	3.4	2.5	2.9	2.6	2.9	2.5	2.5	3.6
September	1.5	3.7	4.3	4.2	2.5	3.2	3.0	1.8	2.9
October	1.1	4.8	3.8	3.6	3.2	3.7	4.3	2.6	3.6
November	2.0	4.9	4.6	7.1	3.3	2.5	4.5	3.4	4.0
December	3.8	5.1	4.5	4.1	3.7	3.9	3.0	5.0	4.6
Mean	2.7	3.8	3.7	3.8	3.2	3.1	3.4	2.9	3.7

Mean Monthly pH

Month	1993	1992	1991	1990	1989	1988	1987	1986	1985
January	7.6	7.3	7.5	7.3	7.5	7.2	7.3	7.4	7.6
February	7.8	7.5	7.3	7.4	7.4	7.1	7.3	7.2	7.3
March	7.9	7.5	7.2	7.3	7.4	7.2	7.3	7.4	7.5
April	7.6	7.4	7.4	7.2	7.4	7.3	7.2	7.8	7.6
May	7.6	7.5	7.3	7.3	7.2	7.1	7.1	7.4	7.7
June	7.6	7.7	7.4	7.1	7.1	7.2	7.1	7.2	7.6
July	7.6	7.7	7.3	7.3	7.1	7.3	7.1	7.3	7.5
August	7.0	7.6	7.4	7.5	7.3	7.4	6.9	7.3	7.3
September	8.0	7.5	7.5	7.6	7.2	7.3	7.2	7.3	7.3
October	8.0	7.4	7.4	7.4	7.8	7.5	7.4	7.4	7.8
November	8.0	7.4	7.7	7.7	7.5	7.3	7.3	7.3	7.3
December	8.0	7.6	7.6	7.5	7.3	7.4	7.1	7.4	7.4
Mean	7.7	7.5	7.4	7.2	7.4	7.3	7.2	7.4	7.5

Table 4.2.5 (Continued)

BOD5-kg/ADt

Month	1993	1992	1991	1990	1989	1988	1987	1986	1985
January	5.43	3.21	17.22	6.16	6.85	4.87	7.23	10.55	8.36
February	4.15	3.50	3.45	5.37	6.03	6.42	9.72	8.38	11.56
March	13.3	4.10	13.43	4.65	8.38	6.99	9.87	9.52	11.99
April	3.92	4.47	7.67	10.39	6.06	4.34	6.57	15.46	10.81
May	4.61	3.57	3.25	4.94	4.63	6.27	5.86	7.47	4.62
June	3.19	1.63	3.51	4.21	5.12	9.90	3.58	8.18	3.72
July	2.01	1.21	3.37	3.75	7.23	7.65	4.88	12.00	5.38
August	1.60	4.01	2.43	6.60	5.35	4.84	4.98	6.79	3.95
September	1.46	4.74	3.42	6.15	7.75	5.29	4.33	7.69	4.07
October	2.20	5.34	4.65	2.95	10.62	5.91	4.91	7.73	6.33
November	4.30	4.08	6.24	8.74	12.82	17.06	6.34	7.34	6.99
December	4.48	8.73	2.64	4.53	6.55	10.37	5.63	6.98	6.78
Mean	4.22	4.05	5.97	5.58	7.28	7.48	6.14	9.01	7.02

Total Suspended Solids - kg/ADt

Month	1993	1992	1991	1990	1989	1988	1987	1986	1985
January	8.14	5.65	15.48	11.84	11.79	12.73	9.41	12.39	16.32
February	6.38	5.90	8.24	8.83	13.21	12.52	12.17	15.17	25.75
March	19.1	6.50	22.73	8.90	18.10	16.29	13.24	16.48	20.44
April	7.39	8.82	12.79	18.45	13.06	9.75	13.21	27.51	21.93
May	9.55	7.69	6.15	15.58	7.90	12.78	11.19	12.80	8.50
June	7.49	5.24	6.90	11.05	9.88	19.01	6.50	12.99	6.19
July	6.29	3.30	6.07	11.25	15.32	16.12	12.31	18.29	7.32
August	5.09	6.19	5.23	14.43	11.97	9.58	12.30	11.71	8.31
September	4.38	8.00	6.97	5.25	14.97	11.64	11.54	12.29	7.76
October	4.19	11.8	7.66	6.53	15.90	11.61	8.79	14.78	5.58
November	4.89	6.89	6.79	5.24	11.72	16.36	11.78	9.06	13.03
December	6.36	14.3	4.40	9.40	12.49	15.97	11.81	9.89	12.16
Mean	7.44	7.52	9.13	10.35	13.03	13.70	11.18	14.43	12.67

TABLE 4.2.6

EFFLUENT DATA SUMMARY FOR PRINCE GEORGE (PE 3868)

Characteristic	Number of Values	Maximum	Minimum	Mean	Std.Dev
Chloride	3	63.2	49.7	58.5	7.6
Coliforms-fecal	33	20000	0	3000+	-
Flow (average)	30	1132	239	491	223
Oxygen-B.O.D.5	37	44	8	16.4	8.8
Oxygen-dissolved	6	9.9	0.5	4.9	3.9
Nitrogen-ammonia	4	9.23	0.13	6.7	4.4
Nitrogen-nitrate/nitrite	4	8.61	1.44	4.62	3.07
Nitrogen-nitrite	4	1.58	0.26	0.71	0.61
pH	16	8.4	6.8	8.1+	-
Solids-suspended	39	54	3	16	10.9
Specific Conductivity	15	1150	820	1014	100
Temperature	7	20	2	14	7.6

PERIOD OF RECORD : 1985 - 1991

\+ MEDIAN VALUE

Values are as mg/L except:

1.)Coliforms as CFU/cL
2.)Flow as m^3/d
3.)pH
4.)Specific Conductivity as μS/cm
5.)Temperature as ^oC

DATA SOURCE: MOE "SEAM" RETRIEVAL SYSTEM

Table 4.2.7
Effluent Data Summary - Prince George Pulp and Intercontinental Pulp (PE 3900)

Characteristic	Number of Values	Maximum	Minimum	Mean	Std.Dev
Abietic Acid	14	0.21	<0.001	0.066	0.068
B.O.D.5	37	133	12	55.1	23.7
Bromodichloromethane	11	<0.001	<0.001	<0.001	-
Bromoform	11	<0.001	<0.001	<0.001	-
Chloroform	11	0.009	<0.001	<0.001+	-
Chlorodibromomethane	11	<0.001	<0.001	<0.001	-
Coliform - fecal	5	410	4	9+	-
Coliform - streptococcus	1	30	30	30	-
Dehydroabietic Acid	14	0.57	<0.001	0.17	0.17
Isopimaric Acid	14	0.29	<0.001	0.094	0.087
Levo Pimaric Acid	14	0.16	<0.001	0.04	0.056
Neoabietic Acid	14	0.081	<0.001	0.017	0.022
Pentachlorophenol	1	0.07	0.07	0.07	-
pH	37	7.5	6.7	6.9+	-
Pimaric Acid	14	0.19	<0.001	0.056	0.057
Sandaraco Pimaric Acid	14	0.026	<0.001	0.007	0.007
Solids - dissolved	38	245	53	142	39.4
Specific Conductivity	38	2600	1350	2178	257
Tetrachlorophenol	1	0.0051	0.0051	0.0051	-

PERIOD OF RECORD: 1985 - 1991

\+ Median Value

All values are as mg/L except:

1.) Coliforms and Streptococcus as CFU/cL

2.) Microtox EC50 as %(V/V)

3.) pH

4.) Specific Conductivity as µS/cm

DATA SOURCE: MOE "SEAM" RETRIEVAL SYSTEM

TABLE 4.2.8
SUMMARY OF DIOXINS AND FURANS IN THE EFFLUENT FROM PRINCE GEORGE AND INTERCONTINENTAL PULP AND PAPER

	Maximum	Minimum	Mean	Std. Dev.
T4CDD - TOTAL	160	9.1	75.7	67.1
2,3,7,8,	140	9.1	56.6	48.6
P5CDD - TOTAL	38	ND	31.5	7.0
1,2,3,7,8,	25	ND	16.0	6.6
H6CDD - TOTAL	180	47	107.3	50.4
1,2,3,4,7,8	4.1	ND	–	–
1,2,3,6,7,8	26	7.3	15.0	6.5
1,2,3,7,8,9	17	ND	12.9	3.9
H7CDD - TOTAL	98	ND	45.8	30.6
1,2,3,4,6,7,8	63	ND	26.2	21.1
O8CDD	430	ND	120.4	173.2
T4CDF - TOTAL	670	84	329.7	224.4
2,3,7,8	300	31	134.7	99.4
P5CDF - TOTAL	96	ND	57.2	31.4
1,2,3,7,8	15	ND	10.0	3.4
2,3,4,7,8	7.7	ND	5.1	1.8
H6CDF - TOTAL	14	ND	–	–
1,2,3,4,7,8	2	ND	–	–
1,2,3,6,7,8	ND	ND	–	–
2,3,4,6,7,8	ND	ND	–	–
1,2,3,7,8,9	ND	ND	–	–
H7CDF - TOTAL	33	ND	12.3	13.9
1,2,3,4,6,7,8	18	ND	–	–
1,2,3,4,7,8,9	ND	ND	–	–
O8CDF	23	ND	–	–
TOTAL TEQ	204.5	15	93.1	81.5
SURROGATE STANDARD RECOVERY				
13C-T4CDD	96	68	83.4	9.8
13C-T4CDF	102	67	81.1	11.5
13C-P5CDD	96	72	88.1	9.2
13C-H6CDD	91	69	79.7	8.4
13C-H7CDD	99	55	73.3	15.2
13C-O8CDD	86	36	54.3	19.7

Table 4.2.9
Effluent Data Summary
Prince George and Intercontinental Pulp and Paper

Flow m3/d Month	1993	1992	1991	1990	1989	1988	1987	1986	1985
January	136630	147179	116402	142734	145188	142160	135395	134900	145944
February	139056	142695	136585	133107	138951	145647	147994	140408	146514
March	102066	140086	132309	139070	136129	144116	145646	126656	145553
April	148569	142804	117986	127378	124767	133050	136799	114049	141358
May	146768	147380	134370	114262	137234	149860	140851	122835	132978
June	161026	155602	144293	145107	157750	158127	153974	156254	149319
July	164719	157992	156618	115018	161202	154940	160257	155295	153551
August	95038	168513	156618	116095	166879	151055	161085	148138	148574
September	126085	169679	156618	93222	162042	151063	145595	124030	133964
October	136345	169679	147103	132940	141028	141682	141357	112519	140784
November	143058	163028	142925	138393	150058	147018	156102	140578	144813
December	140800	136357	139454	117301	139205	131319	147341	143446	125756
Mean	136680	139844	140107	126219	146703	145836	147700	134926	142426

Suspended Solids kg/d Month	1993	1992	1991	1990	1989	1988	1987	1986	1985
January	8820	12805	8795	8840	10430	10910	11880	10210	11420
February	12590	14555	13172	10800	11560	11830	13130	12240	13810
March	5470	15269	13795	11690	10730	12064	16890	12520	13300
April	10880	13566	13656	9660	11690	11600	13240	10310	12850
May	11150	10906	12995	7910	8620	12190	12250	9530	7330
June	12310	13537	13303	11050	12940	13110	11850	13740	9240
July	11130	7742	14096	6830	14800	12690	11800	14750	12620
August	6470	11796	11833	9280	13110	13480	13360	14520	11660
September	11600	12896	13748	5910	10860	12940	10550	13830	9900
October	9740	13744	16733	8060	9200	13260	11080	13460	11710
November	12343	10976	15087	8430	11830	12420	11300	10940	11320
December	9375	8410	14100	9540	9080	10610	10680	12120	11490

Table 4.2.9
(Continued)

Average BOD5 kg/d	1993	1992	1991	1990	1989	1988	1987	1986	1985
January	5940	5446	5335	6040	5610	6200	8120	6400	7860
February	8180	5280	3866	6060	8460	9580	9720	7490	6050
March	3100	5884	3414	7420	4320	10820	7750	8190	5200
April	3720	5569	2703	4570	4300	11230	8380	9110	4180
May	4860	5748	2658	2240	3420	6010	7480	5270	5430
June	5020	7002	3205	6170	5552	8790	7550	4020	4950
July	7320	4424	4176	2240	7420	7250	8460	6270	9210
August	3600	5898	4525	3700	5680	9710	8330	4860	6760
September	4530	5090	2610	2130	6020	8460	4650	4350	12210
October	5380	6278	4142	3290	5560	10150	8970	6050	6940
November	5068	7372	4605	3700	7370	13090	9880	6460	6520
December	5120	5430	7438	4670	5740	4750	5360	8170	7560

Monthly Mean pH	1993	1992	1991	1990	1989	1988	1987	1986	1985
January	7.3	7.3	7.4	7.0	6.9	6.9	6.7	6.8	6.9
February	7.3	7.2	7.2	7.0	6.9	6.7	6.6	6.6	6.9
March	7.2	7.2	7.2	6.9	6.7	7.0	6.8	6.7	6.8
April	7.3	7.1	7.3	7.0	6.9	7.0	6.9	6.7	6.9
May	7.4	7.3	7.2	7.1	7.2	6.9	7.1	6.8	6.8
June	7.2	7.4	7.0	7.0	7.0	6.9	7.0	6.7	6.7
July	7.3	7.5	7.1	7.3	6.9	7.1	7.0	6.6	6.7
August	7.2	7.3	7.2	7.1	6.9	7.0	6.8	6.6	6.7
September	7.3	7.2	7.5	7.0	6.9	7.2	6.9	6.9	6.9
October	7.3	7.1	7.4	6.9	6.9	6.9	6.8	7.0	6.7
November	7.4	7.2	7.3	7.1	6.8	7.1	6.8	7.0	6.6
December	7.3	7.2	7.1	7.2	6.9	7.0	6.8	6.7	6.6
Mean	7.3	7.4	7.2	7.1	6.9	7.0	6.9	6.8	6.8

Dissolved Oxygen mg/L	1993	1992	1991	1990	1989	1988	1987	1986	1985
January	5.0	4.9	5.2	4.6	4.9	6.1	5.9	5.5	5.5
February	4.6	5.2	4.4	6.0	4.5	5.9	5.2	5.0	5.2
March	5.9	5.0	4.1	5.7	5.3	5.3	5.3	4.5	3.8
April	5.8	4.4	5.3	6.3	6.3	4.3	4.4	4.2	3.9
May	4.6	4.8	5.4	5.1	5.6	4.3	5.1	4.8	4.4
June	4.7	5.5	5.1	4.2	5.1	4.4	4.8	5.0	3.3
July	4.2	6.2	5.3	4.3	4.6	4.0	4.1	4.9	3.3
August	4.4	4.7	4.8	5.3	4.4	4.6	4.3	4.9	4.0
September	6.0	5.1	5.3	7.4	4.3	4.9	4.6	5.1	5.4
October	5.3	5.0	5.3	6.9	4.5	5.2	5.0	5.8	4.6
November	6.4	4.7	5.9	6.8	4.7	5.8	5.1	6.4	6.1
December	5.3	5.2	5.3	5.2	5.3	4.9	5.9	5.8	6.5
Mean	5.2	5.1	5.1	5.7	5.0	5.0	5.0	5.2	4.7

Table 4.2.9
(Continued)

RESIN ACIDS (mg/L)

Month	1993	1992	1991	1990	1989
January	1.90	2.14	1.43	2.50	
February	2.19	2.19	1.14	2.63	8.57
March	1.57	1.71	1.33	3.36	2.74
April	1.87	1.33	1.40	2.41	2.58
May	1.44	1.76	0.94	1.94	2.76
June	2.11	2.11	1.20	2.44	2.20
July	2.38	0.93	1.25	1.47	2.90
August	1.99	1.49	1.59	1.45	3.50
September	2.60	1.52	1.04	1.13	2.50
October	2.63	1.88	1.61	1.21	2.50
November	2.34	2.56	1.66	1.38	2.20
December	2.05	2.28	2.25	1.54	2.60
Mean	2.09	1.83	1.40	1.96	3.19

AOX (mg/L)

Month	1993	1992	1991	1990
January	7	10	22.0	30.0
February	6	10	33.0	28.0
March	6	6	28.0	32.0
April	6	11	27.0	27.0
May	6	6	20.0	25.5
June	6	9	20.0	28.0
July	7	7	15.0	15.7
August	7	6	6.0	20.0
September	6	7	6.0	20.5
October	6	7	6.0	18.5
November	6.7	5	6.0	25.0
December	5.6	7	13.0	38.5
Mean	6.3	8	16.8	25.7

TABLE 4.2.10

SUMMARY OF AOX DATA FOR THE EFFLUENTS FROM THE TWO PRINCE GEORGE AREA PULP MILL DISCHARGES : 1989 - 1991

CANFOR YEAR	AOX mg/L	AOX kg/d	AOX kg/t/d	FLOW m3/d
1989	27.6	4026	2.93	147597
1990	25.4	3476	3.01	132208
1991	16.3	2213	1.85	135344
AVERAGE - 89/91	20.2	2784	2.29	136506

NORTHWOOD YEAR	AOX mg/L	AOX kg/d	AOX kg/t/d	FLOW m3/d
1989	28.6	4418	3.56	154600
1990	28.1	4263	6.08	149576
1991	18.7	2698	2.48	141546
AVERAGE - 89/91	22.9	3407	3.68	145823

TOTAL - PR. GEO. YEAR		AOX kg/d		FLOW m3/d
1989		8444		302197
1990		7740		281784
1991		4911		276891
AVERAGE - 89/91		6191		282329

Table 4.2.11

EFFLUENT DATA SUMMARY FOR THE FMC EQUALIZATION POND OVERFLOW

Characteristic	Maximum	Minimum	Mean	Std.Dev
Chlorine Residual	<0.2	<0.1	<0.1+	-
Flow	4285	1825	2959	834
Hydrogen Peroxide	74.3	4.5	27.9	19.9
pH	7.9	7.1	7.4+	-
Suspended Solids	18.8	3.3	7.8	4.3
Temperature	20.5	0.8	10.0	7.0
Total Organic Carbon	28.4	13.3	18.3	4.4

+ Median Value

Values are monthly averages

Data are as mg/L except:

1.) Flow as m^3/d

2.) pH

3.) Temperature as ^oC

Values were reported by FMC to B.C. Ministry of Environment, Lands and Parks

Table 4.2.12
TAXONOMIC SUMMARY OF INVERTEBRATES SAMPLED IN THE FRASER RIVER NEAR PRINCE GEORGE, 1972-1989

EPHEMEROPTERA	
F. Heptageniidae	F. Ephemerellidae
Rithrogena sp.	*Ephemerella* (*Ephemeralla*) *inermis*
Heptagenia sp.	*Ephemerella doddsi*
Cinygma sp.	*Ephemerella spinifera*
Heptageniidae - damaged or unid.	*Ephemerella walkeri* (*fuscata*)
F. Baetidae	*Ephemerella proserpina*
Baetis sp.	*Ephemerella infrequens*
F. Siphlonuridae	*E.* (*Drunella*)*grandis grandis*
Ameletus sp.	*Ephemerella* sp.
F. Leptophlebiidae	F. Ametropodidae
Paraleptophlebia sp.	*Ametropus ammophilus*
Leptophlebiidae - damaged	*Ametropus* sp.

TRICHOPTERA	
F. Brachycentridae	F. Hydropsychidae
Brachycentrus sp.	*Arctopsyche grandis*
F. Lepidostomatidae	*Arctopsyche* sp.
Lepidostoma sp.	*Hydropsyche* sp.
F. Glossosomatidae	F. Rhyacophilidae
Glossosoma sp.	*Rhyacophila* sp.
Glossosomatidae - unid.	F. Limnephilidae
	Homophylax sp.

PLECOPTERA	
Arcynopteryx sp.	*Amphinemoura* sp.
Podmosta sp.	F. Taeniopterygidae
F. Capniidae	*Taenionema* sp.
Capnia sp.	F. Pteronarcyidae
F. Nemouridae	*Pteronarcella badia*
Malenka sp.	*Pteronarcella regularis*
Nemoura sp.	*Pteronarcella* sp.
Zapada (*columbiana*)	*Pteronarcys* sp.
F. Perlodidae	F. Perlidae
?*Skwala* sp.	*Hesperoperla pacifica*
Isogenoides sp.	F. Cholorperlidae
Isoperla sp.	*Paraperla* sp.
Cultus sp.	*Sweltsa* Gp.
	Utaperla sp.
	S.F. Chloroperlinae - unid.

HYDRACARINA
Hygrobates sp.
Libertia sp.

Table 4.2.12
(CONTINUED)

ACARI - unid.
OSTRACODA - unid.
COLEOPTERA
F. Elmidae
Heterlimnius sp.
Polyphaga sp.

COPEPODA
F. Cyclopoidae
Paracyclops sp.
Cyclops sp.
Eucyclops sp.
Cyclopoidae - unid.

DIPTERA	
F. Chironomidae	F. Chironomidae
S.F. Tanypodinae	S.F. Chironominae
Procladius sp.	*Chironomus* (*Chironomus*); *t*
	humni (=*riparius*) group
Ablabesmyia sp.	*Polypedilum* sp.
Tanypus sp.	*Stictochironomus* sp.
Nilotanypus fimbriatus	*Paracladopelma* sp.
Pentaneura sp.	*Phaenopsectra* sp.
?*Thienemannimyia* sp.	*Tanytarsus* sp.
S.F. Chironominae - unid.	*Rheotanytarsus* sp.
Polypedilum sp.	*Micropsectra* sp.
Polypedilum (*Fallax*) sp.	*Robackia demeijeri*
Microtendipes pedellus	*Cyphomella* sp.
Chironomus sp.	*Glyptotendipes* sp.
Rheotanytarsus sp.	*Constempelina* sp.
Glypotendipes sp.	*Cryptochironomus* sp.
Tribelos sp.	*Harnischia* sp.
C. (*Endochironomus*) sp.	S.F. Diamesinae
Pseudochironomus sp.	*Monodiamesa bathyphila*
C. (*Cryptochironomus*) *nais* sp.	*Diamesa* sp.
Tanytarsini sp.	*Syndiamesa pertinax*
S.F. Prodiamesinae	*Pseudodiamesa* sp.
Prodiamesa sp.	*Syndiamesa pertinax* sp.
Monodiamesa sp.	S.F. Orthocladiinae
	Orthocladius (*Orthocladius*) or
	Cricotopus (*Cricotopus*) sp.
S.F. Orthocladiinae	*Brillia* sp.
Psectrocladius sp.	*Corynoneura* sp.

Table 4.2.12
(CONTINUED)

DIPTERA (Continued)	
?*Limnophyes* sp.	*Heterotrissocladius* sp.
Gymnometriocnemus sp.	?*Parakiefferiella* sp.
Cardiocladius sp.	*Krenosmittia* sp.
Symbiocladius sp.	*Cricotopus* sp
Thienemanniella sp.	*Eukiefferiella* sp.
S.F. Orthocladiinae - unid.	F. Empididae
Nanocladius sp.	*Chelifera* sp.
Cardiocladius sp.	*Clinocera* sp.
Trichocladius sp.	*Hemerodromia* sp.
Metriocnemus sp.	Empididae - unid
Orthocladius sp.	F. Tanyderidae
Diplocladius sp.	*Protanyderus margarita*
Paraphaenocladius sp.	F. Tabanidae
Chironomidae sp.	*Tabanus* sp.
Orthocladiinae - damaged	F. Tipulidae
F. Rhagionidae	*Antocha* sp.
Atherix variegata	*Hexatoma* sp.
F. Blepharoceridae	*Limnophila* sp.
Agathon sp.	*Dicranota* sp.
Blepharcocera sp.	Tipulidae - unid.
F. Ceratopogonidae	F. Simulidae
Palpomyia sp.	*Simulium* sp.
Bezzia, Probezzia group	*Prosimulium* sp.
?*Dasyhelia* sp.	*Cnephia* sp.
F. Athericidae	
Atherix pachypus	F. Muscidae - unid
Atherix variegata	

CLADOCERA
F. Alonidae*Alona guttata*

NEMATODA - unid.

COELENTERATA
Hydra sp.

AMPHIPODA
F. Talitridae
Hyalella azteca

Table 4.2.12
(CONTINUED)

OLIGOCHAETA	
F. Naididae	F. Tubificidae
Naidium sp.	*Limnodrilis* sp.
Nais bretscheri	Tubificidae - unid.
Nais (*communis*)	F. Lumbriculidae
Nais sp.	*Kincaidiana hexatheca*
Chaetogaster sp.	*Lumbriculus* sp.
Pristina sp.	F. Enchytraeidae - unid.
Paranais sp.	F. Lumbricidae - unid.
	Oligochaeta - unid.

COLLEMBOLA	
F. Isotomidae *Isotomurus* sp.	F. Sminthuridae

TABLE 4.3.1

EFFLUENT DATA SUMMARY FOR PRINCE GEORGE (PE 1763)

Characteristic	Number of Values	Maximum	Minimum	Mean	Std.Dev
Coliforms-fecal	15	49000	14	2300+	-
Oxygen-B.O.D.5	21	121	12	42.7	26.8
pH	14	8.0	7.1	7.7+	-
Solids-suspended	28	129	2	42	39
Specific Conductivity	14	1980	640	1167	413

PERIOD OF RECORD : 1985 - 1990

+ Median Value

Values are as mg/L except:

1.)Coliforms as CFU/cL
2.)pH
3.)Specific conductivity as µS/cm

DATA SOURCE: MOE "SEAM" RETRIEVAL SYSTEM

Table 4.3.2
EFFLUENT DATA SUMMARY FOR THE BCR INDUSTRIAL PARK DISCHARGE (CITY OF PRINCE GEORGE) PE 5132

Characteristic	Number of Values	Maximum	Minimum	Mean	Std.Dev
BOD_5	138	47	6	19.2	8.9
Carbon-inorganic	4	67	61	64	2.45
Carbon-total	4	105	83	92	9.6
Chloride	8	84.3	73.8	77.8	3.75
Coliforms-fecal	37	200000	130	600+	-
Colour-TAC	8	42	21	31.5	7.3
Flow (avg. monthly)	27	294	161	203	-
Metals : Aluminum-t	12	0.5	0.16	0.25	0.010
:Cadmium-t	8	1.2	<0.5	0.7	0.3
:Chromium-t	12	2.65	0.23	0.62	0.66
:Copper-t	12	0.04	0.01	0.03	0.01
:Iron-t	12	0.45	0.22	0.30	0.07
:Mercury-t	8	<0.05	<0.05	<0.05	0.0
:Manganese-t	12	0.7	0.1	0.25	0.20
:Nickel-t	8	0.008	0.002	0.003	0.002
:Lead-t	8	0.065	0.028	0.053	0.012
:Zinc-t	12	0.66	0.12	0.26	0.17
Nitrogen-ammonia	8	7.86	4.7	6.2	1.0
Nitrogen-Kjeldahl	25	36.2	6.62	24.7	6.7
Nitrogen-nitrate/nitrite	7	1.48	0.92	1.16	0.18
Nitrogen-nitrite	8	0.086	0.052	0.062	0.012
pH	30	8.5	6.6	7.9+	-
Phenols	8	0.024	0.002	0.013	0.007
Phosphorus-ortho diss.	8	1.29	0.242	1.01	0.336
-dissolved	8	1.57	1.21	1.37	0.13
-total	8	1.70	1.31	1.49	0.14
Solids- Dissolved	7	494	46	406.6	160.1
-Suspended	148	101	3	27.2	13.9
Specific Conductivity	10	1570	765	1342	223

Period of Record: 1985-1991

All values are as mg/L except: + Median Value

1.) Cadmium and mercury as µg/L
2.) Coliforms as CFU/cL
3.) Flow (average monthly) as m^3/d
4.) pH
5.) Specific Conductivity as µS/cm

Source of Data: B.C. Environment SEAM Computer System (with additional data for the period April 1990 to December 1991 to supplement records for suspended solids, BOD_5, flow, and fecal coliforms)

Table 4.3.3
EFFLUENT DATA SUMMARY FOR PRINCE GEORGE S.T.P. OUTFALL (PE 146)

Characteristic	Number of Values	Maximum	Minimum	Mean	Std.Dev
Carbon-inorganic	4	72	60	65.5	6.4
-total	4	110	74	97.5	16.2
Chloride	26	121	29.5	69.3	17.1
Coliforms-fecal	39	1685000	<2	240000	-
Colour (TAC)	9	49	15	36.3	9.7
Flow (average)	21	20039	16954	18253	818
Hardness-total	11	175.8	159.1	169.1	-
-calcium	11	48.5	43.3	45.5	1.67
-magnesium	11	14.3	12.4	13.5	0.6
Metals-aluminum(total)	9	0.31	0.12	0.18	0.06
-chromium(total)	11	0.025	<0.005	0.010	0.007
-copper (total)	11	0.07	0.04	0.055	0.009
-iron (total)	11	0.51	0.19	0.34	0.09
-mercury (total)	8	0.00008	<0.00005	<0.00005+	-
-manganese (total)	11	0.32	0.27	0.29	0.02
-molybdenum(total)	11	0.03	<0.01	<0.01+	-
-lead(total)	8	0.005	<0.001	0.003	0.001
-nickel (total)	8	0.005	0.002	0.002	0.001
-zinc (total)	11	0.08	0.03	0.05	0.01
Nitrogen-ammonia	27	31.4	3.38	1.64	6.53
-nitrate/nitrite	27	11.2	<0.02	21.2	2.94
-nitrite	27	7.78	<0.005	0.48	1.48
-Kjeldahl	25	36.2	6.6	24.7	6.7
Oxygen-BOD5	43	47	6	19.0	9.2
pH	26	8.0	7.1	7.6+	-
Phenols	8	0.052	0.011	0.023	0.014
Phosphorus-ortho diss	27	5	2.68	4.07	0.57
-dissolved	27	5.42	3.01	4.35	0.59
-total	28	7.44	3.42	5.01	0.81
Solids-dissolved	7	460	430	444	11.8
-suspended	48	47	3	22.2	10.1
Specific Conductivity	20	970	628	846	88.3
Sulphate	8	36.3	31	34.3	1.58

+ MEDIAN VALUE
PERIOD OF RECORD : 1985 - 1991
Values are as mg/L except:
1) Colour as TAC
2.)Coliforms as CFU/cL
3.)Flow as m^3/d
4.)pH
5.)Specific conductivity as µS/cm

DATA SOURCE: MOE "SEAM" RETRIEVAL SYSTEM

TABLE 4.3.4
MAXIMUM CONCENTRATION OF TOTAL AMMONIA NITROGEN FOR PROTECTION OF AQUATIC LIFE (mg/L-N)

pH	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0 Temp. °C
6.5	27.7	28.3	27.9	27.5	27.2	26.8	26.5	26.2	26.0	25.7	25.5
6.6	27.9	27.5	27.2	26.8	26.4	26.1	25.8	25.5	25.2	25.0	24.7
6.7	26.9	26.5	26.2	25.9	25.5	25.2	24.9	24.6	24.4	24.1	23.9
6.8	25.8	25.5	25.1	24.8	24.5	24.2	23.9	23.6	23.4	23.1	22.9
6.9	24.6	24.2	23.9	23.6	23.3	23.0	22.7	22.5	22.2	22.0	21.8
7.0	23.2	22.8	22.5	22.2	21.9	21.6	21.4	21.1	20.9	20.7	20.5
7.1	21.6	21.3	20.9	20.7	20.4	20.2	19.9	19.7	19.5	19.3	19.1
7.2	19.9	19.6	19.3	19.0	18.8	18.6	18.3	18.1	17.9	17.8	17.6
7.3	18.1	17.8	17.5	17.3	17.1	16.9	16.7	16.5	16.3	16.2	16.0
7.4	16.2	16.0	15.7	15.5	15.3	15.2	15.0	14.8	14.7	14.5	14.4
7.5	14.4	14.1	14.0	13.8	13.6	13.4	13.3	13.1	13.0	12.9	12.7
7.6	12.6	12.4	12.2	12.0	11.9	11.7	11.6	11.5	11.4	11.3	11.2
7.7	10.8	10.7	10.5	10.4	10.3	10.1	10.0	9.92	9.83	9.73	9.65
7.8	9.26	9.12	8.98	8.88	8.77	8.67	8.57	8.48	8.40	8.32	8.25
7.9	7.82	7.71	7.60	7.51	7.42	7.33	7.25	7.17	7.10	7.04	6.98
8.0	6.55	6.46	6.37	6.29	6.22	6.14	6.08	6.02	5.96	5.91	5.86
8.1	5.21	5.14	5.07	5.01	4.95	4.90	4.84	4.80	4.75	4.71	4.67
8.2	4.15	4.09	4.04	3.99	3.95	3.90	3.86	3.83	3.80	3.76	3.74
8.3	3.31	3.27	3.22	3.19	3.15	3.12	3.09	3.06	3.03	3.01	2.99
8.4	2.64	2.61	2.57	2.54	2.52	2.49	2.47	2.45	2.43	2.41	2.40
8.5	2.11	2.08	2.06	2.03	2.01	1.99	1.98	1.96	1.95	1.94	1.93
8.6	1.69	1.67	1.65	1.63	1.61	1.60	1.59	1.58	1.57	1.56	1.55
8.7	1.35	1.33	1.32	1.31	1.30	1.29	1.28	1.27	1.26	1.26	1.25
8.8	1.08	1.07	1.06	1.05	1.04	1.04	1.03	1.03	1.02	1.02	1.02
8.9	0.87	0.86	0.86	0.85	0.84	0.84	0.84	0.83	0.83	0.83	0.83
9.0	0.70	0.70	0.69	0.69	0.69	0.68	0.68	0.68	0.68	0.68	0.68

	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0
6.5	25.2	25.0	24.8	24.6	24.5	24.3	24.2	24.0	23.9	23.8
6.6	24.5	24.3	24.1	23.9	23.8	24.6	23.5	23.3	23.3	23.2
6.7	23.7	23.5	23.3	23.1	23.0	22.8	22.7	22.6	22.5	22.4
6.8	22.7	22.5	22.3	22.2	22.0	21.9	21.8	21.7	21.6	21.5
6.9	21.6	21.4	21.3	21.1	21.0	20.8	20.7	20.6	20.5	20.4
7.0	20.3	20.2	20.0	19.9	19.7	19.6	19.5	19.4	19.3	19.2
7.1	18.9	18.8	18.7	18.5	18.4	18.3	18.2	18.1	18.0	17.9
7.2	17.4	17.3	17.2	17.1	16.9	16.8	16.8	16.7	16.6	16.5
7.3	15.9	15.7	15.6	15.5	15.4	15.3	15.2	15.2	15.1	15.1
7.4	14.2	14.1	14.0	13.9	13.9	13.8	13.7	13.6	13.6	13.5
7.5	12.6	12.5	12.4	12.4	12.3	12.2	12.2	12.1	12.1	12.0
7.6	11.1	11.0	10.9	10.8	10.8	10.7	10.7	10.6	10.6	10.5
7.7	9.57	9.50	9.43	9.37	9.31	9.26	9.22	9.81	9.15	9.12
7.8	8.18	8.12	8.07	8.02	7.97	7.93	7.90	7.87	7.84	7.82
7.9	6.92	6.88	6.83	6.79	6.75	6.72	6.69	6.67	6.65	6.64
8.0	5.81	5.78	5.74	5.71	5.68	5.66	5.64	5.62	5.61	5.60
8.1	4.64	4.61	4.59	4.56	4.54	4.53	4.51	4.50	4.49	4.49
8.2	3.71	3.69	3.67	3.65	3.64	3.63	3.62	3.61	3.61	3.61
8.3	2.97	2.96	2.94	2.93	2.92	2.92	2.91	2.91	2.91	2.91
8.4	2.38	2.37	2.36	2.36	2.35	2.35	2.35	2.35	2.35	2.36
8.5	1.92	1.91	1.91	1.90	1.90	1.90	1.90	1.90	1.91	1.92
8.6	1.55	1.54	1.54	1.54	1.54	1.54	1.55	1.55	1.56	1.57
8.7	1.25	1.25	1.25	1.25	1.25	1.26	1.26	1.27	1.28	1.29
8.8	1.02	1.02	1.02	1.02	1.03	1.03	1.04	1.05	1.06	1.07
8.9	0.83	0.83	0.84	0.84	0.85	0.85	0.86	0.87	0.88	0.89
9.0	0.68	0.69	0.69	0.70	0.70	0.71	0.72	0.73	0.74	0.75

TABLE 4.3.5
AVERAGE 30-DAY CONCENTRATION OF TOTAL AMMONIA NITROGEN FOR PROTECTION OF AQUATIC LIFE (mg/L-N)

Temp. °C

pH	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
6.5	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
6.6	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
6.7	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
6.8	2.08	2.05	2.02	1.99	1.96	1.94	1.92	1.90	1.88	1.86	1.84
6.9	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
7.0	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
7.1	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
7.2	2.08	2.05	2.02	1.99	1.96	1.95	1.92	1.90	1.88	1.86	1.85
7.3	2.08	2.05	2.02	1.99	1.97	1.95	1.92	1.90	1.88	1.86	1.85
7.4	2.08	2.05	2.02	2.00	1.97	1.95	1.92	1.90	1.88	1.87	1.85
7.5	2.08	2.05	2.02	2.00	1.97	1.95	1.93	1.91	1.88	1.87	1.85
7.6	2.09	2.05	2.03	2.00	1.97	1.95	1.93	1.91	1.89	1.87	1.85
7.7	2.09	2.05	2.03	2.00	1.98	1.95	1.93	1.91	1.89	1.87	1.86
7.8	1.78	1.75	1.73	1.71	1.69	1.67	1.65	1.63	1.62	1.60	1.59
7.9	1.50	1.48	1.46	1.44	1.43	1.41	1.39	1.38	1.36	1.35	1.34
8.0	1.26	1.24	1.23	1.21	1.20	1.18	1.17	1.16	1.15	1.14	1.13
8.1	1.00	0.99	0.98	0.96	0.95	0.94	0.93	0.92	0.91	0.91	0.90
8.2	0.80	0.79	0.78	0.79	0.76	0.75	0.74	0.74	0.73	0.72	0.72
8.3	0.64	0.63	0.50	0.49	0.48	0.48	0.48	0.47	0.47	0.46	0.46
8.5	0.41	0.40	0.40	0.38	0.39	0.38	0.38	0.38	0.38	0.37	0.37
8.6	0.32	0.32	0.32	0.31	0.31	0.31	0.31	0.30	0.30	0.30	0.30
8.7	0.26	0.26	0.25	0.25	0.25	0.25	0.25	0.24	0.24	0.24	0.24
8.8	0.21	0.21	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
8.9	0.19	0.17	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
9.0	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13

	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0
6.5	1.82	1.81	1.80	1.78	1.77	1.64	1.52	1.41	1.31	1.22
6.6	1.82	1.81	1.80	1.78	1.77	1.64	1.52	1.41	1.31	1.22
6.7	1.83	1.81	1.80	1.78	1.77	1.64	1.52	1.41	1.31	1.22
6.8	1.83	1.81	1.80	1.78	1.77	1.64	1.52	1.42	1.32	1.22
6.9	1.82	1.81	1.80	1.78	1.77	1.64	1.53	1.42	1.32	1.22
7.0	1.83	1.81	1.80	1.79	1.77	1.64	1.53	1.42	1.32	1.22
7.1	1.83	1.81	1.80	1.79	1.77	1.65	1.53	1.42	1.32	1.23
7.2	1.83	1.81	1.80	1.79	1.78	1.65	1.53	1.42	1.32	1.23
7.3	1.83	1.82	1.80	1.79	1.78	1.65	1.53	1.42	1.32	1.23
7.4	1.83	1.82	1.80	1.79	1.78	1.65	1.53	1.42	1.32	1.23
7.5	1.83	1.82	1.81	1.80	1.78	1.66	1.54	1.43	1.33	1.23
7.6	1.84	1.82	1.81	1.80	1.79	1.66	1.54	1.43	1.33	1.24
7.7	1.84	1.83	1.81	1.80	1.79	1.66	1.54	1.44	1.34	1.24
7.8	1.57	1.56	1.55	1.54	1.53	1.42	1.32	1.23	1.14	1.07
7.9	1.33	1.32	1.31	1.31	1.30	1.21	1.12	1.04	0.97	0.90
8.0	1.12	1.11	1.10	1.10	1.09	1.02	0.94	0.88	0.82	0.76
8.1	0.89	0.89	0.88	0.88	0.87	0.81	0.76	0.70	0.66	0.61
8.2	0.71	0.71	0.71	0.70	0.70	0.65	0.61	0.57	0.53	0.49
8.3	0.57	0.57	0.57	0.56	0.56	0.52	0.49	0.46	0.43	0.40
8.4	0.46	0.46	0.46	0.46	0.45	0.45	0.42	0.39	0.37	0.34	0.32
8.5	0.37	0.37	0.37	0.37	0.37	0.34	0.32	0.30	0.28	0.26
8.6	0.30	0.30	0.30	0.30	0.30	0.28	0.26	0.24	0.23	0.21
8.7	0.24	0.24	0.24	0.24	0.24	0.23	0.21	0.20	0.19	0.18
8.8	0.20	0.20	0.20	0.20	0.20	0.19	0.17	0.16	0.15	0.15
8.9	0.16	0.16	0.16	0.16	0.16	0.15	0.14	0.14	0.13	0.12
9.0	0.13	0.13	0.13	0.13	0.14	0.12	0.12	0.12	0.11	0.10

- the average of the measured values must be less than the average of the corresponding individual values in Table 4.3.4.
- each measured value is compared to the corresponding individual values in Table 4.3.4. No more than one in five of the measured values can be greater than one-and-a-half times the corresponding objective values in Table 4.3.4.

Table 4.3.6
CRITERIA FOR NITRITE-N FOR THE PROTECTION OF FRESHWATER AQUATIC LIFE

Concentration (mg/L-N)		
Chloride	**Maximum Nitrite-N**	**30-day Average Nitrite-N**
<2	0.06	0.02
2-4	0.12	0.04
4-6	0.18	0.06
6-8	0.24	0.08
8-10	0.30	0.10
>10	0.60	0.20

TABLE 4.3.7

EFFLUENT DATA SUMMARY FOR PRINCE GEORGE (PE 4905)

Characteristic	Number of Values	Maximum	Minimum	Mean	Std.Dev
Coliforms-fecal	52	2280000	0	20000+	-
Flow (average)	55	110	6	53.8	30.8
Oxygen-BOD5	53	93	<10	40	20.1
pH	29	8.3	6.5	7.0+	-
Solids-suspended	54	80	10	32.8	15.7
Specific Conductivity	8	1360	562	1008	265

PERIOD OF RECORD : 1985 - 1991

+ Median Value

Values are as mg/L except:

1.)Coliforms as CFU/cL
2.)Flow as m^3/d
3.)pH
4.)Specific conductivity as µS/cm

DATA SOURCE: MOE "SEAM" RETRIEVAL SYSTEM, WITH ADDITIONAL DATA FROM REPORTS SUBMITTED BY THE CITY OF PRINCE GEORGE FOR 1991

Table 4.3.8
EFFLUENT DATA SUMMARY - QUESNEL RIVER PULP (PE 5803)

Characteristic	Number of Values	Maximum	Minimum	Mean	Std.Dev
Bioassay - LC50 - %(V/V)-rainbow trout	62	>100	0.4	56.7	40.1
BOD5	151	35596	101	6781	6959
Carbon - total	30	2260	650	1383	462
Carbon - inorganic	30	400	38	209	90.5
Chloride	2	30	19.9	24.95	-
COD	13	4040	2040	2898	573
Colour - True	17	1500	440	815	363
Flow - average	476	29792	61	12941	3775
Microtox EC50 5 min	40	>100	0.59	27.8	30.6
Microtox EC50 15 min	2	13.5	5.99	9.75	-
Nitrogen - ammonia	25	1.54	0.036	0.18	0.3
Nitrogen -nitrate/nitrite	7	0.07	0.03	0.04	0.02
Nitrogen - nitrite	5	0.037	0.012	0.022	0.009
Oxygen - dissolved	261	6.2	0.0	1.3	1.4
Pentachlorophenol	1	0.0011	0.0011	0.0011	-
pH	314	9.1	6.5	7.6+	-
Phosphorus - total	39	162	1.02	30.2	44.5
Phosphorus - dissolved	8	3.46	0.048	0.77	1.2
Phosphorus-ortho diss	7	6.83	0.037	3.06	2.70
Sodium	23	940	171	586	247
Solids - dissolved	22	4710	1130	2741	1083
Solids - suspended	315	44241	560	10578	6289
Specific Conductivity	38	4080	950	2459	929
Temperature	269	37	22.5	31.6	2.4
Tetrachlorophenol	1	0.0036	0.0036	0.0036	-

PERIOD OF RECORD: 1985 - 1991

+ Median Value
All values are as mg/L except:
1.) Coliforms and Streptococcus as CFU/cL
2.) Microtox EC50 as %(V/V)
3.) pH
4.) Specific Conductivity as µS/cm

DATA SOURCE: MOE "SEAM" RETRIEVAL SYSTEM

Table 4.3.9
MONTHLY EFFLUENT DATA FOR QUESNEL RIVER PULP

DAILY FLOW (m3/d)

Month	1993	1992	1991	1990	1989	1988
January	23070	22604	22030	18736	19453	12534
February	22985	22511	24429	19786	16627	12951
March	23573	23772	23264	17392	21686	12653
April	22749	25065	18819	21029	17523	12398
May	22184	22068	21647	20309	18014	13160
June	21849	22057	23897	21242	18354	13017
July	22697	26015	22339	25763	17316	13694
August	23151	23763	22261	25773	23731	13872
September	23500	21583	25537	21319	19961	17385
October	25413	22513	23857	26846	20902	29792
November	24671	-	24959	26958	19397	26568
December	24622	-	22353	21189	22564	23075
Mean	23372	23195	22949	22195	19627	16758

TOTAL SUSPENDED SOLIDS LOADING (kg/d)

Month	1993	1992	1991	1990	1989	1988
January	19932	6225	6256	9381	10544	23708
February	15538	6631	10701	10798	11169	26588
March	16430	6627	8136	7703	15245	20923
April	12330	6094	8078	7491	11069	18985
May	12933	6623	8015	6991	8038	22534
June	16168	7366	7462	7668	9745	19091
July	15003	6113	8004	5984	7955	18659
August	14562	5401	8353	6570	9245	
September	21879	8036	8417	8627	8007	
October	15349	6385	7707	8685	7408	6264
November	20206	-	9556	7413	8391	13720
December	33018	-	7688	8889	10239	16256
Mean	17779	6550	8198	8017	9755	18673

Table 4.3.9

(Continued)

BOD5 LOADING (kg/d)

Month	1993	1992	1991	1990	1989	1988
January	6713	7049	3666	6256	8828	28377
February	4022	6542	5419	6205	10292	35596
March	4691	4919	9672	5856	11399	24090
April	4391	5461	7183	6940	5992	21817
May	5613	5032	4840	4875	7164	18845
June	4217	4820	7815	4519	6981	15848
July	5288	4497	6263	4716	3117	22458
August	4885	4789	7565	5497	5693	13293
September	4113	5215	7004	6874	5854	18599
October	6633	5653	8406	6363	5326	33874
November	8191	-	9266	8337	5348	12776
December	5171	-	6770	5534	5275	27633
Mean	5327	5398	7624	5998	6772	22767

MINIMUM DISSOLVED OXYGEN (mg/L)

Month	1993	1992	1991	1990	1989	1988
January	1.3	1.5	1.0	0.7	2.0	0.2
February	2.2	2.6	1.4	0.8	0.5	0.2
March	1.7	1.2	1.8	1.0	0.5	0.0
April	2.1	1.2	1.4	1.9	0.5	0.1
May	2.0	1.2	1.9	1.0	0.7	0.2
June	2.6	1.7	2.3	1.4	0.5	0.0
July	3.0	0.8	1.8	0.6	0.8	0.0
August	1.4	2.2	2.1	1.0	0.2	0.1
September	4.1	1.9	2.6	2.0	1.0	0.0
October	2.6	2	1.2	2.6	1.8	0.4
November	4.1	0	0.2	2.6	2.0	0.8
December	2.8	0	1.8	1.6	1.9	1.8
Mean	2.5	1.6				

Table 4.3.9
(Continued)

pH
Range

Month	1993	1992	1991	1990	1989	1988
January	7.2-7.9	7.5-7.8	7.5-8.1	7.6-8.0	7.4-7.9	7.0-7.9
February	7.4-7.9	7.4 - 7.9	7.6-8.0	7.5-7.8	7.4-7.9	7.0-7.7
March	7.5-8.0	7.2 - 7.9	7.4-8.0	7.5-8.1	7.4-7.8	6.9-8.0
April	7.4-7.7	7.3-7.8	7.6-7.9	7.4-8.1	7.7-7.8	7.3-8.0
May	7.5-7.9	7.4-7.8	7.4-7.8	7.6-8.1	7.5-7.8	6.8-7.9
June	7.4-7.9	7.6-8.0	7.3-8.0	7.7-8.0	7.3-7.7	6.7-9.1
July	7.2-7.9	7.4 - 7.9	7.4-7.7	7.5-7.9	7.7-7.9	7.0-7.8
August	7.2-7.7	7.5 - 7.8	7.3-7.8	7.6-8.1	7.6-7.8	6.7-7.7
September	7.5-8.0	7.3-7.7	7.2-7.8	7.5-7.9	7.6-8.3	7.1-7.8
October	7.4-8.0	7.4-7.7	7.3-7.8	7.6-8.1	7.6-7.9	7.0-7.8
November	7.6-8.2	-	7.1-7.6	7.6-8.3	7.8-8.1	7.6-8.1
December	7.5-8.5	-	7.6-8.1	7.6-7.8	7.7-8.0	6.9-7.9

MAXIMUM DAILY TEMPERATURE (^{o}C)

Month	1993	1992	1991	1990	1989	1988	Monthly Mean
January	37.5	36	35	34	32	33	34
February	37.1	36	37	32	35	32	34
March	36.2	38	36	32	37	32	34
April	37.1	38	36	34	37	33	35
May	37.5	36	37	34	36	35	36
June	37.1	37.6	38	35	36	35	36
July	36.5	38.4	37	35	36	35	36
August	38.1	38.7	39	36	36	36	37
September	37.2	38	38	35	34	34	35
October	37.9	37	36	34	33	32	34
November	36.4	-	37	34	34	32	34
December	37.5	-	36	35	34	30	34
Mean	37.2	37	37	34	35	33	

Table 4.3.9
(Continued)

TOXICITY DATA (96-hr LC50) -percent

Month	1993	1992	1991	1990	1989	1988
January	100	100	10	93	32-100	0.4-5
February	100	100	100	60	1.3-80	6-8
March	100	38	100	90	1.6-100	1-100
April	100	56	100	58	68-100	0.4
May	100	100	100	100	100	7.5-32
June	100	100	8	80	100	2.4-100
July	100	26.70	100	100	42-100	34.3
August	100	100	100	83/90	100	2-100
September	100	100	100	100	86.3-100	0.8
October	100	100	100	94	100	1.2-100
November	100	-	19	24	10-100	68.5-100
December	100	100	81	84	100	24-100

Table 4.3.10

EFFLUENT DATA SUMMARY - CARIBOO PULP (PE 1152)

Characteristic	Number of Values	Maximum	Minimum	Mean	Std.Dev
Adsorb. Organic Halides	19	31	11	19.7	6.2
Carbon - total	29	560	233	356	75.4
Carbon - inorganic	29	82	34	6..6	11.6
Chloride	6	748	575	635	65.6
Coliform - fecal	20	460000	<2	320+	-
Colour - True	21	2520	720	1354	524
Colour - TAC	35	2160	840	1386	297
Microtox EC50 5 min	36	>100	5	80.2	25.3
Microtox EC50 15 min	1	>100	>100	>100	-
Nitrogen - ammonia	23	2.18	0.056	0.473	0.566
Nitrogen -nitrate/nitrite	6	0.07	<0.02	0.04	0.02
Nitrogen - nitrite	3	0.048	0.01	0.024	0.021
Pentachlorophenol	1	0.0002	0.0002	0.0002	-
Phosphorus - total	28	1.65	0.379	0.66	0.23
Phosphorus - dissolved	4	0.057	0.016	0.04	0.02
Phosphorus-ortho diss.	3	0.016	0.009	0.012	0.004
Sodium	4	432	337	381	46
Solids - dissolved	13	2210	1690	1953	151
Specific Conductivity	35	2860	2070	2450	216
Sulphate	12	166	95	117	18.2
Tetrachlorophenol	1	0.0005	0.0005	0.0005	-

PERIOD OF RECORD: 1985 - 1991

All values are as mg/L except:

1.) Coliforms as CFU/cL

2.) Microtox EC50 as %(V/V)

3.) pH

4.) Specific Conductivity as µS/cm

DATA SOURCE: MOE "SEAM" RETRIEVAL SYSTEM

TABLE 4.3.11
EFFLUENT DATA SUMMARY - DIOXINS AND FURANS AT CARIBOO PULP AND PAPER IN 1991 (N=9)

pg/L	MAXIMUM	MINIMUM	MEAN	STD DEV
T4CDD - TOTAL	66	<5.7	41.9	25.4
2,3,7,8,	59	6	26.4	17.7
P5CDD - TOTAL	34	<1.9	20.8	14.1
1,2,3,7,8,	9.8	2.1	6.8	3.1
H6CDD - TOTAL	99	11	53.7	26.8
1,2,3,4,7,8	8	<1.8	7.9	0.2
1,2,3,6,7,8	11	4.4	7.6	2.7
1,2,3,7,8,9	14	<5.4	11.6	2.2
H7CDD - TOTAL	42	14	24.3	10.9
1,2,3,4,6,7,8	26	<9.3	18.7	5.5
O8CDD	120	30	86.6	29.5
T4CDF - TOTAL	370	46	178.9	105.8
2,3,7,8	130	12	50.4	35.6
P5CDF - TOTAL	59	<5.7	26.9	20.5
1,2,3,7,8	<5.7	<0.1	–	–
2,3,4,7,8	<5.7	<0.1	–	–
H6CDF - TOTAL	41	<1.4	18.5	15.8
1,2,3,4,7,8	<12	<1.4	–	–
1,2,3,6,7,8	<12	<1.4	–	–
2,3,4,6,7,8	<12	<1.4	–	–
1,2,3,7,8,9	<12	<1.4	–	–
H7CDF - TOTAL	90	<3.1	48.4	43.5
1,2,3,4,6,7,8	63	3.2	36.7	30.6
1,2,3,4,7,8,9	<19	<1.8	–	–
O8CDF	70	<2.9	–	–
SURROGATE STANDARD RECOVERY				
13C-T4CDD	100	55	77.2	15.7
13C-T4CDF	101	54	80.2	15.0
13C-P5CDD	101	50	77.4	16.5
13C-H6CDD	106	44	69.8	20.1
13C-H7CDD	89	39	59.9	18.0
13C-O8CDD	75	21	45.4	17.0

Table 4.3.12
DETAILED EFFLUENT DATA SUMMARY FOR CARIBOO PULP AND PAPER

MAXIMUM FLOW (m3/d)

Month	1993	1992	1991	1990
January	104449	113841	114889	104273
February	105538	107795	110045	104221
March	104740	122287	110803	104612
April	109302	114998	112716	101984
May	106985	113616	116160	104809
June	109083	117061	118202	104345
July	114030	123573	102428	113003
August	118334	120763	104459	118366
September	118240	118300	119935	112381
October	112253	108594	117606	112337
November	106331	109144	109474	114803
December	99856	107697	107404	108525

TOTAL SUSPENDED SOLIDS LOADING (kg/d)

Month	1993	1992	1991	1990
January	3841	5259	11067	11409
February	5104	5498	11591	8205
March	4838	6412	15912	8828
April	3746	6160	11034	10064
May	4816	5880	16209	11077
June	5965	2602	9232	11187
July	4689	1554	8511	14854
August	4896	5612	9006	13076
September	3534	3763	5163	8507
October	3567	5121	5529	11043
November	3441	5539	3479	13489
December	2748	5168	4773	11067

Table 4.3.12
(Continued)

BOD5 LOADING (kg/d)

Month	1993	1992	1991	1990
January	1637	1788	3120	4161
February	1791	1509	3583	3529
March	1839	1521	3607	3011
April	1528	866	3065	2874
May	1471	962	4165	2727
June	1532	534	2165	3167
July	1376	1135	1913	2627
August	1545	2749	2429	3848
September	1346	918	1832	2823
October	1425	1434	1878	2438
November	1426	1846	921	3120
December	1358	1672	1217	3120

DISSOLVED OXYGEN (mg/L)

Month	1993	1992	1991	1990
January	6.4	9.1	0.2-3.0	0.1-2.2
February	5.5	6	0.1-2.0	0.1-5.7
March	6.1	5.1	0.1-1.5	0.1-3.6
April	5.7	5.5	0.1-5.3	0.1-2.2
May	4.8	5	0.1-4.3	0.1-5.6
June	4.7	4.3	0.1-3.8	0.1-2.8
July	4	1.3	0.3-5.2	0.1-4.4
August	3.8	3.4	0.1-1.7	0.1-5.9
September	4.3	5.0	0.1-5.8	0.1-7.7
October	4.8	4.0	0.3-6.9	0.1-4.7
November	6.4	4.8	3.1-5.4	0.1-1.4
December	4.3	5.1	2.3-9.3	0.3-7.1

Table 4.3.12
(Continued)

pH

Month	1993	1992	1991	1990
January	7.3-7.6	6.8-7.6	6.5-7.4	7.0-7.8
February	6.3-7.1	6.8-7.5	6.7-7.3	7.1-10.3
March	7.3-7.7	6.9-7.7	6.7-7.3	7.0-7.7
April	7.4-7.8	7.2-8.1	6.8-7.9	7.0-7.7
May	7.4-7.9	7.2-7.8	6.8-7.4	7.0-7.9
June	7.2-7.8	7.2 - 7.9	6.7-7.4	6.8-7.5
July	7.4-7.9	7.1 - 7.8	6.7-7.5	6.8-7.5
August	7.4-7.6	7.0 - 7.7	6.8-7.7	6.7-8.2
September	7.1-7.6	7.0 - 7.9	6.9-8.1	7.1-8.3
October	7.4-7.8	7.3 - 7.6	6.8-7.9	7.0-7.8
November	7.4-7.7	7.1 - 7.6	6.6-7.6	7.0-7.4
December	7.3-7.6	7.1-7.8	6.5-7.4	6.8-7.9

MAXIMUM TEMPERATURE (°C)

Month	1993	1992	1991	1990
January	26	27	19	28
February	29	26	30	28
March	27	30	32	28
April	30	29	30	28
May	32	32	33	31
June	32	32	33	32
July	33	29	35	33
August	35	33	36	34
September	32	32	34	32
October	29	32	31	29
November	29	30	30	30
December	28	28	27	31
Mean	30	30	31	29

Table 4.3.12

(Continued)

TOXICITY 96-hr LC50 (%)

Month	1993	1992	1991	1990	1989	1988
January	100	>100	56	100	100	100
February	100	>100	100	7.1-100	60-100	6.0-11.0
March	100	>100	85	100	100	11.0-42.0
April	100	>100	100	100	5.0-6.0	56-86
May	100	>100	87	100	-	10
June	100	>100	100	100	8-100	100
July	100	>100	100	87	30-100	75-93
August	100	>100	100	100	8.8-25	100
September	100	>100	100	100	100	100
October	100	>100	100	100	49-100	2-100
November	100	>100	100	100	100	100
December	100	>100	100	100	100	100

Table 4.3.13

EFFLUENT DATA SUMMARY FOR THE CITY OF WILLIAMS LAKE (PE 255)

Characteristic	Number of Values	Maximum	Minimum	Mean	Std.Dev
BOD_5	33	93	7.2	29.3	21.6
Coliforms-fecal	20	560000	37	27750+	-
Flow	37	9722	2142	3323	1223
pH	30	8.1	7.0	7.6+	-
Specific Conductivity	13	1600	1460	1516	43.5
Suspended Solids	33	58	4.7	30.3	13.7

PERIOD OF RECORD: 1985 - 1991

+ Median Value

All values are as mg/L except:

1.) Fecal Coliforms as CFU/cL

2.) Flow as m^3/d

3.) pH

4.) Specific Conductivity as µS/cm

Table 4.3.14
TAXONOMIC SUMMARY OF INVERTEBRATES SAMPLED IN THE FRASER RIVER NEAR QUESNEL, 1984-1989

EPHEMEROPTERA	
F. Heptageniidae	F. Ephemerellidae
Rhithrogena sp	*Ephemerella* (*Ephemerella*) *inermis*
Heptagenia sp.	*Ephemerella infrequens*
Epeorus sp.	*E.* (*Drunella*) *grandis ingens*
F. Baetidae	F. Siphlonuridae
Baetis sp.	*Ameletus* sp.
Baetis (*tricaudatus*)	
F. Leptophlebidae	F. Ametropidae
Paraleptophlebia sp.	*Ametropus* sp.

TRICHOPTERA	
F. Hydropsychidae	F. Leptoceridae
Hydropsyche sp.	*Mysticides* sp.
Parapsyche sp.	*Ceraclea* sp.
F. Brachycentridae	F. Rhyacophilidae
Brachycentrus sp.	*Rhyacophila vagrita*
F. Hydroptilidae	F. Limnephilidae
Hydroptila sp.	*Ecclisomyia* sp.
Hydroptilidae - unid.	

PLECOPTERA	
F. Taeniopterygidae	F. Perlodidae
Taenionema sp.	*Isogenus elongatus*
F. Nemouridae	*Isoperla* sp.
Malenka sp.	*Isogenoides* sp.
F. Perlidae	*Skwala* (?*curvata*)
Classenia sabulosa	*Skwala* (? *paralella*)
F. Chloroperlidae	F. Pteronarcyidae
S.F. Chloroperlinae	*Pteronarcys* sp.
Sweltsa Gp.	*Pteronarcys princeps*
Chloroperlinae - unid.	*Pteronarcella* sp.
F. Capniidae	*Pteronarcella badia*
Capnia sp.	*Pteronarcella regularis*

HYDRACARINA
Lebertia sp.
Sperchon sp.
Hydracarina - unid.

COLEOPTERA	
F. Dytiscidae? - unid.	F. Elmidae
	Narpus sp.
	Elmis sp.

TABLE 4.3.14
(CONTINUED)

OSTRACODA - unid.

COPEPODA	
F. Cyclopoidae *Cyclops* sp. *Paracyclops* sp. *Eucyclops* sp. *Macrocyclops* sp. Cyclopoidae - unid.	F. Harpacticoidae - unid.

DIPTERA	
F. Chironomidae S.F. Tanypodinae *Procladius* sp. *Nilotanypus* sp. *Thienemannimyia* Gp. S.F. Prodiamesinae *Monodiamesa* sp. *Monodiamesa bathyphila* *Prodiames* sp. S.F. Orthocladiinae *Orthocladius* (*Orthocladius*) or*Cricotopus* (*Cricotopus*) spp. *Brillia* sp. *Eukiefferiella* spp. *Psectrocladius* sp. *Thienemanniella* sp. *Krenosmittia* sp. *Cricotopus* sp. *Cardiocladius* sp. *Corynoneura* sp. *Heterotrissocladius* sp. *Rheocricotopus* sp. *Gymnometriocnemus* sp. ?*Synorthocladius* sp. Orthocladiinae - unid. F. Simuliidae *Simulium* sp. F. Athericidae *Atherix variegata*	F. Chironomidae S.F. Chironominae *Polypedilum* (*Pentapedilum*) sp. *Polypedilum* (*Polypedilum*) sp. *Harnischia* sp. *Chironomus* sp. *Micropsectra* sp. *Phaenopsectra* sp. *Rheotanytarsus* sp. *Paracladopelma* sp. *Tanytarsus* sp. *Stictochironomus* sp. *Cryptochironomus* sp. *Cryptotendipes* sp. Chironominae - unid. S.F. Diamesinae *Potthastia* sp. *Diamesa* sp. *Pseudodiamesa* sp. F. Empididae *Chelifera* sp. *Hemerdromia* sp. *Clinocera* sp. F. Tipulidae *Dicranota* sp. *Antocha* sp. *Hexatoma* sp. F. Ceratopogonidae *Bezzia, Probezzia* Gp. *Palpomyia* sp. F. Muscidae - unid.

NEMATODA - unid.

TABLE 4.3.14
(CONTINUED)

COELENTERATA
Hydra sp.

HEMIPTERA
F. Corixidae *Trichocorixa* sp. Corixidae - unid.

ANNELIDA
F. Aeolosomatidae *Aeolosoma* sp.

OLIGOCHAETA	
F. Naididae *Nais* (*communis*) *Chaetogaster crystalinus* *Pristina forelli* F. Enchytraeidae - unid.	F. Tubificidae ?*Tubifex* sp. Tubificidae - unid. F. Lumbriculidae *Kincaidiana hexatheca*

BIVALVIA	
F. Sphaeridae	*Sphaerium nitidum*

COLLEMBOLA	
F. Isotomidae	*Isotomurus* sp.

CLADOCERA
Macrothrix laticornis

TABLE 6.1.1

AMBIENT WATER QUALITY DATA SUMMARY FOR THE FRASER RIVER AT RED PASS

Variable	No. of Values	Maximum	Minimum	Mean	Std. Dev.
Alkalinity	110	64	40.7	52.6	5.8
Chloride	110	0.7	<0.2	0.4	0.1
Colour - Apparent	110	10	<5	5.2	1.1
Hardness -total	110	79.8	45.7	64.3	7.5
-Calcium	111	20.7	12	17.1	1.8
-Magnesium	111	7	1.3	5.3	0.8
Metals-total aluminum	34	0.392	0.035	0.101	0.080
-total cadmium	104	0.004	<0.0001	<0.0001+	-
-total chromium	68	0.1215	<0.0002	0.0084	0.0215
-total copper	104	0.615	<0.0002	0.0409	0.0877
-total iron	86	0.622	0.0008	0.0937	0.1088
-total lead	119	0.019	<0.0002	0.0021	0.0020
-total manganese	104	0.03	<0.002	0.009	0.006
-total mercury	100	0.21	<0.01	0.02	0.02
-total molybdenum	34	0.0001	<0.0001	0.0001	-
-total nickel	34	0.002	0.0007	0.0013	0.0004
-total zinc	104	0.0246	<0.0002	0.0030	0.0041
Nitrogen-nitrate/nitrite	110	0.161	0.012	0.068	0.026
pH	110	8.2	6.9	7.8	0.4
Phosphorus - total	110	0.019	<0.002	0.005	0.003
Potassium	112	0.5	<0.2	0.2	0.0
Sodium	111	1.2	0.3	0.7	0.2
Solids - dissolved	35	191	<10	89.7	27.6
-suspended	48	21	<10	<10+	-
Specific Conductivity	110	160	96.5	130.1	15.4
Sulphate	110	15.2	8	11.9	1.8
Turbidity	110	9	0	1.0	1.5

+ Median Value

All values are as mg/L except:

1.) Apparent Colour as apparent colour units

2.)Total mercury as µg/L

3.)pH

4.)Specific Conductivity as µS/cm

5.)Turbidity as NTU

PERIOD OF RECORD : 1985 - JULY 1991

DATA SOURCE: ENVIRONMENT CANADA NAQUADAT RETRIEVAL SYSTEM

TABLE 6.2.1

AMBIENT WATER QUALITY DATA SUMMARY FOR FRASER RIVER AT HANSARD (SITE E206580)

Characteristic	Number of Values	Maximum	Minimum	Mean	Std.Dev
Alkalinity	2	94.8	57.8	76.3	-
Chloride	6	0.9	<0.5	0.6	0.2
Coliforms-fecal	82	51	1	6+	-
Colour (TAC)	106	33	<1	6.5	6.6
Hardness-total	44	111.7	56.2	76.7	-
-calcium	44	33.8	16.4	24.6	4.84
-magnesium	44	7.39	3.72	5.16	0.93
Metals-aluminum(total)	106	16.1	0.03	1.60	2.34
-chromium(total)	67	0.025	<0.005	0.007	0.003
-copper (total)	43	0.25	0.007	0.016	0.037
-iron (total)	44	15.5	0.12	2.38	2.89
-mercury (total)	1	<0.00005	<0.00005	<0.00005	-
-manganese (total)	44	0.34	0.009	0.048	0.058
-molybdenum(total)	44	0.03	<0.01	0.012	0.005
-lead(total)	2	0.004	0.001	0.0025	-
-nickel (total)	44	<0.05	<0.05	<0.05	-
-zinc (total)	44	0.24	<0.005	0.022	0.036
Nitrogen-ammonia	85	0.165	<0.005	<0.005+	-
-nitrate/nitrite	2	0.13	0.12	0.125	-
-Kjeldahl	2	0.05	0.04	0.045	-
pH	60	8.3	7.6	7.9+	-
Phenols	26	0.007	<0.002	0.003	0.001
Phosphorus-ortho diss	84	0.004	<0.003	<0.003+	-
-dissolved	82	0.007	<0.003	<0.003+	-
-total	2	0.056	0.006	0.031	-
Potassium	3	0.6	0.3	0.4	0.2
Sodium	2	2.1	0.8	1.45	-
Solids-dissolved	112	138	62	98.7	21.3
-suspended	107	334	<1	48	63.4
Specific Conductivity	80	223	105	156	35.6
Sulphate	2	15.3	9.6	12.5	-
Turbidity	2	18	1.6	9.8	-

PERIOD OF RECORD : 1987 - 1991
SOURCE OF DATA : MOE "SEAM" DATA RETRIEVAL SYSTEM

Values are as mg/L except:
1.)Coliforms as CFU/cL
2.)pH
3.)Specific conductivity as µS/cm
4.)Turbidity as NTU

TABLE 6.2.1

(Continued)

Environment Canada Data

Variable	No. of Values	Maximum	Minimum	Mean	Std. Dev.
Alkalinity-total	173	105	43.0	67.9	17.3
Chloride	173	227	102	155.7	34.5
Colour-Apparent	173	120	5	20.4	20
Fluoride	173	0.15	0.02	0.05	0.01
Hardness-calcium	173	36.8	15.6	24.2	5.6
-magnesium	173	9.3	2.6	4.4	1.3
-total	173	121	50.1	78.5	18.8
Metals (total)					
-Aluminum	69	18.8	0.065	1.69	2.73
-Arsenic	167	0.01	0.0001	0.0006	0.0009
-Chromium	95	0.0445	0.0002	0.0049	0.0067
-Cadmium	166	0.0031	0.0001	0.0003	0.0004
-Copper	166	0.4	0.0004	0.017	0.047
-Iron	166	49.9	0.007	2.598	4.80
-Lead	166	0.0233	0.0001	0.0024	0.0033
-Manganese	167	0.523	0.002	0.0521	0.0624
-Mercury	162	0.08	0.005	0.017	0.013
-Molybdenum	69	0.0004	0.0001	0.0002	0.0001
-Nickel	94	0.0452	0.0002	0.0042	0.0061
-Selenium	167	0.0004	0.0001	0.0001	0.0001
-Zinc	165	2.03	0.0003	0.0462	0.246
Nitrogen-dissolved	172	0.43	0.01	0.16	0.09
-nitrate/nitrite	172	0.335	0.002	0.110	0.059
pH	173	8.29	6.70	7.73	0.42
Phosphorus-total	173	0.65	0.002	0.056	0.081
Potassium	173	1.62	0.29	0.47	0.15
Sodium	173	2.3	0.3	1.1	0.5
Solids-dissolved	68	272	10	113.7	42.2
-Suspended	68	342	10	71.2	65.5
-Total	68	486	60	184.8	69.9
Specific Conductivity	173	227	102	155.7	34.5
Temperature	164	21	0	6.2	5.3
Turbidity	173	250	0.3	15.8	24.8

PERIOD OF RECORD : 1984 - 1992
SOURCE OF DATA : DOE "NAQUADAT" DATA RETRIEVAL SYSTEM

Values are as mg/L except:
1.)Coliforms as CFU/cL
2.)Mercury as µg/L
3.)pH
4.)Specific conductivity as µS/cm
5.)Turbidity as NTU

TABLE 6.2.2
SUMMARY OF FRASER RIVER PULP MILL ORGANICS MONITORING - FRASER RIVER AT HANSARD (E206580)

Variable:	Maximum	Minimum	Mean	Std Dev
monochlorophenols	<0.1	<0.05	<0.05+	0
dichlorophenols	<0.1	<0.05	<0.05+	0
trichlorophenols	<0.1	<0.05	<0.05+	0
tetrachlorophenols	<0.1	<0.05	<0.05+	0
pentachlorophenols	<0.1	<0.05	<0.05+	0
monochloroguaiacols	<0.1	<0.05	<0.05+	0
dichloroguaiacols	<0.1	<0.05	<0.05+	0
trichloroguaiacols	<0.1	<0.05	<0.05+	0
tetrachloroguaiacols	<0.1	<0.05	<0.05+	0
monochlorocatechols	<0.1	<0.1	<0.1	0
dichlorocatechols	<0.1	<0.1	<0.1	0
trichlorocatechols	<0.1	<0.1	<0.1	0
tetrachlorocatechols	<0.1	<0.1	<0.1	0
dichloroveratrols	<0.1	<0.1	<0.1	0
trichloroveratrols	<0.1	<0.1	<0.1	0
tetrachloroveratrols	<0.1	<0.1	<0.1	0
monochlorovanillins	<0.1	<0.1	<0.1	0
dichlorovanillins	<0.1	<0.1	<0.1	0
trichlorosyringol	<0.1	<0.1	<0.1	0
2,4,6-tribromophenol (surrogate recovery %)	139%	39%	85.40%	24.80%
adsorbable organo-halides (AOX)	10	<10	10	0

PERIOD OF RECORD : 1990 - 1992 (N=29)

Values are as µg/L unless otherwise indicated

+ Median Value

TABLE 6.2.3

AMBIENT WATER QUALITY DATA SUMMARY FOR NECHAKO RIVER AT PRINCE GEORGE (SITE E206583)

B.C. MoELP Data

Characteristic	Number of Values	Maximum	Minimum	Mean	Std.Dev
Alkalinity	3	67.2	46.5	56	10.5
Chloride	3	2.1	0.6	1.2	0.8
Coliforms-fecal	85	422	1	4+	-
Colour (TAC)	2	23	20	21.5	-
Hardness-total	38	115.8	35.8	50.9	-
-calcium	38	33.5	10	13.9	3.6
-magnesium	38	7.83	2.64	3.93	0.92
Metals-aluminum(total)	97	52.7	<0.01	0.91	5.36
-chromium(total)	40	0.02	0.007	<0.01+	-
-copper (total)	5	0.03	0.002	0.010	0.004
-iron (total)	38	7.86	0.04	0.63	1.3
-mercury (total)	2	<0.00005	<0.00005	<0.00005	-
-manganese (total)	38	0.18	0.008	0.027	0.033
-molybdenum(total)	38	0.07	<0.01	0.012	0.010
-lead(total)	3	0.006	0.001	0.003	0.003
-nickel (total)	38	0.09	<0.05	<0.05+	-
-zinc (total)	38	0.1	<0.005	<0.01+	-
Nitrogen-ammonia	99	0.02	<0.005	0.006	0.002
-nitrate/nitrite	3	0.14	<0.02	0.06	0.07
-Kjeldahl	3	0.4	0.11	0.24	0.15
pH	76	8.1	7.3	7.9+	-
Phenols	44	0.018	<0.002	0.003	0.003
Phosphorus-ortho diss	6	0.007	<0.003	0.004	0.002
-dissolved	88	0.029	<0.003	0.006	0.003
-total	3	0.128	0.01	0.06	0.06
Potassium	3	0.7	0.6	0.7	0.1
Sodium	3	2.6	2.3	2.5	0.2
Solids-dissolved	99	106	48	74.5	10.7
-suspended	99	88	<1	9.5	14.7
Specific Conductivity	79	166	78	108	15.9
Sulphate	3	6.5	3.8	5	1.4
Turbidity	3	100	1.5	36.1	55.4

PERIOD OF RECORD : 1987 - 1991

+ MEDIAN VALUE

Values are as mg/L except:

1) Colour as TAC
2.)Coliforms as CFU/cL
3.)pH
4.)Specific conductivity as µS/cm
5.)Turbidity as NTU

DATA SOURCE: MoELP "SEAM" RETRIEVAL SYSTEM

TABLE 6.2.3
(Continued)

Environment Canada Data

Variable	No. of Values	Maximum	Minimum	Mean	Std. Dev.
Alkalinity-total	172	84.3	33.7	49.5	8.7
Chloride	173	9.8	0.2	0.7	0.8
Colour-Apparent	174	100	5.0	15.4	16.9
Fluoride	174	0.79	0.03	0.06	0.06
Hardness-Calcium	172	24.8	9.9	14.0	2.5
-Magnesium	172	7.4	2.3	3.9	0.8
-Total	173	91.2	0.4	50.7	10.1
Metals (total)					
-Aluminum	57	2.72	0.012	0.405	0.599
-Arsenic	163	0.0017	0.0001	0.0005	0.0002
-Cadmium	166	0.002	0.0001	0.0003	0.0004
-Chromium	85	0.0433	0.0002	0.0032	0.0057
-Copper	166	0.729	0.0004	0.0195	0.0729
-Iron	166	4.7	0.0058	0.4667	0.6989
-Lead	166	0.0188	0.0002	0.0013	0.0021
-Manganese	166	0.146	0.0002	0.0245	0.0238
-Mercury	162	0.53	0.005	0.024	0.044
-Molybdenum	57	0.0031	0.0001	0.0015	0.0004
-Nickel	85	0.0103	0.0004	0.0019	0.0017
-Selenium	163	0.0011	0.0001	0.0002	0.0002
-Zinc	165	1.08	0.0002	0.0152	0.0867
Nitrogen-dissolved	174	24	0.01	0.34	1.81
-nitrate/nitrite	173	23.2	0.002	0.170	1.762
pH	174	8.18	5.8	7.5	0.5
Phosphorus-total	174	0.175	0.002	0.030	0.033
Potassium	173	1.5	0.01	0.71	0.22
Sodium	173	3.8	0.1	2.4	0.4
Solids-dissolved	27	229	29	119.3	48.8
-suspended	29	89	10	26.8	22.1
-total	27	262	46	147.3	56.6
Specific Conductivity	173	175	73.5	108.7	18.5
Temperature	163	25.7	0.0	7.4	6.9
Turbidity	174	30	0.1	3.5	5.7

PERIOD OF RECORD: 1984-1993

All values are as mg/L except:
1. Colour as apparent units
2. Mercury as µg/L
3. pH
4. Specific Conductivity as µS/cm
5. Temperature as ^{o}C
6. Turbidity as NTU

TABLE 6.2.4
B.C. CRITERIA FOR CHLOROPHENOLS

Chlorophenol	Objective (µg/L)*		Chlorophenol	Objective (µg/L)*	
2-MCP	any pH	0.90	2,3,6-TCP	≥ pH 7.3	0.32
3-MCP	any pH	0.50	2,4,5-TCP	< pH 7.9	0.08
4-MCP	any pH	0.70	2,4,5-TCP	≥ pH 7.9	0.24
2,3-DCP	any pH	0.20	2,4,6-TCP	< pH 7.5	0.12
2,4-DCP	any pH	0.30	2,4,6-TCP	≥ pH 7.5	0.50
2,5-DCP	any pH	0.30	3,4,5-TCP	any pH	0.06
2,6-DCP	< pH 7.9	0.30	2,3,4,5-TTCP	< pH 7.5	0.04
2,6-DCP	≥ pH 7.9	0.90	2,3,4,5-TTCP	≥ pH 7.5	0.20
3,4-DCP	any pH	0.20	2,3,4,6-TTCP	< pH 7.1	0.04
3,5-DCP	< pH 8.1	0.12	2,3,4,6-TTCP	≥ pH 7.1	0.30
3,5-DCP	≥ pH 8.1	0.35	2,3,5,6-TTCP	< pH 7.1	0.02
2,3,4-TCP	< pH 7.9	0.10	2,3,5,6-TTCP	pH 7.1-pH 8.1	0.10
2,3,4-TCP	≥ pH 7.9	0.30	2,3,5,6-TTCP	> pH 8.1	0.25
2,3,5-TCP	< pH 7.9	0.08	2,3,4,5,6-PCP	< pH 6.9	0.02
2,3,5-TCP	≥ pH 7.9	0.25	2,3,4,5,6-PCP	pH 6.9-pH 7.9	0.10
2,3,6-TCP	< pH 7.3	0.06	2,3,4,5,6-PCP	> pH 7.9	0.30

*** Maximum concentration**

TABLE 6.3.1

AMBIENT WATER QUALITY DATA SUMMARY FOR THE FRASER RIVER AT STONER (SITE E206182)

Characteristic	Number of Values	Maximum	Minimum	Mean	Std.Dev
Alkalinity	14	89.6	5.2	64.9	22.7
Carbon-inorganic	36	24	12	16.8	3.8
-total	36	29	13	20.9	5.1
Chloride	38	11	1	4.4	3.4
Coliforms-fecal	24	1600	<2	120+	-
Colour (TAC)	37	46	3	18.2	11.8
Hardness-total	36	122.7	58.1	79.3	-
-calcium	36	33.8	17.1	23.1	4.3
-magnesium	36	9.32	3.63	5.25	1.14
Metals-aluminum (diss)	27	0.29	<0.02	0.08	0.05
-aluminum(total)	25	5.52	0.08	1.5	1.6
-chromium (diss)	22	0.005	<0.005	<0.005+	-
-copper (diss)	35	0.02	<0.001	0.006	0.005
-iron (diss)	35	0.28	0.02	0.11	0.07
-iron (total)	36	10.9	0.16	2.38	2.62
-mercury (total)	14	0.00007	<0.00005	<0.00005+	-
-manganese (diss)	35	0.04	<0.01	0.014	0.006
-manganese (total)	36	0.35	0.02	0.07	0.07
-molybdenum(total)	36	0.02	<0.01	<0.01+	-
-lead (diss)	22	0.002	<0.001	<0.001+	-
-nickel (total)	36	<0.05	<0.05	<0.05	-
-zinc (diss)	35	<0.01	<0.01	<0.01	-
-zinc (total)	36	0.08	<0.01	<0.01+	-
Nitrogen-ammonia	40	0.05	<0.005	0.016	0.013
-nitrate/nitrite	36	0.15	0.02	0.07	0.04
-nitrite	14	0.006	<0.005	<0.005+	-
-Kjeldahl	15	0.32	0.12	0.24	0.065
pH	40	8.2	7.5	7.8+	-
Phenols	34	0.009	<0.002	0.003	0.002
Phosphorus-ortho diss	14	0.012	<0.003	0.006	0.003
-dissolved	36	0.019	<0.003	0.008	0.005
-total	14	0.161	0.024	0.053	0.041
Sodium	41	9.8	1.3	4.3	2.7
Solids-total	36	492	108	166	80
-suspended	35	402	1	70	88
-dissolved	37	137	64	99	23
Specific Conductivity	41	290	110	162	45
Sulphate	14	12.6	4.2	8.4	2.9

PERIOD OF RECORD : 1985 - 1991 + Median Value

Values are as mg/L except:
1) Colour as TAC 2.)Coliforms as CFU/cL
3.)pH 4.)Specific Conductivity as µS/cm

DATA SOURCE: MoELP "SEAM" RETRIEVAL SYSTEM

TABLE 6.3.2

AMBIENT WATER QUALITY DATA SUMMARY FOR FRASER RIVER AT MARGUERITE (SITE 0600011)

B.C. MoELP Data

Characteristic	Number of Values	Maximum	Minimum	Mean	Std.Dev
Alkalinity	3	81.3	51.3	63.4	15.8
Chloride	39	11	0.5	3.6	2.8
Coliforms-fecal	86	>2400	<2	83+	-
Colour (TAC)	78	47	<1	19.9	10.7
Hardness-total	32	102.5	44.5	78.1	-
-calcium	32	29.5	13.3	22.9	3.91
-magnesium	32	9.76	2.73	5.10	1.33
Metals-aluminum(total)	115	20	<0.01	1.94	2.74
-chromium(total)	47	0.032	<0.005	0.008	0.004
-copper (total)	32	0.02	0.002	0.010	0.003
-iron (total)	32	16	0.17	2.18	2.94
-mercury (total)	2	<0.00005	<0.00005	<0.00005	-
-manganese (total)	32	0.43	<0.01	0.057	0.076
-molybdenum(tot)	32	0.02	<0.01	<0.01+	-
-lead(total)	3	0.004	0.001	0.002	0.002
-nickel (total)	32	<0.05	<0.05	<0.05	-
-zinc (total)	32	0.05	<0.005	<0.01+	-
Nitrogen-ammonia	98	0.07	<0.005	0.014	0.013
-nitrate/nitrite	3	0.11	<0.02	0.07	0.05
-Kjeldahl	3	0.18	0.1	0.14	0.04
pH	80	8.3	5.5	8.0+	-
Phenols	31	0.026	<0.002	<0.002+	-
Phosphorus-ortho diss	94	0.021	<0.003	0.005	0.004
-dissolved	95	0.025	<0.003	0.008	0.005
-total	3	0.078	0.009	0.040	0.035
Potassium	3	0.8	0.5	0.7	0.2
Sodium	3	8.1	2.2	4.2	3.4
Solids-dissolved	109	158	8	107	28
-suspended	112	549	<1	74	104
Specific Conductivity	92	245	2	158	42
Sulphate	3	11	4.4	7.3	3.4
Turbidity	3	26	1.2	10.5	13.5

PERIOD OF RECORD : 1985 - 1991

Values are as mg/L except:
1) Colour as TAC 2.)Coliforms as CFU/cL
3.)pH 4.)Specific conductivity as µS/cm
5.)Turbidity as NTU

DATA SOURCE: MoELP "SEAM" RETRIEVAL SYSTEM

TABLE 6.3.2

(Continued)

Environment Canada Data

Variable	No. of Values	Maximum	Minimum	Mean	Std. Dev.
Alkalinity-total	174	97	48.0	65.4	11.6
Chloride	178	11.9	0.2	3.9	3.0
Colour-Apparent	178	400	5.0	41.2	45.6
Fluoride	178	0.148	0.0	0.1	0.0
Hardness-Calcium	174	32.7	16.0	21.9	3.6
-Magnesium	174	6.9	2.6	4.3	1.0
-Total	174	110	52.4	72.4	12.9
Metals (Total)					
-Aluminum	73	10.6	0.02	2.3	2.6
-Arsenic	169	0.0067	0.000	0.001	0.001
-Cadmium	169	0.0018	0.0001	0.0004	0.0004
-Chromium	169	0.0096	0.0002	0.002	0.002
-Copper	169	0.1354	0.001	0.012	0.021
-Iron	169	44	0.02	3.5	5.0
-Lead	169	0.0096	0.0002	0.002	0.002
-Manganese	169	0.53	0.01	0.08	0.09
-Mercury	158	0.410	0.005	0.026	0.038
-Molybdenum	73	0.001	0.0001	0.0004	0.0002
-Nickel	101	0.029	0.0002	0.0060	0.0066
-Selenium	169	0.0006	0.0001	0.000	0.000
-Zinc	168	0.974	0.001	0.026	0.099
Nitrogen-dissolved	177	0.90	0.01	0.21	0.11
-nitrate/nitrite	177	0.38	0.02	0.10	0.06
pH	178	8.30	5.90	7.69	0.49
Phosphorus-total	177	1.14	0.01	0.11	0.16
Potassium	178	1.71	0.01	0.62	0.2
Sodium	178	9.90	0.10	3.99	2.3
Solids-dissolved	78	270	24.0	129.8	49.0
-suspended	78	661	10.0	88.8	118.7
-total	78	727	96.0	210.2	116.3
Specific Conductivity	174	247	108	156.5	32.8
Temperature	170	20	0.0	6.3	5.9
Turbidity	178	180.	0.10	21.55	27.83

PERIOD OF RECORD: 1986-1992

Values are as mg/L except :

1.) Colour as apparent colour units

2.) Mercury as µg/L

3.) pH

4.) Specific conductivity as µS/cm

5.) Turbidity as NTU

DATA SOURCE: MoELP "SEAM" RETRIEVAL SYSTEM

TABLE 6.3.3
SUMMARY OF FRASER RIVER PULP MILL ORGANICS MONITORING - FRASER RIVER AT MARGUERITE (0600011)

Variable:	Maximum	Minimum	Mean	Std. Dev.
monochlorophenols	<0.05	<0.05	<0.05	0
dichlorophenols	<0.05	<0.05	<0.05	0
trichlorophenols	0.17	<0.05	0.11	0.036
tetrachlorophenols	0.16	<0.05	0.093	0.059
pentachlorophenols	0.22	<0.05	0.22	<0.05+
monochloroguaiacols	<0.1	<0.05	<0.05+	0
dichloroguaiacols	0.16	<0.05	0.14	0.028
trichloroguaiacols	0.85	<0.05	0.3	0.2
tetrachloroguaiacols	0.39	<0.05	0.04	0.13
monochlorocatechols	<0.1	<0.1	<0.1	0
dichlorocatechols	<0.1	<0.1	<0.1	0
trichlorocatechols	<0.1	<0.1	<0.1	0
tetrachlorocatechols	<0.1	<0.1	<0.1	0
dichloroveratrols	<0.1	<0.1	<0.1	0
trichloroveratrols	<0.1	<0.1	<0.1	0
tetrachloroveratrols	<0.1	<0.1	<0.1	0
monochlorovanillins	0.62	<0.1	0.412	0.215
dichlorovanillins	<0.1	<0.1	<0.1	0
trichlorosyringol	<0.1	<0.1	<0.1	0
2,4,6-tribromophenol (surrogate recovery %)	128%	41%	85.45%	23.71%
adsorbable organo-halides (AOX)	310	<10	121	99.6

+ Median Value

Values are as µg/L unless otherwise indicated

PERIOD OF RECORD : NOVEMBER, 1990 TO MARCH, 1993 (N=53)

TABLE 6.3.4

AMBIENT WATER QUALITY DATA SUMMARY FOR THOMPSON RIVER AT SPENCES BRIDGE (SITE E206586)

Characteristic	Number of Values	Maximum	Minimum	Mean	Std.Dev
Alkalinity	2	44.7	39.5	42.1	-
Chloride	3	4.9	3.1	4.0	0.9
Coliforms-fecal	1	<2	<2	<2	-
Colour (TAC)	2	10	4	7	-
Hardness-total	4	55	42.5	48.2	-
-calcium	4	16.9	13	14.7	1.65
-magnesium	4	3.11	2.44	2.77	0.33
Metals-aluminum(total)	7	0.07	0.02	0.05	0.02
-arsenic (total)	3	<0.001	<0.001	<0.001	-
-cadmium (total)	2	<0.0005	<0.0005	<0.0005	-
-chromium(total)	4	<0.01	<0.01	<0.01	-
-copper (total)	3	0.005	0.002	0.004	0.002
-iron (total)	4	0.1	0.07	0.085	0.013
-mercury (total)	2	<0.00005	<0.00005	<0.00005	-
-manganese (total)	3	0.007	0.002	0.004	0.003
-molybdenum(total)	4	0.01	<0.01	<0.01+	-
-lead(total)	3	0.002	<0.001	0.001+	-
-nickel (total)	4	<0.05	<0.05	<0.05	-
-uranium (total)	43	0.0008	<0.0002	0.0004	0.0002
-zinc (total)	3	<0.005	<0.005	<0.005	-
Nitrogen-ammonia	115	0.024	<0.005	0.006	0.003
-nitrate/nitrite	2	0.11	0.07	0.09	-
-Kjeldahl	2	0.12	0.06	0.09	-
pH	103	8.2	7.1	7.8+	-
Phosphorus-ortho	3	0.005	<0.001	0.002	0.002
-ortho diss	7	<0.003	<0.003	<0.003	-
-dissolved	112	0.017	<0.003	0.004	0.002
-total	4	0.01	0.004	0.007	0.003
Potassium	3	1	0.9	0.9	0.1
Sodium	3	4.8	3.4	4.2	0.7
Solids-dissolved	128	90	44	67	10.4
-suspended	128	138	<1	5.6	13.3
Specific Conductivity	110	135	43	102.5	19.1
Sulphate	3	11.7	9.7	10.5	1.1
Turbidity	3	0.8	0.8	0.8	0.0

PERIOD OF RECORD : 1987 - 1991

+ Median Value

Values are as mg/L except:
1) Colour as TAC 2.)Coliforms as CFU/cL
3.)pH 4.)Specific conductivity as μS/cm
5.)Turbidity as NTU

DATA SOURCE: MoELP "SEAM" RETRIEVAL SYSTEM

TABLE 6.3.4
(Continued)
Environment Canada Data

Variable	No. of Values	Maximum	Minimum	Mean	Std. Dev.
Alkalinity-total	190	64.3	27.5	37.6	5.7
Chloride	193	5.2	0.2	2.3	1.3
Colour-Apparent	195	60	5	9.1	5.7
Fluoride	193	0.14	0.02	0.06	0.02
Hardness-Calcium	190	19.6	9.6	13.5	1.8
-Magnesium	190	5.09	1.2	2.34	0.56
-Total	190	69.9	30.3	43.3	6.7
Metals (Total)					
-Aluminum	78	4.12	0.004	0.255	0.505
-Arsenic	185	0.0013	0.0001	0.0002	0.0002
-Cadmium	186	0.0011	0.0001	0.0002	0.0003
-Chromium	108	0.343	0.0002	0.0051	0.0329
-Copper	186	0.771	0.0002	0.0147	0.0677
-Iron	186	5.14	0.004	0.29	0.49
-Lead	186	0.0206	0.0002	0.0011	0.0020
-Manganese	186	0.139	0.0001	0.0103	0.0135
-Mercury	78	0.0516	0.0002	0.0120	0.0057
-Molybdenum	78	0.001	0.0001	0.0006	0.0002
-Nickel	107	0.0398	0.0002	0.0013	0.0038
-Selenium	185	0.0009	0.0001	0.0002	0.0001
-Zinc	185	2.07	0.0002	0.0166	0.1529
Nitrogen-dissolved	192	56	0.01	0.45	4.03
-nitrate/nitrite	193	55.5	0.002	0.384	3.988
pH	194	8.1	5.7	7.4	0.5
Phosphorus-total	193	0.539	0.002	0.018	0.043
Potassium	193	1.18	0.01	0.84	0.17
Sodium	193	4.7	0.1	2.9	1.1
Solids-dissolved	12	178	47	91.8	38.4
-suspended	12	57	10	18.9	13.3
-total	12	188	57	110.7	42.4
Specific Conductivity	192	142	69.6	103.4	17.3
Temperature	193	20	0	9.2	5.6
Turbidity	194	19	0.1	1.4	1.9

PERIOD OF RECORD: 1984-1993

All values are as mg/L except:
1. colour as apparent units
2. Mercury as µg/L
3. pH
4. Specific Conductivity as µS/cm
5. Temperature as ^{o}C
6. Turbidity as NTU

TABLE 6.3.4
(Continued)

SITE: Thompson River at Spences Bridge
SEAM: E206586

Variable:	Maximum	Minimum	Mean	Std. Dev.
monochlorophenols	<0.05	<0.05	<0.05	0.00
dichlorophenols	<0.05	<0.05	<0.05	0.00
trichlorophenols	<0.05	<0.05	<0.05	0.00
tetrachlorophenols	<0.05	<0.05	<0.05	0.00
pentachlorophenols	<0.05	<0.05	<0.05	0.00
monochloroguaiacols	<0.05	<0.05	<0.05	0.00
dichloroguaiacols	<0.05	<0.05	<0.05	0.00
trichloroguaiacols	<0.05	<0.05	<0.05	0.00
tetrachloroguaiacols	<0.05	<0.05	<0.05	0.00
monochlorocatechols	<0.1	<0.1	<0.1	0.00
dichlorocatechols	<0.1	<0.1	<0.1	0.00
trichlorocatechols	<0.1	<0.1	<0.1	0.00
tetrachlorocatechols	<0.1	<0.1	<0.1	0.00
dichloroveratrols	<0.1	<0.1	<0.1	0.00
trichloroveratrols	<0.1	<0.1	<0.1	0.00
tetrachloroveratrols	<0.1	<0.1	<0.1	0.00
monochlorovanillins	<0.1	<0.1	<0.1	0.00
dichlorovanillins	<0.1	<0.1	<0.1	0.00
trichlorosyringol	<0.1	<0.1	<0.1	0.00
adsorbable organo-halides (AOX)	40	20	30.71	7.30

UNITS: µg/L (ppb) unless otherwise indicated.

PERIOD OF RECORD: AUGUST 1992 - MARCH 1993
(N=15)

TABLE 6.3.5

AMBIENT WATER QUALITY DATA SUMMARY FOR FRASER RIVER AT HOPE (SITE E206581)

Variable	No. of Values	Maximum	Minimum	Mean	Std. Dev.
Alkalinity	2	62.7	61.1	61.9	-
Chloride	3	6.8	3.5	4.9	1.7
Coliforms-fecal	49	540	<2	49+	-
Colour (TAC)	3	19	15	17.3	2.1
Hardness-total	44	99.3	32.6	63.6	-
-calcium	44	29.6	10.6	18.5	2.7
-magnesium	44	7.22	1.48	4.20	0.93
Metals-aluminum(total)	57	13.3	0.11	1.73	2.36
-chromium(total)	44	0.02	<0.005	<0.005+	-
-copper (total)	44	0.89	0.001	<0.01+	-
-iron (total)	44	14.1	0.17	1.8	2.5
-mercury (total)	2	<0.00005	<0.00005	<0.00005	-
-manganese (total)	44	0.46	0.006	0.05	0.07
-molybdenum(total)	44	0.02	<0.01	<0.01+	-
-lead(total)	3	0.005	0.001	0.003	0.002
-nickel (total)	44	0.08	<0.05	<0.05+	-
-zinc (total)	44	0.39	<0.005	0.024	0.058
Nitrogen-ammonia	64	0.021	<0.005	<0.005+	-
-nitrate/nitrite	2	0.12	0.10	0.11	-
-Kjeldahl	2	0.2	0.09	0.15	-
pH	63	8.2	7.4	7.9+	-
Phosphorus-ortho diss	63	0.008	<0.003	<0.003+	-
-dissolved	63	0.013	<0.003	0.005	0.002
-total	3	0.072	0.013	0.033	0.034
Potassium	3	0.9	0.7	0.8	0.1
Sodium	3	6	3.8	4.9	1.1
Solids-dissolved	62	124	48	86	14.9
-suspended	63	380	1	46	63
Specific Conductivity	65	207	84	134	23.7
Sulphate	3	12.9	9.7	11	1.7
Turbidity	3	25	2	10.4	12.7

PERIOD OF RECORD : 1986 - 1991

Values are as mg/L except:
1) Colour as TAC 2.)Coliforms as CFU/cL
3.)pH 4.)Specific conductivity as µS/cm
5.)Turbidity as NTU

DATA SOURCE: MoELP "SEAM" RETRIEVAL SYSTEM

TABLE 6.3.5

(Continued)

Environment Canada Data

Variable	No. of Values	Maximum	Minimum	Mean	Std. Dev.
Alkalinity-total	235	65.2	24.0	51.2	8.0
Chloride	237	6.9	0.2	2.3	1.4
Colour-Apparent	239	200.0	5.0	27.8	25.2
Fluoride	237	0.8	0.0	0.1	0.0
Hardness-Calcium	235	22.2	9.2	17.3	2.4
-Magnesium	235	5.8	0.6	3.5	0.9
-Total	235	77.5	27.5	57.7	9.0
Metals (Total)					
-Aluminum	57	9.0	0.0	2.0	2.2
-Arsenic	234	0.008	0.000	0.001	0.001
-Cadmium	203	0.002	0.000	0.001	0.000
-Copper	203	0.159	0.000	0.009	0.017
-Iron	203	28.0	0.0	2.6	3.6
-Lead	203	0.009	0.000	0.002	0.001
-Manganese	205	0.4	0.0	0.1	0.1
-Mercury	189	0.080	0.005	0.021	0.014
-Molybdenum	57	0.0009	0.0001	0.0006	0.0002
-Nickel	99	0.0242	0.0004	0.0046	0.0050
-Selenium	234	0.002	0.000	0.000	0.000
-Zinc	203	0.097	0.001	0.010	0.012
Nitrogen-dissolved	206	0.8	0.0	0.2	0.1
-nitrate/nitrite	237	0.613	0.002	0.093	0.060
pH	238	8.2	5.8	7.6	0.4
Phosphorus-total	206	0.625	0.002	0.091	0.110
Potassium	237	1.9	0.0	0.7	0.2
Sodium	237	6.0	0.1	3.1	1.3
Solids-dissolved	148	266	31	100.6	39.4
-suspended	150	665	10	74.6	98.6
-total	148	760	43	170	91.7
Specific Conductivity	237	181	59.6	126.2	22.7
Temperature	231	30	0	9.0	5.7
Turbidity	238	135	0	21	23

PERIOD OF RECORD: 1979-1993

Values are as mg/L except:
1) Colour as TAC 2.)Mercury as µg/L
3.)pH 4.)Specific conductivity as µS/cm
5.)Turbidity as NTU

SOURCE OF DATA : DOE "NAQUADAT" DATA RETRIEVAL SYSTEM

TABLE 6.3.6
SUMMARY OF FRASER RIVER PULP MILL ORGANICS MONITORING - FRASER RIVER AT HOPE (E206581)

Variable:	Maximum	Minimum	Mean	Std. Dev.
monochlorophenols	<0.05	<0.05	<0.05	0.00
dichlorophenols	<0.05	<0.05	<0.05	0.00
trichlorophenols	<0.05	<0.05	<0.05	0.00
tetrachlorophenols	0.33	<0.05	<0.05+	0.00
pentachlorophenols	0.87	<0.05	<0.05+	0.00
monochloroguaiacols	<0.05	<0.05	<0.05	0.00
dichloroguaiacols	<0.05	<0.05	<0.05	0.00
trichloroguaiacols	0.86	<0.05	<0.05+	0.00
tetrachloroguaiacols	0.5	<0.05	<0.05+	0.00
monochlorocatechols	<0.1	<0.1	<0.1	0.00
dichlorocatechols	<0.1	<0.1	<0.1	0.00
trichlorocatechols	<0.1	<0.1	<0.1	0.00
tetrachlorocatechols	0.29	<0.1	<0.1+	0.00
dichloroveratrols	<0.1	<0.1	<0.1	0.00
trichloroveratrols	<0.1	<0.1	<0.1	0.00
tetrachloroveratrols	<0.1	<0.1	<0.1	0.00
monochlorovanillins	<0.1	<0.1	<0.1	0.00
dichlorovanillins	<0.1	<0.1	<0.1	0.00
trichlorosyringol	<0.1	<0.1	<0.1	0.00
2,4,6-tribromophenol (surrogate recovery %)	133%	38%	92.4%	18%
adsorbable organo-halides (AOX)	140	10	40	41.6

+ Median Value

Values are as µg/L unless otherwise indicated

PERIOD OF RECORD : MARCH, 1991 TO MARCH, 1993 (N=45)

TABLE 7.0
RECOMMENDED WATER QUALITY MONITORING FOR THE FRASER RIVER FROM MOOSE LAKE TO HOPE

Site Number	Location	Frequency	Date	Variables
New Site New Site	Fraser River at outlet from Moose Lake Fraser River at Red Pass	5 times weekly in 30 days	May - June	Suspended Solids Turbidity
E206580 New Site New Sites New Site New Site E206581	Fraser River @ Hansard Fraser River above Nechako R confluence and below mills outfalls 100 m d/s Northwood 100 m d/s P.G. Intercontinental Fraser River above Quesnel Fraser River below Quesnel Fraser River at Hope	5 times weekly in 30 days once once - 3 replicates per site	January - March	Dissolved oxygen pH Temperature Colour - true Turbidity NH3-N* NO3–N* NO2–N* Suspended solids MF fecal coliform *Escherichia coli* Enterococci chlorine residual AOX chlorophenols Dehydroabietic acid Total Resin acids Dioxins and furans (H2O) Dioxins and Furans (sed)
 E206580 E206182 New Site 0600011 E206581	Site with suitable natural substrate near the following: Fraser R at Hansard Fraser River at Stoner Fraser River above Quesnel Fraser R at Marguerite Fraser River at Hope	once - 6 replicates per site	July–Sept	Periphyton chlorophyll-*a*
	At several sites upstream and downstream from the mills (4 sites @ P.G. & Quesnel in total)	once (15 fish/site)	July-Sept	Dioxins & Furans (fish) (Minimum of 3 species with 5 individuals per species at each site)

*Very low results for these variables compared to the objectives will result in these variables being precluded from further monitoring

GLOSSARY OF TERMS

Bold entries are cross-references

Absorb, Absorption	In chemistry, the movement of one substance into another. In biology, the movement of a substance into an organism through skin, mucous membranes or root hairs, or across a cell membrane. (cf. **Adsorption, Sorption**)
Acidity	Acidity of water is its quantitative capacity to react with a base to a designated **pH**. Acidity contributes to corrosiveness, and influences chemical reactions and biological processes. (cf. **Alkalinity**)
Acute Toxicity	Severe harm or death of an organism brought about by a **toxic** substance or mixture within a short period of time (usually 4 days for fish) after exposure. (cf. **Chronic Toxicity**)
Adsorb, Adsorption	The taking up or attachment of one substance on the surface of another. For example, some **pollutants** in water may be adsorbed onto **suspended solids**. This may alter certain characteristics such as **bioavailability**. (cf. **Absorption, Sorption**)
Aeration	The introduction of air into water. Sewage **effluent** is aerated to create **aerobic** conditions and promote purification. (see **Secondary Sewage Treatment**)
Aerobic	Denotes the presence of free oxygen (gaseous or dissolved) in an environment . (cf. **Anaerobic**)
Algae	Simple **photosynthetic** non-vascular plants, mostly aquatic. Most are microscopic; some reach large sizes. (see **Phytoplankton**)
Algal bloom	Proliferation of one or a few species of **phytoplankton** during favorable growing conditions (e.g., abundant **nutrients** or sunlight). A bloom may colour a body of water if algal concentrations are high enough. Some blooms result in fish kills or threaten human health. (see **Red Tide, Paralytic Shellfish Poisoning (PSP)**)
Alkalinity	The acid-neutralizing capacity of a substance, expressed as a number. (see **Acidity, pH**)

Ambient	Refers to "general" conditions in the environment outside the zone of influence of discharges (for example, ambient water quality in a water body outside **initial dilution zones**, unaffected by local conditions or **site-specific** sources of contamination). Ambient conditions are influenced by **background levels** as well as generalized **anthropogenic** sources and inputs.
Anadromous	**Life cycle** description of certain fish (e.g., many **salmonids**) that hatch in fresh water, mature in salt water, and return to fresh water to reproduce.
Anaerobic	Denotes the absence of free oxygen (gaseous or dissolved) in an environment. Water bodies can become anaerobic due to bacterial decay of organic pollutants using up the available dissolved oxygen in the water. (cf. **Aerobic**, **Anoxic**, **Biochemical Oxygen Demand**)
Anoxic	Oxygen depletion or deficiency; **anaerobic**.
Anthropogenic	Man-made or man-modified. (cf. **Biogenic**)
AOX (Adsorbable Organic Halogen)	A measure of the concentration of total organic chlorine or other halogens in effluent. This is often used as an **indicator** of the level of contamination by organic chemicals.
Aquatic Life, Aquatic Organism	Organism which spends a critical part or all of its **life cycle** in water, and relies on a particular aquatic **habitat** for its survival.
Aromatic	A class of chemical substances (cyclic **hydrocarbons**) that contain at least one benzene ring.
Assimilative Capacity	The loosely-defined upper limit of a particular **ecosystem's** ability to **assimilate** new substances or changes. Beyond this, significant adverse effects may appear.
Background Level	"Natural" level of a substance in an environment. Background levels of some water quality constituents may be high due to regional variations in geochemistry. This is taken into account when setting **water quality objectives**. (cf. **Elevated Level**)
Benthic Organisms	**Aquatic organisms** that lives on or in the bottom of any aquatic habitat. They include **sessile**, creeping and burrowing forms.
Benthos	The sum total of all organisms living on or in the bottom of a particular water body or aquatic habitat.

Bioaccumulation	General term for a process by which chemical substances are accumulated by **aquatic organisms** from water, sediment or food containing the substances. Not synonymous with **bioconcentration** or **biomagnification**.
Bioassay	A test used to evaluate the biological effect of some substance, factor or condition. Often involves determining the **concentration** or **dose** of a chemical substance necessary to affect a test organism under certain conditions. Some bioassays, such as the 96-hour LC50 **toxicity test**, are used to determine **effluent toxicity**. (cf. **LC50, Median Lethal Concentration**)
Bioavailability	The propensity and ability of a chemical substance, or a portion of it, to be **absorbed** into an organism's body or tissues. Some **toxicants** may be transformed into more or less bioavailable forms, depending on environmental conditions or waste treatment methods.
Biochemical Oxygen Demand (BOD)	The amount of oxygen needed to **oxidize** organic and oxidizable inorganic material in water, wastewater or effluent. The 5-day BOD test, which involves bacterial decomposition of a sample, is commonly used in pollution monitoring. High BOD may indicate potential oxygen depletion, adversely affecting aquatic life. (cf. **Chemical Oxygen Demand**)
Bioconcentration	The process by which an aquatic organism accumulates a chemical substance directly from the water. This occurs when the uptake of a substance is greater than the rate at which it is eliminated or **metabolized**. (cf. **Bioaccumulation, Biomagnification**)
Biodegradable	Capable of rapid decomposition, usually by **micro-organisms**.
Bioindicator	An organism which is sensitive to pollution and can therefore be used to measure or indicator of the degree of pollution in its environment.
Biomagnification	Increased concentration or buildup of a substance (e.g., **contaminant**) in organisms at successively higher **trophic levels** up a **food chain**. (cf. **Bioaccumulation, Bioconcentration**)
Biomass	The amount of organic matter in a given **ecosystem**, usually expressed as dry weight per unit area.
Biota	Collectively, the living organisms of a given area including **micro-organisms**, plants, and animals.

Buffer, Buffering Capacity	A solution capable of resisting a change in **pH**. Buffering capacity is the ability of a solution to maintain its pH.
Carcinogen	A chemical substance or physical agent capable of causing cancer.
Characteristic	A distinguishing trait, quality or property. (cf. **Constituent, Property, Variable**)
Chlorinated Organics	Interchangeable with **organochlorines**.
Chlorination	The addition of chlorine to water, sewage or industrial wastes for **disinfection** or other biological or chemical purposes.
Chlorophenols	A group of toxic organic chemicals used as wood preservatives and **pesticides**.
Chlorophyll	Green pigment, essential for **photosynthesis**, found in cells of most higher plants. Used as a measure of **productivity**.
Chronic Toxicity	**Toxicity** involving a stimulus that continues or lingers for a long time, relative to the life span of an organism. Effects may be lethal or **sublethal**, such as reduced growth. (cf. **Acute Toxicity**)
Coliform Bacteria	A group of **micro-organisms** normally found in the intestines of humans and other warm-blooded animals. Their presence in water may indicate contamination from human or animal wastes, hence various types are used as indicators of sanitary quality for certain **water uses**. (see **Enterococci**, ***Escherichia coli***, **Fecal Coliform**, **Microbiological Indicator**)
Colour	see **True Colour**
Composite (sample)	A sample formed by combining two or more individual samples or portions. (cf. **Replicate**)
Concentration	The quantifiable amount of a substance in the environment. (cf. **Dose**)
Contaminant, Contamination	Any foreign substance (physical, chemical or biological) that enters food, air, water, sediment or soil. Unlike **pollution**, does not necessarily imply an effect. Usually taken to mean **anthropogenic** substances introduced into the environment.

Control	An essential part of a test or experiment that duplicates all the conditions of the test but contains none of the material, procedure or circumstance being tested. Used as a standard of comparison in judging experimental effects.
Criteria	A standard upon which a judgement or decision may be based. Criteria form the basis for setting environmental objectives for a specific area. (see **Water Quality Criteria**)
Cumulative	Brought about or increased in strength by successive additions at different times or in different ways. Reduction of water quality in a water body may result from the cumulative effect of many small impacts, as well as from a single large impact.
Data	Individual pieces of information.
Designated Water Use	A **water use** that is to be protected at a specific location. Designated water uses for the purposes of setting **water quality criteria** and **water quality objectives** in British Columbia include: drinking, public water supply and food processing; aquatic life and wildlife; agriculture (irrigation, livestock watering); recreation and aesthetics; and industrial water supply.
Detection Limit	The smallest **concentration** of a substance which can be measured to a specified degree of certainty by a particular analytical method. Instrumental and analytical detection limits also need to be known.
Diffuser	A structure at or near the end of an **outfall**, designed to improve the initial dilution of discharged **effluent**.
Dilution	To diminish the strength of a solution by mixing with or adding more water.
Dioxins	A group of 75 chlorinated organic compounds (**polychlorinated dibenzodioxins**) formed when chlorine reacts with organic materials in certain chemical processes (e.g., pulp & paper bleaching) or during combustion. Some are highly toxic at low concentrations. Dioxins are closely linked to **furans** in their chemical structure, and the two are often discussed together.
Disinfection	The destruction of microorganisms by the use of a chemical agent (disinfectant) such as chlorine. (cf. **Chlorination**).
Dissolved Metals	Metals in solution, as opposed to **total metals**. Metals which pass through a filter with a specified pore size are assumed for environmental purposes to be dissolved.

Dissolved Oxygen	Tiny oxygen bubbles in the water, essential for respiration by most aquatic organisms.
Drainage Basin	An area of land drained by a river and its tributaries. A **watershed.**
Ecosystem	A natural community of organisms occupying a given area. An ecosystem is the sum of many physical, chemical and biological characteristics, including all of the interactions between the organisms and their environment.(cf. **Habitat**)
Ecosystem Tolerance	The ability of an ecosystem to accept anthropogenic substances not required for ecosystem functioning without apparent loss of the ability to function.
Effluent	Liquid waste that is discharged into the environment as a by-product of human activity. Often a complex mixture of **contaminants** which are potential **pollutants**. Under the B.C. *Waste Management Act*, effluent is defined as "a deleterious material flowing in or out of **works**".
Elevated Level	Levels which are significantly higher statistically than those which occur naturally. (cf. **Background Level**)
Enterococci	A type of bacteria normally found in the intestinal tract of humans and animals that acts as an **indicator** of possible fecal pollution in water supplies. (cf. **Coliform Bacteria**)
Environmental Quality	The condition of major components of the environment (air, soil, sediment, water, biota). It is usually assessed against objectives and limits set by environmental and resource agencies, and against subjective perceptions.
Escapement	The number of fish (usually **salmonids**) that return to a spawning ground, usually expressed on an annual basis.
Escherichia coli (*E. coli*)	A type of **coliform bacteria**. An **indicator** of sanitary quality and a potential **pathogen**.
Estuary, Estuarine	The tidal mouth of a river or, more generally, an area where fresh and salt water meet. The salt water is at least occasionally diluted by fresh water.
Eutrophic	A water body which has elevated nutrient input or cycling, resulting in high levels of **biomass production**. (cf. **Oligotrophic**, **Productivity**).

Eutrophication	Increasing **nutrient** content within a water body over time. This natural process may be accelerated by nutrient-rich discharges from agriculture or sewage, resulting in **algal blooms**, excessive growth of **macrophytes**, or undesirable changes in water quality.
Fecal Coliform	A type of **coliform bacteria** normally found in the intestines of humans and other warm-blooded animals, and a potential **pathogen**. Their presence in water may indicate fecal contamination, so they are useful as an **indicator** of sanitary quality. (see **Coliform Bacteria**, **Enterococci**, ***Escherichia coli***)
Floodplain	Land adjacent to a stream channel which is subject to flooding.
Food chain	The flow of nutrients and energy through a sequence of organisms in an **ecosystem**, typically from producers to a series of consumers. Each is the food of the next member in the chain. (cf. **Food Web**)
Food web	Complex network of interconnecting and interacting **food chains** in an ecosystem.
Foreshore	In British Columbia legal usage, the land between mean high tide and mean low tide. (cf. **Intertidal**)
Freshet	A suddenly increased period of flow in a river as a result of spring snowmelt or heavy rainfall.
Fry	Recently hatched fish.
Furans	A group of 135 chlorinated organic compounds (**polychlorinated dibenzofurans**) related to dioxins. Found in many of the same sources as **dioxins**, through similar processes, and also potentially toxic.
Groundwater	Underground water resources within an **aquifer**. Groundwater may be tapped by wells, or form a natural source of surface water at a spring.
Habitat	A geographical place within a particular **ecosystem** where an organism, population or community resides, feeds, reproduces, rears, etc. A habitat can be described on the basis of specific physical, chemical and biological characteristics. Habitats range from large scale (e.g., **ecosection**) to small scale (e.g., a single pond).
Hardness	Measure of the concentration of calcium and magnesium **ions** in water, expressed as milligrams per litre calcium carbonate equivalent.

Headwaters	Tributaries which are the surface water sources of a water body.
Heavy metals	Metals with a high molecular weight (e.g., copper, lead, mercury, cadmium). Generally **toxic** in relatively low concentrations, but some are also essential to life. Widely used and discharged by industry.
Hydrocarbons	**Organic chemicals** containing carbon and hydrogen. Hydrocarbons may be gases, liquids or solids. Their chief sources are coal, natural gas, petroleum and plant life. (cf. **Chlorinated Hydrocarbons**)
Hydrology	The study and measurement of surface water movement and quantity.
Indicator	Something that measures or shows the extent to which an objective has (or has not) been achieved. Over time, this might indicate a trend. (cf. **Bioindicator**)
Indigenous	Non-introduced organisms that occur naturally in British Columbia.
Initial Dilution Zone	An area of **receiving water** adjacent to a **point source** discharge, extending from the point of discharge 100 metres in all directions from the surface to the bottom. **Water Quality Objectives** (except those relating to aquatic organisms) do not apply within an initial dilution zone.
Invertebrate	Animals without backbones.
Landfill	The disposal of **solid waste** by depositing it on land, often in specially prepared and maintained sites.
Larva	The immature form of many animals, often quite different in appearance, behavior and sensitivity to environmental effects than the adult form.
LC 50 (Median Lethal Concentration)	The **concentration** of a test substance which is lethal to 50 % of the exposed test organisms within a given time period, usually one to four days.
Leachate	Liquids which have percolated through a soil and contain substances in solution or suspension. Often used to mean the contaminated, potentially **toxic** runoff from a **landfill**. Under the B.C. *Special Waste Regulation*, leachate also means "any liquid, including suspended materials which it contains, which has percolated through or drained from a **special waste** facility".

Licence	Authorization (e.g., **Water Licence** issued under the B.C. *Water Act*) to perform an action which would otherwise be unlawful.
Loading	The amount of a substance added to a water body per unit area per unit time.
Macrophyte	The larger aquatic plants, including aquatic mosses, liverworts, larger algae and vascular plants.
Metabolism	The sum of all chemical processes in living organisms and cells by which various substances from food and other sources are used to provide energy and building materials for the cell or organism.
Microbiological Indicator	**Micro-organisms** used as indicators of sanitary quality for certain water uses such as drinking, contact recreation, food preparation and shellfish harvesting. (see **Coliform Bacteria**)
Micrograms per litre (µg/L)	One unit of a substance per 1,000,000,000 units of water. 1 µg/L = 1 ppb (part per billion).
Milligrams per litre (mg/L)	One unit of a substance per 1,000,000 units of water. 1 mg/L = 1 ppm (part per million).
Minimum Flow	Minimum streamflows established by regulatory authorities for the purpose of protecting and enhancing **instream uses** and values.
Mixing Zone	Area or location in a water body where individual masses of water are combined or blended.
Monitoring	Continued observation, measurement, and evaluation, with appropriate **controls**, to examine changes over a period of time. For example, water quality in a water body is monitored to ensure that **water quality objectives** are not exceeded.
Non-point Source Pollution	Pollution that comes from **diffuse sources**, carried into water bodies by various forms of **runoff**. It includes micro-organisms, pesticides, fertilizers and other deleterious materials from fields, urban and suburban land and forests.
Not Detectable	Below the **detection limit** of a specified method of analysis.
Nutrient	Organic and inorganic substances necessary for the growth and development of plants and animals. More narrowly, a substance containing phosphorus, nitrogen or potassium, which are essential to plants.

Organic Chemical, Organic Matter	Natural or man-made chemical compounds which are based on carbon chains or rings. Some man-made organic chemicals are toxic, persistent, and mobile in the environment. "Organic matter" is often used to mean plant or animal (i.e., natural as opposed to man-made) material.
Organochlorines	Organic chemicals containing chlorine. Uses include many pesticides and industrial chemicals such as **PCBs**, DDT, and polyvinyl chloride. Interchangeable with **chlorinated organics**.
Outfall	The outlet of a sanitary sewer or stormwater discharge to a body of receiving water.
PAH	A group of chemical compounds (**polycyclic aromatic hydrocarbons**) containing benzene molecules, released into the environment from atmospheric emmissions, especially the burning of fossil fuels. Potential **carcinogens**.
Parameter	A measurable or quantifiable **characteristic** or feature of something. (cf. **Property**, **Variable**)
Particulates	Any finely-divided solid substance suspended in the water. (see **Suspended Solids**)
PCB	A group of at 209 chlorinated organic compounds (**polychlorinated biphenyls**) that are stable, non-corroding, and resistant to heat and **biodegradation**. They may enter **food chains** and are toxic. The use of PCBs is now restricted.
Periphyton	Organisms attached to submerged surfaces (plants, rocks, etc.).
Permit	Written authorization (e.g., **Waste Permit** issued under section 8 of the B.C. *Waste Management Act*) to perform an action which would otherwise be unlawful.
pH	Measure of the **acidity** or **alkalinity** of a substance. The pH scale ranges from 0 to 14, with pH 7 being neutral, less than 7 acid, and more than 7 alkaline.
Phytoplankton	Floating or drifting microscopic plant life. (see **Macrophyte**, **Zooplankton**)
Plankton	Tiny plants (**phytoplankton**) and animals (**zooplankton**) which live in the surface layers of water bodies. Vital first step in many aquatic **food chains**.

Plume	A mass of water discharged by a river, an outfall or some other source into a water body which is not completely mixed and retains measurably different characteristics from the rest of the water body.
Point Source Pollution	Pollution that comes from clearly identifiable stationary sources, such as discharges from industries and municipalities.
Pollutant	A **contaminant** which is harmful to living organisms because normally it does not occur in the environment, or because its **concentration** is too high.
Pollution	The introduction by man, directly or indirectly, of substances or energy into the environment which result or are likely to result in deleterious effects. Water pollution is the **contamination** of a water resource by biological, physical or chemical discharges or introductions which adversely affect the condition of the water, makes the water harmful or unfit for living resources and human health, or limits its usefulness in any manner.
Polychlorinated biphenyl	see **PCB**
Polychlorinated dibenzodioxins	see **Dioxins**
Polychlorinated dibenzofurans	see **Furans**
Polycyclic Aromatic Hydrocarbons	see **PAH**
Primary-contact Recreation	Activities like swimming and water sports where a person has or risks direct contact with water through immersion or ingestion. (cf. **Secondary-contact Recreation**)
Primary Sewage Treatment	First step in sewage treatment. Larger solids are removed by screens or filters, and smaller particles by settling.
Pristine	Used to describe a natural location or habitat unaffected by man and containing no man-made **contaminants**.
Quality Assurance, Quality Control (QA/QC)	Procedures during sample collection and analysis which ensure that the process is under control, properly documented, and will result in data of known precision to an acceptable level of quality.
Raw Water	Untreated surface or groundwater that is available as a source of drinking water. It may or may not be potable.
Receiving Water	Any water body which may be subjected to **pollution** from **point source** or **non-point source** discharges.

Replicate	Repeated operation within a sample collection or analytical procedure. Multiple samples of water taken at the same place and time, or multiple analyses for the same **constituent** in a single sample are examples of replicates. (cf. **Composite**)
Resident (Fish)	Fish which remain in fresh water, often within the same water body, throughout their life cycle. (cf. **Anadromous**)
Runoff	Water from precipitation or snowmelt which flows off the land without sinking into the soil or evaporating.
Safety Factor	A number used to provide an extra margin of safety beyond the known or estimated sensitivities of aquatic organisms. Often applied when there is insufficient information about the toxicity of a particular substance.
Salmonid	Fish such as Pacific salmon, trout and char.
Secondary-contact Recreation	Activities like boating or fishing where a person has limited direct contact with water, and little risk of immersion or ingestion. (cf. **Primary-contact Recreation**)
Secondary Sewage Treatment	Next step after **primary sewage treatment**. Involves the reduction of **biodegradable** substances using activated sludge or trickle filters, and subsequent chlorination of the effluent. The solid by-product of this treatment is **sludge**.
Sediment	Soil particles, sand and other inorganic or organic matter eroded from land and transported and deposited by surface water.
Sidechannel	A branch of a river with both ends connected to the mainstem .
Siltation	Settling of fine **sediments** suspended in water due to a reduction in water velocities.
Site-specific	Something that is located exactly, or has an influence or effect that is limited geographically, as opposed to widespread or project-specific causes and effects.
Slough	A slow-moving branch of a river with one end connected to the mainstem .
Sludge	Liquid waste in a semi-solid form. It is a by-product of **secondary sewage treatment** and some industrial waste treatment processes.

Solid Waste	Waste material that does not have enough liquid to be free flowing. Generally disposed of by incineration or deposition in **landfills**.
Sorption	A general term for either **absorption** or **adsorption**, or a combination of the two. It is often used when the specific mechanism is not known.
Species	A group of organisms that have a high degree of similarity and generally can interbreed only among themselves.
Stratification	Water layers which form in a water body due to differences in density or temperature within the **water column**. Most pronounced when there is little mixing or turbulence within the water body. Profoundly affects other water quality conditions. (cf. Halocline, Thermocline)
Streamflow	The rate at which water passes a given point in a stream, usually expressed in cubic metres per second. (cf. **Minimum Flow**)
Sublethal	Involves a stimulus below the level that causes death.
Substance	Under the *Canadian Environmental Protection Act*, substance means "any distinguishable kind of organic or inorganic matter ... capable of being dispersed in the environment".
Substrate	The bottom material of a water body. Also, the base or surface on which an organism grows.
Suspended Solids	Particles of solid matter, such as wood fibres or soil, present in an undissolved state in water. Suspended solids (also called **non-filterable residue**) contribute to turbidity, and can smother spawning grounds of fish.
Synergism	Two or more substances acting together produce an effect greater than the sum of their individual (separate) effects, or an effect which they were incapable of producing independently. It is the opposite of antagonism.
Threshold Dose or Concentration	The lowest **dose** or **concentration** of a substance at which a specific measurable effect is observed and below which no effect is observed.
Total Metal	A measure of metals **absorbed** or **adsorbed** to particles, as opposed to **dissolved metals**.
Toxic, Toxicity	The potential or capacity of a substance to cause adverse effects in a living organism.

Toxicity Test	A procedure in which the responses of aquatic organisms are used to detect or measure the presence or effect of toxic substances. (cf. **Bioassay**)
Toxin	A toxic or poisonous substance capable of producing an adverse response in an organism, injuring, impairing or killing it.
Turbidity	The cloudy conditions caused by suspended solids in liquids.
True Colour	The colour of water resulting from substances in solution, as opposed to apparent colour due to colloidal or suspended matter.
Uptake	A process by which materials are absorbed and incorporated into a living organism.
Variable	A quantity that may assume any one of a set of values. Something that is variable.
Waste	According to the *B.C. Waste Management Act*, any "actual or potential deleterious substance including air contaminants, litter, effluent, refuse, special wastes, and any other substance designated by the Lieutenant Governor in Council".
Waste Permit	A permit issued under section 8 of the B.C. *Waste Management Act* authorizing the introduction of **wastes** into the environment. It is subject to requirements for protection of the environment.
Waste water	Water that contains and transports residential, municipal or industrial wastes.
Water Allocation	Legal process whereby water use is authorized or reserved for the future.
Water Body	A natural or man-made container or portion thereof which permanently or semi-permanently holds standing or running water. A stream, river, lake, pond, marsh, reservoir, estuary, ocean, etc.
Water Column	Water in a water body extending from a given point on the surface to any depth (usually the bottom). Generally used to locate, describe or characterize the chemical and physical **constituents** at a given depth or over a depth range.

Water Quality Criteria (singular: Criterion)	In British Columbia, numerical values (such as maximum, minimum or range) for physical, chemical, or biological characteristics of water, biota, or sediment which must not be exceeded to prevent specified detrimental effects from occurring to **designated water uses**. They apply province-wide.
Water Quality Guideline	Numerical concentration or narrative statement recommended to support and maintain a **designated water use**.
Water Quality Objectives	In British Columbia, **water quality criteria** adapted to protect the most sensitive **designated water uses** at a specific location with an adequate degree of safety taking local circumstances and **background levels** into account. In a given water body, each objective may be based on the protection of a different water use.
Water Licence	Authorization under the B.C. *Water Act* to construct, maintain and operate works to store, divert and use beneficially a stipulated quantity of water in a specified manner.
Water Use	Human or natural use of water. Sensitive uses which may be impaired by adverse changes in water quality are listed under **designated water uses**, and these uses may be protected by **water quality criteria** and **water quality objectives**. Other (less-sensitive) uses include power generation, storage, waste disposal and assimilation, and navigation.
Watershed	Either the total area drained by a river and its tributaries (the **drainage basin**), or the total area of land contributing **runoff** above a given point on a stream.
Zooplankton	Microscopic floating or drifting animals. (see **Phytoplankton**)