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WATER QUALITY ASSESSMENT AND OBJECTIVES FOR THE FRASER RIVER FROM HOPE TO STURGEON AND ROBERTS BANKS

FIRST UPDATE

TECHNICAL APPENDIX

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This report is part of the British Columbia Ministry of Environment, Lands and Parks’ *Water Quality Assessment and Objectives* series. It has received formal review and approval from the Ministry. Environment Canada’s Fraser River Action Plan provided funds for the production of this report. Its contents do not necessarily reflect the view and policies of Environment Canada.

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1. INTRODUCTION

1.1 Background

Environment Canada and the British Columbia Ministry of Environment, Lands, and Parks are preparing water quality assessments and objectives in priority water basins in British Columbia. This report describes the water quality within the Fraser River from Hope to Sturgeon and Roberts Banks. Presented in this report are data collected from 1985 to June 1994. As such, the assessment focuses on recent information and impacts related to present operations. The objectives are being prepared for use by resource managers.

Previously, Water Quality Objectives have been prepared for the lower Fraser River from Hope to Kanaka Creek (Swain and Holms, 1985a) and from Kanaka Creek to the mouth of the Fraser River (Swain and Holms, 1985b). These will be updated in this report. Water Quality Objectives have been prepared for other regions within the Fraser River Basin as well. These include the Upper Fraser River from Moose Lake to Hope (Swain *et al*., 1997), tributaries to the lower Fraser River along the north shore (Swain, 1989), the Nechako River system (Swain and Girard, 1987), the Thompson River system (Nordin, 1992), the Bonaparte River (Swain, 1986a) and the San Jose River (Nagpal 1993 (a)) .

1.2 Water Quality Objectives - Basic Philosophy

Water Quality Objectives are established in British Columbia for water bodies on a site-specific basis (MELP, 1986). An 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 (MELP, 1986). 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 (MELP, 1986).

Water Quality Objectives are based upon water quality guidelines and water quality criteria. The Canadian Water Quality Guidelines are developed by the Canadian Council of Ministers of the Environment (CCME) to provide information on the effects of water quality characteristics on designated uses of freshwater environments. As such, these guidelines may be used to identify and assess water quality issues and concerns. These same guidelines may also be used as a basis for the development of Water Quality Objectives for specified sites. Similarly, Water Quality Objectives may be based on approved or working B.C. water quality criteria. Water quality criteria describe characteristics of water, biota, or sediment (MELP, 1986) that must not be exceeded to prevent specified detrimental effects from occurring to a water use in a freshwater, marine, or estuarine environment (MELP, 1986). The B.C. Ministry of Environment, Lands, and Parks is in the process of developing approved criteria for water quality characteristics throughout British Columbia, to form part of the basis for permanent objectives. The working guidelines and criteria from which many of the proposed Water Quality Objectives are adapted are discussed in literature referenced in the following chapters.

Currently, Water Quality Objectives have no legal standing and are not directly enforced. However, Water Quality Objectives do provide policy direction to resource managers for the protection of water uses in specific water bodies. Objectives guide the evaluation of water quality; management of fisheries and the province's land base; and the issuing of permits, licences and orders. They provide a reference against which the state of water quality in a particular water body can be checked and help to determine whether basin-wide water quality studies should be initiated. Water Quality Objectives are also standards for assessing the Ministry's performance in protecting water uses. In B.C., point sources of waste water are controlled through the issuance of waste management permits which specify volumes of waste water that can be released as well as the quantities and types of contaminants that can be released. Waste dischargers must abide by limits and regulations set by the Ministry to ensure that the objectives are met.

Exceedance or non-exceedance of the Water Quality Objectives can be used to reflect the effectiveness of existing pollution control regulations. It can also be used to assess the health of a water body and provide an early warning about new or unexpected pollution problems. Remedial action may be required when parameters do not meet Water Quality Objectives. Currently, objectives are only set in water bodies where man-made influences threaten a designated water use, either now or in the future.

When information on local conditions (for example, water quality, water use, aquatic life, waste discharges, etc.) is insufficient and/or the water quality guidelines or criteria for a substance are inadequate for the establishment of scientifically defensible objectives, provisional Water Quality Objectives may be designated. Provisional objectives are deliberately conservative, and a monitoring or study program is specified that will lead to the establishment of permanent objectives. For example, for the estuarine reach of the Fraser River downstream from the main stem, there exist parameters for which no criteria exist appropriate to estuary areas. In such cases, a provisional Water Quality Objective may be adapted from the more conservative and protective freshwater or marine criteria. It is important to note that permanent objectives will be reviewed from time to time and are subject to revision as new information becomes available.

The Water Quality Objectives take into account the use of water to be protected and the existing water quality. Two approaches are used in setting objectives in B.C. For water bodies with exceptionally valuable resources of provincial significance and existing water quality superior to levels indicated in water quality guidelines and criteria, the Objectives are set to avoid degradation of existing water quality. For all other water bodies, the Objectives are set to protect the water quality for the designated water uses. As such, Water Quality Objectives may be used as a basis for improving water quality and will set a goal for corrective measures in cases of water quality degradation. Water Quality Objectives are not to be used to back-calculate a maximum effluent discharge (load or volume).

While effluent control at source provides the principal means of regulating individual waste discharges, it is recognized that the concept of an initial dilution (or initial mixing) zone, wherein effluents mix with receiving waters, is also an important consideration in the management of waste and water quality. The following concepts apply to initial dilution zones. According to the B.C. Ministry of Environment's report, "Principles for Preparing Water Quality Objectives in British Columbia" (1986), ambient Water Quality Objectives do not apply within in area defined by the initial dilution zone. Important exceptions to this principle are Water Quality Objectives that pertain to fish tissues. Objectives for fish tissues apply to all parts of the river, including fish in the initial dilution zone.

The extent of the initial dilution zone should be defined on a site-specific basis, with due regard to water uses, aquatic life, including migratory fish, and other waste discharges. However, if sufficient site-specific data are not available for defining initial dilution zones for the objectives established, provisional initial dilution zones will be defined. Provisional initial dilution zones for application of Water Quality Objectives along the Fraser River from Hope to Sturgeon and Roberts Banks will be defined as follows. In rivers, provisional initial dilution zones are defined as extending up to 100m upstream (in the case of tidal influences) and downstream from a discharge, and occupying no more that 25% of the width of the river from its bed to the surface.

It is recognized that complete mixing may not occur within these designated initial dilution zones and that effluents may remain unmixed or partially mixed for considerable distances, thereby increasing the risk of impacts to water quality and water uses, especially where discharge volumes are large and where there are numerous discharges in close proximity. As such, it is imperative that provisional initial dilution zones be reviewed in light of results of site-specific studies related to water uses, aquatic life, and individual and other effluent discharges, and adjusted if they are found inadequate for the protection of designated water uses. In this document, concentrations at the edge of the initial dilution zones are presented only as indications of the dilution patterns of the given effluent. Remedial action may be enforced in cases where effluent impacts in the initial dilution zones are not acceptable.

In all cases where there are many effluents discharged, there should be consideration of synergistic or additive interactions of physical, chemical, and biological parameters within the dilution zones. To address these concerns, the concentrations of contaminants in effluents must not be acutely toxic prior to discharge and concentrations in the initial dilution zones must not result in acutely toxic conditions, objectionable sludge deposits, floating materials, harmful bioconcentration in biota, and nuisance conditions.

1.3 Description of the Watershed

The Fraser River rises in the Rocky Mountains, drains and area of about 230 000 square kilometres, and flows 1 400 kilometres to its outlet in the Strait of Georgia near Vancouver, British Columbia (Figure 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 basin is so large (approximately 25% of the Province), the conditions throughout the basin influence water quality. Many water quality characteristics vary with sediment concentration, which in turn varies seasonally with flow, which is dependent upon the climatic conditions.

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. Most often, moist eastward flowing air masses from the Pacific are forced over the mountain barriers, resulting in relatively heavy volumes of precipitation on west-facing slopes and considerably drier conditions on east-facing slopes. This is particularly true 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 the 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 and the development of a persistent high-pressure area off the coast result 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, mild winters, cool summers, and long periods free from freezing temperatures. The Coast mountains 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 Valemont has marked contrasts in climate, but generally has warm summers and cool winters.

Salmon runs on the Fraser River are among the largest in the world. The Fraser supports major commercial catches of all five Pacific species, important native food fisheries, and a significant sport fishery.

For the purpose of this water quality assessment, the Fraser River has been divided into six main reaches. These are the Fraser River from Hope to Chilliwack, Chilliwack to Kanaka Creek, Kanaka Creek to the trifurcation at New Westminster, the Fraser River North Arm from New Westminster to the Banks, the Fraser River Main Arm from New Westminster to the Banks, and Sturgeon and Roberts Banks to the mouth of the Fraser River. These reaches are depicted in Figure 2. Although there are many important and influential tributaries feeding into the Fraser River, Water Quality Objectives for the following report are applicable only to the receiving waters of the Fraser River itself. A separate Water Quality Assessment and Objectives report will discuss conditions for the tributaries discharging into the Fraser River.

1.4 Sources of Contaminants

Contaminants entering the Fraser River downstream from Hope can originate from natural or man-made sources. "Contaminants from natural sources include oxygen demanding substances, pathogens, nutrients, sediments, metals which bind to sediments or are present in dissolved form, and possibly polycyclic aromatic hydrocarbons (PAHs) contributed by forest fires" (FREMP, 1990a).

Man-made discharges to the Fraser River upstream from Hope include municipal wastes from Kamloops and Prince George, pulp mill effluents from Kamloops, Quesnel, and Prince George, mining wastes, runoff from sawmills and other industries using wood preservatives, and agricultural runoff. Contaminants discharged by the pulp mills include chlorinated phenolics, chlorinated benzene, dioxins and furans, and resin acids.

"Forestry activities take place in several Fraser River system watersheds upstream of Hope. Contaminants identified with forest activities include sediment, elevated temperature, pesticide residues, and organic debris.” (FREMP, 1990a).

1.5 Impacts of Land Use on Contaminant Loadings

The nature of contaminant loadings from diffuse non-point sources changes as land use changes. For example, in the last several years, the Lower Fraser Valley has been the site of increased residential development, often displacing traditional land uses such as agriculture. Within the Fraser River estuary, it is expected that over the next twenty years, about 200 hectares of vacant land will be switched from industrial use to residential or commercial use (FREMP, 1990b). "The greatest changes in land use in the estuary during the next twenty years will occur in the North Arm of the Fraser river due to urban encroachment." (FREMP, 1990b).

2. HYDROLOGY

The Fraser River drains the western slope of the Rocky Mountain Range and discharges via the Strait of Georgia, near Vancouver, British Columbia, into the northeast Pacific Ocean. The following discussion of the Fraser River from Hope to the mouth of the river encompasses a freshwater riverine stretch as well as an estuarine stretch. At the trifurcation of the river in New Westminster, the river flow divides, with about 15% entering the North Arm, 79% flowing into the Main Arm, and the remaining 6% flowing into Annacis Channel (Drinnan and Clark, 1980). In the North Arm itself, 45% of the flow in the North Arm enters the Middle Arm (Drinnan and Clark, 1980). A further description of flows within the Fraser River Estuary is described in Drinnan and Clark (1980).

The Fraser River exhibits the classical perpetual annual snow melt hydrograph pattern due to its large aerial snowpack and its massive basin storage. High flow months occur from May to August, while low flow months are from January to March. For the Fraser River at Hope, 64% of its annual volume runoff was recorded during the May to August period. The range of flows based on monthly mean discharges for stations shown on Figure 2 is tabulated below:

HYDROMETRIC	STATION	EXTREME MONTHLY MEAN DISCHARGE	
STATION	NUMBER	HIGHEST (m^3/s)	LOWEST (m^3/s)
Fraser R. at Hope	08MF005	10 800	482
Fraser R. at Mission	08MH024	12 400	881
Fraser R. at Port Mann	08MH126	11 900	1 030

Summaries for the flows at these stations are in Tables 1, 2, and 3. The lowest tenth percentile of low mean monthly flows were 610 m^3/s at Hope (March), 977 m^3/s at Mission (February), and 1178 m^3/s at Port Mann (February). These are the flow estimates that will be used to determine the minimum dilution available for effluent discharges.

Ratios of the mean monthly flows for the three sites were calculated (Tables 4, 5, and 6) for those years when flows were measured or estimated using models for the Mission or Port Mann sites. The ratios indicated that the mean monthly flows as measured at Hope increased by a further 28% at Mission and by 44% at Port Mann.

These ratios can also be used to back-calculate summary statistics for the Mission and Port Mann sites based on the flows recorded at Hope from 1912 to 1993. These estimates are in Tables 7 and 8, and generally indicate that the actual tenth percentile low flows may be reduced at each site by about 100 m^3/s if the ratios for the coincident periods are valid for the entire period of flows at Hope (1912 - 1993).

Tidal action influences water movement and residence times in the lower reaches of the Fraser River. During rising tide, heavier salt water flows are generated along the estuary bottom such that within the lower reaches of the river, downstream flow of freshwater at the surface is often accompanied by upriver flow of salt water at lower depths (Thomson, 1981). When strong upstream flows of salt water are concomitant with relatively moderate to low river discharges, the direction of freshwater flows are reversed (Thomson, 1981; Ages and O'Brien, 1985).

Tides in the estuary are mixed semi-diurnal (Kostachuk *et al.*, 1992) with distinct variations in heights of two high and low tides daily. Differences in tidal range occur on a fortnightly basis with spring tides of 5 metres and neap tides averaging 2 metres (Kostachuk *et al.*, 1992). Tidal range increases with distance upstream of the mouth and increasing river discharge (Kostachuk *et al.*, 1992). Stratification varies with tidal range as well as seasonal discharges. At low river discharge (January to March), mixing between fresh water and salt water increases and the estuary is classified as "moderately stratified" (Kostachuk *et al.*, 1992). At high river discharge (May to August), mixing is more restricted and the estuary is classified as a "salt wedge system" (Kostachuk *et al.*, 1992). The distinct salt wedge forms as a result of both the substantial freshwater discharge and the large amplitude salt water tides.

Some time after high tide, the salt wedge begins to retreat, slowly at first, retaining its shape; as the river flows faster with falling tide, the interface between the freshwater and salt water disintegrates. Vigorous surface to bottom mixing is observed during large ebb flows with mixing sufficiently strong to break up the wedge over a large part of the estuary (Ward, 1976). In a very short time, salt water is swept downstream as a homogenous mass of approximately 2 from surface to bottom (Ages and Woollard, 1988). Conditions during an incoming tide and advancing salt wedge are altogether different from conditions at falling tide and retreating wedge (Ages and Woollard, 1988). The pronounced asymmetry between ebb and flood tides likely limits the use of time averages in a monitoring program (Ages and Woollard, 1988). Furthermore, the presence or absence of a salt wedge could give rise to uncertainty regarding the nature of actual water samples and the usefulness of these samples for contaminant monitoring.

Tidal mixing and salinity intrusions change on seasonal and tidal time scales. During freshet conditions from May to August, salinity was confined to the outer 10km of the estuary with salinity at the mouth of the river during most of the tidal cycle and brief intrusions only during floods. When runoff conditions are moderate, salt wedge intrusion can range from the mouth of the river to 18km inland, depending on tidal amplitude. From January to March when river discharges are low, salt wedge intrusion can extend as far as 15 to 30 km inland. Tidal flow has been shown to modify salinity distribution by enhancing mixing during ebb flows (Carey, 1990). Thus, tidal flow dynamics play a prominent role in the exchange of materials across the salt water and freshwater interface.

Reports by A. Ages (1976,1979, 1985, 1987, etc.) define the interactions between salinity intrusions, and contaminant distributions and effects. Current patterns such as tidal flow reversals of freshwater in the lower reaches affect the dilution of effluents, distribution of sediments, and residence times of contaminants (Fraser River Estuary Study Steering Committee, 1978). Salinity likely plays a role in determining the bioavailability of certain contaminants such as chlorophenols (Carey, 1990). Even if site-specific analytical data regarding effluent distribution were complete, it is apparent that salinity and tidal effects render uncertainty concerning the origin, behavior, and fate of the contaminants measured in water samples.

Tides not only affect the movements of water and dissolved contaminants but also those of sediments and sediment-bound contaminants. Sediment transport in the Fraser River estuary is controlled by river discharge volume and velocity, tidal mixing, and the extent of salt wedge intrusion (Kostachuck, 1992). Kostachuk (1992) reports that the primary source of both wash and bed material loads in the estuary is the Fraser River. There exists no evidence for the significant transfer of marine sediment from the Strait of Georgia into the estuary (Kostachuk, 1992). With rising tides, the salt wedge intrusion migrates upstream and deposits suspended bed material. During falling tides, the salt wedge moves seaward and re-suspension begins as the tip of the wedge passes. Re-suspension can then be sustained by accelerating downstream currents (Kostachuk, 1992). A sediment trend analysis completed by GeoSea Consulting (Canada) Limited (FRAP, 1995) revealed the complexity of sediment transport in the lower Fraser River and its estuary. Tidal movements obscure the expected patterns of contaminants and make the analysis of specific effluents impact difficult. Site-specific studies of effluent plumes are necessary to determine such impacts. However, certain patterns can be detected, and it was suggested that since all backwaters are expected to be contaminant accumulation sites, regular sampling in those areas should reflect the state of health of the whole river (McLaren and Pen, 1995). It is apparent that tidal mixing and salinity intrusions are important factors in the fate, behavior, and distribution of contaminants in the lower Fraser River and that Water Quality Objectives must be developed in view of such influences to be sufficiently protective of all designated resource uses.

3. WATER USES

The Fraser River above Hope is used for several competing interests, including use by aquatic life and wildlife, and use for irrigation, livestock watering, drinking water supplies, and recreation.

3.1 Water Quality and Recreational Use Public Survey

To aid in determining the water uses requiring protection for the Fraser River below Hope, the B.C. Ministry of Environment, Lands and Parks, Environment Canada, the Fraser Basin Management Program, and the Fraser River Estuary Management Program sent out over one thousand surveys to stakeholders and concerned citizens of the Fraser River. The survey was also published in two magazines, The Westcoast Mariner and The Westcoast Fisherman (circulation about 10 000 each) and the Richmond News. The Westwater Fly Fishers Association also assisted in distributing approximately two hundred surveys.

The survey solicited public response on their recreational uses of the river, characteristics they value most, and characteristics they believed to be most sensitive to change. An opportunity to express their views on the current water quality of the Fraser River was also provided. The detailed responses have been included in Appendix 1. A summary table of the survey is also included.

The majority of respondents (36%) were from Abbotsford, Chilliwack and Surrey. Duration of interest in the condition of the Fraser River averaged 23 years. Ten of the 156 respondents had been interested for less than 10 years and 116 expressed an interest greater than 10 years. Of those 116, 11 respondents had an interest in the condition of the river for over 50 years.

Out of the 156 respondents, 80% used the Fraser River for hiking and walking, 63% enjoyed bird watching and nature study along the river, and 57% participated in shoreline activities such as picnicking and beachcombing. The fourth most common activity was fishing and/or crabbing (33 %) and the fifth was power boating (25%). Twenty-two per cent of the respondents used the Fraser River for kayaking, canoeing or rowing. Only 7% water ski'd, jet ski'd or wind surfed. Although 12 % of the respondents said they swam in the Fraser River, the areas they reportedly.

Activities appeared to be distributed all along the Fraser River, although Chilliwack and Matsqui were popular for hiking and walking with 6.4% and 7.1% of respondents, respectively. Kayaking, canoeing and rowing were popular pastimes from Hope to the Sturgeon and Robert Banks, but many respondents expressed concern for safety in the North and South Arm due to increased boat traffic. It was interesting to note that while many respondents had seen an increased use of jet skis on the river, only four respondents water skied or jet skied. This may indicate that the Fraser River is a popular destination for skiers living outside the Fraser Valley area or that the level of environmental concern of jet ski operators is high. A survey administered through equipment suppliers may give a more accurate result on the popularity of these sports.

When asked about their views on the current water quality of the Fraser River, 37% agreed the water quality was good or improving while 63% believed the quality to be poor. Many respondents expressed concern for fish stocks and the effects of the water quality on the commercial and sport fishing industries. Silting due to logging, untreated or primary treated sewage discharges, and industrial waste water discharges were considered the greatest threats to water quality. Increased monitoring, stronger regulations with greater enforcement, and higher fines were considered very important in protecting the water uses in the future. Respondents agreed that secondary treatment at Lulu and Annacis was long overdue. Residential development of the foreshore was also a concern and many respondents also noted the illegal and/or permitted discharge of sanitary effluent from commercial and recreational vessels and float homes on the river.

Natural beauty, diversity of plant and animal life, and greenspaces and parks were the three most valued characteristics of the Fraser River (68%, 58%, 54% respectively). 43% of the respondents considered diversity of plant and animal life, while 22% considered natural beauty, to be the most sensitive to change. Non-commercial fishing opportunities were also considered to be highly sensitive to change (14%). Many of the respondents expressed concern that the future use of the tremendous environmental and recreational resource that the Fraser River offers may be jeopardized at the expense of industrial activities. Recreational use of the river was felt to promote a sense of appreciation of the beauty and ecological value of the river and to foster a sense of ownership which encourages public concern for and involvement in the well-being of the Fraser River.

The survey shows that the residents of the lower Fraser River are concerned about water quality and are willing to help. Respondents requested a telephone number to report illegal dumping or discharging to the river. An "Adopt-a Foreshore Trail" program for schools or community groups and an auxiliary fishery officer program were suggested. Greater public education including the publication of monitoring results in local newspapers and information on what homeowners can do to reduce their impact on the water quality were requested. They requested that the financing and organization of volunteer groups should be the responsibility of the industries responsible and not the public or government funded organizations such as FREMP. It was felt that the time and money of those organizations could be better spent on restoration and rehabilitation projects.

3.2 Fisheries Use

3.2.1 Salmon

Mean salmon escapements to the different parts of the Fraser River are summarized in Table 9. The salmon escapements for the Fraser River downstream from Hope are summarized in the following tables from the period 1950 to 1985 from Farwell *et al*. (1987). The returns for the period 1950 to 1989 are presented on a yearly basis in Figure 3.

Summary of Average Salmon Escapements to the Fraser River Downstream From Hope					
	Chinook	**Chum**	**Coho**	Pink*	**Sockeye**
1951-1960	19 640	118 609	48 053	916 429	126 677
1961-1970	9 808	264 123	55 207	661 736	130 245
1971-1980	20 882	338 196	49 005	876 466	190 663
1981-1990	34 968	637 305	52 333	3 863 115	201 870
1991-1992	992	26 087	1 355	112 305	4 696

Summary of Gross Salmon Escapements to the Fraser River System					
	Chinook	**Chum**	**Coho**	**Pink**	**Sockeye**
1951-1960	56 170	130 501	70 726	1 660 434	1 355 906
1961-1970	47 409	322 042	76 476	1 520 566	1 260 421
1971-1980	66 207	338 912	65 016	2 174 953	1 221 431
1981-1990	83 769	518 390	66 169	5 193 524	1 902 622

In 1913 and 1914, Fraser River salmon stocks were devastated by rock slides at Hell's Gate caused by railway construction (Northcote and Burwash, 1991). Fishways to improve the upstream passage of fish at Hell's Gate became operational in 1945.

3.2.2 Other Species

Farwell *et al.*, (1987) reported on the distribution of resident populations of fish in the Fraser River. Below are those species found in the Lower Fraser (Northcote and Burwash, 1991).

Species	Common Name	Lower
Coregonus clupeaformis	Lake whitefish	Introduced (?)
Prosopium williamsoni	Mountain whitefish	Present
Salvelinus confluentus	Bull trout	Present
S. fontinalis	Brook trout	Present, Introduced
Oncorhynchus clarki	Cutthroat trout	Present
O. mykiss	Rainbow trout	Present
O. nerka	Kokanee	Present
Couesius plumbeus	Lake chub	Present
Cyprinus carpio	Common carp	Present, Introduced
Mylocheilus caurinus	Peamouth chub	Present
Ptycocheilus oregonensis	Northern squawfish	Present
Rhinichthys cataractae	Longnose dace	Present
R. falcatus	Leopard dace	Present
Richardsonius balteatus	Redside shiner	Present
Catostomus catostomus	Longnose sucker	Present
C. columbianus	Bridgelip sucker	Present
C. macrocheilus	Largescale sucker	Present
Lota lota	Burbot	Present
Cottus aleuticus	Coastrange Sculpin	Present
C. asper	Prickly sculpin	Present

It has 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 main stem to spawn” (Northcote and Burwash, 1991). Other than the salmon species discussed earlier, these include Pacific lamprey (*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 (Northcote and Burwash, 1991).

3.3 Consumptive Water Uses

Water withdrawn from the Fraser River between Hope and Kanaka Creek is used primarily for irrigation. This is to contrast regions of the Fraser River between Kanaka Creek and the estuaries in which withdrawals are mainly used by industries for purposes such as cooling water and construction. Locations of consumptive water uses from the Fraser River are shown on Figures 4, 5, and 6.

3.4 Recreational Water Uses

Primary-contact recreational water use of the Fraser River waters for activities such as swimming is minimal. Although 9% of respondents to the water quality and recreational use public survey replied that they swam in the Fraser River, closer scrutiny of the waters they described revealed the fact that more swimming occurs in nearby tributaries than in the Fraser River itself.

Rafting is not considered primary-contact recreation, however, the probability of coming into contact with water-borne diseases while rafting would likely be as great as while swimming. The "Fraser River and some 36 of its tributaries are used by over 60 rafting companies" (Northcote and Burwash, 1991). Rafting usually takes place upstream from Hope.

4. PERMITTED WASTE DISCHARGES

Permitted waste discharges can be located on Figures 7, 8, 9, and 10 by their permit number. They will be discussed according to the river reach into which they discharge effluent, and in the chronological order in which the applications for the permits were received. Thus, those reported earliest in the section generally have been discharging for the longest period of time, and those towards the end of this section have been operating for the shortest time period.

To scope this assessment, those discharges which are unchanged from previous assessments will be described only briefly, while those which have had major modifications or have not been described in the past will be reported in more detail. The effects of other discharges, such as air emissions that may affect the Fraser River or a tributary will not be discussed.

4.1 Fraser River from Hope to Chilliwack

4.1.1 City of Chilliwack and District of Chilliwack (PE 39)

The City of Chilliwack and District of Chilliwack operate a secondary waste water treatment plant serving the municipality and immediate area. The effluent is discharged into the river through a submerged outfall located just upstream from the confluence of the Chilliwack Creek and the Fraser River. This operation has been described in the past by Swain and Holms (1985a) The primary treatment facilities consist of headworks and sedimentation tanks. The secondary treatment facilities consist of a fixed-growth-media biofilter plant, clarifiers, anaerobic sludge digesters, belt filter press and chlorination/ dechlorination facilities.

Waste Management Permit PE 39 allows a maximum discharge rate of 45,000 m^3/d, with a 5-day biochemical oxygen demand (BOD5) ≤ 45 mg/L, total suspended solids ≤ 60 mg/L and a 96h LC50 toxicity ≤ 100%. The discharge must also be monitored weekly for pH and ammonia nitrogen.

The conventional activated sludge process has been changed to a biofilter process and chlorine residual between 0.1 and 1.0 mg/L now only needs to be maintained from April 1 to September 30. After dechlorination the effluent must have a chlorine residual below detectable limits.

In the past the outfall discharged into a side channel of the Fraser River which was subject to heavy siltation. According to the permit files this has required dredging and has even caused frequent exposure of the outfall which has proven detrimental to fish eggs. A proposal to extend the outfall to 85 m offshore and approximately 1 000 m further downstream was submitted in January 1994 and is scheduled to commence in early January, 1995. The permit files indicate that initial and subsequent dilution would be increased significantly (average of 200:1) and dilution of less than 1:20 would occur only within the immediate mixing zone. The permit requires that a monitoring program be developed that will annually report on both the pre-discharge and post-discharge periods for the new outfall.

The following table outlines the dilution ratios and concentration potentials for four characteristics of the District of Chilliwack sewage treatment plant. Calculations are based on effluent data from Table 10, Fraser River flow rate data from Chapter Two for the Hope to Chilliwack reach, and the existing outfall location.

		Fraser River Flow Rate 610 m^3/s	
Characteristic	Maximum Discharge	Min. Dilution Complete Mix	Min. Dilution Edge of IDZ
Flow	45 000	1 171:1	293:1
		Potential Increase Complete Mix	Potential Increase Edge of IDZ
Ammonia	27.8	0.02	0.10
Coliform: fecal	28 000	24	96
Suspended Solids	335	0.3	1.1

*Where flow monitoring data were unavailable, permitted maximum discharges were used.
*All values are mg/L except coliform (CFU/cL) and flow (m^3/d).

The maximum discharge of suspended solids (335 mg/L) exceeds the permit allowance (60 mg/L). The limited data (n=1) for fecal coliforms (Table 10) indicate a very high maximum concentration (28 000 CFU/cL) which is a concern, even with dilution, if the area is to be used for recreational activities (Nagpal *et al*, 1995).

Ammonia is not in exceedance when compared to criteria for maximum and average concentrations in Tables 11 and 12, and nitrite is also not in exceedance (Table 13). Although the 5-day BOD maximum discharge value from Table 10 (80 mg/L) exceeds the permitted allowance of 45 mg/L, the mean BOD value (39 mg/L) is within the permit guidelines.

Extending the outfall 85 metres into the river will further increase the dilution. Continued monitoring is recommended to show whether the increased dilution rate is sufficient to lower the concentration levels of BOD and coliforms to acceptable levels.

4.1.2 Corporation of the District of Kent (PE 137)

The Kent Sewage Treatment Plant receives effluent from municipal sewage and domestic septic tanks. It discharges the secondary-treated effluent from a submerged outfall to the Fraser River from the north bank, just north of Bridal Falls. This operation has been described in the past by Swain and Holms (1985a).

Waste Management Permit PE 137 allows a maximum effluent discharge rate of 3 300 m^3/d, with a 5-day BOD ≤ 45 mg/L, total suspended solids ≤ 60 mg/L, chlorine residual between 0.5 and 1.0 mg/L with ≥ one hour contact time at average flow rates, and dechlorination. The thickened sludge is discharged at a maximum rate of 200 m^3/d and applied evenly over a parcel of land of 4 300 m^2, approximately 35 m from the Fraser River. According to the applicant, the nearest residential well is 250 m from the site.

It has been noted in the permit files that in the past, frequent sewage treatment plant bypasses have occurred and there is an anticipated increase in demand on the treatment plant with population increases. It was recommended in March 1994 that the maximum effluent discharge be increased to 3 500 m^3/d, and the sewage treatment facilities be upgraded.

The following table outlines the dilution ratios and concentration potentials for four characteristics of the Kent Sewage Treatment Plant discharge. Calculations are based on effluent data from Table 14 and Fraser River flow rate data from Chapter Two.

		Fraser River Flow Rate 610 m^3/s	
Characteristic	Maximum Discharge	Min. Dilution Complete Mix	Min. Dilution Edge of IDZ
Flow	3 500	15 000:1	3 700:1
		Potential Increase Complete Mix	Potential Increase Edge of IDZ
Ammonia	31.0	0.002	0.008
Coliform: fecal	240 000	16	65
Suspended Solids	88	0.006	0.024

*Where flow monitoring data were unavailable, permitted maximum discharges were used.
*All values are mg/L except coliform (MPN/100 mL) and flow (m^3/d).

The maximum discharges of ammonia (31 mg/L), fecal coliforms (240 000 MPN/100 mL) and suspended solids (88 mg/L) are high. Despite the high dilution available in all scenarios shown, it must be recognized that effluent control at source provides the principal means of regulating individual waste discharges and even water within the IDZ must not present acutely toxic conditions. In fact, it is federal policy that the effluents themselves should not be acutely toxic prior to discharge.

There were no monitoring data available from the Ministry of Environment computerized retrieval system (SEAM) for chlorine residuals for the period of 1985 through 1994. The maximum BOD and suspended solids concentrations recorded in Table 14 (64 mg/L and 88 mg/L respectively) both exceeded the permitted limits (45 mg/L and 60 mg/L) on some occasions.

Continued monitoring is emphasized to ensure that these and other characteristics of the effluent stay within safe concentration limits.

4.1.3 Rempel Brothers Concrete (PE 1982)

Rempel Brothers Concrete Limited discharges effluent from a gravel washing and concrete batch plant into an infiltration pond, located approximately 150 m from the south shore Camp Slough of the Fraser River in Chilliwack. The effluent is gravel wash water and concrete delivery truck wash water.

The permit allows a maximum effluent discharge rate of 225 m^3/d. The infiltration pond has no overflow as it is dredged regularly and surface drainage is diverted away from it. The dredged material is allowed to de-water and is then sold as fill material. The pollution control works are inspected regularly. The permit does not require monitoring of any parameters other than discharge rate. Due to the nature of the discharge, its flow rate and its treatment, it is not anticipated that this discharge will have an impact on the water quality of Camp Sough or the Fraser River.

4.1.4 Westcoast Transmission Limited Rosedale Station #9 (PE 2234)

The Westcoast Transmission Company operates a natural gas compressor station in Rosedale, on the south bank of the Fraser River, near the eastern end of Hope Slough. It discharges cooling water through a submerged outfall into Ferry Slough, which is part of the Fraser River between the mainland and Ferry Island. This operation has been described by Swain and Holms (1985a)

Waste Management Permit PE 2234 allows a maximum effluent discharge rate of 4 000 m^3/d, with a temperature < 27 °C. The minimum dilution available for the maximum discharge to the Fraser River, with complete mixing at low river flow, (610 m^3/s, see Chapter Two for reference) is more than 13 000:1. In the past, all flows exceeded the maximum by a factor of 10, temperatures were always ≤18 °C (Swain and Holms, 1985a).

It was proposed in the Permit to analyze discharge samples daily for oil and grease. Limited data for this characteristic (n=3) are summarized in Table 15. The maximum concentration of 3 mg/L would have minimal effect on the Fraser River water quality. There were no monitoring data available for flow volume or temperature from SEAM for the period of 1985 through 1994.

According to the permit files, the possibility of other contaminants entering the effluent is remote and their effects would be minimal. Due to the nature of the discharge, it is not anticipated that this operation will have a significant impact on the water quality of Ferry Slough or the Fraser River.

4.1.5 Hope Ready Mix (PE 3375)

Hope Ready-Mix Limited discharges effluent from a concrete ready-mix truck washing operation into an infiltration pond located just south from Hope and more than one km from the south bank of the Fraser River. The operation has been described in the past by Swain and Holms (1985a).

Waste Management Permit PE 3375 allows a maximum discharge of 3.4 m^3/d. Daily flows are to be recorded and reported annually. There were no monitoring data available from SEAM for the period of 1985 through 1994. According to the permit files there have been no positive discharges, and the ponds are dredged often enough to prevent overflow of the settling ponds. Therefore, due to the nature of the discharge, its flow rate, treatment and distance from the river, it is not anticipated that this operation will significantly impact the water quality of the Fraser River

4.1.6 District of Hope (Fraser-Cheam) (PE 4125)

The District of Hope operates a municipal sewerage system that collects effluent from Hope and outlying areas of Kawkawa Lake and Silverhope Creek. The sewage treatment plant is located on the west bank of Silverhope Creek, where it joins the Fraser River. Effluent is discharged through a submerged outfall into the Fraser River, from the south bank. The operation has been described in the past by Swain and Holms (1985a).

Waste Management Permit 4125 allows a maximum effluent discharge of 6 819 m^3/d, with a 5-day BOD ≤ 100 mg/L and total suspended solids ≤ 100 mg/L. Effluent flow is to be measured daily, and effluent quality is to be measured quarterly for BOD, suspended solids and fecal coliforms. No chlorination/dechlorination facilities are required.

Although effluent quality has often complied with permit limits, BOD5 and TSS concentrations have very frequently exceeded the criteria of best available control technology (BACT) (Dayton and Knight, 1982) which are a 5-day BOD ≤ 45 mg/L and total suspended solids ≤ 60 mg/L. It is anticipated that permit limits will be amended in the near future such that permit limits will reflect BACT criteria and other Fraser River discharges. It is recommended that the effluent quality be upgraded to meet these standards.

Lagoon Performance Effluent Test Results

Year	Max. BOD mg/L	Max. TSS mg/L	Annual Average BOD mg/L	Annual Average TSS mg/L	Average Flow m3/d
1982	61	48	35	31	1690
1983	33	64	20	40	1630
1984	78	71	45	40	1720
1985	51	82	26	55	1650
1986	37	55	28	33	1930
1987	72	72	40	43	-
1988	41	55	32	43	1910
1989	83	92	56	63	1880
1990	83	68	63	54	2120
1991	49	86	33	33	1970
1992	88	77	46	43	1810
1993	173	125	81	66	2030

Permit Limits:	Max 5-day BOD ≤ 100 mg/L	Max. TSS ≤ 100 mg/L
BACT Criteria:	Max 5-day BOD ≤ 45 mg/L	Max. TSS ≤ 60 mg/L

The following table outlines the dilution ratios and concentration potentials for four characteristics of the District of Hope Sewage Treatment Plant. Calculations are based on effluent data from Table 16 and Fraser River flow rate data from Chapter Two.

		Fraser River Flow Rate 610 m^3/s	
Characteristic	Maximum Discharge	**Min. Dilution Complete Mix**	**Min. Dilution Edge of IDZ**
Flow (m^3/d)	6 819	7 729:1	1 932:1
	Maximum Concentration	**Potential Increase Complete Mix**	**Potential Increase Edge of IDZ**
Ammonia (mg/L)	33.4	0.004	0.017
Fecal Coliform (#/100mL)	13	2	7
Susp. Solids (mg/L)	69	0.009	0.036

The limited data in Table 16 for fecal coliforms (n=6) and ammonia (n=11) indicate high maximum concentrations in the discharge but minimal potential increases, thus having little potential to impact the receiving environment.

4.1.7 Rempel Brothers Concrete (PE 4849)

Rempel Brothers Concrete Limited discharges cement truck wash water from a ready-mix concrete batch plant, to the land adjacent to the south bank of the Fraser River, approximately three km north from Chilliwack. The exterior truck washings are discharged to two infiltration ponds and the interior truck washings are discharged to the nearby settling ponds, authorized under Waste Management Permit PE 1982. The plant has been described in the past in Swain and Holms (1985a).

Waste Management Permit PE 4849 allows a maximum effluent discharge rate of 46 m^3/d. There is no overflow from the infiltration ponds and surface drainage is diverted away from them. The permit does not require monitoring of any other parameters. It is not anticipated that there will be an impact from this discharge on the Fraser River due to the nature of the discharge, its flow rate, treatment and distance from the river.

4.1.8 Valley Rite-Mix Limited (PE 5516)

Valley Rite-Mix Limited discharges effluent from a concrete ready-mix truck washing operation to two connected exfiltration ponds located 0.5 km from the south bank of the Fraser River in Chilliwack. The ponds are located on a gravely flood plain separated from the river by a 12 m wide dike/roadway. The operation has been described in the past by Swain and Holms (1985a).

Waste Management Permit PE 5516 allows a maximum effluent discharge of 17 m^3/d. The settled solids are removed from the ponds and sold as fill. There are no positive discharges. There are no other monitoring requirements as the receiving environment is considered capable of assimilating the effluent with minimal effect. It is not anticipated that there will be an impact from this discharge on the Fraser River due to the nature of the discharge, its flow rate, treatment and distance from the river.

4.1.9 Sunshine Valley Developments (PE 7813)

Sunshine Valley Developments Limited discharges typical septic tank effluent from the Huckleberry Village West Campground located at Sunshine Valley, just east from Hope. The works authorized are septic tanks, siphon tanks and dual disposal fields with a minimum of 214 m of disposal tile.

Waste Management Permit PE 7813 allows a maximum effluent discharge rate of 15.9 m^3/d. No discharged effluent is allowed to bypass the treatment works and sludge and scum are removed from the septic tanks annually. Due to the nature of the discharge, its flow rate, treatment and distance from the river, it is not anticipated that it will have an impact on the water quality of the Fraser River

4.1.10 Cheam View Trout Farms (PE 7886)

This operation has been described briefly in the past by Swain and Holms (1985a). Cheam View Trout Farms discharges effluent from a fish farm located in Chilliwack, less than one kilometre south from Hope Slough. Effluent from fish rearing tanks is discharged to a ditch flowing north into the Hope Slough, which joins with Elk Creek before entering the Fraser about 10 km downstream.

The fish are reared in eight-30 m x 6 m concrete ponds grouped together into four groups of two ponds each. Approximately one-sixth of the end portion of each of the four pond groups is isolated and used as settling basins. The works authorized also include a 700 mm diameter discharge pipe. The water filter backwash and settling basin sludge is removed and discharged to a 10 m x 10 m infiltration pond from which the residue is removed and sold or otherwise disposed.

Permit PE 7886 allows the following: pH 6.5 - 8.5, maximum discharge of 5 450 m^3/d, total suspended solids and both 5-day BOD $\leq$ 10 mg/L, ammonia nitrogen $\leq$ 0.18 mg/L, nitrate nitrogen $\leq$ 1 mg/L, and total phosphorus $\leq$ 0.1 mg/L.

The rearing tanks are vacuumed regularly to minimize the release of solids. No discharged effluent is allowed to bypass the treatment works.

According to the permit files, the Elk Creek/Hope Slough System receiving environment is a salmonid and trout fry rearing habitat as well as a migration route for spawning and juvenile salmon. Parts of the system are under severe stress due to low flow, excessive nutrient inputs and high stream temperatures. Concern was expressed by the Fish and Wildlife Branch that addition of nutrients from the fish farm could encourage eutrophication and raise stream temperatures downstream, thus having a negative impact on the fish habitat. To monitor for such changes, the permit requires monthly sampling both upstream and downstream from the discharge, and that temperatures be taken on-site.

Monitoring data from the permit files for the period of July 1988 through May 1989 are summarized in Table 17. Maximum values for BOD (36 mg/L), suspended solids (122 mg/L), ammonia nitrogen (0.3 mg/L) and phosphorus (0.15 mg/L), all significantly exceeded the permit limits. This indicates that the most sensitive designated uses of the water may not be adequately protected. More recent monitoring data are required to better assess the potential impacts of the discharge.

The 1988 and 1989 ambient monitoring data for Elk Creek, taken from a site just prior to the confluence with Hope Slough did not indicate a problem with regard to phosphorus and ammonia. More recently, data from 1992 indicated extreme levels of ammonia (maximum 25.7 mg/L), phosphorus (4.82 mg/L), and fecal coliforms (67 000 /100 mL) from the same monitoring site (section 7.1.1.4).

These values were obtained from a site in Elk Creek prior to its confluence with the Hope Slough. The further addition of nutrients from the trout farm would increase the impact on the aquatic life downstream. Further monitoring of the Hope Slough, both upstream and downstream of the discharge, is recommended to correlate current data results with the downstream ambient quality.

4.1.11 Grace-Mar Dairy Incorporated (PE 10503)

Grace-Mar Dairy Inc. operates a milk processing operation adjacent to the company Dairy Farm located at Elk Creek, just over four km south from the Fraser River, at Chilliwack. The operation is a processing and retail outlet for dairy products. Effluent consisting of milk processing wash water and daily cleanup water is directed to a storage tank system. The solids are separated out and the liquid portion is used for either barn flushing during the off season, or is combined with liquid manure to be used for irrigation during the growing season. The effluent contains small quantities of milk waste, dairy cleaning solutions (caustic and acids) and large amounts of water.

Waste Management Permit PE 10503 allows a maximum effluent discharge of 22 m^3/d. The treatment facilities consist of a settling tank and a spray irrigation system. According to the permit files, in the past only liquid manure was used for irrigation, and the amount used did not exceed the amount required for crop growth. Therefore the inclusion of milk processing wash water is expected to have minimal impact.

It was calculated in the permit files that two days of evapotranspiration during the growing season will use all the fluid dairy wash water effluent produced in a year. It is therefore anticipated that due to the low discharge volume, treatment and location, this effluent will not have a significant impact on the water quality of the Fraser River.

4.1.12 Valley Helicopters Limited (PR 10720)

Valley Helicopters Limited is authorized to discharge refuse from a dry land log sorting operation to two pits located approximately one km east from the Hope Airport. The refuse is generated by International Forest Products and is composed of 75% soil and 25% woody material, by weight. There are five registered water wells located within 500 m from the landfill site. Because the assessed ground water flow is to the north, any risk of leachate contamination would be to wells located west or north from the site.

Waste Management Permit PR 10720 allows a total maximum refuse discharge of 2 680 m^3 in the life of the permit. Surface drainage is to be diverted away from the landfill and the refuse is to be spread in 0.3 m lifts, and compacted. Upon completion, a final cover is to be applied consisting of $\geq$ 1.0 m of impermeable material, topped by 0.5

m of topsoil which is then graded and seeded to prevent erosion. The Permittee is to collect any leachate generated and/or prevent the leachate from entering any watercourse.

The permit requires three monitoring sites; one upstream and one downstream from the landfill, relative to ground water flow, and one in the landfill itself. The sites are to be monitored for chemical oxygen demand (COD), acidity to pH 8.3, dissolved metals, tannins and lignins and resin acids. They are to be monitored prior to filling, and annually at the time of high water on the Fraser River for three years hence.

There were no monitoring data available from SEAM for the period of 1985 through 1994. However, due to the nature of the discharge and the location relative to the Fraser River, it is anticipated that this operation will not have a significant impact on the water quality of the Fraser River.

4.2 Fraser River from Chilliwack to Kanaka Creek

4.2.1 J. A. M. E. S. STP - Central Fraser Valley Regional District (PE 351).

The Central Fraser Valley Regional District discharges treated effluent from a municipal sewerage system and domestic septic tanks servicing Matsqui, Abbotsford, Mission, Langley and Chilliwack. The STP has been previously described by Swain and Holms (1985a). In 1988 to 1989, the J. A. M. E. S. Plant was upgraded to an advanced secondary treatment facility that uses a combination biofilter/activated sludge system. Single reactor nitrification and step aeration are part of the innovative design that also includes primary and secondary digesters for sludge management. The plant completed installation of an additional secondary clarifier in May 1994 and is currently installing programmable logic control and a secondary trickling filter due for completion in late 1996. The three primary sedimentation tanks average 1 070 m^3 each. An improved outfall with a diffuser was installed in 1986 and is located on the south bank of the Fraser River, west from the Matsqui Slough, and extends approximately 113 m offshore at low water.

Waste Management Permit PE 351 allows the discharge of 45 000 $m^{3/d}$ of effluent with $BOD_5 \leq 45$ mg/L, total suspended solids ≤ 60 mg/L and a Toxicity LT50 of 96 hours. Amendments to Permit PE 351 required chlorination and dechlorination when the river flow is below 2040 m^3/s or when fecal coliform levels in the river exceed 300 MPN/100 mL. Average flow rates of the Fraser River at Mission, over a 24-hour period, must be obtained once a week and monitoring stations maintained 100 m downstream from the outfall for weekly grab samples.

The new system was chosen to handle the high industrial waste shock loads encountered in the spring and summer and has proven to be very effective (Dayton and Knight Limited, 1992a). The monitoring data summarized in Table 18 and Table 19 show the significant decreases after the upgrading for BOD, nitrogen: ammonia, and total suspended solids but not for fecal coliform. The pH remained near 7. With only one value available for fecal coliforms before the upgrading it is not possible to determine if these values have increased or decreased since 1988. The following table indicates that for all the other characteristics the potential increase after complete mixing in the Fraser River would not have an impact on ambient water quality. Chlorination is only required when the background levels for fecal coliforms exceeds 300 MPN/100 mL or the flow rate of the river falls below 2 040 m^3/s. Since the estimated low flow rate used to calculate these potential increases is well below the rate requiring chlorination, this increase should not occur. The permit files show that during 1994 the chlorine levels were all undetectable after dechlorination with sulphur dioxide.

		Fraser River Flow Rate=977 m^3/s	
Characteristic	Maximum Discharge*	Min. Dilution Complete Mix	Min. Dilution Edge of IDZ.
Flow (m^3/d)	45 000	188:1	47:1
	Maximum Concentration	Potential Increase Complete Mix	Potential Increase Edge of IDZ.
Ammonia (mg/L)	18	0	0
BOD (mg/L)	62	0	1
Coliform fecal (#/100 mL)	210 000	1 117	4 468
Suspended Solids (mg/L)	36	0	1

*Where monitoring data were unavailable, maximum allowable discharges were used.

The following table summarizes 1994 monitoring data for fecal coliforms in the receiving environment. The samples were taken from the edge of the initial dilution zone (100 m downstream from the outfall) at the surface and at a depth of 1.2 m at 25 m intervals from the south shore. The data show that the highest concentrations of fecal coliforms are occurring 75 m from shore and appear to be greatest at the surface.

Site	No. of Values	Maximum	Minimum	Mean (Geo. Mean)	Std. Dev.
Surface:					
25 m	20	720	18	72.15 (40.91)	153.43
50 m	20	156	6	35.95 (28.38)	31.67
75 m	20	2 200	4	135.15 (27.39)	486.36
100 m	20	576	8	53.9 (26.55)	124.00
1.2 m depth:					
25 m	20	1 296	10	95.3 (34.04)	283.16
50 m	20	90	10	27.1 (23.67)	17.31
75 m	20	2 200	10	135.15 (28.11)	486.37
100 m	20	141	6	30.35 (23.45)	29.52

*Values are in #/100 mL.

These increased concentrations could be a concern for water license holders downstream from the plant. The water quality criterion allows a fecal coliform concentration ≤ 200 #/100 mL (geom. mean) for irrigation of crops eaten raw and primary contact recreation. It is important to note that the fecal coliform concentrations in the above table only exceeded 100 #/100 mL on two sample dates and that on the date that samples reached 2 200 #/100 mL the sites on either side of the 75 m site were 20 #/100 mL and 18 #/100 mL respectively. This indicates that the dilution of the discharge is not being completed within the dilution zone or an error in analysis occurred. More rigorous sampling of the initial dilution zone is necessary to establish if the chlorination requirements are adequate.

The advanced treatment features incorporated into the J. A. M. E. S. STP process should ensure that high quality effluent continues to be discharged into the Fraser River even with the rapid population growth currently seen in the Central Fraser Valley and other districts serviced by the plant.

4.2.2 Odyssey Holdings Limited (PE 1909)

Odyssey Holdings Limited discharges effluent from a commercial and residential complex in Fort Langley, which includes a restaurant, pub, apartments and offices. The effluent is treated in a secondary treatment plant with a clarifier and discharged by way of a submerged outfall on the south bank of the Bedford Channel at Brae Island. The site has been previously described by Swain and Holms (1985a) under the name Galaxy Investment Corporation. Since then, effluent chlorination has been eliminated.

Waste Management Permit PE 1909 allows effluent to be discharged at a maximum rate of 43.3 m^3/d with BOD_5 ≤45 mg/L and total suspended solids ≤60 mg/L. Effluent volume discharged over a 24-hour period is to be recorded once per week and submitted annually. Limited monitoring results listed in Table 20 indicate that the maximum BOD5 (55mg/L, n=5) and maximum TSS (88 mg/L, n=6) are in non-compliance with the permit.

4.2.3 High Brow Holdings Limited (PE 2310)

High Brow Holdings Limited discharges effluent to the land from a laundromat located in Fort Langley. Lint screens, two septic tanks and two tile disposal fields are used alternately, with sixteen machines in operation. The laundromat has been in existence for almost twenty years without any environmental problems reported.

Waste Management Permit PE 2310 allows a maximum effluent discharge rate of 17 m^3/d. The average percolation rate at the septic fields was reported to be 0.269 min/cm with a BOD_5 of 80 mg/L and 73 mg/L respectively. Since the permit does not require any monitoring there were no data available from SEAM. Due to the site's distance from the Fraser River and the low discharge rate permitted, the impact is considered insignificant.

4.2.4 Cattermole Timber (PR 2530)

A dryland log sorting operation, doing business under the firm name and style of Cattermole Timber, discharges woodwaste and ashes to a landfill located on the property. The operation is on the south bank of the Fraser River less than one kilometre downstream from the Wilson Slough and approximately 10 km west from Chilliwack. As of June 1994, the east side of the landfill was complete and filling was continuing on the west side.

Waste Management Permit PR 2530 allows industrial refuse, consisting of tree bark and wood chunks mixed with sand and gravel, to be discharged to the landfill at a maximum rate of 4 000 m^3/d and requires cover material to be applied once per year. The discharge of contaminants to the air and ash to the landfill from an open burning site were permitted until May 1990.

The permit files indicate there has not been any significant leachate problem associated with the landfill. Monitoring is not required by the permit and data were not available from SEAM. Due to the nature of the refuse being discharged and the distance of the pits from the Fraser River, the site is not expected to have an impact on the ambient water quality of the river.

4.2.5 Corporation of the Township of Langley at Aldergrove (PE 4094)

The Corporation of the Township of Langley discharges effluent from a municipal sewerage system, a Canadian Forces Station and an industrial park at Aldergrove. The outfall, a pre-existing forced main, discharges into the Fraser River, about 1 km downstream from Crescent Island and extends approximately 33 metres from the shore at a depth of three metres at low water. The Aldergrove Sewage Treatment Plant has previously been described by Swain and Holms (1985a).

In 1987, the Canadian Forces Station was connected to the outfall and the permitted discharge increased. A second sewage treatment plant was installed in 1991 to service the Gloucester Industrial Estates. The new plant includes a coarse screen, 6 mm drum screen, two aerated lagoons and chlorination and dechlorination facilities.

Waste Management Permit PE 4094 allows effluent to be discharged to the Fraser River at a maximum rate of 7 500 m^3/d. The effluent characteristics must be ≤ 45 mg/L for BOD_5 and ≤ 60 mg/L for total suspended solids. Since the data available do not include the period after the Gloucester plant hook-up, it is not possible to determine if the effluent discharge is in compliance with the permit.

Data in Table 21 show non-compliance for BOD_5 on occasion, and that fecal coliforms averaged 26 860 MPN/100 mL. A concern for fecal coliforms at the edge of the initial dilution zone is also apparent in the calculations below, showing a potential increase of 85 MPN/100mL. Total suspended solids have also exceeded permitted levels in the past but due to the amount of effluent being discharged and the high dilution ratio of over 10 000:1, the ambient water quality in the Fraser River should not be affected.

Characteristic	Maximum Discharge	Fraser River Flow Rate=977 m^3/s	
		Min. Dilution Complete Mix	**Min. Dilution Edge of IDZ**
Flow (m^3/s)	7500	11 255:1	2 814:1
		Potential Increase Complete Mix.	Potential Increase Edge of IDZ
BOD (mg/L)	64	0	0
Coliform-fecal (#/100 mL)	240 000	21	85
Ammonia (mg/L)	34.8	0.003	0.012
Nitrate/nitrite (mg/L)	20.4	0	0.01
Nitrite (mg/L)	16.7	0.001	0.006
Kjeldahl-N (mg/L)	40.2	0	0.01
Ortho diss P (mg/L)	6.32	0	0
Susp. Solids (mg/L)	109	0	0

*Where monitoring data were unavailable, maximum allowable discharges were used.

A concern for industrial wastes entering the Fraser River after connection to the Gloucester industrial park was raised with the last permit amendment. The Township of Langley has an industrial waste bylaw which limits the amount of waste entering the system. Industries in the park are required to pre-treat or use alternate disposal methods when wastes do not meet the standards and therefore should not be a threat to the ambient water quality of the Fraser River. These sites are currently under review for diversion to the J. A. M. E. S. plant (PE 351).

4.2.6 Bedford House Limited (PE 4430)

Bedford House Inc. is authorized to discharge effluent from a restaurant and lounge located at Fort Langley. The extended aeration sewage treatment plant, grease traps, and holding tank connect to a submerged outfall extending from the south bank of the Fraser River opposite the southeast end of Brae Island in the Bedford Channel. The system is to be connected to a municipal sewage system when facilities become available. Effluent data are summarized in Table 22.

The discharge of effluent is limited to 23 m^3/d by Waste Management Permit PE 4430. The characteristics of the effluent must have a BOD_5 ≤45 mg/ L and total suspended solids ≤ 60 mg/L. Samples must be obtained once every three months and flow measurements taken once per month.

The permit shows non-compliance charges were laid in March 1982 which resulted in a grease trap and holding tank being installed in June 1982. The permit was in compliance for the next two years but from 1986 to 1994 the permit was again out-of-compliance for BOD and total suspended solids on many occasions. Increased monitoring was requested to determine if the system is performing adequately. The results of the monitoring are not yet available.

4.2.7 Valley-Rite Mix Limited (PE 4589)

A ready-mix concrete batch plant, operated by Valley Rite-Mix Limited, discharges truck wash water to two settling ponds and an infiltration pond located on the site. The plant is situated just west from the Abbotsford Airport and has been previously described by Swain and Holms (1985a). The company no longer operates a gravel plant on the site. In February 1994, the Waste Management Permit PE 4589 was amended to reduce the allowable effluent discharge rate and characteristics from 1 637 m^3/d for gravel wash water to 20 m^3/d for typical truck wash water.

The settling ponds are concrete lined and since the infiltration pond is over two km from the nearest body of surface water (Fishtrap Creek to the east and Laxton Lake to the south), contamination from the site is unlikely. Groundwater monitoring data from a nearby well indicate that the pH is not elevated (pH 6.7-6.8) and the company reports that the infiltration pond has been in operation for several years without an overflow (PE 4589). Monitoring data are not required by the permit and therefore unavailable.

4.2.8 Fort Langley Recreations Limited (PR 5437)

Fort Langley Recreations Limited operates a landfill on the south shore of the Bedford Channel, across from MacMillan Island. The site was filled in 0.4 ha. parcels using sawdust and hogfuel from McDonald Cedar Products Limited in Fort Langley to build up the 16 ha. for development. The site has been previously described by Swain and Holms (1985a) and is alongside a previous landfill site operated by the same people under the name Skyway Recreations Limited (PR 3891).

Interior berms no less than 2 m thick line each cell and a final cover no less than 60 cm thick is also required and must be composed of inert material. Waste Management Permit PR 5437 requires that the operation discontinues filling by June 1994 and the dike alongside the river be brought to the same elevation as the landfill and have a minimum 10 m width. The site has not received its final cover as the owner may use the site at a later date. The permit has not been canceled and will require a request for a permit amendment to begin filling again.

The permit files indicate that the upstream site sampling data shows negligible effect on ambient water in the Fraser River and it is expected that this site will also show little or no effect if closure procedures are completed. Current data were not available through SEAM. Since the fill is composed of cedar waste products it is recommended that downstream monitoring be continued to assure there are no leachate problems associated with the landfill.

4.2.9 Langley Forest Industries Limited (PE 5460)

Langley Forest Industries Limited discharges effluent from a shake and shingle mill to the Fraser River. The effluent is from sanitary sewerage facilities serving the mill that includes a secondary treatment package plant with a 1.7 m3/d capacity and a 5 cm PVC pressure pipe discharging below the mean low water. The 3.2 ha. site is located at Langley on the river side of the dike. The closest water license is for irrigation and is located 3.2 km downstream.

The maximum rate of effluent discharge permitted by Waste Management Permit PE 5460 is 1.6 m^3/d with a $BOD_5 \leq 45$ mg/L and a concentration of suspended solids ≤ 60 mg/L. At low river flows and at the maximum rate of discharge, a dilution of over 63,000,000:1 is available with complete mixing. Sample analysis is required every three months and flow data recorded once per month although data were not available on SEAM. The small rate of discharge from this site, with its associated high level of treatment will result in the effluent not having an impact on the water quality of the Fraser River.

4.2.10 School District #75 (Mission) (PE 6703)

School District #75 is responsible for the discharge of treated domestic sewage from Hatzic Junior Secondary School, a school which serves approximately 1200 students. The disposal system was previously described by Swain and Holms (1985a) as discharging to the Fraser River and has since been permitted to discharge to the land through septic tanks, sand filters and three subsurface disposal fields. The school is located less than one km from the north bank of the Fraser River and has a culverted creek on the southeast corner of the lot.

Discharge site "01" includes four-13.64 m^3 septic tanks and a small sand filter/disposal field and is restricted by Waste Management Permit PE 6703 to a maximum discharge rate of 23 m^3/d with a BOD_5 and total suspended solids ≤ 45 mg/L and 60 mg/L respectively. Discharge sites "02" and "03" include eight-13.64 m^3 septic tanks and a sand filter and alternates between two disposal fields with a minimum of 650 m of disposal pipe each. The permit restricts the discharge rate to 71.5 m^3/d with the same characteristics as site "01". Sample analyses of the required characteristics are to be obtained every three months and 24-hour flow rates recorded once per week during the school term.

There were no data available on SEAM. Since the creek has been culverted, contamination from the site is unlikely, however potential groundwater impacts should be investigated. The relatively low effluent discharge rate and the level of treatment provided should result in no risk to the ambient water quality of the Fraser River. Even if the total flows reached the Fraser River, they would be diluted by a factor of over 1,000,000:1 and would therefore be insignificant.

4.2.11 CN Rail (PE 7781)

Canadian National Railways discharges effluent from a groundwater cleanup operation into the Bedford Channel of the Fraser River, near the southeast tip of McMillan Island. The operation began on May 12, 1987 as a result of a chemical spill involving 25 490 L of ethylene dichloride, approximately 180 m south of the location of the cleanup discharge into the channel. The works authorized include an outfall with a diffuser and dechlorination tanks.

Waste Management Permit PE 7781 allows a maximum effluent discharge of 14,000 m^3/d, with an ethylene dichloride concentration ≤ 5 mg/L and a 96h LC50 toxicity of ≥ 100%. The limited data given in the permit files for 1994 show a continuing average concentration of 1.5 mg/L for ethylene dichloride in the effluent, well within the permit limit. It is also reported in the permit files that pumping from the recovery wells is containing the extent of contaminated groundwater. As of April 5, 1994 there have been no reported ethylene dichloride occurrences at a minimum detectable concentration of 0.001 mg/L at either the water supply well for Brae Island campground or the MacMillan Island piezometres. It is therefore anticipated that this operation will have no impact on the water quality of the Fraser River.

4.2.12 Herman Sawmill Limited (PR 7990)

Herman Sawmill Limited operates a dry log sort operation that discharges typical bark and wood debris to a landfill site located on the north shore of the Fraser River, approximately 1.5 km upstream from Matsqui Island at Mission. The landfill is a cellular structure constructed of inert relatively impermeable material. Each cell is limited to the amount of refuse generated in one year and requires monthly intermediate cover and a yearly cover of relatively impermeable, non-combustible soil applied before the rainy season. Refuse contaminated by wood preserving or anti-sapstain chemicals is prohibited.

The operation is authorized by Waste Management Permit PR 7990 to discharge a maximum of 1090 m^3/a and must have a minimum 50% inert soil content. A buffer zone of 15 m separating the site from a drainage ditch, the B. C. Hydro right-of-way, and the southwest property boundary must be maintained. Groundwater monitoring wells were required to be installed by December 31, 1994 to determine the impact of leachate from the landfill on the groundwater and the Fraser River. The annual grab sample analyses for the monitoring wells were to include pH, COD, acidity (pH 8.3), true colour and total resin acids.

The site is located on the north side of the Fraser River dike and the groundwater level is approximately three metres below the unfilled surface. The drainage ditch runs west, infiltrating to the soils approximately 100 m from the river. No leachate contamination was observed from 1988 until June 1994 when a small amount was noted on the east berm. Since the foreshore area is considered an important fish rearing area, the groundwater monitoring wells were recommended. As the monitoring wells were not required until the end of 1994, monitoring data were not available through SEAM or the permit files.

4.2.13 Select Sand Sod Limited(PE 10597)

This sand sod farm produces sod to be used on golf greens for golf courses. Sanitary effluent is discharged from two mobile homes located on the business site, into Bedford Channel of the Fraser River, near the eastern tip of MacMillan Island.

Waste Management Permit PE 10597 allows a maximum discharge of 2.3 m^3/d, with a 5-day BOD ≤ 45 mg/L and total suspended solids ≤ 60 mg/L. The effluent is passed through a rotating biological contactor secondary-type treatment plant and then a submerged outfall, about six m offshore. The outfall is weighted to the river bottom by concrete saddles. According to the permit files, the flows in Bedford Channel offer a dilution ratio for this discharge that is greater than 2 000:1.

There were no monitoring data available from SEAM for the period of 1985 through 1994. However, due to the low volume of this discharge, the high dilution available and the treatment facilities, it is anticipated that this operation will not significantly impact the water quality of the Fraser River.

4.2.14 Derby Reach Holdings Limited (PE 10826)

Derby Reach Holdings Limited discharges effluent from retail commercial businesses and residential units located 500 m from the Bedford Channel of the Fraser River, near the southeast tip of Brae Island, in Fort Langley. The discharge is from a sewage system serving an existing retail mall and as of July 17, 1991, a proposed building of retail commercial space and 16 residential units.

Waste Management Permit PE 10826 allows a maximum effluent discharge of 34.2 m^3/d with a 5-day BOD ≤ 45 mg/L and total suspended solids ≤ 60 mg/L. The works authorized are a secondary sewage treatment plant, effluent flow measurement and sampling facilities, and two disposal fields with a minimum of 172 m of disposal pipe each. The receiving environment is land that has been receiving septic quality effluent from an existing retail commercial building. According to the permit files there have been no problems in the past as a result of this discharge.

There were no data available from SEAM for the period of 1985 through 1994. However, the treatment, the high available dilution if all the effluent were to reach the Fraser River (> 600 000:1 at edge of IDZ), and the past performance of the site, all indicate that this discharge will not significantly impact the water quality of the Fraser River.

4.2.15 Ruskin Centre Enterprises Limited (PE 11089)

Ruskin Centre Enterprises Limited operates a car wash that discharges effluent to the land located approximately 250 m north from the Fraser River, in Ruskin.

Waste Management Permit PE 11089 allows a maximum discharge of 10 m^3/d, with a 5-day BOD ≤ 130 mg/L, total suspended solids ≤ 130 mg/L, total extractable solids ≤ 15 mg/L and a pH range of 6.5 to 8.5. The rinse cycle uses fresh water, but all the other car wash water is recycled with an effluent recycling, settling and oil separation system. The treated effluent is discharged to two "mound" type disposal fields. According to the permit files, the highest groundwater table is approximately 1.2 m below the disposal level.

There were no monitoring data available from SEAM for the period of 1985 through 1994. However, due to the low volume of this discharge and the land treatment facilities, it is anticipated that this operation will not significantly impact the water quality of the Fraser River.

4.2.16 Chilliwack Golf and Country Club (PE 12010)

Chilliwack Golf and Country Club discharges domestic sewage effluent from its clubhouse to the land located approximately two km south from the Fraser River, in Sardis. McGillivray Slough runs along the east and south borders of the golf course and is approximately 100 m north from the clubhouse disposal field.

Waste Management Permit PE 12010 allows a maximum effluent discharge of 25.9 m^3/d. The treatment facilities include one-25.8 m^3 and two-13.6 m^3 septic tanks, a subsurface disposal field with 1 199 m of disposal pipe, and two groundwater observation wells. The clubhouse domestic well is located approximately 100 m north from the disposal field.

There were no monitoring data available from SEAM for the period of 1985 through 1994. However, due to the nature of the discharge, the low volume, the treatment and the location in relation to the river, it is anticipated that this discharge will not significantly impact the water quality of either McGillivray Slough or the Fraser River.

4.3 Fraser River from Kanaka Creek to the New Westminster Trifurcation

4.3.1 Mill and Timber Products Limited (PE 328)

Mill and Timber Products Limited operates a sawmill on the south shore of the Main Stem of the Fraser River, about one km upstream from its confluence with the Brunette River. The operation discharges effluent to the Fraser River from domestic sources within the sawmill. The operation has been described in the past by Swain (1980) and by Swain and Holms (1985b). The works authorized include a packaged extended aeration plant and an outfall that leads into a log boom area, approximately three m from the shoreline.

Waste Management Permit PE 328 allows a maximum discharge of 13.6 m^3/d, with a 5-day BOD ≤ 45 mg/L, total suspended solids ≤ 60 mg/L and chlorine residual between 0.1 and 1.0 mg/L with one hour contact time at average flow rates.

There were no monitoring data available from SEAM for the period of 1985 through 1994. However, due to the small discharge volume, the nature of the wastewater, the dilution available to this discharge (> 7 000 000:1 at low river flows) and the past effluent quality (much better than the permitted requirements), it is anticipated that this operation will not significantly impact the water quality of the Fraser River.

4.3.2 International Forest Products Limited (PE 412)

International Forest Products Limited is a white wood sawmill and planer mill located on the north shore of the Main Stem of the Fraser River, just upstream from the confluence of the Brunette River. The operation has been described in the past by Swain (1980), under the name Fraser Mills, by Swain and Holms (1985b), and most recently in the FREMP/FRAP report (FREMP, 1994a). The lumber from the sawmill is planed and either kiln-dried or treated in a building with anti-sapstain chemical NP-1. Non-contact heat exchange cooling water is discharged into the Fraser River from the north bank.

Permit PE 412 allows a maximum discharge of 60 m^3/d with a maximum temperature of 35^oC and an oil and grease concentration ≤ 5 mg/L (FREMP, 1994a). The available dilution for the maximum allowable discharge, with complete mixing at low river flows (1178 m^3/s), would be about 1 696 000:1.

There were no monitoring data available from SEAM for the period of 1985 through 1994. It was reported in the FREMP/FRAP report that the operation was not out-of-compliance in 1992, and that although stormwater might be expected to contain NP-1 anti-sapstain chemicals, the concentrations were below analytical detection limits (FREMP, 1994a). Therefore, due to the nature of the discharge, the small discharge volume and high dilution rate available, it is anticipated that this discharge will not have a significant impact on the water quality of the Fraser River.

4.3.3 Canadian Forest Products Limited (PR 1655)

Canadian Forest Products Limited discharges refuse to a landfill located on the north side of the Main Stem of the Fraser River, in New Westminster. The operation has been described briefly in the past by Swain and Holms (1985b). The landfill is 6 000 to 8 000 m^3 and is located within one km from the river. The refuse is inert boiler ash discharged with about 90% sand.

Waste Management Permit PR 1655 allows a maximum discharge of 3 m^3/d to the landfill site. The landfill refuse must be maintained with a minimum of 3 m of soil cover. The permit also allows approximately 3 500 m^3 of previously discharged waste to be removed from the landfill site and discharged as fill onto two nearby sites measuring

700 m^3 and 3 500 m^3 respectively. According to the permit files, discharge to the landfill was not authorized to occur after June 4, 1992.

There were no monitoring data available from SEAM for the period of 1985 through 1994. However, due to the nature of the refuse, the soil covers and the small volume discharged, it is not anticipated that this landfill will impact the water quality of the Fraser River.

4.3.4 Coltan Developments (1990) Limited (PE 2632)

Coltan Developments (1990) Limited discharges effluent to septic tanks located near the south shore of the Main Stem of the Fraser River, just south from approximately the middle of Barnston Island. The wastewater originates from washrooms and a cafeteria, serving a factory on the site.

Waste Management Permit PE 2632 allows a maximum discharge of 45.5 m^3/d. The works authorized are a minimum 68 m^3 septic tank and two disposal fields, each with 1 097 m of disposal pipe and observation tees. Sludge and scum are removed from the septic tank annually. No effluent monitoring is required by the permit.

According to the permit files there have been no recorded instances when groundwater levels have been a problem, and fields have been reported as generally dry. The permit has been considered in compliance as of Oct. 27, 1993, as effluent flows have generally stayed below the requirements.

Due to the small volume of effluent, the distance from the river, and that it is being discharged to a well operated soil disposal system, it is anticipated that this operation will not impact the water quality of the Fraser River.

4.3.5 Hammond Cedar Division (IFP) (PE 2756)

Hammond Cedar is a sawmill and planer mill located on the north shore of the Main Stem of the Fraser River, just upstream from Barnston Island. The plant has been described in the past by Swain (1980), Swain and Holms (1985b), and most recently in the FREMP/FRAP report (FREMP, 1994a). The most significant change reported in the

FREMP/FRAP report is that the hydraulic debarker units have been replaced with mechanical debarker units (FREMP, 1994a). Effluent which is discharged to the river comes from three sources: kiln condensate ("01" and "02"), compressor cooling water ("03"), and boiler blowdown water ("04")(FREMP, 1994a).

Waste Management Permit PE 2756 allows the discharge of 50 m^3/d of kiln condensate effluent ("01" and "02"), 2 500 m^3/d of compressor cooling water ("03"), and 40 m^3/d of boiler blowdown water ("04"). The effluents are required to have a temperature ≤ 35^{o}C, oil and grease concentrations ≤ 5 mg/L (for "01", "02" and "03"), a pH range of 6.5 to 8.5 ("04" only), and be non-acutely toxic over 96 hours ("01" and "02") (FREMP, 1994a). There are no treatment works for any of the wastewater streams.

The single set of monitoring data (October 7, 1985) available through SEAM indicates that the sample was slightly basic (pH 7.9) and had a low concentration of both suspended solids (29 mg/L) and BOD (<10 mg/L). Due to the nature of the effluent, the volume of discharge and the high dilution rate available (>39 000:1 with complete mixing, based on a low river flow rate of 1178 m^3/s, calculated in Chapter Two), it was not anticipated that this operation would significantly impact the water quality of the Fraser River. However, more recent data are necessary to make a current conclusive assessment.

4.3.6 Westminster Marine Services Limited (PE 3154)

Westminster Marine Services Limited discharges domestic sewage from an office and shop into the Main Stem of the Fraser River, from the north shore, about two km upstream from the trifurcation. This operation was described in the past by Swain (1980) under the name Swiftsure Towing Co. Limited The works authorized for this waste water discharge are a packaged sewage treatment plant and a submerged outfall.

Waste Management Permit PE 3154 allows a maximum discharge of 1.14 m^3/d of effluent, with a 5-day BOD ≤ 45 mg/L and total suspended solids ≤ 60 mg/L. Although no data were available from SEAM, the permit files state that results of the effluent sampled on April 24, 1990 indicated BOD at 123 mg/L and total suspended solids at 82 mg/L, well above the permitted allowance. However the available dilution is over $89x10^6$:1 for this volume of discharge, (based on a low river flow rate of 1 178 m^3/s, calculated in Chapter Two). This dilution rate would result in concentrations, with complete mixing, of $1.4x10^{-6}$ mg/L for BOD and $9.2x10^{-7}$ mg/L for suspended solids. It is therefore anticipated that due to the high dilution rate available, this discharge will not significantly impact the water quality of the Fraser River.

4.3.7 Stella Jones Inc. (PR 3417) and (PE 3410)

Stella Jones Inc. operates a wood preserving plant in Coquitlam that produces products such as railway ties, marine pilings and utility poles. The operation discharges refuse composed of sawdust, bark and miscellaneous yard debris to a landfill, (Waste Management Permit PR 3417), located approximately 350 m from the north shore of the Fraser River. The plant also discharges cooling water from the wood preserving plant, to a ditch on the south boundary of the plant. This effluent is described as discharge "01" in Waste Management Permit PE 3410 and consists of indirect condenser cooling water and condensate from the heating tank system. Permit PE 3410 has been described in the past by Swain and Holms (1985b) and most recently in the FREMP/FRAP report (FREMP, 1994a), under the name Domtar Limited.

Waste Management Permit PR 3417 allows a maximum discharge of 45 m^3/week. Cover material is to be applied once every 20 days of operation and at least once per month. The company has not used the landfill (PR 3417) for several years but wishes to keep the permit active in the event that waste, mostly from the log peeler, cannot be shipped to a co-generation facility. There were no landfill monitoring data available from SEAM for the period of 1985 through 1994.

Waste Management Permit PE 3410 allows a maximum discharge of 465 m^3/d with the following limits: pH range, $\geq$ 2 units below supply water and $\leq$ 8.5, temperature $\leq$ 35 ^{o}C, oil and grease $\leq$ 5.0 mg/L, phenolics as phenol $\leq$ 0.2 mg/L, pentachlorophenol $\leq$ 1.0 µg/L, tetrachlorophenol $\leq$ 1.0 µg/L, trichlorophenol $\leq$ 1.0 µg/L, chromium $\leq$ 0.20 mg/L, arsenic $\leq$ 0.05 mg/L, and copper $\leq$ 0.10 mg/L.

These characteristics are representative of contaminants from the preservatives used in the wood preserving processes of the plant (FREMP, 1994a). If all the waste water discharge authorized under PE 3410 were to reach the Main Stem of the Fraser River, the minimum dilution available with complete mixing, at low river flows (1 178 m^3/s) would be 218 880:1.

Limited data indicate that temperature, oil and grease concentration and pH range have exceeded the permit limits in the past (FREMP, 1994a and Swain, 1980). As of February, 1994 the boiler has been modified to include an amine injection system to improve pH, and the cooling water discharge pipe has been increased in size from 6 to 18 inches to allow greater flows and reduce the effluent temperature (FREMP, 1994a).

More recent monthly monitoring data from the permit files, for the period from January, 1993 through December, 1994, is summarized in Table 23. The data indicates that, except for pH, all the maximum values of the parameters measured were within the permit limits. Of the 24 measurements for pH, four of them were greater than 0.2 below the tap water supply. However, this is an improvement considering that 6 of the pH measurements showed only a minor drop and 14 showed an increase over the tap water value. As well, the maximum value of pH measured did not exceed the permit limit of 8.5.

Due to the high dilution rate available for the cooling water discharge, and the results from the more recent monitoring data, it is anticipated that the effluent discharge will not significantly impact the water quality of the Fraser River, as long as the treatments continue to work effectively.

According to the permit files, historic activities on the site have resulted in significant environmental impacts. However, due to the small discharge volume and distance from the river, it is not anticipated that this operation will have any future impacts on the Fraser River. Continued monitoring of both the refuse site (PR 3417) and the effluent discharge (PE 3410) is recommended due to the nature of these discharges and their past effects on the receiving environment.

4.3.8 The Corporation of the Township of Langley (PE 4339)

The Corporation of the Township of Langley operates a secondary sewage treatment plant on the south shore of the Fraser River, just upstream from Barnston

Island. The operation has been described in the past by Cain and Swain (1980) and by Swain and Holms (1985b). The works authorized include an aerated flow equalization lagoon, a rotating biological contactor treatment plant, sludge digestion facilities, sludge holding lagoons, effluent disinfection facilities and an outfall. There are also proposed chemical treatment facilities to be completed in February, 1995 and a proposed outfall extension of 10 m to be completed by December 31, 1995.

Waste Management Permit PE 4339 allows a maximum effluent discharge of 12 700 m^3/d, with a 5-day BOD concentration ≤ 45 mg/L, total suspended solids ≤ 60 mg/L and chlorine residual at 0.1 mg/L with one hour's contact time. Ultraviolet disinfection was briefly tried and found to be unsatisfactory, so the backup chlorination / dechlorination system is now being used. The permit also requires that a minimum of 0.5 m of freeboard be maintained in the sludge holding lagoons.

The following table outlines the dilution ratios and concentration potentials for four characteristics of the Langley STP. Calculations are based on effluent data from Table 24 and Fraser River flow rate data from Chapter Two.

		Fraser River Flow Rate 1 178 m^3/s	
Characteristic	Maximum Discharge	Min. Dilution Complete Mix	Min. Dilution Edge of IDZ
Flow (m^3/d)	12 700	8 014:1	2 003:1
		Potential Increase Complete Mix	Potential Increase Edge of IDZ
Ammonia (mg/L)	62	0.008	0.031
Coliform: fecal (#/100 mL)	240 000	30	120
Susp Solids (mg/L)	99	0.01	0.05

*Where monitoring data were unavailable, permitted maximum discharges were used.

The maximum discharge of suspended solids (99 mg/L) is above the permit limits (60 mg/L); however the mean value shown in Table 24 (33 mg/L) is well below. Due to the high dilution available (8 014:1 with complete mixing), the calculated potential increase in concentrations of suspended solids in the river is not significant (0.01 mg/L).

The data for ammonia also indicate a high maximum concentration in the discharge with small potential increases (0.031 mg/L and 0.035 mg/L) due to the high dilution ratios in this area of the Fraser.

The data for fecal coliforms indicate a high potential increase with complete mixing and at the edge of the dilution zone (30 CFU/cL and 120 CFU/cL respectively). The increase in fecal coliform concentrations could be a concern considering the ambient water quality criteria for aquatic life is $\leq$ 43 /100 mL (90th percentile) and $\leq$ 14 /100 mL (median) (Nagpal *et al*, 1995).

The mean concentration for BOD_5, found in Table 24 (52 mg/L) exceeds the permit limit of 45 mg/L. After dilution with complete mixing, however, the concentration is lowered to well below a detection limit of 2 mg/L (0.006 mg/L), and is therefore only of a minor concern.

Due to the treatment of the effluent and the high dilution rate available, it is anticipated that this discharge will not significantly impact the water quality of the Fraser River. Continued monitoring is recommended to determine whether fecal coliforms and other characteristics continue to be frequently out of compliance and if so, what corrective action should be taken.

4.3.9 Valley-Rite Mix Limited (PE 7999)

Valley-Rite Mix Limited operates a ready-mix concrete batch plant located adjacent to the north shore of the Main Stem of the Fraser River, about two km from the downstream tip of Douglas Island. The discharged effluent originates from four sources: truck wash water and storm water from a ready-mix concrete plant ("01" and "04"), storm water from an aggregate stockpile area of the plant ("02") and batch plant wash water and storm water ("03"). Effluent discharge "02" flows through three sumps into a ditch that flows south into the Fraser River. Effluent discharges "01", "03" and "04" flow into three infiltration ponds at the east, south and west borders of the plant site. Discharge "01" has two recycle ponds attached to the infiltration pond.

Waste Management Permit PE 7999 allows a maximum effluent "02" discharge of 100 m^3/d with a pH range of 6.0 - 9.0 and total suspended solids $\leq$ 50 mg/L. This discharge would be diluted a minimum of 1 000 000:1 at low river flows (1 178 m^3/s, see Chapter Two) and with complete mixing. The permit limits the discharge for effluents "01" and "03" to a maximum of 10 m^3/d, and 8 m^3/d for effluent "04".

There were no monitoring data available from SEAM for the period of 1985 through 1994. However, due to the nature of the discharges, their flow rates and treatment, as well their location relative to the river, it is not anticipated that this operation will significantly impact the water quality of the Fraser River.

4.3.10 Highland Foundry Limited (PR 8431)

Highland Foundry Limited is authorized to discharge industrial refuse to a landfill located approximately 250 m from the south bank of Parsons Channel of the Fraser River, directly south of Barnston Island. The refuse is waste sand from a casting operation and slag from a foundry operation, and is composed mostly of inert sands with metal content in relatively insoluble alloy and oxide forms.

Waste Management Permit PR 8431 allows a maximum discharge of 10 m^3/week. Refuse must be placed 1.2 m above the groundwater table and, upon completion, the landfill site is to be capped with asphalt or concrete pavement. According to the permit files there are no water licenses issued downstream, but there are five water wells located within a 300 m radius of the site. Ground water monitoring for metal concentrations and phenols is required every two months, and samples are obtained from three monitoring wells located at the south end, northeast and northwest corners of the site.

The data available from the permit files for the period of 1992 to 1994 indicates relatively low and constant values for the majority of the metals sampled (arsenic, barium, beryllium, bismuth, cadmium, calcium, chromium, cobalt, copper, lead, lithium, manganese mercury and titanium). However, some variables showed large fluctuations in concentrations throughout the monitoring dates: aluminum from <0.005 mg/L to 29.5 mg/L, iron from <0.004 mg/L to 35.4 mg/L, magnesium from 20.8 mg/L to 57.8 mg/L, silicon from 13.7 mg/L to 54.8 mg/L, and sodium from 125 mg/L to 529 mg/L.

Due to the relatively inert nature and low volume of discharge it is anticipated that this landfill will not significantly impact on the water quality of the Fraser River. However, there is a concern for ground water quality being impacted as a result of this operation. Groundwater monitoring is recommended to ensure that the impacts are not of a significant concern.

4.3.11 Montague Grant and Marilyn Lucille Sparks (PE 8519)

Montague Grant and Marilyn Lucille Sparks are authorized to discharge effluent from a 40-unit floating home marina located on the south side of the Fraser River, between Derby Reach and Barnston Island.

Waste Management Permit PE 8519 allows a maximum effluent discharge of 45.6 m^3/d, with $BOD_5 \leq 45$ mg/L and total suspended solids ≤ 60 mg/L. The effluent flows through a rotating biological contactor-type package secondary treatment plant, and is then discharged through an outfall extending approximately five metres beyond the marina, to a minimum depth of three metres.

There were no monitoring data available from SEAM for the period of 1985 through 1994. However, due to the high dilution ratio calculated with complete mixing (> 2 200 000:1 at a low river flow of 1 178 m^3/s in the Main Stem), it is anticipated that this operation will have little impact on the water quality of the Fraser River.

4.3.12 Texada Lime of Canada Incorporated (PE 11351)

Texada Lime of Canada Inc. operates a quick lime processing plant adjacent to the south bank of the Fraser River, just upstream from Barnston Island. The plant processes $CaCO_3$ (lime) to produce CaO (quick lime) for water and wastewater treatment and for soil conditioning for agricultural purposes. Municipal tap water is used as cooling water for an air compressor and an air conditioner. Once the cooling water has been used, it is collected in holding tanks and recycled into the system. Excess cooling water that has not sufficiently cooled in the holding tanks is discharged through a submerged outfall to the Fraser River.

Waste Management Permit PE 11351 allows a maximum discharge of 78.5 m^3/d, with a maximum temperature ≤ 25 ^{0}C, residual chlorine ≤ 0.2 mg/L and pH range between 6.0 and 8.0. With complete mixing at low river flows, the effluent would be diluted by a factor of over 1 000 000:1 (1 178 m^3/s in the Main Stem, see Chapter Two). Effluent monitoring is required once a year and is to include the analysis of metals.

According to the permit files, in August, 1993 the cooling water was sampled, and all the permit limits were met. Therefore, due to the nature of the effluent, the low volume and the high dilution available in the river, it is anticipated that the discharge will not impact the water quality of the Fraser River.

4.3.13 GVRD Port Mann Landfill (AR 12006)

The District of Surrey Port Mann Landfill, which began operation in 1969, is located on the south bank floodplain terrace of the Main Stem of the Fraser River, approximately two km east of the downstream tip of Douglas Island. It lies between the CN Rail yard to the north, and an escarpment rising to the south (Dayton and Knight, 1992b). The operation has been described in great detail in the past in the District of Surrey Port Mann Landfill Phase 3 - Operational Plan (Dayton and Knight, 1992b) and the 1992 Annual Report Landfill Monitoring Program (Dayton and Knight, 1993).

Since 1986, the landfill has received municipal solid waste from District of Surrey residents, all GVRD member municipalities as well as those municipalities participating in the GVRD Solid Waste Management Plan. This represents approximately 60% of the total refuse received, while the other portion originates from the Coquitlam Resource Recovery Plant and from industry within the West Burnco sector. Approximately 140 000 tonnes/year or about 400 tonnes/day of waste from Surrey is currently disposed of at the Port Mann landfill (GVRD, Stage 2, SWMP, 1994).

The Port Mann Landfill is no longer covered under Waste Management Permit AR 12006, but is run under the terms and conditions of an operational plan. Closure of the landfill is scheduled for 1997 (GVRD, Stage 2, SWMP, 1994).

Phase 3 of the operational plan was completed in September, 1987 and offers guidelines for the implementation of leachate collection, landfill gas control and site servicing (Dayton and Knight, 1992b). At present, the landfill facilities include the following: leachate collection system, landfill gas collection and disposal system, leachate barrier, surface runoff water containment and diversion, and landfill construction and final cover (Dayton and Knight Limited, 1993).

Once each landfill section is completed, diversion ditches are constructed to direct drainage to either end of the landfill. Leachate and groundwater generated at the landfill site are collected by underground pipe systems, discharged to the GVS & DD sewer, and eventually treated at the Annacis Island STP before being discharged to the river. The north slope leachate collector is constructed in conjunction with a surface drainage ditch, creating a hydraulic barrier to further assist in preventing northward groundwater movement. Surface runoff from the landfill site flows both north and south to collection ditches or storm drains. Surface runoff water from the CN Rail Thornton Yard property drains northward to the Fraser River. (Dayton and Night Limited, 1992).

The monitoring program set up under the operational plan includes extensive sampling of the north and south slope leachate collectors, groundwater wells, landfills gas and surface runoff. As the surface runoff is the only untreated discharge to the Fraser River, it represents the greatest concern for the water quality of the Main Arm. The 1992 monitoring data represent a compilation of six different sampling sites from around the landfill site, and are summarized in Table 25.

Of the characteristics studied, those whose maximum values exceeded ambient water quality criteria were nitrate/nitrite (1.46 mg/L), BOD (21 mg/L), aluminum (1.34 mg/L), iron (17.1 mg/L), lead (0.007 mg/L) and manganese (1.81 mg/L). However, if all of these were to reach the Main Arm of the Fraser River, only a dilution factor of 100:1 would be required to lower the concentrations to below safe ambient water quality levels (Nagpal *et al*, 1995). As the low flow rate of the Main Arm is approximately $8.64x10^7$ m^3/d, a dilution rate of >100 is likely.

Therefore, due to the monitoring data, the diversion and treatment facilities available and the high dilution rate available in the Main Arm of the Fraser River, it is anticipated that this operation will not significantly impact the water quality of the Fraser River. Continued monitoring is recommended both now and after closure to ensure that the leachate continues to be properly directed to the sewer line, and to ensure that the surface runoff is within volume and contaminant limits so as not to significantly impact the water quality of the nearby Fraser River.

4.3.14 Imasco Minerals Limited (PE 12087)

Imasco Minerals Limited operates a limestone pulverizing plant adjacent to the south bank of the Fraser River, near the east end of Parsons Channel. The permit states that the limestone is "food grade" and is therefore not a heavy metal source. The operation discharges treated stormwater run-off into a ditch on the east side of the property, which then discharges into the Main Stem of the Fraser River. The treatment facilities include a settling basin, a discharge shut-off valve and a discharge pipe.

Waste Management Permit PE 12087 allows a maximum effluent discharge of 826 m^3/d with an annual average of 9 m^3/d, having a maximum total suspended solids $\leq$ 75 mg/L with an annual average $\leq$ 60 mg/L and a pH range 6.5-9.0. The company must also monitor for oil and grease concentrations, quarterly, for one year. Even with the maximum discharge rate and the low river flow (1 178 m^3/s in the Main Stem), the effluent would be diluted by a factor of 123 200:1.

There were no monitoring data available from SEAM for the period of 1985 through 1994.. However, due to the low daily flow, the nature of the effluent, the treatment and the high dilution rate available, it is anticipated that this discharge will not significantly impact the water quality of the Fraser River.

4.3.15 Halliday, Anne (PR 12139)

Anne Halliday is authorized to discharge concrete rubble and sandy soil to an excavated hole that interrupts the dike on the south bank of Barnston Island. A. Halliday intends to locate and construct a building on the site once it is filled. The discharge was authorized to occur until June 7, 1993.

Waste Management Permit PE 12139 allows a total maximum discharge of 2 676 m^3. Upon completion, it is required that the landfill be graded and given a final cover that will prevent erosion.

There were no monitoring data available from SEAM for the period of 1985 through 1994. However, due to the nature of the refuse and the treatment during and after completion, it is anticipated that this discharge will not significantly impact the water quality of the Fraser River.

4.4 Fraser River North Arm from the New Westminster Trifurcation to the Banks

4.4.1 Crown Packaging Limited (Paperboard Ind.) (PE 17, PR 5936)

Crown Packaging Limited is located in New Westminster on the north shore of the North Arm of the Fraser River. The company was recently purchased from Paperboard Industries and continues to operate as paper recycling facility producing paperboard from a variety of waste paper products. Baled, recycled waste paper (old corrugated containers, old newsprint, corrugated cuts, kraft bags and envelopes, coloured and white ledger, and computer paper) is pulped, cleaned, and then processed in paper machines into products such as roofing felt, box board, and corrugated box materials. White water generated in the process is either recycled into the process or treated prior to discharge. Treatment consists of in-plant fibre recovery, clarification, aeration stabilization, and discharge through a submerged outfall into the Fraser River. The discharge also includes sanitary waste which is treated in a package sewage treatment plant. The site has been described in detail in several previous assessments (Swain, 1980, Swain and Holms, 1985b, Swain and Walton, 1992 and Swain and Walton, 1993a) under Belkin Industries and Paperboard Industries Corporation.

Waste Management Permit PE 17 allows effluent to be discharged at a maximum rate of 11 400 m^3/d with treated sanitary wastes comprising only 23 m^3/d of the maximum discharge rate. The characteristics of the combined effluents include: pH range from 6.5-8.0, temperature ≤ 35 ^oC, suspended solids ≤ 4 840 kg/d, BOD_5 ≤ 3 630 kg/d, dissolved oxygen ≤ 2.0 mg/L, the sum of tri-,tetra-l, and pentachlorophenol ≤ 10 µg/L, and 96 hour LC_{50} ≥ 100 %.

Weekly monitoring of the combined discharge is required for solids, BOD_5, dissolved oxygen, temperature and pH as well as monthly monitoring for polychlorinated phenols and toxicity and quarterly monitoring for PCBs. Discharge flow rates are to be recorded daily. The sewage discharge requires quarterly monitoring of daily flow rate and analyses for BOD_5, fecal coliform bacteria, and total suspended solids. Sampling stations are required upstream and 100 m downstream from the combined discharge to analyze for the above parameters in the receiving environment.

There is a permit amendment pending that will restrict the total suspended solids in the discharge to a monthly average of 678 mg/L (1 130 mg/L daily maximum) until March 31, 1996 at which time the permitted discharge for total suspended solids will become 502 mg/L. Effective on approval, BOD_5 will be restricted to a maximum of 377 mg/L and on December 1. 1995, maxima of 45 mg/L BOD and 60 mg/L suspended solids discharge limit will be requested for the package sewage treatment plant (Woodbine, 1995).

Crown Packaging Limited also discharges refuse a landfill located on the site. The refuse includes waste paper fiber with minor amounts of sand, wood, metals and plastic from the paperboard processing. This refuse site has been described in the past by Swain and Holms (1985b).

Waste Management Permit PR 5936 allows a maximum discharge rate of 5.5 dry tonnes/d. The refuse is to be covered once per 20 days of operation and at least once per month. The site is to be operated in a cellular structure with a maximum cell size of 0.4 ha. and perimeter berms made of inert material. Grab samples of the surface drainage area are to be obtained from a culvert on the western side of the landfill area. The samples are to be analyzed quarterly for pH, conductivity, dissolved oxygen, toxicity, total and dissolved iron, total copper and total zinc. Annual analyses for chlorophenols and PCB are to be done each October after a rainfall event.

The refuse site is located in a low lying area which is subject to flooding and has a high water table. Due to past contamination of the site and the origin of the refuse, PCB contamination is a concern although sediment samples taken near the site show PCBs were below detection limit (< 0.010 mg/L) (Swain and Walton, 1993a).

The limited data for the wastewater discharge, summarized in Table 26, covers the period from 1985 to 1994. The high permitted discharge rate (11 400 m^3/d) and the estimated low flow for the North Arm (177 m^3/s) allows a minimum dilution of over 1 300:1 and is sufficient in reducing the contaminates to insignificant levels as is evident in the following table.

Characteristic	Maximum Discharge	Fraser River Flow Rate: 177 m^3/s	
		Min. Dilution Complete Mix	**Min. Dilution Edge of IDZ**
Flow (m^3/s)	11 400	1 341:1	335:1
		Potential Increase Complete Mix.	Potential Increase Edge of IDZ
BOD (mg/L)	676	0.5	2.0
Carbon: inorganic (mg/L)	13	0	0
Carbon: total (mg/L)	360	0.3	1.1
Ammonia (mg/L)	0.263	0	0.001
Suspended Solids (mg/L)	631	0.0	1.9

Three four-hour composite samples collected in 1991 for the FREMP report showed the only metal discharged at a high concentration was total aluminum and was probably due to the mill acid sizing paper with rosin and aluminum sulphate (Swain and Walton, 1991).

Sediment samples were collected adjacent to and near the outfall in the Fraser River. As expected, due to particle size distribution at the sites, the highest concentrations of metals in sediments were usually found at a site (on the opposite shore from Crown Packaging Limited) which had the finest sized particles. The highest PAH and resin acid values in sediments were at a site about 100 metres downstream from the discharge, although the highest concentrations of PAHs when normalized to 1% organic carbon were usually at a site at the point of discharge (Swain and Walton, 1992).

Dioxins and furans were detected in sediment samples collected near the outfall, and about 100 m downstream from the outfall. However, the samples were found to be at concentrations well below the International Joint Commission water quality objective for sediments of 10 pg/g, and at about the same concentration as found at Chatterton Petrochemical in the Main Arm of the river and sampled on the same day (Swain and Walton, 1992).

The effluent from the Crown Packaging site was found to be non-toxic in acute toxicity tests to a variety of test organisms. These organisms included rainbow trout, *Daphnia magna*, and the microtox bacteria. Fish exposed to the effluent during an eight-day test period were found to have higher concentrations of PAHs in livers compared to control fish. This indicates that these substances are in the effluent at levels that create such an effect. The high fat content of livers, and the preferential deposition of organics such as PAHs and PCBs to fatty tissues, would explain why acenaphthene, acenaphthylene, fluorene, naphthalene, and phenanthrene were higher in livers of the exposed fish than in the control fish (Swain and Walton, 1992).

In comparison to the muscle samples from the control fish, those fish exposed to effluent from Paperboard Industries had considerably higher concentrations of chromium, iron, manganese, nickel, 2,3,4,6-tetrachlorophenol, and pentachlorophenol. The largest differences were found for chromium, nickel, and pentachlorophenol, all of which had non-detectable concentrations in the muscle of the control fish. The only water quality guideline, standard, criterion, or objective for any of these substances in fish muscle is a Water Quality Objective for the Fraser River Estuary of a maximum 0.1 μg/g (wet-weight) of total chlorophenols. This objective was not exceeded by the concentrations in the exposed fish (Swain and Walton, 1992).

Of interest is the fact that fish exposed to the effluent from Chatterton Petrochemical Corporation also had higher iron, manganese, and chromium concentrations than in the control fish. This suggests that these metals are being elevated due to exposure to some source other than these two specific industrial discharges. It must be recognized that in the ambient environment, the effluent would be quickly diluted, and fish would not be exposed to 100% effluent concentrations for an eight-day period. Therefore, it is unlikely that the increases seen in the laboratory would be repeated in the Fraser River (Swain and Walton, 1992).

Metal concentrations measured in the sediments from two sites near the Crown Packaging site (the abandoned Domtar site upstream and just downstream from the outfall) were generally the same or slightly lower than those measured at the routine monitoring site upstream in Blind Channel (Site NA-1). Exceptions to this at the upstream site were concentrations of lead, zinc, and certain PAHs which were higher than at Site NA-1. These higher concentrations could likely be attributed to the stormwater inputs, or groundwater inputs from the abandoned Domtar site (Swain and Walton, 1993a).

Acid volatile sulfides (AVS) concentrations were similar at both sites and about three times higher than found at Site NA-1. Sediment toxicity was found to be higher at the downstream site according to two tests; the solid-phase microtox test on the sediments themselves, and the sand dollar bioassay on the sediment extracts (Swain and Walton, 1993a).

Some PAH concentrations increased in a downstream direction. These were benzo (b) fluoranthene (0.051 to 0.047 µg/g), benzo (a) pyrene (0.033 to 0.026 µg/g), and indeno (1,2,3-c,d) pyrene (0.033 to <0.020 µg/g dry-weight). Benzo (a) pyrene is above the no-effects threshold criterion of 0.01 µg/g set for the St-Lawrence River (Environment Canada, 1992) and indeno (1,2,3-c,d) pyrene is below the no-effects threshold criterion of 0.07 µg/g (MELP, 1994). No criterion has been set for benzo (b) fluoranthene. Two individual PAHs were also found to be at or above the water quality objectives for PAHs in sediments in Burrard Inlet. These were fluoranthene and phenanthrene at the upstream site. Fluoranthene was at the concentration for the objective of 0.17 µg/g (dry-weight) which is above the no-effects threshold of 0.02 µg/g but below the minimal effects threshold of 0.6 µg/g set for the St-Lawrence River (Environment Canada, 1992). Phenanthrene was in excess of the objective of 0.15 µg/g (dry-weight) at 0.18 µg/g (dry-weight) and above the no-effects threshold (0.03 µg/g) but below the minimal effects level (0.4 µg/g) set for the St-Lawrence River (Environment Canada, 1992). All the other individual PAHs at both sites were below the other objectives (Swain and Walton, 1993a).

All halogenated and non-halogenated compounds were below detection except for toluene. The toluene concentrations increased from 0.13 µg/g at the upstream site to 0.283 µg/g (dry-weight) at the downstream site (Swain and Walton, 1993a).

4.4.2 Thomas J. Lipton Inc. (PE 36)

Thomas J. Lipton Inc. is authorized to discharge cooling water effluent from a cannery located south from Mitchell Island, approximately 600 m from the North Arm of the Fraser River. The effluent is discharged through an outfall pipe into a municipal ditch that flows east for approximately 1 000 m before reaching the river. This site has been previously described by Swain (1980) and Swain and Holms (1985b)

Waste Management Permit PE 36 allows the effluent to be discharged at a maximum rate of 373 m^3/d with a maximum temperature of 32 °C. Monitoring of the discharge is no longer required as the permit has remained in compliance since 1982.

Due to the nature of the effluent being discharged and the high dilution ratio of over 40 000:1 after complete mixing, the ambient water quality in the Fraser River should not be affected. Since the discharge flows for about 1 000 m in the ditch before reaching the river and the minimum dilution is greater than 4 600:1 at the edge of the initial dilution zone, the temperature of the effluent is expected to reach the ambient temperature in the Fraser River before complete mixing.

4.4.3 MacMillan Bathhurst Inc. (PE 108)

This corrugated cardboard container plant, operated by MacMillan Bathhurst Inc., is located at the northeast end of Lulu Island, on the south bank of the North Arm at New Westminster. The operation has been previously described by Swain[4.1] and Swain and Holms (1985b). The plant discharges cooling water and roof drainage through a wood stave pipe to a ditch that flows along the west and south property lines.

Waste Management Permit PE 108 allows the cooling water to be discharged at a maximum rate of 23 m^3/d with a maximum temperature of 35 ^oC before combining with the roof drainage.

Data collected for dissolved metals from the cooling water discharge during September 1994 are summarized in Table 27. The permit files do not specify if the ditch flows to the North Arm or south to Annacis Channel. Using the lower estimated low flow rate of Annacis Channel (6% of 1 178 m^3/s) to calculate the minimum dilution of 16 616:1, the potential increase would be insignificant for all characteristics. The higher estimated low flow rate of the North Arm (177 m^3/s) would also provide insignificant potential increases. The high dilution ratios associated with the North Arm and Annacis Channel will ensure the ambient water quality in the Fraser River will not be affected by this discharge.

4.4.4 Scott Paper (PE 335)

Scott Paper is located in New Westminster on the north shore of the North Arm of the Fraser River, just downstream from the trifurcation of the Fraser River. This tissue and household paper manufacturing plant has been described in the past by Swain (1980), Swain and Holms (1985b), and most recently in the FREMP/FRAP report (FREMP, 1994a). Effluent which is discharged to the river comes from the paper mills ("02"), while the effluent which was discharged to the river in the past, from the groundwood mill, is now recycled (“01”)(FREMP, 1994a). The discharge “01” has not been canceled from the permit.

The works authorized for "02" include an in-plant fibre recovery facility, three clarifying units, wharf lagoon, sludge press and a submerged outfall which extends approximately 12 m from the dock. The effluent is treated using dissolved air flotation once usable fibre has been recovered and re-circulated in the process (FREMP, 1994a). The works for "01" include an in-plant fibre recovery facility and outfall to the Fraser River.

Waste Management Permit PE 335 allows a weekly average discharge rate of 18,200 m^3/d (maximum 23 000 m^3/d) for "02" and a maximum discharge rate of 1 150 m^3/d for "01". Both discharges require a temperature ≤ 35 °C. The characteristics for "02" also include a pH from 6.0-8.0, dissolved oxygen ≤ 2.0 mg/L, both total suspended solids and BOD_5 ≤ 2 700 kg/d (Pulp and Paper Effluent Regulation requires BOD ≤ 2 303 kg/d) (FREMP, 1994a) and be non-toxic (96h LC50).

The monitoring program required in the permit for "02" includes effluent sampling three times per week for temperature, total suspended solids, dissolved oxygen and pH. Weekly sampling for volatile suspended solids and BOD_5, monthly sampling for colour and quarterly sampling for toxicity are also required.

Monitoring data were not available in the permit files or on SEAM, therefore it is not possible to determine if the discharge has met allowable discharge limits. With a maximum discharge rate of 23 000 m^3/d and an estimated low flow rate of 177 m^3/s for the North Arm, the minimum dilution available would be 665:1 after complete mixing. An assessment of initial dilution zones prepared by FREMP indicate that the dilution based on a single trackings of clusters of drogues was estimated at 4.3:1 at 100m from the discharge (FREMP, 1994d). This same report indicated that the receiving water sample tested showed toxicity to Ceriodaphnia dubia; a reduced number of young was produced and the lowest-observable effect occurred at 25% concentration (FREMP, 1994b).

With respect to metals concentrations in sediments, measurements taken at two sites near the Scott Paper discharge were the same or slightly lower than sediment samples taken at a nearby routine monitoring site in Blind Channel (NA-1). The AVS was found to be higher at the two Scott Paper sites (15.1 and 51 µg/g dry-weight) than at Site NA-1 (11.7 µg/g dry-weight) (Swain and Walton, 1993a).

The toxicity of the sediments from the downstream site was determined to be more toxic than at the site near the Scott Paper discharge. This was based on the results from both the solid-phase microtox test and the sand dollar test on the sediment extract (Swain and Walton, 1993a). A FREMP report states that sediments from Scott Paper were acutely toxic to luminescent bacteria and significantly depressed bacterial light output compared with sediments from reference sites (FREMP, 1994d). A sediment sample collected 100 m upstream from Scott Paper showed sublethal toxicity to Macoma balthica but this area is also subject to input from two combined sewer overflows and the cause of the sediment toxicity could not be determined (FREMP, 1994).

Some PAHs were measurable in the sediments from both the sites but were below Water Quality Objectives for PAHs in sediments from Burrard Inlet. These measurable PAHs were fluoranthene, phenanthrene, and pyrene, which decreased from 0.026 to 0.018 µg/g, 0.029 to 0.018 µg/g, and 0.021 to 0.016 µg/g (dry-weight), respectively (Swain and Walton, 1993a). Fluoranthene is above the no-effects threshold of 0.02 µg/g, phenanthrene is below the no-effects threshold of 0.03 µg/g, and pyrene is borderline of the no-effects threshold of 0.02 µg/g. These thresholds were set for the St-Lawrence River (Environment Canada, 1992).

Toluene was the only halogenated or non-halogenated compound that was not below detection. Toluene concentrations increased from 2.15 µg/g at the downstream site to 0.986 µg/g at the upstream site near the Scott Paper discharge. These concentrations were higher than were found downstream near Paperboard Industries (Swain and Walton, 1993a).

There is no real trend indicating that these two Scott Paper sites have greater or lesser contamination than other North Arm sites for resin and/or fatty acids since some of the acids were at higher concentrations and others at lower concentrations than were measured at Site NA-1 (Swain and Walton, 1993a).

4.4.5 MacMillan Bloedel Limited (PE 1664)

MacMillan Bloedel Limited operates a sawmill located just downstream from the trifurcation at New Westminster on the south shore of the North Arm of the Fraser River. It has been described in the past by Swain (1980) and Swain and Holms (1985b), and most recently in a joint FREMP/FRAP report (FREMP, 1994a). The mill discharges equipment washdown water and cooling water from a planer mill and standby compressor ("02") to a municipal storm water ditch that flows east to the North Arm. Storm water and cooling water from the saw mill ("03") discharge directly to the river.

The works authorized for discharge "02" include two concrete oil separation basins with disposable oil absorption pads. Discharge "03" includes an outfall discharging below the scow dock to the Fraser River. The company eliminated the discharge of cooling water from a lumber dry kiln before March 1993 and the discharge of boiler blowdown effluent was to be discontinued by June 30, 1994 (both at "02"). An application for a permit amendment dated December 22, 1994 to reinstate the boiler blowdown is on file. Steam condensate has been replaced at discharge "03" by the storm water and cooling water from the saw mill.

Waste Management permit PE 1664 allows the discharge of 91 m^3/d for discharge "02" with a maximum temperature of 35 °C and oil and grease ≤ 5 mg/L. Discharge "03" is restricted to an annual average of 320 m^3/d with the same characteristics as discharge "02". Monthly monitoring for temperature and quarterly monitoring for oil and grease are required for both discharges. Additional monitoring at "02" includes quarterly grab sampling for BOD_5, pH, and total suspended solids and a toxicity (96h LC50) once every six months.

The permit has been out of compliance for minor oil and grease exceedances on occasion and the company was requested to rectify the problem. This may have been due the steam condensate which has been discontinued.

Data from the permit files for 1993-94 are summarized in Tables 28 and 29 and show the permit has been in compliance with the maximum flow rates well below permitted rates. The company notes the high concentration of suspended solids at discharge "02" may be due to loose sawdust in the sample. The mean concentration is 51 mg/L which is below the 60 mg/L objective for sawmills. Even at the high concentration of 210 mg/L the minimum dilution ratio of over 168 000:1 based on the maximum recorded discharge of 60 m^3/d and an estimated low flow rate of 177 m^3/s for the North Arm would bring the suspended solids concentration below 1 mg/L. These high dilution ratios (>77 000:1 for "03") reached after complete mixing should assure the ambient water quality in the Fraser River will not be affected by these discharges if the permit remains in compliance.

4.4.6 Western Steel Limited (PR 2086, PE 2087)

A steel and rolling mill, located at the western end of Mitchell Island on the North Arm of the Fraser River, is owned by Western Steel Limited. The company closed the mill in 1988 but has retained a discharge permit (PE 2087) for storm water. The company was ordered to undertake clean up and remediation of the site and is now managing it as a contaminated site. This operation has been described by Swain (1980) and Swain and Holms (1985b).

Waste Management Permit PE 2087 was amended February 3, 1995 to restrict the discharge to storm water run off only (the permit in the past had allowed the discharge of treated sewage and storm water to the river and rolling mill cooling water and scrubber water to settling ponds). The storm water is collected in drainage ditches and discharged through outfalls to the North Branch ("01") and the South Branch ("02") of the North Arm. The maximum allowable discharge rate is 24 000 m^3/d at "01" and 22 000 m^3/d at "02". The characteristics for both discharges include total suspended solids ≤ 50 mg/L, oil and grease ≤ 5 mg/L, pH range 6.5-8.5, dissolved cadmium ≤ 0.02 mg/L, dissolved copper ≤ 0.05 mg/L, dissolved zinc ≤ 0.3 mg/L and dissolved lead ≤ 0.05 mg/L. Flow data and grab sample analyses for the above parameters are required once each quarter, with the first reporting period ending December 31, 1995. Effluent data summarized in Table 30 (n=9) indicate that total suspended solids maximum was above, but mean value was within permit levels(118.0, 35.0 mg/L). Both mean and maximum values for oil and grease were above permit levels(19.0, 8.0 mg/L). Zinc and copper were within permit levels. Minimum pH fell below the permitted range at 6.2. No data was available for cadmium, copper, and lead.

Waste Management Permit PR 2086 authorized the discharge of arc furnace slag, rubble, and unreclaimed steel to a landfill until May 25, 1994. This permit is still in effect. The maximum allowable discharge rate was 13.76 m^3/d. The landfill area was located along the north side of the property, behind a dike with the water table approximately 0.6 m to 1.2 m from the bottom. Drainage ditches surrounding the landfill discharge to the North Arm through outfalls "01" and "02".

The first reporting period for the amended discharge is not required until the end of 1995 and therefore the levels of contaminants that may currently be reaching the river are not available. Since the site is being managed as a contaminated site and clean up and remediation of the site are in progress, the discharge of storm water runoff is not expected to have a significant impact on the ambient water quality of the Fraser River after completion. Further review will be required after results from the first reporting period are submitted.

4.4.7 EOC Holdings Inc. (PR 2510)

This foundry refuse site, located approximately one km upstream from Mitchell Island on the south shore of the North Arm at Richmond, was closed in December 1993. Mainland Foundry and Engineering Limited operated a foundry at the site from the early 1960's to 1991 and discharged sand, slag, sludge and cinders to the landfill. The site has been previously described by Swain and Holms (1985b). Required closure works were completed in 1993 and included 0.5 m by 2 m barrier walls and a 0.3 m thick cap, composed of sand and bentonite.

The permittee, EOC Holdings Inc., is required by Waste Management Permit PR 2510 to maintain six groundwater observation wells on and alongside the landfill area and two surface water sampling sites in the ditches on the south and west side of the property. One grab sample from each monitoring site is required every six months from January 1994 to December 1995 and analyses for pH, conductivity and dissolved metals submitted.

The barrier walls were required for the closure to reduce the migration of metals through the groundwater and conserve the alkalinity provided by underlying peat. Permit files show samples collected in 1990 had phenolics < 1 µg/L and weak acid dissociable cyanide < 0.025 mg/L. Molybdenum, chromium, and selenium were greater than the criteria for protection of aquatic life (molybdenum, 500 µg/L; chromium, 50 µg/L; selenium, 50 µg/L). Data covering the period from 1985 to 1987 and from December, 1993 to December, 1994 are summarized in Tables 31 and 32.

Samples taken from the six groundwater monitoring wells show selenium and chromium were below detection limits (0.0005 mg/L and 0.015 mg /L respectively), however molybdenum still exceeded the criterion in the two north wells within the landfill (maximum 30.1 mg/L). Arsenic was found at a median concentration of 0.0767 mg/L, exceeding the criterion for the protection of aquatic life (0.05 mg/L). The maximum concentrations for cadmium, mercury and zinc also exceeded the criteria of 0.0050 mg/L cadmium, 0.001 mg/L mercury and 0.200 mg/L zinc. The exceedances all occurred in the wells within the landfill whereas the two wells alongside the site were below ambient criteria. Table 33 summarizes the data sampled from the ditch over the period from December 1993 to December 1994. Cadmium (maximum 0.0313 mg/L) was the only metal concentration exceeding criteria of 0.0002 mg/L at hardness less than 60 mg/L and 0.0008 mg/L at hardness 60-120 mg/L for the protection of aquatic life.

The water quality in the ditch does not appear to be significantly affected by the landfill and should not have an impact on the ambient water quality of the river. From the data it appears that some leaching to the groundwater is occurring. The groundwater is flowing north or northeast, towards the Fraser River and therefore could be a concern to ambient water quality in the river. Further sampling of the water quality in the Fraser River near the Mitchell Island site is recommended to determine if the impact on ambient water quality from the groundwater is significant.

4.4.8 Tree Island Industries Limited (PE 3190)

Tree Island Industries Limited operates a metal finishing plant on Tree Island, located at the northeast corner of Lulu Island on the North Arm of the Fraser River, about 3.5 km downstream from the trifurcation. Blind Channel is to the south. Four infiltration lagoons are located on the property, approximately 15 m from the river. The site has been previously described by Swain (1980), Swain and Holms (1985b), and most recently in a joint FREMP/FRAP report (FREMP, 1994a).

The process water from the production of wire and wire products is treated in a waste water treatment plant where it passes through a three-stage neutralization process with caustic. Flocculant is added and the solids separated in a clarifier. Sewage from a septic tank is combined with the treated wastewater before discharge to infiltration lagoon #4 ("01"). This discharge is authorized to December 31, 1997. Non-contact cooling water ("02") from a wire draw machine is discharged directly to the North Arm through a submerged outfall. Sixteen groundwater monitoring wells have been installed.

From June to December, 1994, the plant was authorized to temporarily discharge dewatering effluent ("03") from a mobile sludge filter press, to infiltration lagoon #3. The effluent was from the filtration of centrifuged metal hydroxide sludges produced by the waste water treatment plant since 1991. The sludges were being stored in drums on the site. Thirty thousand drums were treated, and the dewatered cakes were returned to storage in steel drums.

Waste Management Permit PE 3190 allows process water "01" to be discharged at a maximum rate of 2 000 m^3/d, including a maximum of 50 m^3/d of domestic sewage. The effluent must have a pH of 8.0 to 10.5, total suspended solids ≤ 20 mg/L, dissolved lead ≤ 0.1 mg/L, dissolved zinc ≤ 0.2 mg/L, and ammonia ≤ 30 mg/L. The maximum discharge rate for cooling water "02" is 2 500 m^3/d. The cooling water must be non-toxic (96h LC50) with a pH of 6.0 to 8.5, dissolved lead ≤ 0.2 mg/L, dissolved zinc ≤ 0.3 mg/L and the temperature ≤ 27 °C. The permitted rate of discharge for "03" was 300 m^3/d with pH, lead and zinc equivalent to the characteristics for "01". If the discharge does not meet these levels it is to be treated in the waste water treatment plant before discharge to the lagoon.

Monitoring requirements for discharge "01" include continuous monitoring for pH, weekly monitoring for total suspended solids, dissolved zinc, Hartree's energy, and total ammonia, and monthly monitoring for alkalinity, hardness, dissolved boron, cadmium, chromium, copper, lead and manganese, and total nitrate, nitrite and phosphate. Discharge "02" requires weekly monitoring for pH, temperature, dissolved lead and zinc, hardness, conductivity and toxicity. Flow rates (24-hour) are to be recorded weekly for both discharges.

Monitoring data for the cooling water discharge ("02") are summarized in Table 34. Although the levels of zinc (max. 0.29 mg/L) are within the permit levels allowed (0.3 mg/L) they exceed the tentative criterion for the protection of freshwater aquatic life (0.003 mg/L) (Nagpal *et al*, 1995). These findings confirm those discussed in the FREMP/FRAP report (FREMP, 1994a). Lead levels also met permitted values (0.2 mg/L) but the detection limit of 0.08 mg/L was not sufficient to conclude if the discharge met the freshwater aquatic life criterion of 0.003 mg/L.

Sediment samples taken at Tree Island Industries in 1993 showed the highest concentration of metals (FREMP, 1994d). Lead and cadmium concentrations from sediment samples taken in 1992 from a routine monitoring site in Blind Channel (NA-1), adjacent to Tree Island Industries, were found to have decreased from previous sediment samples taken at the site. Nickel concentrations however appeared to have increased. The decrease in lead and cadmium was thought to be due to the elimination of leaded gas in Canada and therefore lower concentrations were reaching the channel through the storm water runoff (Swain and Walton, 1993a). PAH concentrations in the sediment samples from NA-1 were undetectable as were PCBs and chlorophenols (Swain and Walton, 1993a).

The permit files show the discharge to be non-toxic (Toxicity LC50) although chronic toxicity tests with *Ceriodaphnia dubia* showed mortalities of first generation daphnids at concentrations ≥ 50% and reproductive impairment at concentrations of 42% and higher (FREMP 1994a). Five day *in-situ* fish bioassay tests conducted in the Main Arm and Blind Channel near the exfiltration lagoons in May 1993, indicated no observable stress or toxicity to the test fish (IRC Integrated Resource Consultants, 1993).

Acid Volatile Sulfide (AVS) analyses and Simultaneously Extracted Metals (SEM) analyses taken during the in-situ bioassay tests gave AVS/SEM ratios of 1.73 to 3.76 µmoles/g dry weight. It has been proposed that SEM/AVS ratios of less than 1:1 indicate that the metals are precipitated as insoluble, biologically unavailable, metal sulfides (Di Toro *et al.*, 1992). A ratio of 1:1 or higher indicates that the portion of metals (SEM-AVS) that remains unprecipitated as sulfides may be dissolved and hence, bioavailable. However the ratio does not take into account dissolved metal complexes and sediment phases that may also affect bioavailability. The ratio also fails to provide indication of the quantity, concentration, or identity of dissolved metals (Hare *et al.*, 1994). The upstream and downstream reference sites had AVS/SEM ratios of 0.79 and

0.47 µmoles/g dry weight indicating a possible increase in toxicity of the Fraser River sediments near the Tree Island lagoons (IRC Integrated Resource Consultants, 1993).

Table 34 summarizes the monitoring data for the cooling water discharge to the North Arm during 1994. Using the estimated low flow rate for the North Arm (177 m^3/s) and the maximum allowable discharge of 200 m^3/d, the cooling water discharge ("02") has a minimum dilution of over 7 600:1 after complete mixing. The potential increase for the characteristics in Table 34 would therefore be insignificant and are not expected to impact the ambient water quality of the Fraser River. Due to the high concentrations of metals found in the sediments near Tree Island Industries, it is possible that the groundwater may be leaching contaminates from the lagoons.

The metal concentrations were generally higher in the channel than in the main stem (IRC Integrated Resource Consultants, 1993) and therefore it is presumed that the decreased velocity in Blind Channel allows the metals in the groundwater to settle out. Increased treatment may be required for the wastewater discharged to the lagoons.

The additional discharge from "03" was not expected to increase the potential impact of the discharge on the water quality of the Fraser River. According to the permit files, the new steel drums and reduced water content of the stored sludge will help to prevent contamination due to leakage, corrosion or spillage.

4.4.9 Terminal Sawmills Limited (PE 3950)

A sawmill, located on the south shore of Mitchell Island, is operated by Terminal Sawmills Limited and discharges cooling water into the North Arm of the Fraser River through a submerged outfall. The uncontaminated cooling water is from a bank of air compressors used in the operations. The discharge had included treated sanitary effluent until connection to a municipal sewerage system was completed in 1994. The site has been previously described by Swain (1980) and Swain and Holms (1985b).

Waste Management Permit PE 3950 files show that a permit amendment to increase the authorized discharge of cooling water from 2.75 m^3/d to 210 m^3/d is pending. Currently the permit allows a $BOD_5 \leq 45$ mg/L and total suspended solids ≤ 60 mg/L. These characteristic restrictions were required for the discharge of sewage and will probably be discontinued in the amendment and replaced with a maximum temperature requirement of 35 ^{o}C. Monthly monitoring of the cooling water discharge rate and temperature will also be required.

The files also indicate that the permit was out-of-compliance on a number of occasions since the permit was originally issued in 1975. Three spill incidents are on record, for December 2, 1992, April 14, 1993 and January 24, 1994. A ticket was issued for the April, 1993 spill in which 0.34 m^3 of hydraulic fluid spilled into the Fraser River. The January, 1994 spill consisted of 7.28 m^3 of hydraulic oil.

Using an estimated minimum low flow rate of 50% of the North Arm flow (177 m^3/s) to estimate the South Branch flow rate, the proposed discharge rate would have a dilution ratio greater than 36 000:1 after complete mixing. The proposed increase in cooling water discharge would not have an impact on the ambient water quality of the Fraser River at this high dilution.

4.4.10 ABC Recycling (PE 4246)

A. B. C. Recycling Limited discharges effluent to infiltration pits from a metal recycling operation located in Burnaby, approximately 600 m from the north shore of the North Arm and about 3 km downstream from the Main Stem trifurcation. The site has been previously described by Swain and Holms (1985b). The discharges include the blowdown of re-circulated water ("01") from a venturi scrubber and washwater / stormwater ("02") from a pad used for pressure washing and vehicle fueling and maintenance. An open ditch flows to the Fraser River along the east side of the property and is approximately 40 m from the limestone infiltration pit. The original pit, which is no longer used, is about 100 m from the ditch.

The venturi scrubber was installed during upgrading in 1989-91, to treat the air emissions from a scrap wire incinerator. The blowdown water ("01") is also used to cool and wash copper residue after incineration, and then both solutions are re-circulated after treatment in a series of three holding/settling tanks with pH adjustments. The pH adjustment, to a range of 9.5-12, is achieved through the addition of sodium hydroxide and waste potassium hydroxide contaminated with barium. The high pH level is required to provide efficient scrubbing of the acid gases and promote precipitation of heavy metals in the settling tanks. Effluent not reused after treatment in the third tank is discharged to a fourth settling/flow measuring tank (also installed during the upgrading) before discharge to the limestone infiltration pit.

The permitted works for the discharge from the asphalt pad include a sedimentation basin, an oil/water separator, and an infiltration rock pit below the pad. The stormwater runoff and the pressure washwater are anticipated to be contaminated with sediments, diesel fuel, motor oil and detergents. The company plans to asphalt the entire site and install Stormcepts (combined oil/water separator/sediment removal basins) to treat stormwater.

Waste Management Permit PE 4246 allows a maximum effluent discharge rate of 0.22 m^3/d with oil and grease ≤ 10 mg/L for "02". The maximum discharge rate for "01" is 2.3 m^3/d with the following characteristics: dissolved aluminum ≤ 0.5 mg/L, dissolved barium ≤ 1.0 mg/L, dissolved cadmium ≤ 0.1 mg/L, dissolved chromium (hexavalent and trivalent) ≤ 0.6 mg/L, dissolved copper ≤ 1.0 mg/L, dissolved iron ≤ 1.0 mg/L, dissolved lead ≤ 0.5 mg/L, dissolved nickel ≤ 2.0 mg/L, dissolved zinc ≤ 1.0 mg/L, oil and grease ≤ 15.0 mg/L, and pH range 9.5 - 12.0.

Monitoring is required for discharge "01" monthly and is to include dissolved metals, total suspended solids, oil and grease, and pH. Annual monitoring for oil and grease is required for discharge "02". The open ditch is to be monitored quarterly for dissolved metals and pH upstream and downstream from the site. Monitoring data from the ditch samples indicate that there has been no contamination from the infiltration pits. Since the upgrading, monitoring results for "01" have only been received once. Oil and grease and dissolved metals were within permit restrictions but the pH of 8.7 fell below the acceptable range of 9.5 to 12.

Due to the very small amount of effluent discharged, and the fact that no contamination has been evident in the ditch, it is unlikely that there will be any impact on the water quality of the Fraser River.

4.4.11 Doman Forest Products Limited (PE 4960)

Doman Forest Products Limited operates the Silvertree Sawmill Division located north from Mitchell Island on the bank of the North Arm of the Fraser River. The operation was previously owned by Whonnock Industries Limited and has been previously described by Swain (1980) under Rayonier Canada Limited.

The mill discharges effluent from a sawdust recovery system ("01") and compressor cooling water ("02") from the sawmill. The sawdust recovery system includes a containment boom and a double-screen filter unit where the sawdust is filtered from the water by gravity and then removed by conveyor for disposal. The filtered water is piped back to the river.

Waste Management Permit PE 4960 allows the effluent from the sawdust recovery system to be discharged at a maximum rate of 140 m^3/d with total suspended solids ≤ 60 mg/L above the background level. Discharge of the cooling water is allowed at a maximum rate of 80 m^3/d with the temperature ≤ 35 ^oC.

Silvertree Sawmill currently mills only green cedar and although anti-sapstain spray booths were installed in 1989, they are not used and therefore presently do not pose a risk for contamination. Monitoring is not required for the discharges and current data were not available. The minimum dilution of 60 079:1 after complete mixing for "01" indicates that with total suspended solids less than 60 mg/L above background levels, the potential increase of less than 0.001 mg/L would not be considered a significant impact on the Fraser River ambient water quality. If the anti-sapstain facilities are used then there may be a need for site monitoring depending on the degree that treated lumber is covered.

4.4.12 MacMillan Bloedel Limited(PE 5417)

MacMillan Bloedel Limited discharges effluent to the North Arm of the Fraser River from their Specialty Board Division located on the north bank, approximately three km upstream from Mitchell Island. The effluent is from uncontaminated compressor cooling water, drinking fountain overflow and roof standpipe bleeder lines from the mill. The site has been previously described by Swain and Holms (1985b) and since that report the plant converted from a steam-heated press to a gas-fired rolling press, eliminating steam condensate from the discharge. The effluent flows through a company-owned drainage ditch into the North Arm.

Waste Management Permit PE 5417 allows the effluent to be discharged at a maximum rate of 136 m^3/d with a maximum temperature of 35 °C. The permittee is no longer required to monitor effluent and therefore current data are unavailable. Due to the high dilution after complete mixing in the North Arm (>112 000:1) and the nature of the wastewater, the ambient water quality in the Fraser River would not be affected by this discharge.

4.4.13 Construction Aggregates (PE 5833)

Construction Aggregates operates a distribution depot for sand and aggregates located in Richmond at Duck Island, near the bifurcation of the North Arm. The operation discharges effluent from a sand and aggregate truck wash facility to an infiltration pond. The site has been previously described by Swain and Holms (1985b) with no permit amendments since that report.

Monitoring is not required and therefore data are not available for the operation. The permitted quantity ($\leq$ 32 m^3/d) and quality of the effluent discharged from this site to the ground would not have an impact on the ambient water quality in the Fraser River.

4.4.14 Iona STP - Greater Vancouver Sewerage and Drainage District, (PR 5904)

The Iona Island Sewage Treatment Plant, operated by the Greater Vancouver Sewerage and Drainage District, discharges oily sludge (PR 5904) from local oil refineries to biodegradation beds. The plant also discharges settled grit (PE 23) from the sewage treatment process at Iona Island STP and Lulu Island STP to a landfill. The operation has been previously described in a number of reports including Cain and Swain (1980), Swain and Holms (1985b), and Bertold (1992).

The plant is located on Iona Island with the discharge sites at the northeast corner of the property. The biodegradation beds are less than 100 m from the North Arm and the grit landfill (beside the beds) is another 100 m back. McDonald Slough is approximately 250 m to the south. There are four groundwater monitoring wells surrounding the biodegradation beds but not the grit landfill.

Waste Management Permit PR 5904 allows a maximum yearly discharge of 610 m^3 of oily sludges from the cleaning of hydrocarbon storage tanks and oil separators. The sludge is to be applied onto the biodegradation beds in layers to facilitate drying before incorporating it into the soil. Leachate and surface runoff from the beds must be collected and treated in the sewage treatment plant. The discharge of settled grit is authorized by Waste Management Permit PE 23 to a maximum discharge rate of 300 m^3/m. and is to be covered once per week. There are no characteristic restrictions for either site.

Permit files, amended in August 1990, indicate that there had not been a discharge of oily sludge to the biodegradation bed since December 1989 and therefore monitoring of the site was not required until discharge resumed. When monitoring is required, grab samples from each of the four wells are to be taken once every three months. These samples are to be analyzed for oil and grease, total organic carbon, ammonia nitrogen, and dissolved metals (lead, zinc, copper, vanadium, nickel, and chromium). Monitoring of the grit landfill is not required.

Data from the oily sludge biodegradation beds and the monitoring wells are included in Tables 35 and 36.

The permit files do not indicate if the fill sites are lined. If not, the proximity of the biodegradation beds and grit landfill to the North Arm could result in contamination of the river and leachate problem to the North Arm.

4.4.15 Ocean Spray of Canada Limited (PE 6190)

A berry processing plant operated by Ocean Spray of Canada Limited discharges wash water to the North Arm of the Fraser River through municipal ditches and Bath Slough. The plant is located at Richmond, approximately three km south of the North Arm. The works authorized include screens, pumps, a pH neutralizing system, and a discharge line.

Waste Management Permit PE 6190 allows the discharge of wash water from the plant at a maximum rate of 750 m^3/d. The effluent must have a pH range of 6.5-8.5, $BOD_5 \leq 0.6$ g/kg of product, and total suspended solids ≤ 0.5 g/kg of product. During the processing season, monitoring of the effluent is required once each week for pH, once each month for BOD_5 and total suspended solids and once each processing season for toxicity

There were no current data available on SEAM. Due to the nature and treatment of the effluent before discharge to the ditch, it is not expected to have a significant impact on the ambient water quality in the Fraser River.

4.4.16 Rebar Redi Mix Limited (PE 6524)

Rebar Redi Mix Limited operates a concrete batch plant located on the north shore of Mitchell Island. The operation discharges washdown water from a concrete mixer truck to an exfiltration pond situated more than five m from the North Arm. The site has been previously described by Swain and Holms (1985b) with no permit changes since that report.

Discharge monitoring is not required and therefore no data were available for the site. The maximum effluent discharge rate of only 5 m^3/d (six days per week), would be diluted significantly (> 1 000 000:1) if it reached the river. As well, the nature of the discharge will ensure that the ambient water quality in the Fraser River will not be affected.

4.4.17 Chevron Canada Limited (PE 7321)

Chevron Canada Limited discharges effluent from a petroleum bulk storage plant located at Sea Island on the Fraser River. The effluent includes storm water run-off from the plant where gas, diesel and stove oil are stored in tanks on a concrete foundation with concrete walls for spill protection. Storm water contaminated with oil or petroleum products are collected from inside and outside the walled area and discharged to a baffled sump equipped with an oil skimmer. The treated effluent is then discharged to the North Arm of the Fraser River through a steel pipe, approximately 0.2 m above the high water mark. Wood Island Slough is approximately 2 km downstream from the discharge site.

Waste Management Permit PE 7321 allows the effluent to be discharged at an annual average rate of 7 m^3/d (maximum 60 m^3/d) with oil and grease ≤ 5 mg/L, total suspended solids ≤ 20 mg/L, and non-toxic (96 hour LC50 ≥ 100%). Monitoring for oil and grease and total suspended solids are required every three months and for toxicity, every six months.

The permit files indicate a concern from Fish and Wildlife for the level of surfactants requested in the application which may degrade the habitat of the slough located downstream from the discharge site. The surfactants were the result of truck washing and the situation has been rectified by not permitting the washing of trucks and other vehicles on the site. Data were not available from SEAM. With a minimum dilution of over 250 000:1 after complete mixing, it is unlikely that the relatively small amount of discharge from this operation would not have an impact on the ambient water quality in the Fraser River.

4.4.18 Moore-Clarke Co. (Canada) Limited (PE 7963)

A fish feed processing plant, located north from Mitchell Island on the bank of the North Arm of the Fraser River, is operated by the Moore-Clark Company (Canada) Limited. This plant began production in 1988. The water, taken from the Fraser River, is used to cool processing gas in a venturi scrubber before pollution control treatment for odour reduction. The cooling water is then discharged into the North Arm through a submerged diffuser extending approximately five m from the river bank and about 1.5 m below the low tide line. The air in the scrubber is first passed through a cyclone to remove particulates before cooling.

Waste Management Permit PE 7963 allows the cooling water to be discharged at a maximum rate of 1 360 m^3/d and at a temperature less than 32 ^oC. The monitoring program requires that the effluent discharge temperature be monitored and recorded continuously and the flow recorded once per month.

Permit files indicate a concern for suspended solids in the effluent. With the cyclone treatment of the air before cooling, the potential contribution of suspended solids to the effluent is less than 1 ppm which is considered insignificant. The use of a submerged diffuser should facilitate rapid mixing of the effluent to reduce the temperature to background levels within the initial dilution zone. Based on the maximum allowable discharge rate and the estimated low flow of the North Arm (15% of 1 178 m^3/d), the minimum dilution of 2 811:1 at the edge of the initial dilution zone should ensure that the ambient water quality of the Fraser River is not affected by this discharge.

4.4.19 Canadian Forest Products Limited (AE 12039)

The Eburne Sawmills Division, operated by Canadian Forest Products Limited, is located on the south bank of the North Arm, just downstream from the bifurcation at Sea Island. The operation has been previously described by Swain (1980) and Swain and Holms (1985b). Authorization to discharge effluent expired November 19, 1994. The company has discontinued discharging condensate ("01") and cooling water ("02") from a lumber drying kiln to the North Arm of the Fraser River. An application for a new permit has been submitted to the Ministry.

Canadian Forest Products Limited are working in cooperation with the Council of Forest Industries to develop an improved method of kiln drying lumber using high levels of radio energy and partial vacuum. The system collects moisture drawn off the wood during kiln drying instead of discharging it to the air. The cooling water is used for the radio frequency equipment. Monitoring data from the discharges will be used to help determine the effectiveness of the system and the possibility of a permanent installment.

Waste Management Permit Application AE 12039 will require the company to treat the condensate with charcoal filtering before dilution with the cooling water to meet Pollution Control Objectives for the B. C. Forest Industry. The condensate at "01" is to be discharged (prior to mixing with the cooling water) at a maximum rate of 5 m^3/d with total suspended solids ≤ 60 mg/L, BOD_5 ≤ 50 mg/L, temperature ≤ 35 °C, phenols ≤ 0.2 mg/L, a pH of 6.5 to 8.5 and be non-toxic (96hr LC50). The cooling water at "02" is to be discharged at a maximum rate of 500 m^3/d, with a temperature ≤ 35 °C, before combining with the condensate. Grab sample monitoring at "01" (before filtration) for each species of wood treated and at the combined discharge once each month will also be required.

4.5 Fraser River Main Arm from the New Westminster Trifurcation to the Banks

4.5.1 Lafarge Canada Incorporated (PE 42)

This cement plant is located on the north shore of the Main Arm of the Fraser River, just downstream from the south-west tip of Annacis Island. It has been described in the past by Swain (1980) and Swain and Holms (1985b), and most recently in the FREMP/FRAP report (FREMP, 1994a). Effluent comes from three separate sources; process cooling water ("01"), process cooling water combined with stormwater ("02"), and cement truck wash water ("03"). The cooling water ("01") flows untreated into a ditch and then into the Fraser River, while the combined cooling water/storm water ("02") flows untreated directly into the Fraser River. The cement truck wash water ("03") flows through two settling ponds and to an exfiltration field approximately 425 m north from the river bank.

Permit PE 42 allows a maximum discharge of 2 950 m^3/d of non-contact cooling water ("01") and 3 410 m^3/d of combined non-contact cooling water and stormwater ("02"), at a maximum temperature of 32^oC (FREMP, 1994a). Oil and grease are not to exceed 2 mg/L above the concentration in the Fraser River or 10 mg/L, whichever is less (FREMP, 1994a). A maximum discharge of 11 m^3/d is allowed for discharge "03", the cement truck wash water. There are no domestic water license holders downstream. Monthly monitoring for temperature, oil and grease, and total suspended solids are required for discharges "01" and "02". No monitoring is required for the cement truck wash water.

Flow dilution calculations using an estimated low flow of 1 000 m^3/s for the Fraser River in the Main Arm (85% of flow volume at Port Mann quoted in Chapter Two) and the combined flows of discharges "01" and "02" (6 360 m^3/d) show a minimum effluent dilution, with complete mixing, of 13 600:1. The estimated minimum effluent dilution at the edge of the initial dilution zone is 3 400:1.

The monthly monitoring data available from the permit files for discharges "01" and "02" are for January, 1993 through December, 1994, and are summarized in Table 37. The maximum temperature values for both discharges (21 ^oC and 29 ^oC) are well within permit limits of 32 ^oC. The oil & grease mean concentrations are well below 10 mg/L, but the maximum for discharge "01" is 23 mg/L. The oil and grease concentrations are never more than 2 mg/L above the oil & grease concentrations at the Fraser River intake.

The maximum suspended solids concentrations were quite high for both discharges (236 mg/L discharge "01", 358.5 mg/L discharge "02"), but would reach levels after dilution that are well below concern (0.017 mg/L and 0.026 mg/L respectively). Finally, discharge "01" exceeded flow rate limits in November and December, 1993 (maximum flow rate 3 715 m^3/d). The cause was found to be excessive water being pumped from the river for process use, while the unused portion was being returned to the river by the discharge outfall. All of the other flow rates were within the permit limits.

Sediment samples collected by FREMP in 1993 showed toxicity to luminescent bacteria using the solid phase Microtox test. The reason for the toxicity could not be determined through sediment chemistry tests. (FREMP, 1994d).

Swain (1980) noted that the effluent sometimes had elevated suspended solids and pH. The plant also discharges measurable loadings of mercury, iron, lead, zinc, and copper (FREMP, 1994d). A more in-depth and current characterization of this effluent discharge is required to evaluate its impacts on the Fraser River.

4.5.2 Titan Steel & Wire Co. Limited (PE 161) and B.C. Clean Wood Preservers (no permit required)

Titan Steel & Wire Co. Limited is located approximately 250 m from the southeast bank of the Main Arm of the Fraser River (Annieville Channel), just upstream from the northern tip of Gundersen Slough. It is a metal finishing plant which draws rod into wire so that it may be further processed into nails and a variety of wire products. The plant's operations include rod cleaning, wire draw, wire stranding, galvanizing, and patenting. Spent hydrochloric acid from the galvanizing and patenting lines is neutralized with caustic and, after precipitate settling, is discharged to the sanitary sewer. Adjacent to the northern end of Titan Steel lies the B.C. Clean Wood Preserving plant. B.C. Clean Wood uses chromated copper arsenate as a wood preservative substance. Because there is not a point-source discharge from B.C. Clean wood there is no discharge permit. Both

Titan Steel and B.C. Clean Wood have been described in detail in the past in a FREMP report (Swain and Walton, 1992).

There is no discharge referred to currently in the permit files for Titan Steel as discharge "01". Cooling water and stormwater runoff are discharged into a ditch draining to Gundersen Slough of the Fraser River (discharge "02"). The ditch incorporates a large oil separator to trap any discharged oil and draw soap scum, preventing it from being discharged into Gundersen Slough. The ditch merges with a second ditch that carries stormwater runoff from the nearby B.C. Clean Wood Preservers operation. Gundersen Slough is also subject to effects from boat moorage and stormwater runoff from the nearby River Road, the adjacent Acorn sawmill near its west end, and the Fraser-Surrey dock at its east end.

The semi-liquid waste sludge (discharge "03") that results from the neutralization process is currently discharged into a lagoon located on the northeast border of the plant site. The liquid portion of the sludge exfiltrates into the ground. The plant is installing sludge dewatering equipment and has plans to cease discharging to the lagoon.

Waste Management Permit PE 161 allows a maximum discharge rate of 4 650 m^3/d of cooling water ("02") having a temperature range ≤ 26 °C, dissolved zinc concentrations ≤ 0.15 mg/L, and a 96h-LC20 toxicity of 100%. The maximum permitted clarifier sludge discharge ("03") rate is 55 m^3/d.

The cooling water ditch is to be monitored monthly for temperature and dissolved zinc, and semi-annually for toxicity. A sampling port closest to the bottom of the clarifier is to be monitored weekly for pH and semi-annually for many dissolved metals including aluminum, copper and zinc. There were no sludge monitoring data available from SEAM for the period of 1985 through 1994.

Toxicity monitoring results from the permit files for May, 1993, January, 1994 and June, 1994 show that a 96h LC20 >100% was achieved all three times. The reports indicate that there were no rainbow trout mortalities in two of the three tests, and less than 50% mortality in the third.

A summary of the cooling water monitoring data available in the permit files for the period of January, 1993 through September, 1994 is given in Table 38. Although the effluent reached the maximum permitted temperature (26 °C), the average (20 °C) was well below the limit. As well, the maximum flow rate (1 800 m^3/d) was far below the permitted limit of 4 650 m^3/d.

All of the maximum values for metals were well within ambient water quality criteria for aquatic life, except iron and zinc (Nagpal *et al*, 1995). The ambient, aquatic life, water quality criterion for iron is 0.3 mg/L, and for zinc is tentatively 0.03 mg/L (Nagpal *et al*, 1995). Some dilution in Gundersen Slough, however inconsistent, must be taken into account. The mean value for iron (0.3 mg/L) falls within the criterion, and the maximum value (1.6 mg/L) would only require a minimum dilution of 5:1 to meet criterion.

The mean value for zinc (0.04 mg/L) is only slightly high, and the maximum value (0.3 mg/L) would only require a minimum dilution rate of 10:1 to meet ambient criterion. The maximum value given in the permit files (0.15 mg/L) is for dissolved zinc, and is therefore smaller than what the requirement for total zinc would be. However, the maximum value given for total zinc would only require a dilution rate of 2:1 to meet the permitted limit for dissolved zinc.

Monitoring data found in Swain and Walton (1992) represent testing of samples collected September 24, 26 and October 1, 1991. They show that average ammonia concentrations in the ditch water adjacent to B.C. Clean Wood were quite high (0.617 mg/L) in comparison to those in the ditch water from Titan Steel (0.045 mg/L), while nitrate concentrations were higher at Titan Steel (0.086 mg/L) than beside B.C. Clean Wood (<0.005 mg/L). Ortho phosphorus concentrations were similar in each discharge, although the dissolved phosphorus concentration was about three times higher at B.C. Clean Wood.

The highest metal concentrations were in ditch water from the B.C. Clean Wood operation. Concentrations of total and dissolved arsenic, total barium, total and dissolved boron, total and dissolved chromium, total copper, total iron, and total zinc were considerably higher than in the ditch water from Titan Steel. The high copper (0.042 mg/L), arsenic (0.527 mg/L), and chromium (0.084 mg/L) concentrations are not surprising considering that chromated copper arsenate is used as the wood preservative (Swain and Walton, 1992).

Swain and Walton (1992) also discuss monitoring of Rainbow trout, which were caged for a period of eight days in the ditch from Titan Steel, and had no mortalities during that time period. Chemical analyses of these fish showed considerably higher concentrations of PAHs in the muscle of the fish exposed to the effluent than in the control fish which were kept in Vancouver City tap water. These higher mean concentrations were found for acenaphthene, anthracene, fluoranthene, naphthalene, and phenanthrene. These PAHs may have been introduced in road runoff; however, there are no PAH data for the effluents to confirm this. Thus, fish exposed to PAHs from road runoff may begin to accumulate high concentrations of some PAHs. Metal concentrations measured in livers from the exposed fish were lower than in livers from the control fish. Thus, the Titan effluent is not a concern as a source of metals to fish.

In terms of the sources of metals to the slough, sediments from the ditch from B.C. Clean Wood had the highest concentrations of arsenic (1540 µg/g), chromium (2280 µ/g), and copper (3590 µg/g). These metals were also at high concentrations in the ditch water from B.C. Clean Wood. Sediments from the ditch from Titan Steel and Wire had the highest concentrations of cadmium (1.33 µg/g), lead (378 µg/g), molybdenum (14.3 µg/g), and zinc (4 440 µg/g) (Swain and Walton, 1992).

Resin acids could not be detected in sediments from the ditches leading to Gundersen Slough. The highest chlorophenol concentrations near Titan Steel usually were measured in the ditch leading from B.C. Clean Wood. The data for the other sites tend to indicate that there is possibly a second source for these organics. 3,4,5-trichloroguaiacol and tetrachloroguaiacol concentrations are measurable at the remaining sites. Pentachlorophenol concentrations in the sediments at the site about 100 metres southwest from the entry point of the ditch were about twice those measured at the site at the entry point of the ditch (Swain and Walton, 1992).

The results for all the salt water extraction sediment bioassay test procedures using microtox bioluminescence and Daphnia magna showed all the extracts to be non-toxic. The sand dollar test indicated that the greatest toxicity was associated with the sediments from the ditch from B.C. Clean Wood. The toxicity decreased along Gundersen Slough, so that by the site midway along the length of the slough, the sediments were not toxic. A similar result was found for the bioluminescence test conducted on the pore water, although the non-toxic sediments were found in Gundersen Slough itself at all the sites. The solid-phase microtox indicated that all the sediments had greater toxicity than the control sediments from Roberts Bank. The most toxic sediments appear to be in the ditch conveying stormwater drainage from B.C. Clean Wood to Gundersen Slough (Swain and Walton, 1992).

Although there were no sludge monitoring data available, the permit files indicate that monitoring wells show that the lagoons are leaching contaminants such as metals into the ground. From the limited data obtained from Swain and Walton (1991) (n=3 or 4, over one day), it can be concluded that the greatest negative impact on Gundersen Slough is from B.C. Clean Wood. Continued monitoring is recommended on a regular basis for both the ditch and lagoon discharges of Titan Steel and the non-point source discharges from B.C. Clean Wood.

4.5.3 Lulu Island STP (PE 233)

The Lulu Island Sewage Treatment Plant (STP) discharges effluent into the Fraser River from the north shore of the Main Arm, just upstream from Steveston Island. It is operated by the Greater Vancouver Regional District (GVRD) through the Greater Vancouver Sewerage and Drainage District (GVS & DD). The plant provides primary treatment to domestic sewage carried to the plant from the west end of the municipality of Richmond.

The plant has been described in the past by Swain and Holms (1985b), Cain and Swain (1980), the FREMP/FRAP report (FREMP, 1994c) and in great detail in the Greater Vancouver Liquid Waste Management Plan (GVRD, 1988a). The primary treatment works include prechlorination and comminution facilities, two parallel pre-aeration tanks and two parallel sedimentation tanks (Cain and Swain, 1980 and GVRD, 1988a). The effluent is disinfected using chlorine and then dechlorinated using sulfur dioxide, from May 1 through September 30. Treated effluent is discharged via a single, submerged diffuser pipe which extends approximately 180 m into the Main Arm. Grit from the pre-aeration tanks is dewatered and disposed of at the Iona STP. Sludge from the sedimentation tanks is incinerated, and the combustion particulates are discharged to a below-grade, on-site pit (GVRD, 1988a).

The Waste Management Permit was amended in May 1995, however terms and conditions of an Operational Certificate are currently being negotiated (Lai, 1995). The current maximum discharge rate is 132 500 m^3/d, with a maximum BOD5 ≤ 169 mg/L and a maximum total suspended solids ≤ 128 mg/L. When the proposed upgrading is completed, the proposed effluent quality is to be non-toxic, with a BOD5 ≤ 30 mg/L and total suspended solids ≤ 40 mg/L. Although, it is a federal requirement that the effluent be non-toxic, achievement is uncertain. The flow is anticipated to be much greater, with volume estimates around 160 000 m^3/d (Lai, 1995).

The following table outlines the dilution ratios and concentration potential for four characteristics of the Lulu Island STP at current discharge rates. The calculations are based on effluent monitoring data available from the GVRD for January 1991 through December 1994 and Fraser River flow rate data from Chapter Two (with Main Arm flow rate calculated as 85% of the Main Stem flow rate). A summary of all the monitoring data for this period is given in Table 39 and a summary of the loadings for the same years is given in Table 40.

		Fraser River Flow Rate 1 000 m^3/s	
Characteristic	**Maximum Discharge**	**Minimum Dilution Complete Mixing**	**Minimum Dilution Edge of IDZ**
Flow (m^3/d)	132 500	652:1	163:1
		Potential Increase Complete Mix	Potential Increase Edge of IDZ
BOD5-(mg/L)	195	0.3	1.2
Coliform: fecal (#/100 mL)	160 000 000	245 399	981 595
Susp Solids (mg/L)	128	0.20	0.79

Where monitoring data were unavailable, permitted maximum discharges were used.

The maximum BOD concentration (195 mg/L) is higher than the current permitted maximum concentration (169 mg/L), however, the mean BOD concentration (143 mg/L) is below this limit. As well, the dilution rates both with complete mixing and at the edge of the IDZ lower the maximum concentration to levels that are well below a detection limit of 2 mg/L (0.3 mg/L and 1.2 mg/L respectively).

The maximum value for fecal coliforms is very high (160 000 000 MPN/100 mL) and, if consistent, would be a cause for concern, even after dilution (>245 000 MPN/100 mL with complete mixing and >981 000 MPN/100 mL at the edge of the IDZ). However, this value was obtained only twice during the 1991 to 1994 monitoring period, and therefore the median concentration of 2 700 000 MPN/100 mL is likely a more accurate value to use for dilution calculations.

Using the median concentration, the potential increase is 4 141 MPN/100 mL after complete mixing, and 16 564 MPN/100 mL at the edge of the initial dilution zone. These concentrations still cause concern for aquatic life (≤ 43 /100 mL), recreational activities (primary-contact criterion ≤ 200 /100 mL) or general irrigation (≤1000 /100 mL) (Nagpal *et al*, 1995). Actions should be taken to increase treatment and reduce the concentrations of fecal coliforms in this discharge.

The maximum concentration of total suspended solids (128 mg/L) just meets the present criterion (128 mg/L). The dilution table shows that its potential increases both with complete mixing (0.2 mg/L) and at the edge of the initial dilution zone (0.79 mg/L) are below levels of concern.

The GVRD has been ordered by the Ministry of Environment, Lands, and Parks to install secondary treatment at the Lulu Island STP by the end of 1995. However, major construction has not yet started. The treatment will consist of a trickling filter solids contactor (TF-SC).

According to the GVRD Stage 1 Liquid Waste Management Plan of May 1988, this degree of treatment is capable of reducing most toxicity-producing components including toxic organic compounds and heavy metals (except ammonia) to a higher degree than primary treatment. Secondary treatment removes about 40 to 60 percent of most heavy metals, however this would have little effect on the water quality due to the magnitude of the existing background values in the receiving water (GVRD, 1988a).

There were no heavy metal monitoring data available from SEAM or from the GVRD. Continued monitoring of heavy metals, BOD, suspended solids and other parameters will be necessary to ensure the effluent quality meets the current criteria and guidelines as well as the new secondary treatment standards.

4.5.4 Annacis Island STP (PE 387)

The Annacis Island STP is located on the south shore of Annacis Island, near the trifurcation of the Fraser River. It is operated by the GVRD, and provides primary treatment to domestic sewage and industrial effluents carried to the plant from the Fraser Sewerage Area. This sewerage area encompasses all or parts of Burnaby, Coquitlam, Delta, Langley, Richmond, Maple ridge, New Westminster, Pitt Meadows, Port

Coquitlam, Port Moody, Surrey, White Rock and a small portion of Vancouver (Cain and Swain, 1980).

The plant has been described in the past by Swain and Holms (1985b), Cain and Swain (1980), Swain and Walton (1993), the FREMP/FRAP report (FREMP, 1994c) and in great detail in the Greater Vancouver Liquid Waste Management Plan (GVRD, 1988a). The primary treatment works include mechanical screening with four bar screens and four raw sewage pumps, and thirteen pre-aeration tanks. The effluent is disinfected using chlorine and then dechlorinated using sulfur dioxide, from May 1 through September 30 (GVRD, 1988a).

The treated effluent is discharged into Annieville Channel of the Main Arm of the Fraser River, through three submerged diffuser pipes that extend a quarter of the 600 m river width (FREMP, 1994c). Raw sludge from the sedimentation tanks is thickened and discharged to the four on-site sludge lagoons. Excess gas produced in the digestion process is burned in waste gas burners (GVRD, 1988a).

The Waste Management Permit was amended in May 1995, however terms and conditions of an Operational Certificate are currently being negotiated (Lai, 1995). The current maximum discharge rate is 586 000 m^3/d, with a maximum $BOD_5 \leq 169$ mg/L and a theoretical total suspended solids concentration ≤ 128 mg/L. If the proposed upgrading is implemented, the proposed effluent quality will be non-toxic as required by federal guidelines, with a BOD5 ≤ 30 mg/L and total suspended solids ≤ 40 mg/L. However, achievement of the guidelines is uncertain. The flow is anticipated to be much greater than the current, with volume estimates around 966 000 m^3/d (Lai, 1995).

The following table outlines the dilution ratios and concentration potentials for four characteristics of the Annacis STP at current discharge rates. The calculations are based on effluent monitoring data available from the GVRD for January 1991 through December 1994 and Fraser River flow rate data from Chapter Two (Annieville Channel flow rate calculated as 79% of the Main Stem flow rate). A summary of all the monitoring data for this period is given in Table 41 and a summary of the loadings for the same years is given in Table 42.

		Fraser River Flow Rate 930 m^3/s	
Characteristic	Maximum Discharge	Minimum Dilution Complete Mixing	Minimum Dilution Edge of IDZ
Flow (m^3/d)	586 000	137:1	34:1
		Potential Increase Complete Mixing	Potential Increase Edge of IDZ
BOD- 5 (mg/L)	205	1.5	6.0
Coliform: fecal (#/100 mL)	48 000 000	350 365	1 411 765
Susp Solids (mg/L)	132	1.0	3.9

Where monitoring data were unavailable, permitted maximum discharges were used.

The maximum BOD concentration (205 mg/L) is higher than the present theoretical concentration (169 mg/L), however, the mean BOD concentration (136 mg/L) is below this limit. As well, the dilution rate with complete mixing lowers the maximum concentration of BOD to a level below concern (1.5 mg/L, detection limit of 2.0 mg/L).

The maximum fecal coliform concentration (48 000 000 mg/L) is quite high and results in high potential increases (>350 000 mg/L with complete mixing, >1 444 000 mg/L at the edge of the initial dilution zone). Large inputs and relatively low dilution rate available in the channel (137:1) contribute to the high levels. These concentrations are a cause for concern for aquatic life (criterion ≤ 43 /100 mL) or general irrigation (criterion ≤ 1000 /100 mL) or if the river is to be used for recreational activities (primary-contact criterion ≤ 200 /100 mL) (Nagpal *et al*, 1995). Measures should be taken to reduce the fecal coliform counts of this discharge.

The maximum concentration of suspended solids (132 mg/L) results in moderately high potential increases (1.0 mg/L with complete mixing, 3.9 mg/L at the edge of the IDZ) due mostly to the low dilution rate available in the channel. However these levels represent only a minor concern, as the mean suspended solids concentration (6.9 mg/L) results in very small potential increases (0.05 mg/L with complete mixing, 0.2 mg/L at the edge of the IDZ).

On February 18, 1993, water and sediment in the expected zone of influence from the Annacis Island Sewage Treatment Plant (STP) were sampled. Water column samples were collected at the surface and at a depth of four metres. Significant findings of the work were: (Swain and Walton, 1993b)

An outflowing tide was experienced for the entire sampling time. This would result in samples being taken at a time when there were not stagnant water conditions or flow reversals. Thus, multiple dosing of the river water would be at a minimum (i.e., the discharge scenario to show the least effect on water column variables from the sewage discharge).

The most elevated ammonia concentrations were noted with the depth samples 25 and 100 m downstream from the point of discharge. All the ammonia values were less than the MELP criterion to prevent chronic effects; however, the highest measured concentrations were about one-third of this criterion. Therefore, the criterion may be approached with the multiple-dosing scenario although how close to the criterion is open to speculation.

The MELP water quality criteria for bacteriological indicators were usually not achieved at sites either upstream or downstream from the effluent discharge.

For all bacteriological variables and ammonia, the higher concentrations were associated with depth samples. This shows the importance both of using a technique such as the depth sounder to find the effluent plume, and not relying solely on surface samples to assess the impact of this discharge.

Three PAHs (phenanthrene, anthracene, and chrysene) in sediments from a site 200 m downstream from the outfall exceeded certain MELP water quality objectives. These objectives were established for Burrard Inlet on the basis of Puget Sound Apparent Effects Threshold values, and are used as a rough guideline. The presence of these PAHs may indicate a need for improved effluent treatment at the Annacis Island Sewage Treatment Plant, although other potential sources must be eliminated before action based on these findings is taken.

The solid phase microtox toxicity test showed the greatest toxicity to be associated with the sediments collected 200 m downstream from the effluent discharge. The least toxicity was found to be associated with the sediments from the site 50 m downstream. This pattern of toxicity is similar to the concentration distribution found for most PAHs and two (i.e., chromium and iron) of three metals concentrations discussed.

The GVRD has been ordered by the Ministry of Environment, Lands, and Parks to install secondary treatment at the Annacis STP. The secondary treatment facilities will consist of a trickling filter-solids contactor (TF-SC) system and should be completed in 1998.

According to the GVRD Stage 1 Liquid Waste Management Plan of May 1988, secondary-type treatment is capable of reducing most toxicity-producing components including toxic organic compounds and heavy metals (but excepting ammonia) to a higher degree than primary treatment. Although secondary treatment removes about 40 to 60 percent of most heavy metals, this would have little effect on the water quality due to the magnitude of the existing background values in the receiving water (GVRD, 1988a).

There were no heavy metals monitoring data available from SEAM or from the GVRD. Continued monitoring will be necessary to ensure the effluent quality meets the current criteria and guidelines as well as the new secondary treatment standards.

4.5.5 Fraser Wharves (PE 1621)

Fraser Wharves is a vehicle processing facility located on the north shore of the Main Arm of the Fraser River, opposite Deas Island. The operation has been described in the past by Swain (1980) and by Swain and Holms (1985b), and most recently in two separate FREMP/FRAP reports (FREMP, 1994a and FREMP, 1994d).

Permit PE 1621 allows the discharge of effluent from a vehicle de-waxing and washing operation, through a submerged outfall, to the Fraser River. The maximum permitted discharge rate is 160 m^3/d, but the facility is not currently used (FREMP, 1994a), and therefore effluent is no longer discharged to the Fraser River. However, Fraser Wharves Limited continues to maintain an active discharge permit in the event that the de-waxing operation will be required in the future (FREMP, 1994d).

Sediment samples from the initial dilution zone were acutely toxic to luminescent bacteria. The cause of the toxicity could not be determined through sediment chemistry analysis. (FREMP, 1994d).

4.5.6 B.C. Packers Limited (PE 1830)

B.C. Packers Limited is a fish processing plant located on the north shore of the Main Arm of the Fraser River, near the southeast tip of Steveston Island. It was described in the past by Swain (1980) and by Swain and Holms (1985b), and most recently in great detail in the FREMP/FRAP report (FREMP, 1994b).

The effluent comes from two sources: condenser and boiler blowdown water, and process and cooling water. The effluent is treated by a collection and conveyance system, a surge tank, two screens and a dechlorination system. It is discharged through a submerged open-pipe outfall, which extends into Steveston (Cannery) Channel, approximately five m from shore at a depth of 3 m at low water (FREMP, 1994b).

Waste Management Permit PE 1830 states that the company must eliminate all effluent discharges to Cannery Channel, except uncontaminated cooling water, by December 31, 1996, or within 90 days of the date that the Greater Vancouver Regional District completes upgrading of the municipal sewage treatment plant at Lulu Island, whichever occurs first. To fulfill this requirement, all the effluent except the uncontaminated cooling water, will flow through an extended outfall into the Main Arm of the Fraser River.

Waste Management Permit PE 1830 allows the discharge of an average of 4 500 m^3/d with a maximum of 11 800 m^3/d of processing effluent, having a maximum chlorine residual $\leq$ 0.05 mg/L, and a temperature $\leq 32^oC$. The company is required to monitor monthly, twice a month and quarterly for various characteristics including BOD, total suspended solids and ammonia nitrogen. Monitoring data from SEAM, for the years 1985 through 1994, are summarized in Table 43.

The following table outlines the dilution ratios and concentration potentials for four characteristics of the discharge, both at the average permitted discharge rate (4 500 m^3/d, top half of table) and at the maximum permitted discharge rate (11 800 m^3/d, bottom half of table). The calculations are based on effluent monitoring data from SEAM (Table 43) and Fraser River flow rate data from Chapter Two (Cannery Channel flow rate calculated as 5% of the Main Stem flow rate).

		Cannery Channel Flow Rate 50 m^3/s	
Characteristic	Discharge Volume	Min. Dilution Complete Mix	Min. Dilution Edge of IDZ
Flow (m^3/d)	4 500	960:1	240:1
		Potential Increase Complete Mix	Potential Increase Edge of IDZ
Ammonia (mg/L)	45	0.05	0.19
BOD- 5 (mg/L)	1 500	2	6
Susp- Solids (mg/L)	2 240	2	9
Flow (m^3/d)	11 800	366:1	92:1
		Potential Increase Complete Mix	Potential Increase Edge of IDZ
Ammonia (mg/L)	45	0.1	0.5
BOD- 5 (mg/L)	1 500	4	16
Susp Solids (mg/L)	2 240	6	24

Where actual flow rates were unavailable, permitted maximum discharge rates were used.

The dilution factors for both the average permitted flow rate and the maximum permitted flow rate are not very high (960:1 and 366:1 respectively). The maximum measured concentration of ammonia nitrogen is high (45 mg/L). However, ammonia levels after dilution, 0.1 mg/L with complete mixing, and 0.5 mg/L at the edge of the IDZ, are acceptable.

The BOD concentrations after dilution (2 to 4 mg/L with complete mixing and 6 to 16 mg/L at the edge of the IDZ) are high enough above a detection limit of 2 mg/L (American Public Health Assn., 1992) to cause a concern for aquatic life. Freshwater dissolved oxygen criteria for salmon (other than embryo and larval stages) in order to result in no production impairment is given as ≥ 8 mg/L (Nagpal *et al*, 1995), and therefore high levels of BOD can represent a significant threat to fish and other aquatic life.

The concentration levels after dilution for total suspended solids (2 mg/L with complete mixing and 9 mg/L at the edge of the IDZ) are too low to cause a concern at the average discharge flow rate. However, the concentration levels after dilution at the maximum discharge flow rate (6 mg/L with complete mixing and 24 mg/L at the edge of the IDZ) do raise a concern for aquatic life (criterion of ≤ 10 mg/L) (Nagpal *et al*, 1995).

According to the permit files, when all but cooling water discharges are eliminated from Cannery Channel and redirected to the Main Arm, the maximum permitted rate of discharge (except cooling water) will be raised to 6 600 m^3/d. If the Main Arm flow rate is taken to be 75% of its total at this point of discharge (off the south side of Steveston Island), then the dilution rate available for maximum discharge would be > 9 800:1. This would greatly reduce, and possibly eliminate, the current suspended solids concern and any other characteristics whose concentrations are slightly high due to the poor dilution available in Cannery Channel.

A wastewater characterization study of fish processing plant effluents that included B.C. Packers determined that effluent toxicity was demonstrated at all sites tested and that toxicity varied considerably over time (FREMP, 1994b).

Continued monitoring is recommended to determine whether high concentrations of BOD, suspended solids, or other characteristics are a frequent occurrence. It would help determine whether there have been any resulting impacts on the water quality and aquatic life in this reach of the river that could be lessened by the extension of the outfall.

4.5.7 Ocean Fisheries (PE 1975)

Ocean Fisheries is a herring and salmon processing plant located on the north shore of the Main Arm of the Fraser River, opposite Tilbury Island. The facility includes an unloading dock located in a boat basin on the north west side of the processing building, a fish cannery, and two large tanks for preparation and storage of the cooling water used during canning. It was described in the past by Swain (1980) (under the name Cassiar Packing Co. Limited, Richmond Fish Processing Plant), and by Swain and Holms (1985b), and most recently in great detail in the FREMP/FRAP report (FREMP, 1994b).

Discharge "01" is composed primarily of process effluent, with some cooling water and domestic sewage as well. The process effluent is passed through a screen with 0.7 mm openings, prior to discharge. The sewage is treated by a septic tank with an average retention time of 48 hours. The combined flow is then passed through a submerged diffuser, which extends into the river approximately 24 m from shore at a depth of 6 m at low water (FREMP, 1994b). Discharge "02" is domestic sewage from an on-site warehouse, and discharge "03" is domestic sewage from the plant office. Both of these two sewage discharges are treated by septic tanks, with an average retention time of 48 hours and discharged to the river through submerged outfalls.

Permit PE 1975 allows the discharge of an average 960 m^3/d with a maximum of 7 240 m^3/d of processing, cooling water and sewage effluent ("01"), with a chlorine residual ≤ 0.5 mg/L, and temperature ≤ 32^{o}C(FREMP, 1994b). The maximum rate at which effluent "02" may be discharged is 7.5 m^3/d and the maximum rate at which effluent "03" may be discharged is 1.5 m^3/d. The minimum dilution available for the maximum discharge of the process/ cooling/ sewage effluent ("01"), with complete mixing at low river flows (based on a Main Arm flow rate of 1 000 m^3/s), is 11 700:1. The minimum dilutions, with complete mixing, available for the other two sewage discharges ("02" and "03") are $1.2x10^7$: 1 and $5.8x10^7$: 1 respectively.

There were no monitoring data available from SEAM for the period 1985 through 1994. The March, 1994 FREMP/FRAP report (FREMP, 1994b) indicates that flow was within permit limits during 1990, 1991, and 1992. The recorded residual chlorine was approximately 0.1 mg/L. The report had no monitoring data for temperature. A wastewater characterization study of fish processing plant effluents that included B.C. Packers determined that effluent toxicity was demonstrated at all sites tested and that toxicity varied considerably over time (FREMP, 1994b). Due to the nature of the discharges, the treatment provided, and the high dilution rate available, it is anticipated that this operation will not have a significant impact on the water quality of the Fraser River.

4.5.8 Conforce Products (PE 2976)

Conforce Products is a precast concrete manufacturing plant located on the north shore of the Main Arm of the Fraser River, about three km downstream from Annacis Island. The operation has been described in the past by Swain (1980) and by Swain and Holms (1985b).

Discharge "01" consists of process waste water and storm water. These are combined before entering a settling basin, then a process waste water treatment system including both pH neutralization and flocculation systems, and finally an outfall. The outfall flows into the Nelson Road ditch which empties into the Fraser River approximately 200 m downstream. Discharge "02" originates from domestic sewage that enters a septic tank and a secondary sewage treatment plant before entering the Fraser River through a submerged outfall.

Waste Management Permit PE 2976 allows a maximum discharge of 120 m^3/d for effluent "01", with a pH range of 6.5 to 8.5 and total suspended solids concentration ≤ 75 mg/L. The permit allows a maximum discharge of 20 m^3/d for effluent "02" with an annual average discharge of 13.5 m^3/d, having a 5-day BOD concentration ≤ 45 mg/L and a total suspended solids concentration ≤ 60 mg/L. The minimum dilution available for effluent discharge "01", with complete mixing of effluent and Fraser River water, is over 720 000:1. The minimum dilution available for the maximum allowable discharge of effluent "02" is over 4.3×10^6: 1 (using a low river flow rate of 100 m^3/s in the Main Arm).

There were no monitoring data available from SEAM for the period of 1985 through 1994. However, the permit files indicate that discharge "01" has been within permit limits from 1990 through July, 1994. Therefore, due to the low volume of discharge from this operation, the high dilution available in the Fraser River and the level of treatment prior to discharge, it is anticipated that these effluent discharges will not significantly impact the water quality of the Fraser River.

4.5.9 Lions' Gate Fisheries Limited (PE 3139)

Lions' Gate Fisheries Limited is a fish processing plant located on the south shore of the Main Arm of the Fraser River, just upstream from the confluence of Ladner Reach and Sea Reach. It was described in the past by Swain (1980) and by Swain and Holms (1985b), (under the name Long Beach Shellfish Co.), and most recently in great detail in the FREMP/FRAP report (FREMP, 1994b). The effluent being discharged originates from three different sources: discharge "01" is process effluent, discharge "02" is treated sanitary sewage and discharges "03" and "04" are cooling water from an ice bin and a freezing operation.

Waste Management Permit PE 3139 allows an average discharge of 500 m^3/d with a maximum discharge of 800 m^3/d of processing effluent ("01") having a maximum chlorine residual ≤ 0.05 mg/L. The permit allows a maximum discharge of 5 m^3/d of sewage ("02"), having a 5-day BOD ≤ 45 mg/L and total suspended solids concentration

≤ 60 mg/L. The cooling water effluents ("03" and "04") can be discharged at an allowable maximum rate of 20 m^3/d each, with maximum temperatures of 35 °C.

The process effluent is screened prior to discharge through a submerged open-pipe outfall that extends into the river approximately 7 m from shore at a depth of 1 m at low water (FREMP, 1994b). The sewage effluent "02" is treated by a packaged secondary sewage treatment plant, and is discharged into the Fraser River next to discharge "01" through a submerged outfall. The two cooling water discharges flow into the Fraser River just upstream from "01" and "02", through separate discharge pipes.

The following table outlines the dilution ratios and concentration potentials for four characteristics of the operation. Calculations are based on effluent data from Table 44 and a Fraser River low flow rate of 100 m^3/s (1/10th of Main Arm flow rate, which is approximately 85% of the Main Stem flow rate quoted in Chapter Two).

		Fraser River Flow Rate 100 m^3/s	
Characteristic	Maximum Discharge	Minimum Dilution Complete Mixing	Minimum Dilution Edge of IDZ
Flow (m3/d)	800	10 810:1	2 702:1
		Potential Increase Complete Mixing	Potential Increase Edge of IDZ
Ammonia (mg/L)	59	0.005	0.022
BOD, 5-day (mg/L)	1 500	0.14	0.56
Suspended Solids (mg/L)	917	0.08	0.34

Where monitoring data were unavailable, permitted maximum discharges were used.

Monitoring of the process effluent ("01") is required quarterly for total suspended solids, BOD, oil & grease, and residual chlorine. Monitoring of the sewage effluent ("02") is required quarterly for total suspended solids and BOD. The limited data (n=3) that these values are based on were derived in 1985 and 1986. They indicate a high dilution rate (10 810:1), even with the lower flow rate available in the Ladner Reach area (100 m^3/s). This is due mostly to the low volume of discharge (800 m^3/d).

More recent monitoring data given in the FREMP/FRAP report (FREMP, 1994b) indicate that the permitted flow rate (500 m^3/d average and 800 m^3/d maximum) was not exceeded during 1990, 1991 or 1992. The BOD ranged from 42 mg/L to 67 mg/L during this period, and total suspended solids concentrations ranged from 514 mg/L to 1 365 mg/L. Although there were no limits given in the permits, the highest of these BOD and total suspended solids values would be diluted to concentrations in the river of 0.006 mg/L and 0.12 mg/L respectively, well below levels of concern for aquatic life (Nagpal *et al*, 1995). A wastewater characterization study of fish processing plant effluents that included Lions' Gate determined that effluent toxicity was demonstrated at all sites tested and that toxicity varied considerably over time (FREMP, 1994b).

Therefore, due to the low volume and the high dilution rate available, it is not anticipated that this discharge will have a significant impact on the water quality of Ladner Reach of the Fraser River. However, more thorough and consistent monitoring would give a more comprehensive indication of the potential and actual effects that the discharge might be having.

4.5.10 Crown Forest Industries Limited (PE 3265)

Crown Forest Industries Limited discharges effluent from a paper products plant located on the north bank of the Main Arm of the Fraser River, across from the southwest tip of Rose Island, in Richmond. The company manufactures boxes, bags and wrapping paper. The effluent originates from a vacuum pump seal cooling system and is directed through a roof drain line to Woodward's Slough of the Fraser River. The operation has been described in the past by Swain (1980) and by Swain and Holms (1985b).

Waste Management Permit PE 3265 allows effluent to be discharged at a maximum rate of 91 m^3/d, with a maximum temperature ≤ 25 ^oC. The minimum dilution available with complete mixing, at low river flow (1 000 m^3/s) is > 950,000:1.

There are no monitoring requirements as of 1978, so there were no monitoring data available from SEAM for the period of 1985 through 1994. However, the permit files and the two reference reports indicate that this discharge has been within permit limits for temperature and flow in the past (i.e., 1985 and 1986 temperatures were 20^oC and 14^oC respectively). It is therefore anticipated, due to the nature of the discharge and the past compliance with permit limits, that this operation will not have a significant impact on the water quality of Woodward's Slough or the Fraser River.

4.5.11 Tilbury Cement Limited (PE 4513)

Tilbury Cement Limited operates a cement manufacturing plant located on the northwest end of Tilbury Island. It discharges non-contact cooling water, through a submerged diffuser, to the Main Arm of the Fraser River. This operation has been described in the past by Swain (1980) and by Swain and Holms (1985b) (under the name Genstar Limited) and more recently in greater detail in the FREMP/FRAP report (FREMP, 1994a).

Waste Management Permit PE 4513 allows a maximum effluent discharge of 18,200 m^3/d, with a maximum temperature 10 °C above the background temperature of the Fraser River at the cooling water intake. The minimum dilution available, with maximum discharge and a low river flow of 1 000 m^3/s, is greater than 4 700:1.

Monitoring for oil and grease is required yearly, temperature is to be monitored continuously at the intake, the discharge and downstream, and flow is to be monitored daily. A monitoring data summary for the years 1985, 1986 and 1987 is given in Table 45. The maximum concentrations of oil and grease (5 mg/L), total suspended solids (134 mg/L) and the pH range (average = 7.8) are too low to cause concern, even with the high discharge rate.

The weekly temperature and flow monitoring data available in the permit files for the period of January, 1994 through December, 1994 are summarized in Table 46. These data indicate that the discharge reaches a maximum temperature of 26 ^oC, and at the most has only an 8 ^oC increase over the intake temperature (a 10 ^oC increase is permitted). The maximum flow rate (12 600 m^3/d) is also well within the permit limits of 18 200 m^3/d.

Therefore, due to the nature of the discharge and the available dilution, it is not anticipated that this operation will have a significant impact on the water quality of the Fraser River.

4.5.12 Farrell Estates Limited (PE 5230)

Farrell Estates Limited operates an industrial park with marina, restaurant, pub and other commercial sources, on the eastern end of Lulu Island. The operation discharges treated municipal-type wastes to Annacis Channel, near the southwest tip of Annacis Island. The effluent is treated by a secondary sewage treatment plant before being discharged to the channel through a submerged outfall (Swain and Holms, 1985b).

Waste Management Permit PE 5230 allows the effluent to be discharged at a maximum rate of 227 m^3/d, having a 5-day BOD concentration ≤ 45 mg/L, total suspended solids concentration ≤ 60 mg/L and a pH range between 6.0 and 8.0. The dilution available for the maximum discharge, at low flow rates in Annacis Channel (70 m^3/s, 6% of the Main Stem flow rate calculated in Chapter Two), is > 26 000:1. Monitoring of these characteristics is required quarterly, and monitoring of flow is required monthly.

There were no monitoring data available from SEAM for the period of 1985 through 1994. It was reported in the permit files that the operation was out of compliance five times from January, 1990 to December, 1992, for high BOD, suspended solids, or both. The company stated plans to improve output quality through regular maintenance and increasing of sludge pump-outs. Due to past non-compliance and lack of recent monitoring data, it is not possible at this time to determine whether this discharge will significantly impact the water quality of Annacis Channel of the Fraser River.

4.5.13 Bella Coola Fisheries Limited (PE 5400)

This fish processing plant is located on the south shore of Annieville channel of the Main Arm of the Fraser River, directly across from the southernmost side of Annacis Island. It has been described in the past by Swain and Holms (1985b), and most recently in the FREMP/FRAP report (FREMP, 1994b).

There are two separate discharges from this plant, both of which are screened prior to discharge through two submerged "Y" diffusers. These are adjacent to each other and extend into the river, 45 m from shore at a depth of 6 m below low water (FREMP, 1994b). Discharge "01" is a combination of screened fish processing and fish boat unloading effluent, and treated sanitary sewage. The fish processing and fish boat unloading effluent is passed through a 60 mesh screen, and the sewage is treated by a packaged secondary-type aerobic treatment plant. The flows are then combined and discharged through a submerged outfall. Discharge "02" is cooling water from a refrigeration house and storm water runoff. The cooling water is non-contact and has slightly increased in temperature before being discharged to the Fraser River through a submerged outfall.

Waste Management Permit PE 5400 allows a maximum discharge of 1 400 m^3/d of the process effluent/sewage ("01"), having a 5-day BOD concentration ≤ 45 mg/L and a total suspended solids concentration ≤ 60 mg/L. The permit also allows a maximum discharge of 340 m^3/d of cooling/storm water, with a temperature ≤ 32°C.

Monitoring of the temperature of discharge "02" is required quarterly. The fish processing effluent and the domestic sewage are to be monitored quarterly for BOD_5 and total suspended solids. The fish processing effluent is to be monitored for the same parameters and oil and grease as well.

The following table outlines the dilution ratios and concentration potentials for four characteristics of the operation. Calculations are based on effluent data summarized in Table 47 and an Annieville Channel low flow rate of 790 m^3/s (79% of the Main Stem flow rate, quoted in Chapter Two).

		Fraser River Flow Rate 930 m^3/s	
Characteristic	**Maximum Discharge**	**Minimum Dilution Complete Mixing**	**Minimum Dilution Edge of IDZ**
Flow (m3/d)	1 400	57 394:1	14 348:1
		Potential Increase Complete Mixing	Potential Increase Edge of IDZ
Ammonia (mg/L)	17	0.0003	0.0012
BOD, 5-day (mg/L)	549	0.01	0.04
Suspended Solids (mg/L)	276	0.005	0.02

*Where monitoring data were unavailable, permitted maximum discharges were used.

These limited data values (n=3) were obtained from monitoring done in 1985 and 1986. If these values are representative, all of these characteristics, after dilution, are at concentrations that would be below levels of concern, due mostly to the high dilution availability with complete mixing and at the edge of the IDZ.

Data in the FREMP/FRAP report indicates that for 1990, 1991, and 1992 the maximum permitted flow was not exceeded (FREMP, 1994b). The FREMP/FRAP report also stated that in more recent monitoring (1990,1991 and 1992), BOD and total suspended solids concentrations exceeded permit limits most of the time (60 to 2 180 mg/L and 23 to 2 180 mg/L, respectively). Even with these maximum values though, the resulting BOD_5 and total suspended solids concentrations in the river, with complete mixing, are only approximately 0.04 mg/L each.

A wastewater characterization study of fish processing plant effluents that included B.C. Packers determined that effluent toxicity was demonstrated at all sites tested and that toxicity varied considerably over time (FREMP, 1994b).

Therefore, due to the high dilution availability of Annieville Channel, it is not anticipated that either the fish processing/ sewage discharge or the low volume, non-contact cooling water discharge will significantly impact the water quality of the Fraser River.

4.5.14 Fraser River Harbour Commission (PR 6277 and PE 6276)

The Fraser River Harbour Commission owns a 269 ha. landfill (Richmond Landfill) on the middle southern portion of Lulu Island, across from Tilbury Island. The industrial landfill operation began at the site in 1956, and involved the construction of a mattress base overlain by garbage, dirt, or dredged sand pre-load fill. The site is situated on a peat bog underlain by a silt-clay layer that provides an almost impermeable barrier, limiting migration of leachate into the groundwater system. This operation has been previously described by Swain and Holms (1985b).

Landfilling ceased on November 17, 1986. Discharged refuse consisted of 15% municipal putrescibles, 40% municipal and industrial waste and 45% demolition and inert waste. The municipal putrescibles were confined to a 20 ha. area situated on the west end of the site. A gas collection system has been installed over the municipal refuse area. Some of the collected gas is sold, while the excess is flared.

Waste Management Permit PR 6277 allowed a maximum discharge of 454 t/d while the landfill was still operating. Waste Management Permit PE 6276 allows a maximum discharge rate of 10 000 m^3/d of effluent from both the leachate treatment system serving the closed landfill and the storage and processing facility (which holds a maximum of 200 000 m^3 of wood residues and yard waste) located on-site. The effluent characteristics must have a 5-day BOD concentration ≤ 30 mg/L, a total suspended solids concentration ≤ 40 mg/L, an ammonia nitrogen concentration ≤ 10 mg/L and a 96h-LC50 toxicity ≥ 100%. The minimum dilution available for this discharge into the Main Arm of the Fraser River, at low flow rates of 100 m^3/s, is 8 600:1.

A dike and compacted access roadway on the south side are designed to collect leachate and prevent its migration to surface waters and farm lands. The leachate collected in ditches is directed to facultative lagoons with mechanical aeration capabilities. The leachate is then directed to two sand filters connected in series, and is discharged to the ditch flowing along the west side of the site, near its confluence with the Fraser River.

Toxicity is to be analyzed once a month, along with field measurements for dissolved oxygen and temperature. The groundwater, surface water and the discharge itself are monitored by a total of nine wells or sampling locations.

The permit file contains monitoring data for the final discharge from February, 1993 through June, 1994, which are summarized in Table 48. The maximum values quoted for suspended solids (18 mg/L) and ammonia nitrogen (7.6 mg/L) are well within the permit limits of 40 mg/L and 10 mg/L respectively. The maximum value quoted for BOD_5 (75 mg/L) is significantly above the permit limit of 30 mg/L, however the mean value (27 mg/L) is within limits. As well, the high dilution rate available (8 600: 1) would dilute the maximum concentration to 0.009 mg/L, well below the detection limit of 2 mg/L (American Public Health Association, 1992).

The other characteristics (measurements summarized in the table) include dissolved oxygen and temperature, and all have maximum values that, before or after dilution, fall within ambient water quality criteria for aquatic (Nagpal *et al*, 1995). As well, values given in the permit files for 12 different 96h LC50 toxicity tests done between December, 1994 and January indicate that the survival rate was ≥100%.

Therefore, due to the monitoring data and the high dilution rate available, it is anticipated that this discharge will not significantly impact the water quality of the Main Arm of the Fraser River. Continued monitoring is recommended to ensure that the permit limits are continually being met.

4.5.15 The Owners, Strata Plan No. NW2245 (PE 6287)

This company operates a floating home marina on the south bank of Canoe Pass, just downstream from where it branches off the Main Arm of the Fraser River. The operation discharges sewage treated by a rotating biological contactor secondary-type package treatment plant through a submerged outfall extending approximately 100 m from shore into the main channel of Canoe Pass.

Waste Management Permit PE 6287 allows the effluent to be discharged at a maximum rate of 34 m^3/d, having a 5-day BOD concentration ≤ 45 mg/L and a total suspended solids concentration ≤ 60 mg/L. Monitoring is required quarterly for these two characteristics and monthly for flow.

There were no monitoring data available from SEAM for the period of 1985 through 1994. However, due to the low volume of discharge and the treatment, it is anticipated that this operation will not significantly impact the water quality of Canoe Pass of the Fraser River.

4.5.16 Riverbank Village Marina Co-op (PE 6375)

Riverbank Village Marina Co-op discharges treated sewage effluent from a six-unit marine co-operative operation located on the north shore of Annacis Channel of the Fraser River, just downstream from the southwest tip of Patrick Island. The effluent enters a sewage collection and pumping system and is treated by a rotating biological contactor secondary-type sewage treatment plant before discharging to the river through an outfall pipe located below low water.

Waste Management Permit PE 6375 allows effluent to be discharged at a maximum rate of 6.8 m^3/d, having a 5-day BOD concentration ≤ 15 mg/L and a total suspended solids concentration ≤ 15 mg/L. The minimum dilution that this discharge would receive with complete mixing in the Annacis Channel (6% of Main Stem flow = 70.7 m^3/s) is more than 898 000: 1.

Monitoring of the effluent is required quarterly for BOD and total suspended solids and monthly for flow. The following table outlines the dilution ratios and concentration potentials for four characteristics of the operation. Calculations are based on an Annacis Channel low flow rate of 70.7 m^3/s (6% of Main Stem flow rate).

		Fraser River Flow Rate 70.7 m^3/s	
Characteristic	**Maximum Discharge**	**Min. Dilution Complete Mix**	**Min. Dilution Edge of IDZ**
Flow (m3/d)	6.8	898 305	224 576
		Potential Increase Complete Mixing	**Potential Increase Edge of IDZ**
Ammonia (mg/L)	12	0.00001	0.0001
Coliform: fecal (#/100 mL)	13000	0.01	0.06
Suspended Solids (mg/L)	12	0.00001	0.00005

*Where monitoring data were unavailable, permitted maximum discharges were used.

The limited data available for the period of 1985 through 1988 for ammonia (n=6), fecal coliforms (n=2) and total suspended solids (n=7) indicate that all maximum concentrations were well below levels of concern, even at the edge of the initial dilution zone. The maximum concentration of BOD_5 (11 mg/L) is within the permit limits of 15 mg/L. As well, the permit files for April, 1989 indicate that the average flows recorded were approximately 3.0 m^3/d, which is also well within the permit limits of 6.8 m^3/d.

Therefore, due the nature of the discharge, the low volume of flow and the high dilution rate available, it is anticipated that this operation will not have a significant impact on the water quality of Annacis Channel in the Fraser River.

4.5.17 Alpha Manufacturing Incorporated (PR 7707)

Alpha Manufacturing Incorporated operates a landfill located adjacent to the south bank of the Main Arm of the Fraser River, just upstream from Tilbury Island. The landfill began operating in April, 1987, and was amended in March, 1988, to reflect an expansion of the site. The refuse being discharged is classified as inert industrial and contains materials such as concrete, bricks or framing lumber arising from domestic, commercial, institutional or municipal activities in the Lower Mainland.

Waste Management Permit PR 7707 allows an annual average refuse discharge of 320 m^3/d, to a total of 900 000 m^3. The refuse is landfilled in cellular structures that are ≤ one ha. in area, and cover is applied every 20 days. There are buffer strips of native soil and vegetation ≥ 20 m wide along the perimeter of the landfill. The landfill is located on a peat bog underlain by clayey-silt and clayey-sand. According to the permit files, the time of travel for leachate generated at the centre of the landfill to the Fraser River is approximately one year.

There are four monitoring sites in two ditches located on the north (river) border and along the railway running east-west through the centre of the site, as well as eight groundwater wells located on site. Monitoring is required quarterly in the ditches for a variety of characteristics including ammonia, dissolved metals and phenols.

The only monitoring data available from SEAM for the period of 1985 through 1994 was for March 6, 1991. These data are summarized in Table 49. The characteristics measured are total metals such as aluminum, barium, calcium and iron. The maximum values for these were all below levels that would cause concern for aquatic life (Nagpal *et al*, 1995).

As well, the permit files indicate that numerous site inspections show the company has diligently adhered to the permit conditions. The ditch monitoring data in the permit files for June 25, 1987 indicate that the average pH was 7.5, average phenol concentration was 0.005 mg/L, and the only detectable metal was dissolved iron with an average concentration of 1.18 mg/L. The 96h-LC50 toxicity values were ≥ 100%.

The most recent data available are from the permit files, for the period from January, 1994 through October, 1994 and are summarized in Table 50. Data from all four sampling sites were compiled, and only those characteristics that had more than 50% of their values above detection limits were included.

When the maximum, minimum and mean values of each characteristic are compared to the ambient water quality criteria for aquatic life (Nagpal *et al*, 1995), those found to be of concern are phenols (maximum 0.012 mg/L, criteria of 0.001 mg/L), total iron (maximum 29.5 mg/L, criterion of 0.3 mg/L), manganese (maximum 3.71 mg/L, criterion of 0.1 to 1.0 mg/L) and zinc (maximum 0.17 mg/L, criterion of 0.03 mg/L). Total iron had the greatest deviation, however, this parameter is often high due to iron content of suspended sediment, and may not be available to biota (Nagpal *et al*, 1995). There was no criterion available for dissolved iron.

If each of these concentrations (except total iron) were to enter the Fraser River, they need only be diluted by a ratio of 10:1 to be well within ambient quality criteria. Therefore, due to the monitoring data results, the underground leachate travel times and the high available dilution (Main Arm flow rate of $8.6x10^{7}$ m^{3}/d), it is anticipated that this operation will not significantly impact the water quality of the Fraser River.

4.5.18 7437 Holdings Limited, (PR 7709)

7437 Holdings Limited operates a landfill located adjacent to the south bank of the Main Arm of the Fraser River, near the southeast tip of Annacis Island. The refuse being discharged is classified as inert industrial waste and contains materials such as wood, concrete, asphalt, road and roofing materials.

Waste Management Permit PR 7709 allows a monthly average discharge rate of 350 m^{3}/d with a maximum of 76 500 m^{3}/a. The refuse is landfilled in cellular structures that are less than one ha in area, and a cover of relatively impermeable material is applied every 20 days. A buffer zone of 20 m is maintained between the landfill and any ditches.

There are six monitoring sites located in three ditches, one at the north end of the site and two running across the middle. The required monitoring frequency of these ditches was reduced to once a year after the first year of operation. The permit requires monitoring for the following parameters: dissolved metals, pH, phenols, sulphate, resin acids and toxicity.

The monitoring data available from the permit files are from the period of October, 1991 through July, 1993, and are summarized in Table 51. The values quoted are a compilation of data from all six of the landfill monitoring sites. Also included in the permit files were monitoring results from 96h LC50 bioassays, for the period of November 1991 through July 1993, which indicated values $\geq$ 100% for all tests.

Most of the maximum recorded concentrations fall within the ambient water quality criteria for aquatic life (Nagpal *et al*, 1995). Those that exceed criteria include dissolved iron (4.64 mg/L, criterion 0.3 mg/L), dissolved manganese (2.24 mg/L, criterion 0.1 to 1.0 mg/L), dissolved zinc (0.498 mg/L, criterion 0.03 mg/L), and phenols (0.060 mg/L, criteria 0.001 mg/L). However, if all of the leachate was to reach the Main Arm of the Fraser River, near the downstream tip of Annacis Island (low flow rate of about 930 m^3/s), the dilution would be great enough to lower concentrations to well within safe limits (i.e., >100:1).

Therefore, due to the results from the monitoring data and the high dilution rate available, it is anticipated that the leachate from this discharge will not significantly impact the water quality of the Fraser River. Continued monitoring is recommended, however, to ensure that current discharges are within concentration limits safe for aquatic life.

4.5.19 Brown, Robert (PR 7765)

Robert Brown discharges refuse to, and effluent from, a landfill located approximately 50 m south from the Fraser River, near the southwest tip of Annacis Island. The refuse being discharged ("01") is from various excavation, demolition and industrial operations located in the Lower Mainland. The effluent being discharged ("02") is from the landfill leachate treatment facilities. Originally there were two landfills on the site, one of which was covered by Waste Management Permit PR 8169 under the name Robert Brown and Pacific Dock and Storage Limited. This landfill has now been combined with Waste Management Permit PR 7765 to exist as one landfill, operating under Robert Brown.

Waste Management Permit PR 7765 allows an annual average refuse discharge ("01") of 150 m^3/d, with a maximum of 750 m^3/d. The characteristics of the discharge are to be inert solid waste consisting of demolition, excavation and concrete waste, as well as weathered asphalt and road material, and cement dust from cement manufacturing. The permit also allows a maximum effluent discharge ("02") of 150 m^3/d, with the following characteristics: pH range 6.5 to 8.5, $BOD_5 \leq 30$ mg/L, COD $\leq$155 mg/L, dissolved oxygen $\geq$ 5 mg/L, ammonia $\leq$ 5 mg/L, sulphide $\leq$ 0.05 mg/L, phenol $\leq$ 0.2 mg/L, pentachlorophenol $\leq$ 0.0005 mg/L, tetrachlorophenol $\leq$ 0.001 mg/L, suspended solids $\leq$ 40 mg/L, aluminum $\leq$ 2 mg/L, cadmium (dissolved) $\leq$ 0.005 mg/L, chromium $\leq$ 0.1 mg/L, copper (dissolved) $\leq$ 0.05 mg/L, iron (dissolved) $\leq$1.0 mg/L, lead $\leq$ 0.05 mg/L, manganese (dissolved) $\leq$ 0.5 mg/L, mercury $\leq$ 0.00006 mg/L, zinc (dissolved) $\leq$ 0.2 mg/L, and toxicity, 96hr-LC20, $\geq$ 100%.

The leachate is collected by an impervious perimeter berm and pumped to the secondary treatment system, where it is sparged with process air from blowers. It then flows through seven aeration tanks before being discharged to the railway ditch that flows north for about two km and enters the Fraser River. The minimum dilution available for the maximum effluent discharge, with complete mixing with Main Arm Fraser River water at low flow (about 1000 m^3/s) is 577 000:1.

There are 10 sampling sites including four in the railway ditch, one at both the inlet and the outlet of the treatment facilities and four at groundwater monitoring wells. Monitoring is required every six months at the groundwater wells and quarterly at the other sites. Monitoring data found in the permit files for the final discharge (leaving the treatment facilities and entering the ditch) for the period from March, 1993 through December, 1994 are summarized in Table 52.

All of the characteristics, except BOD, COD, sulphide, pentachlorophenol and total suspended solids, were found to have maximum values within the permit limits. The BOD maximum (34 mg/L) was only slightly above the permit limit of 30 mg/L, and with complete dilution would reach a level below a detection limit of 2 mg/L ($5.9x10^{-5}$ mg/L).

The maximum value recorded for COD (182 mg/L) is significantly higher than the permit limit (155 mg/L), however the mean value (117 mg/L) is well within the permit limits. Therefore, with the high available dilution, this increase should not cause a concern.

The maximum values of sulphide (<0.5) and pentachlorophenol (<0.005) were higher than the permit limits by a factor of 10. However, the laboratory monitoring equipment was not able to detect values as low as those required by the permit (≤0.05 mg/L and ≤0.0005 mg/L respectively), and therefore the data are inconclusive. More sensitive monitoring equipment would be required to give an actual value for either of these characteristics.

Finally, the maximum value for suspended solids was double the permit limit of 40 mg/L. This may be a concern for aquatic life, depending on the background levels and the time of year. However, the mean value was below the permit limit.

Therefore, due to the treatment, the available dilution and the monitoring results, it is anticipated that this operation will not significantly impact the water quality of the Fraser River. However, because of episodic elevated levels of sulfide, pentachlorophenol and suspended solids, continued monitoring and potential preventative measures are recommended to ensure the permitted effluent quality is consistently being met.

4.5.20 Shearer Seafood Products Limited (PE 7785)

Shearer Seafood is a fish processing plant located on the north shore, and extreme west end, of Gundersen Slough, where it branches off the Main Arm of the Fraser River. The effluent being discharged into Gundersen Slough originates from process effluent, ice machine cooling water and washdown water containing dilute chlorine based cleaning agents. This operation has been described in great detail in the FREMP/FRAP report (FREMP, 1994b). Effluent is stored in a 2.7 m^3/d holding tank. It is screened as it overflows through a submerged open-pipe outfall that extends into the slough approximately 15 m from shore, at a depth of 3.6 m below low water (FREMP, 1994b).

Permit PE 7785 allows the discharge of a maximum 4.6 m^3/d of processing effluent (FREMP, 1994b). Effluent monitoring is required every six months for BOD, pH, total suspended solids and residual chlorine. Monitoring data from the permit files from April, 1990 to November, 1994 are summarized in Table 53.

A wastewater characterization study of fish processing plant effluents that included B.C. Packers determined that effluent toxicity was demonstrated at all sites tested and that toxicity varied considerably over time (FREMP, 1994b).

The average values for residual chlorine (median <0.2 mg/L) and pH (6.5) are well within levels of concern. However, all BOD_5 values (maximum 578 mg/L and average 346 mg/L) are very high. Considering the low dilution rates available in Gundersen Slough, this could cause localized dissolved oxygen depressions if the effluent is trapped in the slough and not flushed into the river. To reduce BOD concentrations to a safer level (below detection limit of 2 mg/L (American Public Health Assn., 1992), the dilution factor in Gundersen Slough would have to be 170:1 to 290:1.

The maximum and mean values for suspended solids (322 mg/L and 186 mg/L respectively) are also considered to be high relative to the receiving environment. To reduce suspended solids to concentrations safe for aquatic life (10 mg/L) (Nagpal *et al*, 1995), the dilution factor would have to be 20:1 to 30:1. Due to the variable, back eddy effects of the slough, it is difficult to determine a constant, accurate dilution ratio for it.

Due to these results, further investigation is strongly recommended to determine if concentrations of BOD and dissolved oxygen are frequently at levels that would be detrimental to the environment and to ensure that concentrations are consistently within criteria.

4.5.21 Riversbend Floating Home Limited (PE 7945)

Riversbend Floating Home Village Limited discharges treated domestic effluent from residential dwellings and a marina located on the north shore of the Main Arm of the Fraser River, just upstream from the southwest tip of Annacis Island. The effluent is treated by a rotating biological contactor-type secondary sewage treatment plant, and flows through an outfall extending into the river beyond the last residential dwelling, at a minimum depth of 2 m.

Waste Management Permit PE 7945 allows effluent to be discharged at a maximum rate of 22.3 m^3/d, having a 5-day BOD concentration ≤ 45 mg/L and a total suspended solids concentration ≤ 60 mg/L. The dilution available for the maximum discharge, at low flow rates in Annacis Channel (70.7 m^3/s, 6% of the Main Stem flow rate calculated in chapter two), is > 273,000:1. Monitoring is required quarterly for these characteristics and monthly for flow.

There were no monitoring data available from SEAM for the period of 1985 through 1994. However, due to the low volume of discharge, the treatment and the high dilution rate available, it is not anticipated that this operation will significantly impact the water quality of Annacis Channel of the Fraser River.

4.5.22 Ecowaste Industries Limited (PE 8036)

Ecowaste Industries Limited operates a leachate treatment facility for a demolition, construction and excavation waste landfill, located approximately 135 m north from the Main Arm of the Fraser River, near the southwest tip of Tilbury Island. The landfill that Ecowaste Industries service lies between the south end of the facility site and the north bank of the Fraser River. The leachate treatment facility consists of an effluent treatment marsh, an aeration lagoon, an effluent weir and an outfall. The effluent is discharged to a ditch that flows along the north end of the site and into a second ditch flowing south to the Fraser River. The minimum dilution available for this effluent, if the maximum discharge completely mixes with the Fraser River low flow rate (1 000 m^3/s), is > 43 000:1

Waste Management Permit PE 8036 allows a maximum effluent discharge of 2,000 m^3/d with the following characteristics: pH range 6.0 to 8.5, suspended solids ≤ 40 mg/L, BOD_5 ≤ 30 mg/L, dissolved oxygen ≥ 5.0 mg/L, sulphide ≤ 0.5 mg/L, ammonia ≤ 10 mg/L, aluminum ≤ 2.0 mg/L, cadmium (dissolved) ≤ 0.005 mg/L, chromium ≤0.1 mg/L, copper (dissolved) ≤ 0.05 mg/L, lead ≤ 0.05 mg/L, manganese (dissolved) ≤ 0.5 mg/L, mercury ≤ 0.0006 mg/L, zinc (dissolved) ≤ 0.2 mg/L, phenols ≤ 0.2 mg/L, pentachlorophenol ≤ 0.0005 mg/L, tetrachlorophenol ≤ 0.001 mg/L, and toxicity, 96h LC20 ≥ 100%.

There are three sampling sites; one at the effluent weir where the effluent is first discharged to the north end ditch, and two on either end of the ditch. Monitoring frequencies vary from monthly to quarterly, according to which characteristic is being sampled.

Monitoring data from the permit files for the period of November, 1992 to May, 1994 are summarized in Table 54. All the maximum values recorded are within the permit limits, except those for lead (<0.08 mg/L) and manganese (0.57 mg/L). However, these are only slightly above the permit limits (≤ 0.05 mg/L for lead and ≤ 0.5 mg/L for manganese) and after dilution in the Main Arm of the Fraser River, they would reach concentration levels of 1.8×10^{-6} mg/L for lead and 1.3×10^{-5} mg/L for manganese. These values are both well within the criteria for aquatic life (0.003 mg/L lead at water hardness of ≤ 8 mg/L $CaCO_3$, and 0.1 to 1.0 mg/L manganese) and are therefore not of concern (Nagpal *et al*, 1995).

The maximum value given for COD, although not given a permit limit, was significantly high (214 mg/L), as was the average value (185.8 mg/L). However, after dilution these concentrations would be lowered to 0.005 and 0.004 mg/L respectively and would therefore not be of great concern.

Therefore, due to the monitoring results, the treatment facilities and the high dilution rate available, it is anticipated that this treated leachate will not have a significant impact on the water quality of the Fraser River. However, due to potential environmental damage from a discharge of this nature, continued monitoring is recommended.

Monitoring should include permit limits for dissolved and total metals such as silver, arsenic, barium, cobalt, iron, molybdenum, nickel, and tin, as well as permit limits for COD, mineral oil and grease, benzene, and resin acids.

4.5.23 Canadian Holographic Developments Limited (PE 8037)

Canadian Holographic Developments Limited operates a hologram production facility located adjacent to the south bank of the Fraser River, at the riverine end of Canoe Pass. The facility discharges water which is passed through a jacket to cool laser units used in producing small commercial holograms. The water does not contact any of the system components and there are no treatment facilities for the effluent before it is discharged into a ditch that enters a marsh in Canoe Pass. This marsh is considered to be a major producer of organic detritus and fish food organisms that supports large numbers of juvenile salmonids.

Waste Management Permit PE 8037 allows a maximum effluent discharge of 2 m^3/d, with a temperature < 27 ^oC. There were no temperature monitoring data available from SEAM for the period of 1985 through 1994. However, the permit files indicate that tests done in August, October and November 1988, show an increase of between 6.5 to 10 ^oC from influent to effluent water flows (i.e., for August, influent temp. 18 ^oC and effluent temp. 24.5 ^oC). The information in the files also shows that there was a subsequent equal drop of temperature by natural cooling in the ditch, prior to discharge into the marsh.

It is therefore anticipated that due to the very low volume of discharge, the nature of the effluent and the cooling ability of the immediate receiving environment, this discharge will not significantly impact the water quality of either the Canoe Pass marsh or the Fraser River.

4.5.24 Meadowland Peat Limited (PR 8139)

Meadowland Peat Limited operates a landfill whose north end is located approximately 50 m from the south bank of the Main Arm of the Fraser River, near the southwest tip of Annacis Island. The refuse that is discharged to the landfill originates from various excavation, demolition and construction sites located in the Lower Mainland.

Waste Management Permit PR 8139 allows a maximum annual average refuse discharge of 130 m^3/d. The refuse is landfilled in cells that are one ha. in area and are completely encompassed by relatively impermeable berms, prior to discharge. A minimum of 0.15 m of cover material is applied on all exposed solid waste monthly, and a buffer zone of 10 m to 20 m is maintained between the landfill and surrounding ditches or watercourses.

Although there are no specific permit limits for leachate being discharged from the landfill, the permit does require a quarterly monitoring program to analyze a wide range of characteristics from four sample sites in ditches around the landfill area.

The monitoring data available in the permit files are for the period of April, 1994 through January, 1995 and are summarized in Table 55. The data from all four sample sites have been compiled and only those characteristics whose concentrations were above detectable limits have been used. As well, all four sample ditches were tested for 96h LC50 toxicity on April, 1994, October, 1994 and January, 1995, with results ranging from 90 to >100% survival rate.

The characteristics whose maximum values were above water quality criteria for aquatic life (Nagpal *et al*, 1995) were phenols (0.037 m/L, criterion 0.001 mg/L), sulphates (134 mg/L, criterion 100 mg/L), total sulphides (0.053 mg/L, criterion 0.002 mg/L) and total manganese (12.4 mg/L, criteria 0.1 to 1.0 mg/L). The maximum value for COD (215 mg/L) may also represent a concern, although no criterion is given.

However, even if all the leachate was to reach the Main Arm of the Fraser River, the dilution would likely be great enough to lower the concentrations to ambient criteria levels. Therefore, due to the nature of the discharge, the location and the dilution rate available in the Main Arm (flow rate of 8.6×10^7 m^3/d), it is anticipated that this landfill will not have a significant impact on the water quality of the Fraser River.

4.5.25 New West Net Co. Limited (PE 8167)

New West Net is a fish processing plant located on the north shore of Annacis Channel of the Main Arm of the Fraser River, directly across from Patrick Island. This operation has been described recently in great detail in the FREMP/FRAP report (FREMP, 1994b). The effluent emanates from cleaning and washing of fish. It is screened prior to discharge through a submerged diffuser outfall, with ports about every 150 mm, extending into the river approximately 15 m from shore at a depth of 4.5 m at low water (FREMP, 1994b).

Permit PE 8167 allows the discharge of a maximum 22.7 m^3/d of processing effluent, with a maximum 5-day BOD and suspended solids concentrations of 100 and 70 mg/L, respectively. The minimum dilution available with complete mixing in the Annacis Channel at low flow (6% of the Main Stem flow = 70 m^3/s) is > 269 000:1. Monitoring for these parameters as well as pH is required quarterly.

A wastewater characterization study of fish processing plant effluents that included New West Net determined that effluent toxicity was demonstrated at all sites tested and that toxicity varied considerably over time (FREMP, 1994b).

The only data submitted by the company since it began operating in October 1989 dates from August 1994. It was a sample grab from under the "cutting table", and had a pH of 6.38, a BOD concentration of 147 mg/L and total suspended solids concentration of 65 mg/L. As of August 22, 1994 the company was found to be out of compliance due to the level of BOD exceeding the permit limits (by 47 mg/L). Although the dilution rate available in this part of the Fraser is quite high, the reported level of BOD is significantly greater than permitted. More stringent and consistent monitoring is recommended to ensure that this operation does not adversely affect the water quality of the Fraser River.

4.5.26 A D P Holdings Limited (PR 8177)

A D P Holdings Limited operates a landfill whose north end is located approximately 65 m from the south bank of the Main Arm of the Fraser River, near the southwest tip of Annacis Island. The refuse discharged to the landfill is demolition and excavation wastes containing inert materials such as concrete, bricks, wood, weathered asphalt road material, roofing material and soil.

Waste Management Permit PR 8177 allows a maximum refuse discharge of 50 m^3/d as an annual average. The refuse is landfilled in cells that are one ha. in area and are completely encompassed by relatively impermeable berms, prior to discharge. Each cell is required to be completely filled and covered by 0.6 m of impermeable material, such as silty-clay, before proceeding to the next cell. A minimum of 0.15 m of cover material is to be applied on all exposed solid waste monthly and a buffer zone of 10 m to 20 m is to be maintained between the landfill and surrounding ditches or watercourses.

Although there are no specific permit limits for leachate being discharged from this landfill, the permit does require a quarterly monitoring program to analyze a wide range of characteristics from six sample sites in ditches around the landfill area.

There were no monitoring data available from SEAM for the period of 1985 through 1994. However, due to the nature of the discharge, the location and the dilution rate available in the Main Arm (flow rate of $8.6x10^7$ m^3/d), it is anticipated that this landfill will not have a significant impact on the water quality of the Fraser River.

4.5.27 Primex Forest Products Limited (PE 8424)

Primex Forest Products Limited discharges domestic sewage effluent from washroom and lunchroom facilities from a small sawmill located on a spit of land, on the south bank of the Main Arm of the Fraser River, between Annieville Channel and Gundersen Slough. The effluent is treated by a package secondary-type sewage treatment plant prior to being discharged to Annieville Channel through an outfall. The outfall is strapped to vertical pilings extending approximately 18.3 m from the shoreline and about 2 m below low water level. Chlorination is not required because of the small volume of the discharge and its possible adverse effects on fisheries.

Waste Management Permit PE 8424 allows a maximum effluent discharge of 3.8 m^3/d, having a maximum 5-day BOD concentration ≤ 45 mg/L and a maximum total suspended solids concentration ≤ 60 mg/L. The minimum dilution available for the maximum effluent discharge, with complete mixing with the Annieville Channel water at low flow (79% of the Main Stem flow rate) is > $2.1x10^7$: 1.

Although monitoring is required on a quarterly basis, there were no data available from SEAM for the period of 1985 through 1994. However, due to the very small volume of discharge, the treatment and the high dilution available, it is anticipated that this operation will not significantly impact the water quality of Annieville Channel of the Main Arm of the Fraser River.

4.5.28 S. M. Properties Limited (PE 8430)

S.M. Properties own a fish processing plant under the name S.M. Products, located on the south shore of the Main Arm of the Fraser River at the point where Ladner Reach forks to Sea Reach and Canoe Pass. This operation has been described in great detail in the FREMP/FRAP report (FREMP, 1994b). The effluent originates from wash down water from a fish unloading dock and processing waste water from the plant. It is screened prior to discharge through a submerged open-pipe outfall, which extends into the river approximately one m from shore, at a depth of one m at low water (FREMP, 1994b).

A wastewater characterization study of fish processing plant effluents that included S.M. Products determined that effluent toxicity was demonstrated at all sites tested and that toxicity varied considerably over time (FREMP, 1994b).

Permit PE 8430 allows the discharge of a maximum 23 m^3/d of processing effluent, having a 96h-LC50 toxicity $\geq$ 100%. If the Fraser River flow rate in the Ladner Reach area is calculated at one-tenth the Main Arm flow rate, the minimum dilution available for maximum discharge at low river flows and complete mixing is over 380,000:1.

The monitoring program consists of quarterly grab sampling and analysis for the effluent and flow rate. There were no monitoring data available in the permit files or SEAM for the period of 1985 through 1994. However, due to the nature of the effluent (essentially uncontaminated quality), the treatment and the dilution availability of Ladner Reach at the point of discharge, it is anticipated that this operation will not have a significant impact on the water quality of the Fraser River.

4.5.29 Wes-Del Marina (1987) Limited (PE 8436)

Wes-Del Marina Limited discharges treated effluent from a 19-capacity floating home development located near the south bank of Canoe Pass, approximately one km from the Main Arm of the Fraser River. The operation discharged raw sewage from its commencement on December 19, 1989 until the sewage treatment works began on February 10, 1991.

The effluent is treated by a rotating biological contactor secondary-type sewage treatment plant, containing three components: a primary clarifier, a four-stage rotating bioreactor and a secondary clarifier. The outfall extends 85 m from the shore, to a depth of three m below the low water level. As of September, 1994 there were seven floating homes connected to the sewage treatment plant.

Waste Management Permit PE 8436 allows a maximum discharge of 21.6 m^3/d of effluent, having a 5-day BOD concentration ≤ 45 mg/L and a total suspended solids concentration ≤ 60 mg/L. Canoe Pass is approximately 300 m wide at the point of discharge. According to the permit files, the flow rates at Canoe Pass range from $3.3x10^6$ m^3/d to $40x10^6$ m^3/d. This would mean that at the lowest flow rates and maximum discharge, the minimum dilution available would be $1.5x10^5$:1, although the tidal influence may affect river flows significantly.

Monitoring is required quarterly for BOD_5 and total suspended solids, and monthly for flow. There were no data available from SEAM for the period of 1985 through 1994. However, the permit files stated that the only two effluent flow samples received since the beginning of the operation indicated BOD_5 concentrations < 10 mg/L in 1992 and 12 mg/L in 1993, as well as total suspended solids concentrations < 1 mg/L in 1992 and 15 mg/L in 1993. These levels are well within the permit limits.

Therefore, due to the low volume of discharge, the level of treatment provided and the high dilution available, it is anticipated that this operation will have little impact on the water quality of Canoe Pass of the Fraser River.

4.5.30 Apollo Concrete Products (PE 11030)

Apollo Concrete Products operates a concrete batch plant located on the south bank of the Main Arm of the Fraser River near the southwest tip of Annacis Island. The company manufactures textured concrete patio slabs. The water used to wash and scrub the concrete slabs to remove excess material and expose the aggregate for texture contains dissolved cement residue and particulate matter.

Waste Management Permit PE 11030 allows a maximum discharge of 20 m^3/d of the wash water. It is collected, clarified in a 1 m^3 box, partially recycled and the excess is discharged to an infiltration pond measuring 25 m long, 8 m wide and 2 m deep. Even if all the infiltrated effluent was to reach the Fraser River, the minimum dilution available with complete mixing in the Annacis Channel (79% of the Main Stem flow rate) would be > $4.0x10^6$:1. Settled residue is removed from the infiltration pond and the clarification box, dewatered, and used on site as road surface material. The effluent from this dewatering process is returned to the infiltration pond.

According to the permit files the infiltration pond is located on top of an acidic bog, and so it was not deemed necessary to monitor the discharge for pH or total suspended solids. Due to the low volume of discharge, the high dilution available as well as the nature of the effluent and the treatment, it is not anticipated that this operation will have a significant impact on the water quality of the Fraser River.

4.5.31 Rempel Brothers Concrete Limited (PE 12181)

Rempel Bros. Concrete Limited discharges effluent from a ready-mix concrete plant located on the south bank of the Main Arm of the Fraser River, near the southwest end of Annacis Island. The effluent is concrete truck wash water and storm water. There is a covered culvert running along the north side of the property which becomes an open ditch flowing along the west side.

Waste Management Permit PE 12181 allows a maximum effluent discharge of 35 m^3/d, and it is to be monitored annually for flow rate and quarterly for pH range. The effluent flows to three settling basins, each measured approximately 5 m x 15 m x 2 m, where the solids are settled and the clarified water is recycled to the plant. Even if all the infiltrated effluent was to reach the Fraser River, the minimum dilution available with complete mixing in the Annacis Channel (79% of the Main Stem flow rate) would be > $2.2x10^6$:1. The excess water is discharged to two exfiltration basins (each approximately 5 m x 6 m x 15 m). The yard is contoured to catch the solid laden storm water which is treated by the settling basins. The settled solids are removed and stored in two solid drying bins, before being trucked to an off-site landfill.

There were no data available from SEAM for the period of 1985 through 1995. According to the permit files, the only possibility of ditch contamination would be from yard drainage during heavy, prolonged rainfalls, in which case the effluent would be diluted and have no significant impact on the environment. It is therefore anticipated that, due to the low flow rate and the treatment, this discharge will not have a significant impact on the water quality of the Fraser River.

4.6 Sturgeon and Roberts Banks

4.6.1 Iona STP-Greater Vancouver Sewerage and Drainage District (PE 23)

The Iona Island sewage treatment plant, operated by the Greater Vancouver Sewerage and Drainage District (G. V. S. & D. D.), is located on Iona Island at Richmond and services the City of Vancouver, University Endowment Lands, the Vancouver Airport and portions of Burnaby and Richmond. The plant discharges treated effluent to the Strait of Georgia via a long sea outfall but is included here since the original outfall that extends approximately 4 000 m onto the Sturgeon Banks. This outfall is used as an emergency backup system during power outages and the sludge lagoons are located approximately 50 m from the North Arm.

The STP has been previously described in a number of reports including Cain and Swain (1980), Swain and Holms (1985b), and the Greater Vancouver Regional District (GVRD, 1988a). The influent is chlorinated (if required), screened and the grit settled out and landfilled on site (Section 4.4.14). The screened effluent is then treated in 15 pre-aeration and sedimentation tanks with a summer design average dry weather flow of 4.67 m^3/s. The sludge and scum are then separated by treatment in two raw sludge thickeners and four fixed-cover (anaerobic) digesters and then discharged to four lagoons that have a total area of 11.5 ha. and a side water depth of 4.3 m. The sludge from the lagoons is air dried and stockpiled on site pending new disposal techniques and the supernatant is recycled back to the plant. The primary treated effluent is dechlorinated (if required) and pumped through the 7 742 m long sea outfall and 500 m diffuser, approximately 7 km west from Iona Island.

During power outages the plant discharges the primary treated effluent to the old chlorination tank and then to the old outfall. This outfall is an open channel running along the south side of the Iona Jetty, approximately 6 700 m before discharging to the edge of Sturgeon Bank. The channel is submerged at high tide and the diluted effluent is dispersed directly onto the Bank. Before the new outfall was connected in 1988, there was serious concern for the impact of the discharge on Fraser River fisheries and the health risks associated with primary contact recreation at nearby beaches (GVRD, 1988a). In 1981, court action against the G. V. S. & D. D. resulted in a court order and subsequently the improved long sea outfall (Iona STP Study Group, 1982).

Waste Management Permit PE 23 restricts the effluent discharge rate to 1 530 000 m^3/d with a $BOD_5 \leq 130$ mg/L and total suspended solids ≤ 100 mg/L. Chlorination and dechlorination are required from May to September. There are six groundwater monitoring wells surrounding the sludge lagoons that are monitored monthly for cadmium, zinc, lead, copper and mercury. The digester sludge, supernatant and sludge products are also monitored for metals. Extensive analysis is required for the long sea outfall effluent discharge monitoring program.

The sludge lagoons are situated approximately 50 m from the North Arm of the Fraser River. Data for the supernatant and sludge discharged to the lagoons are summarized in Tables 56 and 57. The following table identifies the potential increase to the North Arm if all the supernatant discharged to the lagoons reached the river. The flow data are based on the recorded discharge rates for supernatant to the southwest lagoon for 1993-94 and the estimated low flow rate of the North Arm (177 m^3/s).

Characteristic	Maximum Discharge	Fraser River Flow Rate=177 m^3/s	
		Minimum Dilution Complete Mix	Minimum Dilution Edge of IDZ
Flow	765	19994:1	4999:1
		Potential Increase Complete Mix.	Potential Increase Edge of IDZ
Arsenic	2.6	0.00013	0.00052
Cadmium	0.17	0.00001	0.00003
Chromium	3.13	0.00016	0.00063
Copper	28.9	0.00145	0.00578
Iron	326	0.01630	0.06522
Lead	5.82	0.00029	0.00116
Manganese	7.98	0.00040	0.00160
Mercury	0.15	0.00001	0.00003
Nickel	0.962	0.00005	0.00019
Zinc	15	0.00075	0.00300

*All values are in mg/L, except flow (m^3/s).

As the table shows, the potential increase is minimal and since it is highly unlikely that all the discharge would infiltrate to the river it is not expected to have an impact on the ambient water quality of the Fraser River. However, monitoring data for the sludge lagoon groundwater monitoring wells (Table 58) show high concentrations of metals indicating that the groundwater may be leaching metals from the infiltration lagoons. The oily sludge bed and grit bed are also located on the property (Section 4.4.14) and may also be having an impact on the groundwater. Further groundwater and receiving environment monitoring near the infiltration lagoons should be undertaken to determine the impact on the ambient water quality.

A soil cap and provision of adequate surface slopes are usually required to help control infiltrating water (FREMP 1990b). In areas of significant rainfall, however, infiltration and leachate generation cannot be prevented by a soil cover (FREMP 1990b). A rule of thumb for infiltration assumes that 50% of annual precipitation in excess of 500 mm will emerge as leachate, and doubling this will allow a safety margin (Atwater, 1980). In this case, the amount of leachate generated in the Fraser River estuary area could be between 1,850,000 and 3,700,000 m^3/a (see following table) (FREMP 1990b). Local circumstances should be considered rather than a rule of thumb; the 24th Avenue fill is covered by a paved road, for example, so infiltration will be minimal there. Leachate can also be generated by groundwater flows through the fill mass (FREMP 1990b).

POSSIBLE ANNUAL LEACHATE GENERATION FROM MUNICIPAL LANDFILLS, FRASER RIVER ESTUARY AREA (FREMP 1990b)

Landfill	Area (ha.)	Average Annual Precipitation (mm)	Leachate Generation* Minimum (m3)	Leachate Generation* Maximum (m3)
24th Avenue	0.07	1060	230	460
Bear Creek	0.9	1525	4,615	9,230
Braid Street	31	1650	178,250	356,500
Burns Bog	75	1010	191,250	382,500
City of Langley	5.5	1500	27,500	55,000
Cottonwood	10	1650	57,500	115,000
Elgin	2.5	1140	8,000	16,000
Johnston Road	0.2	1575	1,075	2,150
Kerr Road	27	1040	72,900	145,800
Leeder Avenue	27	1650	155,250	310,500
Port Coquitlam	1.5	1750	9,375	18,750
Port Mann	15	1575	80,625	161,250
Richmond	265	1000	662,500	1,325,000
Semiahmoo Bay	0.2	990	490	980
Sperling Avenue	2	1525	10,250	20,500
Stride Avenue	10	1500	50,000	100,000
Terra Nova	60	1650	345,000	690,000
TOTAL	**534**		**1,854,810**	**3,709,620**

*Based on 50% of precipitation over 500 mm as minimum and 100% over 500 mm as maximum leachate generated. Precipitation extrapolated from Wright and Trenholm (1969). (FREMP 1990b)

For 1979, Atwater (1980) estimated that the leachates coming from all municipal refuse landfills in the Fraser River estuary area accounted for 2% of the COD, 6 to 7% of the ammonia, 6% of the iron, and about 2% of the zinc entering the lower Fraser each day from all sources. For each tonne of refuse landfilled, an anticipated 5 - 10 kg of solids having a COD of 7.5 to 15 kg will be leached out, along with about 1 kg of ammonia (FREMP 1990b).

The fate of uncollected leachate in the Fraser River estuary area is not well known (FREMP 1990b). Leachate that escapes to the environment may impact either surface waters or groundwater. Leachates that flow a long distance through the ground may be attenuated, but much leachate flows only a short distance before discharging as leachate springs running into ditches or streams (FREMP 1990b). Given the distribution of landfills, their respective sizes, and development trends, the Main Stem may receive the greatest leachate volume but the greatest impacts may still occur on the small streams (FREMP 1990b).

Leachate flows from the Kerr Road and Stride Avenue landfills were also found to be acutely toxic, and consist of much more significant flows. Leachate from the Langley City landfill, while not acutely toxic, have resulted in heavy bacterial and fungal growth in Pleasantdale Creek that likely has impacted the fisheries resource (FREMP 1990b). Terra Nova leachate has caused elevated ammonia levels in Como Creek during low flow periods (FREMP 1990b).

5. NON-POINT SOURCE DISCHARGES

Introduction

Non-point source pollution comes from diffuse sources as opposed to direct sources such as an effluent discharge drain. Non-point source discharges are carried into water bodies by various forms of runoff and include micro-organisms, pesticides, fertilizers and other deleterious materials. Anthropogenic sources of non-point source discharges include, but are not limited to: forestry; urban stormwater runoff; sawmills; septic tanks; underground storage tanks; floating homes, houseboats, and live-aboards; marine timbers; bridge-sandblasting and repainting; ship building, repair, and maintenance facilities; log handling debris and leachates; dredging; flooding and soil erosion; airports. These are discussed in this section.

5.1 Forestry

The timber resource statistics for the Fraser basin were included in Boeckh *et al.* (1991). For the areas actually directly adjacent to the Fraser River and not within its tributaries (e.g., Nechako River), the following was reported:

	Lower Fraser	Fraser Basin (Total)	% Lower Fraser of Fraser River Basin
Total Forest Area (ha.)	471 750	21 180 610	2.23
Operable Forest Area (ha.)	157 037	9 591 232	1.64
Operable Volume (m^3)	35 734 000	1 794 937 000	1.99
Unsalvaged Losses (m^3/a)	5 300	1 294 500	0.41
Allowable Annual Cut (m^3/a)	756 100	24 597 900	3.07

These data indicate that forestry is of minor importance from a harvesting perspective in the lower Fraser River and its tributaries in comparison to the remainder of the basin. However, logs are imported to the wood manufacturing plants, especially in the estuary area, from outside the basin. In discussing the impacts of forestry harvesting on the upper Fraser River and its tributaries, Swain *et al.* (draft report) concluded that although forest harvesting can result in a high sediment load to the water bodies, the high natural sediment load of the Fraser River itself would result in forestry impacts being most important on tributaries, but of minor concern on the main stem of the Fraser River (Swain *et al*., draft). Thus, forest harvesting will be of little concern below Hope.

Impacts from other aspects of wood processing operations are discussed in sections which follow in this chapter, or have been described in Chapter 4.

5.2 Agriculture

The amount of farmland in the Fraser Basin has been reported (Boeckh *et al.*, 1991 and Schreier *et al.*, 1991) as follows for the main Fraser River reach:

	Lower Fraser	**Total Basin**
% of area in Farmland	9.6	4.5
Farmland (ha.)	68 694 (6.5% of basin)	1 050 867
% Improved *	76	31
% Crops	55	-
% Pasture	27	-
Area fertilized (ha.)	33 176	131 420
Application rate (t/ha.)	0.54	0.26
Number of grazing animals	179 026	656 333
Stocking Density (#/ha.)	2.61	0.62
Number of chickens	17 515 928	18791 061
Number of pigs	145 640	175 019
Pesticide use (ha. sprayed)	19 294	29 275

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

Some very important information is apparent in this table. First, the stocking density of grazing animals is about four times higher than in the remainder of the basin, with over 25% of these types of animals being in the Lower Fraser basin. As well, virtually all the pigs and chickens raised in the Fraser Basin are in the Lower basin.

The estimates for nutrient coefficients proposed by Bangay (Swain, 1987) were used to determine potential loadings from cattle (7.92 kg P and 68 kg N per animal per year). Using the data for grazing animals, and assuming all were cattle, the potential yearly loading could be 1 417 885 kg P and 12 173 768 kg N in the lower Fraser reach. For pigs and chickens, estimates used by FREMP (1990c) of 0.15 kg P/a/animal and 0.43 kg N/a/animal for broiler chickens and 4.98 kg P/a/animal and 18.9 kg N/a/animal for pigs were used to determine loadings of 725 287 kg P and 1 752 596 kg N for pigs and 2,627,294 kg P and 7 531 578 kg N for chickens.

For the purpose of this assessment, the following assumptions will be made:

(1) all of the phosphorus and nitrogen generated reach the Fraser River (which will never happen), and

(2) the nutrients are transported to the river with runoff during a release period of two weeks during November following a six-month build-up during the dry summer period of the year.

Using a flow of 563 m^3/s for the lower Fraser River at Hope (10-year 7-day low flow), 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	
	P	N	P	N
Grazing Animals	2.08	17.9	1.04	8.95
Pigs	1.06	4.04	0.53	2.02
Chickens	3.86	11.06	1.93	5.53

These calculated values indicate that nutrients from these three classes of animals could increase concentrations in the river. However, the assumptions are likely overly simplistic, in light of the fact that 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 main concern would lie with nutrients that reach well-lit tributaries.

The actual volume of runoff from agricultural areas to the lower Fraser River would vary according to the amount of precipitation received. More runoff would occur in the estuary area than further upstream along the valley towards the Hope area. Total runoff can be estimated from land area and average rainfall, and an assumed runoff coefficient. GVRD estimates used the area in Agricultural Land Reserves, an average precipitation for each reach of the Fraser River Estuary, an estimated amount of irrigation, and a runoff coefficient of 0.3 to derive a runoff total of 632,000 m3/d, or 230,700,000 m3/a, from agricultural areas within the Fraser River Estuary (Bangay, 1976).

The data for pesticide use indicate that pesticides were used on 66% of the farmland in the lower Fraser reach. Ninety percent of all insecticides used in the Basin and 56% of all fertilizers were applied to lands downstream from Hope. Depending upon the distance of the treated areas from the river, the application rate for the pesticide, and the types of pesticides, the types and quantities of pesticides that may reach the river would vary. 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. As was the case with nutrients from grazing animals, the main concern would lie with pesticides that reach tributaries. FREMP stated an area of concern for the estuary was the Crescent Slough on the Main Arm where field runoff might concentrate relatively small amounts of pesticides in small quantities of slow-moving water (1990c). "Another area of concern is on the North Arm where pesticides used on cranberry farms may be washed into the estuary when flooded fields are drained following berry harvest" (FREMP, 1990c).

5.3 Urban Stormwater Runoff

Typical concentrations for different variables were prepared under the Fraser River Action Plan (Stanley and Associates, 1992) and selected variables are presented below. These ranges were based in part on B. C. studies reported by Hall and Anderson (1988) Lawson *et al*.. (1985), Swain (1983), and Bennett (1983).

Contaminant	Range	Concentration
Suspended Solids (mg/L)	100-150	125
Fecal Coliforms (#/100 mL)	20-24 000	12 000
Total Nitrogen (mg/L)	1.5-2.0	1.75
Total Phosphorus (mg/L)	0.3-0.4	0.35
Lead (µg/L)	100 - 200	150
Copper (µg/L)	20 - 50	35
Zinc (µg/L)	100 - 200	150
Nickel (µg/L)	20 - 30	25
Arsenic (µg/L)	10 - 15	13
PAH (µg/L)	0.3 - 12	1

Contaminant concentrations vary between sites, between storm events at any site, as well as with season. Mean monthly urban runoff volumes and contaminant loadings were quantified by FRAP for 25 municipalities totalling 91% of the basin population in the Fraser Basin (Stanley and Associates, 1992). The Lower Fraser Region in the Fraser Basin is the largest contributor of urban runoff to the Fraser River Basin, and the locations of the highest runoff volumes are shown below (Stanley and Associates, 1992).

Municipality	10^6 m^3/a	Municipality	10^6 m^3/a
City of Burnaby	81	City of Richmond	64.4
District of Pitt Meadows	6.0	District of Langley	36.2
City of Coquitlam	32.8	District of Surrey	31.7
City of Vancouver	30.2	**Total Estimated**	282

Using the typical concentrations and total estimated flows, as well as the low flow estimate of 1178 m^3/s at Port Mann, these discharges would be diluted by a factor of 9.27:1. This dilution would result in potential increases of 13.5 mg/L of suspended solids, 1295 CFU/cL fecal coliforms, 16.2 µg/L each of lead and zinc, 3.8 µg/L of copper, and 0.11 µg/L of PAHs.

5.4 Sawmills

Most of what follows in this section has been drawn directly from Envirochem Special Projects Inc. (1992). Some sawmills continually process treated lumber, while other mills exclusively cut cedar for portions of the year (depending on market demand), thereby reducing the storage area used for treated lumber. The loading estimates for the Fraser River were based on an average total yard area of 22 370 m^2 when actual storage yard areas were unknown.

Envirochem sampled stormwater runoff at mills using anti-sapstain chemicals during January and February 1992. Chlorophenols were identified as a likely major source of toxicity in runoff, while PAHs were considered to be insignificant relative to other chemicals (ESP Inc., 1992).

5.5 Contributions From Septic Tanks

Most of this section has been drawn directly from FREMP (1990c). Approximately 135 septic tanks are installed at locations along the North and Main Arms below the water table, and it is assumed that they do not work effectively for this reason. Contaminants of concern are BOD, suspended solids, ammonia, and pathogens. Estimated BOD and suspended solids loadings are 17,115 kg/year, 1,710 kg/year of ammonia, and a most probable number of 16.3×10^{15} fecal coliforms/year. These are less than 1% of those from the Annacis Sewage Treatment Plant.

ESTIMATED LOADINGS FROM SEPTIC TANKS,
FRASER RIVER ESTUARY, 1987

		Loadings(kg/year)			
Reach	**Residences (estimated)**	**BOD**	**Suspended Solids**	**Ammonia**	**Fecal Coliforms ($x 10^{15}$)**
Fraser R. North Arm	15	315	315	30	0.3
Fraser R Main Arm	120	2,520	2,520	250	2.4
Kanaka Creek	900	1,890	1,890	190	1.8
Pitt River	2,000	4,200	4,200	420	4
Coquitlam River	300	630	630	65	0.6

NOTES: It is assumed that only 10% of the actual loadings could enter the water body, except for the North and Main Arm where 100% is assumed.
(Source: GVRD, 1988b)

5.6 Underground Storage Tanks

Most of what follows in this section has been extracted directly from FREMP, 1990d. Underground storage tanks in the Fraser River estuary area are primarily for the storage of petroleum products. There are underground tanks at 545 service stations in the GVRD, and about 75,000 domestic heating oil tanks. As most of the Greater Vancouver area is served by natural gas, most domestic fuel tanks are abandoned, but many still contain some amount of oil. Very few domestic tanks were taken out of service in a systematic way that would have left the tanks environmentally benign.

All tanks are subject to corrosion that may result in groundwater-contaminating leaks. In sewered areas, material from leaking tanks may infiltrate sewer lines and discharge to sewage treatment plants or directly to ditches and streams. In rural areas, leaking tanks could contaminate groundwater supplies.

5.7 Floating Homes, Houseboats, Live-aboards

Most of what follows in this section has been extracted directly from Reference 1.11. Waste management for floating homes is part of a larger regulatory issue. About

150 to 175 floating homes on the Fraser River are illegal as they do not meet municipal zoning requirements or Harbor Commission leasing regulations. Floating homes may be moored in places that are convenient for their owners, and raw sewage may be discharged over the side. While some marinas service their floating homes with water and sewer connections, they may not be zoned for floating homes. Concerns regarding illegal floating homes are for discharges of untreated sewage direct to the Fraser River. Loadings were estimated to be as follows:

Characteristic	**Concentration[1] (mg/L)**	**Flow/Loading[2] (kg/a)**
Discharge (m^3/a)	-	72 562
BOD_5	250	18 141
Suspended Solids	250	18 141
Ammonia	25	1 814
Fecal Coliforms	24 000 000 MPN/100 mL	1 700 x 10^{13}

1 Assumed similar to that in the influent sewage to the Lulu Island Sewage Treatment Plant.
2 Based on 175 vessels discharging 1 136 L/d/unit.

There are about 60 live-aboards in the Fraser River estuary area. As live-aboards usually have fewer facilities than floating homes, total discharge and loadings from these vessels are less than one third that of floating homes (FREMP, 1990a).

5.8 Shipping, Fishing Boats, Pleasure Craft

Most of what follows in this section is drawn directly from FREMP, 1990d. Estimates of sewage generated from boats in the estuary depend on the number of onboard sewage facilities, on-shore pump-out facilities, rate of use of pump-out facilities versus discharge overboard, number of boats, volume of usage, estimated by person-days of boating, and amount of sewage generated for each person day. Studies in Puget Sound suggest pump-out facilities there are inadequate to deal with the volume of use required to fulfill the intent of their regulations. The proportion of vessels with marine sanitation devices, and the availability of pump-out facilities, is lower in the Fraser Estuary than it is in Puget Sound.

Annually, over 500 freighters enter the Fraser ports, along with occasional cruise ships. Over 800 fishing boats moor at Steveston, Ladner, Annieville, and other properties, plus another 300 during peak periods. There are over 40 marinas, wharves, docks, or boat launch areas along the Fraser River estuary and Boundary Bay, with over 2,000 berths.

5.9 Marine Timbers

Most of what follows in this section is drawn directly from FREMP, 1990d. Almost all marine timbers used in the Fraser River estuary are preserved with creosote, a coal-tar distillate consisting principally of liquid and solid aromatic hydrocarbons, including polyaromatic hydrocarbons (PAHs). Relative compositions of creosote components vary from batch to batch due to differences in the character of the tar and the distillation process, but the PAH content is usually around 50%. Naphthalene and the other low molecular weight PAHs usually predominate. The low molecular weight PAHs are generally more acutely toxic to aquatic organisms, while most high molecular weight PAHs are carcinogenic (FREMP, 1990a). High PAH levels in sediments have been indicated by incidences of tumors and liver lesions in bottom dwelling fish from other geographical locations. Creosote treated marine timbers are a suspected source of PAHs to the Fraser River Estuary.

There are 1,444 m of timber training structures at Steveston Island and Sapperton, a 430 m timber and steel structure at the New Westminster river trifurcation, 6,588 m of timber and rock structures at the New Westminster trifurcation, Sapperton Island, and Albion Island. All log storage areas in the estuary have dolphins or pilings to which the booms are moored (FREMP, 1990a).

5.10 Bridge-Sandblasting and Repainting

Most of what follows in this section is drawn directly from FREMP, 1990d. There are 20 road or rail bridges over the Fraser River within the estuary, and several more bridges over Fraser River upstream from the estuary and in its tributaries. Those that are wooden trestle bridges or that rest on wooden pilings are generally preserved with creosote, and are included in the marine timbers section above. The others are steel or concrete structures which require periodic maintenance and repainting (FREMP, 1990a)

Bridge-sandblasting and repainting may introduce sand, slag, and paint particles to receiving waters unless this is prevented. These contaminants can cause an impact on aquatic organisms through toxicity, turbidity, clogging of gills, and smothering of benthic vegetation (FREMP, 1990a).

5.11 Ship Building, Repair, and Maintenance Facilities

Most of what follows in this section is drawn directly from FREMP, 1990d. One major and several smaller ship-building, repair, and maintenance facilities are located in the estuary. These include: B.C. Ferries Corp., B.C. Packers Limited, Progressive Marine Limited, Purvis Navcon Shipyard Limited, Rivtow Shipyards, Shore Boat Builders Limited, Tom-Mac Shipyards Limited, and Vito Steel Boat and Barge Construction Limited. These facilities construct, convert, alter, or repair a variety of ships and barges, frequently in dry dock. Activities include cargo or fuel tank cleaning, abrasive removal of paint, and repainting (FREMP, 1990a).

Environmental concerns are centered on the release of metal-based blasting abrasives, old paint debris, and spills of waste oil, solvent, and paint. Metal and organic contaminants may accumulate in sediments, and cause biologic toxic responses. When dredged, these contaminated sediments present a further problem of safe disposal (FREMP, 1990a).

Swain and Walton (1992) investigated contaminated sediments adjacent to two such operations; one in the Main Arm and one in the North Arm. At B.C. Ferries in the Main Arm, concentrations of metals in the sediments from the three sites in the backwater area near the refit/servicing area were similar to or slightly higher than those found at a site in Ewen Slough. Lead concentrations in the sediments near the docking area were considerably higher than at the other sites, at 18.4 µg/g (dry-weight) (Swain and Walton, 1992).

Acid Volatile Sulfide (AVS) concentrations were quite high when compared to AVS concentrations at the Ewen Slough monitoring site. The sediment extracts were non-toxic using the sand dollar test. Using the solid-phase microtox test, it was determined that the most toxic sediments were near the docking area (Swain and Walton, 1992).

The highest concentrations of individual PAHs was found at a site furthest from the river, except for dibenzo(a,h)anthracene which could not be detected (<0.020 µg/g dry-weight) at any of the sites. The concentrations of several individual PAHs at all three sites exceeded the water quality objectives for PAHs in the sediments in Burrard Inlet. These PAHs include fluoranthene (objective of 0.17 µg/g dry-weight), phenanthrene (objective of 0.15 µg/g dry-weight), and pyrene (objective of 0.17 µg/g dry-weight). As well, the fluorene concentration of 0.064 µg/g (dry-weight) at the site furthest from the river exceeded the objective of 0.05 µg/g (dry-weight) (Swain and Walton, 1992).

The objective for PCBs was achieved at all sites except opposite the mooring area near the river. All the chlorophenols and most of the PCBs were below varying detection limits (except a detectable value for PCB 1260 of 0.05 µg/g dry-weight at the site near the river but across the backwater area from the docking area) (Swain and Walton, 1992).

The highest concentrations of resin and/or fatty acids were at the site opposite the docking area near the river for all other acids. Except for sandaracopimaric acid, the concentrations at that site exceeded the maximum concentrations for the five replicates reported at the Ewen Slough site. There were low concentrations of organotins which were generally spread equally around the backwater area (Swain and Walton, 1992).

At the Celtic Boat Yard in the North Arm, concentrations of metals were about the same as found in sediments from McDonald Slough. Exceptions to this were lead, which was slightly higher, and zinc which was higher, possibly indicating a slight influence from stormwater discharges (Swain and Walton, 1992).

AVS concentrations were less at one site and greater at the second site, than those measured at the McDonald Slough routine monitoring site. The sand dollar test on the sediment extracts showed that sediments from near the opening to the river were non-toxic and those further removed were toxic. The results from the solid-phase microtox test concurred with the relative toxicity of the sediments, that the sediments near the opening to the river were more toxic than those further away (Swain and Walton, 1992).

PAH concentrations were generally lower than found at the McDonald Slough site, and were below the water quality objectives for PAHs in sediments from Burrard Inlet (Swain and Walton, 1992).

Three of the resin and/or fatty acids were higher at the Celtic Boat Yard than at the McDonald Slough site, an area where log booms are stored frequently. The three acids were abietic (1.68 compared to 1.14 µg/g dry-weight), chlorodehydroabietic (0.404 compared to 0.093 µg/g dry-weight), and pimaric (0.55 compared to 0.23 µg/g dry-weight). This was also the case at the North Arm boat launch site (Swain and Walton, 1992). Organotin concentrations in the sediments were higher at the site located closer to the opening of the backwater area to the river, although there is no direct evidence that the ships were responsible for these elevated values (Swain and Walton, 1992).

5.12 Log Handling Debris and Leachates

Most of what follows in this section is drawn directly from FREMP, 1990d. The Fraser River Estuary is an important log handling area for the B.C. coastal forest industry. Forty processing operations are located in the estuary, consuming 25% of coastal timber production. Logs are stored in the river for mill supply and for protection against marine borers. It was determined that the freshwater storage space leased in the estuary, 3,217 ha. of the estuarine area, is sufficient for current needs (FREMP, 1990a).

Debris control was also identified as a management issue needing clarification and study (FREMP, 1990a). Log abrasion, bark removal, and debris deposition occur during towing, barge dumping, bundle breaking, sorting, and storage. Debris smothers benthic organisms and habitat. Decaying debris may result in oxygen depletion or hydrogen sulfide production. Leachates are released from freshly cut logs (FREMP, 1990a). Other problems related to log storage include: grounding, shading, scouring and alteration of currents. While these are not strictly water quality concerns, they do affect aquatic life habitat.

5.13 Dredging

Most of what follows in this section is drawn directly from FREMP, 1990d. Annual dredging is required to maintain shipping channels in the river. Periodic dredging is also required to maintain depths in shipping berths and sawmill sorting ponds. New dock construction, or requirements for fill material, may require that sediments be excavated. Clean dredgate is routinely disposed of in deep water, at disposal sites on the outer estuary at Sandheads and Point Grey, or used as on-shore fill. However, if the sediments to be dredged are contaminated, handling and disposal become more complex; this is the contaminated sediment problem (FREMP, 1990a).

Sediments which are dredged from the Fraser River are analyzed prior to dredging as required by Environment Canada in support of applications for ocean disposal permits under the Canadian Environmental Protection Act, Part VI. Environment Canada's *Interim Contaminant Testing Guidelines for Ocean Disposal, Pacific and Yukon Region*, (revised 1993 August) provides guidelines for the sampling, analysis and reporting associated with proposed ocean disposal activities. FREMP (1994e) summarized the sediment analysis data from the Fraser River Estuary (as well as those from other sources), and assessed them relative to *British Columbia Standards for Managing Contamination at the Pacific Place Site* (BCS).

"In conclusion, the sediments from the Fraser River Estuary are considered uncontaminated and contain natural background levels for metals and organics. Less than 1% of all the samples analyzed showed any sign of contamination when compared against the BCS. Upstream from the trifurcation not a single sample showed elevated levels of any contaminant when compared to the BCS." (FREMP, 1990e).

5.14 Flooding and Soil Erosion

Most of what follows in this section is drawn directly from FREMP, 1990d. Cranberries are harvested during October-November by flooding fields with river water, and collecting the floating berries. The water is then discharged back into the river. Wood waste berms are used to keep the water on the fields, and wood waste is used for field access roads. Waste management concerns lie in the amount of wood waste leachate and pesticide residue in the water returned to the river. Cranberry farms are concentrated along the North Arm (FREMP, 1990a).

Soil erosion occurs with runoff and peaks during flooding. From a waste management perspective, soil erosion has two potential contaminant problems. One is the presence of soil particles in water as sediments. These increase turbidity, decrease light penetration in the water, adversely affect photosynthesis, and affect predator/prey relations through impacts on visibility. When sediments settle out, they may smother bottom vegetation, fish habitat, and fish eggs. The second potential problem is the introduction of contaminants that are adsorbed to the soil particle. Nutrients such as phosphorus and pesticides such as DDT and parathion readily adsorb to soils and are relatively immobile unless the soil is moved (FREMP, 1990a).

5.15 The Vancouver International Airport (Middle Arm)

One of the only known attempts to characterize runoff from the Airport area was undertaken by Swain and Walton (1992) when samples of sediments from one ditch leading to the middle Arm were collected. Most of the metals concentrations measured in the river sample were at concentrations approximately equal to those from the McDonald Slough site. This was not the case for the sediment sample collected from the ditch leading to the river (Swain and Walton, 1992).

The sample from the ditch had 1.95 µg/g (dry-weight) of cadmium, compared to concentrations 0.22 to 1.45 µg/g that we reported for a survey of five ditches leading to Boundary Bay. The lead concentration in the ditch (68.4 µg/g dry-weight) is quite high, and in fact is higher than reported for 4 of 5 ditches leading to Boundary Bay (12.9 to 81.8, mean 31.3 µg/g dry-weight). The zinc concentration in the ditch was 216 µg/g compared to a range from 62.6 to 173 µg/g (dry-weight), in those same five ditches. The source of the cadmium, zinc, and lead to the ditch should be investigated. The presence of cadmium, lead, and zinc in high concentrations suggests that stormwater runoff may contribute these metals, although the presence of high cadmium concentration suggests that paint may be a source of cadmium to the ditch (Swain and Walton, 1992).

The AVS concentrations were determined to be low in the river but very high concentrations in the ditch sample. The two toxicity tests on the extracts from the sediments were non-toxic. The solid-phase microtox test indicated considerable toxicity for the ditch sample. In fact, that sample was the most toxic of all sediments tested for this survey, according to the solid-phase microtox test procedure. The samples from the river were among the least toxic reported for this survey using this test procedure (Swain and Walton, 1992).

Concentrations of PAHs in the sediments from the ditch were about ten times higher than we found in the river sediments. The PAH concentrations in the river were less than the maximum for all the replicates from the McDonald Slough site NA-2, and were less than or equal to the water quality objectives for PAHs in the sediments from Burrard Inlet. In the ditch, all the individual PAHs exceeded the water quality objectives for PAHs in the sediments from Burrard Inlet, except acenaphthene (0.028 µg/g compared to the objective of 0.05 µg/g dry-weight) and naphthalene (0.025 µg/g compared to 0.2 µg/g dry-weight). It is suspected that these high sediment PAH concentrations may be responsible for the high toxicity noted using the solid-phase microtox test procedure (Swain and Walton, 1992).

The objective for PCBs was not achieved in the ditch sample where a concentration of 0.152 µg/g (dry-weight) of PCB 1254 was measured. This was the highest PCB 1254 concentration measured in this survey (Swain and Walton, 1992).

Resin and/or fatty acids concentrations were less than those measured in sediments from the McDonald Slough site. In fact only two acids were in measurable concentrations in the ditch sample, indicating that the ditch is unlikely to be a source of acids to the river (Swain and Walton, 1992).

6. AMBIENT WATER QUALITY AND PROPOSED WATER QUALITY OBJECTIVES FOR THE FRASER RIVER

The development of Water Quality Objectives for the Fraser River is based on the principle of protecting and conserving the most sensitive water uses of the river. To accomplish this, established limits such as the B.C. Approved and Working Criteria (Nagpal *et al*., 1995) and the Canadian Water Quality Guidelines (CCME, 1987); as well as environmental parameters such as local water quantity and quality, water movement, and salinity intrusion; and socio-economic factors such as competing water uses must be considered.

6.1 Fraser River from Hope to Chilliwack

The Hope to Chilliwack region of the Fraser River contains an abundance of pasture and grasslands used for agriculture and ranching; accordingly, livestock watering and irrigation must be considered important water uses. The river is also one of the most important migration routes for salmonids, therefore, water quality must be consistent with good fish health. Less commonly, this reach of the river is used for industry and recreation (Swain and Holms, 1985a).

Sensitive aquatic life requires the most stringent water quality criteria and will therefore be the basis for most criteria.

6.1.1 Water Chemistry

Water chemistry was tested at eight sites between Hope and Chilliwack. Sites 0301506, 0301507, 0301508 and 0301509 are located around the Chilliwack sewage treatment plant. Sites E207393, E207394 and E207603 record data in the area of the Kent outfall. Site E206581 (joint Environment Canada/B.C. MELP) is located in Hope (Figure 7). Data are summarized in Tables 59, 60, 61, 62, 63, 64, 65 and 66, respectively. The Hope site contains the most complete data set and in cases where no data are available for downstream sites, the data collected at Hope are used to extrapolate values for the entire section between Chilliwack and Hope. The SEAM data collected between 1985 and 1994 are augmented by information from the technical appendix "Fraser River

Sub-Basin From Hope to Kanaka Creek Water Quality Assessment and Objectives" completed in 1985 (Swain and Holms, 1985a).

6.1.1.1 pH and Alkalinity

The data between Hope and Chilliwack indicates little to no change in the pH. There are no significant trends or changes in pH between Kent and Chilliwack with all values being slightly basic and ranging from 7.2 - 8.2 with a mean of 7.8 (see following table). This is well within permitted criterion of 6.5 - 9.0 for sensitive aquatic life (McKean and Nagpal, 1991). Although the data indicate the same mean pH for the Fraser River at Hope, the data were of a much wider range with values from 5.6 to 8.2 (see following table). The lower value is not within the criterion range for the protection of aquatic life, however, the report states that this value is questionable and that much of the data are low biased. From the data presented, the Fraser River from Hope to Chilliwack appears to have a pH that is consistent and stable (McKean and Nagpal, 1991).

The maintenance of near-neutral pH is important in order to minimize the formation of toxic un-ionized ammonia (Swain and Holms, 1985a). <u>For this reason, a Water Quality Objective for pH of 6.5 to 8.5</u> is proposed for all discrete samples of water collected between Hope and Chilliwack outside the initial dilution zone.

pH VALUES MEASURED AT THE PROVINCIAL MONITORING SITES BETWEEN HOPE AND CHILLIWACK

		Measured pH				Criteria pH	
Site	Location	Number	Max	Min	Mean	Irrigation	Aquatic Life
301506	Chilliwack STP (75m U/S)	26	8.2	7.7	7.9	5 - 9	6.5-9.0
301507	Chilliwack STP (100m	26	8.1	7.2	7.7	5 - 9	6.5-9.0
301508	Chilliwack STP (200m	1	8.2	8.2	8.2	5 - 9	6.5-9.0
E207393	Kent STP U/S	13	8.1	7.6	7.9	5 - 9	6.5-9.0
E207394	Kent STP IDZ	4	7.8	7.3	7.6	5 - 9	6.5-9.0
E207603	Kent STP (100m D/S)	7	8.1	7.9	8	5 - 9	6.5-9.0
E206581	Hope *	98	8.2	5.6	7.8	5 - 9	6.5-9.0

* This is a joint Provincial/Federal monitoring site.

Alkalinity is a measure of buffering capacity with higher values being more able to accommodate fluctuations in pH. Only the Hope site (E206581) had available alkalinity data. The river is moderately buffered to acidic inputs, with a mean alkalinity concentration 61.9 mg/L (n=2).

6.1.1.2 Hardness and Metals

Hardness is an important determinant of the toxicity of several metals. Water of higher hardness is generally less toxic to aquatic biota than softer water of the same metal concentration.

The Hope site (E206581) had the only available calcium and magnesium data (n=44). These figures were used to estimate hardness for this section of the river. Between 1985 and 1994, the mean hardness was calculated to be 63.5 mg/L $CaCO_3$, which is considered moderately soft (<75 mg/L) (SEAM, 1994). This is an increase from the mean value of 56.6 mg/L $CaCO_3$ recorded between 1966 and 1980 (Swain and Holms, 1985a). There is no hardness criterion set for the protection of aquatic life, but values do exceed the criteria for some industrial processes such as those using boilers. The criteria for these industries is between 0.07 and 1.0 mg/L $CaCO_3$ (CCME, 1987). No Water Quality Objective are proposed for water hardness for this reach of the Fraser River.

Metal values also were extrapolated from the Hope site as it was the only site with available data.

Aluminum

The approved criterion for the maximum dissolved aluminum concentration for freshwater aquatic life is 0.1 mg/L with a 30-day average concentration of 0.05 mg/L at pH >6.5 (Butcher, 1988). However, the data collected were measured as total, not dissolved aluminum. The criterion for livestock watering was expressed as total aluminum but this is not the most stringent criterion. The maximum concentration measured at Hope was 13.3 mg/L, well above the 5 mg/L maximum criterion for livestock watering (Butcher, 1988). The mean of the collected data was 1.77 mg/L (n=65) but there is no 30-day average to compare this to. It should be noted that out of 12 dates having an aluminum concentration above 2 mg/L, eight also had high suspended solids concentrations. These samples were collected in summer when the river flow and erosion rates are high. This suggests that much of the aluminum may be associated with suspended solids rather than dissolved. It is impossible to know how much of the total aluminum was dissolved and therefore it can not be determined whether the aluminum concentrations are above the criterion for the protection of aquatic life.

Arsenic

SEAM data collected between 1985 and 1994 report that total arsenic concentrations measured at Hope were all below detection limits which ranged from < 0.001 to < 0.3 mg/L. Only two of the eleven samples meet the criterion of 0.05 mg/L for the protection of aquatic life. The other nine had detection limits of 0.1 mg/L. As such, it can not be determined whether the concentrations measured at the time meet the criterion for the protection of aquatic life. However, even without taking the detection limit into account, all values are within approved livestock and irrigation levels of 1.0 mg/L (Health and Welfare Canada, 1989 and CCREM, 1987). Previous data reported a mean value of 0.001 mg/L (Swain and Holms, 1985a).

Cadmium

Approved guidelines and criteria for total cadmium are based on water hardness. At a hardness of 63.5 mg/L CaCO3, the maximum approved cadmium level for freshwater aquatic life is 0.00002 mg/L(CCREM, 1987). Total cadmium levels from the Fraser were all below detection which ranged from < 0.0005 mg/L to < 0.01 mg/L. Because the approved criteria for total cadmium is below detection limits for measurements, no decisive conclusions can be made about whether cadmium levels are of concern.

Chromium

Total chromium levels were found to range from <0.005-0.02 mg/L and to have a mean concentration of 0.008 mg/L. All values are within the criterion of 0.02 mg/L for the protection of freshwater fish while detection limits exceed the 0.002 mg/L limit for freshwater plankton (Health and Welfare Canada, 1989, CCREM, 1987). Of the 44 measured values, 24 were below the detection limit of 0.01 mg/L and 17 had were below the detection limits of 0.005 mg/L. Data collected in 1973 had a maximum concentration of 0.0008 mg/L (Swain and Holms, 1985a). This indicates that the total chromium concentrations may be much lower than the detection limits allowed to measure.

Copper

Total copper levels ranged from < 0.001- 0.89 mg/L with a median of <0.01 mg/L. Copper criteria are based on the water hardness levels. According Singleton (1987), when the hardness is greater than 50 mg/L CaCO3, the maximum allowed copper concentration is calculated as follows:

copper (µg/L) = [0.094 (hardness) +2]

and the maximum average criterion is:

copper (µg/L) = [0.04 (average hardness)]

Based on a water hardness of 63.5mg/L as determined from sampling data collected between 1985 and 1994, the maximum copper criterion for the Hope to Chilliwack area based on water hardness measured is 7.97 µg/L and the maximum average is 2.54 µg/L. Both maximum and average copper concentrations exceed these criteria.

Iron

Total iron levels fell in a wide range from 0.17 mg/L to 14.1 mg/L. The mean value of 1.79 mg/L exceeds the 0.3 mg/L guideline for freshwater aquatic life (Health and Welfare Canada, 1989, CCREM, 1987). The highest total iron values were recorded during high flow periods between May and August (see Section 2). 41 of the 44 values exceeded the limit for aquatic life. These values are considerably greater than those collected between 1973 and 1976 which had values ranging from 0.025 mg/L to 4.0 mg/L and an average concentration of 0.806 mg/L (Swain and Holms, 1985a). Total iron is often high due to the iron content of suspended sediments. Further investigation may be required to determine whether the increase in iron levels is a trend that could lead to harmful effects or if it reflects a wider sampling effort.

Lead

Approved B.C. criteria for maximum lead levels for aquatic life (Nagpal, 1987) are calculated as follows:

$$\text{Maximum Lead } (\mu g/L) < \exp\,[1.273\ \ln(\text{hardness})-1.460]$$

Based on measured water hardness at Hope, the maximum criterion for lead is 0.0458 mg/L. Measured total lead levels were between < 0.001-0.1 mg/L with a median of < 0.1 mg/L (n=44). This value exceeds the criterion of 0.0458 mg/L for the protection of aquatic (Nagpal, 1987) but like the data for arsenic, some data were questionable. Effort should be made to ensure future detection limits are lower than the criterion so these concerns can be addressed.

Manganese

Total manganese concentrations ranged from <0.006 mg/L to 0.46 mg/L with a mean value of 0.049 mg/L (n=44). Values for data collected between 1985 and 1994 are slightly higher than those found between 1965 and 1976 which ranged from 0.002 mg/L to 0.37 mg/L with a mean of 0.041 mg/L (Swain and Holms, 1985). B.C. approved and working criteria specify that concentrations between 1 and 10 mg/L are considered safe for the protection of aquatic life, therefore, total manganese does not appear to be a concern for the biota. However, the more stringent criterion for the protection of drinking water use is 0.05mg/L and is exceeded by receiving waters in the Fraser River.

Mercury

The two total mercury concentrations measured were less than the detection limit of 0.00005 mg/L which is not low enough to ensure compliance with the proposed maximum 30-day average of 0.00002 mg/L (Nagpal, 1989).

Molybdenum

Total molybdenum levels were between < 0.01-0.02 mg/L with a median of < 0.01 mg/L (n=44) which is within criterion of 0.01 mg/L for the most stringent use, irrigation of forage crops (Cu:Mo $\leq$ 2:1) in poorly drained soil (Swain, 1986). No detectable concentrations were found between 1973 and 1974 when detection limits were as high as 0.05 mg/L (Swain and Holms, 1985a).

Nickel

Total nickel concentrations at Hope were between <0.05-0.08 mg/L with a median of <0.05 mg/L. This exceeds 0.025 mg/L for the protection of sensitive aquatic life (with water hardness of 0-60 mg/L $CaCO_3$) (CCREM, 1987)) but values are not conclusive because 43 of the 44 values were lower than the detection limit of 0.05 mg/L. The median value taken from 1973 and 1974 was less than 0.001 mg/L which is within criteria parameters (Swain and Holms, 1985a).

Zinc

The approved zinc criterion for freshwater aquatic life is tentatively set at 0.03 mg/L although phytoplankton may be affected at much lower levels (Health and Welfare Canada, 1989, CCREM, 1987). The mean zinc level of 0.024 mg/L is below the approved criterion, but it is considerably higher than reported from 1969 - 1976 (0.007 mg/L) (Swain and Holms, 1985a).

Total levels of arsenic, cadmium, chromium, copper, iron, lead and nickel exceed approved criteria, often exceeding these values by 1000 times but all of the metals except iron have detection limits too high to determine their true concentration. The values for lead and zinc appeared high and may have increased from earlier reports. Only total metal concentrations are reported; these values are greatly influenced by high flow and erosion rates. During spring freshet, between April and June, the flow rate and water volume in the Fraser increases, in the order of 1000 m^3/s in February compared to 4000 m^3/s in August (see Section 2 - Hydrology). This increased flow resuspends particles and detritus. High suspended solids concentrations contribute to elevated metal levels (see Section 2). Metal values were not considered to be a concern for water quality in the Fraser River between Hope and Chilliwack.

6.1.1.3 Dissolved Oxygen and Oxygen-Consuming Materials

The dissolved oxygen content of a body of water indicates its capacity for maintaining aerobic aquatic life. The oxygen requirements of fish and other aquatic organisms are influenced by the life stage of an organism, activity level of an organism, time of year, and ambient temperature. Because the oxygen content of water decreases with temperature and salinity, a fish breathing in warm or saline waters exerts more energy than the same fish utilizing cold freshwater to obtain an equal volume of oxygen and its metabolic oxygen demand increases concomitantly. Consequently, meaningful oxygen criteria must consider the dissolved oxygen content, critical oxygen available to fish, as well as temperature and salinity effects on activity level and metabolism in order to provide a full measure of protection to aquatic life (Davis, 1975).

It is important to note that low oxygen levels in the presence of some toxicants such as ammonia and some metal salts increase the lethality of the toxicants on some fish. Little information is available concerning the effects of low levels of dissolved oxygen on invertebrates. However, Davis (1975) reported that changes in community composition are to be expected from changes in natural oxygen conditions.

It is found that salmonids have higher oxygen demands than non-salmonids (6.5 mg/L) and that salmonids in their early stages are more demanding (11.0 mg/L) than adults (8.0 mg/L) (Davis, 1975; USEPA, 1986). Sites between Hope and Chilliwack have dissolved oxygen concentrations ranging from 8.9-11.1 mg/L with a mean of 10.0 mg/L. Within this stretch, sites near Kent and Chilliwack had values between 9.5 and 10.3 mg/L (Water Quality in B.C. Objectives Attainment 1993, 1994). Although the Fraser River is vital to salmonids, it is not within water quality objectives for the protection of hatching eggs, embryo, and larval salmonids (Davis, 1975; USEPA, 1986).

While it is more conventional to express water oxygen levels in terms of oxygen concentration (mg oxygen/ L of water) than percent saturation, it is proposed that the dissolved oxygen levels be specified in terms of percent saturation as well. While the percent saturation of dissolved oxygen will reflect changes in temperature and salinity, an absolute measure of dissolved oxygen content will not. Below 75% saturation, the blood of adult salmonids cease to be fully saturated (Samis, personal communication). According to Davis (1975), early stages of coho salmon (5.1-14.8cm) suffer increased levels of acute mortality in waters polluted with toxic discharges when dissolved oxygen levels are below 80% saturation.

To maintain high oxygen concentrations, and using the criteria from Truelson (1997) as a basis, a Water Quality Objective for the Fraser River from Hope to Chilliwack is that the instantaneous minimum should not be less than 5 mg/L and the 30-day mean should not be lower than the higher of 80% saturation or 8.0 mg/L. In spawning areas where fish eggs are incubating or areas utilized by young fish, the Water Quality Objective is an instantaneous minimum of not less than 9 mg/L and a 30-day mean not lower than 11.0 mg/L (November to April).

DISSOLVED OXYGEN CONCENTRATIONS MEASURED AT THE PROVINCIAL MONITORING SITES BETWEEN HOPE AND CHILLIWACK

		Dissolved Oxygen Concentrations (mg/L)				**Dissolved Oxygen Criteria (mg/L)**	
Site	Location	No. of Values	Max	Min	Mean	Salmonids	Non-Salmonids
301506	Chilliwack STP (75m U/S)	4	10.3	9.5	10	embryo 8-11	embryo 5-6.5
301507	Chilliwack STP (100m D/S)	6	10.4	8.9	9.8	adult 5-8	adult 4-6
301508	Chilliwack STP (200m D/S)	1	11.6	11.6	11.6		
301509	Chilliwack STP (300m D/S)	1	11.1	11.1	11.1		
E207393	Kent STP U/S	4	10.2	9.8	10		
E207603	Kent STP (100m D/S)	4	10.1	9.9	10		

6.1.1.4 Solids, Turbidity and Colour

The restriction on suspended solids is important because it indicates the concentration of materials that may be damaging to fish gills or causing siltation of spawning beds. Langer (1980) reported that a 55% decrease in salmon egg survival resulted from a 12% increase in suspended solids, considering that under good conditions only 9 to 30% salmon eggs survive to emergence (Lill *et al.*, 1983), this parameter should be examined closely. Because the Fraser River is naturally very silty, especially at high flow, this parameter is of particular importance. Suspended solids are increased downstream from a discharge site and criteria require that the induced increase be no more than 10% above background levels where background levels are ≥100 mg/L or 10 mg/L over background levels where background levels are ≤100 mg/L (Singleton, 1985).

Suspended solids concentrations appear to be quite variable with values ranging from 1 to 380 mg/L (n=81)(see following table). Values over 100 mg/L occurred between April and July, while lower values were sampled in February and March. There are no data for upstream and downstream solids in the same time period, so no comparison can be made to the criterion. Data collected between 1965 and 1980 had an even wider range with values reaching almost 600 mg/L (Swain and Holms, 1985a). High values were measured during the freshet and high suspended solids are a natural occurrence in the Fraser River during periods of high flow.

SUSPENDED SOLIDS CONCENTRATIONS MEASURED AT THE PROVINCIAL MONITORING SITES BETWEEN HOPE AND CHILLIWACK

		Measures of Suspended Solids (mg/L)				Suspended Solids Criteria (mg/L)
Site	**Location**	**No. Of Values**	**Max**	**Min**	**Mean**	**Aquatic Life**
301507	Chilliwack STP (100m D/S)	1	27	-	-	10% increase above background when background ≥10
E207393	Kent STP U/S	5	7	1	4	10mg/L increase above background when background ≤10
E207394	Kent STP IDZ	4	52	4	26	10% increase above background when background ≥10
E206581	Hope	71	380	1	48	10% increase above background when background ≥10

Only a small number of turbidity observations (n=3) were available from the Hope site (E206581), and numbers presented should be viewed only as an estimate. The turbidity ranged from 2 to 25 NTU. A maximum turbidity of 5 NTU is required for the protection of aquatic life (Health and Welfare Canada, 1989). Clearly, this reach of the Fraser is in exceedance of criteria for aquatic life. There are not enough data to determine seasonal trends. Data collected from 1965 to 1980 also have a wide range, from 0.2 NTU to 210 NTU, and seasonal trends were not available (Swain and Holms, 1985a).

The colour criterion for contact recreation is 15 true colour units (TCU) (Health and Welfare Canada, 1989). Of the four samples collected from the Fraser River, measures did not consistently meet the criterion; the maximum concentration was 21 TCU while the average was 18 TCU. This mean is slightly lower than the average of 21.3 TCU recorded from 1965 to 1980 (Swain and Holms, 1985a). The range of values recorded from 1965 to 1980 was <5 TCU to 300 TCU. This wide range is most likely temporally related to normal flow rates and freshets of the river.

6.1.1.5 Nutrients

Ammonia criteria are dependent on pH and temperature; at higher pH and temperatures, lower concentrations of total ammonia nitrogen can be tolerated. Based on the maximum pH of 8.2 among sites and a temperature flux of 15-17 ^{o}C, the criterion for the 30-day average concentration for total ammonia nitrogen is 0.606 mg/L while the criterion for the maximum concentration for any discrete sample of water collected outside the initial dilution zone would be 3.62 mg/L (Nagpal, 1994). Only the site 300m downstream from the Chilliwack STP had an average 30-day concentration (0.8 mg/L) above the specified level. All values were found to be between 0.007 mg/L and 0.977 mg/L N, with the exception of one site (E207394) that had an average of 6.136 mg/L N (see following table). This site also exceeded maximum ammonia concentrations when all other sites were between 1/3 and 1/376 of criteria maxima (Nordin and Pommen, 1986). This can be explained by the fact that this site is within the initial dilution zone (IDZ) of the Kent sewage treatment plant. The data located downstream from the Kent outfall (E207603) had ammonia concentrations (mean<0.007 mg/L) within approved standards. However, the values were higher than data collected in 1993; these ranged from <0.005 - 0.006 mg/L (Water Quality in BC Objectives Attainment 1993, 1994). <u>Ammonia can be very toxic to fish and therefore, to protect the Fraser River as a spawning ground, the following water quality objectives have been set: the 30-day average concentration of total ammonia nitrogen should not exceed the concentration listed in Table 12 while the maximum concentration of total ammonia nitrogen should not exceed the concentration listed in Table 11. Where these levels are exceeded, it is recognized that the use of the waters by aquatic life are not adequately protected.</u>

AMMONIA CONCENTRATIONS MEASURED AT THE PROVINCIAL MONITORING SITES BETWEEN HOPE AND CHILLIWACK

		Ammonia Concentrations (15-17°C)				Ammonia Criteria when Temperatures are 15-17°C	
Site	Location	No. Of Values	Max	Min	Mean	*Average Conc. for Aquatic Life	Max Conc. for Aquatic Life
301506	Chilliwack STP (75m U/S)	32	0.136	0.005	0.016	@ pH 7.3: 1.78-1.53	15.4-15.2
301507	Chilliwack STP (100m D/S)	31	3.84	<0.005	<.977	@ pH 7.4: 1.78-1.53	13.9-13.7
301508	Chilliwack STP (200m D/S)	2	0.238	0.137	0.188	@ pH 7.5: 1.78-1.54	12.3-12.2
301509	Chilliwack STP (300m D/S)	17	2.08	0.135	0.8	@ pH 7.6: 1.79-1.54	10.8-10.7
E207393	Kent STP U/S	18	0.023	<0.005	<0.008	@ pH 7.7 1.79-1.54	9.3-9.2
E207394	Kent STP IDZ	4	14.1	0.475	6.136	@ pH 7.8 1.53-1.32	8.0-7.9
E207603	Kent STP (100m D/S)	12	0.015	<0.005	<0.007	@ pH 7.9 1.3-1.12	6.8-6.7
E206581	Hope	72	0.021	0.005	0.007	@ pH 8.0 1.09-.94	5.7-5.6

*approved values depend on temperature and pH so listed pH values are examples and do not correspond to the given sites

Criteria for nitrite are dependent on the chloride content of water; as the chloride level increases, criteria for nitrite also increase. Because chloride data are limited (n=3), the minimum recorded value was used to provide the most protective nitrite criterion possible. Five of the six sites from which data was available had maximum values less than the approved maximum of 0.06 mg/L and average concentrations less than the approved 30-day average of 0.02 mg/L (calculated using an average chloride concentration of < 2 mg/L) (see following table) (Nordin and Pommen, 1986). The one site (0301507) that exceeded the maximum had a detection limit above the criterion average. Swain and Holms (1985) reported a maximum concentration of 0.005 mg/L at Hope from 1977 to 1979. This was exceeded by three sites, 0301507, 0301508 an 0301509, with maximum concentrations of 0.132 mg/L, 0.006 mg/L and 0.055 mg/L respectively. The Chilliwack sewage treatment plant appears to have significant effects on the ammonia concentrations as all of these sites are located between 100 m and 300 m downstream. In order to protect fish health, a maximum and an average Water Quality Objective for nitrite related to the chloride concentration as shown in Table 13 is proposed. These values are consistent with uncontaminated sites upstream.

NITRITE CONCENTRATIONS MEASURED AT THE PROVINCIAL MONITORING SITES BETWEEN HOPE AND CHILLIWACK

		Nitrite Concentrations (mg/L)				Nitrite Criteria
Site	Location	No of Values	Max	Min	Mean	Aquatic Life
301506	Chilliwack STP (75m u/s)	16	0.005	<0.005	<0.005	Maximum 0.06 mg/L, 30-day Average 0.02 mg/L
301507	Chilliwack STP (100m d/s)	15	0.132	<0.005	<0.033	“
301508	Chilliwack STP (200m d/s)	2	0.006	0.005	0.006	“
301509	Chilliwack STP (300m d/s)	15	0.055	0.005	0.005	“
E207393	Kent STP u/s	1	0.005	0.005	0.005	“
E207603	Kent STP (100m d/s)	1	0.005	0.005	0.005	“

The maximum criterion for nitrate/nitrite for the protection of freshwater aquatic life is 200 mg/L N and the approved average concentration is 40 mg/L N (Nordin and Pommen, 1986). All eight values measured in 1993 were below 0.2 mg/L N (see following table). Mean values are comparable to those recorded between 1965 and 1980 of 0.112 mg/L N (Swain and Holms, 1985a).

NITRATE/NITRITE CONCENTRATIONS MEASURED AT THE PROVINCIAL MONITORING SITES BETWEEN HOPE AND CHILLIWACK

		Concentrations of Nitrate/ Nitrite (mg/L)				Nitrate/ Nitrite Criteria (mg/L)
Site	Location	No of Values	Max	Min	Mean	Aquatic Life
301506	Chilliwack STP (75m U/S)	2	0.12	0.12	0.12	max.: 200; avg.: 40
301508	Chilliwack STP (200m D/S)	2	0.13	0.12	0.13	“
E207393	Kent STP U/S	1	0.05	0.05	0.05	“
E207603	Kent STP (100m D/S)	1	0.05	0.05	0.05	“
E206581	Hope	2	0.12	0.1	0.1	“

Of the four sites tested for phosphorus, three had maximum concentrations less than 0.5 mg/L. Site E207394, which is within the initial dilution zone of the Kent outfall, had a maximum of 5.07 mg/L and a mean of 2.08 mg/L. There is no criterion for total phosphorus concentration in streams and rivers but the criterion proposed for lakes to prevent excess algal growth specifies concentrations of 0.005-0.015 mg/L (Nordin, 1985). When phosphorus concentrations are high, there is a high risk of excessive periphyton growth (Swain, 1994). None of the data meet the lake criterion, however the stream velocity and turbidity (making the environment light and not nutrient-limited) would likely allow for higher phosphorus concentrations in the river while remaining safe for biota. The mean concentration of the data collected since 1985 at Hope (0.033 mg/L) was slightly lower than the mean for data recorded at Hope between 1965 and 1976 (0.07 mg/L) (Swain and Holms, 1985a). Based on the limited data, phosphorus levels are not considered to be a concern in the Fraser River between Hope and Chilliwack.

TOTAL PHOSPHORUS CONCENTRATIONS MEASURED AT THE PROVINCIAL MONITORING SITES BETWEEN HOPE AND CHILLIWACK

		Concentrations of Total Phosphorus (mg/L)				**Total Phosphorus Criterion (mg/L)**
Site	Location	No. Of Values	Max	Min	Mean	Aquatic Life
301506	Chilliwack STP (75m U/S)	2	0.495	0.352	0.424	none proposed
E207393	Kent STP U/S	5	0.02	0.017	0.019	none proposed
E207394	Kent STP IDZ	4	5.07	0.124	2.077	none proposed
E206581	Hope	3	0.72	0.013	0.033	none proposed

6.1.1.6 Bacteriological Indicators

Fecal coliforms ranged from 2 to 41,000 CFU/cL with an average geometric mean of 121.5 CFU/cL (n=29). The geometric means often exceeded provincial criteria for all uses except the general irrigation criterion (1000 CFU/100 mL). In order to protect irrigation use for crops eaten raw, the proposed Water Quality Objective is the geometric mean should not exceed 200 CFU/100 mL fecal coliforms in any 30-day period with five samples collected as a minimum. The objective of 200 CFU/100 mL is presently exceeded by individual maxima at Sites 0301506 (230 CFU/100 mL), 0301507 (41000 CFU/cL), E207393 (1260 CFU/100 mL), E207603 (4200 CFU/cL), and E206581 (210 CFU/100 mL). Values varied widely and did not follow a seasonal trend. Numbers were lower from April to October when chlorination occurs but some of the highest values were also within this time period. Fecal coliform counts recorded in 1977 had a much smaller range of 20 MPN/cL to 480 MPN/cL (Swain and Holms, 1985a). Unfortunately, the units are not the same so direct comparisons are difficult. It would appear that although mean values are similar, the range of values was much greater in SEAM data collected since 1985. In contrast, the 1993 values have smaller ranges and lower maxima (Water Quality in BC Objectives Attainment 1993, 1994).

Escherichia coli (*E. coli*) numbers ranged from 2 to 290 CFU/cL with an average geometric mean of 29.7 CFU/cL (weighted average of all sites). This is generally within the 200 CFU/cL maximum criterion for livestock and the 77 CFU/cL (geometric mean) requirement for the irrigation of crops eaten raw (Warrington, 1988). In order to protect general livestock watering as well as the consumption of crops eaten raw, a provisional Water Quality Objective of no more than 77 CFU/cL *Escherichia coli* as a geometric mean has been proposed.

Enterococci had an average geometric mean of 13.7 CFU/cL (weighted average of all sites) which meets the maximum criterion of 50 CFU/cL for livestock and the criterion of 20 CFU/cL (geometric mean) for crop irrigation (Warrington, 1988). In order to protect general livestock uses, as well as crop irrigation, a provisional Water Quality Objective of 20 CFU/cL *Enterococci* as a geometric mean has been proposed.

Pseudomonas aeruginosa were also present but the median of geometric means (at four sites) was <2 CFU/cL which meets the criterion of 10 CFU/cL for irrigation with public or livestock access (Warrington, 1988). However, at Site E207603, maximum values reached 26 CFU/cL. Other maxima were in the range of 3 CFU/cL to 5 CFU/cL. As *Pseudomonas aeruginosa* bacteria may be introduced to the Fraser River from the sewage treatment plants, a provisional Water Quality Objective is proposed. This objective is that the 75th percentile of *Pseudomonas aeruginosa* in at least five samples collected within a 30-day period between the months of April and October should not exceed 10 CFU/100 mL, outside of initial dilution zones as described in Section 6.2.1.1.

Coliform counts, especially fecal coliforms, reached levels high enough to render irrigation of some crops harmful.

FECAL COLIFORM CONCENTRATIONS MEASURED AT THE PROVINCIAL MONITORING SITES BETWEEN HOPE AND CHILLIWACK

		Fecal Coliform Count (CFU/cL)		
Sites	Location	range	geom. mean	1993 range
301506	Chilliwack STP (75m U/S)	6-230	65	6-122
301507	Chilliwack STP (100m D/S)	2-41000	384	27-608
301508	Chilliwack STP (200m D/S)	40-140	75	9-39
E207393	Kent STP U/S	9-1260	78	-
E207603	Kent STP (100m D/S)	5-4200	85	5-44
E206581	Hope	11-210	37	-

OTHER MICROBIOLOGICAL INDICATOR CONCENTRATIONS MEASURED AT THE PROVINCIAL MONITORING SITES BETWEEN HOPE AND CHILLIWACK

		Coliform Count (CFU/cL)								
		Escherichia coli			***Enterococci***			***Pseudomonas aeruginosa***		
Sites	Location	range	# of samples	geom. mean	range	# of samples	geom. mean	range	# of samples	geom. mean
301506	Chilliwack STP (75m U/S)	11-110	4	33	2-36	4	9	2-4	4	2
301507	Chilliwack STP (100m D/S)	11-290	4	53	2-45	4	18	<2-3	5	med.<2
301508	Chilliwack STP (200m D/S)	n/a	0	n/a	n/a	0	n/a	n/a	0	n/a
E207393	Kent STP U/S	14-58	4	22	8-47	4	15	<2-5	4	med.<2
E207603	Kent STP (100m D/S)	2-58	3	11	6-35	4	13	<2-26	4	med.<2

6.1.1.7 Organics

Chlorophenols were sampled only at the long-term comprehensive monitoring site at Hope (E206581). Monochlorophenols were found to have concentrations less than detection limits of 0.05 µg/L of 0.1 µg/g (n=50). Recommended guidelines for chlorinated phenols specify that the concentrations of total monochlorinated phenols for the protection of aquatic life should not exceed 7 µg/L (CCREM, 1987). Thus, it appears that individual monochlorophenols were within their respective criteria. Research indicates that fish exposed to chlorophenols, chloroguaiacols, and extractable organochlorine substances bioconcentrate these contaminants in proportion to their aqueous concentrations (Servizi *et al*., 1993).

PCBs were at concentrations below 0.05 µg/L. Detection limits were not low enough to ensure concentrations were below approved criterion of 0.0001 µg/L for the protection of aquatic life; however, it does meet the less stringent criterion of 0.5 µg/L for irrigation (Nagpal, 1992).

6.1.2 Sediment Chemistry

Sediment data are taken from an organochlorine study of the Fraser and Thompson rivers prepared by Dwernychuk (1991). As part of an ongoing sampling program in the vicinity of ten pulpmills in interior British Columbia, samples were collected from the Thompson River and from the Fraser River between Prince George and the Banks in 1990 and 1991. Sediment data from the one sampling site of interest at Hope was collected on March 31, 1990 as a single, sediment grab sample and was analyzed for TCP (trichlorophenol), TeCP (tetrachlorophenol), PCP (pentachlorophenol), TCG (trichloroguaiacol), TeCG (tetrachloroguaiacol), TCC (trichlorocatechol), TeCC (tetrachlorocatechol), dioxins and furans. No dioxins, furans or other organochlorines were detected in sediments collected at upstream control sites.

The particle distribution was 69.1% silt or clay and 30% sand. The relative size of sediment particles can change considerably from year to year based on a number of variables including flow rates in the river and the amount of suspended particles introduced from land sources. Particle size is significant because smaller particles have a larger surface-area-to-volume ratio than larger particles and are thus able to adsorb higher concentrations of contaminants. Particle size composition of sediments is discussed in terms of sand (particles 0.063 mm - 2.00 mm in diameter) and silt and clay (particles <0.063 mm in diameter).

Total trichlorophenol was below the detection limit of 0.001 µg/g for all reaches of the river (Beak Consultants, 1991). This concurs with the 1989 and 1992 reports by Swain and Walton that report no detectable levels (<0.005 µg/g) (Swain and Walton 1990 and 1993) for the lower portion of the river.

The Hope site had one of the highest tetrachlorophenol concentrations in the river with a concentration of 0.0035 µg/g. Sediments collected from two sampling sites at the mouth had undetectable levels (Beak Consultants, 1991). Tetrachlorophenols were also undetectable (0.005 µg/g) at Ewen Slough (near the mouth) in 1989, 1990 and 1992 when sampled by Swain and Walton. This decrease in the concentration may be due to tidal influences or settling (Swain and Walton 1990, 1991, and 1993).

Pentachlorophenols followed exactly the same trend. Concentrations were undetectable up river, reached a maximum at Hope of 0.0028 µg/g and decreased near the mouth (Beak Consultants, 1991). Since chlorophenols are likely of anthropogenic origins and are not generally measurable in uncontaminated areas, it is proposed that a Sediment Quality Objective originally proposed for the lower Fraser River in 1985 of 0.01 µg/g (dry-weight) for the sum of mono-, di-, tri-, tetra-, and penta as an average of at least three discrete samples be maintained. This value is not likely to be exceeded in uncontaminated areas.

Trichloroguaiacol concentrations also followed this trend. The concentration in Hope was 0.0025 µg/g (Beak Consultants, 1991). Carey and Hart (1988) also detected guaiacols in the Fraser estuary.

Tetrachloroguaiacol was found in low levels in all of the river except two sites upstream from Prince George. The highest level measured was at Hope with a concentration of 0.0021 µg/g (Beak Consultants, 1991).

The highest concentrations of both trichlorocatechol and tetrachlorocatechol were recorded at Hope with concentrations of 0.016 µg/g and 0.039 µg/g, respectively. It is suspected that the Thompson River may be a major contributor to the lower Fraser River because concentrations at Dog Creek, located upstream from the Thompson, had no detectable levels (Beak Consultants, 1991).

The most toxic dioxin, 2,3,7,8-TCDD, was not detected in any portion of the river but furans were found in all lower Fraser sites (including Hope) except for one site at the mouth. Unlike the other organic contaminants, the highest concentration of furans was found at the mouth. Furans were also detected in the Thompson River and may be contributing to concentrations in the lower Fraser River (Beak Consultants, 1991). As dioxins and furans may be originating in effluents from the upstream pulp and paper mills, a Sediment Quality Objective is proposed for dioxins and furans in the Fraser River from Hope to Kanaka Creek. This objective is that the total TEQ of all PCDDs and PCDFs in any discrete sample also not exceed 0.25 pg/g. Both of these objectives apply only outside of initial dilution zones as described in Section 1.0.

With the exception of furans, all compounds tested reached maximum values between Hope and Mission and then decreased toward the mouth of the river. This may be due to an increase in sedimentation rates as the river widens and subsequently loses velocity.

6.1.3 Analysis of Benthic Invertebrates

Benthic invertebrate sampling is strongly advocated for the assessment of river pollution and its suitability is apparent in many respects. Benthic invertebrates serve important ecological functions: in addition to being integral components of the food web that supports other aquatic life, invertebrates function as shredders, grazers, and filter feeders of other biota, breaking down organic matter and recycling nutrients for their own use as well as utilization by other organisms. Moreover, their inherent restrictions in mobility and relatively long life spans (Northcote, 1976) render benthos effective recorders of water quality conditions in specific locations in a river. Chapman and Brinkhurst (1979, 1981a, 1981b, 1981c, 1981d, 1982, 1984) agree with Northcote *et al.* (1976) in their establishment that the abundance and composition of the benthic macrofauna in the Lower Fraser River vary with location and substrate. The variation in location may reflect ambient receiving environment quality that is influenced by point and non-point source anthropogenic discharges as well as natural changes in water quality as impacted by salinity intrusions, substrate composition, or seasonal changes in temperature or river flow.

Benthic invertebrate data were collected and analyzed by Northcote *et al.* (1976). Two monitoring stations were established between Hope and Chilliwack to assess the environmental impacts of forested areas and agricultural developments along this reach of the Fraser River. When bottom grab samples were collected with a Peterson grab of $626cm^2$ in 1972 and a Ponar grab with a slightly smaller area of $529cm^2$ (upstream n= 30, downstream n=30), the total abundance of benthos in the reach of the river at the two monitoring stations was approximately 1000 organisms per square metre for both sites with downstream measures being marginally higher than upstream measures. Biomass of the benthic fauna were between 1 and 2 g/m^{-2} with upstream measures being higher than downstream measures.

The following table lists the benthos collected by Northcote *et al*. (1976) from both sites.

Occurrence of Taxa in Benthic Samples from the Lower Fraser River between Hope and Chilliwack			
Group and Subgroup	**Taxa- Name**	**U/S**	**D/S**
ANNELID WORMS			
Oligochaetes	Oligochaete	√	√
INSECTS			
Ephemeropterans (Mayflies)	***Baetis***		√
	Ephemerella	√	
Trichopterans (Caddis flies)	**Hydropsychidae**	√	
Dipterans (True flies)	Empididae		√
	Ceratopogonidae	√	√
	Unidentified dipteran		√
	Monodiamesa	√	√
	Prodiamesa	√	
	Brillia	√	
	Cricotopus	√	√
	Eukiefferiella		√
	Heterotrissocladius	√	
	Parakiefferiella		√
	Psectrocladius	√	√
	Paracladius	√	√
	Chironomus	√	√
	Demicryptochiromus	√	
	Paracladopelma	√	√
	Polypedilum	√	√
	Stictochiromus	√	√
	Paratanytarsus	√	√
	Stempellina		√
	Tanytarsus	√	√
LAMPREYS	*Ammocoete*	√	√
	# Sensitive Taxa	**6**	**6**
	TOTAL	**19**	**19**

(Northcote *et al.*, 1976)

Note: Bold-faced text indicates taxa classified as sensitive to organic pollution.

The composition of benthos collected was dominated by oligochaete worms and dipteran flies (Northcote *et al.*, 1976). Also present, were mayflies and caddis flies. The non-saline conditions of the reach between Hope and Chilliwack are evidenced by the presence of freshwater species. The measures of biodiversity used in the survey by Northcote *et al.* (1976) are Simpson's index and the Shannon-Wiener function. Simpson's index ranges in value from a minimum of 0 which denotes very low diversity to a maximum of 1-1/T where T is the total number of taxa; Simpson's index is more reflective of numerically dominant taxa than rare ones. The Shannon-Wiener function ranges from values well below 1 to values over 2 and often as high as 3 or 4 in many unpolluted waters. It is important to interpret these measures of diversity with caution because confounding variables such as substrate composition and salinity of the interstitial waters in the bed sediments may have non-anthropogenic origins. Related to the Shannon-Wiener index is "equitability" which describes the degree to which the total number of individuals in a community are evenly distributed between the various taxa (Northcote *et al.*, 1976) and is defined as the ratio between the observed Shannon-Wiener diversity function of a community and the maximum diversity that would be expected for a community with that given number of taxa. With a range from 0 to 1, benthic communities in unpolluted waters are generally above 0.5, however, the function is sensitive to even slight levels of stream degradation, in which case, equitability plummets to values below 0.3 (Weber, 1973).

Two measures of diversity employed by Northcote *et al*. in their 1976 survey were Simpson's Index and the Shannon-Wiener function. Low levels of diversity are indicated by low values for both measures and are attributable to anthropogenic pollution or natural events such as seasonal salinity intrusions or changes in river composition of the sediment sampled. The monitoring stations situated between Hope and Chilliwack are not normally impacted by salinity intrusions and tidal activity. As such, differences in diversity can not be correlated with such seasonal occurrences. Substrate type was believed to be influential to the diversity measurements. As such, diversity measurements were made for two substrate types. Mud and mud-sand is substrate with a high silt to sand ratio while sand and sand-gravel is substrate with a low silt to sand ration.

Northcote's data report an index of 0 to 0.535 levels of diversity in mud and mud-sand substrate and an index of 0 to 0.484 levels of diversity in sand and sand-gravel where 0 is indicative of low diversity and values approaching 1 are indicative of very high diversity. Simpson's index is more reflective of numerically dominant taxa than rare taxa. Meanwhile, the observed Shannon-Wiener function calculated for mud and mud-sand substrates is 1.561 while the function for sand and sand-gravel is 1.366. The range of possible values for the Shannon-Wiener function is below 1 to reflect very low levels of diversity to values of 3 and 4 to reflect the high diversities of many unpolluted waters (Northcote *et al.*, 1976). Equitability is the degree to which the total number of individuals in a community are evenly distributed between various taxa and is defined as the ratio between the observed Shannon-Wiener function of a community and the maximum diversity expected for a community with that given number of taxa. Equitability ranges form 0 to 1 with values generally greater than 0.5 for benthic communities in unpolluted streams. The calculated measures of equitability in mud and mud-sand was 0.758 and in sand and sand-gravel was 0.676. These values reflect favorable environmental conditions given that even slight levels of degradation are still capable of reducing equitability to values below 0.3 (Weber, 1973). Although absolute values calculated for the two major substrate types differed, the same general trend was reflected by both (Northcote *et al*., 1976).

Northcote *et al*. (1976) further categorized the macro invertebrates into classes considered tolerant, facultatively tolerant, or sensitive to organic pollution. The proportion of invertebrates from each class in a given sample indicate water quality relative to other sites in an area, or can show how the same site has changed over time (Dwernychuk, 1985). The prevalence of pollution-tolerant invertebrates and the relative rarity of pollution-sensitive species is typical of more highly polluted areas whereas the prevalence of pollution sensitive invertebrates despite the concomitant presence of tolerant species suggests that the sample is collected from an area less impacted by pollution. Invertebrates designated as tolerant to organic pollution include oligochaetes, especially tubificids such as *limnodrilus hoffmeisteri* and *tubifex tubifex*, leeches, and certain dipterans such as psychodids. Facultative groups that can populate both polluted and clean habitats include larval dipterans from families such as the ceratogonids, larval chironomids such as cryptochironomous, polypedilum, and strictochironomus, molluscs such as pulmonate snails and the bivalve *Pisidia*, as well as crustacean isopods such as *Asellus*. Sensitive invertebrates that prefer cleaner waters include mayflies, caddis flies, stone flies, and chironomids such as *Diamesa, Brillia, Cricotopus, Parakiefferiella, Psectrocladius, Orthocldius, Trienemanniella, Stenochironomus, Tribelos, Micropsectra, Paracladopelma, Paratanytarsus*, and *Tanytarsus*.

According to the classification scheme derived by Northcote *et al*., it is apparent that upstream and downstream monitoring stations between Hope and Chilliwack are inhabited by approximately equal proportions of pollution-sensitive invertebrates. Furthermore, the taxa of all sensitive biota populating the upstream and downstream sites are the same except for *Brillia* which was found upstream but not downstream and *Parakiefferiella* and *Baetis* which were collected at the downstream station but not the upstream station. Pollution tolerant biota were represented by oligochaete worms at both upstream and downstream stations.

6.1.4 Analysis of Fish

There are no available SEAM data for contaminant concentrations in fish for the Hope to Chilliwack reach, therefore a number of previous studies will be compared to determine trends and potential problems in this reach of the river. The Fraser River Estuary Study from 1980, and the 1990/91 and 1992 monitoring reports of the Fraser and Thompson river are primarily concerned with industrial contaminants while the 1983 report by Singleton primarily discusses metal concentrations. Fish sampled by Westwater Research Centre in 1972/73 were analyzed for both metal concentrations (Northcote, 1975) and for organics (Johnson, 1975).

6.1.4.1 Metals

Few criteria exist for metal concentrations in fish tissues. Exceptions to this are arsenic, lead, and mercury, which have criteria set for concentrations in edible tissues due to a concern for the health of individuals who consume these fish. For those metals which are of little concern to human health, concentrations in fish tissues from uncontaminated areas are generally used as guidelines or goals for metal concentrations.

Data concerning trace metal levels in Fraser River fish between Hope and Chilliwack are available from a report by Singleton (1983). One site was sampled in this reach in 1980. Muscle and liver tissue of largescale sucker, peamouth chub, sockeye salmon, and white sturgeon were analyzed for trace metals, PCBs and other toxic organic contaminants at a site near Chilliwack. Where possible, these data are compared to 1972/73 data from a Westwater Research Centre report (Northcote *et al.*, 1975) All data are presented as wet-weight unless specifically noted. Some concentrations have been converted from dry-weight to wet-weight by assuming an eighty percent moisture content.

Arsenic

Muscle arsenic concentrations were below the detection limit of 2.0 µg/g dry-weight (0.4 µg/g wet-weight) in 1980 and 1972/73 surveys (Singleton, 1983 and Northcote, 1975). The levels reported in the Fraser River fall within the ranges of contaminated lakes but meet the Canadian Food and Drug Directorate for arsenic tolerance level of 3.5 µg/g in fish protein (Stancil, 1981).

Arsenic tends to accumulate in fish livers. It was found in the liver of only one of nine white sturgeon tested at Chilliwack in a concentration of 0.43 µg/g. Arsenic may have been present in the other 8 samples but the detection limits for those ranged from 0.43 µg/g to 0.72 µg/g (Singleton, 1983). White sturgeon are anadromous and concentrations measured were similar to those reported in marine species from other surveys. More recent data are needed to determine whether arsenic concentrations in fish tissues is a concern in the Fraser River.

Cadmium

In 1980, all cadmium levels in fish muscle were below detection limits ranging from 0.17 µg/g to 0.25 µg/g. The 1972/73 survey also reported no detectable cadmium concentrations in this reach of the river (Northcote *et al.*, 1975).

In contrast, Singleton (1983) reported cadmium in the livers of all largescale suckers, sockeye salmon and white sturgeon tested. The concentrations ranged from 0.33 µg/g in the white sturgeon to 1.28 µg/g in the sockeye salmon (Singleton, 1983). These values exceed the Health and Welfare Canada (1977) recommended cadmium tolerance level of 0.2 µg/g in the meat of livestock for human consumption. While Mathis and Cummings (1973) found no evidence of biomagnification, Lucas et al . (1970) and Brown and Chow (1977) did find that cadmium tends to concentrate more in visceral organs than in the muscle tissue of fish. This research is exemplified in the large number of detectable values in the liver samples analysis in 1980. Fish in the lower reaches of the river did not exhibit elevated levels of cadmium. Site-to-site comparisons were not meaningful due to small sample sizes.

Chromium

Chromium was not detected in any muscle tissue taken from fish collected between Hope and Chilliwack in 1980 (detection limits were between 0.14 µg/g and 0.25 µg/g) (Singleton, 1983). This contrasts the 1972/73 survey which reported the highest concentration (2.0 µg/g) in a largescale sucker collected between Hope and Chilliwack (Northcote *et al*., 1975). The Canadian Food and Drug Directorate has no recommended consumption guidelines for chromium. More recent data are needed to assess whether chromium levels in the Fraser are of concern.

Chromium was not found in any of the liver samples taken from fish in the Hope - Chilliwack region. The data indicate that the liver may not be an active site for the accumulation of chromium in fish; this conclusion is supported by data collected by Singleton in 1983.

Copper

Copper was detected in 24 of the 38 muscle samples taken from fish between Hope and Chilliwack (Singleton, 1983). In fact, 62% of the samples taken downstream from Hope and 76% upstream, had levels exceeding the detection limit of 0.2 µg/g. The three highest values were found in sockeye salmon: 0.63 µg/g, 0.58 µg/g and 0.50 µg/g. The lowest value of <0.17 µg/g was taken from a largescale sucker. When other sites are examined, the 1980 data shows no significant variation between sites, although the highest values are found in the upper river (Singleton, 1983). It is important to note that higher upstream values may be indicative of natural background levels or they may be indicative of contamination by various anthropogenic point and non-point source discharges. Comparison with 1972/73 data indicate a significant decrease in copper concentrations downstream from Hope (Northcote *et al.*, 1975). These lower levels may be due to differences in analytical techniques or the diversion of municipal and industrial wastewaters to treatment facilities.

Copper does not appear to be biomagnified through trophic levels of the aquatic food web but it does accumulate in the individual animals. Detectable levels were found in all liver tissue samples in concentrations between 12.7 µg/g and 71.3 µg/g. The highest value (71.3 µg/g) was found in sockeye salmon (Singleton, 1983). High values in the sockeye seemed to be typical of other sites as well. The values found in liver tissues represent large increases from those found in muscle tissues. For sockeye, liver concentrations were about 125 times those found in muscle tissue.

Northcote *et al*. (1972) found that the average copper concentrations for five species of fish from the Okanagan Basin Lakes range from 1.1 to 3.1 µg/g for composited muscle samples. These values are similar to those found in other B.C. lakes.

The Canadian Food and Drug Directorate has removed the copper tolerance level of 100 µg/g in marine and freshwater animal products for human consumption because it was considered unnecessary as no health problems had been recorded. Copper concentrations in the tissues of fish collected from the Fraser River from Hope to Chilliwack are well within this level.

Iron

Iron was found in all of the fish muscle tissues collected at Chilliwack in the 1980 survey. The minimum of 1.79 µg/g and the maximum of 9.41 µg/g were both found in largescale sucker. Mean values were relatively constant between species. Peamouth chub had the highest mean at 6.4 µg/g and squawfish had the lowest mean at 3.8 µg/g (Singleton, 1983). When compared to other sites, values also appear relatively constant. These values are comparable to the 4.15 µg/g and 6.4 µg/g found at Chilliwack (Singleton, 1983). Values are similar to those collected in 1972/73 so concentrations do not appear to be changing with time.

Iron was found in all the liver tissue samples collected at Chilliwack in concentrations higher than those found in muscle tissues. For example, largescale suckers had values of 140 µg/g in liver compared to 4.15 µg/g in muscle. White sturgeon and sockeye salmon had mean concentrations of 300 µg/g and 64.8 µg/g in liver tissue compared to muscle tissue concentrations of 4.70 µg/g and 5.9 µg/g, respectively (Singleton, 1983). The elevated hepatic iron concentrations are attributable to normal metabolic activity and the highly vascularized nature of the liver. Based on the data available, iron is not considered a concern to fish in the Fraser River.

Lead

Lead was not detected in muscle tissue samples taken from Chilliwack in 1980 (Singleton, 1983). However, 14 of the 18 detected concentrations (273 samples) were in the lower reach of the river, between Hope and Chilliwack. Detection limits at Chilliwack were between <0.15 µg/g and <0.22 µg/g with the exception of sockeye salmon data that had detection limits between <0.25 µg/g and <0.32 µg/g (Singleton, 1983). All values are below the 0.5 µg/g tolerance level defined by the Canadian Food and Drug Directorate (1979) for human consumption of fish protein.

Demayo *et al.* (1980) reported that there was no evidence to suggest that lead is biomagnified through the food web. This finding is supported by the data from 1980 (Singleton, 1983). With detection limits similar to those of muscle (0.22-0.32 µg/g), there were still no detected levels of lead in liver tissues (Singleton, 1983). In 62 British Columbia lakes tested for lead, the mean concentration was 0.7 µg/g with a range of 0.1 µg/g to 5.3 µg/g (Peterson *et al.*, 1970). This suggests that the Fraser River lead levels are lower than the average for B.C. lakes.

Manganese

Manganese was found in all but eight of the 37 samples. Concentrations ranged from < 0.2 µg/g to 0.76 µg/g, both the maximum and the minimum values were obtained in largescale sucker. The concentrations of manganese in largescale suckers were among the highest concentrations found in the entire river. The second highest value (0.39 µg/g) was found in a white sturgeon. There does not appear to be significant differences within species among sites (Singleton, 1983). Nevertheless, mean 1980 values of about 0.3 µg/g were lower than the mean 1972/73 values around 0.4 µg/g (Northcote *et al*., 1975). This decrease may be due to differences in analytical techniques used during the two time periods or the fact that municipal and industrial wastewaters are now being diverted to primary sewage treatment plants. Uthe and Bligh (1971) found that industry has little effect on magnesium concentrations.

Manganese was found in all liver tissue samples taken from Chilliwack at values five to ten times higher than in muscle tissue. Because the values do not change with the site, these concentrations may be a due to natural background concentrations in the river.

Mercury

Mercury was detected in all but three of 37 muscle tissues samples taken from Chilliwack in the 1980 survey. This was typical of the rest of the river where mercury was detected in 90% of the samples. The concentrations ranged from <0.05 µg/g to 1.23 µg/g. Only the lower North Arm and the Chilliwack sites had concentrations greater than the tolerance level of 0.5 µg/g designated by Canadian Food and Drug Directorate (1979) for mercury in fish products for human consumption. All of these values were found in largescale squawfish. In fact eight of ten largescale squawfish samples exceeded 0.5 µg/g at the Chilliwack site (Singleton, 1983). These levels are not uncommon for B. C waters. However, there are no known anthropogenic sources of mercury that would explain the high values found at the Chilliwack site and in the North Arm. All the 1980 values are slightly lower than those found in 1972/73 with the exception of those for white sturgeon in the North Arm.

Between species, the highest concentration was found in prickly sculpin and northern squawfish in 1972/73 and northern squawfish in 1980 (no prickly sculpin were tested). Northcote *et al*. (1975) suggested that this trend is related to trophic levels in the food web with higher trophic status fish (prickly sculpin and northern squawfish) exhibiting the highest mercury concentrations. Fimreite *et al*. (1971) reported similar findings while Jernelov and Lann (1971) argued that mercury was accumulated primarily through the water (Fimreite *et al*., 1971; Jernelov and Lann, 1971).

Mercury was found in all the liver tissues tested but levels were lower than those found in muscle tissues. This suggests that Fraser River fish are eliminating mercury faster than they are accumulating it.

Molybdenum

Molybdenum was not detected (1.0 µg/g dry-weight) in any of the resident fish tissue samples taken in the Hope to Chilliwack reach in 1972/73 or 1980.

A single migrating adult sockeye salmon captured between Hope and Chilliwack had a molybdenum concentration above detection limit in the liver at 0.21 µg/g (Singleton, 1983). It is not known exactly what is causing the high levels in these fish but it is thought to be related to the marine waters the fish recently traveled through. More recent data are needed to determine whether molybdenum is a concern to fish in the Fraser River.

Nickel

No detectable amounts of nickel were found in the muscle tissue of fish taken downstream from Hope in either the 1972/73 survey or in the 1980 survey. The values that were detected in the upper reaches were assumed to be due to natural deposits as there are no anthropogenic sources of nickel in the north reaches of the river. Uthe and Bligh (1971) tested for nickel in an industrial area (Great Lakes) and in an industrial free site (Moose Lake, Manitoba) and found all concentrations <0.05 µg/g.

Mathis and Cummings (1973) found no evidence of biomagnification of nickel through the food web. No detectable amounts of nickel were found in any of the liver tissue samples. As such, it may be concluded that nickel is neither biomagnified through the foodweb nor is the liver an active site of nickel accumulation.

Zinc

Zinc was detected in all muscle samples collected in 1980. The concentrations ranged from 2.39 µg/g in white sturgeon to 8.56 µg/g in squawfish (Singleton, 1983). Mathis and Cummings (1973) found similar zinc level in carnivorous and omnivorous fish from the two Fraser River surveys indicating that diet may not be the primary uptake mechanism for zinc.

Zinc was found in all liver tissue samples tested at concentrations five to ten times higher than in corresponding muscle tissue. Values ranged from 22.3 µg/g to 39.5 µg/g; both the minimum and maximum were found in white sturgeon. Largescale sucker, sockeye salmon, and white sturgeon had similar concentrations. These values are comparable to those found in other British Columbia waters.

It has been reported that low levels of zinc can inhibit oxygen metabolism in bluegill liver mitochondria (Hiltibran, 1971). The Canadian Food and Drug Directorate (1979) removed the 100 µg/g tolerance level on zinc because no human health problems had been recorded. More recent information is required to determine whether zinc is a concern in the Fraser River.

6.1.4.2 Organics

6.1.4.2.1 Polychlorinated Biphenyls (PCBs)

PCBs are synthetic organics that were used in electrical transformers, paint, plastic, rubber, printing ink, paper coating, etc. (Garrett, 1980). Due to their persistence and detriment to the environment, PCB use was discontinued in the 1970's. Data for PCBs were gathered from a Chilliwack site in 1980 where a white sturgeon with a total PCB concentration of 0.6 µg/g (Singleton, 1983) was collected. White sturgeon is an anadromous fish and it is possible that the high PCB levels were accumulated downstream in the North Arm. The total PCB concentration was below the criterion of 2.0 µg/g for human consumption but above the limit of < 0.5 µg/g stated by the National Academies of Science and Engineering (1974) for the protection of aquatic life. More recent data are required to assess the current situation for PCBs in the Fraser River between Hope and Chilliwack.

6.1.3.2.2 Phthalate Esters

Phthalate esters are used in industrial processes primarily to increase the flexibility of plastics. They were once thought to be exclusively synthetic compounds but there is now evidence that they may occur naturally in plants and possibly be biosynthesized by some micro-organisms (Leah, 1977). Leah (1977) reports that phthalates bioaccumulate in some fish but when these fish are transferred to clean water, they are capable of cleansing over half the contamination in one week through degradation and elimination.

Three phthalates were found consistently throughout the river in the muscle tissue of largescale suckers: di-n-octyl phthalate, butyl benzyl phthalate, and butyl isodecyl phthalate. It should be noted however, that di-n-octyl phthalate may have been contaminated in the lab (Singleton, 1983). Di-n-octyl phthalate values from the Chilliwack site varied from 11 µg/g to 28 µg/g with a mean of 15.6 µg/g. If a value of 28 µg/g may be eliminated as an outlier, all remaining values would be below 15 µg/g. Butyl benzyl was detected in four out of five fish samples taken at Chilliwack. The values ranged from <0.01 µg/g to 0.079 µg/g with a mean value of 0.05 µg/g. Butyl isodecyl was detected in three of the five fish sampled at Chilliwack. The values ranged from < 0.2 µg/g to 1.0 µg/g with a mean of 0.53 µg/g. No Canadian guidelines or provincial criteria currently exist for phthalates esters in the tissues of fish. Therefore, no recommendations can be made at this time.

6.1.4.2.3 Organochloride Pesticides

Data on organochloride pesticides were collected by Westwater Research Centre in 1972/73 (Garrett, 1980). The data shows that various organochloride pesticides were detected in most species. p,p-DDE, which is a breakdown product of DDT, was found in all fish sampled. In the Hope to Chilliwack region, values ranged from 0.0033 µg/g to 0.106 µg/g with a mean of 0.035 µg/g. All values were well below the Health and Welfare Canada guideline of 5 µg/g for DDT and its breakdown products. DDT and DDE were not detected (2.0 ng/g) in species taken between Hope and Chilliwack with two exceptions. Eight rainbow trout just upstream from Chilliwack had a mean DDT concentration of 0.0011 µg/g and 16 largescale suckers had mean DDT and DDD concentrations 0.0011 µg/g and 0.0012 µg/g respectively. Heptachlor was not detected, probably because it is quickly degraded into heptachlor epoxide. Accordingly, heptachlor epoxide was detectable in three northern squawfish and 16 largescale suckers with mean concentrations of 0.0023 µg/g and 0.0048 µg/g respectively. Lindane, alpha- and gamma-chlordane and aldrin were all undetected (2 ng/g) (Garrett, 1980). Dieldrin, a breakdown product of aldrin, is the most common contaminant of US river basins but was only detected in muscle tissue from 16 largescale suckers in the Fraser River with a mean concentration of 0.0011 µg/g.

The measured levels of organochloride pesticides are low relative to levels measured at contaminated sites such as those found in the Great Lakes. Furthermore, the organochlorides detected between Hope and Chilliwack did not vary with location and no point sources have been identified. The low inputs are likely due to agricultural runoff, atmospheric fallout, or sources of contamination further upstream from Hope. For these reasons, and because organochloride pesticide levels are below the Health and Welfare Canada guideline of 5µg/g, no Objective is proposed for organochlorine pesticides.

6.1.4.2.4 Dioxins

Dioxin concentrations are reported in 1990/1991 and 1992 organochlorine studies. The 1990/91 study tested mountain whitefish, largescale sucker, Dolly Varden and rainbow trout while the 1992 study tested mountain whitefish, rainbow trout, cutthroat trout and crayfish.

In 1991, 2,3,7,8 T_4CDD dioxin was found in all eight composite (of six individuals each) mountain whitefish sampled. The fish collected downstream from Hope had much lower levels than those found upstream at Quesnel. The composite samples taken at Hope had muscle and liver concentrations of 1.9 pg/g and 4.8 pg/g, respectively. This indicates that dioxins are being taken up all along the river, from Mission to Prince George (Beak Consultants, 1991). The 1992 values for mountain whitefish were lower than 1990/1991 values at all sites. At Hope, analysis of muscle samples indicated a slight decrease from 1.9 pg/g to 1.4 pg/g. No other dioxins were detected in the muscle of fish taken downstream from Hope (Beak Consultants, 1993).

Largescale sucker collected at Hope in 1990/91 had 2,3,7,8 T_4CDD concentrations below detection limits (0.2 pg/g) in muscle tissues. Liver concentrations were detected but did not meet quantification criteria. The highest muscle and liver concentrations were 5.1 pg/g and 80 pg/g respectively in fish collected upstream from Williams Lake (Beak Consultants, 1991). The 1992 survey did not test largescale suckers.

Dolly Varden were tested for 2,3,7,8 T_4CDD in 1990/91. No Dolly Varden were collected from Hope but very low levels were detected in muscle tissues from fish collected near Mission (0.9 pg/g) and liver concentrations were not-detected (0.1 pg/g). These small quantities indicate that although point sources appear to originate upstream, the organochlorides are still widespread in the Fraser River (Beak Consultants, 1991). The 1992 survey did not test Dolly Varden.

2,3,7,8 T_4CDD was not detected in the muscle or liver tissues of rainbow trout collected at Hope. In fact, 2,3,7,8 T_4CDD was only detected in rainbow trout collected at the Williams Lake and Mission sites in 1990/91. At the site near Mission only liver tissue concentrations were detected (mean of 14 pg/g)(Beak Consultants, 1991). Minute quantities of octachlorodibenzodioxin were detected in samples from Hope (3.1 pg/g).

Dioxins were not detected at varying detection limits in cutthroat trout sampled at two sites between Hope and Chilliwack in 1992.

Hope was the only site sampled in the 1990/91 and 1992 studies that fell within the reach of river between Hope and Chilliwack. In both studies, dioxins were only found in mountain whitefish. The concentrations were lower in the 1992 study compared to the 1990/91 study. The Toxic Equivalents (TEQ) values were also lower. In 1992, the muscle and liver TEQs were 1.6 pg/g and 0.6 pg/g respectively. This is a decrease from 1990 values of 2.7 pg/g and 6.2 pg/g.

The draft B.C. criterion for the protection of aquatic life from long-term chronic effects associated with dioxin and furan exposure and uptake is more stringent than the Health and Welfare food tolerance level. The criterion will be adapted for use as the Water Quality Objective applicable to the Fraser River from Hope to Chilliwack. A provisional Water Quality Objective of 50 pg/g TEQ in lipid tissues of fish is not to be exceeded in this reach of the Fraser River. All TEQs presently meet the recommended guideline. Declines in dioxin concentrations since 1990 may be due to reduced organochlorine loading by the pulpmills and lumbermills. However, due to the fact that these chemicals have no use as such, are exclusively anthropogenic, are very persistent in nature and relatively resistant to microbial degradation, are bioconcentrated within organisms, and are biomagnified through trophic levels, careful monitoring should be continued.

6.1.4.2.5 Furans

At Hope, muscle and liver tissue concentrations of 2,3,7,8,T_4CDF were 7.8 pg/g and 14 pg/g respectively (Beak Consultants, 1991). Although all concentrations of 2,3,7,8 ,T_4CDF throughout the river were lower in 1992 (Beak Consultants, 1993), the decreases at Hope were not as pronounced as in other reaches. Muscle concentrations decreased from 7.8 pg/g in 1990/91 to 2 pg/g in 1992 and liver tissue concentrations decreased from 14 pg/g to 6.4 pg/g.

Largescale suckers were only tested in the 1990/91 survey. At Hope, the muscle tissue concentration of a composite sample composed of six individual fish was 0.5 pg/g while the liver concentration was higher at 4.6 pg/g. Higher liver concentrations indicate that furans are stored in the hepatic tissues (Beak Consultants, 1991). No 1992 data are available for comparison.

In 1990, the highest muscle and liver concentrations for rainbow trout,7.9 pg/g and 9 pg/g respectively, were taken from samples at Hope. By 1992, all furan levels in muscle tissue had decreased from 7.9 pg/g in 1990 to 0.8 pg/g and liver concentrations decreased from 9.0 pg/g to 2.3 pg/g (Beak Consultants, 1993).

Furans were detected in minute quantities in cutthroat trout at two sites located between Hope and Chilliwack in 1992. Muscle concentrations for the two sites were 3 pg/g and 1.7 pg/g. No other dioxin congeners were detected in the cutthroat composites analyzed in 1992 (Beak Consultants, 1993).

The data indicates that there is a widespread, low level presence of furans in the Fraser River. The limited data and absence of guidelines do not allow for recommendations to be made at this time.

6.1.4.2.6 Chlorophenols

Chlorophenols are widely used as wood preservatives in the lumber and pulp and paper industries. In 1980, fish were tested for a number of di-, tri-, tetra-, and pentachlorophenols with detection limits of 0.5 µg/g, 0.02 µg/g, 0.01 µg/g and 0.01 µg/g respectively. Only pentachlorophenol was detected. Three of five largescale suckers collected from Chilliwack had detectable muscle concentrations: 0.007 µg/g, 0.017 µg/g and 0.069 µg/g..

The 1990 survey tested mountain whitefish, largescale sucker, Dolly Varden and rainbow trout. At Hope, there was no detectable tri- tetra- or pentachlorophenols in the tissue of any of the species tested except the rainbow trout. The rainbow trout had detectable liver concentrations of all three chlorophenols. Trichlorophenol had a liver composite concentration of 26 ng/g. Tetrachlorophenol and pentachlorophenol had composite concentrations of 11.0 ng/g and 5.5 ng/g respectively (Beak Consultants, 1991). All of these values meet the strictest maximum criteria for aquatic life toxicity of tri- and pentachlorophenols of 50 000 ng/g and 20 000 ng/g respectively (Warrington, 1993).

The existing Water Quality Objective for chlorophenols in the lower Fraser River is a maximum concentration of 0.1 µg/g (wet-weight) in fish muscle for all chlorophenols combined. This value was based on the goal of no increase in chlorophenol concentrations over present conditions; however, a new provisional Tissue Quality Objective of 0.2 µg/g (wet-weight) for the sum of mono-, di-, tri-, tetra- and pentachlorophenol in any single sample or a composite sample in any species is proposed for the upper Fraser River. This Objective reflects the Ministry criteria for 2,4-dichlorophenol alone.

6.2 Fraser River - Chilliwack to Kanaka Creek

6.2.1 Water Chemistry

Water chemistry was measured at six provincial monitoring sites on the Fraser River between Chilliwack and Kanaka Creek from January, 1985 to December, 1994. These sites (E207391, E207392, E207602, 0301548, 0301549 and 0301550) are shown in Figure 8. The data are summarized in Tables 67, 68, 69, 70, 71, and 72. Sites E207391, E207392 and E207602 are associated with the Joint Abbotsford-Matsqui Environmental Systems (JAMES) Sewage Treatment Plant (STP). Site E207391 is located upstream from the STP discharge, E207392 at the discharge site and Site E207602 is 100 metres downstream from the discharge. Sites 0301548, 0301549 and 0301550 are associated with the Aldergrove STP: Site 0301548 is located 50 metres upstream from the STP, Site 0301549 located in the initial dilution zone of the STP, and Site 0301550 located 100 metres downstream from the STP.

In addition, references are made to the results of a study conducted at Mission between January, 1993 and March, 1994, by the Fraser River Estuary Management Program (FREMP) in which water samples were taken at two-week intervals and analyzed for a number of variables (Tables 73 and 74) (Morse, 1994). Results are also compared to those reported for the water quality in the Fraser River sub-basin based on data collected to about December 1982, and published in 1985 (Swain and Holms, 1985a).

6.2.1.1 pH and Alkalinity

The Fraser River from Chilliwack to Kanaka Creek is basic, with mean pH at six provincial monitoring sites ranging from 7.6 to 8.1 (n=56). This range represents a slight increase from the mean pH of 7.8 reported in 1985 (Swain and Holms, 1985a). Maxima varied from 7.4 to 8.3, well within the water quality criterion range of 6.5 to 9.0 (McKean and Nagpal, 1991). The mean pH measured at Mission in 1993/94 was 7.55 (n=30) (Table 73). These near-neutral pH values should be maintained in order to minimize ammonia toxicity near sewage treatment plant discharges. For this reason, a provisional Water Quality Objective is proposed for pH. The objective, applicable to discrete samples collected outside the provisional initial dilution zones of effluents, is that the pH of any discrete sample should not be outside the range of 6.5 to 8.5. Initial dilution zones of effluents are provisionally defined as extending no further than 25% across the river width, from the bed to the surface, and no further than 100 m downstream. More site specific data are required to define a more permanent and defensible initial dilution zone. By restricting the upper limit of pH to 8.5 instead of 9.0, the percentage of un-ionized ammonia in aqueous ammonia solution will be about one-third that which would be available at pH 9.0 (Trussell, 1972).

The mean alkalinity at Mission was 48.2 mg/L $CaCO_3$ at pH 4.5, with a range of 38.3 to 58.4 mg/L (n=30 - Table 73). As such, it was virtually identical to the mean alkalinity of 46 mg/L $CaCO_3$ at Mission prior to 1982 (Swain and Holms, 1985a). This mean value indicates that the Fraser River has a low sensitivity to acid inputs for aquatic life according to the water quality criterion (Swain, 1987).

6.2.1.2 Hardness and Metals

Hardness values were available at only one (Site E207602) of the six monitoring sites between Chilliwack and Kanaka Creek. Hardness at this site ranged from 46.2 to 51.0 mg/L $CaCO_3$, with a mean value of 49.5 mg/L $CaCO_3$ (n=5) (Table 76). This represents a slight increase over the mean value of 46 mg/L reported in the 1985 report (Swain and Holms, 1985a). The hardness values measured at Mission in 1993/94 were slightly higher, ranging from 39.8 to 63.2 mg/L with a mean value of 55.1 mg/L(n=30) (Table 73). The mean calcium concentration (14.4 mg/L) and the minimum concentration (13.9 mg/L) measured at Site E207602 represent a low sensitivity to acid inputs based on the water quality criterion (Swain, 1987). The maximum magnesium concentration at Site E207602 was 3.55 mg/L (mean 3.31 mg/L) (n=5). The maximum concentrations of calcium and magnesium measured at Mission were 18.6 mg/L and 5.09 mg/L with means 15.9 mg/L and 3.73 mg/L, respectively (n=30).

Metal concentrations in the Fraser River between Chilliwack and Kanaka Creek were measured only at Site E207602 of the six provincial monitoring sites.

Aluminum

The mean concentration of dissolved aluminum was 0.06 mg/L, with a maximum concentration of 0.10 mg/L. These values are below the maximum dissolved aluminum concentration of 0.2 mg/L recommended for recreation and aesthetics and the maximum value is equal to the criterion for the protection of aquatic life when pH about 6.5 (Butcher, 1988). Total aluminum concentrations measured at Mission in 1993/94 had a mean value of 0.59 mg/L, with values ranging from <0.02 mg/L to 5.6 mg/L. The maximum value occurred at the same time the maximum value for suspended solids was measured (377 mg/L, compared to the mean value of 65 mg/L) in May, 1993, suggesting that a large portion of the aluminum is associated with particulate matter. As such, it is not biologically active and will not affect aquatic life. However, when this high concentration of aluminum is not included in the data base, the mean concentration decreases to 0.41 mg/L, which is still above criterion. The concentration of dissolved aluminum was not available in the 1985 report. Concentrations of total aluminum are similar to those reported for Hope (Section 6.1.1.2) and probably reflect ambient conditions of the Fraser River rather than anthropogenic inputs.

Arsenic

Concentrations of arsenic were below the minimum detectable limit of 0.04 mg/L for each sampling period at Site E207602. The concentrations of arsenic measured at Mission in 1993/94 ranged from <0.0001 to 0.0017 mg/L, much lower than the criteria of 0.05 mg/L arsenic for drinking water, and the protection of aquatic life (Health and Welfare Canada, 1989; CCREM, 1987). Therefore, arsenic does not appear to be of concern for aquatic life in this reach of the Fraser River.

Cadmium

Cadmium concentrations were measured only at Mission in 1993/94. The median concentration of cadmium was less than the minimum detectable limit of 0.0002 mg/L. The maximum concentration measured was 0.0011 mg/L. This value occurred in early May, 1993, when mean flow rates increased from 2 366 m^3/s to 5 555 m^3/s due to the spring freshet (Table 2). In addition, the concentration of suspended solids at this time was higher than average (59 mg/L). It is therefore likely that this high concentration was due to spring runoff, and was associated with suspended particulate matter. Of the 30 periodic samples taken, only two exceeded the minimum detectable limit of 0.0002 mg/L. These two measurements (as high as 0.0011 mg/L) also exceeded the water quality criterion of a maximum concentration of 0.0002 mg/L at a hardness of less than 60 mg/L $CaCO_3$ (CCREM, 1987).

Chromium

Chromium was measured as part of the monitoring program in Mission conducted in 1993/94. The median concentration was below the detection limit of 0.001 mg/L for the 30 samples taken. Nine values exceeded the minimum detectable limits, with a maximum concentration of 0.011 mg/L. This maximum value was measured concurrently with the maximum concentrations of suspended solids in May, 1993, suggesting that high concentrations are due in part to suspended solids introduced during freshet. The water quality guideline for the protection of aquatic life from harmful effects of chromium is 0.002 mg/L (CCREM, 1987). This guideline maximum was exceeded by three of the 30 samples. As these concentrations are probably due in part to suspended solids, these infrequent excursions over the criterion are probably not a concern to aquatic life. Therefore, no objective is proposed for chromium. Further monitoring is recommended to determine whether these high metal concentrations are definitely linked to high levels of suspended sediments.

Copper

The mean concentration of copper measured at Mission in 1993/94 was 3 μg/L. This value exceeds the 30-day average water quality criterion for freshwater aquatic life of less than or equal to 2 μg/L (Singleton, 1987), but is less than the maximum concentration of 6.7 μg/L recommended based on an average water hardness of 49.5 mg/L $CaCO_3$ (Singleton, 1987). Of the 30 samples measured, 11 exceeded the 30-day average water quality criterion, while six were below the minimum detectable level of 1μg/L. The maximum concentration of copper measured was 12 μg/L. This value was measured in May, 1993, when suspended solids were extremely high (377 mg/L versus the mean value of 40 mg/L) and during a period when flow rates in the Fraser River traditionally tend to increase greatly due to spring freshet (Table 2).

Iron

The mean concentration of total iron measured at Site E207602 was 1.83 mg/L, with a maximum value of 2.57 mg/L. This is well above the maximum concentration of 0.3 mg/L recommended for the protection of aquatic life (Health and Welfare Canada, 1989; CCREM, 1989). However, much of this iron is suspected to be bound to suspended solids and as such, not biologically available. Dissolved iron concentrations represent a more accurate measurement of the amount of iron which affects aquatic life. The mean concentration of dissolved iron was 0.09 mg/L, with a maximum value of 0.14 mg/L. Water quality criteria do not exist for dissolved iron, so a comparison with that data is not possible. The maximum iron concentration (9.22 mg/L) measured at Mission corresponds to the maximum concentration of suspended solids (377 mg/L). The mean concentration of iron measured at Mission was 0.739 mg/L. When the maximum concentration is excluded from the calculations, the mean concentration decreases to 0.436 mg/L and the maximum concentration decreases to 2.34 mg/L; both values are still above criterion for the protection of aquatic life.

Lead

The median concentration of lead measured at Mission in 1993/94 was below the detection limit of 0.001 mg/L. The maximum value reported was 0.003 mg/L, which is less than the 30-day average water quality criterion for the protection of freshwater aquatic life of 0.005 mg/L at a mean water hardness less than or equal to 50 mg/L CaCO3

(Nagpal, 1987). Only four of the 30 values measured exceeded the minimum limits of detection. Therefore, concentrations of lead are not considered to be of concern in this reach of the river.

Manganese

The mean manganese concentration measured at Site E207602 was 0.06 mg/L, with a maximum value of 0.07 mg/L (n=5). The mean concentration of manganese measured in Mission in 1993/94 was 0.034 mg/L, with a maximum concentration of 0.292 mg/L (n=30). The water quality criterion for manganese is between 0.1 and 1.0 mg/L for the protection of freshwater aquatic life, and all values measured were within or below this range.

Nickel

The concentrations of nickel measured at one of the six monitoring sites (Site E207602) between Chilliwack and Kanaka Creek was less than the minimum detection limits of 0.01 mg/L for all five samples taken at this site. The mean concentration of nickel measured in Mission in 1993/94 was 0.002 mg/L with a maximum value of 0.015 mg/L (n=30). These values are all below the water quality criterion of 0.025 mg/L at hardness between 0 and 60 mg/L $CaCO_3$ (CCREM, 1987). Fifteen of the 30 values measured were below the minimum detection limit of 0.001 mg/L for nickel. Therefore, nickel concentrations are not a concern in this reach of the Fraser River.

Zinc

Zinc concentrations were measured at one of the six monitoring sites (Site E207602) between Chilliwack and Kanaka Creek. All four samples taken had a concentration of 0.01 mg/L. The mean concentration of total zinc measured in Mission in 1993/94 was 0.007 mg/L, with a maximum value of 0.07 mg/L. The water quality criterion is tentatively set at a maximum value of 0.03 mg/L for the protection of freshwater aquatic life (CCREM, 1987), though phytoplankton are affected at levels as low as 0.014 mg/L (International Joint Commission Great Lakes Science Advisory Board, 1987). The mean value for the samples from Mission is well below the criterion, although two of the 38 values measured exceeded both the 0.014 mg/L and the 0.03 mg/L criteria.

These infrequent excursions over the criteria may be of concern. However, as there are no known anthropogenic sources of zinc in the Fraser River upstream from Kanaka Creek, no Water Quality Objective is proposed for zinc concentrations between Chilliwack and Kanaka Creek.

Other metals measured at Mission in 1993/94 were mercury, cobalt and selenium. All of the samples for each metal were below the minimum detectable limits (0.00005 mg/L, 0.015 mg/L and 0.0005 mg/L, respectively). As shown in the table below, the detection limits of all metals were below the maximum water quality criteria for these compounds (Nagpal, 1989; National Academy of Sciences, 1972; CCREM, 1987) while the detection limit of mercury is above the 30-day average criterion. Therefore, while it can be concluded that mercury, colbalt and selenium have mean concentrations that meet their respective maximum water quality criteria, it is difficult to accurately relate mean mercury concentrations with its 30-day average criterion.

Metal	Mean Concentration (mg/L)	Water Quality Criteria (mg/L)
Mercury	< 0.00005	Maximum 0.0001, 30-day Average ≤ 0.00002
Cobalt	<0.015	Maximum 0.05
Selenium	<0.0005	Maximum 0.001

6.2.1.3 Dissolved Oxygen and Oxygen-Consuming Materials

The mean concentration of dissolved oxygen measured at Mission in 1993/94 was 11.1 mg/L with a minimum concentration of 8.8 mg/L. Water quality criteria for the concentration of dissolved oxygen is determined based on the oxygen requirements of salmonid species which tend to be the most sensitive aquatic species to low oxygen concentrations. The dissolved oxygen water quality criterion for salmonid embryo and larvae is a minimum of 11.0 mg/L for no production impairment (U.S. Environmental Protection Agency, 1986) and 102.7% oxygen saturation for the critical oxygen level for supplying oxygen demand and non-oxygen dependent metabolism (Davis, 1975). Because there are sources of oxygen consuming wastes being discharged to the river, and dissolved oxygen concentrations measured in units of percent saturation are more reflective of temperature and salinity effects on the bioavailability and use of dissolved oxygen, a provisional water quality objective specified in units of percent saturation is proposed for the protection of hatching and early salmonids. To maintain high oxygen concentrations, and using the criteria from Truelson (1997) as a basis, a Water Quality Objective for the Fraser River from Hope to Chilliwack is that the instantaneous minimum should not be less than 5 mg/L and the 30-day mean should not be lower than the higher of 80% saturation or 8.0 mg/L. In spawning areas where fish eggs are incubating or areas utilized by young fish, the Water Quality Objective is an instantaneous minimum of not less than 9.0 mg/L and a 30-day mean not lower than 11.0 mg/L (November to April). These are the dissolved oxygen water quality objectives for the reach of the Fraser River from Chilliwack to Kanaka Creek.

6.2.1.4 Solids, Turbidity, and Colour

The mean concentration of suspended solids measured at Mission between 1993/94 was 40 mg/L, with a maximum concentration of 377 mg/L. Only nine of the 30 measurements exceeded 40 mg/L, and all of these occurred between the end of April, 1993 and the end of July, 1993. Maximum suspended solids concentrations correspond to the period of maximum flow for the Fraser River, between May and August.

6.2.1.5 Nutrients

The mean ammonia concentration for the six provincial monitoring sites between Chilliwack and Kanaka Creek on the Fraser River range from 0.008 mg/L at Site 0301550 to 0.500 mg/L at Site E207392. The highest concentrations occurred at the monitoring sites located directly at the discharge from the JAMES and Aldergrove STPs. The maximum concentration of ammonia was 1.19 mg/L, measured at Site E207392. Mean concentrations upstream and downstream from the initial dilution zone are 0.008 mg/L and 0.038 mg/L. The water quality criteria for average 30-day concentrations of total ammonia nitrogen for the protection of freshwater aquatic life are related to the temperature and pH of the water (see Tables 11 and 12). As the values for temperature and pH increase, the average 30-day allowable concentration decreases. The maximum value of 1.19 mg/L occurred in February, 1988. The water temperatures at Mission for this month (5° C, from FREMP Mission data) can be used to approximate the water temperature near the JAMES outfall. The pH of the water near the JAMES outfall during this sampling period was 7.6. The maximum recorded value (1.19 mg/L) is less than the water quality criterion (Nordin and Pommen, 1986) for 30-day concentrations of 1.95 mg/L for this temperature and pH. With mean pH between 7.6 and 8.1, and with a maximum water temperature of about 19° C, all recorded values are well below the 30-day average concentrations of 0.655 mg/L to 1.33 mg/L recommended for the protection of freshwater aquatic life. The mean ammonia concentration measured at Mission in 1993/94 was 0.019 mg/L, with a maximum value of 0.043 mg/L. These values are all well below the water quality criteria for average 30-day concentrations for the protection of freshwater aquatic life based on a mean pH of 7.6 and a maximum water temperature of 19° C.

It was estimated in Sections 4.2.1 and 4.2.12 that theoretically, discharges from the JAMES and Aldergrove STPs could increase ammonia concentrations by as much as 0.412 mg/L under low flow conditions at the edge of the initial dilution zone (as described in Section 6.2.1.1). Therefore a provisional Water Quality Objective for total ammonia is proposed for the Fraser River, from Chilliwack to Kanaka Creek. This objective is that the maximum and 30-day average concentrations should not exceed the values listed in Tables 11 and 12. The objective applies to discrete samples, collected from outside of initial dilution zones of effluents as described in Section 6.2.1.1.

Nitrate/nitrite concentrations were measured once each at four of the six provincial monitoring sites on the Fraser River between Chilliwack and Kanaka Creek (E207391, E207602, 0301548 and 0301550; Tables 74, 76, 77 and 79). Values ranged from 0.04 mg/L to 0.05 mg/L. The mean concentration of nitrate/nitrite measured at Mission was 0.116 mg/L; the maximum concentration was 0.318 mg/L. The water quality criteria for nitrate/nitrite is a maximum concentration of 10 mg/L for the protection of drinking water, and recreation and aesthetics (Nordin and Pommen, 1986). All values are well below criteria. In Sections 4.2.2 and 4.2.13, it was estimated that potential increases of nitrate/nitrite from the JAMES and Aldergrove STPs would be negligible even under low flow conditions, so no Water Quality Objective is considered necessary for this reach.

Nitrite concentrations were measured at four of the six provincial monitoring sites (E207391, E207602, 0301548 and 0301550; Tables 74, 76, 77 and 79: n=9) . The maximum concentration of 0.007 mg/L was the only measurement which exceeded the minimum detection levels of 0.005 mg/L for nitrites. All values are well below the water quality criterion requiring an average concentration of no more than 0.02 mg/L (with chloride concentrations < 2 mg/L) for the protection of freshwater aquatic life (Nordin and Pommen, 1986). Nitrite concentrations were not measured at Mission. In order to protect fish health, a maximum and an average Water Quality Objective for nitrite related to the chloride concentration as shown in Table 13 is proposed. These values are consistent with uncontaminated sites upstream.

Phosphorus concentrations were measured at four of the six sites on the Fraser River (Sites E207392, E207602, 0301548, and 0301549, Tables 75, 76, 77, and 78). Mean total phosphorus concentrations ranged from 0.0332 mg/L to 0.149 mg/L; the maximum recorded concentration was 0.344 mg/L (n=21). The mean concentration of total phosphorus measured at Mission in 1993/94 was 0.058 mg/L; the maximum recorded concentration was 0.478 mg/L (n=30). Mean concentrations are all well above the maximum water quality criterion for total phosphorus concentration of 0.01 mg/L (Nordin, 1985). Phosphorus concentrations are often the limiting factor to algal growth. However, due to high suspended solids concentrations in the Fraser River, light penetration, and not phosphorus concentration, is the limiting factor for algae production. Therefore, phosphorus concentrations are not a major concern and no Water Quality Objective is proposed.

6.2.1.6 Bacteriological Indicators

Fecal coliform counts were recorded for the six monitoring sites (E207391, E207392, E207602, 0301548, 0301549 and 0301550). Sites upstream and downstream from the discharges from the JAMES and Aldergrove sewage treatment plants were measured in both CFU/cL and MPN/100 mL, while measurements taken in the provisional initial dilution zones were measured in MPN/100 mL only. Coliform counts taken at Mission were recorded in MPN/100 mL. Geometric means for coliforms at those sites measured in CFU/cL (E207391, E207602, 0301548, and 0301550) ranged from 53 to 296 CFU/cL. At both the JAMES and the Aldergrove sites, the single geometric means measured were lower downstream from the STP discharge than upstream. The highest values were measured up and downstream from the Aldergrove STP where the maximum value was 9500 CFU/cL and the second largest value was 2100 CFU/cL. All samples measured in CFU/cL were taken between April and October, the period during which irrigation and recreation tends to occur. The monitoring site upstream from the Aldergrove STP (0301548) was the only one to exceed the water quality criterion for fecal coliforms of ≤ 200 CFU/cL (Warrington, 1988), with a geometric mean of 296 CFU/cL.

Of the coliform counts that were measured in MPN/100 mL, geometric mean values for samples taken between April and October ranged from 70 MPN/100 mL at Site E207602 (downstream from the JAMES STP) to 140 MPN/100 mL at Site 0301550 (downstream from Aldergrove STP). In contrast to the samples measured in CFU/cL, the values obtained downstream from the Aldergrove STP doubled the values obtained upstream. All measures for fecal coliforms were below the water quality criterion for fecal coliforms of ≤ 200 MPN/100 cL during the irrigation and recreation seasons (Warrington, 1988). During the winter season (November to March), the geometric mean values of coliform counts exceeded the criterion, with values that ranged from 278 to 420 MPN/100 mL, with a maximum concentration of 1100 MPN/100 mL. The geometric mean of coliform concentrations at Mission was 120 MPN/100 mL during the winter months and 28 MPN/100 mL between April and October. The maximum value was 800 MPN/100 mL in the winter and 500 MPN/100 mL in the summer.

In Sections 4.2.1 and 4.2.12, it was estimated that theoretically, discharges from the JAMES and Aldergrove STPs could increase fecal coliform concentrations by as much as 670 CFU/cL. In order to protect irrigation water supplies, a provisional Water Quality Objective for fecal coliforms in the Fraser River between Chilliwack and Kanaka Creek is proposed. This Objective states that the geometric mean of at least five samples measured in a 30-day period between April and October should not exceed 200 CFU/100 mL. This Objective applies only to samples collected outside of initial dilution zones as described in Section 6.2.1.1.

Escherichia coli , *Enterococci*,, and *Pseudomonas aeruginosa* bacteria were measured upstream and downstream from both the JAMES and the Aldergrove STPs (E207391, E207602, 0301548, and 0301550). The geometric mean of concentrations of *E.coli* ranged from 27 CFU/cL to 65 CFU/cL at the four sites, with a maximum concentration of 320 CFU/cL(n=17). The geometric means were below the water quality criterion for *E. coli* geometric mean ≤ 77 CFU/100 mL for the irrigation of crops eaten raw (Warrington, 1988). All values were measured between April and October. As there is the potential for *E. coli* bacteria to be introduced to the Fraser River from the JAMES and Aldergrove STPs, a provisional Water Quality Objective is proposed to protect irrigation water supplies. The objective is that the geometric mean of *E. coli* bacteria in a least five samples collected within a 30-day period between April and October should not exceed 77 CFU/100 mL. The objective applies only outside of initial dilution zones as described in Section 6.2.1.1.

The geometric mean concentrations of *Enterococci* ranged from 4 CFU/cL to 11 CFU/cL, with a maximum concentration of 24 CFU/cL (n=16). The geometric means are all below the water quality criterion for Enterococci, a geometric mean of ≤ 20 CFU/cL for the irrigation of crops eaten raw (Warrington, 1988). All values were measured between April and October. As *Enterococci* bacteria may be introduced from the JAMES or Aldergrove STPs, a provisional Water Quality Objective is proposed to protect irrigation water supplies. This objective is that the geometric mean of *Enterococci* in at least five samples collected within a 30-day period between April and October should not exceed 20 CFU/100 mL.

The concentration of *Pseudomonas aeruginosa* ranged from a median value of less than the detection limit (2 CFU/cL) to a geometric mean of 3 CFU/cL, with a maximum concentration of 4 CFU/cL (n=14). The most stringent water quality criterion for *Pseudomonas aeruginosa* that is applicable in this area is a 75th percentile of ≤ 10 CFU/100 mL for the protection of irrigation with public or livestock access and secondary-contact recreation (Warrington, 1988). All values were well below these criteria. All samples were collected between April and October. As *Pseudomonas aeruginosa* bacteria may be introduced to the Fraser River from the JAMES and Aldergrove STPs, a provisional Water Quality Objective is proposed. This objective is that the 75th percentile of *Pseudomonas aeruginosa* in at least five samples collected within a 30-day period between the months of April and October should not exceed 10 CFU/100 mL, outside of initial dilution zones as described in Section 6.2.1.1.

6.2.1.7 Organics

All samples analyzed for organic compounds were taken from the FREMP Mission monitoring site. In all samples, the majority of the compounds tested had concentrations below detectable limits. These data are shown in Table 74.

Two of the chlorophenols tested, pentachlorophenol and 2,4,6-trichlorophenol, were present above detectable limits in some samples. However, the median concentrations of these compounds were below the detectable limit of 0. 001 µg/L. The maximum concentrations were: 0.004 µg/L for pentachlorophenols, and 0.006 µg/L for 2,4,6-trichlorophenol. The interim Water Quality Toxicity Criterion for the protection of aquatic life for pentachlorophenols is a maximum concentration of 0.10 µg/L at a pH between 6.9 and 7.9, and for 2,4,6-trichlorophenol is 0.50 µg/L at a pH greater than 7.5 (Warrington, 1993). All concentrations were well below the criterion.

All guaiacols and catechols present in any samples above detection limits had median values below the detection limit of 0.002 µg/L except 4,5-dichloroguaiacol, which had a mean concentration of 0.004 µg/L. No water quality criteria have been set for guaiacols or catechols, but concentrations of these compounds are low and probably not a concern.

The median concentration of 3,4,5-trichloroveratrole was < 0.002 µg/L. Four values out of 16 exceeded the minimum detection limit of 0.002 mg/L, and the maximum concentration was 0.006 µg/L. Both 5,6-dichlorovanillin and 6-chlorovanillin had median concentrations of less than 0.002 µg/L, with maximum concentrations of 0.002 µg/L for 5,6-dichloro-vanillin and 0.007 µg/L for 6-chlorovanillin. One value of nonylphenol (0.006 µg/L) exceeded the minimum detection limit of 0.002 µg/L. Myristic and palmitric acid were present in concentrations of 0.5 µg/L and 0.7 µg/L respectively, in one of four samples analyzed. No water quality criteria exist for these compounds, but it does not appear that they are a concern in this reach of the Fraser River.

6.2.2 Sediment Chemistry

Six sediment samples were collected and analyzed from the Langley Bar area of the Fraser River (Figure 8) in March, 1994 by Environmental Services (Environmental Services, 1994) (Tables 75 and 76). Sediment Quality Criteria cited for significant concentrations of metals were determined using the Screening Level Concentrations (SLC) approach. This approach determines limits of effects based on the highest concentration of a non-polar substance that co-occurs with approximately 95% of the benthic infauna. It is assumed that increased concentrations of the substance will lead to a concomitant decrease in the percentage of infauna present.

6.2.2.1 Metals

The mean concentration of arsenic in the six sediment samples collected was 2.97 µg/g, with a maximum concentration of 3.66 µg/g. The lowest-effects level Sediment Quality Criterion for arsenic is 6 µg/g (Jaagumagi, 1992a). All concentrations were well below this value. A no-effects threshold was set at 3 µg/g for the St-Lawrence River (Environment Canada, 1992); the mean approaches this value and the maximum concentration is above.

Concentrations of cadmium were well below the lowest-effects level Sediment Quality Criterion for freshwater sediment of 0.6 µg/g (Jaagumagi, 1992a), with a mean concentration of 0.12 µg/g and a maximum concentration of 0.14 µg/g.

The Sediment Quality Criterion of 26 µg/g of chromium for freshwater sediment is the lowest level at which effects can be measured (Jaagumagi, 1992a). The mean concentration of chromium measured in sediment was 32.1 µg/g and the maximum concentration was 42.9 µg/g. Five of the six samples tested for chromium exceeded the sediment quality criterion. Because the Langley Bar is mid-channel of the Fraser River, upstream of major industrialized sites, potential sources of chromium should be investigated. Further monitoring of chromium concentrations is recommended.

The mean concentration of copper measured at the Langley Bar was 14.9 µg/g, with a maximum value of 15.9 µg/g. These values lie just below the Sediment Quality Criterion lowest-effects level of 16 µg/g for copper in freshwater sediment (Jaagumagi, 1992a).

The lowest-effects level Sediment Quality Criterion for lead is 31 µg/g in freshwater sediment (Jaagumagi, 1992a). All samples taken at Langley Bar had lead concentrations well below this value, with a mean of 2.7 μg/g and a maximum concentration of 3.3 μg/g.

The mean concentration of mercury (0.027 μg/g) and the maximum value (0.036 μg/g) were well below the lowest-effects level Sediment Quality Criterion for mercury in freshwater sediment of 0.2 μg/g (Jaagumagi, 1992a).

All samples exceeded the lowest-effects Sediment Quality Criterion for nickel in freshwater sediment of 16 μg/g (Jaagumagi, 1992a). Although the mean and maximum concentrations (28.8 μg/g and 33.1 μg/g respectively) were well below the severe-effects level of 75 μg/g. It must be recognized that nickel is bioaccumulated in some aquatic organisms with bioconcentration factors being highest in aquatic plants, intermediate in invertebrates, and lowest in fish (CCREM, 1987). Exceedance of the lowest effects level is therefore of concern and further monitoring of nickel is recommended.

All samples tested for selenium had concentrations below the detection limit of 0.10 μg/g. The detection limit for selenium is well below the Sediment Quality Criterion of 5 μg/g (International Joint Commission, 1981).

Samples tested for silver had concentrations below the detection limit of 2.0 μg/g. However, the Sediment Quality Criterion for silver is 0.5 μg/g (Persaud *et al.*, 1992), below the limits of detection for silver used in the analysis. Therefore, it is not possible to determine if the concentrations of silver present may be detrimental to aquatic life.

Mean (42.0 μg/g) and maximum (44.9 μg/g) concentrations of zinc were well below the lowest-effects level for zinc of 120 μg/g (Jaagumagi, 1992a).

6.2.2.2. Organics

All the organics measured along the Langley Bar had concentrations below the varying detection limits (<0.020 μg/g for polyaromatic hydrocarbons and chlorinated phenols, <0.050 μg/L for polychlorinated biphenyls, and <50 μg/g for oil and grease) of all samples. All polyaromatic hydrocarbons and chlorinated phenols measured during this survey are listed in Table 76.

Sediment samples were also collected at Mission by Hatfield Consultants as part of their 1990/91 comprehensive organochlorine study (Dwernychuk *et al.*, 1991). Organochlorines, polychlorinated dibenzodioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) were measured for this study. Sediment at this site was composed of 20.7% sand (0.063 mm - 2.00 mm) and 79.3% clay and silt (<0.063 mm).

Of the chlorophenols measured at Mission by Hatfield Consultants in 1990, all trichlorophenols concentrations were below detection limits (0.001 µg/g). Concentrations of both 2,4,5,6-tetrachlorophenol and 2,3,4,5-tetrachlorophenol were also below detection limits (<0.001 µg/g). Measurable amounts of both 2,3,4,6-tetrachlorophenol (0.0068 µg/g) and pentachlorophenol (0.0022 µg/g) were present. Since chlorophenols are likely of anthropogenic origins and are not generally measurable in uncontaminated areas, it is proposed that <u>a Sediment Quality Objective originally proposed for the lower Fraser River in 1985 of 0.01 µg/g (dry-weight) for the sum of mono-, di-, tri-, tetra-, and penta as an average of at least three discrete samples be maintained</u>. This value is not likely to be exceeded in uncontaminated areas.

The guaiacols and catechols measured in 1990 (n=1) were present in concentrations of 0.0018 µg/g for 3,4,5-trichloroguaiacol, 0.0014 µg/g for tetrachloroguaiacol, 0.010 µg/g for 3,4,5-trichlorocatechol, and 0.0063 µg/g for tetrachlorocatechol.

Of the dioxins and furans measured in sediments at Mission in 1990 (Dwernychuk *et al*., 1991), only total H_6CDD and O_8CDD, and 2,3,7,8-T_4CDF were present in measurable amounts (concentrations of 4.9 pg/g, 51 pg/g and 3.6 pg/g, respectively). A preliminary report on PCDDs uses the International Toxicity Equivalency Factor (ITEF) method to evaluate the toxicity of complex mixtures of PCDDs and PCDFs. These equivalency factors are based on the toxicity of each compound relative to the most toxic PCDD congener, 2,3,7,8-T_4CDD. The total TEQs for the given concentration of these compounds is 0.80 pg/g. That is, the interim guideline for maximum concentrations of total toxic equivalents of PCDDs and PCDFs in sediment (0.25 pg/g) for the protection of freshwater aquatic life is exceeded by the total TEQs for the compounds measured.

In general, Dwernychuk *et al*. (1991) found that concentrations of organochlorines were higher in sediments between Hope and Mission than in the upper Fraser River (south of Hansard). They suggested that these increases may be due in part to increased sedimentation rates caused by decreased flow rates as the river widens and the slope decreases, as well as organochlorine contributions from the Thompson system. Since organochlorines can be increased in this reach from upstream sources, a Sediment Quality Objective is proposed for dioxins and furans in sediments. The Objective is that the total TEQ for PCDDs and PCDFs should not exceed 0.25 pg/g in any discrete sediment sample collected outside of provisional initial dilution zones as described in Section 1.0.

6.2.3 Analysis of Benthic Invertebrates

Benthos were collected by Northcote *et al*. (1976) for the reach of the Fraser River from three monitoring stations between Chilliwack and Kanaka Creek. Station 10 is the downstream site allochthonously impacted by surrounding agricultural inputs as well as urban and industrial discharges from nearby Mission, in addition to upstream influences to water quality. Station 11 is located mid-reach between Chilliwack and Mission and is affected by the terrestrial influence of agricultural regions and grassland terrains to the north and forested lands to the south as well as upstream discharges. Finally, station 12 is further upstream in the reach where surrounding land uses include agriculture and industrial activity, and some forestry.

The bottom fauna collected by Peterson grabs of 626 cm^2 and Ponar grabs of 529 cm^2 were similar for all three sites as well as similar to upstream measures of abundance. Values were just above 1,000 organisms per square metre at station 10 (n=25), station 11 (n=25), and station 12 (n=30) (*Northcote et al*., 1976). Biomass measured at stations 10 and 12 were lowest while the biomass measured at station 11 was highest. All values were between 1 and 2 g/m2 with station 12 having a lower average biomass than upstream stations between Hope and Chilliwack and downstream stations 10 and 11.

The taxa collected from their respective stations are listed below (Northcote *et al*., 1976).

Occurrence of Taxa in the Benthic Samples from the Lower Fraser River between Chilliwack and Kanaka Creek

Group and Subgroup	Taxa Name	Downstream	Midstream	Upstream
NEMATODE WORMS	Nematode	√	√	√
ANNELID WORMS				
Oligochaetes	Oligochaete	√	√	√
CRUSTACEANS				
Mysids	*Neomysis mercredis*	√	√	
ARACHNIDS	Hydracarina			√
INSECTS				
Ephemeropterans (Mayflies)	***Heptagenia***	√		
	Ephemerella		√	√
Plecopterans (Stoneflies)	**Nemouridae**	√		
	Perlodidae			√
Trichopterans (Caddis flies)	**Hydropsychidae**		√	√
Coleopterans (Beetles)	Hydrophilidae		√	√
	Emidae			√
Dipterans (True flies)	Empididae	√		√
	Tabanidae		√	
	Ceratopogonidae		√	√
	Simuliidae			√
	Unidentified tanypodinae	√	√	√
	Monodiamesa	√	√	√
	Cricotopus	√	√	√
	Heterotrissocladius		√	√
	Orthocladius	√		
	Parakiefferiella	√	√	
	Psectrocladius	√		
	Paracladius	√	√	√
	Chironomus	√	√	√
	Cryptochiromus	√		
	Paracladopelma	√	√	√
	Polypedilum	√	√	√
	Stictochiromus	√	√	√
	Micropsectra		√	√
	Paratanytarsus	√		
	Stempellina		√	√
	Tanytarsus	√	√	√
	Zavrelia		√	
LAMPREYS	Ammocoete	√	√	√
	# Sensitive Species	9	6	5
	TOTAL	21	23	24

(Northcote *et al.*, 1976)

Note- Bold-faced text indicates the name of organic pollution sensitive organisms.

From the list, it is apparent that dipteran flies are found in the greatest diversity. Again, the freshwater nature of this reach of the Fraser River is not expected to support an abundance of marine invertebrates (Northcote *et al*., 1976). Upstream stations were characterized by a greater variety of taxa. When data from all stations in this reach of the Fraser River are combined and averaged, Simpson's index of diversity of benthos associated with mud and mud-sand was 0.682 (Northcote *et al*., 1976), higher than all other reaches sampled. Similarly, the Shannon-Wiener function was highest as the only value above 2 among all other functions calculated for reaches of the river. A function greater than 2 is typical of unpolluted areas. An equitability value of 0.744 is equally admirable, although this value is slightly lower than the value obtained at the upstream reach between Hope and Chilliwack.

Average diversity parameters measured in sand and sand-gravel substrate collected between Chilliwack and Kanaka Creek are not as extreme with a Simpson index of 0.452 and a Shannon-Wiener function of 1.214 (Northcote *et al*., 1976). Both values are marginally lower than those for the upstream reach between Hope and Chilliwack where Simpson's index was 0.484 and the Shannon-Wiener function was 1.366 (Northcote *et al*., 1976). In contrast, the equitability calculation revealed that individuals of their respective communities are more evenly distributed between various taxa collected downstream (0.771) than upstream(0.676) (Northcote *et al*., 1976). Again, the value is typical (>0.5) of benthic communities in unpolluted streams (Weber, 1973).

It is of significance that although the mud and mud-sand component of bottom sediments supported a greater number and mass, fewer pollution sensitive taxa were detected at the closest station (Station 12) than upper stream sites. With increasing distance downstream, the number of taxa sensitive to organic pollution increase and are greatest at station 10 which is presumably influenced by the surrounding urban, industrial, and agricultural activity, as well as upstream authochthonous water quality. Sensitive taxa sampled at all three monitoring stations, between Chilliwack and Kanaka Creek were: *Cricotopus*, *Paracladopelma*, and *Tanytarsus*, all of which are dipteran flies. Sensitive organisms collected at the two upstream stations (11 and 12) but not the downstream station (10) included *Hydropsychidae* caddis flies and Micropsectra dipteran flies. Sensitive taxa that were collected at downstream station 10 but not upstream stations 11 and 12 included *Heptagenia* mayflies, *Nemouridae* stone flies, and dipteran *Orthocladia*, *Psectrocladia*, and *Paratanytarsus*.

6.2.4 Analysis of Fish

A number of chlorinated compounds were measured in both fish and liver tissues collected from near Chilliwack and Mission between November 1990 and February 1991 (Dwernychuk *et al.*, 1991). Composites of liver and muscle tissues from largescale sucker, mountain whitefish, Dolly Varden, and rainbow trout were analyzed for chlorophenols, guaiacols and catechols at ASL Laboratory, and PCDDs and PCDFs at Seakem Laboratory.

Of the chlorophenols, guaiacols and catechols measured in the composite muscle samples, only 3,4,5-trichloroguaiacol (at a concentration of 1.8 µg/g wet-weight in the largescale sucker) and tetrachloroguaiacol (at a concentration of 1.8 µg/g wet-weight in the Dolly Varden muscle sample) were present in concentrations above detection limits.

Insufficient liver tissue was collected from the largescale sucker, mountain whitefish, and one of two rainbow trout composites to measure concentrations of chlorophenols, guaiacols and catechols. Of the compounds measured, 2,4,6-trichlorophenol, 2,3,4,6-tetrachlorophenol, pentachlorophenol, 3,4,5-trichloroguaiacol and tetrachloroguaiacol were present in measurable amounts in both the Dolly Varden liver composite and the remaining rainbow trout composite. The compounds 3,4,5-trichlorocatechol and tetrachlorocatechol were present in the rainbow trout liver composite only. Concentrations of all compounds were higher in the rainbow trout liver composite than in the Dolly Varden. The existing Water Quality Objective for chlorophenols in the lower Fraser River is a maximum concentration of 0.1 µg/g (wet-weight) in fish muscle for all chlorophenols combined. This value was based on the goal of no increase in chlorophenol concentrations over present conditions; however, a new provisional Tissue Quality Objective of 0.2 µg/g (wet-weight) for the sum of mono-, di-, tri-, tetra- and pentachlorophenol in any single sample or a composite sample in any species is proposed for the upper Fraser River. This Objective reflects the Ministry criteria for 2,4-dichlorophenol alone.

Of all PCDDs and PCDFs measured in muscle and liver tissues, T_4CDF was the only ubiquitous compound with a maximum concentration of 20 pg/g wet-weight in a Dolly Varden liver. The compound 2,3,7,8-T_4CDD appeared in measurable amounts in four of ten samples analyzed, with a maximum concentration of 20 pg/g in a composite mountain whitefish liver sample. Total P_5CDD was only present in measurable amounts in a Dolly Varden muscle sample at a concentration of 0.4 pg/g. Total H_6CDD was present in measurable amounts in three of 10 samples analyzed with a maximum concentration of 16 pg/g in a mountain whitefish liver composite. Total P_5CDF was detected in one of 10 samples analyzed at a concentration of 0.8 pg/g in a Dolly Varden muscle sample. Two of ten samples contained detectable concentrations of total H_6CDF with the maximum concentration of 18 pg/g occurring in a Dolly Varden liver sample. These two samples also contained detectable concentrations of total H_7CDF, and the Dolly Varden liver sample again had the highest concentration measured, at 24 pg/g. Finally, O_8CDF was measured in one of the 10 samples analyzed at a concentration of 0.7 pg/g in a Dolly Varden muscle sample. Lipid concentrations of these fish was not supplied in the report, so their toxicity relative to the interim guidelines for the concentrations of these compounds in fish tissues can not be determined. However, it would appear that concentrations of PCDDs and PCDFs may be a concern in fish tissues in the North Arm.

Dwernychuk *et al.* (1991) found low levels of organochlorine compounds upstream from Prince George indicating that fish which contain organochlorines are capable of migrating into waters not containing these compounds. They also found that "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". The draft B.C. criterion for the protection of aquatic life from dioxins and furans is the <u>proposed tissue quality objective for these compounds in the lipids of fish</u>. The proposed Objective is that <u>the total TEQs for lipid concentrations of PCDDs and PCDFs should not exceed 50 pg/g in the lipids of fish tissues and fish eggs collected in between Chilliwack and Kanaka Creek</u>.

6.3 The Fraser River from Kanaka Creek to the New Westminster Trifurcation

6.3.1 Water Chemistry

The stretch of river between Kanaka Creek and the New Westminster trifurcation is referred to as the Main Stem. There is moderately heavy use of the river at this point. The water uses considered when developing criteria for the Main Stem include irrigation, secondary - contact recreation, and the preservation of wildlife and sensitive aquatic life (Swain and Holms, 1985b).

The Main Stem was sampled at three ambient sites (Figure 9). Site E206965 is located between Barnston and Douglas Islands. Site E206966 is located just upstream from the Brunette River. The third and last site, 0300005, is at the Pattullo Bridge. The small number of sites and limited sampling at each site may decrease confidence when data are variable. The most complete set of data is taken from Site 0300005 and therefore this information is extrapolated to the entire section of the river when data from other sites are not available. The data from the three sites on the Main Stem between Kanaka Creek and the New Westminster trifurcation have been collected since 1985 and are summarized in Tables 77, 78 and 79 respectively.

6.3.1.1 pH and Alkalinity

The average pH between Kanaka Creek and the trifurcation at Site 0300005 was 7.9 which is very similar to upstream values; however, values ranged from 6.4-9.6 and 10 of the 14 values are on the extremes of this range. The high pH values occurred in August and low pH values in March. Reports from 1979 indicate that pH ranges were much smaller (7-8), and that there were no apparent seasonal trends (Swain and Holms, 1985b). The Assessment and Objective Study for 1993 which tested Sites E206965 and 0300005 found the ranges to be 7.4 - 7.8 and 7.5 - 7.7 respectively (Water Quality in B.C.: Objectives Attainment in 1993, 1994). The extreme variation in the pH values taken from SEAM data since 1985 represents a thousand-fold increase in acid concentration which is highly improbable. The pH values from Hope are more typical of the Fraser River and a comparison of Hope data and Site 0300005 data suggests that there may have been errors in field sampling techniques at Site 0300005. Although the mean pH is within criterion for freshwater aquatic life (6.5-9.0) (McKean, and Nagpal, 1991), the questionable data make conclusions impossible. Only one pH value was available at Site E206965: 7.9 which is within normal parameters. No data were available from Site E206966. The provincial criteria for pH sets a range of 6.5 to 9.0 for the protection of aquatic life. <u>However, in order to minimize the effect of unionized ammonia on fish, an objective pH range of 6.5 to 8.5 is proposed for the Fraser River.</u>

No alkalinity data were available but calcium levels around 14.4 mg/L suggest a moderate buffering capacity to acid inputs. This is consistent with results from data collected from 1978-1984 which reported alkalinity values from 40 - 50 mg/L. Data from 1970 - 1978 also show similar values (Rocchini *et al.*, 1979). The river has a poor buffering capacity against bases therefore alkaline discharges to the river should be minimized to protect against ammonia toxicity. The alkalinity appears to be stable over time with no seasonal changes.

6.3.1.2 Hardness and Metals

A mean river hardness of 38.0 mg/L was calculated using calcium and magnesium data from Site 0300005 (n=10). This is slightly lower than the 40 to 60 mg/L reported by Drinnan and Clark in 1979 (Drinnan and Clark, 1980) and confirmed by Swain and Holms (1985b).

Limited metal data in this portion of the river make firm conclusions impossible. Furthermore, many of the measurements had detection limits that were too high to ensure that criteria were met. For these reasons, the metal data must be considered estimates.

Cadmium

Water with a hardness between 0-60 mg/L has a maximum cadmium criterion level of 0.0002 mg/L to ensure the protection of freshwater aquatic life (Health and Welfare Canada, 1989 and CCREM, 1987). Cadmium levels were measured to be less than 0.01 mg/L but these measurements are not accurate enough to ensure that the criterion is met .

Chromium

The criterion for chromium is set at 0.02 mg/L for the protection of freshwater fish and 0.002 mg/L in order to ensure the health of phyto- and zooplankton (CCREM, 1987). All measurements were recorded as < 0.01 mg/L (n=10) which meets the criterion for fish but can not be used to draw conclusions about freshwater plankton. Data collected from 1979 and 1980 report mean levels of 0.006 mg/L (Swain and Holms, 1985b). Neither this study nor the Fraser River Estuary Study of 1979 (Rocchini *et al.*, 1979) consider chromium a concern.

Cobalt

The lowest reported level of cobalt that has any effect on freshwater aquatic life is 0.05 mg/L (NAS, 1972). Again, the detection limits were too high, as all values were recorded as < 0.1 mg/L .

Copper

Copper at Site 0300005 ranged in concentration from 0.001 mg/L to 0.05 mg/L with a mean of 0.009 mg/L. In water with a hardness of 38 mg/L Ca CO_3, the criterion maximum is 0.0056 mg/L (Singleton, 1987). Two of the ten values exceeded this maximum. Data reported in 1984 shows a maximum copper concentration of 0.012 mg/L and an average of 0.003 mg/L (Swain and Holms, 1985b). All values were taken between January and March when high flow rates should not have been a factor in the high concentrations.

Copper can be increased from stormwater discharges or combined sewer overflows near New Westminster. The following Water Quality Objectives are proposed for the protection of aquatic life. The maximum total copper concentration should not exceed the product of 0.094 (hardness) + 2 µg/L. Furthermore, the 30-day average copper concentrations should not exceed 2 µg/L when water hardness is less than 50 mg/L, and when water hardness is greater than 50 mg/L should not exceed 0.04 (average hardness). The mean values apply to a minimum of five weekly samples collected over a thirty-day period while the maximums apply to discrete samples.

Iron

Iron concentrations at Site 0300005 range from 0.31 to 0.78 mg/L with an average concentration of 0.48 mg/L (n=10). This exceeds the criterion of 0.3 mg/L for the maintenance of freshwater aquatic life (CCREM, 1987). These values reflect a substantial decrease from 1979 -1980 levels which ranged from 0.5 to 6 mg/L (n=10) (Swain and Holms, 1985b). Since earlier reports by Drinnan and Clark (1980) also showed high concentrations, it is felt that these were naturally occurring and probably due to the iron content of suspended sediments; therefore, it seems unlikely that the elevated levels are of anthropogenic origin.

Lead

With a water hardness of 38 mg/L $CaCO_3$, the criterion for the maximum concentration of lead for the safety of freshwater aquatic life is 0.023 mg/L and the 30-day average is < 0.004 mg/L (Nagpal, 1987). Lead was found in concentrations ranging from 0.001- < 0.1 mg/L (n=10). The mean concentration was 0.047 mg/L, one order of magnitude above criterion. However, more precise data reported had a range of 0.001 to 0.005 mg/L (Swain and Holms, 1985b).

To ensure that lead concentrations remain low now that leaded gasoline has been eliminated in Canada, a Water Quality Objective is proposed for lead concentrations for the protection of aquatic life. The Objective is that the 30-day average concentration of total lead should not exceed 3.31 + 1.273 exp (ln (average hardness) - 4.705 µg/L, and that the maximum value measured must be ≤1.273 exp (ln (average hardness) - 1.460 µg/L. The 30-day average is calculated from at least five weekly samples taken in a period of 30 days (Nagpal, 1994).

Manganese

Manganese was found in levels ranging from 0.02 to 0.03 mg/L at Site 0300005. These are within the criterion maximum concentration of 2 mg/L for irrigation water (Health and Welfare Canada, 1989). Freshwater life is not affected until concentrations exceed 1-10 mg/L (American Fisheries Society, 1979).

Since manganese is now used as a fuel additive in gasoline and would be present in stormwater and in combined sewer overflows, a Water Quality Objective is proposed. For the protection of aquatic life, the Water Quality Objective for the Main Stem of the Fraser River requires that discrete water samples collected from this reach of the river not exceed 100 µg/L.

Molybdenum

In all samples, molybdenum was found in concentrations < 0.01 mg/L (n=10). This meets the stringent criterion of irrigation water, which must have no more than 0.01 mg/L in some cases (Swain, 1986b). All values easily meet the maximum criterion of 2 mg/L for the protection freshwater aquatic life.

Nickel

Nickel concentrations may affect freshwater aquatic life at concentrations of 0.025 mg/L (CCREM, 1987). Measured values ranged from < 0.05 to 0.08 mg/L with a median value of <0.05 mg/L (n=10) at Site 0300005. These values were often not accurate enough to make an accurate assessment of water quality with respect to the criterion, but the maximum value did exceed the criterion and was greater than reported in 1979-1980 (0.01 and 0.02 mg/L) (Swain and Holms, 1985b). This may indicate a seasonal increase but the majority of the data is within criterion.

The data presented suggest that concentrations of chromium, manganese and molybdenum are not of concern. Measurements for cadmium, cobalt and nickel were not precise enough and they were not in sufficient numbers to ensure an accurate assessment with respect to the criteria. Levels of copper, iron and lead in this area are in excess of their respective criteria. Some of the high values may be due to natural background variations associated with freshet or precipitation events. These high metal levels may be associated with high suspended solid concentrations and would not be readily available to aquatic life. If these increases are due to suspended solids, they are of little immediate concern to aquatic life (Swain and Holms, 1985b).

Storm water runoff could increase zinc concentrations under low flow conditions. Therefore, a Water Quality Objective is proposed for zinc concentrations in the Main Stem. This objective states that the mean concentration of zinc in at least five samples measured in a 30-day period should not exceed 14 µg/L, and no single value should exceed 30 µg/L.

6.3.1.3 Dissolved Oxygen and Oxygen-Consuming Materials

Data from 1980 and a later report in 1991 (Beak Consultants, 1991) show that the Fraser River has high dissolved oxygen (DO), often near saturation. The average concentration for Site 030005 in 1979 and 1980 was 11 mg/L (Swain and Holms, 1985b). Values were seasonal with the lowest values occurring in late summer and the highest in the winter (Drinnan and Clark , 1980). Five samples taken for Site 0300005 in September and October of 1991 had a mean DO of 9.0 mg/L (Beak Consultants, 1991). Samples taken during the same period in 1992 had a mean DO of 8.7 mg/L (Beak Consultants, 1993). In 1991, the Greater Vancouver Sewerage and Drainage District tested the receiving waters at four sites in the Main Stem. All sites were tested in May and June when values should be at a minimum. There was no site-to-site differences noted with values varying randomly from 10.5 mg/L to 11.5 mg/L (Beak Consultants, 1991). Generally, dissolved oxygen concentrations in the Main Stem varied seasonally but were consistent year to year. As dissolved oxygen is an essential element of fish health, and the Fraser River is a major spawning ground for salmonids and other fish, and using the criteria from Truelson (1997) as a basis, a Water Quality Objective for the Fraser River from Kanaka Creek to the trifurcation is that the instantaneous minimum should not be less than 5 mg/L and the 30-day mean should not be lower than the higher of 80% saturation or 8.0 mg/L. In spawning areas where fish eggs are incubating or areas utilized by young fish, the Water Quality Objective is an instantaneous minimum of not less than 9 mg/L and a 30-day mean not lower than 11.0 mg/L (November to April)..

6.3.1.4 Solids, Turbidity and Colour

Suspended solids are an important factor in fish health as they can contribute to gill inflammation and disease. At Site 0300005, solids were found in concentrations between 1 and 14 mg/L, with a mean value of 7.2 mg/L. The highest values occurred during freshet (March - July) when increased flow resuspends bottom sediment and cause increased erosion. Water quality criteria are primarily concerned with the increase in suspended solids downstream from an outfall. Because there are no data upstream and downstream from an outfall, no analysis can be made. However, there has been a substantial decrease since the 1979-1982 values which averaged 67 mg/L (Swain and Holms, 1985b).

There were no available data on turbidity or colour.

6.3.1.5 Nutrients

Nitrogen and phosphorus concentrations are often limiting factors in algal growth. Large changes in these values may strain the oxygen content of the water system, harming fish and other aquatic life. However, due to the turbid nature of the Fraser River, an increase in nutrient concentration is unlikely to cause a growth increase. Only Site 0300005 had data available and only ammonia concentrations were recorded. Data from other river sections will have to be used as an indication of other nutrient values.

The amount of ammonia that can be present in the water without affecting oxygen content or growth rates is largely dependent on the pH and the temperature. As there seemed to be significant pH changes between March and August, ammonia content will be discussed using low and high pH values and a temperature variation between 15-17^{o}C. All ammonia samples were collected in January and February when pH was recorded at around 6.4. At this pH, the criterion would allow ammonia concentrations up to 24.2 mg/L with a 30-day average concentration of 1.52 mg/L (Nordin and Pommen, 1986). No ammonia tests were done in August when pH was upwards of 9.0 but criterion would allow ammonia levels up to 0.704 mg/L with a 30-day average concentration concentrations of 0.121 mg/L (Nordin and Pommen, 1986). The highest recorded ammonia concentration was 0.093 mg/L and the mean concentration was 0.060 mg/L. The values were highest during low flow and lowest during freshet. These values are well within all criteria but are higher than the mean of 0.016 mg/L recorded between 1979 and 1982 (Swain and Holms, 1985b). <u>Due to the toxic effects of ammonia on fish, a 30 day average objective of 0.944 mg/L, and a maximum objective of 5.64 mg/L has been proposed in order to protect spawning fish (pH of 8.0 and water temperature of 17^{o}C)</u> (See Tables 11 and 12).

6.3.1.6 Bacteriological Indicators

Coliforms data were collected from Site 0300005. This section of the river, like the previous sections, contains high fecal coliform counts and moderately high total coliforms. Fecal coliform counts ranged from 20 to 3200 CFU/cL with a mean of 311 CFU/cL (n=29). This exceeds criteria of 200 CFU/cL for livestock watering, irrigation of crops eaten raw, and primary and secondary contact recreation (Warrington, 1988). In

1991, the Greater Vancouver Sewerage and Drainage District measured fecal coliforms at four sites in the Main Stem. The values for all sites varied from < 20 MPN/100 mL to 300 MPN/100 mL. The mean values increased sequentially downstream from 62 MPN/100 mL at Douglas Island to 116 MPN/100 mL at the trifurcation (Beak Consultants, 1991). These values can not be directly compared to the criteria due to different units of measurement but it appears that the values have decreased since 1985 although generally, the coliform counts are still high. In order to protect the water for irrigation use, a Water Quality Objective is proposed for fecal coliforms of 200 CFU/100 mL (geometric mean) in any one sample. This objective is not presently being met at Site 0300005 (3220 CFU/mL).

E.coli counts had a maximum count of 56 CFU/cL which meets the most stringent criterion applicable to this reach, < 77 CFU/100 mL(geometric mean), for the irrigation of crops eaten raw (Warrington, 1988). In order to protect irrigation use, a provisional water quality of 77 CFU/100 mL E. coli as a geometric mean concentration from at least five samples collected during a 30-day period.

Enterococci was found in concentrations between 9 and 26 CFU/cL with a mean of 37 CFU/cL (n=5). These values meet the criterion of 50 CFU/100mL for general livestock uses. More data are needed to determine whether the high values measured are common and if seasonality is a factor. In order to protect irrigation use, a provisional water quality of 20 CFU/100 mL Enterococci as a geometric mean concentration from at least five samples collected during a 30-day period.

No data were available for P. aeruginosa.

6.3.1.7 Organics

Significant research has been conducted by J.H. Carey regarding chlorophenols and polychlorinated biphenyls (PCBs) in the Fraser River estuary. Carey (1988, 1990) reports that although permitted upstream pulp mill discharges contain no 2, 3, 4, 6 tetrachlorophenols (2, 3, 4, 6 TeCP) and polychlorinated phenols (PCPs), runoff from rain waters have reached levels that ranged from lethal to harmful to the growth and reproduction of fish. Furthermore, because the release of compounds are affected by the tidal cycle, the influx of 2, 3, 4, 6 TeCP and PCP are very episodic or pulse like (Carey, 1990). Finally, salinity variations are known to influence the speciation of chlorophenolics

(Carey, 1990). At pH levels of approximately 7.76, chlorophenolics are predominately in dissociated form which is much more soluble in water than undissociated forms. The development of water quality objectives and monitoring programs must consider these behaviours (Carey, 1990).

Data on organics were available from Sites E206965 and E206966. The monochlorophenols (4 ChlPhen (n=10) and 3 ChlPhen (n=9)) were measured and found to have mean concentrations < 0.0001 mg/L. There are no criteria available for maximum water concentrations of these compounds for the protection of freshwater aquatic life (Warrington, 1993).

Polychlorinated phenols (PCP) were found in concentrations < 0.0001 mg/L (n=10) but no criterion was available for comparison. As chlorophenols levels are almost exclusively due to anthropogenic sources, an objective of 0.0001 mg/L (maximum) chlorophenols in any discrete water column is proposed. This value is unlikely to be exceeded by uncontaminated waters. It was met by all available data which indicates that PCPs are not a concern in the Main Stem of the Fraser River (Water Quality in B.C.: Objectives Attainment in 1993, 1994).

6.3.2 Sediment Chemistry

Salinity intrusions as well as the re-suspension and deposition of sediments have implications for the uptake, accumulation, and distribution of contaminants in the estuary. In turn, these factors influence the bioavailability, effects, and fate of contaminants. Sediment transport in the Fraser River estuary, which occurs as both bed load and suspended load, is controlled by river conditions as well as tidal action and salt wedge position (Kostachuck *et al.*, 1992). The primary source of both wash and bed material loads in the estuary is the Fraser River (Kostachuk *et al.*, 1992). There is no evidence for significant transfer of marine sediment from the Strait of Georgia to the estuary (Kostachuk *et al.*, 1992); marine influence is apparent in another form. The estuarine salt wedge plays an important role in the re-suspension and deposition of sandy bed material. As the tide rises, the saline intrusion migrates upstream into the channel and suspended bed sediment is deposited. During falling tides, the salt wedge moves seaward and re-suspension begins as the tip of the wedge passes. Re-suspension is then sustained by accelerating downstream currents (Kostachuk *et al*., 1992).

Sediment data were collected at Sites E206965 and E206966 (Tables 80 and 81). The data are quite limited at both sites. For this reason, there is substantial emphasis being placed on alternate sources and previous reports. With the exception of PCBs (total) and PCPs, the majority of the sediment data from SEAM was collected in 1989 or previously, making the 1992 FREMP report the most recent data available.

The criteria are based on a 1% organic carbon content although the actual content is slightly lower, ranging from 0.6% to 0.65% and unless otherwise mentioned, criteria were based on screening level concentrations (SLC). SLC is an approach that estimates the highest concentration of selected chemical that co-occur with approximately 95% of the infauna. Another approach that may be used is sediment - water equilibrium partitioning (EP). This establishes criteria for individual chemicals at concentrations in sediment that ensures that the concentrations in interstitial water do not exceed those of the EPA which are assumed to protect infaunal organisms (Swain and Holms, 1985b).

6.3.2.1 Particle Size

Due to the higher surface area of fine particles, chemical contaminants are generally greater in areas with a high silt content. The data taken from SEAM is about 78% very fine or fine sand. This is comparable to the particle size distribution found in the FREMP report of 1987 and these measurements will be used as a comparison. However, the FREMP report from 1992 contained the most recent data and at that report indicates that the sediment collected was 56.9% silt. Therefore, it will be compared to 1989 data that has a similar sediment composition. Figures 11 and 12 show the relationship between particle size and metal concentrations.

6.3.2.2 Metals

Total metal concentrations tended to vary greatly with the season. Values taken from January to March were generally well within criteria limits but values taken in July and August, when flow rates were high, indicated levels in exceedance of criteria.

New aluminum data were not available but data from 1992 shows concentration ranged from 1.84 µg/g to 2.15 µg/g with an average value of 2.00 µg/g(Swain and Walton, 1993a). There is no criterion for this parameter at this time.

Arsenic concentrations at both Site E206965 and Site W206966 appear high but all the values which exceeded the criterion of 6 µg/g (Jaagumagi, 1992a) lowest-effects level had detection limits of 30 µg/g. All values from 1989 were below the criterion. The values ranged from 4.18 µg/g to 5.15 µg/g (Swain and Walton, 1990) and as the particle sizes in 1989 were finer, SEAM values would be expected to be lower than these. Values from 1992 were measured as less than 25 µg/g. Due to the large detection limit, no trends can be projected (Swain and Walton, 1993a).

All cadmium levels at Sites E206965 and E206966 were below the 0.6 µg/g (Jaagumagi, 1992a) permitted by criterion for freshwater. Values ranged from 0.2 µg/g to 0.24 µg/g and means were 0.22 and 0.21 µg/g (n=6). These values are comparable to the 0.22 µg/g average measured in 1989 (Swain and Walton, 1990) and the 0.18 µg/g average found in 1992 (Swain and Walton, 1993a).

Chromium concentrations were recorded in the 30 µg/g - 40 µg/g range during August. These levels exceed the lowest-effects level 26 µg/g for freshwater (Jaagumagi, 1992a). The concentrations fell to accepted limits when flow rates decreased in winter months. The values were similar to those measured in January of 1987 which averaged 20.7 µg/g (Swain and Walton, 1988). Chromium values in 1989 were considerably higher, with values ranging from 45.6 µg/g to 49.6 µg/g; however, the particle sizes were smaller (Swain and Walton, 1990). When 1989 data are compared to 1992 data with the effects of sediment composition controlled for, the concentrations reflect an increase, with 1992 data showing concentrations between 51 µg/g and 64 µg/g (Swain and Walton, 1993a).

Copper at Site E206965 was found in concentrations from 14 µg/g to 39.2 µg/g with an average concentration of 23.9 µg/g (n=15). At Site E206966, values were lower, the concentrations ranging from 13 µg/g to 25.4 µg/g and an average of 15.6 µg/g (n=11). Both sites exceed the criterion of 16 µg/g based on the lowest-effects level for freshwater (Jaagumagi, 1992a). These values are high and fairly stable when the effects of sediments composition are considered. The 1987 data show an average concentration of 17 µg/g (Swain and Walton, 1988). In years where the silt content was higher, the copper concentrations were higher as well but, they were consistent. In 1989, at Site

E206965, the copper concentration was found to be 37.8 µg/g (Swain and Walton, 1990). In 1992, it was 33.7 µg/g (Swain and Walton, 1993a).

At Site E206965, iron was found in concentrations ranging from 15 200 µg/g to 34 600 µg/g with the higher values appearing in August. The mean was 22 420 µg/g (n=15). At Site E206966, the mean was slightly lower at 17 282 µg/g (n=11). These values have decreased somewhat from the averages found in similar sized particles in 1987 of 17 050 µg/g (Site E206965) and 16 350 µg/g (Site E206966) (Swain and Walton, 1988). Samples from 1989 and 1992 had a higher silt content and therefore values are expected to be higher. This is true of 1989 where samples from Site E206965 had a mean of 34 600 µg/g and samples from Site E206966 had a mean of 26 600 µg/g (Swain and Walton, 1990). However, data from 1992 shows average iron concentrations for Sites E206965 and E206966 of 3.42 µg/g and 3.29 µg/g respectively (Swain and Walton, 1993a). This is a very large decrease. In sediments with a high silt content the lowest-effects level criterion for freshwater of 21 200 µg/g (based on SLC) was often exceeded (Jaagumagi, 1992a). In fine and very fine sand, the samples were close to the criterion limit.

Lead levels ranged from 6.55 µg/g to 20 µg/g at Site E206965 (mean 10.01 µg/g) (n=15) and 6.9 µg/g to 30 µg/g at Site E206966 (mean 12.2 µg/g) (n=11). Samples taken in 1987 show nearly identical levels (Swain and Walton, 1988). These values are below the lowest-effects level for freshwater aquatic life (31 µg/g) (Jaagumagi, 1992a). Furthermore, 1992 samples have shown a significant decrease in lead. Due to the higher silt content in 1992, a higher lead concentration would be expected; however, all of the values are lower. The maximum value is only 7.3 µg/g and the mean is 6.7 µg/g (Swain and Walton, 1993a).

Manganese at Site E206965 was found in concentrations between 328 µg/g and 728 µg/g with a mean of 478 µg/g (n=15). At Site E206966, values were slightly lower, 330 µg/g to 537 µg/g with a mean of 353 µg/g (n=11). This is comparable to samples taken in 1987 that showed mean concentration of 368.7 µg/g (Swain and Walton, 1988). In sediments with high silt content such as the samples taken at Site E206965 and E206966 in 1989 and 1992, the manganese concentration is higher as expected. The 1989 values have a mean concentration of 595.2 µg/g (Swain and Walton, 1990) The 1992 values showed a substantial increase, with the mean concentration reaching 695.6 µg/g (Swain and Walton, 1993a). It should be noted that some of the values exceed the lowest-effects level criterion of 460 µg/g but all values meet the severe-effects level of 1100 µg/g (Jaagumagi, 1992a).

At Site E206966, mercury levels ranged from 0.039 - 0.13 µg/g. At Site E206965, mercury levels were within that range. These levels are well within the 0.2 µg/g criterion (Jaagumagi, 1992a) and show a slight decrease from concentrations found in 1987. The average went from 0.062 µg/g in 1987 (Site E206965) (Swain and Walton, 1988) to 0.54 µg/g in 1992 (Site E206965) (Swain and Walton, 1993a). Concentrations at Site E206966 show a similar decrease despite changes in sediment particle sizes between the two sample sets.

Molybdenum was below detection limits in both 1989 and 1992 data.

Nickel seems to be a problem at sites E206965 and E206966 with all 26 values exceeding the freshwater criterion of 16 µg/g(Jaagumagi, 1992b). Values ranged from 28 to 55.1 µg/g at Site E206965 and from 31 to 42.9 µg/g at Site E206966. This is an increase from 1987 data at Site E206965; the average increased from 30.9 µg/g to 38.4 µg/g (Swain and Walton, 1988). The concentration at Site E206966 was unchanged from the 32 µg/g found in 1987 (Swain and Walton, 1988). When 1989 and 1992 data are compared (they have a similar particle size distribution) there is also an increase shown. The 1987 data has a maximum of 55 µg/g and a mean of 51.4 µg/g (Swain and Walton, 1988) whereas 1992 data has a maximum of 63.8 µg/g and a mean of 54.4 µg/g (Swain and Walton, 1993a).

The 1989 data for zinc show concentrations between 184 µg/g and 220 µg/g (Swain and Walton, 1990). These concentrations exceed the lowest-effects level criterion of 120 µg/g (based on SLC) but meet the severe-effects level criterion of 820 µg/g (Jaagumagi, 1992a) The 1992 samples show a substantial decrease with a maximum value of 90.7 µg/g and a mean of 85.05 µg/g (Swain and Walton, 1993a). These values meet all criteria.

6.3.2.3 Organics

6.3.2.3.1 Polycyclic Aromatic Hydrocarbons (PAHs)

The polycyclic aromatic hydrocarbons (PAH) tested at both sites E206965 (n=5) and E206966 (n=1) were:, benzo-[g]-perylene, benzo-[k]-fluoranthene, chrysene, dibenzo[a,h]anthracene, indenopyrene, and pyrene. Anthracene, benz[a]anthracene, benzo[a]pyrene, and naphthalene were tested at Site E206995 only (n=5).

The lowest-effects level criteria were used based on the screening level concentration (SLC). With two exceptions, all values for PAHs were within criteria limits (Nagpal, 1993 (b) and Persaud *et al.*, 1992). One of the five values for dibenzo-[a,h]-anthracene (0.089 µg/g) at site E206965 exceeded its criterion of 0.05 µg/g and the maximum value for indenopyrene at site E206965 exceeded its criterion of 0.07 µg/g. All concentrations of benzo[a]pyrene were above the no-effects threshold of 0.01 µg/g but below the minimal-effects threshold of 0.5 µg/g set for the St-Lawrence River (Environment Canada, 1992). All concentrations of naphthalene were above the no-effects threshold of 0.02 µg/g but below the minimal-effects threshold of 0.4 µg/g set for the St-Lawrence River (Environment Canada, 1992).

A 1989 report has similar results with all levels below detection limits with the exception of benzo[a]pyrene which had a maximum concentration of 0.10 µg/g, dibenzo [a,h] anthracene with a concentration of 0.089 µg/g and indeno[1,2,3-C,D] pyrene with a concentration of 0.098 µg/g (all at Site E206965) (Swain and Walton, 1990). The 1990 study also tested for acenaphthene, acenaphthylene, benzo[b]fluoranthene, benzo[g,h,i]perylene, fluoranthene, fluorene, naphthalene, and phenanthrene all of which were below detection limits (Swain and Walton, 1990). The values in the 1992 report were similar to those of the 1989 report except for considerable decreases in the maximum concentration of benzo[a]pyrene from 0.10 µg/g in 1989 to <0.020 µg/g in 1992 (Swain and Walton, 1993a). There were also decreases in indeno[1,2,3-c,d]pyrene from 0.098 µg/g in 1989 to 0.037 µg/g in 1992 (Swain and Walton, 1993a). The concentrations for all the PAHs were below Water Quality Objectives for nearby Burrard Inlet and therefore of little concern to aquatic organisms living in the sediments.

6.3.2.3.2 Chlorophenols and Polychlorinated Biphenyls (PCBs)

Salinity distributions in the estuary play an important role in determining the extent of chlorophenol sorption onto sediment because the dissociated form predominates in the saline environment and is more water soluble than the undissociated form (Carey, 1990). There are no sampling reported data from SEAM on chlorophenols but the 1989 survey tested for trichlorophenol, tetrachlorophenol and pentachlorophenol. All were below the detection limit of 0.005 µg/g (Swain and Walton, 1990). In 1992, these compounds were also below the detection limit of 0.005 µg/g but at Site E206965, 3,4,5-trichloroguaiacol, 3,4,5- trichlorocatechol and tetrachlorocatechol were found in detectable amounts with maximum values of 0.002 µg/g, 0.029 µg/g and 0.32 µg/g respectively (Swain and Walton, 1993a). At Site E206966, these compounds were again detected in the following concentrations: 3,4,5- trichloroguaiacol had a maximum concentration of 0.001 µg/g (n=5), 3,4,5-trichlorocatechol had a maximum of 0.31 µg/g (n=5) and tetrachlorocatechol had a maximum of 0.028 µg/g (n=5) (Swain and Walton, 1993a). Since chlorophenols are likely of anthropogenic origins and are not generally measurable in uncontaminated areas, <u>a Sediment Quality Objective of 0.01 µg/g (dry-weight) as an average of at least three discrete samples has been proposed</u>. This value is not likely to be exceeded in uncontaminated areas and as it is not presently met by sediments in the Main Stem, it is reasonable to assume that there is some chlorophenol contamination.

All data collected for polychlorinated biphenyls (PCBs) at Sites E206965 and E206966 had values below the detection limit of 0.01 µg/g. This is within the no effect criterion limit of 0.02 µg/g (Nagpal, 1992) based on equilibrium partitioning. Although PCBs were detected at Site E206965 in 1985, measurements were below the detection limit of 0.02 µg/g in 1987 and below 0.01 µg/g in 1989 and 1992 (Swain and Walton, 1988, 1990 and 1993). PCBs are rarely used any more but in order to prevent further degradation, or a build up in the food web an <u>objective of 0.02 µg/g, as an average of at least three discrete surface sediment samples, is proposed for the total of all PCBs</u>.

6.3.2.3.3 Pesticides

The organochlorine pesticides tested were aldrin, chlordane alpha, chlordane gamma, Dieldrin, DDE, DDD, DDT, Endrin, heptachlor, heptachlor epoxide, Lindane, and methoxy chloride (n=6). At Sites E206965 and E206966, aldrin, chlordane (alpha and gamma), Dieldrin, and DDD had measured values below the 0.001 µg/g detection limit. The criteria for all of these chemicals is greater than the detection limit, ranging from 0.002 µg/g to 0.008 µg/g (Jaagumagi, 1992b).

The lowest-effects level for DDT is 0.008 µg/g (Jaagumagi, 1992b) and all collected data had values below 0.003 µg/g. DDE was found in minute quantities (0.0005 µg/g) and was well within the 0.005 µg/g criterion (Jaagumagi, 1992b). Endrin was found in concentrations of 0.0005 µg/g which is below the low-effects level of 0.003 µg/g (Jaagumagi, 1992b). Heptachlor was measured as less than or equal to 0.0005 µg/g which is not precise enough to determine whether the minimal effects threshold criterion of 0.0003 µg/g set for the St-Lawrence River is met (Environment Canada and MOE Quebec, 1992).

Data from 1987, 1989 and 1992 also have detection limits too high. Heptachlor epoxide also has detection limits (0.01 µg/g) which are too high to determine if the proposed sediment quality guideline (0.0045 µg/g) (Hart *et al*., 1988) or criterion concentration (< 0.005 µg/g) (Jaagumagi, 1992b) have been met. However, the 1987 report measures values as <0.001 µg/g which meets criteria. Lindane had measured concentrations of 0.001 µg/g, below the minimal effects threshold of 0.003 µg/g set for the St-Lawrence River (Environment Canada, 1992). Methoxy chloride had measured concentrations of 0.005 µg/g but no criteria exist to compare these to. With one exception, data from 1987, 1989, and 1992 reports also show all values below detection limits. The exception was a tributary study in 1987.

A site located on the Fraser River at Barnston Island (near site E206965) was found to have Dieldrin concentrations of 0.009 µg/g. All data from 1987 came from Site T-7 (close to Site E206965) of a tributary study. Studies from 1989 and 1992 also tested for endosulfan I and II, endosulfan sulfate and toxaphene. For both years, Sites E206965 and E206966 showed these compounds to be below detection limits of 0.001 µg/g, 0.01 µg/g, and 0.03 µg/g respectively. No criteria are available at this time to compare these values with.

6.3.2.3.4 Phthalate Esters

At Sites E206965 and E206966, bis(2-ethylhexyl)phthalate was found in concentrations ranging from 0.11 µg/g to 1.44 µg/g. There is no proposed criterion for freshwater but one of six values exceeded the marine criterion of 0.78 µg/g (Washington State Dept. of Ecology, 1991). Diethyl phthalate was found in concentrations of less than 0.1 µg/g. There is no freshwater criterion, but values are well below the maximum proposed limit of 1.1 µg/g (Washington State Dept. of Ecology, 1991) for lowest-effects level in marine environments. Dimethyl phthalate, with a concentration less than 0.1 µg/g, is below the proposed 0.53 µg/g limit for no effect (lowest-effects data was not available) (Washington State Dept. of Ecology, 1991). Di-n-butyl phthalate and di-n-octyl phthalate have maximum measured concentrations of 0.1 µg/g (both sites) and 0.37 µg/g (site E206965) respectively. This is well below their allowed maximum of 17 µg/g and 45 µg/g respectively (Washington State Dept. of Ecology, 1991). These data were collected in 1989 (1989, FREMP).

6.3.2.3.5 Dioxins and Furans

The most toxic dioxin, 2,3,7,8-TCDD, was not detected in any portion of the river but furans were found in all lower Fraser sites (including Hope) except for one site at the mouth. Unlike the other organic contaminants, the highest concentration of furans was found at the mouth. Furans were also detected in the Thompson River and may be contributing to concentrations in the lower Fraser River (Beak Consultants, 1991). As dioxins and furans may be originating in effluents from the upstream pulp and paper mills, a Sediment Quality Objective is proposed for dioxins and furans in the Fraser River from Kanaka Creek to New Westminster. This objective is that the total TEQ of all PCDDs and PCDFs in any discrete sample also not exceed 0.25 pg/g. Both of these objectives apply only outside of initial dilution zones as described in Section 1.0.

6.3.2.4 Conclusions

Chromium and nickel concentrations increased whereas iron, lead, mercury and zinc concentrations decreased. Manganese and chromium concentrations were acceptable whereas copper concentrations were high. Data were insufficient to determine trends for arsenic. It seems that all PCBs and PAHs are below criteria or minimal effects thresholds.

Some pesticides had detection limits too high to determine whether they met criteria, others lacked criteria to which to be compared, but the ones that did have criteria and for which detection limits were below those criteria, were present in acceptable concentrations. All phthalate esters lack appropriate criteria and therefore no Objectives have been set.

6.3.3 Analysis of Benthic Invertebrates

The Main Stem reach of the Fraser River is of significance because it is to this reach that the tip of the salt wedge migrates under extreme low flow conditions (Ages, 1975; Kostachuk, 1992). Chapman and Brinkhurst's study (1979) on seasonal changes in interstitial salinities found that peak interstitial salinities at the New Westminster trifurcation can reach just under 5‰ throughout February and March. Unfortunately, the samples analyzed by Northcote *et al.* (1976) were only collected between spring and late autumn when the river volume is highest and the tip of the migrating salt wedge is further downstream. As such, it is unlikely that the data collected by Northcote *et al.* (1976) are representative of both freshwater and marine benthos; therefore, data will be considered in light of freshwater conditions only. A more detailed discussion of the effects of seasonal salinity variations on benthic fauna will be presented in section 6.4.3.

Three monitoring stations were placed within the reach of study along the Fraser River (Northcote *et al*., 1976). Stations 7, 8, and 9 were sequentially placed between New Westminster and Whonnock to encompass a wide assortment of influential land uses. Station 7 was located near New Westminster which is largely industrial and urban, while station 8 was just downstream from Barnston Island, south of Haney and north of Langley which are generally agricultural, and station 9 was located upstream near Whonnock where the influences are mostly agricultural and forestry related.

As in the other two reaches, samples collected by Peterson grabs of 626cm^2 and Ponar grabs of 529 cm^2 were analyzed according for the following parameters: relative abundance, biomass, diversity of fauna, and community composition by benthos sensitive to organic pollutants. The up-reach station at Whonnock (station 9) had a relative abundance of approximately 1.000 organisms/m^2 (n=25) which is similar to stations further upstream. Likewise, station 9 had a wet-weight biomass of 1 to 2 g/ m^2 which is also similar to the measure at station 10. In both measures of relative abundance and biomass, station 8 showed a sudden decrease in values. Unexpectedly, the relative abundance of benthos at the urban and industrial station 7 increased above levels measured at Hope. Concomitantly, the biomass at station 7 increased from the low levels measured at station 8 to the levels measured at station 9. This suggests that the individual organisms collected downstream at station 7 are generally smaller or lighter than benthos collected upstream at station 9.

Although the number of benthic invertebrates collected throughout the reach of the Fraser River from Kanaka Creek to New Westminster is marginally higher than the number of organisms sampled from Chilliwack to Kanaka Creek, the diversity of benthic fauna at the downstream reach is much reduced from the upstream reach. While the average number of taxa found in the reach upstream from Kanaka Creek was 7.368 taxa, the average number collected in the reach downstream from Kanaka Creek was 4.926 taxa in mud and mud-sand substrate. Simpson's index and the Shannon-Wiener function both showed similarly large decreases of 0.682 at upstream stations to 0.496 at downstream stations and 2.069 at upstream stations to 1.377 at downstream stations, respectively. While the equitability decreased from 0.744 at the upstream stations to 0.697 at the downstream stations, the value remained above 0.5 which is typical of unpolluted waters (Weber, 1973). It is of interest that the same decreasing pattern is not evident in substrate made up of sand and sand-gravel. There is a slight decrease in the average number of taxa from the upstream stations (3.66 taxa) to the downstream stations (3.451 taxa). Downstream stations have a higher index of 0.469 and a higher function of 1.275 than upstream stations with an index of 0.452 and a function of 1.214. Further, the equitability value increased significantly from 0.771 at the upstream stations to 0.853 for the reach between Kanaka Creek and New Westminster. The following is a list of taxa identified in the Main Stem of the Fraser River.

Occurrence of Taxa in Benthic Samples from the Lower Fraser River between Kanaka Creek and New Westminster

Group and Subgroup	Taxa Name	Downstream	Midstream	Upstream
ANNELID WORMS				
Oligochaetes	Oligochaete	√	√	√
MOLLUSCS				
Pelecypods	*Mytilus edulis*	√		
	Pisidium		√	
CRUSTACEANS				
Cladocerans	*Eurycerus*	√		
Mysids	*Neomysis mercredis*	√	√	√
Amphipods	*Anisopammarus confervicolus*		√	
	Asellus		√	
INSECTS				
Ephemeropterans (mayflies)	*Ephemerella*	√	√	
Trichopterans (Caddis flies)	Psychomyiidae		√	
	Empididae			√
	Ceratopogonidae	√	√	√
	Unidentified tanypodinae	√	√	√
	Monodiamesa	√	√	√
	Cricotopus		√	
	Heterotrissocladius	√		√
	Orthocladius	√		
	Psectrocladius			√
	Chironomus	√	√	√
	Cryptochiromus	√		
	Demicryptochiromus		√	√
	Paracladopelma	√	√	√
	Polypedilum	√	√	√
	Stictochiromus	√	√	√
	Tribelos	√		
	Micropsectra			√
	Paratanytarsus	√		√
	Tanytarsus		√	√
LAMPREYS	Ammocoete	√	√	√
	# Sensitive Taxa	4	3	5
	TOTAL	18	18	17

(Northcote *et al.*, 1976)

Note: Bold-faced text indicate organisms that are sensitive to organic pollution.

Positively correlated with the decrease in the average number of taxa from upstream reaches to the Main Stem is the decrease in the number of organic pollution sensitive taxa from upstream reaches to the Main Stem as well as the decrease in number of sensitive taxa from the upstream station 9 to the downstream station 7 within the Main Stem. All taxa sensitive to pollution were dipteran flies. Sensitive taxa collected at upstream stations 8 and 9 but not the downstream station 7 were: *Cricotopus, Psectrocladus, Micropsectra*, and *Tanytarsus*. Only *Paracladopelma* was found at all three stations. Orthocldius and Tribelos were sampled only at station 7. Pollution tolerant oligochaete worms populated all three stations throughout the Main Stem.

In 1985, Swain (1986c) conducted a survey on the levels of metal, PCBs, and chlorophenols in benthic organisms of the Main Stem. Listed below are the parameters examined and the respective benthic fauna in which the characteristics were found. From the upstream sampling site near Barnston Island, chironomids, lampreys, oligochaetes, and crustacea were collected; from the downstream sampling site at Sapperton Channel, diptera, lampreys, and oligochaetes were collected. Because lampreys and oligochaetes were sampled from both upstream and downstream sites in the Main Stem, spatial trends may be investigated for each of the characteristics measured. Many crustacea and chironomids are filter feeding benthos. As such, they are sensitive detectors of environmental contaminants. Finally, the numerous taxa of dipteran insects indicates their ubiquitous nature. Their presence may indicate pollution tolerance in some cases.

	Contaminant Concentrations Measured in Bottom Fauna Collected from the Main Stem of the Fraser River						
	Barnston Island (Upstream)				Sapperton Channel (Downstream)		
Characteristic	Chironomids	Lampreys	Oligochaetes	Crustacea	Diptera	Oligochaetes	Lampreys
INORGANIC							
Aluminum	1220	1910	5010	1510	2470	3730	122
Boron	<1	<1	27	31	3	4	17
Barium	19	22	73	109	39	103	10
Calcium	5 410	3 860	10 400	90 400	5 560	7 500	3 250
Cadmium	1	<1	<1	<1	<1	<1	<1
Chromium	5	4	35	26	14	14	14
Copper	55	37	188	271	46	56	156
Iron	2 760	3 140	10 400	4 170	7 950	8 930	2 920
Magnesium	1 650	1 310	4 140	2 010	2 240	3 180	541
Manganese	268	239	770	1 010	300	354	203
Molybdenum	<1	<1	<1	<1	<1	2	<1
Nickel	<5	7	<5	<5	15	18	<5
Lead	<10	<10	<10	<10	<10	<10	<10
Tin	<5	<5	<5	<5	<5	<5	<5
Strontium	23	13	39	343	31	30	14
Tellurium	<20	<20	<20	<20	<20	20	<20
Titanium	43	58	355	72	125	117	12
Thallium	<20	<20	<20	<20	<20	<20	<20
Vanadium	4	4	20	<1	14	14	<1
Zinc	177	115	180	211	108	179	1 870
NUTRIENT							
Total Phosphorus	7 010	4 090	5 610	11 900	6 840	7 340	4 340
ORGANICS (wet)							
Total PCBs	<0.1	<0.1	-	-	-	-	-
PCP	0.06	0.05	-	-	-	-	-
TCP	0.03	<0.01	-	-	-	-	-

6.3.4 Analyses of Fish

The latest data on fish tissue contaminants is available from FREMP work collected in 1994 and reported in draft in 1995. The report compares this fish tissue data to data in a 1988 Fraser River Estuary Monitoring report, a 1985 survey and an earlier 1980 report. Most of the fish data from the 1980 report were compared to a Westwater Research Centre fish sampling program conducted in 1972 and 1973.

The 1972/73 program reported on northern squawfish, largescale sucker, peamouth chub and white sturgeon for DDT, DDE, DDD, aldrin, Dieldrin, alpha-chlordane, gamma-chlordane, heptachlor epoxide and Lindane at Barnston Island and Sapperton Channel. Mountain whitefish, white sturgeon, largescale sucker, northern squawfish, peamouth chub, rainbow trout and cutthroat trout were also examined for PCBs, HCB, and tetra- and pentachlorinated phenols at the same two sites, although for some contaminants such as PCBs and chlorinated phenols, samples were frozen and analyzed in 1978. The 1985 survey also had sampling sites at Barnston Island and Sapperton Channel. Peamouth chub, Dolly Varden, and prickly sculpin were tested for metals, chlorophenols, and PCBs. Lastly, the 1988 survey sampled only from Barnston Island. However, the most complete spectra of tests were done at this site. Largescale sucker, northern squawfish, peamouth chub, redside shiner, and staghorn sculpin were tested for metals, chlorophenols, PCBs, phthalate esters, PAHs and organochlorine pesticides. For easier comparison, dry-weights have been converted to wet-weights where necessary. An eighty percent moisture content has been assumed when values were not reported.

6.3.4.1 Metals

Arsenic

In the 1985 survey, with dry-weight detection levels of 25 µg/g (wet-weight ~5 µg/g), no arsenic levels could be detected in fishes tested at Barnston Island or Sapperton Channel (Swain, 1986c). However, the 1988 survey had much lower detection limits, 0.005 µg/g (wet-weight), and arsenic levels for all the fishes muscles sampled (largescale suckers, northern squawfish, peamouth chub and redside shiners) were essentially the same in the Main Stem as downstream. For example, the largescale sucker had a mean wet-weight arsenic concentration of 0.08 µg/g in the Main Stem, compared to 0.06 µg/g in the Main Arm and 0.07 µg/g in the North Arm (Swain and Walton, 1989).

Largescale suckers, northern squawfish and peamouth chub from the Main Stem had slightly lower values than fish of the same species from the North or Main Arms. The MOE tested rainbow trout, cutthroat trout, Dolly Varden and whitefish. The concentrations ranged from 0.022 µg/g in cutthroat trout to 0.034 µg/g in Dolly Varden. There is significant variability between the species tested, but generally, the mean arsenic concentration in Fraser River fish muscle are two or more times greater than in fish from uncontaminated lakes. This could not be statistically tested due to variability between the data sets (Swain and Walton, 1989). Liver arsenic levels were not tested in a sufficient number of fish in the Main Stem. The fact that arsenic was found at all the sites tested and that the mean concentrations from these sites were not significantly different, indicates that the arsenic levels are unlikely to be due to anthropogenic sources in the Estuary area. All concentrations were well below the criterion for the protection of human health of 3.5 µg/g (MELP, 1994).

Arsenic Levels in Fish Muscle From the Main Stem (Swain and Walton, 1989)*					
Fish Species	**Number of Values**	**Maximum**	**Minimum**	**Mean**	**Std. Dev.**
Largescale Sucker	4	0.51/0.10	0.14/0.03	0.39/0.08	0.17
Northern Squawfish	6	0.43/0.08	0.14/0.03	0.29/0.05	0.12
Peamouth Chub	6	0.42/0.09	0.24/0.04	0.34/0.06	0.07
Redside Shiner	7	0.14/0.03	0.06/0.01	0.11/0.02	0.34

* All measurements are dry/wet-weights µg/g

Cadmium

When reported in 1986, most samples had no detectable cadmium in muscle tissue above 0.04 µg/g on a wet-weight basis. However, Dolly Varden tested at Barnston Island showed a liver concentration of 0.064 µg/g (Swain, 1986c). In 1988, only one of 23 samples (a largescale sucker) from the Main Stem had measurable cadmium levels (wet-weight detection limit 0.005 µg/g) in muscle tissue but several values were detected in liver (Swain and Walton, 1989). The sample size was too small to make accurate comparisons but the largescale sucker, northern squawfish and peamouth chub all had much higher levels ranging from 0.068 µg/g in liver tissue of northern squawfish to 0.13 µg/g in the livers of peamouth chub. These values are still considerably lower than MOE liver values from uncontaminated lakes (average mean of 0.222 µg/g)(Swain and Walton, 1989). Cadmium concentrations are not a concern in the Main Stem at this time.

Cadmium Levels in the Liver of Fish From the Main Stem*					
Fish Species	**Number of Values**	**Maximum**	**Minimum**	**Mean**	**Std. Dev.**
Largescale Sucker	1	0.051	N/A	N/A	N/A
Northern Squawfish	2	0.068	0.026	0.047	N/A
Peamouth Chub	1	0.13	N/A	N/A	N/A
Dolly Varden	1	0.064	N/A	N/A	N/A

*All measurements are wet-weight (µg/g) and taken from Swain and Walton (1988) unless otherwise noted
**Taken from Swain (1986c) in wet-weight.

Chromium

Chromium was detected in all muscle samples taken in 1985 (Swain, 1986c) and in 1988 (Swain and Walton, 1989). Muscle concentrations in the Main Stem in 1986 were tested in peamouth chub, Dolly Varden, and prickly sculpin. The highest muscle chromium concentration in the lower Fraser River in 1985 was 0.28 µg/g wet-weight found in a prickly sculpin from Sapperton Channel. There does not appear to be a correlation between environmental compartments, as the highest chromium content in sediments and leeches was from Annacis Channel (Swain, 1986c). In 1988, the highest mean chromium concentrations in fish muscle were found in the North Arm, with statistically significant variability ($p>0.05$) occurring between North Arm and Main Stem sites for peamouth chub. The mean values between sites were similar only for northern squawfish with 0.03 µg/g in the Main Stem and 0.08 µg/g in the North Arm (wet-weight). Starry flounder and redside shiners were excluded from discussion due to possible contamination in the laboratory (Swain and Walton, 1989). Within the Main Stem, the mean chromium concentrations in muscle for the largescale sucker (0.05 µg/g) and the northern squawfish (0.03 µg/g) were statistically similar but there was significant variability between the largescale sucker and the peamouth chub (0.02 µg/g) (wet-weight) (Swain and Walton, 1989). Chromium concentrations in the muscle tissue of fish does not appear to be a concern in the Main Stem.

Chromium Levels in the Muscle of Fish from the Main Stem*					
Fish Species	**Number of Values**	**Maximum**	**Minimum**	**Mean**	**Std. Dev.**
Largescale Sucker	4	0.38/0.07	0.20/0.04	0.27/0.05	0.08
Northern Squawfish	6	0.38/0.07	0.04/0.007	0.18/0.03	0.12
Peamouth Chub	6	0.16/0.03	0.05/0.01	0.10/0.02	0.04
Peamouth Chub**		1.62/0.032			
Redside Shiner	7	2.92/0.64	0.85/0.19	1.91/0.43	0.72
Dolly Varden		1.05/0.019			
Prickly Sculpin**		1.72/0.028			

* All measurements are in µg/g (dry/wet-weight) and are taken from Swain and Walton (1988) unless otherwise noted
**Taken from Swain (1986)

There are insufficient data to support an analysis of chromium levels in the livers of fish in the Main Stem. Singleton (1983) suggested that the liver may not be an active site for the accumulation of chromium in fishes and a detailed comparison of species and sites tends to support that hypothesis.

Copper

The 1985 copper levels in the muscle tissue of peamouth chub and Dolly Varden from Barnston Island and prickly sculpin from Sapperton Channel were between 0.3 and 0.4 µg/g (wet-weight. There was no apparent correlation to sediment of benthic organism concentrations (Swain, 1986c). The 1988 survey of muscle tissues from largescale sucker, northern squawfish, peamouth chub and redside shiner from Barnston Island showed the highest concentration of copper to be in largescale suckers (n=4), with a value of 0.33 µg/g wet-weight. Copper concentrations in northern squawfish (n=6) of the Main Stem (0.32 µg/g) were statistically higher than the 0.24 µg/g concentration found in northern squawfish in the North Arm (n=18). However, the mean copper concentrations of largescale sucker, northern squawfish and peamouth chub in the Main Stem (n=4, 6, and 6) and North Arm (n=17, 18, and 13) were statistically similar (0.33 µg/g, 0.32 µg/g, and 0.29 µg/g, respectively). The mean value for the redside shiner (n=7) from the Main Stem was 1.04 µg/g which is substantially higher than the other fish species (Swain and Walton, 1989).

Copper Levels in Muscle of Fraser River Fish From the Main Stem*					
Fish Species	**Number of Values**	**Maximum**	**Minimum**	**Mean**	**Std. Dev.**
Largescale Sucker	4	1.86/0.37	1.31/0.25	1.70/0.33	0.26
Northern Squawfish	6	2.03/0.38	1.53/0.27	1.74/0.32	0.19
Peamouth Chub	6	1.9/0.30	1.25/0.26	1.60/0.29	0.26
Redside Shiner	7	5.39/1.18	3.43/0.83	4.62/1.04	0.68

* All values are measured as µg/g (dry/wet-weight) as cited in Swain and Walton, 1989

Liver samples collected from Barnston Island in 1985 had a copper concentration of 23.3 µg/g (wet-weight) in Dolly Varden (Swain, 1986c). This is over 56 times the concentration found in the muscle tissue of Dolly Varden (0.38 µg/g) but these ratios were noted by Singleton as typical of other water bodies (Singleton, 1983). The1988 liver data from the Main Stem are insufficient for analysis. There is substantial variability between species and location.

Iron

In 1986, iron was tested only in the muscle tissue of peamouth chub and Dolly Varden at Barnston Island and prickly sculpin at Sapperton Channel. Dolly Varden had the lowest concentration at 3.59 µg/g and prickly sculpin had the highest concentration at 4.79 µg/g (wet-weight) (Swain, 1986b). The 1988 survey sampled largescale sucker, northern squawfish, peamouth chub and redside shiner at Barnston Island. The mean iron concentrations in muscle for the Main Stem were : largescale sucker, 7.09 µg/g; peamouth chub, 3.96 µg/g; northern squawfish, 5.15 µg/g. The largescale sucker showed an increase in iron concentration in the muscle between 1985 and 1988. The northern squawfish has maintained a fairly constant concentration while the peamouth chub muscle iron concentration have decreased since 1985.

Iron Levels in Muscle of Fraser River Fish from the Main Stem*

Fish Species	Number of Values	Maximum	Minimum	Mean	Std. Dev.
Largescale Sucker	4	44.9/8.8	31.3/5.9	36.6/7.09	6.10
Northern Squawfish	6	37.8/6.84	18.1/3.24	28.1/5.15	8.32
Peamouth Chub	6	27.7/4.74	18.4/2.89	22.1/3.96	3.37
Redside Shiner	7	166/36.2	76.7/18.5	113/25.5	28.2

*All values are measured as µg/g (dry/wet-weight) as cited in Swain and Walton, 1989.

The 1985 survey reported a Dolly Varden at Barnston Island with an iron concentration of 64.1 µg/g (wet-weight) in the liver (Swain, 1986c). Singleton suggested that this may be correlated to sediment concentrations (Singleton, 1983). There was an inadequate number of liver samples collected for an accurate estimate of iron concentrations in the liver of any given species of fish in the Main Stem.

Lead

In 1985, lead concentrations in fish muscles were all low: <0.258 µg/g (wet-weight) in peamouth chub and Dolly Varden at Barnston Island, and prickly sculpin at Sapperton Channel (Swain, 1986c). The 1988 data also had low values. In fact, if the same detection limit had been used, no detectable amounts would have been found. All lead concentrations, in all species, were below the wet-weight of 0.8 µg/g alert level established by the MOE for edible portions of fish for the protection of human health (Nagpal, 1987). In 1988, lead data for peamouth chub in the Main Stem were too variable to compare. For largescale suckers, the mean of 0.02 µg/g wet-weight was statistically similar to the mean value of 0.03 µg/g in the northern squawfish and the 0.03 µg/g in the redside shiners (Swain and Walton, 1989).

Lead Levels in Muscle of Fraser River Fish from the Main Stem*					
Fish Species	**Number of Values**	**Maximum**	**Minimum**	**Mean**	**Std. Dev.**
Largescale Sucker	4	0.11/0.02	0.07/0.01	0.09/0.02	0.02
Northern Squawfish	6	016/0.03	0.13/0.02	0.15/0.03	0.01
Peamouth Chub	6	0.14/0.03	0.12/0.02	0.13/0.02	0.98
Redside Shiner	7	0.17/0.04	0.11/0.03	0.13/0.03	0.13

* All values are measured as µg/g (dry/wet-weight) as cited in Swain and Walton, 1989.

In 1985, lead concentrations in the liver of Dolly Varden were measured to be 1.03 µg/g wet-weight at Barnston Island. The highest lead concentration in the lower Fraser River did not correspond to high sediment or benthic organism concentrations in the area (Swain, 1986c). In the 1988 survey, there were no data for lead concentrations in the livers of fish from the Main Stem.

Manganese

In 1980, Singleton (1983) found the manganese concentrations in the muscle of largescale sucker and northern squawfish to be 0.30 µg/g and 0.25 µg/g (wet-weight) respectively. These concentrations are significantly lower than the corresponding 0.5 µg/g and 0.44 µg/g (wet-weight) reported in a 1972/73 study. In 1985, the manganese concentrations of prickly sculpin, peamouth chub and Dolly Varden were less than the detection limit of 1 µg/g but this detection limit is too high for useful comparisons (Swain, 1986c). In 1988, largescale sucker, northern squawfish, peamouth chub and redside shiner were tested. The peamouth chub had concentrations similar to the 1980 study but largescale sucker and northern squawfish had muscle concentrations that were higher, similar to those found in 1972/73. Compared to the mean of 0.293 µg/g (wet-weight) in uncontaminated lakes, largescale suckers, northern squawfish and peamouth chub had manganese concentrations of similar magnitude while redside shiner had concentrations considerably higher (Swain and Walton, 1989).

Manganese Levels in Muscle of Fraser River Fish from the Main Stem*					
Fish Species	**Number of Values**	**Maximum**	**Minimum**	**Mean**	**Std. Dev.**
Largescale Sucker	4	2.19/0.41	1.78/0.34	2.02/039	0.19
Northern Squawfish	6	3.33/0.62	1.09/0.20	2/08/0.28	1.01
Peamouth Chub	6	1.69/0.29	1.08/0.17	1.34/0.24	0.26
Redside Shiner	7	20.1/4.38	10.2/2.46	14.6/3.29	3.48

* All values are measured as µg/g (dry/wet-weight) as cited in Swain and Walton, 1989.

There are no current Main Stem data available for manganese concentrations in fish liver.

Mercury

Mercury was tested in 1972/73, 1980, and 1988. The muscle data for northern squawfish, largescale sucker and peamouth chub in all three surveys show northern squawfish to have the highest concentrations. Singleton (1983) supported Northcote *et al.* (1975) who proposed that mercury levels are related to trophic level and that northern squawfish have higher concentrations of mercury because they are higher level consumers. Another prominent trend is the decrease in concentrations since 1972/73. Mercury muscle concentrations in the northern squawfish has decreased from about 0.78 µg/g in 1972/73 to 0.6 µg/g in 1980 and 0.35 µg/g in 1988 (wet-weight). Concentrations in the largescale sucker have been steadily declining from about 0.27 µg/g in 1972/73 to 0.11 µg/g in 1988. Similarly, mercury concentrations in the muscle of peamouth chub have decreased from 0.3 µg/g to 0.125 µg/g (wet-weight) from 1972 to 1988. All values from 1988 were below the 0.5 µg/g wet-weight criterion proposed by MOE. Within the site, the mean mercury concentration of the largescale sucker (0.11 µg/g) was similar to the peamouth chub mean of 0.12 µg/g, but lower than the mean of the northern squawfish of 0.35 µg/g (wet-weight). The peamouth chub had a concentration of 0.12 µg/g which is higher than the 0.06 µg/g of the redside shiner (wet-weight).

Mercury Levels in Muscle of Fraser River Fish from the Main Stem*

Fish Species	Number of Values	Maximum	Minimum	Mean	Std. Dev.
Largescale Sucker	4	0.85/0.17	0.32/0.06	0.55/0.11	0.26
Northern Squawfish	6	2.57/0.48	1.10/0.21	1.89/0.35	0.55
Peamouth Chub	6	0.77/0.12	0.49/0.10	0.65/0.12	0.12
Redside Shiner	7	0.32/0.07	0.16/0.04	0.27/0.06	0.06

* All values are measured as µg/g (dry/wet-weight) as cited in Swain and Walton, 1989.

There were no fish liver mercury data from the Main Stem.

Molybdenum

There was no detectable amount (1µg/g dry-weight or ~ 0.2 µg/g wet-weight) of molybdenum in the muscle of fish from the Main Stem in 1985 (Swain, 1986c). In 1988, the detection limit was lowered to 0.01 µg/g wet-weight and molybdenum remained undetected in fish from the Main Stem (Swain and Walton, 1989). Molybdenum levels in the liver were below the 1 µg/g dry-weight (or 0.2 µg/g wet-weight) detection limit in 1985 (Swain, 1986c). The highest molybdenum concentration found in the Main Stem in 1988 was in a largescale sucker at Barnston Island (0.22 µg/g wet-weight) (Swain and Walton, 1989).

Nickel

Nickel was not detectable above the detection limit of 1 µg/g dry-weight (0.2 µg/g wet-weight) in the muscle of fish collected from the Main Stem by Singleton in 1980 (Singleton, 1983) or in 1985 (Swain, 1986c). Detectable amounts were found in the 1988 survey when detection limits were lowered to 0.01 µg/g (Swain and Walton, 1989). The muscle concentration of nickel in largescale suckers, northern squawfish and peamouth chub from the Main Stem was 0.06 µg/g wet-weight.

Nickel Levels in Muscle of Fraser River Fish from the Main Stem*

Fish Species	Number of Values	Maximum	Minimum	Mean	Std. Dev.
Largescale Sucker	4	0.43/0.08	0.28/0.06	0.33/0.06	0.07
Northern Squawfish	6	0.42/0.08	0.22/0.04	0.31/0.06	0.08
Peamouth Chub	6	0.43/0.09	0.21/0.04	0.32/0.06	0.08
Redside Shiner	7	2.65/0.58	0.94/0.21	1.84/0.41	0.70

* All values are measured as µg/g (dry/wet-weight) as cited in Swain and Walton, 1989.

There were insufficient liver samples from the Main Stem to test for nickel.

Strontium

Strontium was measured only in the 1986 study. In the Main Stem, muscle tissue values ranged from < 0.189 µg/g (wet-weight) in Dolly Varden from Barnston Island to 0.66 µg/g (wet-weight) in prickly sculpins from Sapperton Channel. Only Dolly Varden at Barnston Island were tested for strontium concentrations in the liver, the concentration was <0.284 µg/g (wet-weight)(Swain, 1986c).

Titanium / Vanadium

Titanium and vanadium were metals tested only in the 1985 study. Both were undetectable (<0.284 µg/g) in Dolly Varden liver from Barnston Island (Swain, 1986c).

Zinc

Zinc concentrations in the muscle of fish from the Main Stem in 1985 had concentrations ranging from 3.78 µg/g to 7.10 µg/g wet-weight. The maximum value of 7.10 µg/g was from a prickly sculpin from Sapperton Channel. The maximum concentration in a benthic organism was in a lamprey collected from Sapperton Channel[SD1], indicating that there may be some correlation between environmental compartments at Sapperton Channel[SD2] (Swain, 1986c). In the 1988 report, the mean zinc concentrations were very similar within each species. The largescale sucker had a concentration of 5.27 µg/g; the northern squawfish, 4.47 µg/g,; the peamouth chub, 5.28 µg/g, for the Main Stem (Swain and Walton, 1989). The mean values have changed very little from values in 1972/73 and 1980, although the maximum values have decreased. The values vary with the species, not the site, and have not changed over time so zinc levels are most likely naturally occurring. The redside shiner is a bit of an enigma with a concentration of 26.6 µg/g wet-weight, much higher than concentrations found in any of the other three species. Within the Main Stem, the largescale sucker has values significantly similar to northern squawfish and peamouth chub although the northern squawfish has values significantly lower than the peamouth chub.

Zinc Levels in Muscle of Fraser River Fish from the Main Stem*					
Fish Species	**Number of Values**	**Maximum**	**Minimum**	**Mean**	**Std. Dev.**
Largescale Sucker	4	31.4/6.15	25.0/5.03	27.2/5.27	2.88
Northern Squawfish	6	30.8/5.79	20.6/2.85	24.5/3.37	2.41
Peamouth Chub	6	32.7/5.62	27.8/4.75	29.5/5.28	1.75
Redside Shiner	7	140/30.5	103/24.8	118/26.6	12.8

*All values are measured as µg/g (dry/wet-weight) as cited in Swain and Walton, 1989.

There were not enough zinc liver data for the Main Stem to draw conclusions.

6.3.4.2 Organics

6.3.4.2.1 Chlorophenols

The 1985 study tested the muscle tissue of peamouth chub and Dolly Varden at Barnston Island for levels of pentachlorophenol and tetrachlorophenol. When both contaminants were present, pentachlorophenol was found in greatest concentrations with the highest concentration (0.03 µg/g (wet-weight)) measured in a peamouth chub. The concentration of tetrachlorophenol was at or below the detection limit of 0.01 µg/g (wet-weight). In the liver, both compounds were 0.01 µg/g (wet-weight) (Swain, 1986c). No evidence of the accumulation of chlorinated compounds in the tissues was found at that time.

In the 1988 study, trichlorophenol was tested in the muscle of largescale sucker, northern squawfish, peamouth chub, and redside shiner. The largescale sucker had a concentration of 0.002 µg/g (wet-weight) in the Main Stem. Within the Main Stem, the wet-weight of 0.006 µg/g trichlorophenol in the peamouth chub was statistically higher than the 0.003 µg/g found in the northern squawfish or the 0.002 µg/g found in the largescale sucker. The data from the redside shiner was too variable to analyze. There were no liver samples taken from the Main Stem (Swain and Walton, 1989).

In edible tissues tested in 1972 and 1973 (Garrett, 1980), tetrachlorophenol was undetectable at a detection limit of 0.001 µg/g. When largescale sucker, northern squawfish, peamouth chub and redside shiner taken from Barnston Island were tested for tetrachlorophenol in 1988, all samples had concentrations lower than the detection limit of 0.0002 µg/g (wet-weight). Liver samples also had undetectable levels but because the detection limit was only 0.025 µg/g, no conclusion could be drawn as to whether concentrations were accumulating(Swain and Walton, 1989).

Edible tissues of northern squawfish, largescale sucker, peamouth chub and white sturgeon were tested for pentachlorophenol in 1978 (Garrett, 1980). Concentrations ranged from undetectable in white sturgeon to 0.027 µg/g in northern squawfish, peamouth chub and redside shiner. In 1988, the largescale sucker had a wet-weight concentration of 0.001 µg/g for all sites. Values for northern squawfish and peamouth chub were also similar with values of either 0.001 µg/g or 0.002 µg/g at all sites. The highest concentration of 0.004 µg/g (wet-weight) was found in a redside shiner in the Main Stem. All other species at this site had concentrations of 0.001 µg/g or 0.002 µg/g. Concentrations in liver samples were all undetectable with a detection limit of 0.025 µg/g (wet-weight). This detection limit is not low enough to determine if there is a risk of accumulation. Since chlorophenol contamination is due almost exclusively to anthropogenic sources, a provisional Tissue Quality Objective of 0.2 µg/g (wet-weight) for the sum of mono-, di-, tri-, tetra- and pentachlorophenol in any single sample or a composite sample in any species is proposed. This objective is achieved by all fish muscle tissue analyzed in the 1988 survey (Swain and Walton, 1989).

6.3.4.2.2 Polychlorinated Biphenyls (PCBs)

PCBs have undergone a significant decrease in the last twenty years. Data collected in 1972 and1973 (Garrett, 1980) showed PCB levels were detected with greater frequency and at higher concentrations than any other contaminants. In the Main Stem, levels ranged from 0.058 µg/g in white sturgeon to 0.297 µg/g in peamouth chub and Dolly Varden at Barnston Island. Values for peamouth chub and Dolly Varden char were below the detection limit of 0.1 µg/g (wet-weight) for all tissue samples (Swain, 1986c). In 1988 at the same site, fish had mean muscle concentrations between 0.01 µg/g and 0.06 µg/g (wet-weight) which is five to ten times less than the 1993 Water Quality Objective of

0.5 µg/g (edible tissue wet-weight) (Water Quality in B.C.: Objectives Attainment in 1993, 1994). The largescale sucker had a mean concentration of 0.01 µg/g in the Main Stem. Within the site, the highest mean concentration was the redside shiner (0.06 µg/g) but the data were significantly different from values found in other species at the same site. Only one largescale sucker liver sample and one peamouth chub liver sample were analyzed from the Barnston Island site. Both had PCBs in concentrations of <0.05 µg/g. The northern squawfish had detectable PCBs in both of the two samples taken at Barnston Island. The mean was 0.19 µg/g (Swain and Walton, 1989). The 1993 Water Quality Objective of 0.5 µg/g (wet-weight) was achieved for all tissues (Water Quality in B.C.: Objectives Attainment in 1993, 1994) as was the 1994 approved and working criteria of 2.0 µg/g for edible tissue (Nagpal, 1992). Even the criterion of 0.1 µg/g (wet-weight) for wildlife consumption was met in all fish muscle except for the maximum concentration measured in redside shiner (Nagpal, 1992). However, all the liver concentrations for fish from the Main Stem exceeded this criterion. Since the source of PCBs is almost strictly anthropogenic and chronic effects are still being debated, it is proposed that the 1993 Tissue Quality Objective of 0.5 µg/g (wet-weight) be modified to 0.1 µg/g (wet-weight) to protect wildlife from the consumption of whole fish.

6.3.4.2.3 Phthalate Esters

The 1988 report by Swain and Walton is the only available source of information concerning phthalate esters concentrations in fish from the Main Stem. Six phthalate esters were measured: dimethyl, diethyl, di-n-butyl, butylbenzyl, di-n-octyl and bis(2-ethylhexyl).

In 1988 largescale sucker, northern squawfish, peamouth chub and redside shiner were tested for dimethyl phthalate levels at Barnston Island. No detectable concentrations (0.01 µg/g wet-weight) were recorded in muscle tissue. Liver samples were analyzed for the first three species and none had concentrations above the detection limit of 0.5 µg/g wet-weight (Swain and Walton, 1989). It was impossible to determine if dimethyl phthalate was accumulating in liver due to the high detection limit of liver samples.

Diethyl phthalate levels were tested in the same species and sites as above. Quantities of sample were insufficient to obtain mean concentrations. The Main Stem had the lowest maximum concentration for largescale sucker, northern squawfish, redside shiner and peamouth chub. The largescale sucker had a maximum concentration of 0.21

µg/g (wet-weight); the northern squawfish had maximum concentration of 0.42 µg/g; the peamouth chub had concentrations below the 0.004 µg/g detection limit; and the eight redside shiners had a maximum concentration found was 0.07 µg/g (wet-weight). Most values were above the maximum background concentration of 0.11 µg/g indicating some muscle contamination (Swain and Walton, 1989). No fish sampled in the Main Stem had liver concentrations greater than the detection limit of 0.2 µg/g. However, the sample sizes were too small to say conclusively that there was not a build up in the tissues.

Di-n-butyl had a maximum background concentration of 0.07 µg/g. All maximum values were in excess of this concentration, indicating that some muscle contamination was occurring. The largescale sucker has a wet-weight concentration of 0.07 µg/g. In the northern squawfish from the Main Stem, wet-weight concentration was 0.09 µg/g. The peamouth chub concentration was measured to be 0.15 µg/g. The small sample size only allowed examination of maximum concentrations which ranged from 0.2 µg/g in the peamouth chub to 2.71 µg/g in the northern squawfish.

Butyl benzyl had the highest mean concentration in the Main Stem. Largescale suckers had mean concentration of 0.06 µg/g wet-weight in the Main Stem. The concentration in the northern squawfish was 0.06 µg/g. The peamouth chub had a concentration of 0.07 µg/g in the Main Stem. Within the Main Stem, the concentrations in all the species were very similar. There were no average liver concentrations for the Main Stem but maximum values ranged from 0.26 µg/g in largescale suckers to 0.76 µg/g in peamouth chub (Swain and Walton, 1989).

Di-n-octyl phthalate had a maximum background concentration of 0.11 µg/g so muscle tissue concentrations in excess of this could be assumed to be due to contamination. In all cases , the maximum values were highest in Main Stem. The largescale sucker had a maximum wet-weight concentration of 0.04 µg/g. Muscle concentration in the peamouth chub from the Main Stem was 0.11µg/g. For the northern squawfish, samples in the Main Stem had a maximum concentration of 0.18 µg/g. Within the Main Stem, only the northern squawfish and the peamouth chub had average concentrations to compare. The northern squawfish had a mean wet-weight concentration of 0.08 µg/g which was statistically similar to the mean concentration of 0.04 µg/g found in the peamouth chub(Swain and Walton, 1989). Both of these have maximum and mean values less than 0.11 µg/g, so concentrations may be due to background. The detection limit in the liver was 0.5 µg/g which is substantially greater than the 0.01 µg/g limit for muscle tissue(Swain and Walton, 1989). Since the maximum muscle concentrations are below 0.5 µg/g, no conclusions regarding the accumulation of di-n-octyl phthalate in the tissues is possible.

Bis(2-ethylhexyl) has a background concentration of 0.094 µg/g and therefore any concentration exceeding this value is assumed to be due to contamination. A mean concentration could not be calculated for the largescale sucker but the maximum wet-weight concentration was 0.043 µg/g. The average concentration of the northern squawfish in the Main Stem was 0.09 µg/g. The mean concentration of peamouth chub in the Main Stem was measured to be 0.12 µg/g (Swain and Walton, 1989).

Mean liver concentrations for the Main Stem were only available for the northern squawfish. The mean wet-weight concentration of 0.95 µg/g is about ten times higher than found in the muscle tissue. This implies that bis(2-ethylhexyl) phthalate is accumulating in the liver of these fishes.

No criteria exist for concentrations of phthalic acid esters in fish tissues and few data were available for comparison.

6.3.4.2.4 Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs are commercially used compounds, naturally present in coal and petroleum, and can also be formed during the incomplete combustion of hydrocarbons. The most recent data involving PAH contaminants in fish comes from a 1988 report by Swain and Walton. In this report, fish were tested for the following substance (wet-weight detection limits are indicated in parenthesis): acenaphthene (0.004 µg/g), acenaphthylene (0.004 µg/g), anthracene (0.004 µg/g), benzo[a]anthracene (0.01 µg/g), benzo[a]pyrene (0.02 µg/g), benzo[b]fluoranthene(0.02 µg/g), benzo[ghi]perylene (0.02 µg/g), benzo[k]fluoranthene (0.02 µg/g), chrysene (0.01 µg/g), dibenzo[ah]anthracene (0.02 µg/g), fluoranthene (0.01 µg/g), fluorene (0.004 µg/g), indeno[1,2,3-cd]pyrene (0.02 µg/g), naphthalene (0.004 µg/g), phenanthrene (0.004 µg/g) and pyrene (0.01 µg/g). The fish tested in the Main Stem were largescale sucker, northern squawfish, peamouth chub, and redside shiner. None of the PAHs measured in the muscle tissues of the four species of fish were present in detectable amounts.

The detection limit for liver concentrations was five times higher than it was for muscle concentrations so it was surprising that some compounds were found in detectable amounts. Naphthalene was the most consistently found PAH. The mean concentration in northern squawfish was 0.059 µg/g. Fluorene was detected in a largescale sucker at a maximum concentration of 0.020 µg/g. Pyrene was found in peamouth chub in the Main Stem with a maximum concentration of 0.070 µg/g. Phenanthrene was detected in largescale sucker (0.025 µg/g), northern squawfish (0.033 µg/g) and peamouth chub (0.060 µg/g) in the Main Stem. The fact that some PAHs appear to be accumulating in livers is of concern, indicating that there may be a need for non-point source control strategy for stormwater.

To protect consumers of fish and shellfish, an objective is proposed as follows: the maximum concentrations of benzo (a) pyrene in edible tissues should not exceed 4 µg/kg for consumers of up to 50 grams per week, 2 µg/kg for consumers of up to 100 grams per week, and 1 µg/kg for consumers of up to 200 grams per week.

6.3.4.2.5 Organochlorine Pesticides

The organochlorine pesticides measured in 1988 (with detection limits in parenthesis) were: aldrin (0.2 µg/g), alpha-chlordane (0.2 µg/g), gamma-chlordane (0.2 µg/g), dieldrin (0.2 µg/g), DDT (0.2 µg/g), DDD (0.2 µg/g), DDE (0.1 µg/g), endrin (0.2 µg/g), endosulfan I (0.1 µg/g), endosulfan II (0.4 µg/g), endosulfan sulfate (2.0 µg/g), heptachlor (0.2 µg/g), heptachlor epoxide (2.0 µg/g), lindane (0.1 µg/g), methyoxychlor (1.0 µg/g), and toxaphene (10 µg/g). Only DDE was quantified frequently enough in all species to calculate means and will be the only pesticide discussed. In the northern squawfish, DDE concentration in the Main Stem was measured at 13.4 µg/g. DDE concentrations of the peamouth chub in the Main Stem was 2.92 µg/g. Within the Main Stem, the data between the northern squawfish, the peamouth chub and the redside shiner were too variable to assess. Several pesticides were detected occasionally and are tabled below (Swain and Walton, 1989).

Organochlorine Pesticides* (Swain and Walton, 1989)				
Pesticide	**Fish Species**	**Location**	**No of Values**	**Maximum**
alpha-chlordane	peamouth chub	Barnston Is.	4	3/0.62
	redside shiner	Barnston Is.	8	2/0.48
gamma-chlordane	no. squawfish	Barnston Is.	6	10/1.79
	peamouth chub	Barnston Is.	4	2/0.42
	redside shiner	Barnston Is.	8	4/0.87
dieldrin	largescale sucker	Barnston Is.	4	5/0.95
	no. squawfish	Barnston Is.	6	5/0.91
DDT	largescale sucker	Barnston Is.	4	6/1.13
	no. squawfish	Barnston Is.	6	1/0.187
	redside shiner	Barnston Is.	8	1/0.224
DDD	largescale sucker	Barnston Is.	4	6/1.13
	no. squawfish	Barnston Is.	6	26/4.65
	redside shiner	Barnston Is.	8	43/0.094
DDE	no. squawfish	Barnston Is.	6	72/13.5
	peamouth chub	Barnston Is.	4	17/2.92
	redside shiner	Barnston Is.	8	120/26.2

6.3.4.2.6 Dioxins and Furans

Dwernychuk *et al.* (1991) found low levels of organochlorine compounds upstream from Prince George indicating that fish which contain organochlorines are capable of migrating into waters not containing these compounds. They also found that "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". The draft B.C. criterion for the protection of aquatic life from dioxins and furans is the proposed tissue quality objective for these compounds in the lipids of fish. The proposed Objective is that the total TEQs for lipid concentrations of PCDDs and PCDFs should not exceed 50 pg/g in the lipids of fish tissues and fish eggs collected in between Chilliwack and Kanaka Creek.

6.3.4.3 General Fish Health

In a 1995 FREMP Monitoring Program Report, peamouth chub health was detailed for fish collected at Barnston Island in the Main Stem, at a reference site at Mission, and in the North and Main Arms. The fish were tested for fin erosion, skin aberrations, hindgut inflammation, gill, spleen, liver and kidney abnormalities as well as parasitic infection.

Fin erosion and skin aberrations are conditions often associated with degraded estuarine or coastal environments. Barnston Island peamouth had high incidents of fin erosion (5%). As well, 5% of the Barnston Island fish tested had mild to moderate skin aberrations (Roome, 1995).

The condition of the gills is an indicator of general fish health. Gill abnormalities were examined both with visual inspection and histology (visual, <5% Barnston; histology, 31% Barnston). The most common abnormality in all test sites was gill aneurysm. Whether this is a result of industrial pollution cannot be determined because of the high prevalence of this abnormality at the reference site. Protozoans were found in the gill tissues of 31% of the Barnston Island fish.

Barnston Island fish had almost double the visual occurrence of spleen abnormalities as Mission fish (13% vs. 7%). However, histological analysis showed 100% of the fish at both Barnston Island and the Mission reference site with abnormalities and myxosporeans of the spleen. Melanosis, the presence of melanin in an abnormal location, occurred in higher abundance at the Mission reference site than Barnston Island or the Main and North Arms.

Histological analysis of fish from both Barnston Island revealed that 100% of the fish were found to have hemorrhaging and myxosporean parasites in the tissue. However, baseline information on the distribution of protozoans in the Fraser River peamouth chub is unavailable, and so these abnormalities may not be a true reflection of pathological processes, but may represent real pigmentation levels and protozoan distributions in these populations (Roome, 1995).

Visual inspection of the liver of test fish revealed abnormal livers in 77% of Barnston Island fish. Histology also revealed a higher incident of fatty infiltration in the liver of Barnston Island fish (5%) than Mission fish (2%). The much higher percentage of abnormalities found through visual inspection versus histology may indicate that visually abnormalities were merely differences in species organ conditions (Roome, 1995).

Due to the similarities and high rates of abnormalities in the results from both Barnston Island and the Mission reference site, it is difficult to interpret the data to confirm whether these conditions are an effect of decreased environmental water quality.

6.4 Fraser River - North and Middle Arms

6.4.1 Water Chemistry

There is a distance of approximately 35km between New Westminster and the mouth of the Fraser River (Ages and O'Brien, 1985). At New Westminster, the Fraser River divides into three separate flows: the North Arm, the Annacis Channel, and the Main Arm. The North Arm receives 16% of the total flow of the Main Stem (Drinnan and Clark, 1980). Further downstream, the North Arm divides to yield the Middle Arm which diverts 45% of the flow from the North Arm (Drinnan and Clark, 1980). When river discharges are moderate to low (September to April), tidal action and salinity intrusion extend upstream to influence water chemistry and contaminant bioavailability in the North and Middle Arms of the Fraser River (Carey, 1990). Consequently, tidal action and salt wedge intrusion, are important factors that must be considered in the development of Water Quality Objectives. Federal Water Quality Guidelines developed by the CCREM (1987) apply only to inland surface waters and groundwaters, and not to estuarine waters. Where there are no B.C. Approved and Working Criteria developed for saline waters in which there exist contaminants of concern to designated water uses, provisional Water Quality Objectives may be proposed using the most conservative guideline or criteria for freshwater.

Water chemistry was measured at nine provincial monitoring sites in the North Arm between the New Westminster trifurcation and Sturgeon Banks from January, 1985 to December, 1994 (Figure 10). Seven of these sites (E207396, E207397, E207398, E207399, E207401, E207403, and 0300002) are in the North Arm and two (E207601, E207600) are located in the Middle Arm of the Fraser River. Sites E207396 and E207397 are located upstream and downstream from Crown Packaging, respectively. Sites E207398 and E207399 are located upstream and downstream from the Scott Paper discharge, respectively. Site E207401 is located downstream from Mitchell Island, and Site E207403 is located downstream from Richmond Recycle. Sites E207601 and E207602 are located upstream and downstream from the Vancouver International Airport, respectively. The data from these sites are summarized in Tables 82, 83, 84, 85, 86, 87, 88, 89 and 90, respectively. Some sediment chemistry was measured at six of these sites (E207396, E207397, E207398, E207399, E207401, E207600) (Tables 91, 92, 93, 94, 95 and 96, respectively). These data are compared to those collected at the Oak Street Bridge by FREMP between January, 1993 and March, 1994 at two-week intervals (Tables 97 and 98, Figure 10). Data were also collected by FREMP from three sloughs (McDonald, Eburne and Tree Island, Figure 10) in February 1993 and February 1994, both near the surface and near the bottom of the sloughs (Tables 99, 100, 101, 102, 103, and 104). Beak Consultants collected some dissolved oxygen concentrations in these sloughs (Table 105). The GVRD collected limited water quality data at their monitoring sites 5-11 (Figure 10, Table 106).

6.4.1.1 pH and Alkalinity

The mean pH was slightly basic, ranging from 7.6 to 7.8, and consistent among all nine monitoring sites. However, a wide range of values was measured at four of the sites (0300002, E207398, E207600 and E207601), with maximum values of about 9.6 and minimum values of 6.4 at each. The mean pH reported by FREMP at the Oak St. Bridge was 7.4, with values ranging from 6.9 to 7.7. The pH values measured at the three sloughs also fall within this range. These values represent a slight decrease in mean pH since the 1985 report (Swain and Holms, 1985b). The range of values are similar to those reported upstream (Section 6.1.1.1).

Changes in the pH of the North Arm are effected by combined-sewer overflows, as well as effluent carried up the Main Arm and into the North Arm from the Annacis STP by tidal flow. Consequently, <u>a provisional Water Quality Objective for pH is proposed for the North Arm</u>. The objective is that <u>the pH of any discrete sample should fall within the</u>

range of 6.5 to 8.5 outside of initial dilution zones for the protection of sensitive aquatic life by minimizing the quantities of un-ionized ammonia formed in the river. Initial dilution zones in areas affected by tides, will be defined as extending no further than 100 metres upstream or downstream from the discharge, from the bed to the surface, and no further than 25% across the width of the river.

The mean total alkalinity measured by FREMP was 44 mg/L $CaCO_3$, with values ranging from 32.7 to 58.7 mg/L $CaCO_3$. This mean value is slightly higher than the 42 mg/L reported by Swain and Holms (1985), and represents a slight decrease from the mean value of 46.3 mg/L $CaCO_3$ measured at Mission (Section 6.2.1.1). The alkalinity of Tree Island Slough was within this range, while both McDonald and Eburne Sloughs were considerably higher, with values ranging from 59.4 to 98.7 mg/L. All mean values were well above the >20 mg/L threshold water quality criteria for the protection of freshwater aquatic life (Swain, 1987). These values indicate a low sensitivity to acid inputs.

6.4.1.2 Hardness and Metals

Hardness was measured at seven of the nine Fraser River monitoring sites (0300002, E207396, E207397, E207398, E207399, E207600, and E207601). Mean values ranged from 50 to 387 mg/L $CaCO_3$ at these sites. The minimum reported concentration was 32 mg/L $CaCO_3$ (at Site E207398) and the maximum concentration was 1582 mg/L $CaCO_3$ (at Site 0300002). This high hardness reflects the intrusion of seawater with high concentrations of calcium and magnesium.

The mean hardness reported by FREMP for the Oak St. Bridge site was 144.7 mg/L $CaCO_3$, with a minimum value of 39.9 mg/L $CaCO_3$. The hardness measured in Tree Island Slough was within this range while water hardness at McDonald and Eburne Sloughs was much higher, ranging from 1 060 mg/L to 5 030 mg/L (again reflecting seawater intrusion). The mean concentration of calcium ranged from 14.3 mg/L to 34.6 mg/L at the seven monitoring sites and at the FREMP site; this range represents a low sensitivity to acid inputs according to the water quality criteria (Swain, 1987). Calcium concentrations were low (<20 mg/L) at Tree Island Slough and higher in McDonald and Eburne Sloughs where values ranged from 78.1 to 304 mg/L. Concentrations of total magnesium varied greatly among sites with mean values ranging from 3.5 to 66.6 mg/L. Again, concentrations were low in Tree Island Slough (<28 mg/L) and higher in McDonald and Eburne Sloughs (210-1 040 mg/L). These sloughs are closer to the Banks and would therefore have a greater frequency of saltwater intrusion due to tidal effects.

Most metal concentrations were measured at seven of the nine monitoring sites (0300002, E207396, E207397, E207398, E207399, E207600, and E207601). Detection limits for many of the metals changed during the period in which data were collected due to a change in laboratories used to analyze the water samples.

Aluminum

The mean concentration of total aluminum ranged from 0.19 mg/L to 0.95 mg/L at the seven sites where it was measured. The maximum reported value was 2.31 mg/L at Site E207398. The mean value of total aluminum measured at the Oak St. Bridge was 0.5 mg/L, with a maximum value of 3.37 mg/L (n=44). Aluminum concentrations in the three sloughs were within this range. No water quality criteria exist for the protection of aquatic life from total aluminum concentrations; while water quality criteria have been established for concentrations of dissolved aluminum, dissolved aluminum was not measured at any of the sites. Measurements of total suspended solids were not available for the seven monitoring sites, but comparisons of total suspended solids and total aluminum concentrations in the Oak St. Bridge data show a very strong correlation between these variables, with higher concentrations of aluminum present concurrently with high concentrations of suspended solids. This suggests that much of the aluminum present in the river is associated with suspended solids and not detrimental to aquatic life. Therefore, no Water Quality Objective is proposed for aluminum concentrations in the North Arm.

Arsenic

The concentration of total arsenic was measured at six of the Fraser River monitoring sites. Median values for five of the sites were below the minimum detectable limit of 0.04 mg/L. At the sixth site (E207600), three of the five measurements were 0.05 mg/L (the remainder being less than 0.04 mg/L). The maximum concentration was 0.13 mg/L, measured at Site E207601. The concentration of arsenic measured at the Oak St. Bridge ranged from 0.0003 to 0.0013 mg/L, with a mean value of 0.0006 mg/L (n=44). The concentration of arsenic in the sloughs was low, with a maximum value of 0.0039 mg/L. The freshwater criteria for the protection of aquatic life, drinking water, and recreation is a maximum of 0.05mg/L while the marine criterion is more stringent, requiring that the 4-day average concentration of arsenic not exceed 0.036 mg/L. It is apparent that while the more conservative marine criterion for arsenic exceeds the detection limit for much of the data collected, thereby rendering such data difficult to interpret, exceedances of the water quality criterion do occur. These exceedances indicate that aquatic life may not be adequately protected in the North Arm of the Fraser River. However, as no significant source of arsenic exists in the North Arm, no Water Quality Objective is proposed for this reach.

Barium

The concentration of total barium was measured only at the FREMP Oak St. Bridge site and in the three sloughs. Values ranged from 0.013 to 0.051 mg/L, with a mean value of 0.018 mg/L. Concentrations at the sloughs were within this range. These values are within the freshwater criterion of 1 mg/L for the protection of drinking water uses (Nagpal, 1994) and slightly exceed the marine criterion of 0.5 mg/L for the protection of aquatic life from minimal risks (Nagpal, 1994). Therefore, barium concentrations do not appear to be of concern in the North Arm.

Cadmium

The concentration of total cadmium was measured at seven of the nine sites. All measurements were below detection limits which were lowered from 0.01 mg/L to 0.002 mg/L during the monitoring program. Both detection limits exceed the water quality criteria of 0.0002 mg/L at a hardness of less than 60 mg/L for the protection of freshwater aquatic life and 0.0001 mg/L for the protection of marine aquatic life; therefore, interpretation of the data is inconclusive. The median concentration measured at the FREMP Oak St. Bridge site was < 0.0002 mg/L. Minimum detection limits changed at this site also and the highest concentration measured was 0.0001 mg/L, below the marine water quality criterion. It cannot be concluded with the available data, that cadmium is a metal of concern.

Chromium

The median concentration of total chromium measured at the seven sites was less than the minimum detection limits of 0.01 mg/L at three of the sites, and 0.002 mg/L at the remaining four sites. Detection limits were later lowered to 0.002 mg/L at all seven. Four of the 233 samples taken at these sites exceeded the freshwater quality criterion of 0.002 mg/L which is more stringent than the marine criterion of a 4-day average of 0.050 mg/L. The maximum concentration measured was 0.02 mg/L. The four samples which exceeded the criterion were taken on two different days and were near detection limits of 0.01 mg/L for all samples. The concentration of suspended solids was relatively high at three of the four sites (between 44 and 53 mg/L), suggesting that some of the chromium may have been associated with suspended sediments and thus unavailable to aquatic organisms. The median concentration of chromium measured at the FREMP Oak Street Bridge site was less than the minimum detection limit of 0.001 mg/L; the maximum concentration of 0.007 mg/L exceeded the criterion. The two concentrations which exceeded the criterion at the FREMP Oak Street Bridge site were associated with quite high suspended solids (76 mg/L and 224 mg/L); therefore, some of the chromium could have been biologically unavailable. The concentrations of chromium in the three sloughs were at or below the detection limit of 0.001 mg/L and therefore below the criterion. The infrequent excursions above the criterion may be of concern to aquatic life. Because there are no known significant anthropogenic sources of chromium in the North Arm, no Water Quality Objective is proposed for this compound.

Cobalt

Total cobalt concentrations were measured only at the FREMP Oak Street Bridge site (n=43) and at the three slough sites. All concentrations were below minimum detection limits (which were lowered from 0.015 to 0.004 mg/L at the Oak Street Bridge Site and from 0.045 to 0.015 mg/L in the sloughs during the monitoring program). These values were below the water quality criterion of 0.050 mg/L for the protection of freshwater aquatic life (Nagpal, 1994). No marine criteria are currently available for cobalt. Cobalt concentrations are not considered to be of concern.

Copper

The mean concentration of total copper ranged from less than 0.002 mg/L to 0.004 mg/L at the seven sites where it was measured. The maximum reported value was 0.021 mg/L at Site E207398 (upstream from Scott Paper Products, Figure 10). The mean concentration of copper measured by FREMP at the Oak Street Bridge site was 0.003 mg/L; the maximum concentration was 0.008 mg/L (n=44). The maximum concentration measured in the sloughs was 0.003 mg/L in Eburne Slough. In an estuarine environment, the water quality criteria for copper are a 30-day average concentration ≤0.002 mg/L, and a maximum concentration of 0.003 mg/L (Singleton, 1987). Many of the copper concentrations measured were less than the maximum criterion, but the relatively high mean concentrations at some of the sites and the occasional excursion above the maximum criterion suggest that copper concentrations may be a concern in the North Arm.

Mean concentrations of copper reported by Swain and Holms (1985) between 1979 and 1980 for this reach ranged between 0.004 mg/L and 0.005 mg/L. They suggest that copper concentrations have long been above the water quality criteria. Large episodic pulses in copper concentrations (the concentration of copper at Site E207398 two days prior to the maximum recorded value of 0.021 mg/L was < 0.002 mg/L) are likely due to the strong anthropogenic influence of storm drains in the North Arm. In Section 5.3, it was estimated that urban stormwater runoff could increase copper concentrations by as much as 3.8 µg/L under low flow conditions. It is apparent that Water Quality Objectives are needed in this reach for the protection of sensitive designated water uses of the estuarine North and Middle Arms of the Fraser River. The following Water Quality Objectives are proposed for the protection of aquatic life. The maximum total copper concentration in the estuarine receiving environment should not exceed 3 µg/L, while in fresh water areas, it should not exceed the product of 0.094 (hardness) + 2 µg/L. Furthermore, the 30-day average copper concentrations should not exceed 2 µg/L in the estuarine environment or when water hardness is less than 50 mg/L, and in freshwater with water hardness greater than 50 mg/L should not exceed 0.04 (average hardness). The mean values apply to a minimum of five weekly samples collected over a thirty-day period while the maximums apply to discrete samples.

Iron

All total iron measurements from the provincial and FREMP monitoring sites exceeded both freshwater and marine water quality criteria. The mean concentration of total iron ranged from 0.43 to 1.29 mg/L; the maximum concentration was 3.22 mg/L at Site E207601 (in the Middle Channel). The water quality criteria for total iron are a maximum value of 0.3 mg/L for the protection of drinking water and freshwater aquatic life (Nagpal, 1994) and 0.05mg/L iron for the protection of marine aquatic life from minimum risk to total iron exposure (Nagpal, 1994).

Despite these exceedances, no water quality objectives are proposed for the North and Middle Arms as there are strong indications that these elevated concentrations are natural and not of concern. High concentrations of total iron were also measured upstream between Hope and Kanaka Creek (Sections 6.1.1.2, 6.2.1.2), so it would appear that natural concentrations exceed the water quality criteria for iron. Furthermore, because maximum total iron concentrations are temporally and spatially correlated with maximum loadings of total suspended solids, there is reason to believe that high iron concentrations are attributable to iron molecules sorbed to these suspended particulates. Iron adsorbed to suspended sediment is biologically unavailable to aquatic life and not of concern.

Lead

The maximum concentration of total lead measured at the provincial monitoring sites in the North Arm was 0.024 mg/L at Site E207601. Concentrations ranged from a median of less than 0.003 mg/L to a mean of 0.004 mg/L at these sites. Samples of lead collected from the FREMP Oak Street Bridge site had a median of < 0.001 mg/L and a maximum value of 0.001 mg/L (n=38). The concentrations of lead in the three sloughs were below detection levels for all samples (detection levels decreased from 0.003 to 0.001 mg/L during the monitoring program). The water quality criterion for the protection of aquatic life in estuarine environments is a 30-day average for total lead of ≤ 0.002 mg/L with 80% of the values being no more than 0.003 mg/L and maximum values being no more than 0.140 mg/L. The average is to be calculated for at last five weekly samples taken in a period of 30 days (Nagpal, 1994). Mean and median values for all sites, except the FREMP site were above the 30-day average criterion. Mean values reported by Swain and Holms (1985) in 1979-80 were between 0.001 and 0.002 mg/L, with a maximum recorded valued of 0.04 mg/L, suggesting a slight increase in lead concentrations has occurred since that time. In Section 5.3, it has been estimated that urban stormwater runoff could increase lead concentrations by as much as 16.2 μg/L. These estimates are likely high since they are based on lead concentrations in road runoff when leaded gasoline was available. However, to ensure that values remain low, a Water Quality Objective is proposed for lead concentrations for the protection of estuarine aquatic life. The Objective is that the 30-day average concentration of total lead should not exceed 2 µg/L, that 80% of the values used to calculate the 30-day average must be ≤3 µg/L, and that the maximum value measured must be ≤140 µg/L. The 30-day average is calculated from at least five weekly samples taken in a period of 30 days (Nagpal, 1994). For freshwater situations, the average should be less than 3.31 + 1.273 exp (ln (average hardness) - 4.705 µg/L, while the maximum should be less than 1.273 exp (ln (average hardness) - 1.460 µg/L This objective applies outside of provisional initial dilution zones as described in Section 1.0.

Manganese

Of the samples measured at the provincial sites for total manganese, the mean concentration ranged from 0.02 mg/L to 0.042 mg/L and the maximum value was 0.102 mg/L at the provincial sites. The samples taken by FREMP at the Oak Street Bridge site had a mean of 0.036 mg/L manganese and a maximum value of 0.17 mg/L (n=44). All concentrations in the sloughs were less than 0.027 mg/L. The water quality criterion for manganese is a maximum of between 0.1 and 1.0 mg/L for the protection of freshwater aquatic life. In a salt water environment, 0.1 mg/L manganese protects aquatic life. Since manganese is now used as a fuel additive in gasoline and would be present in stormwater, a Water Quality Objective is proposed. For the protection of both freshwater and marine aquatic life, the Water Quality Objective for the North and Middle Arms of the Fraser River requires that discrete water samples collected from this reach of the river not exceed 100 µg/L.

Mercury

The concentrations of mercury at the FREMP Oak Street Bridge site (n=44) and the three slough sites were below detection limits of 0.05 µg/L in all samples taken. This detection limit exceeds the 30-day average water quality criterion of 0.02 µg/L for the protection of estuarine aquatic life, therefore, so a discussion of the potential concern of mercury concentrations is difficult. Mercury concentrations were not measured as part of the 1985 monitoring program (Swain and Holms, 1985b). Current data are necessary to determine if mercury should be considered a concern in this reach of the Fraser River.

Nickel

The median concentration of total nickel measured in the North Arm ranged from <0.01 mg/L to <0.05 mg/L. The minimum detection limits for nickel changed during the collection period due to a change in analytical techniques. The water quality criterion for total nickel is a maximum of 0.025 mg/L at a hardness of 50 mg/L for the protection of freshwater aquatic life (CCREM, 1987). For the protection of marine aquatic life, the water quality criteria for total nickel is a 4-day average of 0.0083 mg/L (Nagpal, 1994). Because the detection limit is above criterion, an interpretation of the ambient water quality data measured at the higher detection limit is not possible. The mean concentration of nickel measured at the FREMP Oak Street Bridge site was 0.004 mg/L, with a maximum value of 0.017 mg/L (n=44). The maximum concentration of nickel measured by FREMP in the sloughs was 0.016 mg/L. Thus, the criteria were met by the mean concentration the Oak Street Bridge. However, more precise data are needed to assess whether nickel levels at other sites of the reach are of concern.

Zinc

The concentrations of total zinc measured at the provincial monitoring sites in the North Arm of the Fraser River ranged from a median of < 0.01 mg/L to a mean of 0.018 mg/L. The maximum recorded concentration was 0.18 mg/L at these sites. The mean concentration of zinc measured at the FREMP Oak Street Bridge site was 0.012 mg/L with a maximum concentration of 0.09 mg/L (n=44). The maximum concentration in the three sloughs was 0.004 mg/L. The water quality criterion is tentatively set at a maximum value of 0.03 mg/L for the protection of freshwater aquatic life (CCREM, 1987), although phytoplankton are affected at levels as low as 0.014 mg/L (International Joint Commission Great Lakes Advisory Board, 1987). Water quality criteria for aquatic life in marine environments are less stringent with a 4-day average concentration of 0.086 mg/L and a 1-hour average concentration of 0.095 mg/L. Some salt water plants are affected at levels as low as 0.019 mg/L (Nagpal, 1994). The mean concentration at three of the monitoring sites (Sites E207397, downstream from Crown Packaging, E207398, upstream from Scott Paper Products, and E207600, the first Airport site) exceeded the criterion for the protection of freshwater phytoplankton, and 21 of the 294 samples exceeded the criterion of 0.03 mg/L for the protection of freshwater aquatic life. These excursions over the criterion may be of concern because they imply that aquatic life is not adequately protected, maximum concentrations are higher than those measured upstream between Chilliwack and Kanaka Creek (Section 6.2.1.2), and temporal trends indicate that current maxima higher than those measured in 1979-80 (Swain and Holms, 1985b). In Section 5.3, it has been estimated that anthropogenic storm water runoff could increase zinc concentrations by as much as 16.2 μg/L under low flow conditions. Therefore, a Water Quality Objective is proposed for zinc concentrations in the North Arm. This objective states that the mean concentration of zinc in at least five samples measured in a 30-day period should not exceed 14 μg/L, and no single value should exceed 30 μg/L. These objectives apply to samples collected from outside of initial dilution zones only, as described in Section 1.0.

6.4.1.3 Dissolved Oxygen and Oxygen-Consuming Materials

Dissolved oxygen was measured at four (0300002, E207398, E207600, and E207601) of the nine provincial monitoring sites on the North Arm of the Fraser River. Mean concentrations ranged from 10.2 to 12.0 mg/L, with a minimum concentration of 6.9 mg/L at Site 0300002. The mean concentration of dissolved oxygen at the FREMP Oak Street Bridge site was 10.7 mg/L, with a minimum value of 8.4 mg/L. Mean dissolved oxygen concentrations measured at seven GVRD monitoring sites in the North

Arm (GVRD 5, 6, 7, 8, 9, 10 and 11, Figure 10) ranged from 9.4 to 10.2 mg/L with a minimum concentration of 8.5 mg/L (n=48) (Table 106). Mean values are above the water quality criterion minimum of 8 mg/L which would result in no production impairment on the later (post-larval) stages of salmonid development but below the minimum criterion requirements of 11.0 mg/L for the protection of earlier embryonic and larval stages (U.S. Environmental Protection Agency, 1986). Four of the 41 samples collected from the Oak Street Bridge site (0300002) and one of the Airport sites (E207600)values are less than the less stringent criterion of 8.0 mg/L.

These concentrations of dissolved oxygen represent a slight decrease from those reported in 1985 by Swain and Holms for the North Arm. The mean concentration of dissolved oxygen measured in 1979-80 was about 10.9 mg/L, and all values were greater than or equal to 9.7 mg/L. This is consistent with increases in BOD loadings and, in some years, temperatures. However, the FREMP study and the monitoring undertaken in the sloughs in recent years may reflect more accurately dissolved oxygen conditions due to the more intensive effort of sampling and indicate that dissolved oxygen concentrations have not decreased.

Dissolved oxygen concentrations were also measured one metre below the surface and one metre above the bottom of McDonald, Eburne, and Tree Island Sloughs (Figure 10) by FREMP in February of 1993 and again in February 1994 as part of their water quality survey (Tables 99, 101, 103). The minimum dissolved oxygen concentration measured was 10.2 mg/L (in the sample taken one metre above the bottom of McDonald Slough).

Beak Consultants (1991, 1993) also conducted a monitoring program in these sloughs which included dissolved oxygen measurements, twice each in 1991 and 1992. Parameters including dissolved oxygen and conductivity were measured at one-foot intervals from the surface of the slough to the bottom. There was a very consistent, gradual decrease in oxygen concentrations with depth. This gradual decrease continued to approximately two feet of the bottom at which point oxygen concentrations tended to decrease more rapidly. The most severe case occurred in Eburne Slough in July, 1992, when dissolved oxygen concentrations decreased from 8.0 mg/L to 2.0 mg/L in the bottom foot of the slough. The largest decreases in dissolved oxygen were generally associated with salt wedge intrusion at greater depths. Mean surface concentrations of dissolved oxygen in the sloughs ranged from 9.0 to 9.5 mg/L, while those in the bottom foot ranged from 5.3 to 7.2 mg/L (Table 105). Although oxygen concentrations were generally high in most of the water column, allowing fish to occupy these depths if oxygen concentrations in the bottom water decrease, it can not be concluded with certainty that fish will actively avoid waters of low dissolved oxygen content in search of more oxygen rich areas. Furthermore, the long term effects of displacing fish from their native depths is undesirable.

To maintain high oxygen concentrations, and using the criteria from Truelson (1997) as a basis, a Water Quality Objective for the North and Middle Arms is that the instantaneous minimum should not be less than 5 mg/L and the 30-day mean should not be lower than the higher of 80% saturation or 8.0 mg/L. In spawning areas where fish eggs are incubating or areas utilized by young fish, the Water Quality Objective is an instantaneous minimum of not less than 9 mg/L and a 30-day mean not lower than 11.0 mg/L (November to April)..

6.4.1.4 Solids, Turbidity, and Colour

Suspended solids concentrations were measured at the FREMP Oak St. Bridge site. The mean concentration was 32 mg/L, with values ranging from 5 mg/L to 224 mg/L (n=44) (Table 97). This represents a decrease in concentration from 1979/80 when mean values measured at the Oak Street Bridge were 63 mg/L and values ranged from 12 to 140 mg/L (n=6) (Swain and Holms, 1985b). In Section 5.3, it was estimated that urban stormwater runoff could increase suspended solids concentrations by 13.5 mg/L. The water quality criteria for suspended solids concentrations are: an increase of 10 mg/L when background concentrations are <100 mg/L, and an increase of 10% above background concentrations when background levels exceed 100 mg/L (Singleton, 1985). Therefore, increases in suspended solids due to urban stormwater runoff could cause the receiving environment to exceed the criteria.

For this reason, a provisional Water Quality Objective for suspended solids in the North Arm is proposed. This objective is that for waters where background levels ≤100 mg/L suspended solids, induced suspended solids concentrations should not increase by more than 10 mg/L. For waters where background levels exceed 100 mg/L, suspended solids concentrations must not increase by more that 10% of background levels.

Dissolved solids measured at the FREMP site had a mean value of 764 mg/L, with values ranging from 43 to 4080 mg/L. Maximum concentrations of dissolved solids occurred between January 25, 1993 and March 23, 1993. This reflects the intrusion of salt water (with high dissolved solids concentrations) associated with high winter tides and low flows of fresh water in the Fraser River.

6.4.1.5 Nutrients

The mean concentration of total ammonia ranged from 0.014 mg/L to 0.036 mg/L at the provincial and FREMP sites in the North Arm. The concentration of total ammonia measured in the sloughs fell within this range. The maximum ammonia concentration recorded was 0.104 mg/L at Site E207398 in February, 1989. The water quality criteria for average 30-day concentrations of total ammonia nitrogen for the protection of marine aquatic life are related to the temperature, pH, and salinity of the water (see Tables 11, 12, 157 and 158). As temperature and pH values increase, the 30-day allowable concentration decreases. In contrast, as salinity increases, the 30-day average criterion increases. Therefore, more stringent criteria are established for freshwater than saline waters. The water temperature measured at the FREMP Oak Street Bridge site for February was 5° C, and the mean pH at Site E207398 was 7.7. At this temperature and pH, the freshwater criterion is an average 30-day concentration of 1.95 mg/L total ammonia (Nordin and Pommen, 1986). All values are well below this criterion. Ammonia nitrogen values measured in 1979 and 1980 were less than 0.05 mg/L (Swain and Holms, 1985b).

There are situations near discharges where ammonia concentrations can be a concern in the North Arm, due to stagnant water conditions or other phenomena. As such, a Water Quality Objective is proposed for ammonia to protect aquatic life. The Objective is that the maximum and 30-day average ammonia concentrations should not exceed the concentrations listed in Tables 11 and 12 for the respective temperatures and pH values. The objectives apply to discrete samples, collected from outside of initial dilution zones of effluents.

Nitrate/nitrite concentrations were measured at two of the monitoring sites in the North Arm (E207600, E207601). Mean values ranged from 0.04 to 0.05 mg/L; the maximum recorded concentration was 0.07 mg/L. Nitrate/nitrite concentrations measured at the FREMP Oak Street Bridge site had a mean value of 0.145 mg/L, with a maximum concentration of 0.362 mg/L. This value is higher than the mean value recorded at this site from 1979 to 1980 of 0.11 mg/L (Swain and Holms, 1985b). The concentration of nitrate/nitrite in the sloughs ranged from 0.2 mg/L to 0.424 mg/L. The water quality criteria for nitrate is a maximum concentration of 10 mg/L for the protection of recreation and aesthetics (Nordin and Pommen, 1986). All values are well below this criterion.

Nitrite concentrations measured at the provincial monitoring sites did not exceed the minimum detection limits of 0.005 mg/L. This value is well below the water quality criterion for nitrite of 0.20 mg/L as an average concentration (with a chloride concentration of greater than 10 mg/L) for the protection of freshwater aquatic life (Nordin and Pommen, 1986). There are currently no criteria for the protection of marine aquatic life. The Annacis sewage treatment plant can have significant effects on the ammonia concentrations at times of stagnant water and tidal reversals. In order to protect fish health, a maximum and an average Water Quality Objective for nitrite related to the chloride concentration as shown in Table 13 is proposed. These values are consistent with uncontaminated sites upstream.

Total phosphorus was present at a mean concentration of 0.05 mg/L and a maximum concentration of 0.06 mg/L at the Oak Street Bridge and upstream from Scott Paper. The mean concentration of total phosphorus at the FREMP Oak Street Bridge site was 0.07 mg/L; the maximum value was 0.23 mg/L. The water quality criterion for total phosphorus in lakes is a maximum concentration of between 0.005 to 0.015 mg/L (Nordin, 1985); no criteria exist for streams or rivers. Although phosphorus is often the limiting factor for algae production in lakes, it is not the limiting factor in the Fraser River, where light penetration (due to high suspended solids concentrations) is the major limitation.

6.4.1.6 Bacteriological Indicators

The majority of fecal coliform measurements from the seven provincial sampling sites (0300002, E207396, E207397, E207398, E207399, E207600, and E207601) were reported in units of CFU/cL. Geometric means at the seven sites ranged from 78 to 205 CFU/cL; the maximum concentration was 2 900 CFU/cL occurring upstream from Scott Paper Products. One value at each of five sites (0300002, E207396, E207397, E207398 and E207399) was measured in MPN/100 mL between 1985 and 1995; these ranged from 220 to 540 MPN/100 mL. Fecal coliforms were also monitored at seven GVRD sites (GVRD 5, 6, 7, 8, 9, 10, and 11), and geometric means ranged from 50.3 to 181.4 MPN/100 mL. All samples were taken between the months of April and October when the uses of Fraser River water in this area may include irrigation of crops eaten raw (for example, lettuce, cabbage, broccoli or cauliflower) and secondary recreation (e.g. jet skiing and wind surfing). The water quality criterion for the most sensitive water use (the protection of irrigation of crops eaten raw) is a geometric mean ≤200 CFU/cL (Warrington, 1988). Only data from the Oak Street Bridge site (Site 0300002) exceeded the criterion, with a geometric mean of 205 CFU/cL. The single value measured in MPN/100 mL at the provincial sites exceeded the criterion at all five of the sites (0300002, E207396, E207397, E207398 and E207399); further data are required to evaluate fecal coliform concentrations at these sites. All geometric means measured at the GVRD sites were below the criterion.

Fecal coliform concentrations measured at the FREMP Oak Street Bridge site during the summer months had a geometric mean of 103 MPN/100 mL and a range of 14 to 2 200 CFU/cL. These values are markedly reduced from fecal coliform concentrations measured between 1979 and 1980, when the median value reported at Site 0300002 was 930 MPN/100 mL and the maximum concentration was 9 200 MPN/100 mL. Winter concentrations of fecal coliforms at this site had a geometric mean of 2 314 MPN/100 mL and a range of 500 to 17 000 MPN/100 mL. Concentrations of fecal coliforms in the three sloughs ranged from 800 to 5 000 MPN/100 mL. These were measured in February when there is likely to be no irrigation of crops eaten raw; therefore, there values are not subject to the criterion. Because of the potential for fecal coliform concentrations to increase by urban stormwater runoff (increase by 1295 CFU/cL) and by the transport of fecal coliforms from upstream due to currents and from the Annacis STP by tidal effects, a Water Quality Objective for fecal coliform concentrations is proposed. This Objective is that the geometric mean of at least five fecal coliform measurements made in a 30-day period should not exceed 200 CFU/100 mL between April and October. This objective applies outside of initial dilution zones (as described in Section 6.4.1.1) only.

The geometric means of *E. coli* bacteria ranged from 51 to 78 CFU/cL; the maximum concentration was 110 CFU/cL. The water quality criterion for *E. coli* in water used for irrigation of crops eaten raw is a geometric mean ≤ 77 CFU/cL (Warrington, 1988). The criterion was barely exceeded at the Oak Street Bridge site (Site 0300002) where the geometric mean was 78 CFU/cL. All samples were taken between April and October. Therefore, a Water Quality Objective for *E. coli* bacteria is proposed for the North Arm. This Objective states that the geometric mean of at least five *E. coli* measurements made within a 30-day period between April and October should not exceed 77 CFU/100 mL, outside of initial dilution zones as described in Section 1.0.

The geometric means of concentrations of Enterococci bacteria at the provincial monitoring sites ranged from 21 to 36 CFU/cL; the maximum concentration was 49 CFU/cL. The geometric mean of *Enterococci* bacteria measured at the seven GVRD sites was 55.9 CFU/cL and the maximum concentration was 140 CFU/cL. All geometric means exceeded the water quality criterion for water used to irrigate crops eaten raw (geometric mean ≤ 20 CFU/cL) (Warrington, 1988). Therefore, concentrations of *Enterococci* may be of concern in this area. The Water Quality Objective proposed for *Enterococci* is that the geometric mean of at least five samples collected within a 30-day period between April and October should not exceed 20 CFU/100 mL. This Objective applies to all areas outside of initial dilution zones as described in Section 1.0.

The concentration of *Pseudomonas aeruginosa* bacteria measured at the provincial monitoring sites were below detection limits of 2 CFU/cL in all samples, which meets the water quality criterion for the protection of primary-contact recreation of ≤ 2 CFU/100 mL (75th percentile). However, as *Pseudomonas aeruginosa* may be introduced to the North Arm through combined sewer overflows or from the Annacis STP by tidal action, a Water Quality Objective is proposed for concentrations of *Pseudomonas aeruginosa* in the North Arm. The Objective is that the geometric mean of at least five samples collected within a 30-day period between the months of April and October should not exceed 2 CFU/100 mL, outside of initial dilution zones as described in Section 6.4.1.1.

6.4.1.7 Organics

Two organics (3-monochlorophenol (3ChlPhen) and 4-monochlorophenol (4ChlPhen)) were monitored at four of the North Arm Fraser River sites (E207397, E207399, E207401 and E207600), and 4ChlPhen was measured once at Sites E207396 and E207403 (Figure 10). The remainder of the organic compounds discussed in this section are reported for the FREMP Oak Street Bridge site and the three sloughs monitored by FREMP.

6.4.1.7.1 Chlorophenolics

Chlorophenol bioavailability is heavily influenced by salinity. Some water quality criteria have been developed for estuarine conditions, however, the development is not comprehensive. Where water quality criteria have not been confidently defined, interim criteria may be expressed. The median concentration of 4-monochlorophenol measured at the six sites was generally less than 0.1 µg/L, though the single value reported for Site E207403 was 0.1 µg/L. The maximum reported concentration was 0.4 µg/L at Site E207397. This value is less than the interim water quality criterion for aquatic life of 0.7 µg/L to prevent toxicity. For this reason, 4-monochlorophenol concentrations do not appear to be of concern.

All measured concentrations of 3-monochlorophenol were less than minimum detection limits of 0.1 µg/L, well below the interim water quality criterion for aquatic life of 0.5 µg/L to prevent toxicity. Therefore, 3-monochlorophenol concentrations are not a concern in the North Arm.

Concentrations of tetra- and trichlorophenols were usually below the detection limit of 0.001 µg/L, and maximum concentrations measured at the FREMP Oak Street Bridge site were well below the water quality criteria for the protection of aquatic life from toxicity (Warrington, 1993). This was also the case for the majority of compounds measured in the three sloughs. However, the concentration of both 2,3,4,6- and 2,3,5,6-tetrachlorophenol in one of the samples taken from Eburne Slough was 2.1 µg/L, well above the water quality criteria for the protection of aquatic life for these compounds. The criterion for 2,3,4,6-tetrachlorophenol at a pH ≥7.1 is 0.30 µg/L, and for 2,3,5,6-tetrachlorophenol at a pH between 7.1 and 8.1 is 0.10 µg/L. Therefore, these compounds may be of concern in Eburne Slough, and Water Quality Objectives are proposed for the protection of aquatic life. The objective for 2,3,4,6-tetrachlorophenol is that concentrations of 2,3,4,6-tetrachlorophenol should not exceed 0.04 µg/L when pH values are <7.1 and should not exceed 0.30 µg/L when pH values are ≥7.1. The objective for 2,3,5,6-tetrachlorophenol is that concentrations should not exceed 0.02 µg/L at a pH <7.1, 0.10 µg/L at a pH of 7.1-8.1, and 0.25 µg/L when the pH is >8.1. These Objectives apply outside of initial dilution zones as described in Section 1.0.

Pentachlorophenols were measured at six of the provincial monitoring sites (E206396, E207397, E207399, E207401, E207403 and E207600). Median values for PCPs at these sites ranged from <0.1 to 0.1 µg/L, with a maximum recorded value of 0.3 µg/L. The median concentration of PCPs at the FREMP Oak Street Bridge site was less than the detection limit of 0.001 µg/L, with a maximum value of 0.013 µg/L. The interim toxicity water quality criterion for PCPs for aquatic life is 0.1 µg/L at a pH between 6.9 and 7.9; this value was exceeded by two of the 43 measurements taken.

A study conducted in 1984 on sources of chlorophenols in the North Arm indicated that "2,4,-dichlorophenol, 2,3,5- and 2,4,6-trichlorophenol...likely entered the estuary from upstream sources whereas the source of 2,3,4,6-tetrachlorophenol and pentachlorophenol was likely lumber mills within the estuary" (Carey *et al.*, 1988). Monitoring conducted as part of a similar study in 1986 supports this statement (Carey and Hart, 1988). As pentachlorophenol is highly toxic and the most persistent chlorophenol in the environment (Swain and Holms, 1985b), a Water Quality Objective is proposed for this compound. The Objective is that the concentration of 2,3,4,5,6-pentachlorophenol should not exceed 0.10 µg/L at a pH of 6.9-7.9. When the pH is less than 6.9, concentrations of pentachlorophenol should not exceed 0.02 µg/L. This objective applies outside of initial dilution zones only, as described in Section 1.0.

The median concentrations for all guaiacols and catechols were below the detectable limits of 0.002 µg/L at the Oak Street Bridge site. The compounds present in highest concentrations were 4,5-dichloroguaiacol (0.018 µg/L in Tree Island Slough, 0.014 µg/L at the Oak Street Bridge), and 3,4,5-trichlorocatechol (0.012 µg/L at the Oak Street Bridge). No water quality criteria exist for these compounds. As such, it cannot be concluded at this time whether any water uses are not protected.

The median concentration of 3,4,5-trichloroveratrole was < 0.002 µg/L; the maximum concentration was 0.004 µg/L at the Oak Street Bridge site. Similarly, median concentrations of 5,6-dichlorovanillin, 6-chlorovanillin, and nonylphenol at the Oak Street Bridge were below their detection limits of 0.002 µg/L, with maximum concentrations for each compound being 0.003 µg/L, 0.012 µg/L and 0.003 µg/L respectively. As was the case for catechols and guaiacols, there are no water quality criteria for these compound and the potential concern at these concentrations cannot be evaluated.

6.4.1.7.2 Resins and Fatty Acids

The median concentration of linoleic acid at the Oak Street Bridge site was < 0.5 µg/L; the maximum concentration was 1 µg/L. Linoleic acid was also present in measurable amounts in Eburne Slough, with a maximum concentration of 0.8 µg/L. Myristic, palmitric and stearic acids were present in measurable amounts in each of the three sloughs, with maximum concentrations of 0.7 µg/L (in all sloughs), 1.6 µg/L (in Tree Island Slough) and 1.7 µg/L (also in Tree Island Slough), respectively. Oleic acid was present in measurable amounts in both Eburne and Tree Island sloughs (maximum concentration 1.2 µg/L in Eburne Slough). No water quality criteria have been set for any of these acids; therefore, evaluation of the possible effects of these concentrations is not possible at the present time.

Concentrations of dehydroabietic acid were below detection limits (0.5 µg/L) at all sites, and well below the water quality criterion of 8 µg/L for this compound when pH > 7. The greatest concentration of total resin and fatty acids was 12.6 µg/L at the Eburne

Slough site, which is about one-half the criterion for total resin acids with a pH > 7 of 25 µg/L. Therefore, the total concentration at all sites were below this criterion.

The median concentration of the anti-sapstain compound TCMTB was less than the detection limit of 0.005 mg/L, while the maximum concentration was 0.007 mg/L at the Oak Street Bridge site. The concentration of this compound was below the detection limits (0.005 mg/L) in all samples taken from the three sloughs. No water quality criterion exists for this compound, but the most sensitive 96 hour LC50 was 15 µg/L for Chinook salmon (Hanssen *et al*., 1991) and values are well below this threshold so it does not appear that TCMTB is of concern in the North Arm.

6.4.1.7.3 Organochlorine Pesticides and PCBs

The concentration of DDD pp' was usually less than 0.005 µg/L (with a maximum concentration of 0.011 µg/L) at the Oak Street Bridge site and was not measured in any of the sloughs. No criterion exists for this compound.

The median concentration of hexachlorobenzene was less than 0.0005 µg/L at the Oak Street Bridge site, and the maximum concentration was 0.001µg/L (at the Oak Street Bridge site and in McDonald Slough). These concentrations are below the Canadian Water Quality Guideline of 0.0065 µg/L for the protection of freshwater aquatic life (CCREM, 1987).

6.4.1.7.4 Polyaromatic Hydrocarbons (PAHs)

Polyaromatic hydrocarbons can enter the North Arm through stormwater runoff. These were tested only in the three sloughs. Nine of the 22 hydrocarbons tested were present in measurable amounts in at least one of the sloughs. Benz(a)anthracene was present in all three sloughs, with a maximum concentration of 0.03 µg/L in both McDonald and Tree Island sloughs, well below the water quality criterion of 0.1 µg/L to prevent both chronic and photo-toxic effects on freshwater aquatic life (Nagpal, 1993 (b)). No criteria were recommended for the protection of marine aquatic life due to insufficient data.

Chrysene was measured at both Eburne and Tree Island sloughs with a maximum concentration at the detection limit of 0.01 µg/L. This is below the marine criteria for the protection of aquatic life. No water quality criterion has yet been recommended for the protection of freshwater aquatic life from chrysene due to insufficient data (Nagpal, 1993 (b)).

Benz(b+k)fluoranthene was present at the detection limit of 0.01 µg/L in two of four samples taken at Tree Island Slough. No water quality criterion has been set for this compound.

Pyrene was present in measurable amounts in each of the three sloughs. The maximum concentration was 0.03 µg/L in Tree Island Slough and 0.02 µg/L in Eburne Slough. The water quality criterion for pyrene is a maximum concentration of 0.02 µg/L for the protection of freshwater aquatic life from photo-toxic effects, so concentrations in both Tree Island Slough and Eburne Slough may be of concern to aquatic life. Therefore, a Water Quality Objective is proposed for pyrene. This objective is that the concentration of pyrene in any discrete sample should not exceed 0.02 µg/g outside of initial dilution zones as described in Section 1.0.

Acenaphthene was present in measurable amounts in each of the three sloughs with a maximum concentration of 0.03 µg/L in both Eburne and Tree Island sloughs. The B.C. water quality criterion for acenaphthene is a maximum concentration of 6 µg/L for the protection of marine and freshwater aquatic life from chronic effects; apparently, all measured concentrations were well below the criterion. The maximum concentration is also below the Canadian Interim Guideline of 1.4 µg/L for the protection of freshwater aquatic life.

Fluoranthene was present in measurable amounts in each of the three sloughs. The maximum concentration was 0.03 µg/L in Eburne Slough. The water quality criterion for fluoranthene is a maximum concentration of 0.2 µg/L for the protection of marine and freshwater aquatic life, so all measurements were well below the criterion.

Naphthalene was present in measurable amounts in all three of the sloughs with a maximum concentration of 0.14 µg/L in both Eburne and Tree Island sloughs. This value is well below the water quality criterion of 1 µg/L for the protection of marine and freshwater aquatic life.

Phenanthrene was present in measurable amounts in all three of the sloughs with a maximum concentration of 0.1 µg/L in Eburne Slough, thereby meeting the water quality criterion concentration of 0.3 µg/L for the protection of freshwater aquatic life from chronic effects of phenanthrene.

The remainder of the organic compounds measured at the FREMP Oak Street Bridge Site were below minimum detectable limits and criteria for all samples taken.

In summary, all PAHs were within criteria except for pyrene, which was present in amounts which met or exceeded the water quality criterion at both Tree Island and Eburne Sloughs.

6.4.2 Sediment Chemistry

The North and Middle Arms of the Fraser River are impacted by tidal action and salinity intrusions between September and April when river discharges are moderate to low (Carey, 1990) During this period, tidal activity and salt wedge position play important roles in the deposition and re-suspension of sediment which in turn, have implications for the uptake, accumulation, and distribution of contaminants in the estuary.

Correspondingly, these factors influence the bioavailability, effects, and fate of contaminants.

Most of the sediment chemistry data discussed in this section have previously been reported in various Fraser River Estuary Monitoring documents (Swain and Walton, 1988; Swain and Walton, 1990; Swain and Walton, 1991; Swain and Walton, 1993a). Most of the sediment monitoring conducted in the North Arm between 1987 and 1992 took place at two provincial monitoring sites: Sites NA-1 and NA-2. Site NA-1 is located in the Upper North Arm along the south shore opposite Crown Packaging and NA-2 is located at McDonald Slough. Other sites used for individual monitoring programs are described in the following section. Along with site descriptions, the particle size distribution of the sediments collected at each site is also discussed for each site and each year.

In 1987, metal concentrations were measured at the two provincial sites (NA-1 and NA-2, Figure 10) as part of a benthos and sediment monitoring program (Swain and Walton, 1988). The sediment composition at Site NA-1 was 60.5% silt and clay and 39.5% sand and at Site NA-2, there was 54.1% silt and clay and 45.7% sand.

In 1989, samples were also collected at Sites NA-1 and NA-2 (Swain and Walton, 1990). At Site NA-1, a mean of 91.6% of the sediment was composed of silt and clay, and 6.4% sand. Sediments at Site NA-2 had a mean of 99.7% silt and clay and 0.2% sand. The definition of particle sizes for clay, silt and sand was slightly different in 1989. For this year, particles <0.074 mm in diameter were designated silt and clay, and particles <3.00 mm and ≥ 0.074 mm in diameter designated sand. Therefore this category might appear artificially inflated compared to other years.

In 1990, sediment data were collected at Site NA-1 in an examination of sediment chemistry and toxicity (Swain and Walton, 1991). A mean of 94.2% of the sediment at this site was silt and clay, and 5.8% sand. In this study, analysis of metal and organics concentrations in each fraction (silt and clay particles and sand particles) as well as in a complete sample were conducted.

The 1991 monitoring program consisted of the analysis and discussion of sediment samples collected from four sites near the outfall from Crown Packaging (Swain and Walton, 1992). The composition of sediments collected at these sites ranged from 52 to 92.6% silt and clay, and from 7.4 to 48% sand.

Finally, the 1992 monitoring program had data collected from a number of sites in the North Arm. These data are divided into four sections, based on the types of sites monitored. The first section deals with ambient sediment samples collected from Sites NA-1 and NA-2. These samples are not associated with any specific discharge. The mean composition of sediments by particle size at Site NA-1 was 97.0% silt and clay, and 3.0% sand. At Site NA-2, a mean of 76.4% of the sediment was silt and clay and 23.6% was sand.

The second section deals with samples taken from areas associated with specific discharges. Two samples each were taken from near Scott Paper, Crown Packaging and the Celtic Boat Yard, and one sample taken from near the McDonald Beach Boat Launch, for a total of seven samples from these four areas. The first site near Scott Paper had a sediment composition of 77% silt and clay and 23% sand. The second site near Scott Paper had a composition of 53% silt and clay and 47% sand. The two samples near Crown Packaging had a composition of 62.2% and 42.8% sand and 38.8% and 57.2% silt and clay, respectively. The sediment collected at the North Arm Boat Launch was 87.4% silt and clay and 12.6% sand. The two sites near Celtic Boat Yard had sediment compositions of 92.3 and 99.3% silt and clay, and 7.7 and 0.7% sand, respectively. Therefore, in general, concentrations of contaminants would be expected to increase in a downstream direction as particle sizes decrease.

The third section discusses data collected from a site in the Middle Arm near the airport (Figure 10). Sediments at the Middle Arm site were composed of 81.7% silt and clay and 18.3% sand.

The final section discusses sediment samples collected in Eburne Slough. Three samples were taken near this slough, with percent compositions of the slough 99.4% silt and clay and 0.6% sand at the first site, 98.8% silt and clay and 1.2% sand at the second site, and 94.4% silt and clay and 5.6% sand at the third site. The data discussed in this report for sediment quality in 1992 are presented and results discussed in Swain and Walton (1993).

In general, there was a strong correlation between particle size and relative concentrations of metals in sediments (Figures 13, 14). Therefore, changes in contaminant concentrations between years at the same site may be attributable to relative sediment sizes more than actual changes in metals present. Sediment Quality Criteria cited for significant concentrations of metals were determined using the Screening Level Concentrations (SLC) approach unless otherwise stated.

6.4.2.1 Metals

Arsenic

The detection limits used to measure arsenic concentrations in 1987 and 1992 (30 µg/g and 25 µg/g, respectively) were much lower than the marine sediment quality criterion for arsenic of 33 µg/g for low range effects based on the National Status and Trends Program Approach when river discharges were moderate to low. All samples collected in 1987 and 1992 were below the detection limits of 30 µg/g and 25 µg/g, respectively. Therefore, it can be concluded that concentrations were below the marine criterion set for low range effects.

The mean arsenic concentrations measured in 1989 at Site NA-1 (7.14 µg/g) and Site NA-2 (9.4 µg/g) exceeded the marine Sediment Quality Criterion of 33 µg/g for the protection of aquatic life from low range effects (Jaagumagi, 1992a).

The mean concentrations of arsenic in all sediment fractions collected at Site NA-1 in 1990 were below the low range effects level of 33 µg/g, with the highest mean value being 7.33 µg/g. The mean concentrations measured in 1990 show an increase from those measured in 1989, but the maximum value was considerably lower. This increase may be due in part to the decrease in particle size between 1989 and 1990 at Site NA-1.

In 1991, Swain and Walton found that all four samples taken near Crown Packaging contained arsenic concentrations below the low effects range criterion of 33 µg/g for marine environments. Because all samples had arsenic concentrations below the marine criterion for low range effects, no water quality objective is proposed for this reach of the Fraser River.

Chromium

Mean concentrations of chromium at both North Arm sites in all the years samples were collected exceeded the lowest-effects level Sediment Quality Criterion of 26 µg/g for freshwater when river discharges are high and below the low range effects level for marine environments when river discharges are moderate to low (Jaagumagi, 1992a). Concentrations in 1987 were higher in the lower North Arm (Site NA-2), with a mean of 29.7 µg/g and a maximum of 45 µg/g, than in the upper North Arm (Site NA-1), where the mean was 26.9 µg/g and the maximum concentration 28.0 µg/g. These values were above the B.C. criterion of 37.3 µg/g for freshwater sediment quality guideline (TEL) but all values were below the low range effects criterion (80 µg/g) for marine environments (Nagpal, 1994).

In 1989, the mean value was 59.5 µg/g and the maximum value was 60.6 µg/g at Site NA-2, while the mean concentration at Site NA-1 was 53.6 µg/g and the maximum value, 55.9 µg/g. These values are also above the lowest effects level criterion for freshwater environments but below the low range effects criterion for marine environments. Concentrations increased considerably from those measured at these sites in 1987. This increase may be due in part to the decrease in particle size.

Samples taken at Site NA-1 in 1990 had a mean concentration of 59.8 µg/g and a maximum value of 65.1 µg/g. Again, these values are above the lowest effects level criterion for freshwater but below the low range effects criterion for marine environments. Furthermore, sample measurements show an increase over concentrations measured in 1987 and 1989. Some of this increase in concentration may be due to the decrease in particle size at this site from 1987.

In 1992, the mean and maximum concentrations were highest upstream at NA-1, with a mean concentration of 65.4 µg/g and a maximum concentration was 70.8 µg/g. The mean concentration at Site NA-2 was 62.66 µg/g and the maximum concentration was 65.7 µg/g. As in the past, all values are above the lowest effects level criterion for freshwater but below the low range effects criteria for salt water environments and concentrations at both sites increased over previous years.

Chromium concentrations in all four samples taken in 1991 near Crown Packaging exceeded the B.C. lowest-effects level Sediment Quality Criterion of 26 µg/g (Jaagumagi, 1992a) but met the B.C. low range effects criterion for marine aquatic life.

Concentrations of chromium exceeded the lowest-effects freshwater Sediment Quality Criterion of 26 µg/g in all four of the areas monitored in 1992 that were associated with discharges (Scott Paper, Crown Packaging, McDonald Beach Boat Launch, and Celtic Boat Yard), with mean values ranging from 51.3 µg/g to 66.1 µg/g.

The maximum value occurred near the Celtic Boat Yard. These mean values met the low range effects criterion of 80µg/g based on the NSTPA.

When river discharges are moderate to low, tidal action and salinity intrusions extend up the North and Middle Arms, rendering the sediment pore waters saline. Although the freshwater criterion has been exceeded at all sites, the marine criterion, which is more appropriate during low flow conditions, is met. As such, chromium concentrations are currently not of concern. However, of significance is the temporal increase in chromium concentrations in the North Arm. Chromium levels in the North Arm should be monitored closely for possible exceedances in the future. Furthermore, reasons for the continuous increase in concentrations should be investigated.

Copper

The mean concentration of copper for each site exceeded the freshwater lowest-effects Sediment Quality Criterion of 16 µg/g but met the marine low range effects criterion for the five years that monitoring occurred. All values were below the severe-effects level of 110 µg/g (Jaagumagi, 1992a). A majority of the values were above the Canadian draft interim TEL of 35.7 µg/g but below the PEL of 197 µg/g (Environment Canada, 1995).

The mean concentration of copper in 1987 was 27.5 µg/g at Site NA-1 and 26.0 µg/g at Site NA-2, with maximum concentrations of 32 µg/g at Site NA-1 and 40.0 µg/g at Site NA-2 (Swain and Walton, 1988).

In 1989, concentrations of copper were higher downstream at Site NA-2, with a mean value of 56.8 µg/g and a maximum concentration of 58 µg/g than at Site NA-1, where the mean was 42.0 µg/g and the maximum value was 43.9 µg/g. These values were considerably higher than those measured at the same sites in 1987, although this may be due in part to decreased particle size in the sediments.

At Site NA-1 in 1990, the mean concentration was 45.8 µg/g and the maximum concentration was 47.8 µg/g. These concentrations are slightly higher than those measured at this site in 1989.

In 1991, the four samples collected near Crown Packaging had a maximum concentration of 48.0 µg/g which exceeds the freshwater criterion for low level effects but meets the marine criterion for low-range effects.

In 1992, concentrations were higher upstream at Site NA-1, with a mean concentration of 48.56 µg/g and a maximum concentration of 49.6 µg/g. There was a slight increase in concentration at this site from 1990. The mean concentration at Site NA-2 was 43.14 µg/g, with a maximum concentration of 45.3 µg/g. These values show a decrease from those measured at this site in 1989.

All concentrations of copper measured in the four areas monitored in 1992 associated with discharges (Scott Paper, Crown Packaging, McDonald Beach Boat Launch, and Celtic Boat Yard) exceeded the lowest-effects Sediment Quality Criterion of but met the marine low level effects range, with values ranging from 27 µg/g to 53.8 µg/g. Some values were above the Canadian draft interim TEL of 35.7 µg/g (Environment Canada, 1995). The highest concentrations occurred near the Celtic Boat Yard. Values were well below the severe-effects level of 110 µg/g. In general, concentrations increased in a downstream direction from Scott Paper to the Celtic Boat Yard. This increase is expected on the basis of the decreased particle size in a downstream direction.

Iron

The mean concentration of iron exceeded the lowest-effects criterion of 21 200 µg/g at all sites during the five years of monitoring. No marine criterion has been established at this time. The severe-effects level of 43 766 µg/g (Jaagumagi, 1992a) was never exceeded, although concentrations approached this criterion at Site NA-1 in 1990 and 1992, and at Site NA-2 in 1989 and 1992.

In samples collected in 1987 from Site NA-1, the mean concentration of iron was 22 340 µg/g, with a maximum concentration of 25 300 µg/g. The mean concentration at Site NA-2 was slightly lower, at 21 710 µg/g, but the maximum concentration was higher than that measured at Site NA-1, with a value of 28 300 µg/g.

Mean concentrations of iron were almost identical at the two sites (39 780 µg/g at Site NA-1 and 39 740 µg/g at Site NA-2) in 1989, with a maximum concentration of 41 800 µg/g at Site NA-1 and 42 400 µg/g at NA-2. The 1989 iron concentrations are much higher than those measured during the 1987 monitoring program.

Iron concentrations measured at Site NA-1 in 1990 had a mean concentration of 41 100 µg/g in the total sample. This mean value is slightly higher than that measured at this site in 1989. The maximum concentration (43 000 µg/g in the total sample) approached the severe-effects level of 43 766 µg/g (Jaagumagi, 1992a).

In 1992, the mean concentration at NA-1 was 41 900 µg/g (maximum concentration of 43 700 µg/g), virtually identical to those measured at this site in 1990. The concentration of iron at NA-2 was slightly lower than that measured at Site NA-1, with a mean concentration of 38 100 µg/g and a maximum concentration of 39 300 µg/g.

The concentration of iron in sediments measured in 1991 at all four sampling sites near Crown Packaging exceeded the lowest-effects level Sediment Quality Criterion of 21 600 µg/g (Jaagumagi, 1992a) in 1991, although the maximum concentration of 36 400 µg/g was below the severe-effects level of 43 766 µg/g (Jaagumagi, 1992a).

In 1992, all samples collected at the four areas associated with discharges (Scott Paper, Crown Packaging, McDonald Beach Boat Launch, and Celtic Boat Yard) contained iron concentrations exceeding the lowest-effects Sediment Quality Criterion of 21 200 µg/g, with values ranging from 28 200 µg/g to 42 800 µg/g. Concentrations generally increased downstream, with the highest concentration occurring near the Celtic Boat Yard. The maximum value measured at the Celtic Boat Yard (42 800 µg/g) approached the severe-effects level of 43 766 µg/g for iron.

The temporal and spatial increases in iron concentrations should be monitored and their causes investigated. Furthermore, marine criteria should be researched and established.

Lead

Concentrations of lead in individual sediment samples collected between replicate sites in the North Arm in 1987 ranged from less than detection limits (<10 µg/g) to 30 µg/g dry-weight (Swain and Walton, 1988) at both NA-1 and NA-2. The highest concentrations were just below the B.C. lowest-effects level threshold of 31 µg/g (Jaagumagi, 1992a) as well as the EPA interim criterion for marine sediment at 1% organic carbon, and were higher than those in either the Main Arm or Main Stem for that year. These values were comparable to the range of 20 to 25 µg/g dry-weight reported in 1985 (Swain, 1986c). High values were probably due to the large number of stormwater outfalls to the North Arm, as Swain (1983) found that lead concentrations in sediments associated with stormwater were 180 µg/g dry-weight.

In 1989, lead concentrations ranged from 13.8 to 19.1 µg/g at NA-1 and from 21.3 to 24.0 µg/g at NA-2. Higher concentrations at NA-2 may have been due to the smaller particle size at this site. All values were below the EPA marine interim criterion and were generally lower than those measured in 1987.

The maximum concentration measured in a total sediment sample from NA-1 in 1990 was 15.0 µg/g.

Maximum concentrations of lead measured in the North Arm in 1992 were 11.3 µg/g at NA-1 and 10.9 µg/g at NA-2. These values show a decrease from previous years. Lead concentrations measured near Scott Paper, Crown Packaging, the Celtic Boat Yard and the North Arm Boat Launch ranged from 11.3 to 17.4 µg/g. Concentrations measured at three sites in Eburne Slough were also within this range.

Lead concentrations in sediments in the North Arm decreased each year since 1987, and concentrations at all times have been less than the lowest-effects threshold. The decrease is probably due to the phasing out of leaded gasoline, and should therefore continue. Thus, it does not appear that lead concentrations in sediments are a concern in the North Arm, and no objective is proposed.

Manganese

The mean concentration of manganese in 1987 was below the lowest-effects freshwater Sediment Quality Criterion of 460 µg/g (Jaagumagi, 1992a) at both sites on the North Arm (441.5 µg/g at Site NA-1 and 325.1 µg/g at NA-2). However, the maximum concentration of 503 µg/g measured at NA-1 exceeded the lowest-effects criterion. No marine sediment quality criteria have yet been established.

The mean concentration of manganese in 1989 was 595.2 µg/g at Site NA-1, with a maximum concentration of 666 µg/g. The concentration downstream at NA-2 was slightly lower, with a mean concentration of 553 µg/g and a maximum concentration of 571 µg/g. All values were above the lowest-effects Sediment Quality Criterion and concentrations were higher than those measured in 1987.

In 1990, concentrations of manganese in all of the sample fractions at Site NA-1 exceeded the lowest-effects level of 460 µg/g (Jaagumagi, 1992a), with a mean of 1 003 µg/g and a maximum of 1 090 µg/g in the complete sample. The maximum concentration approached the severe-effects level of 1 100 µg/g (Jaagumagi, 1992a). These concentrations are considerably higher than those measured in 1989.

The mean concentration of manganese measured at Site NA-1 in 1992 was 779.8 µg/g, with a maximum concentration of 802 µg/g. These values are lower than those measured at this site in 1990. Concentrations were lower downstream at Site NA-2 than at NA-1, with a mean concentration of 482.8 µg/g and a maximum concentration of 494 µg/g. Again, these values are lower than those measured at this site in 1989.

In 1991, concentrations of manganese exceeded the lowest-effects level at all four sites near Crown Packaging; the maximum concentration of manganese was 750 µg/g.

In 1992, concentrations of manganese exceeded the lowest-effects Sediment Quality Criterion of 460 µg/g in all four of the areas associated with discharges (Scott Paper, Crown Packaging, McDonald Beach Boat Launch, and Celtic Boat Yard), with values ranging from 475 µg/g to 631 µg/g. The highest concentration occurred near Crown Packaging. No downstream trend was evident in the sediment concentrations of manganese. All values were well below the severe-effects level of 1 100 µg/g for manganese.

Freshwater sediment quality criteria based on the lowest effects level were often exceeded while criteria based on severe effects were usually met. Marine sediment quality have yet to be developed and temporal and spatial trends in manganese concentrations should be monitored.

Nickel

The concentration of nickel in all sediment samples taken at both NA-1 and NA-2 in all years exceeded the B.C. lowest-effects freshwater Sediment Quality Criterion of 16 µg/g as well as the marine sediment quality criterion of 30 µg/g based on the lowest effects range.

In 1987, the mean concentration of nickel at Site NA-1 was 35.9 µg/g, with a maximum concentration of 38 µg/g, at Site NA-2, the mean was 36 µg/g, with a maximum value of 44 µg/g.

The mean concentration at Site NA-1 was 51.4 µg/g in 1989, with a maximum concentration of 55 µg/g. The concentration of nickel at Site NA-2 was very similar, with a mean of 53.3 µg/g and a maximum concentration of 55.2 µg/g. These concentrations were considerably higher than those measured in 1987.

In 1990, the mean concentration at Site NA-1 was 57.8 µg/g, with a maximum concentration of 60.7 µg/g in the complete sample. These values show a further increase from concentrations measured at this site in 1989.

The mean concentration of nickel measured at Site NA-1 in 1992 was 67.3 µg/g, with a maximum concentration of 68.3 µg/g. Concentrations were lower downstream at Site NA-2, with a mean concentration of 57.2 µg/g and a maximum concentration of 60 µg/g. Concentrations at both sites were higher than in previous years.

In 1991, concentrations of nickel in the sediment samples collected near Crown Packaging exceeded the lowest-effects level of 16 µg/g (Jaagumagi, 1992a) by 4-times and doubled the marine low effects level of 30 µg/g in all four samples in 1991, with a maximum concentration of 64.7 µg/g.

In 1992, the concentration of nickel in the four sample areas associated with discharges (Scott Paper, Crown Packaging, McDonald Beach Boat Launch, and Celtic Boat Yard) ranged from 45.6 to 60.2 µg/g, again, well above the lowest-effects freshwater criterion of 16 µg/g and the marine criterion of 30 µg/g. No downstream trend in concentrations was evident.

It is apparent that the less stringent but more appropriate marine sediment quality criterion of 30 µg/g nickel is constantly exceeded. Furthermore, the concentrations of nickel at each site are increasing with time. This is to indicate that the aquatic life in this reach of the Fraser River are not adequately protected from the effects of nickel exposure and uptake. As such, <u>a maximum Water Quality Objective of 30 µg/g nickel is proposed for the North and Middle Arms of the Fraser River.</u>

Zinc

The mean concentrations of zinc at Sites NA-1 (69.7 µg/g) and NA-2 (76.4 µg/g) were below the freshwater sediment criterion set for the lowest effects threshold and the marine criterion based on the lowest effects range, of 120 µg/g (Jaagumagi, 1992a) in 1987. However, the maximum concentration of 143 µg/g at Site NA-2 exceeded this value.

Zinc concentrations in the 10 samples taken at the Sites NA-1 and NA-2 were higher than the freshwater and marine criterion (Jaagumagi, 1992a) in 1989, with a mean concentration of 200 µg/g at NA-1 and 136.8 µg/g at NA-2. The maximum concentration of 220 µg/g (at Site NA-1) was below the Canadian draft interim PEL of 315 µg/g (Environment Canada, 1995) and the B.C. severe-effects threshold of 820 µg/g (Jaagumagi, 1992a). Concentrations at both sites were considerably higher than those measured at the same sites in 1987.

All samples taken at NA-1 in 1990 had zinc concentrations equal to or below the lowest-effects criterion of 120 µg/g (Jaagumagi, 1992a); the maximum concentration (occurring in the complete sample) equaled this threshold. Concentrations were lower than those measured at this site in 1989.

In 1992, the mean concentration of zinc at Site NA-1 (131.2 µg/g) exceeded the lowest-effects level Sediment Quality Criterion for zinc of 120 µg/g (Jaagumagi, 1992a), with a maximum concentration of 134 µg/g. Concentrations were much lower downstream at Site NA-2, where the maximum value of 108 µg/g fell below the criterion.

The concentrations of zinc (25.9 to 32 µg/g) in all samples taken near Crown Packaging in 1992 were below the lowest-effects level Sediment Quality Criterion.

Three of seven samples measured at the four sites associated with discharges (Scott Paper, Crown Packaging, McDonald Beach Boat Launch, and Celtic Boat Yard) contained zinc concentrations above the lowest-effects level Sediment Quality Criterion of 120 µg/g; the maximum value measured was 136 µg/g near the Celtic Boat Yard. This value is well below the severe-effects level of 820 µg/g. Zinc concentrations generally increased in a downstream direction.

6.4.2.2 Organics

A total of seven sites (NA-1, NA-2, NA-3, NA-4, NA-5, NA-6, and NA-7) in the North Arm were monitored for PCBs and chlorophenols during the 1987 program.

Samples collected from Sites NA-1 and NA-2 as part of the 1989 monitoring program were tested for PCBs and chlorophenols, as well as a number of phthalate esters, polyaromatic hydrocarbons and organochlorine pesticides.

Site NA-1 was monitored in 1990 for chlorophenols, PCBs, PAHs, and organochlorine pesticides.

The monitoring program in 1991 tested samples from near Crown Packaging for PAHs, organochlorine and organophosphate pesticides, chlorinated phenols and PCBs, resin acids and monocyclic aromatic hydrocarbons.

Samples taken in 1992 were tested for concentrations of halogenated and non-halogenated volatiles, PAHs, chlorinated phenols, PCBs, organochlorine and organophosphate pesticides, and resins and fatty acids.

6.4.2.2.1 Polycyclic Aromatic Hydrocarbons (PAHs)

One of the potential sources of PAHs to the estuarine environment are creosote-treated pilings common in the Lower Fraser River. Naphthalene and phenanthrene are two of the major constituents of creosote, and both are capable of migrating into the water column (Ingram, 1982). These compounds can then be deposited to the sediments.

Acenaphthylene

The maximum concentration of acenaphthylene measured at Site NA-2 in 1989 was 0.053 µg/g, thereby exceeding the freshwater no-effects threshold of 0.01 µg/g based on the Background Approach (Environment Canada and Ministry of the Environment of Quebec, 1992) and meeting the more appropriate 0.66 µg/g marine criterion for no adverse effects on biota (Nagpal, 1994). Acenaphthylene concentrations were below the criteria in the remainder of the years when it was analyzed.

The concentration of acenaphthylene at one of the three sites in Eburne Slough in 1992 barely exceeded the freshwater no-effects criterion and met the marine no adverse effects criterion, with a concentration of 0.011 µg/g.

These occasional excursions over the criterion may be of concern to freshwater aquatic life. Therefore, <u>a Sediment Quality Objective is proposed for acenaphthylene</u>

when sediment pore waters are non-saline: during the high river flow months between May and August, the concentration of acenaphthylene in any discrete sample should not exceed 0.01 µg/g. Between September and April, when sediment conditions are saline, higher levels of acenaphthylene in sediment are tolerable: during these low flow months, the concentration of acenaphthylene should not exceed 0.66 µg/g. These Sediment Quality Objectives apply to all sediment outside of the initial dilution zones described in Section 1.0 and are based on an organic carbon content of 1%.

Phenanthrene

The maximum concentration of phenanthrene at Site NA-1 in 1989 was 0.40 µg/g, considerably higher than the freshwater Sediment Quality Criterion of 0.04 µg/g (Nagpal, 1993 (b)) as well as the marine Sediment Quality Criterion of 0.0867 µg/g based on the low range effects threshold. However, the mean concentration (n=5 at each site) of this compound at both sites (<0.02 µg/g) and the maximum concentration at Site NA-2 (<0.02 µg/g) were well below the freshwater threshold.

The maximum (0.074 µg/g) and mean (0.053 µg/g) concentration of phenanthrene measured in 1990 at NA-1 exceeded the freshwater criterion but met the marine criterion (Nagpal, 1993(b)).

Phenanthrene was present in measurable amounts in two of the four samples taken near Crown Packaging in 1991. Both concentrations exceeded the freshwater sediment quality criterion for phenanthrene, with the maximum concentration being 0.22 µg/g.

The maximum concentration of phenanthrene at Site NA-1 in 1992 was 0.042 µg/g, barely exceeding the more stringent freshwater criterion. The mean concentration at this site fell below this threshold. The mean concentration of phenanthrene at Site NA-2 was 0.116 µg/g, with a maximum concentration of 0.17 µg/g; these values were much higher than the freshwater criterion but within the marine criterion, the usual situation at this site located at the downstream end of the North Arm and subject to virtually continuous salinity conditions in its bottom waters.

In 1992, concentrations of phenanthrene in sediment were also above the freshwater criterion for the protection of aquatic life at five of the seven sites associated with discharge. The maximum concentration of 0.18 µg/g was measured near Crown Packaging. Again, sites near Scott Paper had concentrations below the threshold. The maximum concentration of phenanthrene in Eburne Slough in 1992 was 0.26 µg/g, exceeding the sediment quality criterion for this compound.

As concentrations of phenanthrene continually exceed the sediment quality criterion, this compound may be a concern to aquatic life in the North Arm. Therefore, a Sediment Quality Objective is proposed for phenanthrene. For the protection of both freshwater and marine aquatic life, the long-term objective is that phenanthrene concentrations should not exceed 0.04 µg/g when sediment pore waters are non-saline: during the high river flow months between May and August in any discrete sample collected outside of initial dilution zones as described in Section 1.0 and are based on an organic carbon content of 1%. Between September and April, when sediment conditions are saline and during the short-term, higher levels of phenanthrene in sediment are tolerable: during these low flow months, the concentration of phenanthrene should not exceed 0.0867 µg/g (dry-weight).

Naphthalene

In 1992, mean concentrations of naphthalene exceeded both the freshwater and marine sediment quality criterion of 0.01 µg/g at both NA-1 (n=5) and NA-2 (n=5); the maximum concentration at Site NA-2 was 0.03 µg/g (Nagpal, 1993 (b)).

Two of the samples collected near Crown Packaging had measurable amounts of naphthalene; both exceeded the sediment quality criterion of 0.01 µg/g (Nagpal, 1993 (b)). The maximum concentration of naphthalene measured was 0.038 µg/g.

Concentrations of naphthalene exceeded the sediment criterion all sites in three of the four monitoring areas associated with discharges (Scott Paper, Crown Packaging, McDonald Beach Boat Launch, and Celtic Boat Yard); only those samples collected from the site near Scott Paper had concentrations below this level. The maximum concentration measured was 0.036 µg/g at one of the sites near Crown Packaging.

The maximum concentration of naphthalene measured in Eburne Slough was 0.035 µg/g, which is above the sediment quality criterion.

These excursions over the criterion suggest that naphthalene concentrations may be of concern. Therefore, a Sediment Quality Objective is proposed for naphthalene. The objective is that the concentration of naphthalene should not exceed 0.01 µg/g in any discrete sample collected outside of initial dilution zones as described in Section 1.0 and are based on an organic carbon content of 1%.

Other Hydrocarbons

The freshwater sediment quality criterion for anthracene is 0.6 µg/g (Nagpal, 1993 (b)); no marine sediment quality criteria have been developed. One of seven samples taken in the four monitoring areas associated with discharges (Scott Paper, Crown Packaging, McDonald Beach Boat Launch, and Celtic Boat Yard) exceeded the freshwater quality criterion. This sample (with a concentration of 0.68 µg/g) was taken at one of the two sites near Crown Packaging. Three of seven samples exceeded the Sediment Quality Criterion of 0.02 µg/g based on SBA (Environment Canada and Ministry of the Environment of Quebec, 1992). Since PAHs are present in North Arm sediments, a water quality objective for anthracene is proposed that the maximum anthracene concentration in sediments should not exceed 0.6 µg/g (dry-weight) based on an organic carbon content of 1%.

The concentration of benzo(a)pyrene at Site NA-1 was below the detection limits of 0.02 µg/g for this compound in all samples in 1992. The concentration at Site NA-2 was 0.065 µg/g with a maximum concentration of 0.11 µg/g, exceeding the no-effects threshold of 0.01 µg/g based on SBA (Environment Canada and Ministry of the Environment of Quebec, 1992) and the freshwater Sediment Quality Criterion of 0.06 µg/g (Nagpal, 1993 (b)). Therefore, a water quality objective is proposed for benzo (a) pyrene in sediments: a maximum concentration of 0.06 µg/g (dry-wt) based on an organic carbon content of 1%.

In 1992, the mean concentration of benzo(ghi)perylene at Site NA-2 exceeded the no effect threshold Sediment Quality Criterion of 0.1 µg/g based on SBA(Environment Canada and Ministry of the Environment of Quebec, 1992), and the maximum concentration at this site (0.21 µg/g) exceeded the lowest-effects level of 0.17 µg/g (Persaud *et al.*, 1992). Concentrations of benzo(ghi)perylene were generally below detection limits at Site NA-1.

The remainder of the hydrocarbons tested for at all sites were present in concentrations below detection limits and/or well below existing Sediment Quality Criteria. Based on an organic carbon content of 1%, these PAHs and respective proposed objectives are: acenaphthene, maximum of 0.15 µg/g (dry-weight); fluorene, maximum of 0.2 g/g (dry-weight); acridine, maximum of 1 µg/g (dry-weight); fluoranthene, maximum of 2 µg/g (dry-weight); chrysene, maximum of 0.2 µg/g (dry-weight); dibenzo (a,h) anthracene, maximum of 0.005 µg/g (dry-weight); and benzo (a) anthracene, maximum of 0.2 µg/g (dry-weight).

6.4.2.2.2 PCBs and Chlorophenols

In the North and Middle Arms, the extent of chlorophenol sorption to sediment is influenced by salt wedge position as dissociated forms predominate over undissociated forms in saline environments (Carey, 1990). The concentrations of all PCBs and chlorophenols at both Sites NA-1 and NA-2 were below detection limits for all the years in which they were tested.

In 1987, the majority of sediment samples from Sites NA-3, NA-4, NA-5, NA-6 and NA-7 had concentrations of PCBs below detection limits (<0.02 µg/g). However, the concentration of Aroclor 1254 at Site NA-5 was measurable at 0.10 µg/g. This exceeds the lowest-effects freshwater sediment quality criterion of 0.06 µg/g (Jaagumagi, 1992b). No marine criterion is available for comparison.

In 1992, no PCBs were present in measurable concentrations at any of the monitoring sites associated with discharges (Scott Paper, Crown Packaging, McDonald Beach Boat Launch, and Celtic Boat Yard). No PCBs were present in measurable amounts at the Middle Arm site. PCBs were not present in amounts above detection limits (0.01 µg/g) at all three sites in Eburne Slough. The approved criteria for total PCBs in both freshwater and marine sediments is 0.02 µg/g based on 1% organic carbon content (Nagpal 1992). Because PCBs have been detected in the past in the North Arm, a Sediment Quality Objective is proposed for the protection of aquatic life. The Objective is that based on a 1% content of organic carbon, the maximum concentration of total PCBs in sediment should not exceed 0.02 µg/g outside of initial dilution zones, as described in Section 1.0.

At the monitoring sites associated with discharges in 1992, three of the twelve chlorinated phenols tested were present in measurable concentrations. 3,4,5-Trichloroguaiacol was present in measurable amounts at five of the seven sites (one site near Scott Paper and one site near Crown Packaging had concentrations below measurable levels). Tetrachlorocatechol and 3,4,5-trichlorocatechol were present in measurable amounts at all seven of the sites, with maximum concentrations of 0.021 µg/g (near Scott Paper and Crown Packaging) and 0.043 µg/g (near Celtic Boat Yard). No criteria exist for these compounds at the present time.

The majority of phenols were not present in measurable amounts in the Middle Arm. Both 3,4,5-trichlorocatechol and tetrachlorocatechol were present, in concentrations of 0.015 µg/g and 0.01 µg/g respectively. No criteria exist for these compounds.

The majority of chlorinated phenols were not present above detection limits in Eburne Slough. Those that were present in measurable amounts at all three sites were 3,4,5-trichloroguaiacol (maximum concentration 0.003 µg/g), 3,4,5-trichlorocatechol (maximum 0.042 µg/g) and tetrachlorocatechol (maximum concentration of 0.021 µg/g). Tetrachloroguaiacol was present at the detection limit of 0.001 µg/g at one of the three sites.

Of the four guaiacols and catechols tested for in 1990 at Sites NA-1 and NA-2, only 2,4,5-trichloroguaiacol and tetrachloroguaiacol were present in measurable concentrations. The maximum concentrations measured for these compounds were 0.004 µg/g for 2,4,5-trichloroguaiacol and 0.003 µg/g for tetrachloroguaiacol, both measured from the complete sample. No Sediment Quality Criteria exist for these compounds.

Of the guaiacols and catechols tested for in 1992 at Sites NA-1 and NA-2, maximum concentrations occurred for tetrachlorocatechol (0.048 µg/g) and 3,4,5-trichlorocatechol (0.04 µg/g) at Site NA-2. No criteria have been set for these compounds.

PCP was present at the detection limit of 0.002 µg/g at Sites NA-5, NA-6 and NA-7 in 1987. The remaining sites (NA-3 and NA-4) had concentrations below this limit.

No criterion exists for this compound in sediments. Tetrachlorophenol was present at the detection limit of 0.002 µg/g at Sites NA-4, NA-6 and NA-7, and present at 0.003 µg/g at Site NA-5 in 1987. Concentrations at Site NA-3 were below the detection limit. No criterion exists for this compound in sediments. Since chlorophenols are likely of anthropogenic origins and are not generally measurable in uncontaminated areas, it is proposed that a Sediment Quality Objective originally proposed in 1985 of 0.01 µg/g (dry-weight) for the sum of mono-, di-, tri-, tetra-, and penta as an average of at least three discrete samples be maintained. This value is not likely to be exceeded in uncontaminated areas and as it is not presently met by sediments in the North Arm, it is reasonable to assume that there is some chlorophenol contamination.

6.4.2.2.3 Organochlorine Pesticides

Both DDD and DDE were present in measurable amounts at Site NA-1 in 1989. The maximum concentrations were 0.005 µg/g and 0.0006 µg/g, respectively. The mean values were at or below detection limits for both substances (0.001 µg/g and 0.0005 µg/g respectively). The maximum concentrations of DDD and DDT were above the marine sediment quality criterion of 0.002 µg/g based on the low-effects range according to the National Status and Trends Program Approach (NSTPA). The remaining 14 organochlorines were not detected. No Sediment Quality Criteria exist for these compounds.

All organochlorine pesticides were present in concentrations below varying detection limits for all sediment fractions at both sites in the remaining years that they were tested for. No Sediment Quality Criteria exist for the majority of these compounds. However, for endrin, both the freshwater no-effects level criterion of 0.0005 µg/g and the marine low-effects criterion of 0.00002 µg/g are equal to or exceed the detection limit of 0.0005 µg/g for samples collected in 1992. Similarly, the detection limit of heptachlor collected in 1989, 1990, and 1992 exceeded the marine criterion of 0.00004 µg/g and met the freshwater criterion of 0.0003 µg/g based of the background approach. Finally, the detection limit of heptachlor epoxide collected in 1989 and 1992 exceeded the freshwater lowest-effects criterion. As such, it is not possible to conclude whether these compounds are at concentrations endangering aquatic life in the sediments in the North and Middle Arms of the Fraser River.

All organophosphate pesticides were present in concentrations below detection limits in 1991 and 1992 (Swain and Walton, 1992). Further monitoring and research are required to determine the impacts of these compounds on the Fraser River sediments.

6.4.2.2.4 Phthalate Esters

Phthalate esters (dimethyl, diethyl, di-n-butyl, butyl benzyl, di-n-octyl, and bis(2-ethylyhexyl)) are ubiquitous in the environment, were only tested in 1989, and were present below detection limits (0.10 µg/g) for all but di-n-butyl and bis(2-ethylyhexyl). The maximum 0.47 µg/g di-n-butyl concentration at NA-2 and 0.71 µg/g bis(2-ethylyhexyl) concentration were below sediment quality criteria of 2.2 µg/g for no adverse effects and 0.78 µg/g for minor adverse effects, respectively.

6.4.2.2.5 Polychlorinated Dibenzodioxins and Dibenzofurans

A number of polychlorinated dibenzodioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) were measured as part of the 1990 monitoring program. A preliminary report on PCDDs uses the International Toxicity Equivalency Factor (ITEF) method to evaluate the toxicity of complex mixtures of PCDDs and PCDFs (CCME, 1995). These equivalency factors are based on the toxicity of each compound relative to the most toxic PCDD congener, 2,3,7,8-T_4CDD. The draft guideline for maximum concentrations of 2,3,7,8-T_4CDD in sediment is 0.25 pg/g for the protection of freshwater aquatic life (CCME, 1995). The maximum concentration of 2,3,7,8-T_4CDD measured in sediments at Site NA-1 was 1.9 pg/g dry-weight, well above the provisional guideline.

The sum of all maximum concentrations of PCDFs and PCDDs multiplied by their equivalency factors was 7.67 pg TEQ/g, 30 times the draft guideline.

Concentrations of PCDDs were generally measurable in the North Arm (though detection limits reported by the laboratory varied with each sample analyzed), while they were generally below detection in the Main Arm and Main Stem. This may be due in part to the smaller particle size of the sediments at the North Arm site relative to those in the Main Arm and Main Stem. In general, detection limits were an order of magnitude larger than the draft guideline, so sediments in those areas may also have exceeded guidelines. Concentrations of the majority of PCDFs were below detection limits in all reaches of the Fraser River.

Dioxins and furans were also analyzed in sediment samples taken from downstream from Scott Paper and Crown Packaging in 1989 (Tuominen and Sekela, 1992). Three samples were taken at various distances downstream from each site, and concentrations of silt and clay in the samples ranged from 37.0% to 67.6%. The PCDD/PCDF TEQs ranged from 0.386 pg TEQ/g to 21.4 pg TEQ/g with the higher values occurring at the sites downstream from Scott Paper, exceeding the draft guideline of 0.25 pg TEQ/g. There was no obvious relationship between sediment size and total TEQs at the various sites. No PCDDs or PCDFs were measured from samples taken at the same time from a site near Hope even though detection limits were generally high at this site (possibly due to sample matrix interference).

As dioxins and furans may be originating in effluents from the upstream pulp and paper mills, or possibly in effluent from STPs, combined sewer overflows, and urban runoff (Bertold, 1992), a Sediment Quality Objective is proposed for dioxins and furans in the North Arm. This objective is that the total TEQ of all PCDDs and PCDFs in any discrete sample also not exceed 0.25 pg/g. Both of these objectives apply only outside of initial dilution zones as described in Section 1.0.

6.4.2.2.6 Resin and Fatty Acids

Resin and fatty acids were included as part of the 1992 monitoring program. The majority of these compounds were present in amounts greater than detection limits (0.05 µg/g) at Sites NA-1 and NA-2. However, as no Sediment Quality Criteria exist for these compounds, it is not possible to state the significance of their concentrations. The compounds present in the highest concentrations at the ambient sites were dehydroabietic acid (2.49 µg/g), isopimaric acid (1.95 µg/g) and abietic acid (1.14 µg/g); all maxima were measured at Site NA-2.

In 1992, resin and fatty acids present in measurable amounts at the four sites associated with discharges in 1992 were: abietic acid (1.68 µg/g near Celtic Boat Yards), chlorodehydroabietic acid (0.303 µg/g near Celtic Boat Yards), dehydroabietic acid (1.75 µg/g near Celtic Boat Yards), dischlorodehydroabietic acid (0.418 µg/g near Scott Paper), isopimaric acid (1.13 µg/g near Crown Packaging), pimaric acid (0.55 µg/g near Celtic Boat Yards), and sandaracopimaric acid (0.702 µg/g near McDonald Boat Launch). Levopimaric and neoabietic acids were not present in measurable amounts at any of the seven sites.

Resin and fatty acids present in concentrations above detection limits in the Middle Arm and their maximum concentrations were: abietic acid (0.498 µg/g), chlorodehydroabietic acid (0.107 µg/g), dehydroabietic acid (0.839 µg/g), dischlorodehydroabietic acid (0.051 µg/g), isopimaric acid (0.315 µg/g), pimaric acid (0.108 µg/g), and sandaracopimaric acid (0.175 µg/g). Levopimaric and neoabietic acids were not present in measurable amounts at either site.

Resin and fatty acids appearing in measurable amounts in Eburne Slough and their maximum concentrations were: abietic acid (0.279 µg/g), chlorodehydroabietic acid (0.098 µg/g), dehydroabietic acid (0.476 µg/g), isopimaric acid (0.231 µg/g), pimaric acid (0.107 µg/g), and sandaracopimaric acid (0.088 µg/g). Levopimaric, dichlorodehydroabietic, and neoabietic acids were not present in measurable amounts at any of the sites.

6.4.2.2.7 Volatile Compounds

Volatile compounds (chlorobenzene; 1,2-dichlorobenzene; 1,3-dichlorobenzene; 1,4-dichlorobenzene; benzene; ethylbenzene; styrene; toluene; meta- and para-Xylene; and ortho-Xylene) were measured as part of the 1992 monitoring program. All halogenated (<0.001 µg/g) and non-halogenated volatiles benzene and ethyl benzene <0.005 µg/g; styrene < 0.001 µg/g; and meta- and para-Xylene; and ortho-Xylene < 0.010 µg/g) were not present in concentrations above detection limits at all sample sites, with the exception of toluene. Toluene was present in measurable amounts at both sites near Scott Paper and at both sites near Crown Packaging. The maximum concentration of this compound was 2.15 µg/g, at a site near Scott Paper. No sediment criterion exists for this compound.

6.4.2.3 Provincial Monitoring Sites

The following section summarizes data which consists of PCBs, PCPs, 3-monochlorophenol, and 4-monochlorophenol concentrations measured in sediments at six of the provincial monitoring sites (E207396, E207397, E207398, E207399, E207401, and E207600) between 1985 and 1995.

PCBs were not detected at any of the sites, where the minimum detection limit was 0.02 µg/g. This detection limit is equal to the water quality criterion for PCBs so these compounds are probably not a concern. The concentration of PCPs ranged from a median value of less than 0.005 µg/g to a mean of 0.038 µg/g with a maximum recorded value of 0.13 µg/g. No water quality criterion has been set for concentrations of PCPs in sediments.

Samples of 3-monochlorophenol had median concentrations less than detection limits of 0.005 µg/g and a maximum recorded concentration of 0.038 µg/g. Concentrations of 4-monochlorophenol ranged from a median value of less than detection limits (0.005 µg/g) to a mean value of 0.013 µg/g. No sediment quality criteria exist for these compounds.

6.4.3 Analysis of Benthic Invertebrates

As mentioned in Section 6.3.3, the leading tip of salinity intrusion extents past the upper limit of the North Arm of the Fraser River at the New Westminster trifurcation during the low flow months of February and March. With the greater density of marine waters, the salt wedge sweeps along the river bed and pushes upstream as overlying freshwater discharges into Sturgeon and Roberts Banks. Despite the diurnal variations in salinity of the water immediately above the sediment bed, interstitial salinities cycle only with seasonal changes in river flow (Chapman and Brinkhurst, 1979). As the transition zone between salt and fresh interstitial waters shifts upstream and downstream in relation to freshwater discharge, seasonal shifts in the distribution of benthic fauna are apparent (Chapman and Brinkhurst, 1979). The implications of such spatial and temporal trends are that the impacts of pollution on benthos abundance, biomass, diversity, and tolerance will be confounded with natural influences of salinity intrusion and concomitant changes in substrate composition with tidal action and the re-suspension of the salt wedge. For instance, freshwater species at the river mouth may exist in large numbers during high flow conditions but disappear at low flow conditions when the salinity of interstitial waters increase. Simultaneously, euryhaline organisms such as polychaetes may shift upstream, replacing freshwater benthos as the transition zone between salt and fresh interstitial waters migrates upstream.

In addition to the strong authochthonous influences of estuarine dynamics on benthic invertebrates, it is suspected that the intense urban and industrial activity of the North Arm affects changes in benthic infauna over and above natural changes. The data collection conducted by Northcote *et al*. (1976) in 1972 and 1973 coincided with the 1972 occurrence of one of the largest freshets on record starting earlier and ending later than in previous years. Sampling was scheduled only during high flow months of late summer to late autumn 1972, and spring and late summer 1973. Again, three monitoring stations were selected within the reach, the uppermost sampling site was station5 at Annacis Channel. Stations 1 and 2 were situated at the mouths of the North Arm and the Middle Arm, respectively. The study conducted by Chapman and Brinkhurst (1979) subsequent to the study by Northcote *et al*. (1976) supports data previously reported. The bottom fauna of the lower Fraser River reaches its maximum abundance and biomass at or near the mouth of the North Arm with annual averages ranging from 3,000 organisms/m^2 at stations 1 (n=30) and 2 (n=30) to just over 15,000 organisms/m^2 at station 5 (n=30) near the middle of the North Arm (Northcote *et al*., 1976). Maximum densities at station 5 approach 70,000 organisms/m^2. The annual average biomass for each site ranged from over 3 to 7 g/m^2 while the maxima occurred at stations 1 and 5 with values of approximately 30 g/m^2. Both number and biomass averages are positively correlated with the levels of fine particle substrates.

Meanwhile, interpretation of average diversity parameters for benthic fauna is more difficult as parameters appear contradictory. The average number of taxa isolated and identified from finer mud and mud-sand fractions was 6.245, suggesting higher diversity in the North Arm than all other reaches. In contrast, Simpson’s index showed a decrease in value from upstream reaches for the same substrate type (0.361) as did the Shannon-Wiener function (1.083); these decreases suggest that the lowest diversity of all reaches examined occurred in the North Arm, and that the North Arm is polluted.

Likewise, the average number of taxa calculated for the sand and sand-gravel fractions was high at 6.095, suggesting greater diversity than all other reaches of the lower Fraser River. In contrast, Simpson’s index of 0.420 and the Shannon-Wiener function of 1.265 were marginally lower than values for upstream reaches. Similarly, the lowest equitability value (0.531) was calculated for the North Arm reach. However, if the Weber (1973) generalization were applied, the value would suggest conditions typical for unpolluted waters. It is highly unlikely that the North Arm is pristine.

The following table lists all organisms collected and identified from benthic samples collected from the North Arm. Although organisms such as daphnia are not truly benthic and are more appropriately considered epibenthic, if not planktonic, these organisms were collected in the grabs and isolated from the samples. As such, they are included in the table.

Occurrence of Taxa in Benthic Samples from the North Arm of the Lower Fraser River

Group and Subgroup	Taxa Name	Downstream	Midstream	Upstream
FLATWORMS	Planarian	√		√
NEMERTEAN WORMS	Nemertina		√	
NEMATODE WORMS	Nematode	√	√	√
ANNELID WORMS				
Polychaetes	*Eteone*	√	√	
	Nereis limnocola	√	√	
	Amphicteis	√	√	
	Polydora	√		
	Prionospio	√		
	Glycinde	√		
	Armandia	√		
Oligochaetes	Oligochaete	√	√	√
Hirudeans	Leech		√	√
MOLLUSCS				
Pelecypods	*Mytilus edulis*	√	√	
	Pisidium			√
	Macoma	√	√	
CRUSTACEANS				
Cladocerans	*Daphnia*	√	√	
	Eurycerus			
Copepods	Calanoids			
	Cyclopoids			
	Harpacticoids	√	√	
Mysids	*Neomysis mercredis*	√	√	√
Cumaceans	*Cumella*	√	√	
Amphipods	*Corophium*	√	√	√
	Anisopammarus confervicolus	√	√	√
	Trichophoxus		√	√
Tanaids	*Tanaids*		√	
Isopods	*Gnorimosphaeroma*		√	
	Asellus			√
Decapods	*Crangon franciscorum*	√	√	
		√		
ARACHNIDS	Hydracarina			√
INSECTS				
Coleopterans (Beetles)	Haliplidae			√
Dipterans (True flies)	Tipulidae			
	Psychodidae			√
	Dolichopodidae	√		√
	Tabanidae		√	
	Ceratopogonidae	√	√	√
	Chaoboridae			√
	Unidentified dipteran	√	√	√
	Unidentified tanypodinae		√	√
	Diamesa			**√**
	Monodiamesa		√	√
	Cricotopus		**√**	**√**
	Heterotrissocladius			√
	Chironomus	√	√	√
Dipterans (True flies) (continued)	*Cryptochiromus*	√	√	√
	Paracladopelma			**√**
	Polypedilum		√	√
	Stictochiromus	√	√	√
LAMPREYS	Ammocoete			√
	# SENSITIVE TAXA	**0**	**1**	**3**
	TOTAL	**26**	**29**	**28**

From the list, the decreased presence of organic pollution sensitive taxa is obvious. Only three sensitive taxa were identified from grab samples collected at station 5: these organisms were dipteran *Diamesa, Crictopus, and Paracladopelma*. Cricotopus was the only sensitive organism collected from station 2. No sensitive taxa were identified from samples collected form station 1. Pollution tolerant organisms were prevalent at all stations: oligochaete worms dominated stations 1, 2, and 5; leeches were collected from stations 2 and 5; and dipteran *Psychodidae* was found at station 5.

In addition to the study conducted by Northcote *et al*. (1976), a survey was performed by Swain (1986c) on the concentrations of metals, nutrients, PCBs, and chlorophenols in the North Arm of the Fraser River. Two monitoring stations were located in this reach: upstream at New Westminster and downstream near the mouth of the river between Iona Island and Sea Island. Both are areas heavily impacted by urban and industrial activity; however, during moderate-to-high flow months, the interstitial salinities decrease to resemble freshwater at the upstream site while the downstream site remains marine. The benthic invertebrates tested by Swain (1986c) included chironomid flies at the upper North Arm station, and crustacean amphipods, polychaete worms, and molluscan pelecypods at the lower North Arm station. Although invertebrates collected from the upstream and downstream sites cannot be compared for spatial trends due to differences in behaviours and life cycles, the accumulated concentrations detected in the filter feeding species is of interest.

	Contaminant Levels Detected in Benthic Fauna Collected from the North Arm of the Fraser River			
	New Westminster (Upstream)	Iona Island (Downstream)		
Characteristic	Chironomids	Amphipods	Polychaetes	Pelecypoda
INORGANICS				
Aluminum	1020	1630	4150	2280
Boron	7	15	<1	<1
Barium	26	91	31	41
Calcium	3 540	63 600	5 220	227 000
Cadmium	<1	<1	<1	<1
Chromium	9	8	12	6
Copper	91	81	57	21
Iron	3 320	5 190	11 600	6 600
Magnesium	1 590	5 380	4 850	2 140
Manganese	165	236	172	110
Molybdenum	<1	<1	3	3
Nickel	<5	7	16	8
Lead	<10	<10	<10	15
Tin	<5	<5	<5	10
Strontium	17	978	58	988
Tellurium	<20	<20	<20	28
Titanium	54	51	115	73
Thallium	<20	<20	<20	61
Vanadium	7	7	16	8
Zinc	172	165	190	68
NUTRIENT				
Total Phosphorus	6450	12 400	4 200	971
ORGANICS				
Total PCBs (wet)	-	-	<0.1	<0.1
Pentachlorophenol (wet)	-	-	0.8	0.01
Tetrachlorophenol (wet)	-	-	1.7	0.02

The effects of salinity intrusion are apparent in the dramatic increases in calcium concentrations in the crustaceans and the molluscs sampled from the downstream stations. Salinity effects on calcium concentrations were also included in the non-calciferous polychaete worms. Species specific differences in physiology may account for some of the patterns in metal concentrations. For instance, high iron concentrations were measured in polychaetes and pelecypoda which contain iron compounded hemoglobin in their circulatory systems while high concentrations of copper were measured in chironomids and amphipods whose circulatory fluids are copper-based.

6.4.4 Analyses of Fish

The majority of data used for this section was reported in a document which discusses a 1988 fish monitoring program (Swain and Walton, 1989). Threespine stickleback, peamouth chub, largescale sucker, northern squawfish, starry flounder and sculpin were caught at Site NA-2 in McDonald Slough (Figure 10) as well as in the Main Arm (Site MA-2) and the Main Stem (Site MS-1). Muscle and liver tissues were analyzed for metals, chlorophenols, PCBs, phthalate esters, PAHs, and organochlorine pesticides. Concentrations of these compounds in North Arm fish are compared with those caught in the Main Arm and Main Stem, as well as to the results of a 1980 survey conducted by Ministry of Environment, Lands, and Parks (Singleton, 1983). Fish were collected over the entire length of the Fraser River in the 1980 survey including two sites in the lower North Arm and one site in the Upper North Arm. Also referenced, are data from a 1985 survey conducted by the Ministry of Environment, Lands, and Parks of sediments, benthic organisms and fish in the lower Fraser River (Swain, 1986b). Fish were sampled as part of the 1985 survey on the North Arm (Site NA-1), the Main Arm (MA-1), and the Main Stem (MS-2).

6.4.4.1 Metals

MoE (Singleton, 1983) tested metal concentrations in liver and muscle tissues of a number of salmonids (rainbow trout, cutthroat trout, and Dolly Varden) as well as mountain and lake whitefish. Concentrations in the species analyzed in the North Arm are compared to these data (though it is suggested levels would vary among species, the data are offered as evidence of natural variation).

Aluminum

Aluminum concentrations in fish were measured only for the 1985 survey (Swain, 1986c). Concentrations in both liver and muscle tissues were highest in fish caught in the North Arm. One staghorn sculpin caught in the lower North Arm had a concentration of 28 µg/g dry-weight in its muscle tissue; the other four sculpins and all other species in this reach had concentrations <10 µg/g (dry-weight). The sculpin which had the high muscle tissue concentration had concentrations of aluminum in its liver below detection limits (2 µg/g dry-weight). The maximum concentration of aluminum in liver tissues was 12 µg/g (dry-weight) in a rainbow trout.

Arsenic

Arsenic was present in measurable amounts in all fish tested in the North Arm, with detection limits of 0.005 µg/g wet-weight (0.025 µg/g dry-weight). Arsenic concentrations in muscle tissues were highest in staghorn sculpins and starry flounders, with a mean concentration of 0.17 µg/g wet-weight (0.96 µg/g dry-weight) in the sculpins and 0.19 µg/g wet-weight (1.16 µg/g dry-weight) in the flounders. While concentrations of arsenic were below detection limits for all of the samples in 1980, the much higher detection limits make comparison difficult. Only one of the starry flounder muscle tissue samples collected in 1988 contained arsenic concentrations exceeding the limits of detection used in the 1980 study.

Arsenic Concentrations in Muscle Tissues of Fish from the North Arm*.					
Species	**No. of Values**	**Maximum**	**Minimum**	**Mean**	**Std. Dev.**
Largescale Sucker	17	0.75/0.15	0.11/0.02	0.37/0.07	0.14
Northern Squawfish	18	0.94/0.19	0.19/0.04	0.50/0.10	0.17
Peamouth Chub	13	0.50/0.10	0.17/0.04	0.34/0.07	0.11
Staghorn Sculpin	7	1.55/0.31	0.69/0.10	0.96/0.17	0.31
Starry Flounder	3	2.42/0.57	0.33/0.04	1.16/0.19	1.11
Threespine Stickleback	2	0.71/0.12	0.35/0.06	0.53/0.09	-

*All measurements are dry/wet-weight, µg/g
(Swain and Walton, 1989)

Arsenic concentrations were higher in livers than in muscle tissues, with maximum concentrations of 0.45 µg/g wet-weight in the starry flounder and 0.42 µg/g wet-weight in the northern squawfish. Comparison with arsenic concentrations in fish caught in 1980 (Singleton, 1983) is difficult because detection limits used in that study were high (2.0 µg/g dry-weight, 0.4 µg/g wet-weight). Five of 43 liver samples taken in 1980 had concentrations of arsenic above detection limits, and two of the 26 liver samples collected in 1988 had concentrations above these limits, though all were well below the maximum concentration of 1.04 µg/g measured in the 1980 study.

Arsenic Concentrations in Liver Tissues of Fish from the North Arm*.					
Species	**No. of Values**	**Maximum**	**Minimum**	**Mean**	**Std. Dev.**
Largescale Sucker	6	0.11	ND	0.051	0.225
Northern Squawfish	8	0.42	0.047	0.256	0.135
Peamouth Chub	9	0.42	0.071	0.25	0.141
Staghorn Sculpin	2	0.26	0.16	0.21	-
Starry Flounder	1	0.45	-	-	-

*All measurements are wet-weight, µg/g

(Swain and Walton, 1989)

Concentrations of arsenic in fish muscle and liver tissues were two to three times higher in fish collected from the North Arm than in fish from uncontaminated lakes; however, statistical comparison of these data are not possible due to significant variability between the data sets. It is not apparent that arsenic concentrations are increasing with time.

Cadmium

Concentrations of cadmium in muscle tissues were below detection limits for all fish captured in the North Arm in 1985 and 1988 (0.02 µg/g dry-weight and 0.025 µg/g dry-weight, respectively). One of 273 muscle tissue samples collected along the length of the Fraser in 1980 had concentrations exceeding the detection limit of 1.0 µg/g dry-weight (0.2 µg/g wet-weight). The much higher detection limits used in the 1980 survey do not permit a straight forward comparison of these data, but it does not appear that concentrations of cadmium are increasing in fish muscle tissues in this reach.

Cadmium concentrations in fish caught in the North Arm were higher in liver tissues than muscle, with a maximum concentration of 0.27 µg/g (wet-weight) occurring in the liver of a staghorn sculpin. The maximum concentration of cadmium in fish livers collected in the 1985 survey occurred in a staghorn sculpin from the lower North Arm which had a concentration of 0.138 µg/g (wet-weight). Concentrations in both 1985 and 1988 were lower than those found in fish liver tissues collected in 1980 when a maximum concentration of 0.52 µg/g was measured. The detection limit for cadmium in 1980 was 0.2 µg/g dry-weight, equal to the Health and Welfare Canada (1977) cadmium tolerance level in the meat of livestock for human consumption. Only one of the 26 fish caught in the North Arm in 1988 had concentrations of cadmium in their liver tissue exceeding 0.2 µg/g (dry-weight).

Cadmium Concentrations in Liver Tissues of Fish from the North Arm*.					
Species	**No. of Values**	**Maximum**	**Minimum**	**Mean**	**Std. Dev.**
Largescale Sucker	6	0.13	ND	0.06	0.044
Northern Squawfish	8	0.037	ND	-	-
Peamouth Chub	9	0.10	0.030	0.060	0.020
Staghorn Sculpin	2	0.27	0.077	0.174	-
Starry Flounder	1	0.052	-	-	-

*All measurements are wet-weight, µg/g.

(Swain and Walton, 1989)

Chromium

Concentrations of chromium in muscle tissues had a high degree of variability both between and among species in the North Arm. Concentrations were highest in starry flounders, but it is suspected that contamination of these samples may have occurred. Concentrations were also high in the muscle tissues of two threespine sticklebacks caught in the North Arm in 1988, with a mean value of 1.26 µg/g wet-weight (7.29 µg/g dry-weight). Concentrations were similar to those measured in muscle tissue samples collected in 1985 when values in the North Arm ranged from 0.105 to 0.318 µg/g (wet-weight).

Chromium Concentrations in Muscle Tissues of Fish from the North Arm*.					
Species	**No. of Values**	**Maximum**	**Minimum**	**Mean**	**Std. Dev.**
Largescale Sucker	17	0.75/0.14	0.31/0.06	0.41/0.08	0.11
Northern Squawfish	18	0.84/0.17	0.28/0.06	0.41/0.08	0.29
Peamouth Chub	13	1.35/0.30	0.40/0.10	0.73/0.16	0.29
Staghorn Sculpin	7	4.59/0.70	0.98/0.18	2.76/0.48	1.53
Starry Flounder	3	20.2/2.50	0.68/0.16	12.6/2.05	10.5
Threespine Stickleback	2	8.20/1.41	6.38/1.10	7.29/1.26	-

*All measurements are dry/wet-weight, µg/g

(Swain and Walton, 1989)

In 1988, concentrations of chromium in liver tissues of North Arm fish were considerably lower than those found in muscle tissues. The maximum observed concentration was 0.37 µg/g (wet-weight) in a peamouth chub. Concentrations measured in 1985 ranged from 0.21 to 0.43 µg/g (wet-weight) in the North Arm. Concentrations were also low in liver tissues collected for the 1980 survey. Singleton (1983) suggested that the liver may not be an active site for chromium accumulation.

Chromium Concentrations in Liver Tissues of Fish from the North Arm*.

Species	No. of Values	Maximum	Minimum	Mean	Std. Dev.
Largescale Sucker	6	0.11	0.05	0.085	0.025
Northern Squawfish	8	0.08	<0.01	0.046	0.024
Peamouth Chub	9	0.37	<0.01	0.12	0.122
Staghorn Sculpin	2	0.11	<0.01	-	1.53
Starry Flounder	1	0.07	-	-	-

*All measurements are wet-weight, µg/g

(Swain and Walton, 1989)

Copper

Concentrations of copper were generally higher in liver tissues than in muscle tissues. The maximum concentration of copper in liver tissue in the North Arm in 1988 was 9.67 µg/g (wet-weight) in a starry flounder. Liver concentrations recorded in the 1985 survey ranged from 0.75 µg/g (wet-weight) in a staghorn sculpin to 18.5 µg/g (wet-weight) in a rainbow trout. Concentrations were also high in the 1980 survey, with large range of concentrations between species. No values were recorded specifically from the North Arm area, so a comparison with more recent data is not possible.

Copper Concentrations in Liver Tissues of Fish from the North Arm*.					
Species	**No. of Values**	**Maximum**	**Minimum**	**Mean**	**Std. Dev.**
Largescale Sucker	6	4.67	1.58	3.75	1.15
Northern Squawfish	8	6.52	2.81	5.08	1.44
Peamouth Chub	9	6.56	1.67	3.06	1.43
Staghorn Sculpin	6	6.82	6.40	6.61	-
Starry Flounder	1	9.67	-	-	-

*All measurements are wet-weight, µg/g

(Swain and Walton, 1989)

The concentration of copper in muscle tissues in 1988 ranged from a minimum of 0.15 µg/g (wet-weight) in a largescale sucker to 1.58 µg/g (wet-weight) in a threespine stickleback. This range was similar to that found in the 1980 and 1985 surveys.

Copper Concentrations in Muscle Tissues of Fish from the North Arm*.					
Species	**No. of Values**	**Maximum**	**Minimum**	**Mean**	**Std. Dev.**
Largescale Sucker	17	1.46/0.28	0.71/0.15	1.03/0.20	0.16
Northern Squawfish	18	1.73/0.32	0.82/0.16	1.18/0.24	0.27
Peamouth Chub	13	2.93/0.62	1.40/0.35	1.85/0.39	0.42
Staghorn Sculpin	7	5.20/0.79	1.89/0.35	2.91/0.50	1.48
Starry Flounder	3	8.74/1.08	1.08/0.26	5.82/0.94	4.14
Threespine Stickleback	2	9.20/1.58	8.37/1.44	8.79/1.51	-

*All measurements are dry /wet-weight, µg/g

(Swain and Walton, 1989)

Iron

In 1988, the maximum mean iron concentration in muscle tissues of 12 µg/g (wet-weight) occurred in the staghorn sculpin, but there was a very high degree of variability within this species (samples from starry flounder were thought to be contaminated and are therefore not included). Concentrations were generally within the range of values reported for the 1980 survey (Singleton, 1983). Values measured in the 1985 survey ranged from 3.89 µg/g to 9.15 µg/g (wet-weights); both the maximum and minimum were measured in staghorn sculpins.

Iron Concentrations in Muscle Tissues of Fish from the North Arm*.

Species	No. of Values	Maximum	Minimum	Mean	Std. Dev.
Largescale Sucker	17	56.7/11.2	20.4/3.75	35.1/6.84	9.97
Northern Squawfish	18	40.9/7.73	14.7/3.04	22.1/4.34	6.96
Peamouth Chub	13	34.9/7.54	15.9/3.13	24.0/5.02	5.68
Staghorn Sculpin	7	190/28.9	23.2/4.15	69.1/12.0	74.2
Starry Flounder	3	1261/156	22.5/5.33	811/131	685
Threespine Stickleback	2	419/72.1	346/59.5	383/65.8	-

*All measurements are dry/wet-weight, µg/g
(Swain and Walton, 1989)

Mean iron concentrations in livers were higher than in muscle tissues in all years of sampling. For all concentrations measured in 1988, the range was from 49.4 µg/g in a peamouth chub to 145 µg/g in a northern squawfish and largescale sucker (samples from starry flounder were thought to be contaminated and are therefore not included here). This range was similar to that measured in 1985, when the minimum concentration of iron in liver tissue was 19.4 µg/g and the maximum was 158 µg/g (wet-weight). In both the 1985 and 1988 surveys, the muscle tissue sample containing the lowest concentration of iron came from a fish caught in the North Arm, and mean concentrations in this reach were generally lower than other reaches in 1988.

Iron Concentrations in Liver Tissues of Fish from the North Arm*.					
Species	**No. of Values**	**Maximum**	**Minimum**	**Mean**	**Std. Dev.**
Largescale Sucker	6	145	70.3	111	30.7
Northern Squawfish	8	145	90.1	117	18.1
Peamouth Chub	9	120	49.4	96.1	24.8
Staghorn Sculpin	6	131	88.6	109	21.3
Starry Flounder	1	166	-	-	-

*All measurements are wet-weight, µg/g

(Swain and Walton, 1989)

Lead

Lead concentrations in muscle tissue were measurable in only 18 of 273 samples collected in 1980 (detection limit 1.0 µg/g dry-weight, 0.2 µg/g wet-weight). Because the limits of detection used in the 1988 survey were 20 times lower than those used in the 1980 survey, a much higher proportion of the samples had lead concentrations above detectable limits. The highest concentration of lead in fish muscle tissue from the North Arm in 1980 was 0.34 µg/g wet-weight in an adult sockeye salmon, while in 1985, the maximum concentration decreased to 0.238 µg/g (wet-weight) in a rainbow trout and in 1988 the maximum concentration was only 0.10 µg/g in a peamouth chub. It is apparent that lead concentrations in muscle tissue decreased between 1980 and 1988. The highest mean concentration of lead in muscle tissues in 1988 by species was 0.07 µg/g (wet-weight) in the starry flounder. All values were well below the criterion for fish consumed by humans of a maximum concentration of 0.8 µg/g wet-weight (Nagpal, 1987) and the tolerance level of 0.5 µg/g defined by the Canadian Food and Drug Directorate (1979).

Lead Concentrations in Muscle Tissues of Fish from the North Arm.*					
Species	**No. of Values**	**Maximum**	**Minimum**	**Mean**	**Std. Dev.**
Largescale Sucker	17	0.25/0.05	0.08/0.02	0.16/0.03	0.06
Northern Squawfish	18	0.31/0.06	0.09/0.02	0.18/0.03	0.07
Peamouth Chub	13	0.44/0.10	0.07/0.01	0.22/0.05	0.25
Staghorn Sculpin	7	0.33/0.07	0.15/0.03	0.21/0.04	0.06
Starry Flounder	3	0.67/0.08	0.14/0.03	0.44/0.07	0.27
Threespine Stickleback	2	0.28/0.05	0.25/0.04	0.27/0.05	-

*All measurements are dry/wet-weight, µg/g

(Swain and Walton, 1989)

Concentrations of lead in liver tissues were similar to those measured in muscle tissues for the 1980 samples, significantly higher in 1985, and lower in 1988. In 1980, the highest concentration detected in a fish from the North Arm was 0.29 µg/g; this maximum was measured in a largescale sucker. In 1985, the highest liver concentration of lead measured in a North Arm fish was 0.90 µg/g and in 1988, the highest concentration was 0.17 µg/g (wet-weight); both maxima were detected in the northern squawfish.

Lead Concentrations in Liver Tissues of Fish from the North Arm*					
Species	**No. of Values**	**Maximum**	**Minimum**	**Mean**	**Std. Dev.**
Largescale Sucker	6	0.09	0.05	0.068	0.018
Northern Squawfish	8	0.17	<0.01	0.086	0.047
Peamouth Chub	9	0.08	<0.01	0.044	0.027
Staghorn Sculpin	2	0.08	0.07	0.075	-
Starry Flounder	1	<0.01	-	-	-

*All measurements are wet-weight, µg/g

(Swain and Walton, 1989)

Concentrations of lead in muscle tissues appear to be decreasing with time. The fact that leaded gasoline is no longer sold commercially has probably been a large factor in this decrease. Hepatic lead concentrations are more difficult to interpret. After the ban of leaded gas in 1978, lead concentrations in fish livers peaked at 0.90 μg/g which is significantly above the criterion 0.5 μg/g for the protection of fish proteins consumed by humans. This was followed by a reduction in liver tissue concentration to levels below the criterion. Because lead is known to accumulate in liver tissues, fish must be closely monitored for levels approaching the criterion.

Manganese

Fish muscle tissues measured in 1988 showed that mean concentrations of manganese in muscle tissues of fish from the North Arm were similar in the largescale sucker, northern squawfish, peamouth chub, and staghorn sculpin; concentrations ranged from 0.19 μg/g in the squawfish to 0.41 μg/g (wet-weight) in the sculpin. Concentrations in the starry flounder and threespine stickleback were much higher, with mean values of 3.91 μg/g to 7.22 μg/g (wet-weight) in the stickleback. The range of values for the largemouth sucker, northern squawfish, peamouth chub and staghorn sculpin are similar to that of the 1980 study. Concentrations in the starry flounder and threespine stickleback greatly exceed the maximum value for the entire length of the Fraser River (0.76 μg/g wet-weight. Concentrations of manganese measured in fish muscle tissue in 1985 were very low in all samples, with a maximum concentration of 0.16 μg/g (wet-weight).

Manganese Concentrations in Muscle Tissues of Fish from the North Arm.*

Species	No. of Values	Maximum	Minimum	Mean	Std. Dev.
Largescale Sucker	17	2.61/0.54	0.96/0.20	1.64/0.32	0.52
Northern Squawfish	18	1.76/0.34	0.36/0.07	0.95/0.19	0.43
Peamouth Chub	13	1.90/0.42	0.87/0.19	1.35/0.28	0.37
Staghorn Sculpin	7	6.22/0.95	0.71/0.13	2.35/0.41	2.47
Starry Flounder	3	38.9/4.82	0.97/0.23	24.1/3.91	20.3
Threespine Stickleback	2	44.1/7.59	39.8/6.85	42.0/7.22	-

*All measurements are dry/wet-weight, μg/g

(Swain and Walton, 1989)

Manganese concentrations in livers were generally between five and ten times greater than those found in muscle tissues in the 1980, 1985 and 1988 studies. Mean concentrations in 1988 ranged from 0.69 µg/g in the northern squawfish to 2.11 µg/g (wet-weight) in the peamouth chub. The maximum concentration measured in 1985 was 1.34 µg/g (wet-weight).

Manganese Concentrations in Liver Tissues of Fish from the North Arm. *					
Species	**No. of Values**	**Maximum**	**Minimum**	**Mean**	**Std. Dev.**
Largescale Sucker	6	2.62	0.68	1.54	0.81
Northern Squawfish	8	0.89	0.50	0.69	0.16
Peamouth Chub	9	3.78	0.74	2.11	1.46
Staghorn Sculpin	2	0.96	0.85	0.905	0.26
Starry Flounder	1	0.60	-	-	-

*All measurements are wet-weight, µg/g

(Swain and Walton, 1989)

Mercury

Both mean and maximum concentrations of mercury have been steadily decreasing from 1972 to 1988 (Swain and Walton, 1989). Mean concentrations in 1988 ranged from 0.03 µg/g in the threespine stickleback to 0.39 µg/g in the northern squawfish. The maximum concentration measured in 1988 was 0.50 µg/g in a northern squawfish. This value meets the maximum criterion for lead in the edible portions of fish and shellfish of 0.5 µg/g wet-weight (Nagpal, 1989; Canadian Food and Drug Directorate, 1979). At this concentration, the safe quantity for weekly consumption on a regular basis is 210 g wet-weight (Nagpal, 1989). A northern squawfish was also found to have the highest mercury concentrations in muscle tissue from the 1980 survey, with a maximum concentration of 1.23 µg/g. Concentrations measured in 1985 ranged from 0.07 µg/g to 0.26 µg/g (wet-weights).

Mercury Concentrations in Muscle Tissues of Fish from the North Arm.*					
Species	**No. of Values**	**Maximum**	**Minimum**	**Mean**	**Std. Dev.**
Largescale Sucker	17	0.58/0.12	0.28/0.05	0.40/0.08	0.10
Northern Squawfish	18	2.70/0.50	1.39/0.29	1.98/0.39	0.32
Peamouth Chub	13	1.32/0.22	0.82/0.21	1.08/0.23	0.17
Staghorn Sculpin	7	0.77/0.14	0.38/0.06	0.56/0.10	0.14
Starry Flounder	3	0.54/0.13	0.18/0.02	0.32/0.05	0.19
Threespine Stickleback	2	0.20/0.03	0.20/0.03	0.20/0.03	-

*All measurements are dry/wet-weight, µg/g

(Swain and Walton, 1989)

Mean liver concentrations of mercury measured in 1988 ranged from 0.028 µg/g in the largescale sucker to 0.325 µg/g in the staghorn sculpin. Concentrations measured in 1985 ranged from 0.02 to 0.12 µg/g (wet-weight).

Mercury Concentrations in Liver Tissues of Fish from the North Arm.*					
Species	**No. of Values**	**Maximum**	**Minimum**	**Mean**	**Std. Dev.**
Largescale Sucker	6	0.070	0.014	0.028	0.021
Northern Squawfish	8	0.18	0.069	0.118	0.036
Peamouth Chub	9	0.17	0.071	0.10	0.034
Staghorn Sculpin	2	0.48	0.17	0.325	-
Starry Flounder	1	0.18	-	-	-

*All measurements are wet-weight, µg/g

(Swain and Walton, 1989)

Molybdenum

The majority of fish sampled in 1988 had muscle concentrations of molybdenum below detection limits of 0.05 µg/g wet-weight (<0.25 µg/g dry-weight). Exceptions to this were some of the staghorn sculpins and starry flounders, and both of the threespine sticklebacks. The maximum concentration found in the lower Fraser River during this sampling survey was 0.23 µg/g (wet-weight) in one of the two threespine sticklebacks taken from the North Arm. All samples taken in 1985 had concentrations less than detection limits of 1.0 µg/g dry-weight; only cutthroat trout and rainbow trout were measured at lower detection limits of 0.224 µg/g and 0.693 µg/g wet-weight, respectively. It appears that molybdenum concentrations are higher in the North Arm than in other areas of the lower Fraser River. However, mean concentrations were considerably lower than mean values for fish from uncontaminated lakes with the exception of the threespine stickleback, which had similar concentrations.

In 1980, the majority of muscle tissues in which molybdenum was measured came from migrating salmon caught in the North Arm. Therefore, the detectable concentrations of molybdenum may have been linked to the marine environment from which the salmon had migrated.

Detectable Molybdenum Concentrations in Muscle Tissues of Fish from the North Arm.*					
Species	**No. of Values**	**Maximum**	**Minimum**	**Mean**	**Std. Dev.**
Staghorn Sculpin	7	0.29/0.04	<0.25/ <0.05	<0.25/ <0.05	-
Starry Flounder	3	1.24/0.15	<0.25/ <0.05	median 0.98/0.12	-
Threespine Stickleback	2	1.36/0.23	1.28/0.22	1.32/0.23	-

*All measurements are dry/wet-weight, µg/g

(Swain and Walton, 1989)

Molybdenum concentrations were generally higher in livers than muscle tissues collected during the 1980, 1985 and 1988 surveys. The maximum concentration in fish liver tissue (0.22 µg/g wet-weight) was from a starry flounder in the North Arm. This concentration equals the maximum concentrations found in largescale suckers from the Main Arm and Main Stem. In general, mean concentrations of molybdenum in the livers of Fraser River fish in 1988 were about one-half those found in fish from uncontaminated lakes. No molybdenum criteria are currently available for evaluating and interpreting the data.

Molybdenum Concentrations in Liver Tissues of Fish from the North Arm.*					
Species	**No. of Values**	**Maximum**	**Minimum**	**Mean**	**Std. Dev.**
Largescale Sucker	6	0.20	0.10	0.16	0.036
Northern Squawfish	8	<0.05	<0.05	<0.05	-
Peamouth Chub	9	0.20	0.12	0.154	0.026
Staghorn Sculpin	2	0.10	<0.05	0.075	-
Starry Flounder	1	0.22	-	-	-

*All measurements are wet-weight, µg/g

(Swain and Walton, 1989)

Nickel

The 1988 survey found maximum concentrations of nickel to range from 0.96 µg/g wet-weight in a staghorn sculpin to 2.67 µg/g wet-weight in a starry flounder. Concentrations of nickel in muscle tissues from the majority of fish caught in the North Arm were considerably lower than in fish from uncontaminated lakes except for starry flounder and threespine stickleback that had concentrations twice as high as those from uncontaminated lakes. Nickel was not detected in the lower reaches of the Fraser River in either the 1980 or 1985 surveys (detection limits 0.2 µg/g wet-weight compared to 0.01 µg/g for the 1988 survey).

Nickel Concentrations in Muscle Tissues of Fish from the North Arm*					
Species	**No. of Values**	**Maximum**	**Minimum**	**Mean**	**Std. Dev.**
Largescale Sucker	17	0.44/0.08	0.11/0.02	0.22/0.04	0.09
Northern Squawfish	18	0.46/0.09	0.09/0.02	0.20/0.04	0.09
Peamouth Chub	13	5.57/1.08	0.23/0.05	1.25/0.26	1.72
Staghorn Sculpin	7	6.31/0.96	0.49/0.09	2.83/0.49	2.44
Starry Flounder	3	21.5/2.67	0.43/0.10	12.8/2.08	11.0
Threespine Stickleback	2	15.3/2.63	12.8/2.20	14.1/2.42	-

*All measurements are dry/wet-weight, µg/g

.(Swain and Walton, 1989)

Mean concentrations of nickel in liver tissues from the North Arm in 1988 ranged from 0.076 µg/g wet-weight in the northern squawfish to 0.145 µg/g wet-weight in the largescale sucker. Nickel was not detected in the 1985 survey or in any of 43 liver samples collected along the length of the Fraser River in 1980; however, the higher detection limits used in earlier studies (0.02 µg/g wet-weight in 1980 and 1985 compared to 0.01 µg/g wet-weight in 1988) make comparison of results difficult. Concentrations measured in 1988 were higher in the livers than muscle tissues of largescale suckers, northern squawfish, peamouth chub, and staghorn sculpin.

Nickel Concentrations in Liver Tissues of Fish from the North Arm.*					
Species	**No. of Values**	**Maximum**	**Minimum**	**Mean**	**Std. Dev.**
Largescale Sucker	6	0.20	0.09	0.145	0.054
Northern Squawfish	8	0.12	<0.01	0.076	0.033
Peamouth Chub	9	0.24	<0.01	0.123	0.086
Staghorn Sculpin	2	0.12	0.07	0.095	-
Starry Flounder	1	0.10	-	-	-

*All measurements are wet-weight, µg/g

(Swain and Walton, 1989)

Zinc

In 1988, concentrations of zinc in muscle tissues were similar in peamouth chub, northern squawfish, largescale sucker, and staghorn sculpin, with means ranging from a minimum of 5.00 µg/g wet-weight in squawfish to a maximum of 6.27 µg/g wet-weight in sculpin. This range is narrower than the range measured in 1985, when the minimum concentration in a North Arm sample was 3.58 µg/g (wet-weight) in a cutthroat trout, and the maximum concentration 7.3 µg/g (wet-weight) in a staghorn sculpin. In contrast, monitoring results of 1988 revealed that concentrations were much higher in the starry flounder and threespine stickleback than any other species collected, with means of 16.8 µg/g and 31.6 µg/g wet-weight, respectively.

Zinc Concentrations in Muscle Tissues of Fish from the North Arm.*

Species	No. of Values	Maximum	Minimum	Mean	Std. Dev.
Largescale Sucker	17	32.4/6.64	21.1/4.02	27.5/5.36	3.86
Northern Squawfish	18	31.6/5.91	20.5/3.73	25.4/5.00	2.34
Peamouth Chub	13	35.0/7.56	22.6/5.70	28.2/5.89	4.08
Staghorn Sculpin	7	52.6/8.00	28.3/4.78	36.1/6.27	8.73
Starry Flounder	3	144/17.9	37.5/8.89	104/16.8	57.9
Threespine Stickleback	2	195/33.5	172/29.6	184/31.6	-

*All measurements are dry/wet-weight, µg/g

(Swain and Walton, 1989)

Concentrations of zinc were generally about five to ten times higher in livers than in muscle tissues for the 1980, 1985, and 1988 surveys. Furthermore, liver concentrations have increased between 1980 and 1988. Mean concentrations from the 1988 survey in the North Arm ranged from 13.7 µg/g wet-weight in the peamouth chub to 64.2 µg/g wet-weight in the staghorn sculpin. Values measured in the 1985 survey ranged from 18.5 µg/g to 57.4 µg/g (wet-weights). This range is similar to that recorded in the 1980 survey, where concentrations of zinc in liver tissues ranged from 17.7 µg/g to 49.6 µg/g wet-weight along the length of the Fraser River.

Zinc Concentrations in Liver Tissues of Fish from the North Arm.*

Species	No. of Values	Maximum	Minimum	Mean	Std. Dev.
Largescale Sucker	6	28.5	15.1	22.5	4.75
Northern Squawfish	8	19.3	12.9	15.5	1.95
Peamouth Chub	9	14.5	12.0	13.7	0.81
Staghorn Sculpin	2	70.1	58.3	64.2	-
Starry Flounder	1	31.0	-	-	-

*All measurements are wet-weight, µg/g

(Swain and Walton, 1989)

6.4.4.2 Organics

6.4.4.2.1 Chlorophenols

Concentrations of trichlorophenols were below detection limits (<0.0002 µg/g wet-weight) in the staghorn sculpin and threespine stickleback muscle tissue samples collected in the North Arm in 1988. Mean muscle concentrations in other species ranged from 0.002 µg/g (wet-weight) in the largescale sucker to 0.007 µg/g (wet-weight) in the northern squawfish. No trichlorophenols were measured in the muscles of five largescale suckers caught in the upper North Arm in 1980; however, the detection limit was 100 times larger than that used in 1988 (0.02 µg/g). Trichlorophenols were not measured as part of the 1985 survey.

Trichlorophenols were measured in the liver tissues of only two of eight northern squawfish from the North Arm in 1988 when the detection limit was 0.025 µg/g. Concentrations in these fish were 0.047 and 0.094 µg/g wet-weight. The criterion for trichlorophenols is 50 µg/g for the protection of aquatic life (Warrington, 1993). This detection limit was considerably higher than that used for muscle (0.0002 µg/g) so a direct comparison of concentrations in liver and muscle tissues is not possible. However, no trichlorophenols were present in measurable amounts in fish from either the Main Arm or Main Stem. Liver tissue was not tested for trichlorophenols in either the 1980 or 1985 survey.

Tetrachlorophenol was not present in detectable amounts (<0.0002 µg/g wet-weight) in fish muscle tissues collected during the 1988 survey. Concentrations in fish muscle tissue from the 1985 survey ranged from <0.01 µg/g to 0.03 µg/g wet-weight. Tetrachlorophenols were not detected in the muscle tissue of any largescale suckers taken from the North Arm in 1980 (<0.01 µg/g), but muscle tissues from fish taken from the North Arm in 1972-73 by the Westwater Research Centre (Garrett, 1980) ranged from 0.028 to 0.062 µg/g in two staghorn sculpins to 0.018 µg/g in one northern squawfish. Therefore, it appears that tetrachlorophenol concentrations may be decreasing in North Arm fish.

Tetrachlorophenol was present in measurable concentrations (≥0.025 µg/g) in only one liver sample from the North Arm (0.028 µg/g in a peamouth chub). Liver concentrations were not measured in the 1980 or 1985 surveys. No tissue quality criterion has been set for evaluating the monitoring data for tetrachlorophenols.

Mean concentrations of pentachlorophenol in the muscle tissues of fish from the North Arm in 1988 ranged from 0.0004 µg/g in staghorn sculpins to 0.002 µg/g in the northern squawfish. Fish taken from the upper North Arm in 1980 had pentachlorophenol concentrations in their muscle tissues ranging from 0.016 to 0.043 µg/g (wet-weight). This range is similar to the range found in the 1985 survey when concentrations were between 0.02 and 0.03 µg/g wet-weight. Pentachlorophenol was detected in only one liver sample collected in the 1988 survey (0.090 µg/g wet-weight in a peamouth chub). The criterion based on flavour impairment for pentachlorophenol for the protection of aquatic life is 20 µg/g, well above the concentrations measured (Warrington, 1993).

The existing Water Quality Objective for chlorophenols is a maximum concentration of 0.1 µg/g (wet-weight) in fish muscle for all chlorophenols combined. This value was based on the goal of no increase in chlorophenol concentrations over present conditions; however, a new provisional Tissue Quality Objective of 0.2 µg/g (wet-weight) for the sum of mono-, di-, tri-, tetra- and pentachlorophenol in any single sample or a composite sample in any species is proposed . This Objective was met in all cases in fish caught in the North Arm during the 1988 survey, and reflects the Ministry criteria for 2,4-dichlorophenol alone.

6.4.4.2.2 PCBs

Mean muscle concentrations of PCBs measured in 1988 ranged from 0.02 µg/g wet-weight in the peamouth chub to 0.04 µg/g wet-weight in the largescale sucker. Mean liver concentrations ranged from below detection (<0.05 µg/g wet-weight) in the single starry flounder sampled to 0.506 µg/g wet-weight in the nine peamouth chub. In the 1980 survey, the majority of fish with detectable limits of PCBs (0.3 µg/g wet-weight) had concentrations ranging from 0.4 µg/g to 0.8 µg/g. Concentrations measured in 1985 were all below detection limits (<0.1 µg/g wet-weight). Therefore, it appears that PCB concentrations are decreasing in the North Arm. Since the source of PCBs is almost strictly anthropogenic and chronic effects are still being debated, it is proposed that the 1985 Tissue Quality Objective of 0.5 µg/g (wet-weight) be modified to 0.1 µg/g (wet-weight) to protect wildlife from the consumption of whole fish. This objective was achieved by all samples taken in the 1988 survey.

6.4.4.2.3 Phthalate Esters

Six phthalate esters were measured in the 1988 survey. These were dimethyl, diethyl, di-n-butyl, butyl benzyl, di-n-octyl, and bis(2-ethylhexyl). Phthalate esters measured as part of the 1980 survey were dimethyl, diethyl, diisobutyl and diamyl phthalates (not detected at any sites during this survey) and di-n-octyl, butyl benzyl and butyl isodecyl phthalates (which were present in almost all samples taken in 1980).

Dimethyl phthalate was measured in the muscle tissues of some individuals from the North Arm with concentrations ranging from 0.07 μg/g (wet-weight) in a staghorn sculpin to 0.21 μg/g (wet-weight) in a threespine stickleback. Concentrations in liver tissues were below detection limits for all samples (<0.5 μg/g wet-weight). Dimethyl phthalate was also not present in measurable amounts in any of the fish tested as part of the 1980 survey. This was likely due to the high detection limit (10 μg/g wet-weight).

Mean muscle concentrations of diethyl phthalate ranged from below detection limits (0.004 μg/g wet-weight) in the starry flounder and threespine stickleback to 0.30 μg/g wet-weight in the peamouth chub. The "maximum background" contamination from the laboratory is 0.11 μg/g, so values exceeding this would indicate that muscle tissue was being contaminated by diethyl phthalate. No diethyl phthalate was measured in the 1980 survey, probably due to the high detection limit (<10 μg/g wet-weight). Concentrations in liver tissues measured in 1988 were measurable only in the North Arm (>0.2 μg/g wet-weight), with a maximum concentration of 6.57 μg/g in a peamouth chub.

Mean concentrations of di-n-butyl phthalate in muscle tissue from the North Arm in 1988 ranged from 0.06 μg/g in the peamouth chub samples to 0.12 μg/g (wet-weights) in the largescale suckers. Di-n-butyl phthalate was not measured as part of the 1980 survey. Concentrations of di-n-butyl phthalate were considerably higher in liver tissues than in muscle tissues, with maximum concentrations ranging from 0.21 μg/g wet-weight in the staghorn sculpin to 4.70 μg/g wet-weight in the northern squawfish in 1988.

Mean butyl benzyl phthalate concentrations in muscle tissues from fish caught in the North Arm in 1988 ranged from 0.01 µg/g in the staghorn sculpins to 0.04 µg/g in the northern squawfish. Values exceeding 0.046 µg/g would be considered to exceed "maximum background" levels of contamination from the laboratory, so interpretation of the actual contamination occurring in the North Arm is difficult. The maximum concentrations for all species were below the "maximum background" level. Concentrations measured in the 1980 survey ranged from 0.029 to 0.042 µg/g in five largescale suckers caught in the upper North Arm. Concentrations were higher in livers than in muscle tissues measured in 1988, with mean values ranging from 0.029 µg/g in the peamouth chub to 1.13 µg/g in the northern squawfish.

The concentrations of di-n-octyl phthalate in muscle tissue of the majority of fish sampled in 1988 in the North Arm were below detection limits (0.01 µg/g wet-weight). Maximum concentrations ranged from 0.019 µg/g wet-weight in the muscle of largescale sucker to 0.18 µg/g wet-weight in the muscle of northern squawfish. Concentrations measured as part of the 1980 survey were considerably higher, with values in the North Arm ranging from 12 to 17 µg/g wet-weight. Di-n-octyl phthalate concentrations in liver tissues were detectable (>0.5 µg/g) in the northern squawfish in the North Arm (maximum concentration 0.5 µg/g). The high detection limit compared to that of muscle tissue (0.01 µg/g) did not allow for an assessment of potential accumulation in livers.

Mean concentrations of bis (2-ethylhexyl) phthalate in muscle tissue from the 1988 survey ranged from below detection limits (<0.01 µg/g wet-weight) in the starry flounder, threespine stickleback, and largescale sucker to 0.11 µg/g wet-weight in the northern squawfish. Values in excess of 0.094 µg/g were considered to exceed "maximum background" levels of contamination from the laboratory, therefore, many of the samples which had measurable concentrations less than this level may have been due to contamination from the laboratory or other sources. Concentrations in liver samples were much higher, with means ranging from below detection limits (<0.5 µg/g wet-weight) in the staghorn sculpin to 1.24 µg/g wet-weight in the northern squawfish.

Since phthalate esters are ubiquitous and no guidelines exist for them in the tissues of fish, no objectives are proposed.

6.4.4.2.4 PAHs

PAHs were measured as part of the 1988 survey only. Detectable concentrations in muscle tissues were present only in North Arm fish, due probably to the considerable stormwater runoff that this reach receives. PAHs were found in considerably more liver samples than muscle tissue despite the fact that detection limits for livers were five times those of muscle tissues for each compound. Therefore, it is likely that PAHs are accumulating in livers.

To protect consumers of fish and shellfish, an objective is proposed as follows: the maximum concentrations of benzo (a) pyrene in edible tissues should not exceed 4 µg/kg for consumers of up to 50 grams per week, 2 µg/kg for consumers of up to 100 grams per week, and 1 µg/kg for consumers of up to 200 grams per week.

6.4.4.2.5 Organochlorine Pesticides

The most commonly measured organochlorine pesticide in both muscle and liver tissues in 1988 were alpha- and gamma- chlordane, dieldrin, DDT, DDD, and DDE (Swain and Walton, 1989). Values appear to be lower than those measured in the 1972-73 survey (Garrett, 1980) and are not likely to be a serious environmental problem. Maximum values in muscle tissue were: 2.33 µg/g alpha chlordane from a staghorn sculpin; 1.77 µg/g gamma-chlordane, 6.98 µg/g DDD, and 18.4 µg/g DDE from a northern squawfish; and 2.1 µg/g dieldrin and 0.96 µg/g DDT from a largescale sucker.

6.4.4.2.6 Dioxins and Furans

Dioxins and furans were measured in fish collected upstream and downstream from the lower Fraser River mills (Scott Paper and Crown Packaging) as part of a study conducted in 1989 on concentrations of dioxins and furans in sediment and fish samples collected near pulp and/or paper mills in B.C. (Tuominen and Sekela, 1992). Fish were collected upstream from the paper mills near Hope and concentrations of dioxins and furans were compared to those in fish caught near Scott Paper and Crown Packaging. Levels of 2,3,7,8-T_4CDF and total T_4CDF measured in fish at both the upstream site and near the paper mills were similar. The dioxin 2,3,7,8-T_4CDD was detected in one fish (a peamouth chub) caught at the upstream site, at a concentration of 0.83 pg/g wet-weight. Draft tissue residue guidelines are applied on a lipid-weight basis, assuming that all of the compound is present in the lipids and converting this total body weight. On this basis, the total concentration was 13.8 pg/g, well below the draft CCME guideline of 50 pg/g for the protection of aquatic life. However, since these compounds are measurable in sediments in the north Arm and have the potential to enter the food chain, this draft guideline is proposed as the objective for dioxins and furans in fish.

6.4.4.3 General Fish Health

As part of a FREMP 1994 study of fish health in the Fraser River (FREMP, 1995), peamouth chub (*Mylocheilus caurinus*) were collected from four reaches of the Fraser River (the North Arm, Main Arm, Main Stem, and from a reference site near Mission), and starry flounder (*Platichthys stellatus*) were collected from sites in the North Arm and Main Arm. These fish were examined for general health, based on the frequency of various abnormalities and the presence of parasites.

On the basis of visual assessment, North Arm peamouth chub had a greater frequency of skin aberrations, thymus hemorrhage, kidney abnormalities, and hindgut inflammation than peamouth chub from other reaches. Similarly, Main Arm peamouth chub also had higher frequencies of kidney abnormalities than upper stream peamouth chub. North and Main Arm peamouth had the greatest number of kidney abnormalities by visual assessment. These conditions indicate poorer water quality in the North Arm compared to other reaches.

Further analysis for gill and spleen abnormalities by visual and histological means suggest that this evidence is inconclusive and qualifications are necessary. Peamouth chub sampled in the Mission reach had the highest prevalence of gill abnormalities by both visual and histological assessment. Main Stem chub had more spleen abnormalities by visual assessment, and Main Stem and Mission chub had a greater mean severity of spleen abnormalities by histological assessment. Finally, Main Arm flounder was slightly higher in spleen abnormalities than North Arm fish.

Concentrations of a number of contaminants in both starry flounder and peamouth chub were also analyzed in this report (FREMP, 1995). Composites were made of liver, muscle and bile samples from the fish to ensure sufficient material for accurate analysis. Muscle and bile samples from five fish were combined for each composite while livers from up to 50 fish were combined into a single sample. Muscle tissues from both species had a lower incidence of commonly detected contaminants than liver tissues. This may have been due to the lower fat content of muscle tissue or bioaccumulation in liver tissue.

Contaminants in Muscle Tissues

Contaminant concentrations were generally low in starry flounder muscle tissues. However, fat corrected concentrations of chlorinated hydrocarbons were significantly higher in Main Arm samples of starry flounder muscle than in fish from the North Arm. Chlorophenolic compounds and dioxins and furans were detected infrequently (1 of 46 and 0 of 22, respectively) in starry flounder muscle from either reaches. Trace metal (see FREMP,1995 for list of metals) concentrations were very similar in muscle samples from the two reaches.

North Arm peamouth chub muscle composites had the lowest concentration of the three co-planar PCBs. Within each reach, concentrations of individual PAHs were similar; however, between reaches, fish collected from North Arm had the highest concentrations. In contrast, while concentrations of trace elements within each reach was similar, the North and Main Arms had lower concentrations than did the Main Stem.

Contaminants in Liver Tissues

Of the 48 PCB congeners detected in starry flounder livers, all but three were present in higher concentrations in North Arm composites than Main Arm fish. Both of the chlorophenols detected in starry flounder livers (2,4,6 trichlorophenol and 3 chlorocatechol) were present in considerably higher concentrations in North Arm samples than Main Arm. Six 2,3,7,8-substituted dioxin/furan congeners were detected in starry flounder tissues at concentrations that were often as high or higher in North Arm than in Main Arm fish, though this trend was not significant. Five of the eight PAHs commonly detected in the liver composites were higher in the Main Arm samples than in the North Arm samples. Four of 12 pesticide residues detected were more concentrated in the North Arm than the Main Arm. Organic contaminants were consistently at higher concentrations in North Arm starry flounder liver composites; this reflects the higher concentrations of PCB congeners in the North Arm.

Of the seventy-two PCB congeners commonly detected in peamouth chub livers, there was a strong tendency for the highest concentration of any single congener to occur in the North Arm. In contrast, of the seven chlorophenols commonly detected, there was a tendency for North Arm composites to have the lowest concentration. Within each reach, individual congeners were found in similar concentrations, however, between reaches, peamouth chub liver composites collected from the North Arm had the highest concentrations of twelve 2,3,7,8 substituted dioxins and furans and seven PAH congeners frequently detected in peamouth chub (see FREMP, 1995 for list). Eighteen pesticide residues were commonly detected in peamouth chub livers; none differed significantly in concentration within each reach, but there was a significant tendency for concentrations to be higher in composites from the North Arm.

6.5 Fraser River Main Arm from the New Westminster Trifurcation to the Banks

For the purpose of this report, the Main Arm will be defined as the reach of the Fraser River between the trifurcation at New Westminster and the mouth of the river at Roberts Bank. Drinnan and Clark (1980) indicated that at the New Westminster trifurcation, 79% of the outfall enters the Annieville Channel, while 6% enters and Annacis Channel. The two channels again join downstream from Annacis Island to reform the Main Arm (Swain and Holms, 1985b). The river in this area can be influenced quite strongly by the tides and consequently has a varying salt concentration.

The Main Arm is in a heavily industrialized area and is used extensively. Boating and fishing are common activities in this area and several areas are permitted to flood for irrigation purposes. Furthermore, the Fraser is an important migratory route for at least twenty species of adult and juvenile salmon. Therefore, the water uses which should be protected in the Main Arm include irrigation , livestock watering, secondary-contact recreational uses, and the protection of sensitive aquatic life (Swain and Holms, 1985b).

6.5.1 Water Chemistry

There are eight sampling sites between the Trifurcation and the Mouth (Figure 10). Sites 0301308 and 0301311 are located in the Annieville Channel by Annacis Island. Sites E105892, E105893 and E207407 are located near the Lulu Island STP. Sites E207604 and E207605 are in the slower moving waters of Ladner Slough. Data from these sites are summarized in Tables 107, 108, 109, 110, 111, 112, and 113, respectively. Lastly, there is data collected by the Fraser River Estuary Management Program (FREMP) for the area around Tilbury (T-1 on map) from January of 1993 to January of 1994. Data will be compared to a 1985 report by Swain (1985) and two field reports from 1991 and 1993 (Beak Consultants Limited, 1991; Beak Consultants Limited, 1993).

6.5.1.1 pH and Alkalinity

The approved water quality criterion for pH is between 6.5-9.0. However, a Water Quality Objective for pH from 6.5 - 8.5 is proposed for the Main Arm from New Westminster to the Banks in order to minimize the quantities of un-ionized ammonia present in the river due to anthropogenic activity. Swain indicates the pH range from 1979-1982 was 6.8-8.6 with a median value of 7.8 (Swain and Holms, 1985b). SEAM data collected in the Main Arm from 1987 and 1988 is consistent with this, showing a range from 7.5 - 8.0. However in 1990 and 1991, pH values fell in a wide range from 6.4 - 9.5. Furthermore, at sites 0301308 and 0301311 located at Annacis island, 14 of the 44 samples taken had values greater than 9 or less than 7. The high values were found in August and the low values in March. This represents more than a thousand fold increase in pH from March to August. The possibility of an anthropogenic source causing this is highly improbable but no natural cause could be found either. A possible explanation is experimental or sampling error. Data collected in 1994 is again predictable with a range of 7.4 - 7.9 and a mean value of 7.67. Lastly, FREMP data collected at Tilbury showed a mean pH of 7.46.

There is no recent alkalinity data available from provincial sites but past reports from Swain (1985) give alkalinity ranges from 38.8 - 54.3 mg/L $CaCO_3$ with a mean value of 45.3 mg/L $CaCO_3$. This is similar to the 1993 FREMP data from Tilbury which recorded alkalinity values from 36.3 mg/L to 55.7 mg/L with a mean of 44.4 mg/L $CaCO_3$. Both data sets indicate a fairly good buffering capacity to acids but a very poor buffering capacity to alkaline discharges (Drinnan and Clark, 1980). This is confirmed by calcium concentrations well above the 8 mg/L criterion for mild acid sensitivity (Nagpal *et al*, 1995).

6.5.1.2 Hardness and Metals

With an average calcium concentration of 30.0 mg/L and an average magnesium concentration of 39.96 mg/L (SEAM 1985-), the calculated hardness was 238.76 mg/L $CaCO_3$. This value is much higher than the 45.9 mg/L $CaCO_3$ reported in 1985 (Swain and Holms, 1985b) and the 74.2 mg/L $CaCO_3$ reported from the Tilbury data. This may be due to salt water intrusion at the collection site and although the data are sparse, the few sites with correlated conductivity measurements seem to verify this assumption.

Calcium ranged in concentration from 11.4 mg/L to 164 mg/L with a mean value of 30.25 mg/L but only eight of 88 values were greater than 40 mg/L. Tilbury data are more consistent and without the extremely high values: it has a mean of 16.3 mg/L. The criteria state that calcium levels under 4 mg/L will make freshwater life extremely sensitive to acid inputs and concentrations between 4 mg/L and 8 mg/L will make them moderately sensitive (Swain, 1985). Therefore, according to the criteria, the Main Arm of the river should have a low sensitivity to acid when waters are non-saline. No water quality criterion has yet been developed for estuarine environments periodically impacted by tidal activity and salinity intrusions.

Magnesium was found in concentrations between 2.61 mg/L and 405.0 mg/L but with the exception of one value, all data greater than 16.5 mg/L were found at sites around Lulu Island. Likewise, only five of 48 values at Tilbury exceeded 7.0 mg/L. The values increase dramatically around Lulu Island, and some exceed the criterion for industry, which varies from 0.01 mg/L to 25 mg/L depending on the process (CCREM, 1987). However, magnesium has few health consequences and is not considered a primary toxicant.

Aluminum

The proposed maximum dissolved aluminum concentration for the protection of freshwater aquatic life (pH > 6.5) is 0.1 mg/L (Butcher, 1988); the 30-day average criterion is ≤0.05 mg/L. Total aluminum concentrations in this reach of the Fraser River are consistently in exceedance of these criteria. SEAM data collected since 1985 reveal concentrations ranging from 0.1 mg/L to 2.52 mg/L with a mean value of 0.95 mg/L. Data collected by FREMP from Tilbury in 1993 had a lower mean of 0.71 mg/L but this is still above the maximum and 30-day average criterion limits. These high values should be interpreted with caution because the monitoring program measured total aluminum concentrations while the criterion is set for dissolved aluminum.

Arsenic

Arsenic was found in trace amounts with means and maxima equal to or less than 0.05 mg/L (n=31). These values meet the proposed criterion of 0.05 mg/L for freshwater aquatic life (CCREM, 1987). No criterion has been developed for estuarine or marine aquatic life. The detection limit for the aforementioned study (0.04 mg/L) is too high for meaningful comparison of data with those from the 1985 survey where some values were below the detection limit of 0.02 mg/L. However, more precise data collected from Tilbury in 1993 shows arsenic levels between 0.0004 - 0.001 mg/L. This suggests that earlier data had levels lower than detection limits and were below criterion limitations.

Barium

Barium was found in concentrations ranging from 0.001 mg/L to 0.05 mg/L with an average mean of 0.017 mg/L (n=45). This is consistent with FREMP data from Tilbury. All values are within the criteria maximum, and 30-day average of 5 mg/L and 1 mg/L, respectively, for the protection of freshwater aquatic life (Haywood and Drinnan, 1983) and 0.5 mg/L for the protection of marine aquatic life (Nagpal, 1994).

Boron

Boron has a proposed criterion limit of 5 mg/L for the protection of marine aquatic life (National Academy of Sciences, 1972). Measured values were well below this level, ranging in concentration from less than 0.01 to 0.39 mg/L (n=31). These number are identical to data from 1980 - 1983 (Swain and Holms, 1985b).

Beryllium

The criterion for beryllium proposes that for concentrations under 0.0068 µg/L there is a risk level of only 1:1 000 000 to freshwater aquatic life (U.S. EPA, 1986). The beryllium concentrations measured were barely detectable with all concentrations measured below the 1 µg/L detection limit. The detection limit is too high to determine whether beryllium is within the criterion mentioned above but concentrations measured were below the chronic criteria of 5.3 µg/L for freshwater aquatic life (U.S. EPA, 1986). Furthermore, beryllium exists in levels below the marine criterion of 100 µg/L for minimal risk to aquatic life.

Bismuth

Bismuth was also barely detectable. All samples were found to have a concentration less than 0.02 mg/L. There is no proposed criterion, therefore, no comparison can be made.

Cadmium

All cadmium levels were below the detection limit of 10 µg/L, which is too high to determine whether concentrations meet the strictest criterion of 0.1µg/L for the protection of aquatic life in marine waters. More precise data are needed to determine whether cadmium is of concern in this reach.

Chromium

Chromium concentrations were below the detection limit of 0.02 mg/L. Data from Tilbury was more precise and levels were found to be even lower, with 34 of 38 values less than 0.001 mg/L. This is a decrease from the 0.007 mg/L average found before 1985 (Swain and Holms, 1985b). Criteria for chromium proposed for the protection of freshwater aquatic life are: 0.02 mg/L for fish and 0.002 mg/L for phyto- and zooplankton (CCREM, 1987). The criterion for the protection of marine aquatic life is a 4-day average concentration of 0.050mg/L chromium (VI) (Nagpal, 1994). All data available since 1985 meet the freshwater and marine criteria for the protection of fish but are not precise enough to ensure plankton are adequately protected.

Cobalt

All measurements were found in concentrations less than the detection limit of 0.1 mg/L. Tilbury values had a lower detection limit and concentrations were found to be less than 0.015 mg/L. The lowest reported level causing effects in freshwater aquatic life is 0.05 mg/L (NAS, 1972); although the provincial data has detection limits too high to ensure that this criterion is met, the Tilbury data (1993, 1994) does not indicate any problems. No criterion has been established for the protection of marine aquatic life from cobalt.

Copper

Copper concentrations ranged from less than 0.001 mg/L to 0.02 mg/L and have an average concentration of 0.003 mg/L (n=92) which is consistent with 1993 FREMP data from Tilbury. Comparison with previous data shows that although the range is the same, the average concentration has decreased slightly from 0.005 mg/L, recorded in the early 1980's (Swain and Holms, 1985b) to 0.003 mg/L recorded since 1985. The B.C. approved and working criteria for the protection of aquatic life in estuarine environments is a 30-day average concentration of 0.002 mg/L copper (Nagpal, 1994).

Although the concern for potential increases in copper is not as high as in the north Arm of the Fraser River, stormwater and STP discharges do take place to the Main Arm. The following Water Quality Objectives are therefore proposed for the protection of aquatic life. The maximum total copper concentration in the estuarine receiving environment should not exceed 3 µg/L, while in fresh water areas, it should not exceed the product of 0.094 (hardness) + 2 µg/L. Furthermore, the 30-day average copper concentrations should not exceed 2 µg/L in the estuarine environment or when water hardness is less than 50 mg/L, and in freshwater with water hardness greater than 50 mg/L should not exceed 0.04 (average hardness). The mean values apply to a minimum of five weekly samples collected over a thirty-day period while the maximums apply to discrete samples.

Iron

Total iron was found in concentrations ranging from 0.14 mg/L to 4.02 mg/L with a median value of 0.83 mg/L. The Tilbury data had a slightly higher mean of 1.07 mg/L but there was one extremely high value. If this value is excluded, the mean value is 0.75 mg/L. Both of the provincial SEAM median and the Tilbury average are lower than the 2.7 mg/L found between 1975 and 1980 (Swain and Holms, 1985b). Despite the decrease, values are still above criterion. The maximum total iron concentration for the preservation of freshwater aquatic life is 0.3 mg/L (CCREM, 1987), while marine organisms are considered to be at minimal risk when concentrations are no greater than 0.05 mg/L (NAS, 1972). Only seven of the 43 iron measurements taken at Tilbury and ten of the 76 taken from the provincial sites meet the more relaxed criterion for freshwater aquatic life. This information is difficult to interpret because both measured data and criteria are for total iron which includes iron associated with suspended sediment, a form which is not extracted by fish, without measurements for dissolved iron and iron precipitates which are bioavailable for uptake by fish. As such, the degree of concern attributable to criteria being exceeded is abstract. Further study is required to determine whether present iron concentrations threaten aquatic life in this reach of the Fraser River.

Lead

The only available lead data are from the 1993 FREMP study at Tilbury. The 39 values had a range from less than 0.001 mg/L to 0.004 mg/L with a mean of 0.0012 mg/L. The B.C. criterion for the protection of aquatic life from lead in an estuarine environment is a 30-day average concentration ≤0.002 mg/L lead. Although the mean concentration measured at Tilbury in 1993 was below criterion, there are some values that double it. As such, the following Water Quality Objective is proposed for lead in the Main Arm of the Fraser River from New Westminster to the Banks for the protection of estuarine aquatic life. The 30-day average concentration of total lead should not exceed 2 µg/L, that 80% of the values used to calculate the 30-day average must be ≤3 µg/L, and that the maximum value measured must be ≤140 µg/L. The 30-day average is calculated from at least five weekly samples taken in a period of 30 days (Nagpal, 1994). For freshwater situations, the average should be less than 3.31 + 1.273 exp (ln (average hardness) - 4.705 µg/L, while the maximum should be less than 1.273 exp (ln (average hardness) - 1.460 µg/L This objective applies outside of provisional initial dilution zones as described in Section 1.0.

Manganese

Manganese was found in concentrations between 0.019 mg/L and 0.132 mg/L with a mean concentration of 0.037 mg/L. Only three of 76 values exceed the 100 µg/L criterion for the protection of freshwater aquatic life (American Fisheries Society, 1979) and marine molluscs (Nagpal, 1995). Because the Main Arm can be heavily influenced by tidal action and salinity intrusion, and because manganese is expected in stormwater as a substitute for lead in gasoline, a Water Quality Objective is proposed for the protection of both freshwater and marine aquatic life: the concentration of manganese in the Main Arm should remain below 100 µg/L.

Mercury

Mercury was measured only at Tilbury during the 1993 FREMP survey. All concentrations were below the detection limit of 0.05 µg/L which is within the maximum allowed concentration of 2 μg/L for the protection of estuarine aquatic life but not precise enough to assure that the maximum allowable 30-day average of 0.02 μg/L is met (Nagpal, 1989).

Molybdenum

SEAM data for molybdenum indicate all concentrations were below the detection limit of 0.04 mg/L. More precise FREMP data (n=43) measured at Tilbury had all concentrations less than 0.001 mg/L. All values meet the 30-day average criterion of <1 mg/L and the maximum criterion of 2 mg/L for the protection of freshwater aquatic life (Swain, 1986a). No estuarine or marine criteria have been established for molybdenum.

Nickel

SEAM data for nickel values were all below detection limits that ranged from 0.008 mg/L to 0.05 mg/L while the FREMP survey found the average concentration at Tilbury to be 0.002 mg/L. Swain (1986c) reported data with a mean of 0.01mg/L. Although more recent SEAM data and FREMP data are not precise enough for comparison with the marine criterion of a 4-day average concentration of 0.0083 mg/L nickel, the values collected by Swain (1986c) indicate some exceedances. Nickel is not expected to increase in the Main Arm due to anthropogenic activities.

Potassium

Potassium concentrations range from 0.7 mg/L to 14.4 mg/L. This broad scope is due to the varying salt water intrusion in the samples and shows the effect of the tide on this section of the river. The tide has the greatest effect in January and February when flow rates are low (see section two: Hydrology). In freshwater, the concentration of potassium rarely reaches 20 mg/L and is generally below 10 mg/L (CCREM, 1987). Although potassium is not known as a threat to aquatic life, it must be recognized that watering supplies for livestock should not exceed 20 mg/L for the sanitation of dairy supplies (CCME, 1987). As discussed in Section 5.2, the stocking density of grazing animals is approximately four times greater than the density in the remainder of the basin (Boeckh *et al*., 1991 and Schreier *et al*., 1991); therefore, monitoring of potassium is recommended to ensure that the use of the lower Fraser River for livestock watering is not under-protected.

Silver

The BC marine criteria are 1.5 µg/L as an average and 3.0 µg/L as a maximum silver concentration (Warrington, 1996). The B.C. criterion for silver requires that water levels do not exceed 0.05 µg/L as a mean or 0.10 µg/L as a maximum (hardness < 100 mg/L) in order to protect freshwater aquatic life (Warrington, 1996). Unfortunately, the detection limits of the SEAM samples taken were too high to determine if these criteria were met. The measurements only show the concentrations to be either less than 0.03 mg/L or less than 0.01 mg/L, depending on the test used. In contrast, the data from Tilbury had a detection limit of 0. 1 µg/L and all but two of the 38 values were less than this detection limit. Further monitoring with adequate detection limits is recommended.

Sodium

Sodium concentrations at Annacis (Sites 0301308 and 0301311) ranged from 3.59 mg/L to 362.0 mg/L with only one of the nine values higher than 10.0 mg/L. The high value represents sea water intrusion at one time. Sodium values at Tilbury also tended to be variable, ranging from 2.0 -574.0 mg/L. Since the high sodium values were correlated to high specific conductance they are most likely due to salt water intrusion.

Zinc

All zinc data are taken from the 1993 FREMP monitoring data for Tilbury. The concentration ranged from 0.001 mg/L to 0.07 mg/L with a mean of 0.0078 mg/L. The draft maximum criterion for freshwater fish is 7 µg/L for water with hardness less than 90 mg/L (CCME draft, 1996). Only three of the 39 values exceeded this criterion. Marine criteria are more relaxed, requiring maximum zinc levels to be ≤10 µg/L (CCME draft, 1996). All available data met the marine criterion.

Since stormwater can increase zinc concentrations, a Water Quality Objective is proposed for zinc concentrations in the Main Arm. This objective is that the mean concentration of zinc in at least five samples measured in a 30-day period should not exceed 14 µg/L, and no single value should exceed 30 µg/L. These objectives apply to samples collected from outside of initial dilution zones only, as described in Section 1.0.

6.5.1.3 Dissolved Oxygen and Oxygen-Consuming Materials

Dissolved oxygen (DO) values were recorded at Sites 0301308 and 0301311 and ranged from 8.4 mg/L to 13.6 mg/L with five of the 20 values below 9.0 mg/L (SEAM, 1985). The average concentration for these two sites was 11.05 mg/L while the average concentration at Tilbury was 10.32 mg/L. In 1991, between September and October, five DO samples were taken at Sites 0301308 and 0301311 (up- and downstream from the Annacis discharge). The mean concentration was exactly the same (9.96 mg/L) for both sites (Beak Consultants, 1991). In 1992, samples were collected from the same sites in the same time period. Again, the values were exactly the same (8.7 mg/L) (Beak Consultants, 1993).

The Greater Vancouver Sewerage and Drainage District collected data from five sites in the Main Arm of the river in both 1990 and 1992. The 1990 data was collected approximately every two months from February to November. There was no significant difference in the mean concentrations between sites; values ranged from 8.6 mg/L to 12.7 mg/L. However, seasonal trends were apparent with the lowest value occurring in August and the highest in February. A similar situation was found in 1992. Values ranged from 9.3 mg/L to 12.4 mg/L but the mean values were similar at all sites. Again the low values were found in August and the highs in February.

Four sloughs were also measured in 1991, 1992, and 1993. Gundersen Slough, Eburne Slough, Ladner Slough, and Deas Slough all had surface DO concentrations between 8 mg/L and 9 mg/L. In 1992, the surface DO concentrations were between 9.4 mg/L and 9.8 mg/L; in 1993, DO concentrations were between 9.8 mg/L and 12 mg/L.

It seems that dissolved oxygen in the Main Arm is seasonal but stable, and in the Sloughs, dissolved oxygen concentrations are improving. However, the Main Arm of the Fraser River is heavily influenced by salinity intrusions which in turn, affect the bioavailability of dissolved oxygen and the oxygen requirements of fish. To maintain high oxygen concentrations, and using the criteria from Truelson (1997) as a basis, <u>a Water Quality Objective for the Main Arm is that the instantaneous minimum should not be less than 5 mg/L and the 30-day mean should not be lower than the higher of 80% saturation or 8.0 mg/L. In spawning areas where fish eggs are incubating or areas utilized by young</u>

fish, the Water Quality Objective is an instantaneous minimum of not less than 9 mg/L and a 30-day mean not lower than 11.0 mg/L (November to April).

6.5.1.4 Solids Turbidity and Colour

Criteria for suspended solids are given as a percentage of the natural background suspended solids. A ten percent increase in suspended solids above natural background levels is considered dangerous for aquatic life. Suspended solids upstream from Annacis island (Site 0301308) ranged from 5 NTU up to 70 NTU with an average concentration of 29 NTU. Suspended solids downstream from Annacis ranged from 4 NTU to 61 NTU with an average of 20 NTU. This shows a decrease in suspended solids concentrations downstream from the outfall. Furthermore, the overall solids are not significantly different from those found at Lafarge Cement (one kilometre downstream from Annacis) in 1980. There is, however, the potential for increases in suspended solids near discharges.

For this reason, a provisional Water Quality Objective for suspended solids in the Main Arm is proposed. This objective is that for waters where background levels ≤100 mg/L suspended solids, induced suspended solids concentrations should not increase by more than 10 mg/L. For waters where background levels exceed 100 mg/L, suspended solids concentrations must not increase by more that 10% of background levels..

There are no data available on turbidity or colour.

6.5.1.5 Nutrients

The criteria for ammonia are based on the pH, temperature, and salinity of the water. Generally, the lower the pH and temperature and the higher the salinity, the more ammonia can be tolerated without detectable toxic effects. Therefore, the most protective water quality criteria are set based on the highest pH (9.0) and temperature (18.9°C) data and the lowest salinity measures (10g/kg) for which criteria are available. The water quality criterion for total ammonia nitrogen are an average 30-day concentration ≤0.108 mg/L, calculated from at least five weekly samples within a 30-day period, while no single discrete sample taken from outside the initial dilution zone above the maximum concentration of 0.740 mg/L (Nagpal, 1994) for the protection of both freshwater and marine aquatic life within the Main Arm of the Fraser River.

All sites had very similar dissolved ammonia concentrations. The SEAM values measured since 1985 ranged from 0.005 mg/L to 0.196 mg/L with an average of 0.05 mg/L. Five sites in the Main Arm were tested for ammonia by the Greater Vancouver Sewerage and Drainage District in 1992. Concentrations ranged from 0.01 mg/L to 0.15 mg/L. Mean concentrations increased downstream from 0.045 mg/L upstream from the Annacis outfall near Gundersen Slough to 0.065 mg/L downstream from the Steveston area. The 1993 data from Tilbury had a lower average of 0.030 mg/L. Currently, the maximum concentration criterion is met. Mean concentrations appear to meet the 30-day average criterion, however, these mean concentrations may not be calculated according to the specifications required by the 30-day average criterion.

There are situations near discharges where ammonia concentrations can be a concern in the Main Arm, especially near the Annacis STP discharge, due to stagnant water conditions or other phenomena. As such, a Water Quality Objective is proposed for ammonia to protect aquatic life. The Objective is that the maximum and 30-day average ammonia concentrations should not exceed the concentrations listed in Tables 11 and 12 for the respective temperatures and pH values. The objectives apply to discrete samples, collected from outside of initial dilution zones of effluents.

The Annacis sewage treatment plant can have significant effects on the ammonia concentrations at times of stagnant water and tidal reversals. In order to protect fish health, a maximum and an average Water Quality Objective for nitrite related to the chloride concentration as shown in Table 13 is proposed. These values are consistent with uncontaminated sites upstream

Phosphorus data was only available for the Annacis sites (0301308 and 0301311) and the concentrations fell between 0.04 mg/L and 0.08 mg/L with an average value of 0.06 mg/L. Tilbury data was very similar with an average of 0.07 mg/L. However, there is no proposed criteria for phosphorus concentrations in streams. The values exceed the 0.005 - 0.015 mg/L criterion for lakes but this is not a good indicator because flow rates decrease the rate limiting effect of phosphorus on algal growth (Nordin, 1985).

6.5.1.6 Bacteriological Indicators

Fecal coliform criteria allow a maximum of 200 CFU/100 mL for general livestock use and a geometric mean of 200 CFU/100 mL for the irrigation of crops eaten raw (Warrington, 1988). Upstream from Annacis, fecal coliform counts ranged from 13 CFU/100 mL to 40600 CFU/100 mL and had a geometric mean of 195 CFU/100 mL. Downstream, the range was smaller (22 CFU/100 mL to 19700 CFU/100 mL) but the geometric mean was higher at 265 CFU/100 mL. The 1992 data from the Greater Vancouver Sewerage and Drainage District does not show an increase downstream at Annacis but does report higher values with upstream and downstream geometric means of 906 MPNs/100 mL and 886 MPN/100 mL, respectively. SEAM data also showed the Lulu Island plant with an increase in fecal coliform downstream from the site. The upstream count ranged from 33 CFU/100 mL to 800 CFU/100 mL with a geometric mean of 152 CFU/100 mL. The downstream site had counts up to 3600 CFU/100 mL and a geometric mean of 283 CFU/100 mL. The 1992 data from the Greater Vancouver District not only showed increases downstream from the plant but also showed considerably higher counts than recorded by SEAM. Geometric means up- and downstream from the Lulu Island discharge were 582 MPN/100 mL and 1850 MPN/100 mL. <u>In order to protect general livestock uses and all irrigation uses, a Water Quality Objective for the geometric mean of at least five samples collected in a 30-day period of 200 CFU/100 mL fecal coliforms is proposed for the period from April to October.</u>

Escherichia coli (*E. coli*) was tested up- and downstream from the Annacis sewage treatment plant and upstream from Lulu Island. There were no significant changes in the *E. coli* count downstream from the Annacis outfall. Maximum counts were 71 CFU/100 mL both upstream and downstream and geometric means were 43 CFU/100 mL upstream and 48 CFU/100 mL downstream. The Lulu Island plant had higher values with a maximum of 190/100 mL and a geometric mean of 93 CFU/100 mL upstream. No downstream data are available for comparison. All values meet the maximum criterion of 200 CFU/100 mL for general livestock use although disinfection (10 CFU/100 mL 90th percentile) or partial treatment (100 CFU/100 mL 90th percentile) of the water would be required to make it suitable for closely confined animals (Warrington, 1988). The site upstream from Lulu Island exceeds the criterion of 77 CFU/100 mL (geom. mean) for the irrigation of crops eaten raw (Warrington, 1988). <u>In order to protect general livestock uses and all irrigation uses, the following Water Quality Objectives have been set for *E.*</u>

coli in the Main Arm: the geometric mean calculated from at least five discrete samples is not to exceed 77 CFU/100 mL in the period from April to October.

Enterococci counts had similar results. At Annacis, maxima were 21 CFU/100 mL upstream and 24 CFU/100 mL downstream while geometric means were 14 CFU/100 mL upstream and 18 CFU/100 mL downstream. Values upstream from Lulu Island were higher than at Annacis. Maximum values reached 100 CFU/100 mL while the geometric mean was 30 CFU/100 mL. No downstream values were available. Annacis meets the maximum criterion of 50 CFU/100 mL for general livestock use but Lulu Island does not (Warrington, 1988). Partial treatment (25 CFU/100 mL 90th percentile) may be required for closely confined animals at both sites. Again Lulu Island exceeds the criterion of 20 CFU/100 mL (geom. mean) for the irrigation of crops eaten raw (Warrington, 1988). In order to protect general livestock uses and all irrigation uses, the following Water Quality Objectives have been set for *Enterococci* in the Main Arm: the geometric mean calculated from at least five discrete samples is not to exceed 20 CFU/100 mL in the period from April to October..

Coliform counts are fairly high in the river even before the sewage treatment plants with values increasing towards the mouth. Annacis shows no significant changes *in E. coli* or *Enterococci* downstream from the outfall. There appear to be increases in the fecal coliform counts downstream from both plants although increases downstream from Lulu Island are more pronounced. Effluent counts were as high as 160 000 000 CFU/100 mL and at maximum output and low flows, dilution may only reach 245 399 CFU/100 mL (see Section 4). The Lulu Island STP is in the planning stages of upgrading to a secondary treatment facility but the completion date for the process has not been set (Ellis, 1995 pers. com.).

6.5.1.7 Organics

Organics were collected in the water column at the mid-river section in the Main Arm at Tilbury Slough, and at three sloughs monitored by FREMP in 1993/1994. The sloughs were Ladner, Deas, and Gundersen.

6.5.1.7.1 Chlorophenolics

Chlorophenol bioavailability is heavily influenced by salinity. Some water quality criteria have been developed for estuarine conditions, however, the development is not comprehensive.

All measured concentrations of 4-monochlorophenol were less than minimum detection limits of 0.001 µg/L, well below the interim water quality criterion for aquatic life of 0.7 µg/L to prevent toxicity. Therefore, 4-monochlorophenol concentrations are not a concern in the Main Arm.

Concentrations of di-, tri-, and tetrachlorophenols were usually below the detection limit of 0.001 µg/L, and maximum concentration of 2,4,6-trichlorophenol (0.004 µg/L) 2,3,4,6-tetrachlorophenol (0.004 µg/L), and pentachlorophenol (0.006 µg/L) measured at the FREMP Tilbury Island site were well below the water quality criteria (0.12, 0.04, and 0.02 µg/L, respectively) for the protection of aquatic life from toxicity (Warrington, 1993). This was also the case for the majority of compounds measured in the three sloughs. Since high concentrations of chlorophenols were not measured in the water column and since the use of chlorophenols is decreasing, ensuring protection of water quality will use water quality objectives for other environmental compartments.

The concentrations for most guaiacols and catechols were below the detectable limits of 0.002 µg/L at the Tilbury site. The compounds present in highest concentrations as was the case for the North Arm were 4,5-dichloroguaiacol (0.013 µg/L), and 3,4,5-trichlorocatechol (0.012 µg/L). No water quality criteria exist for these compounds**.** As such, it cannot be concluded at this time whether any water uses are not protected; however the fact that these compounds were in similar concentrations in both the North Arm and Main Arm implies that their source is upstream from the trifurcation..

6.5.1.7.2 Resins and Fatty Acids

Two concentrations of linoleic acid at the Tilbury site were 0.5 µg/L and 0.9 µg/L. Oleic, palmitric and stearic acids were present in measurable amounts at the Tilbury site, with maximum concentrations of 1.8 µg/L, 3.3 µg/L and 3.4 µg/L, respectively. These three fatty acids were also present in the February 1993 surface samples collected from Deas and Ladner sloughs.. No water quality criteria have been set for any of these acids; therefore, evaluation of the possible effects of these concentrations is not possible at the present time.

All concentrations of the anti-sapstain compound TCMTB at Tilbury and in the sloughs were less than the detection limit of 5 µg/L. No water quality criterion exists for this compound, but the most sensitive 96 hour LC50 was 15 µg/L for Chinook salmon (Hanssen *et al*., 1991) and values are well below this threshold so it does not appear that TCMTB is of concern in the Main Arm.

6.5.1.7.3 Organochlorine Pesticides and PCBs

All concentrations of organochlorine pesticides were below detection limits at both the Tilbury site and the three slough sites.

6.5.1.7.4 Polyaromatic Hydrocarbons (PAHs)

Polyaromatic hydrocarbons can enter the Main Arm through stormwater runoff or combined sewer overflows near the trifurcation. These were tested only in the three sloughs. The highest concentrations of LPAH, HPAH, and TPAH were recorded in Gundersen Slough at concentrations of 1.1 µg/L, 0.6 µg/L, and 1.1 µg/L, respectively. Pyrene was present in both Ladner and Gundersen sloughs at maximum concentrations of 0.03 and 0.14 µg/L, respectively, above the water quality criteria of 0.02 and 0.01 µg/L to prevent both chronic and photo-toxic effects on freshwater aquatic life (Nagpal, 1993 (b)). No criteria were recommended for the protection of marine aquatic life due to insufficient data.

Gundersen Slough also had measurable concentrations of benzo (a) pyrene (0.02 µg/L) and phenanthrene (0.37 µg/L) which exceeded water quality criteria of 0.01 µg/L for each characteristic. The PAH most frequently exceeding criteria (0.02 µg/L) was pyrene with maxima of 0.03 µg/L in Ladner Slough and 0.14 µg/L in Gundersen Slough.

In summary, all PAHs were within criteria except for pyrene, benzo (a) pyrene and phenanthrene, which were present in amounts which met or exceeded the water quality criterion at both Ladner and Gundersen sloughs.

6.5.2 Sediment Chemistry

There were SEAM data collected since 1985 from Sites 0301308 and 0301311 at Annacis, from E105892 and E105893 at Lulu Island, from E206969 (MA-1) at Upper Annacis Channel, from E206970 (MA-2) at Ewen Slough and from E207624 at Deas Slough. These data are summarized in Tables 114, 115, 116, 117, 118, 119, and 120, respectively. The most complete analysis was done for Sites E206969 and E206970 and data from these sites may be extrapolated to other areas when applicable. Additional information is available from FREMP reports for 1987, 1989, 1990, and 1992 as well as a 1985 survey by Swain (1986c), a survey by Harding *et al.* (1988), and the report of Sediment Testing of the Navigation Channel (1994). The 1992 report tested Annacis and Ewen Slough in February and March. Annacis Channel was tested again in May 1992 to determine seasonal variation. All the values taken in May were about the same or lower than the values collected in February except where specifically mentioned. The FREMP reports are most easily compared because of similar particle size (72 -100% silt). The 1994 report will be looked at only for trends because sediments collected were taken from the navigation channel, not the sloughs, and the particle distribution is primarily (96%) sand, not silt. This makes contaminant levels look deceptively low.

The following table gives the percentage of silt and clay in the samples for the years being compared. Silt and clay have been grouped together for convenience. They are defined as particles < 0.063 mm or as particles that will pass through a 270 mesh filter (0.053 mm). Sediments from the 1994 report were not taken from the same sites as the other surveys. The relationships between sediment size and metal concentrations are shown in Figures 15 and 16.

% Silt and Clay (270 mesh)

Site	1985	1987	1989	1990	1992	1994
Annacis Channel	97.63	79.46	99.9 are < 0.074	N/S	72.4	1.6*
Ewen Slough	93.6	80.85	99.9 are < 0.074	83.3	75.5	3.0**

* Sites 18 and 19 from the 1994 report
** Sites 4, 5, and 6 from the 1994 report

6.5.2.1 Metals

Aluminum

Between 1985 and 1994, SEAM data reported higher aluminum concentrations at the Annacis Channel (Site 206969: 12 060 µg/g) than downstream at Ewen Slough (Site 206970: 13 610 µg/g). Previously, the 1985 survey by Swain (1986c) showed higher average aluminum concentrations at Annacis Channel (13 400 µg/g) and lower concentrations at Ewen Slough (12 933 µg/g). It is apparent that current values for samples collected from the Main Arm are greater than those from the North Arm, which in turn, are greater than those from the Main Stem. This spatial trend in aluminum concentrations follows the spatial trend for silt content. There appears to be a correlation between higher aluminum content and a higher proportion of small particles to which aluminum has greater surface area to adhere. There are currently no aluminum criterion established for the evaluation of aluminum values in sediment.

Aluminum Concentrations (µg/g) in Main Arm Sediment

Year	Upstream Annacis Channel	Downstream Ewen Slough	References
1985-1994	12 060	13 610	SEAM (1985-1994)
1985	13 400	12 933	Swain, 1986c
Criterion	None		

Arsenic

Arsenic was undetectable in 1985 (Swain, 1986c), 1987 (Swain and Walton, 1988) and 1992 (Swain and Walton, 1993a) when the detection limits were 25 µg/g, 30 µg/g and 25 µg/g, respectively. The survey by Harding *et al.* (1988) also reported undetectable arsenic concentrations in 1985 and 1986 at Ewen Slough with detection limits of only 8 µg/g when the silt concentrations for the samples were lower (32.8% and 50.4% for 1985 and 1986, respectively). SEAM data since 1985 gives median values of <30 µg/g at Site E206969 and Site E206970. FREMP reports from 1989 and 1990 show considerably lower levels. The mean concentrations in 1989 were 5.93 µg/g (Annacis) and 6.94 µg/g (Ewen Slough) (Swain and Walton, 1990). This is comparable to the 1990 mean value of 6.5 µg/g at Ewen Slough (Swain and Walton 1991). Both reports relate an increase in concentration downstream to smaller particle size. However, the 1990 report also shows that concentrations increase downstream even when similar size particles are compared (Swain and Walton, 1991). For particles < 0.063, concentrations increased from 4.27 µg/g in the Main Stem to 7.83 in the Main Arm (Swain and Walton 1991). The 1994 data also showed increases downstream but they were not as pronounced. Concentrations of 3.27 µg/g upstream increased to 4.024 µg/g downstream, although the concentrations were also much lower overall compared to previous years (Akhurst, 1994). The Canadian draft interim sediment quality guidelines are: 5.90 µg/g TEL for freshwater and 7.24 µg/g for marine environments (Environment Canada, 1995). Most values with low enough detection limits, met the B.C. lowest-effects level criterion of 6 µg/g for freshwater. This is most likely due to the larger particle size and faster flow where the samples were collected. Generally, arsenic does not appear to be increasing however, the higher downstream values may not be due entirely to smaller particle sizes.

Arsenic Concentrations (µg/g) in Main Arm Sediment

Year	Upstream/ Annacis Channel	Downstream/ Ewen Slough	References
1985	<25	<25	Swain, 1986c
1985		<8	Harding *et al.*, 1988
1986		<8	Harding *et al.*, 1988
1987	<30	<30	Swain and Walton, 1988
1989	5.93	6.94	Swain and Walton, 1990
1990		6.50	Swain and Walton, 1991
1992	<25	<25	Swain and Walton 1993a
1994	3.27	4.024	Akhurst, 1994
1985-1994	<30	<30	SEAM, 1985-1994
Guidelines	Freshwater: 5.90TEL		Environment Canada, 1995
	Marine: 7.24 TEL		Environment Canada, 1995
Criterion	Freshwater : 6.0		Nagpal, 1994

Barium

The 1985 survey reported that barium concentrations decreased downstream toward the mouth. Mean values ranged from 111.7 µg/g at Annacis Channel to 74 µg/g at Ewen Slough further downstream (Swain, 1986c). A similar trend was observed in the 1987 report when mean concentrations ranged from 102.9 µg/g to 69.7 µg/g at the same sites (Swain and Walton, 1988). SEAM data concurred. Site E206969 at Annacis Channel had a mean concentration of 103 µg/g and downstream, at Site E206970 (Ewen Slough), the mean concentration was reduced to 70 µg/g. However, data from 1994 shows no such trend. Mean values taken at 19 sites on the Main Stem vary randomly from 49.4 µg/g to 104 µg/g. In fact, the highest value (104 µg/g) was found close to the mouth while the lowest value (49.4 µg/g) was found approximately 3.25 km downstream from Annacis Island (Akhurst, 1994). The differences in the 1994 survey make comparisons difficult. All other data show a definite downstream decrease that is most likely due to tidal influences rather than particle size distribution. No criteria are currently available for evaluation of the data.

Mean Barium Concentrations (µg/g) in Main Arm Sediment

Year	Upstream/ Annacis Channel	Downstream/ Ewen Slough	References
1985	111.7	74	Swain, 1986c
1987	102.9	69.7	Swain and Walton, 1988
1994	49.4	104	Akhurst, 1994
1985-1994	103	70	SEAM, 1985-1994
Criterion	None proposed		

Boron and Beryllium

Boron and Beryllium were only reported in the 1985 survey and both were below the detection limit of 1 µg/g (Swain, 1986c). No criteria exist for these metals.

Cadmium

Cadmium concentrations in the sediment have remained essentially the same. All sediment samples from 1985 at Annacis Island had cadmium concentrations of 0.35 µg/g while the downstream site at Ewen Slough had slightly higher values ranging from 0.35 µg/g to 0.40 µg/g; there is no obvious relationship to particle distribution (Swain, 1986c) The 1986 data from Ewen Slough shows a similar value of 0.24 µg/g (Harding *et al.*, 1988). The SEAM data collected between 1985 and 1994 had a mean concentration of 0.30 µg/g. FREMP samples from 1987 had undetectable concentrations when the detection limit was 0.30 µg/g (Swain and Walton, 1988). The 1989 survey had a lower detection limit than 1987 and recorded mean concentrations of 0.30 µg/g at Annacis Channel and 0.26 µg/g at Ewen Slough (Swain and Walton, 1990). The 1990 survey reported a correlation between particle size and concentration. In the Main Arm, cadmium concentrations of 0.55 µg/g were found in sand (particle size 0.063- 2 mm) compared to 0.58 µg/g in silt and clay (particle size < 0.063 mm) from the same site. Furthermore, the report described a trend of increasing concentration downstream when particles of similar size were compared. Silt from the Main Stem had a mean concentration < 0.25µg/g while further downstream, Main Arm silt had a mean concentration of 0.58 µg/g (Swain and Walton 1991). Similarly, the 1992 survey by Swain and Walton (1993a) found that samples taken at Annacis had an average concentration of 0.13 µg/g while further downstream at Ewen Slough, samples had a mean of 0.20 µg/g. These values are lower than those reported in previous years.

Nijman and Swain (1990) have proposed a Water Quality Objective for cadmium in sediments from Burrard Inlet of a maximum of 1.0 µg/g (dry-weight) (Nijman and Swain, 1990). This objective would easily be achieved if applied to the lower Fraser River. All values meet the 0.6 µg/g lowest-effects criterion for freshwater (Jaagumagi, 1992b) and the draft interim marine sediment quality guidelines TEL of 0.676 µg/g (Environment Canada, 1995).

Cadmium Concentrations (µg/g) in Main Arm Sediment

Year	Upstream/ Annacis Channel	Downstream/ Ewen Slough	References
1985	0.35	0.35-0.40	Swain, 1986c
1986		0.24	Harding *et al.*, 1988
1987	<30	<30	Swain and Walton, 1988
1989	0.30	0.26	Swain and Walton, 1990
1990		0.55	Swain and Walton, 1991
1992	0.13	0.20	Swain and Walton 1993a
1985-1994		<30	SEAM, 1985-1994
Guideline	Marine: 0.676 (draft)		Environment Canada, 1995
Criterion	Freshwater: 0.60 for lowest effects		Jaagumagi, 1992b
Objective	Burrard Inlet: 1.0		Nijman and Swain, 1990

Chromium

According to Swain (1986), finer sediments in the Main Arm are responsible for the higher chromium concentrations of about 36 µg/g compared to 31 µg/g found in the Main Stem (Swain, 1986c). This trend can also be applied to sites within the Main Arm; sites closer to the mouth have both higher silt percentages and higher chromium concentrations. The SEAM data agree with this generalization, with mean values of 36 µg/g at Annacis and 40.2 µg/g downstream at Ewen Slough. The values and trends are similar to those reported in the 1987 FREMP survey (29.6 µg/g at Annacis and 34.8 µg/g at Ewen Slough). However, later FREMP reports have much higher values. The 1989 survey had mean values of 53.3 µg/g at Annacis 50.9 µg/g at Ewen Slough and reported that these values may even be low and inaccurate (Swain and Walton, 1988). In 1990, the mean concentration at Ewen Slough was 54.8 µg/g (Swain and Walton 1991). The 1992 report has values even higher with mean concentrations of 65.48 µg/g at Annacis and 54.92 µg/g at Ewen Slough (Swain and Walton, 1993a). Most values exceed the lowest-effects level criterion of 26 µg/g for freshwater (Jaagumagi, 1992b) but meet the low range effects criterion of 80 µg/g for saline waters (Nagpal, 1994). It is possible that some of the initial increases from 1987 to 1989 were due to a change in the laboratory doing the analysis but values appear to have risen after the change as well.

The 1994 data from the Main Stem had a wide range from 20.7 µg/g to 52.6 µg/g and a mean of 33.3 µg/g (Akhurst, 1994). This mean is similar to those reported in 1986 and 1987; however, the particle size was almost entirely sand in the 1994 report and almost all silt in the earlier studies. Therefore, values would be expected to be lower. Furthermore, the 1994 sites were taken in the navigation channel where higher flow rates and lower values were expected. Generally, the chromium concentrations have increased since 1987.

Chromium Concentrations (µg/g) in Main Arm Sediment

Year	Upstream/ Annacis Channel	Downstream/ Ewen Slough	References
1985	36	31	Swain, 1986c
1987	29.6	34.8	Swain and Walton, 1988
1989	53.3	50.9	Swain and Walton, 1990
1990		54.8	Swain and Walton, 1991
1992	65.48	54.92	Swain and Walton, 1993a
1985-1994	36	40.2	SEAM, 1985-1994
Criteria	Freshwater: 26 (lowest effects), 110 (severe effects)		Nagpal, 1995
	Marine: 80 for low range effects		Nagpal, 1995

It has been documented in the past that large quantities of chromium could be discharged through the Lulu STP. Given this possibility, and the high chromium concentrations in the sediments, <u>a long-term Sediment Quality Objective of 26 µg/g chromium (maximum) is proposed for the protection of freshwater aquatic life.</u>

Cobalt

The 1985 survey (Swain, 1986c) reports no significant trends in cobalt concentrations with mean values from 15 to 18 µg/g and no relationship to particle size

(Swain, 1986c) The 1987 values were all at the detection limit of 10 µg/g (Swain and Walton, 1988). All SEAM values were also less than the detection limit of 10 µg/g. The 1992 survey had significantly higher values of 19.80 µg/g at Annacis and 17.98 µg/g at Ewen Slough even though the particle distribution and season was similar to those in 1987 (Swain and Walton, 1993a). The increase may be due in part to a change in the laboratory doing the analysis.

Cobalt Concentrations (µg/g) in Main Arm Sediment

Year	Upstream/ Annacis Channel	Downstream/ Ewen Slough	References
1985	15-18		Swain, 1986c
1987	<10	<10	Swain and Walton, 1988
1992	19.8	17.98	Swain and Walton 1993a
1985-1994	<10	<10	SEAM, 1985-1994
Criterion	None proposed		

Copper

Stancil (1980) reported copper concentrations ranging from 17 to 19.6 in 1979. As such, the significant increase in copper levels measured in 1985 raised concern that there was a potential new source of copper to the river (Swain, 1986c). However, copper concentrations in the Main Arm have increased only slightly since 1985. The 1985 survey had mean concentrations of 39 µg/g at Annacis and 41.7 µg/g at Ewen Slough (Swain, 1986c). In 1987, the means of 33 µg/g and 42 µg/g at Annacis Channel and Ewen Slough, respectively (Swain and Walton, 1988), while in 1989, concentrations were 42.5 µg/g and 41.7 µg/g, respectively (Swain and Walton, 1990). In 1990, the average concentration was 40.5 µg/g at Ewen Slough (Swain and Walton 1991) and in 1992, the concentrations were 41.6 µg/g and 41.5 µg/g at Annacis Island and Ewen Slough, respectively (Swain and Walton, 1993a).

SEAM data collected between 1985 and 1994 report similar numbers as in 1986 with mean values of 33.6 µg/g at Annacis Channel and 38.8 µg/g at Ewen Slough. The 1994 values were lower however, the range was wider; values ranged from 11.1 to 17.7 µg/g with the exception of one value at FR 3A (located at the mouth) of 32 µg/g (Akhurst, 1994). The lower values are likely due to the larger particle sizes found near the mouth of the river. Most values exceed the lowest-effects level of 26 µg/g for freshwater (Jaagumagi, 1992b) but all values meet the low range effects criterion for marine environments. The concentrations measured are also in excess of the Canadian draft interim guidelines TELs of 35.7 µg/g for freshwater and 18.7 µg/g for marine environments (Environment Canada, 1995).

Nijman and Swain (1990) have proposed a Water Quality Objective for copper in sediments from Burrard Inlet of a maximum of 100 µg/g (dry-weight) (Nijman and Swain, 1990) while Swain (1989) proposed a long term objective of 30 µg/g for the Brunette River system (Swain, 1989). While copper concentrations measured in the Main Arm of the Fraser River would meet the Burrard Inlet site-specific objectives, they exceed the Brunette River site-specific objectives. No sediment quality objective is proposed at this time for the Main Arm of the Fraser River because copper concentrations have remained relatively constant and consistently meet the marine criterion for protection of aquatic life from low range effects. Because no estuarine criteria are available, the marine criterion is considered the most appropriate restriction with which to evaluate sediment of the Main Arm which is regularly impacted by salinity intrusion.

Copper Concentrations (µg/g) in Main Arm Sediment

Year	Upstream/ Annacis Channel	Downstream/ Ewen Slough	References
1979	17.0	19.6	Stancil, 1980
1985	39	41.7	Swain, 1986c
1987	33	42	Swain and Walton, 1988
1989	42.5	41.7	Swain and Walton, 1990
1990		40.5	Swain and Walton, 1991
1992	41.62	41.46	Swain and Walton 1993a
Guidelines	Freshwater: 35.7 TEL (draft)		Environment Canada, 1995
	Marine: 18.7 TEL (draft)		Environment Canada, 1995
Criteria	Freshwater: 26 for lowest effects level		Jaagumagi, 1992b
	Marine: 70 for low range effects		Nagpal, 1994
Objectives	Burrard Inlet: 100 (dry-weight)		Nijman and Swain, 1990
	Brunette River: 30 (long term objective)		Swain, 1989

Iron

The 1985 survey revealed that iron concentrations in the Main Arm were approximately 31 000 µg/g (Swain, 1986c). SEAM data collected since 1985 showed a slightly lower means of 28 600 µg/g at Annacis and 30 373 µg/g at Ewen Slough. The

1987 means of 24 830 µg/g and 27 830 µg/g at respective sites, appear lower but are comparable when particle size is considered (Swain and Walton, 1988). The 1989 and 1990 values show large increases which may be due in part to higher silt percentages or differences in analytical laboratory techniques. The 1989 values for Annacis and Ewen Slough were 38 025 µg/g and 35 460 µg/g, respectively (Swain and Walton, 1990). The total concentration in 1990 for Ewen Slough was 36 800 µg/g (Swain and Walton 1991) which represents a large downstream increase from the Main Stem (28 800 µg/g) even when particles of the same size were compared. For silt particles, concentrations were 29 400 µg/g in the Main Stem , 36 100 µg/g in the North Arm and 46 300 µg/g in the Main Arm (Swain and Walton 1991). Values do not appear to be increasing but there is some evidence that there is a true downstream increase in iron concentrations. All means exceed the lowest-effects level criterion of 21 200 µg/g and indicate a consistent increase with time. More research is required to determine the cause of these high values.

Iron Concentrations (µg/g) in Main Arm Sediment

Year	Upstream/ Annacis Channel	Downstream/ Ewen Slough	References
1985	31, 000		Swain, 1986c
1987	24, 830	27, 830	Swain and Walton, 1988
1989	38, 025	35, 460	Swain and Walton, 1990
1990		36, 800	Swain and Walton, 1991
1985-1994	28, 600	30, 373	SEAM, 1985-1994
Criterion	Freshwater : 21, 200 for lowest effects		Nagpal, 1994

Lead

Lead values collected in the Main Arm in 1985 had means of 21 µg/g at Annacis Channel and 23.7 µg/g at Ewen Slough (Swain, 1986c). Since 1985, values have been steadily declining. In 1987, values were 16.7 µg/g and 17.1 µg/g (Swain and Walton, 1988). In 1989, they were 11.7 µg/g and 10.8 µg/g at Annacis Channel and Ewen Slough, respectively (Swain and Walton, 1990). In 1990, the total dry-weight concentration at Ewen Slough was 13.2 µg/g (Swain and Walton 1991) and in 1992, mean values were 8.4µg/g at Annacis Channel and 8.34 µg/g at Ewen Slough (Swain and Walton, 1993a). The decrease has occurred regardless of the differences in particle size, the season in which samples were collected, the number of replicates, and the change of laboratories between 1987 and 1989. This decrease has been attributed to the phasing-out of leaded gasoline and its total elimination in 1990. The 1994 lead concentration in the Main Arm ranges from 2.5 µg/g to 6.8 µg/g with a mean concentration of 3.6 µg/g (Akhurst, 1994). Due to the large sand percentage, the decrease may appear greater than it actually is. All means meet the lowest-effects criterion of 31 µg/g for freshwater (Jaagumagi, 1992b) and the Canadian draft interim guideline TEL of 30.2 µg/g for marine sediments (Environment Canada, 1995).

Nijman and Swain (1990) proposed a Water Quality Objective of 30 µg/g for lead in sediments of Burrard Inlet (Nijman and Swain, 1990). Swain (1989) proposed an objective of 5 µg/g for the Brunette River (Swain, 1989). If these objectives were applied to the lower Fraser River, the objective for Burrard Inlet would easily be achieved, while the objective for the Brunette River would not. No Water Quality Objective is proposed for lead at this time since it is expected that values will continue to decline until an equilibrium is reached which reflects levels closer to natural background.

Lead Concentrations (µg/g) in Main Arm Sediment

Year	Upstream/ Annacis Channel	Downstream/ Ewen Slough	References
1985	21	23.7	Swain, 1986c
1987	16, 667	17.143	Swain and Walton, 1988
1989	11.7	10.8	Swain and Walton, 1990
1990		13.2	Swain and Walton, 1991
1992	8.4	8.34	Swain and Walton 1993a
Guideline	Marine: 30.2 TEL (draft)		Environment Canada, 1995
Criterion	Freshwater: 31 for lowest effects		Nagpal, 1994
Objectives	Burrard Inlet: 30		Nijman and Swain, 1990
	Brunette River: 5		Swain, 1989

Manganese

Mean manganese values from SEAM data collected between 1985 and 1994 were 590 µg/g and 591 µg/g at Annacis Channel and Ewen Slough, respectively. These data do not suggest a correlation to particle size. Very similar values were found for all the FREMP data. In 1987, the averages of concentrations measured at the Annacis Channel and Ewen Slough were: 542.2 µg/g and 624.9 µg/g, respectively (Swain and Walton, 1988) and in 1989, they were 709 µg/g and 522.6 µg/g, respectively (Swain and Walton, 1990). In 1990 at Ewen Slough, the mean was 626 µg/g for total sediments and 842 µg/g for silt (Swain and Walton 1991). The 1992 values were: 675.4 µg/g for Annacis Channel and 562.6 µg/g for Ewen Slough (Swain and Walton, 1993a). All means exceed the lowest-effects level of 460 µg/g (Jaagumagi, 1992b). However, the values have not changed greatly over time and do not seem to be linked to particle size. Their unchanging nature is an indication of background levels. As such, no Water Quality Objective is proposed for manganese.

Manganese Concentrations (µg/g) in Main Arm Sediment

Year	Upstream/ Annacis Channel	Downstream/ Ewen Slough	References
1987	542	624.9	Swain and Walton, 1988
1989	709	522	Swain and Walton, 1990
1990		626	Swain and Walton, 1991
1992	675.4	562.6	Swain and Walton 1993a
1985-1994	<30	<30	SEAM, 1985-1994
Criterion	Freshwater : 460 for lowest effects		Jaagumagi, 1992b

Mercury

Swain (1986c) notes that in samples collected in 1985, mercury concentrations increased significantly from the undetectable levels (varying detection limits) reported by Stancil in 1980 (Swain, 1986c; Stancil, 1980). This suggests the influence of an upstream mercury source. SEAM data collected between 1985 and 1994 slightly exceeds Swain's data, giving mean values of 0.067 µg/g at Annacis Channel (Site E206969) and 0.074 µg/g at Ewen Sough (Site E206970). The 1986 and 1989 reports have similar particle distribution making them easy to compare. For Annacis Channel and Ewen Slough, the mean concentrations are 0.06 µg/g and 0.07 µg/g in 1985 (Swain, 1986c) and 0.057 µg/g and 0.061 µg/g in 1989 (Swain and Walton, 1990). Reports from 1987, 1990, and 1992 may be similarly compared. Their respective mean concentrations are 0.071 µg/g, 0.070 µg/g and 0.05 µg/g for Annacis Channel and 0.08 µg/g, 0.061 µg/g and 0.05 µg/g for Ewen Slough (Swain and Walton, 1988, 1991 and 1993). This may indicate a decrease in mercury concentration since 1985. The 1994 data are lower. The first three of the 19 sites tested in the Main Arm were located around the mouth and had mercury concentrations of 0.34 µg/g, 0.57 µg/g and 0.53 µg/g (Akhurst, 1994). With the exception of these three sites, all values are fairly consistent with a mean concentration of 0.031 µg/g (Akhurst, 1994). Because of the difference in particle distribution and site location, it is difficult to conclude whether this is a true decrease. With the exception of some 1994 data, all values meet the lowest-effects freshwater criterion of 0.2 µg/g (Jaagumagi, 1992b), the low range effects marine criterion of 0.15µg/g (Nagpal, 1994), and the Canadian draft interim guidelines TELs of 0.19 for freshwater and 0.13 for marine sediments (Environment Canada, 1995). Nijman and Swain (1990) proposed a Water Quality Objective for mercury in sediments of Burrard Inlet of 0.15 µg/g (dry-weight) (Nijman and Swain, 1990), while Swain (1989) proposed a long term objective for the Brunette River system of 0.07 µg/g (dry-weight) (Swain, 1989). If the objectives were applied to the Fraser River, the concentrations would meet the long-term objective for Burrard Inlet but not the one for the Brunette River system.

Mercury Concentrations (µg/g) in Main Arm Sediment

Year	Upstream/ Annacis Channel	Downstream/ Ewen Slough	References
1980	<detection limit	<detection limit	Stancil, 1980
1985	0.06	0.07	Swain, 1986c
1987	0.071	0.08	Swain and Walton, 1988
1989	0.057	0.061	Swain and Walton, 1990
1990	0.70	0.061	Swain and Walton, 1991
1992	0.05	0.05	Swain and Walton 1993a
1994		0.34, 0.57, 0.53	Akhurst, 1994
1985-1994	0.067	0.074	SEAM, 1985-1994
Guideline	Freshwater: 0.19 TEL		Environment Canada, 1995
	Marine: 0.13 TEL		Environment Canada, 1995
Criteria	Freshwater: 0.2 for lowest effects		Jaagumagi, 1992b
	Marine: 0.15 for low range effects		Nagpal, 1994
Objectives	Burrard Inlet: 0.15 (dry weight)		Nijman and Swain, 1990
	Brunette River: 0.07 (dry weight)		Swain, 1989

Molybdenum

In 1985, measures of molybdenum in the Main Arm were between 7 µg/g and 9 µg/g with means of 7.7 µg/g and 8.3 µg/g for Sites E206969 and E206970, respectively (Swain, 1986c). SEAM data was much lower. All fourteen measures were < 1 µg/g or < 2 µg/g. The FREMP surveys of 1987, 1989, 1990 and 1992 all recorded molybdenum as less than the detection limits of 2 µg/g, 1 µg/g, 1.5 µg/g, and 5 µg/g, respectively (Swain and Walton 1988, 1991, 1993 and Swain, 1989) . Likewise, all data recorded for 1994 was measured as < 4 µg/g (Akhurst, 1994). No criterion exists for molybdenum in sediments.

Molybdenum Concentrations (µg/g) in Main Arm Sediment

Year	Upstream/ Annacis Channel	Downstream/ Ewen Slough	References
1985	7.7	8.3	Swain, 1986c
1987	<2	<2	Swain and Walton, 1988
1989	<1	<1	Swain and Walton, 1990
1990	<1.5	<1.5	Swain and Walton, 1991
1992	<5	<5	Swain and Walton 1993a
1985-1994	<1-<2		SEAM, 1985-1994
Criterion	None proposed		

Nickel

In 1985, there was a spatial trend in nickel concentrations with downstream sites having lower levels than upstream sites: 43.3 µg/g at Annacis Channel compared to 41.3 µg/g at Ewen Slough (Swain, 1986c). This trend is not true of SEAM data: the Annacis site had a mean of 41.9 µg/g while the Ewen Slough site had a mean of 43.6 µg/g. Harding *et al.* (1988) reported similar or slightly higher levels in 1985 and 1986 (47 µg/g and 40 µg/g respectively) despite the fact that the silt percentages were much lower (32.8% and 50.4 % respectively). This may be due to different analytical techniques as no other reports from this time period indicate an increase in nickel concentration.

The 1987 FREMP survey had levels of 37.8 µg/g in Annacis and 40.6 µg/g in Ewen Slough (Swain and Walton, 1988). These values were higher than in the North Arm and the Main Stem, probably because of differences in particle size. The 1989 values of 52.3 µg/g at Annacis Channel and 49.5 µg/g at Ewen Sough are substantially higher than any previously reported levels (Swain and Walton, 1990). This may be due to a greater silt content or to the change in the laboratories doing the analysis. The 1990 survey of Ewen Slough had a mean nickel concentration of 52.1 µg/g total or 70.4 µg/g in silt (Swain and Walton 1991). This indicates a relationship to particle size but the increases in downstream sites were also apparent when particles of the same size were compared. In particles smaller than 0.063 mm (silt), Main Stem concentrations were 46.5 µg/g but Main Arm concentrations were 70.4 µg/g (Swain and Walton 1991). The 1992 means were greater than those found in 1990. Mean values were 65.08 µg/g at Annacis and 51.9 µg/g at Ewen Slough (Swain and Walton, 1993a). Because the particle size was actually larger in 1992, this may indicate a true increase in concentration.

In contrast, 1994 levels were lower than previous data, possibly due to lower silt content. Values ranged from 23.3 µg/g to 49.4 µg/g with a mean of 31.94 µg/g (Akhurst, 1994). All maxima exceed the lowest-effects level of 16 µg/g for freshwater sediment, the low range effects criteria of 30 µg/g for marine sediment, and the draft interim marine TEL of 15.9 µg/g (Environment Canada, 1995). Nijman and Swain (1990) proposed a water quality objective for nickel of a maximum of 45 µg/g (dry-weight) in the sediments from Burrard Inlet (Nijman and Swain, 1990). This objective would not be achieved in the Fraser River.

Nickel Concentrations (µg/g) in Main Arm Sediment

Year	Upstream/ Annacis Channel	Downstream/ Ewen Slough	References
1985	43.3	41.3	Swain, 1986c
1985	47		Harding *et al.*, 1988
1986	40		Harding *et al.*, 1988
1987	37.8	40.6	Swain and Walton, 1988
1989	52.3	49.5	Swain and Walton, 1990
1990		52.1	Swain and Walton, 1991
1992	65.08	51.9	Swain and Walton 1993a
1994	31.94		Akhurst, 1994
1985-1994	41.9	43.6	SEAM, 1985-1994
Guideline	Marine: 15.9 TEL (draft)		Environment Canada, 1995
Criteria	Freshwater: 16 for lowest effects		Nagpal, 1994
	Marine: 30 for low range effects		Nagpal, 1994
Objective	Burrard Inlet: 45		Nijman and Swain, 1990

An objective is not proposed for nickel in sediments at this time since Ewen Slough values seem to have remained stable from 1989 to 1992 when the same laboratory performed analyses, and there do not appear to be increases upstream from Annacis Channel that can be attributed solely to anthropogenic activity.

Strontium

Strontium values were only available for 1985 and 1987. In 1985 (Swain, 1986c), values decreased downstream from 39 µg/g at Annacis Channel to 37.7 µg/g at Ewen

Slough (Swain, 1986c). These values do not indicate particle size correlation. The 1987 values of 40.8 µg/g and 41.3 µg/g at Annacis Channel and Ewen Slough, respectively, were not statistically different from 1985 values (Swain and Walton, 1988). No criteria for strontium in sediment exists presently for comparison.

Strontium Concentrations (µg/g) in Main Arm Sediment

Year	Upstream/ Annacis Channel	Downstream/ Ewen Slough	References
1985	39	37.7	Swain, 1986c
1987	40.8	41.3	Swain and Walton, 1988
Criterion	None proposed		

Selenium

When selenium was measured in 1994, 17 of 19 values had concentrations at or below the detection limit of 0.10 µg/g. Two detected values, 0.11 µg/g and 0.24 µg/g were found at Sites FR3 and FR5 which are located at or near the mouth (Akhurst, 1994). Due to differences in particle size, it can not be determined whether this is a decrease from 0.28 µg/g (Annacis) and 0.29 µg/g (Ewen Slough) reported in the 1992 survey (Swain and Walton, 1993a). All values are below the maximum criterion of 5 µg/g for the protection of freshwater (International Joint Commission, 1981).

Silver and Tin

Silver and tin were only measured in the 1994 survey. All values were below the detection limits of 2.0 µg/g and 30 µg/g respectively (Akhurst, 1994). The detection limit for silver is too high to determine if Ontario's freshwater sediment guideline of 0.5 µg/g (Persaud *et al.*, 1992) or the draft interim marine TEL of 0.73 µg/g (Environment Canada, 1995) are met.

Titanium

Titanium values in the Main Arm in 1985 were 287 µg/g and 283 µg/g for Annacis Channel and Ewen Slough, respectively. These numbers are greater than the 210 µg/g and 265 µg/g found in the Main Stem (Swain, 1986c). This may suggest a correlation to particle size but no other data are available to confirm this. Furthermore, no water quality criteria are available to evaluate these concentrations. As such, no Water Quality Objective is proposed for titanium at this time.

Thallium

Thallium could not be detected above the detection limit of 20 µg/g in the sediments from the Main Arm in 1985 (Swain, 1986c). Detection limits were exceeded in the Main Stem where there is a lower silt content. Therefore, no apparent correlation existed between thallium values and particle size. No criterion exists for thallium at this time.

Vanadium

Vanadium was tested in the 1985 survey and was seen to increase slightly in a downstream direction from 33.3 µg/g at Annacis Channel to 33.7 µg/g at Ewen Slough (Swain, 1986c). The 1987 values also increased downstream from 25.8 µg/g at Annacis to 29.1 µg/g at Ewen Slough but were not statistically different (Swain and Walton, 1988). However, these values were determined to be statistically lower than the 1985 values. The lower values of 1987 were probably due to an increase in particle size. No vanadium criteria have been established to allow for further interpretation of these data.

Zinc

In the 1985 survey, zinc was found in concentrations of 70 µg/g at Annacis and Ewen Slough (Swain, 1986c). Harding *et al*. (1988) report a similar concentration of 73.8 µg/g at Ewen Slough in the same year. The 1987 concentrations were mean values of 63.4 µg/g at Annacis and 73.5 µg/g at Ewen Slough. In 1989, the mean concentrations were 106.5 µg/g and 102 µg/g at Annacis and Ewen Slough, respectively (Swain and Walton, 1990). The values are much greater than those found in 1985; this is most likely due to smaller particle sizes and possibly due to a change in the analyzing laboratory. The lower value at the downstream site may be explained by differences in sampling dates. The 1990 data had a total mean concentration at Ewen Slough of 140 µg/g and a zinc concentration in the silt fraction of 163 µg/g, indicating a downstream increase in zinc concentrations even when particles of the same size are compared (Swain and Walton 1991). Finally, zinc concentrations in 1992 were 97.42 µg/g and 88.46 µg/g for Annacis Channel and Ewen Slough, respectively (Swain and Walton, 1993a). These values are greater than the 1987 values which have a similar particle distribution and sampling time although they were analyzed by a different laboratory. Likewise, the 1989 values are greater than the 1985 values of similar particle size; again the analyzing laboratory was different.

With the exception of the 1990 concentration at Ewen Slough, values met the lowest-effects level criterion of 120 µg/g for zinc in freshwater sediments and the draft interim marine TEL of 124 µg/g (Environment Canada, 1995). A long term objective for zinc in sediments in the Brunette River system (Swain, 1989) is a maximum of 70 µg/g (dry-weight) (Swain, 1989), while a long term objective for Burrard Inlet is a maximum of 150 µg/g (dry-weight) (Nijman and Swain, 1990). If applied to the Fraser River, only the objective of 150 µg/g would have been achieved at all times.

Zinc Concentrations (µg/g) in Main Arm Sediment

Year	Upstream/ Annacis Channel	Downstream/ Ewen Slough	References
1985	70	70	Swain, 1986c
1985		73.8	Harding *et al.*, 1988
1987	63.4	73.5	Swain and Walton, 1988
1989	106.5	102	Swain and Walton, 1990
1990		140	Swain and Walton, 1991
1992	97.42	88.46	Swain and Walton 1993a
Guideline	Marine: 124 TEL (draft)		Environment Canada, 1995
Criteria	Freshwater: 120 for lowest effects		Nagpal, 1994
	Marine: 120 for low range effects		Nagpal, 1994
Objectives	Burrard Inlet: 150		Nijman and Swain, 1990
	Brunette River: 70		Swain, 1990

Many of the metals concentrations were related to particle size distribution, therefore, values were higher downstream. However, the 1990 report shows that if similar sized particles are compared, there is still a downstream increase for arsenic, cadmium, iron, nickel and zinc. Chromium, cobalt, nickel and zinc show increases but due to a change in analyzing laboratory, there is doubt as to whether cobalt and zinc showed true increases. Lead and mercury showed decreases. When compared to objectives set for Burrard Inlet and for the Brunette River, cadmium, copper, lead, mercury and zinc met the objectives for the Burrard Inlet but not the objectives for the Brunette River. Nickel did not meet the Burrard Inlet objective.

6.5.2.2 Organics

6.5.2.2.1 Chlorophenols

The 1985 report found no detectable (0.005 µg/g wet-weight) concentrations of chlorophenols (Swain, 1986c). The 1987 survey reported identical results with the exception of tetrachlorophenol that was reported at the detection limit of 0.003 µg/g dry-weight (0.005 µg/g wet-weight moisture content of 32.5 %) (Swain and Walton, 1988). The 1989, 1990, and 1992 reports all had undetectable levels (0.005 µg/g dry-weight) of tri-, tetra-, and pentachlorophenols (Swain and Walton, 1990, 1991, 1993). The SEAM data only recorded total chlorophenol concentrations. Maximum concentrations ranged from undetectable (0.005 µg/g) at Sites E206969 and E206970 to 0.07 µg/g at Site E105893. As chlorophenols are almost exclusively produced by man, a Sediment Quality Objective for the sum of all chlorophenols (mono-, di-, tri-, tetra-, and penta) of 0.01 µg/g (maximum) is proposed. This value is exceeded by maximums at Site 0301311 (0.064 µg/g) and Site E105893 (0.07 µg/g) which are downstream from the Annacis and Lulu Island sewage treatment plants, respectively. The upstream values at both these plants was less than the detection limit of 0.02 µg/g.

6.5.2.2.2 Polychlorinated Biphenyls (PCBs)

PCBs were not detectable in any samples in the Main Arm for surveys done in 1985 (Swain, 1986c), 1987 (Swain and Walton, 1988), 1989 (Swain and Walton, 1990), 1990 (Swain and Walton 1991), or 1992 (Swain and Walton, 1993a). The respective dry-weight detection limits were: 0.012 µg/g (39% moisture), 0.004 µg/g (24.4 % moisture), 0.01 µg/g, 0.01 µg/g, and 0.01 µg/g. They were also not measured above the detection limit of 0.02 µg/g at Sites 0301308, 0301311, E105892, E105893 and E207624 and the detection limit of 0.01 µg/g at Site E206970. All values meet the proposed provisional Sediment Quality Objective for total PCBs of a maximum of 0.02 µg/g, the no-effects level based on EqP for these compounds (Nagpal, 1992). This proposed objective applies outside of initial dilution zones, as described in Section 1.0.

6.5.2.2.3 Chlorinated Catechols and Guaiacols

Chlorinated catechols and guaiacols were tested in surveys from 1990 and 1992. The 1990 report found no detectable chlorinated catechols (<0.001) but did find 2,4,5-trichloroguaiacol and tetrachloroguaiacol above detectable limits at Ewen Slough (Swain and Walton 1991). However, the sediments at Ewen Slough contained three or four times the silt content of other sites which indicates an association with small particles. In 1992, 3,4,5-trichlorguaiacol and tetrachloroguaiacol were found in concentrations of 0.001 µg/g and < 0.001 µg/g, respectively. 3,4,5-trichlorocatechol and tetrachlorocatechol were detected as well; they had concentrations of 0.013 µg/g and 0.011 µg/g, respectively (Swain and Walton, 1993a). There are currently no marine or freshwater criteria to which levels of chlorinated catechols and guaiacols may be compared.

6.5.2.2.4 Polycyclic Aromatic Hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons (PAHs) are naturally present in coal and petroleum and are formed during the incomplete combustion of hydrocarbons (Garrett, 1982). The PAHs measured in the 1989, 1990, and 1992 surveys are acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(ghi)perylene, benzo(k)fluoranthene, chrysene, dibenzo(ah)anthracene, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, naphthalene, phenanthrene, and pyrene (Swain and Walton, 1990, 1991, 1993). The maximum values for each PAH in 1989, 1990, and 1992 are listed below.

PAH Concentrations in the Main Arm*

PAH	1989** Annacis Channel	1989** Ewen Slough	1990** Ewen Sough	1992** Annacis Channel	1992** Ewen Slough	Criteria	Guidelines
acenaphthene	< 0.005	< 0.005	< 0.005	< 0.005	0.011	F: 0.15 M: 0.15	M: 0.00671
acenaphthylene	< 0.005	< 0.005	< 0.005	<0.005	0.007	F: 0.01 M: 0.661	M: 0.00587
anthracene	< 0.005	<0.005	0.006	0.010	0.023	F: 0.06	M: 0.0469
benzo(a)anthracene	< 0.010	<0.010	0.012	0.33	0.051	F: 0.2	F: 0.0317 M: 0.0748
benzo(a)pyrene	<0.020	0.98	<0.020	0.025	0.025	F: 0.06 M: 0.06	F: 0.0319 M: 0.0888
benzo(b) fluoranthene	0.51	0.69	<0.020	0.045	0.052	-	-
benzo(ghi) perylene	<0.02	<0.02	<0.020	0.032	<0.020	F: 0.10 M: 0.31	-
benzo(k) fluoranthene	0.06	0.15	<0.020	<0.020	<0.020	F: 0.24	-
chrysene	<0.010	<0.010	0.19	0.037	0.061	F: 0.1 M: 0.2	F: 0.0571 M: 0.108
dibenzo(ah) anthracene	<0.02	0.370	<0.020	<0.020	<0.020	F: 0.005 M: 0.060	M: 0.00622
fluoranthene	0.036	0.085	0.029	0.066	0.15	F: 2.0 M: 0.60	F: 0.111 M: 0.113
fluorene	< 0.005	<0.005	0.006	0.008	0.02	F: 0.2 M: 0.2	M: 0.0212
indeno(123cd) pyrene	0.17	0.32	<0.020	0.031	<0.02	F: 0.07 M: 0.34	-
naphthalene	<0.005	0.13	0.012	0.010	0.025	F: 0.01 M: 0.01	M: 0.0346
phenanthrene	0.02	<0.005	0.023	0.052	0.098	F: 0.04 M: 0.225	M: 0.0867
pyrene	0.021	<0.010	0.027	0.058	0.13	F: 0.49 M: 0.35	F: 0.053

* measured in µg/g dry-weight

** maximum values

F (Freshwater Sediment Criterion/Guideline)

M (Marine Sediment Criterion/Guideline)

A freshwater criterion has been set at 0.6 µg/g (BCMELP, 1994) for anthracene. Although anthracene concentrations have risen from < 0.005 µg/g in 1989 (Swain and Walton, 1990) to 0.010 µg/g (Annacis Channel) and 0.023 µg/g (Ewen Slough) in 1992 (Swain and Walton, 1993a), they remain below the criterion. Particle sizes were larger in

1992, therefore, lower anthracene concentrations than those measured were expected. Since stormwater is discharged to the Fraser River, an Objective is proposed for anthracene of a maximum of 0.6 µg/g dry-weight.

Benzo(a)anthracene concentrations are also rising. In 1989, values were below the detection limit of 0.010 µg/g at both upstream Annacis Channel and downstream Ewen Slough sites (Swain and Walton, 1990). In 1990, values at Ewen Slough increased to 0.012 µg/g (Swain and Walton 1991) and in 1992, concentrations reached 0.33 µg/g at Annacis and 0.051 µg/g at Ewen Slough (Swain and Walton, 1993a). All values except those collected in 1992 at Annacis Channel were below the freshwater sediment criterion of 0.2 µg/g (Nagpal, 1994) and below the interim marine sediment guideline TEL of 0.0748 µg/g. Both sites sampled in 1992 had concentrations that exceeded the freshwater sediment quality guideline TEL of 0.0317 µg/g (Environment Canada, 1995). Since stormwater is discharged to the Fraser River, an Objective is proposed for benzo (a) anthracene of a maximum of 0.2 µg/g dry-weight.

Benzo(a)pyrene had a concentration of 0.098 µg/g in 1989 (Swain and Walton, 1990) which exceeded the criteria of 0.06 µg/g for freshwater and marine sediments (BCMELP, 1994) as well as the Canadian draft freshwater sediment quality guideline TEL of 0.0319 µg/g (Environment Canada, 1995). Concentrations were lower in 1990 (<0.020 µg/g) (Swain and Walton 1991) and 1992 (0.025 µg/g) (Swain and Walton, 1993a). These reductions were likely due to larger particle sizes. A no-effects threshold for benzo(a)pyrene was set at 0.01 µg/g for the St-Lawrence River (Environment Canada, 1992), the concentrations measured exceed this threshold. Since stormwater is discharged to the Fraser River, an Objective is proposed for benzo (a) pyrene of a maximum of 0.06 µg/g dry-weight.

Chrysene concentrations appear to be increasing from below detection limits of <0.010 µg/g in 1989 (Swain and Walton, 1990) to 0.019 µg/g in 1990 and 0.061 µg/g in 1992 (Swain and Walton, 1993a) at Ewen Slough. These concentrations remain below the freshwater (0.1 µg/g) and marine sediments (0.2 µg/g) criteria (BCMELP, 1994) as well as the Canadian draft marine sediment quality criterion of 0.108 µg/g. Since stormwater is discharged to the Fraser River, an Objective is proposed for chrysene of a maximum of 0.2 µg/g dry-weight.

Dibenzo (a,h) anthracene levels at Annacis Channel remained below detection limits of 0.02 μg/g between 1989 and 1992, and decreased at Ewen Slough from 0.370 μg/g in 1989 to below detection limits of 0.02 μg/g in 1990 and 1992. The detection limit is higher than the B.C. criteria of 0.005 μg/g for freshwater sediments and 0.060 μg/g for marine sediments, as well as the Canadian draft marine sediment quality guideline TEL of 0.00622 μg/g. As such, it is difficult to interpret the measured data in light off adverse effects to biota. Since stormwater is discharged to the Fraser River, an Objective is proposed for dibenzo (a,h) anthracene of a maximum of 0.005 μg/g dry-weight.

Naphthalene values have been quite variable, however, all maximum concentrations at Ewen Slough since 1989 have exceeded the freshwater and marine sediment criteria of 0.01 μg/g (Nagpal, 1993 (b)) and met the marine sediment quality guideline of 0.0346 μg/g (Environment Canada, 1995). In 1989, the concentration was 0.13 μg/g (Swain and Walton, 1990). In 1990, it was just above the criteria at 0.012 μg/g (Swain and Walton 1991) and in 1992, the concentration was 0.025 μg/g (Swain and Walton, 1993a). Since stormwater is discharged to the Fraser River, an Objective is proposed for naphthalene of a maximum of 0.01 μg/g dry-weight.

Phenanthracene concentrations at Annacis Channel rose from 0.02 μg/g in 1989 (Swain and Walton, 1988) to 0.052 μg/g in 1992 (Swain and Walton, 1991). Similarly, at Ewen Slough, concentrations rose dramatically from <0.005 μg/g in 1989 (Swain and Walton, 1988) to 0.023 μg/g in 1990 (Swain and Walton, 1989), and 0.098 μg/g in 1992 (Swain and Walton, 1991). In 1992, concentrations measured at both upstream and downstream sites exceeded the freshwater sediment criterion of 0.04 μg/g while concentrations measured downstream toward the mouth of the river exceeded the marine sediment quality guideline of 0.0867 μg/g. Phenanthracene is not likely to occur naturally and its spatial and temporal increases indicate anthropogenic influences. For these reasons, and because sediment in the Main Arm of the Fraser River is heavily influenced by salinity intrusions, a long-term Sediment Quality Objective to protect both freshwater and marine aquatic life of a maximum 0.04 μg/g when sediment pore waters are non-saline: during the high river flow months between May and August in any discrete sample collected outside of initial dilution zones as described in Section 1.0 and are based on an organic carbon content of 1%. Between September and April, when sediment conditions are saline and during the short-term, higher levels of phenanathrene in sediment are tolerable: during these low flow months, the concentration of phenanthrene should not exceed 0.087 μg/g (dry-weight).

Pyrene exhibited similar temporal and spatial trends with concentrations at Annacis Channel increasing from 0.021 µg/g in 1989 (Swain and Walton, 1988) to 0.058 µg/g in 1992 (Swain and Walton, 1991) and concentrations at Ewen Slough increasing steadily from <0.010 µg/g in 1989 (Swain and Walton, 1988) to 0.027 µg/g in 1990 (Swain and Walton, 1989) and 0.13 µg/g in 1992 (Swain and Walton, 1991). All measures were below the lowest effects criterion of 0.49 µg/g for freshwater sediments and the low range effects criterion of 0.35 µg/g for marine sediments (Nagpal, 1994). 1992 data both upstream and downstream of the reach exceed the interim draft freshwater sediment quality guideline TEL of 0.053 µg/g (Environment Canada, 1995). No Sediment Quality Objectives are proposed at this time.

All other PAHs listed were below the respective criteria. Maximum concentrations of indeno (1,2,3-c,d) pyrene exceeded the 0.07 µg/g freshwater criterion at both sites in 1989 but were below the criterion for all other samples. All values were below the marine sediment quality criterion of 0.34 µg/g. Maximum values for benzo (b) fluoranthene and benzo (k) fluoranthene decreased at both sites over the years sampled whereas maximum fluorene values increased at both sites for the same period. Maximum fluoranthene values increased at the Annacis Island site but decreased at the Ewen Slough site. Based on an organic carbon content of 1%, these PAHs and respective proposed objectives are: acenaphthene, maximum of 0.15 µg/g (dry-weight); fluorene, maximum of 0.2 µg/g (dry-weight); acridine, maximum of 1 µg/g (dry-weight); acenaphthylene (May and August) maximum of 0.01 µg/g or (September and April) maximum of 0.66 µg/g; and fluoranthene, maximum of 2 µg/g (dry-weight).

All available SEAM data were collected in 1989 and discussed by Swain (1990). Anthracene, benzo [a] anthracene, chrysene, naphthalene, and phenanthrene have shown increases from 1989 values despite an increase in the particle sizes of later surveys supporting evidence that PAHs have been increasing significantly over the past few years.

6.5.2.2.5 Phthalate Esters

Only 1989 data on phthalate esters were available and most values were below the detection limit. Only di-n-octyl and bis(2-ethylhexyl) were significantly over the detection limit of 0.10 µg/g. Di-n-octyl had a concentration of 0.23 µg/g at Ewen Slough while bis(2-ethylhexyl) had concentrations of 0.63 µg/g at Annacis Channel and 1.22 µg/g at

Ewen Slough) (Swain and Walton, 1990). Even values which significantly exceeded the detection limit were below the lowest Apparent Effects Threshold level (AET) for Puget Sound. In recognition of the ubiquitous nature of phthalates and difficulties inherent in analyzing samples for phthalates, Swain (1989) questions whether this is indicative of a major source of phthalates to the river. All available SEAM data was collected in 1989 and are therefore the data reported by Swain (1990).

6.5.2.2.6 Organochloride Pesticides

The organochloride pesticides tested for in the 1989, 1990 and 1992 surveys were aldrin, alpha-chlordane, gamma-chlordane, DDD, DDE, DDT, dieldrin, endrin, endosulfan I, endosulfan II, endosulfan sulphate, heptachlor, heptachlor epoxide, lindane, methoxychlor, and toxaphene. The detection limits are listed below. In 1989, all pesticides were below detection limits except DDE which was found at the detection limit of 0.0005 µg/g (Swain and Walton, 1990). All available SEAM data were collected in 1989 and are the same as data reported by Swain and Walton (1990) in the 1989 FREMP report. In 1990 and 1992, none of the organochloride pesticides could be detected at either Annacis Channel or Ewen Slough for any particle size (Swain and Walton, 1991 and 1993).

Organochloride Pesticide Detection Limits in 1989, 1990, and 1992

Organochloride Pesticide	Detection limit µg/g	Organochloride Pesticide	Detection limit µg/g
aldrin	<0.001	endosulfan	<0.001
alpha-chlordane	<0.001	endosulfan II	<0.001
gamma-chlordane	<0.001	endosulfan sulfate	<0.01
dieldrin	<0.001	heptachlor	<0.0005
DDD	<0.001	heptachlor epoxide*	<0.01
DDE	<0.0005	lindane	<0.001
DDT	<0.001	methoxychlor	<0.005
endrin	<0.0005	toxaphene	<0.03

*The detection limit in 1990 was <0.005 µg/g

6.5.2.2.6 Organophosphate Pesticides

Organophosphate pesticides tested for in 1992 were: azinophos methyl, carbonphenothion, diazinon, dimethoate, fensulfothion, fenthion, fonofos, malathion, methamidophos, mevinphos, parathion, parathion methyl, and phosmet. All compounds were below the detection limits (Swain and Walton, 1993a). Detection limits are listed below. No criteria are available for these compounds.

Organophosphate Pesticide Detection Limits

Organophosphate Pesticide	Detection limit µg/g	Organophosphate Pesticide	Detection limit µg/g
azinophos methyl	<0.050	malathion	<0.010
carbophenothion	<0.010	methamidophos	<0.050
diazinon	<0.020	mevinphos	<0.050
dimethoate	<0.020	parathion	<0.010
fensulfothion	<0.010	parathion methyl	<0.020
fenthion	<0.020	phosmet	<0.030
fonofos	<0.020		

6.5.2.2.8 Dioxins and Furans

Dioxins and furans have similar chemical structures and biological effects. There are about 75 dioxins, the most toxic of which is 2,3,7,8-TCDD. Other forms of dioxins are 10 - 10,000 times less toxic while all of the 135 furan compounds are 2 - 10 000 times less toxic. In 1990 and 1992 surveys, the dioxins tested were T_4CDD, P_5CDD, H_6CDD, H_7CDD and O_8CDD. The detection limits varied with each sample analyzed. In 1990, detectable levels of H_6CDD, H_7CDD, and O_8CDD were found (Swain and Walton 1991). In 1992, three replicate samples in Annacis Channel were tested. Detectable levels of all T_4CDD, P_5CDD, H_6CDD, H_7CDD and O_8CDD were found (Swain and Walton, 1993a). Results are summarized below.

Maximum Dioxin Concentrations in the Main Arm*

Dioxin		1990	1992-A1	1992-A2	1992-A3
T4CDD	**total**	<3.9	4.3	2.6	1.7
	2,3,7,8-	<3.9	<0.2	<0.2	<0.2
P5CDD	**total**	<6.6	3.3	0.9	1.3
	1,2,3,7,8	<6.6	<0.4	<0.3	<0.2
H6CDD	**total**	74	18	12	19
	1,2,3,4,7,8	<6.3	<0.5	<0.6	<0.5
	1,2,3,6,7,8	14	2.6	1.7	2.3
	1,2,3,7,8,9	<6.3	1.7	-	1.6
H7CDD	**total**	170	54	57	50
	1,2,3,4,6,7,8	81	24	26	20
O8CDD		540	160	290	150

* data are measured in pg/g
** 1990 values are taken from Ewen Slough

Dioxin levels appear to have decreased since 1990 although higher detection limits and smaller particle sizes in 1990 often make analysis inconclusive. With the exception of 1,2,3,4,6,7,8-H_7CDD, none of the specific compounds measured in 1990 had detection limits low enough to conclude that values decreased. Furthermore, true decreases were difficult to assess because the 1990 and 1992 samples were obtained at different sites with inherent differences in particle sizes. 1990 samples were collected from Ewen Slough which has higher silt levels than Annacis Channel where samples were collected in 1992. The only compound for which a criterion was available is T_4CDD and all concentrations were above the 0.01 pg/g International Joint Commission sediment quality objective (Boddington *et al.*, 1990).

The 1990 and 1992 surveys tested for the furans T_4CDF, P_5CDF, H_6CDF, H_7CDF and O_8CDF. A summary table is shown below.

Maximum Furan Concentrations in the Main Arm*

Furan		1990**	1992-A1	1992-A2	1992-A3
T_4CDF	**total**	25	5.4	3.4	4.6
	2,3,7,8	15	1.6	1.3	1.6
P_5CDF	**total**	<2.5	3.0	1.7	3.0
	1,2,3,7,8	<2.5	<0.2	<0.2	<0.2
	2,3,4,7,8	<2.5	<0.2	<0.2	<0.2
H_6CDF	**total**	57	10	7.6	12
	1,2,3,4,7,8	<4.9	<0.4	<0.4	<0.5
	1,2,3,6,7,8	<4.9	<0.4	<0.4	<0.5
	2,3,4,6,7,8	<4.9	<0.4	<0.4	<0.5
	1,2,3,7,8,9	<4.9	<0.4	<0.4	<0.5
H_7CDF	**total**	110	18	11	16
	1,2,3,4,6,7,8	31	<0.4	4.4	6.5
	1,2,3,4,7,8,9	<5.1	7	<0.5	<0.5
0_8CDF		72	9.2	5.5	7.4

*measurements in pg/g
**1990 values are from Ewen Slough

All the total furan concentrations studied in the Main Arm decreased in concentration between 1990 and 1992 survey, except total P_5CDF. Total P_5CDF increased from <2.5 pg/g in 1990 (Swain and Walton 1991) to 3.0 pg/g in 1992 (A1 and A3) (Swain and Walton, 1993a). The compound 2,3,7,8-T_4CDF decreased in concentration from 15 pg/g in 1990 (Swain and Walton 1991) to an average of 1.5 pg/g in 1992 (Swain and Walton, 1993a). 1,2,3,4,7,8,9- H_7CDF appeared to increase from <5.1 pg/g in 1990 (Swain and Walton 1991) to 7 pg/g at A1 in 1992 (Swain and Walton, 1993a). Other 1992 sites had values below detection limits but other 1990 detection limits were too high to determine if specific furans had decreased. It is difficult to determine whether these are true decreases because the 1990 values were taken from Ewen Slough which has a higher silt content than Annacis Channel where 1992 values were obtained.

Toxic equivalents (TEQs) were calculated using the maximum concentrations of dioxins and furans. When a value was below the detection limit, the detection limit was used as the maximum. For 1992, the maxima of the three sites were averaged. The TEQs decreased from 1990 to 1992. The TEQ in 1990 was calculated to be 11.21 ng/kg while in 1992, it dropped to 1.965 ng/kg. This is a very significant decrease however, the detection limits were higher in 1990 and as detection limits were used for unmeasurable values the 1990 TEQ is skewed high. A Sediment Quality Objective of 0.25 pg/g TEQ total dioxins and furans for any single sample is proposed in order to protect freshwater aquatic life. Both the 1990 and the 1992 TEQ values exceed this objective.

6.5.2.2.9 Resin and Fatty Acids

Resin and fatty acids were tested for the first time in 1992. Abietic acid, chlorodehydroabietic acid, dehydroabietic acid, dichlorodehydroabietic acid, isopimaric acid. neoabietic acid, pimaric acid and sandaracopimaric acid were measured at Annacis Channel and at Ewen Slough. Levopimaric acid and neoabietic acid were consistently below the detection limit of <0.050 µg/g at both Annacis Channel and Ewen Slough (Swain and Walton, 1993a). Dichlorodehydeoabietic acid was also consistently below the detection limit at Annacis Channel but was measured at 0.067 µg/g in during the low flow month of February at the downstream site of Ewen Slough (Swain and Walton, 1993a). Other temporal trends were observed in dehydroabietic acid, isopimaric acid, pimaric acid, and sandaracopimaric acid which increased in concentrations between February and May of 1992 (Swain and Walton, 1993a), as well as abietic acid and chlorohydroabietic acid which decreased in concentrations between February and May (Swain and Walton, 1993a). Downstream increases were evident in all resin acids except pimaric acid which decreased in concentration between Annacis Channel and Ewen Slough, and levopimaric acid and neopimaric acid which remained below detection limits.

Concentration of Resins and Fatty Acids in 1992 Sediments*

Resin/Fatty Acid	Annacis Channel-February	Ewen Slough-February	Annacis Channel-May
Abietic acid	0.370	0.384	0.290
Chlorodehydroabietic acid	0.073	0.125	<0.050
Dehydroabietic acid	0.406	0.510	0.473
Dichlorodehydroabietic acid	<0.05+	0.067	<0.050
Isopimaric acid	0.337	0.360	0.436
Levopimaric acid	<0.050	<0.050	<0.050
Neoabietic acid	<0.050	<0.050	<0.050
Pimaric acid	0.232	0.184	0.279
Sandaracopimaric acid	0.170	0.314	0.529

*Measured in µg/g

6.5.2.2.10 Halogenated and Non-Halogenated Volatiles

Halogenated and non-halogenated volatiles were tested for the first time in May 1992. All compounds were under detection limits (Swain and Walton, 1993a). The halogenated volatiles, namely, chlorobenzene, 1,2-dichlorobenzene, 1,3-dichlorobenzene, and 1,4-dichlorobenzene were all below the detection limit of <0.001 µg/g. The non-halogenated volatiles tested and their detection limits are benzene (<0.005 µg/g), ethylbenzene (<0.005µg/g), styrene (<0.001 µg/g), toluene (<0.01 µg/g), meta- & para-xylene (<0.01 µg/g), and ortho-xylene (<0.01 µg/g).

6.5.2.3 Toxicity

A variety of tests were used to determine toxicity at the various sites in the 1990 and 1992 toxicity surveys. The first test was the 10-day *Hyella azteca* test which involves measuring the effect of sediment samples on a freshwater amphipod crustacean. The second was the 25-minute exposure microtox solid-phase test which uses the bioluminescent bacterial species *Photobacterium phosphoreum.* The microtox liquid phase test was also performed using the same photobacterium. Furthermore, the alga *Daphnia magna* and sand dollar sperm bioassays were performed (Swain and Walton, 1993a).

The *Hyella azteca* test simply measures the survival rate of the organism. Since one of the two controls in 1992 only had an 80% survival rate, only values less than this can be considered an indication of a toxicity problem. In 1992, both Annacis Channel and Ewen Slough sites had survival rates between 80% and 100% with a mean of 94% (Swain and Walton, 1993a). The results suggest that no toxicity problems exist at either site.

The solid phase microtox measures the EC50, which is the effective concentration (%) to cause a 50% reduction in the light emitted by the phosphorescent bacteria. Uncontaminated samples are defined as having at least a 2% EC50. In 1990, both Annacis Channel and Ewen Slough sites were non-toxic for all particle sizes at all replicates sites. In 1992, the EC50 values varied from 0.95% to 1.26% (mean 1.12%) at Annacis Channel, while values from Ewen Slough ranged from 0.47% to 0.94% (mean of 0.74%) (Swain and Walton, 1993a). Both sites exceed the clean sediment values indicating both sites may have a toxicity concern.

The 1992 tests performed on *Daphnia magna* and the liquid phase microtox conclude that both sites were non-toxic. The sperm bioassay of the sand dollar Denaster excentricus was completed in 1990 and 1992. The 1990 and 1992 surveys indicate that the sites at Ewen Slough were non-toxic. The 1990 survey did not test the Annacis site, however, the 1992 survey reported only one of five replicates were considered non-toxic at Annacis Channel. Three of the remaining four had values of 73%, 74%, and 77% fertilization at contamination levels of 100%. The FID50 (percent sediment to inhibit 50% fertilization) of the last replicate was 91.9%. This agrees with SEM/AVS values calculated in 1992.

The SEM/AVS ratios compare the total concentration (in moles/kg) of simultaneously extractable metals (SEM) (cadmium, copper, lead, mercury, nickel, and zinc) to the concentration of acid volatile sulphide (AVS). A ratio greater than 1:1 indicates potential toxicity due to the bioavailability of metals in excess of sulfides to which the metals normally bind. At Annacis Channel, five replicate sites had mean SEM/AVS ratios of 4.46. At Ewen Slough, the five replicates had mean SEM/AVS ratios of 0.334 (Swain and Walton, 1993a). This indicates a potential concern at Annacis Channel but not at Ewen Slough. Processes other than sulphide binding may occur that would render these sediments less toxic.

6.5.3 Analysis of Benthic Invertebrates

As is the case for North Arm, the Main Arm extends from the New Westminster trifurcation to the mouth of the Fraser River. Although urban and industrial development along the Main Arm has occurred similarly to the North Arm, the extent of development is much less and areas along the Main Arm are utilized for agriculture. It is of significance that while seasonal variations in interstitial salinity and substrate composition in the Main Arm resemble those of the North Arm, potential sources of point and non-point source discharges differ. Again, three monitoring stations were situated along this reach: two stations were located at the mouth of the river (station 3 near Ewen Slough and station 4 near Canoe Pass) while one station was located midway along the Main Arm near Tilbury and Deas Islands.

Average abundance and biomass of Peterson grabs of 626 cm^2 and Ponar grabs of 529 cm^2 were lower in the Main Arm than the North Arm (Northcote *et al*., 1976). Occasionally, seasonal averages at the Main Arm stations were higher than upstream river stations. The average annual abundance of the Main Arm stations ranged from approximately 1,000 organisms/m^2 to over 2,000 organisms/m^2 with numbers at the downstream station 3 (n=30) generally higher than at the mid-reach station 6 (n=30). Similarly, numbers at station 6 were generally lower than upstream station 7 (n=30) in the Main Stem. The average biomass of benthos collected from the Main Arm stations ranged from approximately 0.5 to 2 grams/m^2. Again, the average biomass at station 3 often exceeded the average biomass at station 6. Similarly, the biomass at station 6 was lower than upstream stations of the Main Stem.

The diversity of benthic fauna characteristic of the Main Arm was also examined in Northcote *et al*.'s survey (1976). The average number of taxa collected from mud and mud-sand substrate (4.870) in the Main Arm is also lower than the average diversity (6.245) in the same substrate type from the North Arm (Northcote *et al*., 1976). The same trend is found in sand and sand-gravel with an average of 4.138 taxa collected in the Main Arm compared to an average of 6.095 collected in the North Arm (Northcote *et al*., 1976). The pattern is not reflected in Simpson's index where diversity of taxa in mud and mud-sand substrate is 0.396 which is similar to 0.361 found in the North Arm and the diversity of taxa in sand and sand-gravel is 0.488 which is similar to 0.420 found in the North Arm (Northcote *et al*., 1976). Likewise, the Shannon-Wiener function for mud and mud-sand substrate in the Main Arm is 1.097 and 1.083 in the North Arm; the function for sand and sand-gravel substrate in the Main Arm is 1.309 in the Main Arm and 1.265 in the North Arm (Northcote *et al*., 1976). In contrast to the description of diversity presented by the average diversity parameter, the equitability calculation suggests that diversity is higher in the Main Arm with a value of 0.572 than the North Arm with a value of 0.474 in mud and mud-sand substrate (Northcote *et al*., 1976). This same pattern is suggested for sand and sand-gravel substrate with an equitability of 0.722 in the Main Arm and 0.531 in the North Arm (Northcote *et al*., 1976).

Listed below are the taxa collected and identified from all three stations in late summer to early autumn of 1972, late autumn of 1972, and spring and late summer of 1973. It is important to note that average to high flows are typical of these sampling times and that the extent of salinity intrusion is not as great as during periods of low flow conditions. However, Chapman (1981, 1984) reports that saline interstitial waters that are high in silt content are relatively constant in salinity despite diurnal changes in the salinity of overlying waters. Therefore, it would be reasonable to expect that samples collected earlier in the year would consist of more haline organisms while samples collected later in the year would contain more fresh water organisms.

Occurrence of Taxa in Benthic Samples from the Main Arm of the Lower Fraser River

Group and Subgroup	Taxa Name	Downstream (north)	Downstream (south)	Upstream
CTENOPHORES	*Pleurobrachia*	√		
NEMERTEAN WORMS	Nemertina		√	
NEMATODE WORMS	Nematode	√	√	
ANNELID WORMS				
Polychaetes	*Eteone*		√	
	Nereis limnocola	√	√	
	Amphicteis		√	
Oligochaetes	Oligochaete	√	√	√
Hirudeans	Leech			√
MOLLUSCS				
Pelecypods	*Mytilus edulis*	√		
	Pisidium			√
	Macoma	√	√	
CRUSTACEANS				
Cladocerans	*Daphnia*		√	
	Eurycerus			√
Copepods	Calanoids	√	√	
	Cyclopoids		√	
	Harpacticoids		√	
Mysids	*Neomysis mercredis*	√	√	√
Amphipods	*Corophium*	√	√	√
	Anisopammarus confervicolus	√	√	√
	Trichophoxus	√	√	
Isopods	*Gnorimosphaeroma oregonensis*	√	√	√
	Asellus			√
Decapods	*Crangon franciscorum*		√	
				√
INSECTS				
Odonatans (Dragonflies)	Anisoptera		√	
Dipterans (True flies)	Tipulidae	√		
	Psychodidae	√		√
	Ceratopogonidae	√	√	√
	Unidentified dipteran		√	
	Unidentified chironomid			√
	Unidentified tanypodinae	√		√
	Monodiamesa	√	√	√
	Cricotopus	**√**		
	Heterotrissocladius			√
	Paracladius	√		
	Chironomus		√	√
	Cryptochiromus	√		√
	Paracladopelma		**√**	**√**
	Polypedilum	√	√	√
	Stictochiromus	√	√	√
	Stempellina			√
LAMPREYS	Ammocoete			√
	Number of Sensitive Taxa	**1**	**1**	**1**
	TOTAL	**22**	**25**	**23**

The absence of organic pollution sensitive taxa is apparent. Only one taxa of sensitive organism was collected from each station over the course of two years of sampling.

Paracladopelma was found at both upstream station 6 and station 4 which was at the south site at the mouth of the river but not station 3 at the north site at the mouth of the river. Cricotopus was found only at the station 3. Pollution-tolerant oligochaetes were found at all three stations while tolerant leeches were found only at the less saline station 6 and tolerant psychodids were found only at the saline stations 3 and 4.

Swain (1986c) also surveyed benthic fauna in the Main Arm of the Fraser River; the following contaminants were detected in the tissues of lampreys, leeches, oligochaetes, chironomids, and pelecypods collected from the upstream monitoring station at Annacis Channel, and the tissues of amphipods and polychaetes collected from the downstream monitoring station at Ewen Slough. As was the case for benthic invertebrates sampled in the North Arm, the upstream and downstream taxa differed; this is reflected in the species specific patterns of metal contamination in the various taxa.

	Main Arm						
	Annacis Channel (Upstream)					Ewen Slough (Downstream)	
Characteristic	**Lamprey**	**Leeches**	**Oligochaete**	**Chironomids**	**Pelecypoda**	**Amphipods**	**Polychaetes**
Aluminum	693	929	3810	3030	570	2220	3060
Boron	<1	87	8	<1	6	<1	<1
Barium	13	44	96	58	132	207	36
Calcium	4100	6370	11500	5700	339000	19400	8220
Cadmium	<1	<1	<1	4	<1	<1	5
Chromium	4	48	17	11	7	8	14
Copper	43	125	108	93	19	154	87
Iron	2110	5160	8440	8150	4320	5820	11000
Magnesium	874	1240	2670	2640	305	3110	3260
Manganese	247	453	475	445	2470	1590	306
Molybdenum	<1	<1	<1	2	5	3	5
Nickel	8	96	<5	12	<5	19	12
Lead	<10	<10	<10	<10	24	<10	<10
Tin	<5	<5	<5	<5	16	<5	<5
Strontium	14	23	37	27	358	352	83
Tellurium	<20	<20	<20	<20	<20	<20	20
Titanium	25	47	151	90	22	67	102
Thallium	<20	<20	<20	<20	97	<20	<20
Vanadium	6	<1	14	11	5	7	11
Zinc	158	814	259	178	31	157	298
Total Phosphorus	4530	8170	5690	4670	1140	9190	7200
Total PCBs (wet)	-	-	-	-	-	<0.1	<0.1
Pentachlorophenol (wet)	-	-	-	-	-	<0.01	0.04
Tetrachlorophenol (wet)	-	-	-	-	-	<0.01	0.07

6.5.4 Analysis of Fish

The most recent data available for fish toxicity in the Main Arm is a 1988 report by Swain and Walton. Largescale sucker, northern squawfish, peamouth chub, staghorn sculpin and starry founder were collected at Ewen Slough (MA-2). The results are compared to 1985 and 1980 surveys to determine trends in the data. All data are given as wet-weight unless otherwise specified.

6.5.4.1 Metals

Aluminum

Aluminum was below the detection limit (2 µg/g dry-weight) in the muscle of all fish (n=9) collected in the Main Arm in the 1985 survey even though the highest sediment concentration was found in this reach of the river (Swain, 1986c). However, aluminum was detected in the livers of some of these fish. The highest concentration was 78.1 µg/g (dry-weight) found in a cutthroat trout from Annacis Channel (MA-1). The lowest concentration was 67 µg/g (dry), also in a cutthroat trout from Annacis Channel. Concentrations were not reported in the 1980 or 1988 reports. Aluminum is not considered a priority toxicant.

Arsenic

Arsenic was not detected (2 µg/g dry-weight or 0.4 µg/g wet-weight) in the muscle of any fish (n=48) collected in 1980 (Singleton, 1983). The 1988 survey had considerably lower detection limits (0.025 µg/g dry-weight or 0.005 µg/g wet-weight) and arsenic was detected in the five species tested (n= 44) (Swain and Walton, 1989). Only one starry flounder from the Main Arm in 1988 had an arsenic concentration greater than the 1980 detection limit. Mean values ranged from 0.02 µg/g to 0.25 µg/g with the majority of high values coming from staghorn sculpin and starry flounder. Generally, these values are two or three times greater than values from a number of uncontaminated lakes in B.C. (Swain and Walton, 1989) but they easily meet the 1991 Canadian Food and Drug Directorate for arsenic in freshwater animal products for human consumption of 3.5 µg/g (Stancil, 1981). No tissue quality criterion is available for evaluation of salt water animal products.

In 1980, concentrations of arsenic in all liver samples taken from fish in the Main Arm were below detection limits (which ranged from 0.55 µg/g to 0.79 µg/g) except one sample taken from a white sturgeon in Deas Slough that had a concentration of 0.9 µg/g (Singleton, 1983). In the 1988 survey mean values of 16 composite samples ranged from 0.129 µg/g to 0.21 µg/g (Swain and Walton, 1989). Detection limits in 1980 were too high to compare this data; based on the one value that exceeded the detection limit, values appear to have decreased. The values are significantly similar within each site as well as within species at other sites. All the liver concentrations are greater than the 0.023 µg/g to 0.028 µg/g range found in uncontaminated lakes and show bioaccumulation as reported by Demayo *et al.* (1979).

Generally, arsenic liver concentrations are higher than muscle concentrations and both muscle and liver concentrations are two to three times higher than in uncontaminated lakes. However, there is no evidence of biomagnification through trophic levels of the food web (Hunter *et al.*, 1981). All samples are well within the Food and Drug Directorate of 3.5 µg/g. As such, no Tissue Quality Objective is proposed at this time.

Cadmium

In 1980 and 1985, cadmium was not detectable (0.2 µg/g wet- weight) in the muscle tissue of any samples collected in the Main Arm (Singleton, 1983 and Swain, 1986c). In 1988, detection limits were lower (0.005 µg/g wet-weight) and cadmium was detected in only two of seven staghorn sculpin samples and five of eight starry flounder samples from the Main Arm (Swain and Walton, 1989). Maximum values were 0.014 µg/g in the staghorn sculpin and 0.03 µg/g in the flounder (Swain and Walton, 1989). Due to differences in detection limits, these values may or may not be lower than concentrations found in 1980 (Singleton, 1983).

In 1980, cadmium was not detected in the livers of largescale suckers or peamouth chub whose analyses had detection limits of 0.27 µg/g and 0.36 µg/g, respectively. It was however, detected in the livers of all the white sturgeons taken from Deas Slough: concentrations in four white sturgeon ranged from 0.30 µg/g to 0.74 µg/g with an average of 0.45 µg/g (Singleton, 1983). In 1985, different species were sampled: three of four cutthroat trout tested had detectable liver concentrations and an average of 0.33 µg/g

(Swain, 1986c). In 1988, detection limits were lower (0.005 µg/g) and most samples taken from the Main Arm had concentrations above detection. Mean values ranged from < 0.005 µg/g in northern squawfish to 0.174 µg/g in staghorn sculpin. Generally, the values are lower than the range of 0.023 µg/g to 0.028 µg/g found in uncontaminated lakes although some values were very close (Swain and Walton, 1989).

All surveys found liver concentrations to be higher than muscle concentrations. This is supported by Brown and Chow (1977) who report that cadmium tends to accumulate in the visceral organs rather than muscle tissues. There is no apparent tendency for a biomagnification effect in the food web. The liver values for 1988 are lower than for 1980 and lower than values recorded for uncontaminated lakes in B.C. (0.218 µg/g to 0.247 µg/g) (Swain and Walton, 1989). No Tissue Quality Objectives are proposed for cadmium at this time.

Chromium

With a detection limit of 0.2 µg/g, chromium was not detected in the muscle tissue of 44 samples collected in 1980 (Singleton, 1983). In 1985, all samples showed an increase from 1980 chromium levels: more recent values ranged from 0.257 µg/g to 0.317 µg/g. By 1988, muscle concentrations were lower. In fact, all samples had chromium concentrations below the 1980 detection limit. Samples collected in 1988 had mean concentrations that ranged from 0.04 µg/g in ten northern squawfish and seven peamouth chub to 1.11 µg/g in the eight starry flounders. This range does not include values for two species that may have been contaminated in the lab.

In 1985 the average concentration in livers ranged from 0.208 µg/g in rainbow trout to 0.406 µg/g in cutthroat trout (Swain, 1986c). These values are comparable or slightly higher than the range of 0.283 µg/g to 0.347 µg/g found in uncontaminated lakes in B.C. The mean values in livers in 1988 were lower than those from 1985 and fell below levels for uncontaminated lakes. The mean concentrations ranged from 0.065 µg/g to 0.20 µg/g. There is no apparent correlation between sites or species (Swain and Walton, 1989).

Chromium does not appear to bioaccumulate or biomagnify (Swain and Walton, 1989) and there is no Food and Drug Guideline for chromium. As such, no Tissue Quality Objective is proposed for chromium.

Copper

In the 1980 survey, all copper concentrations in muscle were below 0.6 µg/g. Largescale sucker (n=10) and peamouth chub (n=11) had similar average concentrations in muscle of 0.332 µg/g and 0.336 µg/g respectively. Likewise, Dolly Varden (n=7), with a mean concentration of 0.25 µg/g was similar to staghorn sculpin (n=4 composite) and northern squawfish (n=7) with mean concentrations in muscle of 0.278 µg/g and 0.23 µg/g, respectively (Singleton, 1983). The 1985 concentrations in muscle are higher than those seen in 1980. Values range from 0.42 µg/g in a cutthroat trout from Annacis Island to 0.518 µg/g in a Dolly Varden from Annacis (Swain, 1986c). These higher values may be due to differences in laboratory techniques because values from the 1988 survey are comparable to 1980 data. The mean concentration of copper in the muscle of the largescale sucker (n=12) in the Main Arm in 1988 was 0.27 µg/g. The northern squawfish (n=10) collected from the Main Arm had a mean concentration of 0.34 µg/g and the starry flounder (n=8) had a mean concentration of 0.94 µg/g. The staghorn sculpin (n=7) had a mean concentration of 0.35 µg/g. There is no need for a Canadian Food and Drug Directorate.

Copper concentrations in the livers of fish were variable depending on the species analyzed. In 1980 survey, values ranged from 3.61 µg/g in one composite (of 21) peamouth chub sample to 8.46 µg/g in one composite (of 6) largescale sucker and a mean (n=4) of 10.80 µg/g in white sturgeon (Singleton, 1983). In the 1985 survey, liver concentrations ranged from 4.75 µg/g to 28 µg/g, both of these values in cutthroat trout samples collected at Annacis Channel (Swain, 1986c). The 1988 data are especially variable. Liver samples were taken from largescale sucker, northern squawfish, peamouth chub and staghorn sculpin. Only northern squawfish and peamouth chub had similar values in the Main Arm (3.45 µg/g and 3.08 µg/g, respectively). With the exception of North and Main Arm peamouth chub in that had liver concentrations of copper of 3.06 µg/g and 3.08 µg/g, respectively, there were no similarities within species. Bioaccumulation in the liver is significant. In contrast, there is no evidence of biomagnification through trophic levels (Swain and Walton, 1989).

Iron

Iron was detected in all muscle tissues sampled in the Main Arm in the 1980, 1985, and 1988 surveys. In 1985, values ranged from 3.8 µg/g to 6.2 µg/g (Swain, 1986c) and in 1988, values ranged from 3.81 µg/g to 5.53 µg/g, respectively (Swain and Walton, 1989). In 1980, the staghorn sculpin and the peamouth chub had the highest values of 7.58 µg/g and 6.83 µg/g which were comparable to each other but higher than the 3.38 µg/g and 4.01 µg/g found in the northern squawfish and largescale sucker, respectively (Singleton, 1983). This species specific trend was also noted in the 1988 data. Again, the concentrations in staghorn sculpin and peamouth chub were comparable (5.53 µg/g and 5.07 µg/g, respectively) and higher than concentrations in largescale sucker and northern squawfish whose values were in turn, comparable to each other (3.81 µg/g and 3.87 µg/g). This trend is not evident in other reaches of the river (Swain and Walton, 1989).

Iron was also detected in all fish liver samples taken in the Main Arm and values were substantially higher than those found in muscle tissue. In 1980, largescale suckers had a liver iron concentration of 119 µg/g which was higher than the 99.6 µg/g found in the peamouth chub. Four white sturgeons taken from Deas Slough had much higher concentrations with an average of 278.75 µg/g (Singleton, 1983). All 1985 values were between 59.2 µg/g(one Dolly Varden) and 212 µg/g (one of five cutthroat trout) which is within the range reported by Singleton (Swain, 1986c). The 1988 values were nearly identical to those reported in 1980 for species sampled in both surveys: largescale sucker had a mean iron concentration of 119 µg/g in both 1980 (one composite of five) and 1988 (n=4) surveys, peamouth chub had a concentration for a composite of 21 individuals of 99.6 µg/g in 1980 and a mean concentration (of 4) of 97.7 µg/g in 1988. In 1988, largescale sucker and northern squawfish (n=4) had similar values of 119 µg/g and 118 µg/g while peamouth chub (n=4) and staghorn sculpin (n=3) had similar values of 97.7 µg/g and 109 µg/g.

Iron was detected in all muscle and liver tissues taken from fish in the Main Arm for all surveys. Muscle concentrations are generally similar for all reaches of the river and values reported in 1988 are similar to those reported in 1985 and 1980. Therefore, it is probable that higher liver concentrations are due to the greater degree of vascularization necessary for normal metabolic function of the liver. Iron is not a concern in Fraser River fish.

Lead

Sources of lead to the Fraser River are most likely from automobiles and industry. A much larger population and the increased industrialization in the lower reaches of the river make this area the most susceptible to lead contamination. In the 1980 survey, Singleton reported 18 detectable (0.2 µg/g) levels of lead in 273 muscle samples from Fraser River fish. Thirteen of these were detected in fish from the Main Arm. Lead was detected in the muscle tissue of one of seven Dolly Varden collected, three of eleven peamouth chub, three of five staghorn sculpins, and six of seven northern squawfish: values ranged from <0.18 µg/g to 0.21 µg/g (Singleton, 1983). Measurements were recorded as dry-weights that when converted to wet-weight values, were below the Food and Drug Directorate criterion of 0.5 µg/g and the alert value for fish protein of 0.8 µg/g (Nagpal, 1987). In 1985, values were similar to those reported by Singleton (1983). All muscle concentrations (n=8) were at or below the detection limit of 0.258 µg/g (Swain, 1986c). In 1988, the detection limit was lowered to 0.01 µg/g. Only peamouth chub (n=7) and staghorn sculpin (n=7) were tested and their concentrations were 0.01 µg/g and 0.02 µg/g respectively. The values are similar within each site; there appears to be no consistency between sites (Swain and Walton, 1989).

In 1980, concentrations in the liver tissues of largescale sucker and peamouth chub were < 0.27 µg/g and 0.36 µg/g, respectively. In 1985, all values were below the detection limit of 0.258 µg/g, except two cutthroat trout with concentrations of 0.66 µg/g and 2.05 µg/g (Swain, 1986c). In 1988, detection limits were lowered. Largescale sucker (n=4) and staghorn sculpin (n=3) had mean concentrations of 0.078 µg/g and 0.12 µg/g. These values are approximately four times lower than in uncontaminated B.C. lakes (Swain and Walton, 1989). No Tissue Quality Objective is proposed for lead at this time.

Manganese

Manganese concentrations in muscle have not varied considerably between 1980 and 1985. In 1980, there was little species specific variation in manganese concentrations between sites: values ranged from 0.21 µg/g in peamouth chub(n=11) to 0.30 µg/g in white sturgeon (n=5). In 1985, all fish (n=8) taken from the Main Arm had manganese concentrations below the detection limit of 0.2 µg/g (Swain, 1986c). The mean values for the fish collected in 1988 ranged from 0.17 µg/g in northern squawfish (n=10) to 0.27 µg/g in largescale sucker(n=12). The mean concentration of manganese in peamouth chub (n=7) was 0.20 µg/g while the average in staghorn sculpin (n=7) was 0.23 µg/g. Starry flounder (n=8) was anomalous with a concentration of 5.83 µg/g. With the exception of starry flounder, concentrations were similar to those from uncontaminated lakes in B.C. (0.265 µg/g - 0.324 µg/g) (Swain and Walton, 1989).

Liver concentrations were considerably higher than muscle concentrations. In 1980, concentrations ranged from 0.985 µg/g in white sturgeon(n=4) to 3.28 µg/g in one composite of six individual largescale sucker (Singleton, 1983). The 1985 values ranged from 0.85 µg/g in a Dolly Varden to 1.98 µg/g in a rainbow trout (Swain, 1986c). Again, this is higher than corresponding muscle values but lower than liver concentrations reported in 1980. In 1988, concentrations exhibited a high degree of species specific variability. Largescale sucker had manganese liver concentrations exceeding those from 1980 with a maximum of 15.2 µg/g and a mean (n=4) of 6.0 µg/g. Northern squawfish (n=4) and peamouth chub (n=4) had similar mean concentrations of 0.83 µg/g and 0.81 µg/g respectively. The mean concentration of staghorn sculpin (n=3) was higher, at 1.24 µg/g. With the exception of largescale sucker, all 1988 values are approximate those found in uncontaminated B.C. lakes (1.37 µg/g - 1.76 µg/g) (Swain and Walton, 1989).

Generally, manganese concentrations in fish muscle have changed very little and are comparable to values obtained from samples collected from uncontaminated lakes. Liver values have decreased between 1980 and 1988. Most liver concentrations measured in 1988 are comparable to concentrations typical of uncontaminated sites. The cause of the high levels of manganese in the livers of largescale suckers is unknown; quality control data does not suggest an experimental error.

Mercury

In 1980, the muscle tissues of Dolly Varden, largescale sucker, peamouth chub, staghorn sculpin, northern squawfish and white sturgeon were analyzed for mercury concentrations. It was found that mercury concentrations were generally low with mean concentrations ranging from 0.27 µg/g in Dolly Varden (n=6) and northern squawfish (n=7) to 0.29 µg/g in peamouth chub (n=11) (Singleton, 1983). Values decreased in 1985 with muscle concentrations ranging from 0.07 µg/g in one rainbow trout to 0.19 µg/g in one cutthroat trout. In 1988, values were higher than those measured in 1985, and more similar to values reported in 1980. Mean concentrations detected in 1988 ranged from 0.04 µg/g in eight starry flounder to 0.27 µg/g in ten northern squawfish. Within the Main Arm, northern squawfish (n=10) and peamouth chub (n=7) had similar values (0.27 µg/g and 0.24 µg/g) and largescale sucker (n=12) and staghorn sculpin (n=7) had similar values (0.10 µg/g and 0.07 µg/g). Northcote *et al*. (1975) suggest that concentration may be correlated to trophic level with species of higher trophic status having a higher concentration. The higher values found in the northern squawfish support this theory of biomagnification. All values recorded for the Main Arm are below the Food and Drug Directorate for fish protein of 0.5 µg/g but Lindahl and Schwanbom (1971) found that when fish were exposed to mercury levels as low as 0.232 µg/g for 10 days, the exposure impaired the ability of the test fish to compensate for torque in a rotary flow apparatus. Fraser River fish may be exposed to mercury levels causing such sub-lethal effects.

Liver concentrations are generally lower than muscle concentrations. In 1980, concentrations for largescale sucker (n=1), peamouth chub (n=1) and white sturgeon (n=4) were 0.07 µg/g, 0.09 µg/g and 0.058 µg/g respectively (Singleton, 1983). In 1985, values ranged from <0.05 µg/g in cutthroat trout to 0.13 µg/g also in cutthroat trout (Swain, 1986c). The 1988 values are similar, ranging from 0.03 µg/g in largescale sucker (n=4) to 0.14 in three staghorn sculpin (Swain and Walton, 1989). The fact that liver concentrations are lower than muscle concentrations may suggest that the rate of elimination exceeds the rate of uptake by the test species.

Molybdenum

Molybdenum was undetected (detection limits <0.2 µg/g) in all muscle and liver tissues sampled from the 1980 and 1985 surveys. In 1988, detection limits were lowered to 0.05 µg/g. Starry flounder had mean muscle concentrations at the detection limit but the lab indicates that the starry flounder may have been contaminated. All other species had undetectable amounts (Swain and Walton, 1989).

Liver concentrations in 1988 ranged from 0.087 µg/g in staghorn sculpins to 0.19 µg/g in largescale suckers (Swain and Walton, 1989). The mean concentration of 0.138 µg/g in peamouth chub was significantly lower than the mean value of 0.19 µg/g for largescale suckers and significantly higher than the mean values of 0.087 µg/g for staghorn sculpins and 0.093 µg/g for northern squawfish. Molybdenum concentrations in the livers of Fraser River fish are about a half those of fish in uncontaminated B.C. lakes (0.249 µg/g to 0.34 µg/g) (Swain and Walton, 1989). Molybdenum is not a concern is Fraser River fish.

Nickel

Nickel was not detected in the muscle or liver tissues of any fish collected in the 1980 and 1985 surveys with detection limits of <0.9-< 1.22 µg/g in 1980, and 0.2 µg/g in 1985 (Singleton, 1983; Swain, 1986c). In 1988, the detection limit was lowered to 0.01 µg/g and nickel was detected. With the exception of starry flounder (0.64 µg/g), muscle tissue concentrations for all species in the Main Arm were similar. Largescale sucker, northern squawfish, and peamouth chub all had mean concentrations of 0.05 µg/g, and staghorn sculpin had a mean concentration of 0.08 µg/g. All muscle concentrations found in fish from the Main Arm are below levels found in uncontaminated B. C. lakes of 1.11 µg/g to 1.14 µg/g (Swain and Walton, 1989).

The 1988 liver concentrations of nickel were more variable. The mean nickel concentrations in the livers of northern squawfish (0.06 µg/g) and peamouth chub (0.043 µg/g) were similar to each other and to respective muscle values of 0.05 µg/g for both species. Mean concentrations in the livers of largescale suckers and staghorn sculpins were similar with values of 0.183 µg/g and 0.20 µg/g, respectively; similarly, these liver concentrations exceed muscle concentrations for both species. All values in the Main Arm are lower than those reported for uncontaminated lakes (1.15 µg/g to 1.20 µg/g) (Swain and Walton, 1989). Nickel concentrations have maintained consistent low levels. No Tissue Quality Objective is proposed for nickel at this time.

Zinc

Zinc was detected in all muscle samples taken from fish in the Main Arm. In 1980, mean values ranged from 2.36 µg/g in white sturgeon to 8.84 µg/g in peamouth chub. There was one extreme value of 33 µg/g in a peamouth chub taken from Ewen Slough but all other values were less than 11 µg/g (Singleton, 1983). With the exception of this extreme value, concentrations were generally lower than those found in 1972/73, although values were not significantly different (Garrett, 1980). The lower values may be due to different testing procedures or the diversion of industrial waste to sewage treatment plants. Fish size may also play a role in the contamination level. Singleton reports a significant negative correlation to size which may indicated that zinc is taken up through the skin or gills not through diet (Singleton, 1983).

In 1985, concentrations in fish muscle in the Main Arm were slightly lower than in previous surveys with concentrations falling between 3.3 µg/g in a cutthroat trout and 4.9 µg/g in a Dolly Varden from Annacis Channel (Swain, 1986c).

Values remained unchanged in 1988. With the exception of starry flounder, mean values ranged from 4.44 µg/g in northern squawfish (n=10) to 5.69 µg/g in peamouth chub (n=7). The concentration of 4.71 µg/g in largescale sucker (n=12) was similar to the 4.44 µg/g reported in northern squawfish (n=10) and the 5.07 µg/g in staghorn sculpin (n=7) but lower than the 5.69 µg/g found in peamouth chub (n=7) . Starry flounder zinc muscle concentrations were very high in the Main Arm (21.0 µg/g) (Swain and Walton, 1989). Fraser River fish are on the high end of the range for zinc from fish in uncontaminated lakes as reported by Rieberger (1992).

Zinc liver concentrations were generally four to five times higher than corresponding muscle concentrations. In 1980, liver samples were analyzed in largescale sucker, peamouth chub and white sturgeon. Mean concentrations ranged from 17.7 µg/g in one composite peamouth chub (n=21) to 27.8 µg/g in four white sturgeon (Singleton, 1983). Liver concentrations measured in two Dolly Varden and five cutthroat trout in 1985 are similar to liver values reported by Singleton (1983). Values ranged from 21.4 µg/g to 66.7 µg/g with a median value of 29.05 µg/g. The value of 66.7 µg/g found in a Dolly Varden from Ewen Slough is the only value over 35 µg/g (Swain, 1986c).

In 1988, liver concentrations were similar to values reported by Singleton (1983) with the exception of staghorn sculpin values. Mean concentrations in largescale sucker (n=4), northern squawfish (n=4), and peamouth chub (n=4) were 25 µg/g, 15.5 µg/g, and 13.3 µg/g, respectively. Staghorn sculpin zinc liver concentrations (n=3) are much higher with a mean concentration of 54.9 µg/g and a maximum of 63.9 µg/g; quality control data predicts that zinc values are accurate or slightly below true values. Liver concentrations in Fraser River fish fall well within the range established by Rieberger (1992) for uncontaminated B.C. lakes. In 150 fish tested in a number of lakes, Peterson found 99% of the fish had zinc concentrations between 9 µg/g and 86 µg/g. Only low levels of zinc are required for enzyme activity in fish. Levels higher than this may be tolerated due to the presence of metallothionein which is thought to be synthesized by fish as an adaptive response to higher zinc concentrations. The protein is binds zinc in order to protect key biochemical processes (Marafante, 1976).

Generally, zinc concentrations in the liver have remained constant and levels were below those reported for uncontaminated sites. Concentrations appear to be negatively correlated to fish size and may indicate uptake through the skin or gills. Liver levels are four to five times higher than muscle levels but are within the range for uncontaminated sites. As the levels are similar to other B. C. waters, it is concluded that levels were due to the ubiquitous nature of zinc and therefore no Tissue Quality Objectives are proposed at this time. More recent data is required to determine whether zinc levels have remained acceptable.

6.5.4.2 Organics

6.5.4.2.1 Chlorophenols

In 1980, tri- , tetra-, and pentachlorophenols were tested in the tissues of 25 largescale suckers. Two of the five samples taken at Ewen Slough, near the mouth of the Main Arm, had trichlorophenol concentrations above the detection limit of 0.02 µg/g wet-weight (0.060 µg/g, 0.080 µg/g) (Singleton, 1983). In 1988, the detection limit was lowered to 0.0002 µg/g but trichlorophenol was detected in only two (northern squawfish and starry flounder) of 44 samples (Swain and Walton, 1989).

Tetrachlorophenols were detected at concentrations from trace to 0.037 µg/g in the muscle tissues of five staghorn sculpins collected in 1972/73 study (Garrett, 1980). Tetrachlorophenol was also detected in the 1980 survey: the five values taken from the muscle tissues of largescale suckers at the mouth of the Main Arm ranged in concentrations from the detection limit of 0.01 µg/g to 0.25 µg/g and had a mean concentration of 0.097 µg/g (Singleton, 1983). Tetrachlorophenol was undetectable (n=8) in 1985 (<0.01 µg/g) (Swain, 1986c). In 1988, tetrachlorophenols were detected in one of 11 largescale suckers, one of ten northern squawfish, and one of six staghorn sculpins at levels of 0.002 µg/g, 0.013 µg/g, and 0.003 µg/g, respectively. All other samples in the Main Arm had muscle concentrations that were less than the detection limit of 0.0002 µg/g (Swain and Walton, 1989).

Pentachlorophenol was detected in four of five largescale sucker muscle tissue samples taken from Ewen Slough in 1980. They ranged in concentration from <0.10 µg/g to 0.19 µg/g (Singleton, 1983). In 1985, muscle samples (n=8) had undetectable levels of pentachlorophenol (<0.01 µg/g) in the Main Arm (Swain, 1986c). In 1988, all species had some detectable pentachlorophenol in their muscles when the detection limit was 0.0002 µg/g. For all species in the Main Arm, the mean concentration of pentachlorophenol (n=42) in 1988 was 0.001 µg/g (Swain and Walton, 1989).

Liver concentrations of chlorophenols were only tested in the 1988 survey when the detection limit was <0.025 µg/g which is much higher than the limit used to analyze muscle samples (0.0002 µg/g). Trichlorophenols (n=16) were not detected in any fish liver tissues. Tetrachlorophenol was detected in two of three staghorn sculpins with concentrations of 0.89 µg/g and 0.048 µg/g, and one of four northern squawfish with concentration of 0.038 µg/g. Pentachlorophenol was detected in one of three staghorn sculpins (0.30 µg/g) and in one of four northern squawfish (0.027 µg/g). The fact that liver concentrations exceeded muscle concentrations suggests that chlorophenols accumulate in liver tissues; however, because the detection limit for liver tissues is high compared to the detection limit of muscle, this can not be confirmed (Swain and Walton, 1989).

The existing Water Quality Objective for chlorophenols is a maximum concentration of 0.1 µg/g (wet-weight) in fish muscle for all chlorophenols combined. This value was based on the goal of no increase in chlorophenol concentrations over present conditions; however, <u>a new provisional Tissue Quality Objective of 0.2 µg/g (wet-weight) for the sum of mono-, di-, tri-, tetra- and pentachlorophenol in any single sample or a composite sample in any species is proposed .</u> This Objective was met in all cases in fish caught in the Main Arm during the 1988 survey, and reflects the Ministry criteria for 2,4-dichlorophenol alone.

6.5.4.2.2 Polychlorinated Biphenyls (PCBs)

PCBs were not detected (<0.3 µg/g) in muscle tissues collected in 1980 but Johnston *et al.*(1975) note that in 1972/73, muscle tissues from four of 25 fish tested in the Main Arm exceeded the detection limit of 0.3 µg/g. One value, taken from a northern squawfish, had a concentration of 1.9 µg/g (Garrett, 1980). No PCBs were detected in the 1985 survey that had a detection limit of <0.1 µg/g (Swain, 1986c). In 1988, the detection limit was 0.001 µg/g and all species had detectable concentrations. Largescale sucker, northern squawfish, and peamouth chub had mean concentrations of 0.02 µg/g, 0.03 µg/g, and 0.03 µg/g, respectively.

Concentrations of PCBs in the liver were only available from the 1988 report (Swain and Walton, 1989). Mean values for largescale sucker, northern squawfish and staghorn sculpin are: 0.105 µg/g, 0.083 µg/g, and 0.12 µg/g, respectively. As well, one of four peamouth chub had a detectable concentration of 0.17 µg/g. These values are substantially higher than those found in muscle tissue (Swain and Walton, 1989). .

All PCB concentrations are within the objective of 0.5 µg/g and have decreased since the 1970's. This decrease is most likely due to restricted use of products containing PCBs. However, due to the persistence of PCBs in the environment and their detrimental effects on aquatic life, consistent monitoring is recommended. PCBs are not used extensively anymore. Since the source of PCBs is almost strictly anthropogenic and chronic effects are still being debated, it is proposed that the 1985 Tissue Quality Objective of 0.5 µg/g (wet-weight) be modified to 0.1 µg/g (wet-weight) to protect wildlife from the consumption of whole fish. This objective was likely achieved by all samples taken in the 1988 survey.

6.5.4.2.3 Chlorobenzene

Chlorobenzenes were used as fungicides in agriculture but were restricted in 1971 due to their detrimental effects to the environment. The procedure for measuring chlorobenzene concentrations relies on the detection of hexachlorobenzene (HCB) which is a very persistent compound. In 1980 it was not detectable above the detection limit of 0.001 µg/g. This is an improvement from a 1972/73 study that reported levels ranging from trace to 0.019 µg/g (Garrett, 1980); all species examined in the study had an average less than 0.01 µg/g. No up- or downstream trends were noted. It is suspected that the widespread distribution is due to the extent of industrial and agricultural activity and consequently, the numerous sources of chlorobenzene. By 1978, no detectable HCB concentrations were present in fish collected from the Main Arm (Garrett, 1980). Hexachlorobenzene concentrations declined in the mid to late seventies and have remained below detection. This reduction is likely due to restrictions placed on the use of this chemical. Chlorobenzenes do not appear to be a concern to fish at the present time.

6.5.4.2.4 Phthalate Esters

Phthalic acid esters have a low acute toxicity and bioaccumulation is evident. Dimethyl was undetectable in fish muscle (n=5) in the 1980 survey when the detection limit was high (10 µg/g) (Singleton, 1983). Dimethyl was also undetectable in 1988 (n=43) when the detection limit was lowered to 0.01 µg/g (Swain and Walton, 1989).

Diethyl phthalate was not detected (10 µg/g) in the muscle tissues of five fish sampled in 1980, but when the detection limit was lowered in 1988, diethyl was detected in all five species. All of the mean and maximum values exceeded the average background concentration of 0.088 µg/g measured in blank samples from the lab (see table below). Northern squawfish (n=12), peamouth chub (n=8) and staghorn sculpin (n=6) had similar mean values of 0.23 µg/g, 0.23 µg/g and 0.24 µg/g, respectively. Largescale sucker (n=9) and starry flounder (n=8) values differed with mean concentrations of 0.60 µg/g and 0.14 µg/g, respectively.

Concentrations (µg/g) of Phthalate Esters in the Muscle Tissue of Fish in the Main Arm*

		Maximum and Mean Concentrations				
Phthalate Ester	**Background Levels**	**Largescale Sucker**	**Northern Squawfish**	**Peamouth Chub**	**Staghorn Sculpin**	**Starry Flounder**
dimethyl	0.088	ND	ND	ND	ND	ND
diethyl	0.088	1.15/ 0.6	0.76/ 0.23	0.43/ 0.23	0.46/ 0.24	0.31/ 0.14
di-n-butyl	0.098	0.07/ 0.04	0.2/ 0.06	0.28/ 0.08	0.5/ 0.15	0.1/ 0.06
butyl benzyl	0.046	0.03/ 0.02	0.04/ 0.03	0.12/ 0.04	0.13/ 0.04	0.08/ 0.04
di-n-octyl	0.11	0.035/ -	0.02/ -	0.10/ -	0.12/ -	0.06/ -
bis(2ethhex	0.094	0.032/ ND	0.12/ 0.07	0.10/ 0.05	0.10/ -	0.10/ 0.05

* wet-weight concentrations

Di-n-butyl was detected in the muscle of all species tested in the Main Arm. While the mean concentrations measured largescale sucker, northern squawfish, peamouth chub and starry flounder were below the maximum background concentration of 0.098 µg/g, most maximum values exceeded the maximum background concentration, indicating that contamination by di-n-butyl is occurring in fish muscle.

Diisobutyl and diamyl phthalate were tested for in the 1980 survey and were not detected at 10 µg/g(Singleton, 1983).

The muscle tissues of four of five largescale suckers tested had detectable concentrations of butyl isodecyl in 1980: concentrations were 0.38 µg/g, 0.81 µg/g, 0.96 µg/g, and 2.0 µg/g, respectively. The highest average concentration of butyl isodecyl in the five largescale suckers was 0.87 µg/g at Ewen Slough (Singleton, 1983).

Butyl benzyl was detected in the muscle tissues of all five largescale suckers tested in the Main Arm in 1980 as well as all species tested in 1988. In 1980, the average concentration for muscle samples collected from Ewen Slough was 0.053 µg/g which was comparable to upstream sites (Singleton, 1983). In 1988, the mean concentrations ranged from 0.02 µg/g to 0.04 µg/g. This range is below the maximum background concentration of 0.046 µg/g. However, the maximum concentrations of peamouth chub, staghorn sculpin, and starry flounder exceeded the background level with concentrations of 0.12 µg/g, 0.13 µg/g, and 0.08 µg/g, respectively. Largescale sucker and northern squawfish had maximum muscle concentrations that did not exceed background in the Main Arm.

Di-n-octyl was detected in the muscle tissues of all five largescale suckers sampled at Ewen Slough in 1980: the average concentration was 11.04 µg/g (Singleton, 1983). In 1988, no mean muscle concentrations were calculated but detectable levels were reported in the species examined. Maximum values ranged from 0.02 µg/g in northern squawfish to 0.12 µg/g in staghorn sculpin. With the exception of staghorn sculpin, all concentrations were below the maximum background concentration of 0.11 µg/g (Swain and Walton, 1989). There is no significant evidence of di-n-octyl contamination in fish muscle tissue.

Bis(2-ethylhexyl) was detected in all species but means were only calculated for northern squawfish, peamouth chub, and starry flounder: these means were similar with values of 0.07 µg/g, 0.05 µg/g, and 0.05 µg/g, respectively. Maxima ranged from 0.032 µg/g in largescale sucker to 0.12 µg/g in northern squawfish; all other maxima were 0.10 µg/g. All species except largescale sucker had some values exceeding the background concentration of 0.094 µg/g suggesting contamination of fish muscle by bis(2-ethylhexyl).

Concentrations (µg/g) of Phthalate Esters in the Liver Tissue of Fish in the Main Arm*

		Maximum and Mean Concentrations				
Phthalate Ester	**Background Levels**	**Largescale Sucker**	**Northern Squawfish**	**Peamouth Chub**	**Staghorn Sculpin**	**Starry Flounder**
dimethyl	-	ND	ND	ND	ND	ND
diethyl	0.35	ND/ND	ND/ND	ND/ND	ND/ND	ND/ -
di-n-butyl	-	1.86/1.23	1.73/0.88	2.10/ -	9.39/ -	1.00/ -
butyl benzyl	-	5.63/3.02	4.03/ 1.79	0.57/ 0.39	0.54/ 0.45	0.58/ -
di-n-octyl	-	ND/ND	ND/ND	ND/ND	ND/ND	ND/ -
bis(2) ethyl hexyl	0.061	ND/ND	1.95/ -	5.22/ 2.68	4.71/ 2.70	1.42/ -

*measurements in wet-weight

In 1988, dimethyl phthalate was not detected in any liver samples taken from the Main Arm (<0.5 µg/g) but this detection limit is too high to determine if dimethyl phthalate is accumulating. Diethyl was not detected above the detection limit of 0.2 µg/g in any sample from the Main Arm. Di-n-butyl was detected in all species. Maximum values ranged from 1.00 µg/g in starry flounder to 9.39 µg/g in staghorn sculpin (Swain and Walton, 1989). All detectable liver concentrations were higher than all muscle values; this suggests that di-n-butyl is accumulating in the liver. Butyl benzyl concentrations in the liver are also much higher than those detected in muscle. In the Main Arm, maximum liver concentrations for peamouth chub, staghorn sculpin, and starry flounder were similar with values of 0.57 µg/g, 0.54 µg/g, and 0.58 µg/g. Maxima for largescale sucker and northern squawfish are considerably higher at 5.63 µg/g and 4.03 µg/g, respectively. Bioaccumulation does appear to be occurring. Di-n-octyl was not detected in any samples from the Main Arm. The maximum liver concentration of bis(2-ethylhexyl) was similar for northern squawfish (1.95 µg/g) and starry flounder (1.42 µg/g). Peamouth chub and staghorn sculpin had significantly higher maxima of 5.22 µg/g and 4.71 µg/g, respectively. Mean concentrations of bis(2-ethylhexyl) were only calculated for peamouth chub (2.68 µg/g) and staghorn sculpin (2.70 µg/g). Largescale suckers had no detectable concentrations of the compound. All detectable concentrations of bis(2-ethylhexyl) measured in fish collected from the Main Arm were higher than the maximum background concentration of 0.61 µg/g and higher than concentrations found in muscle tissue. Bis(2-ethylhexyl) appears to be accumulating in the tissues of fish.

All six phthalates except for dimethyl phthalate were detected in muscle tissues collected in 1988. There was evidence of bioaccumulation of di-n-butyl, butyl benzyl, and bis(2-ethylhexyl) in liver. Phthalate acid esters may be a concern in Fraser River fish from the Main Arm.

6.5.4.2.5 Polycyclic Aromatic Hydrocarbons (PAHs)

There were no detectable concentrations of any of the following polycyclic aromatic hydrocarbons in fish muscle tissues collected and tested in 1988.

PAH	Detection Limits
acenaphthene	0.004 µg/g
acenaphthylene	0.004 µg/g
anthracene	0.004 µg/g
benzo(a)anthracene	0.01 µg/g
benzo(a)pyrene	0.02 µg/g
benzo(b)fluoranthene	0.02 µg/g
benzo(ghi)perylene	0.02 µg/g
benzo(k)fluoranthene	0.02 µg/g
chrysene	0.01 µg/g
dibenzo(ah)anthracene	0.02 µg/g
fluoranthene	0.01 µg/g
fluorene	0.004 µg/g
indeno(1,2,3-cd)pyrene	0.02 µg/g
naphthalene	0.004 µg/g
phenanthrene	0.004 µg/g
pyrene	0.01 µg/g

In 1988, liver detection limits were five times higher than those in muscle and yet, detectable concentrations were found in fish livers collected from the Main Arm. Acenaphthene was detected in the hepatic tissue of one of four northern squawfish at a concentration of 0.035 µg/g. Acenaphthylene was detected in peamouth chub, staghorn sculpin and starry flounder with maximum liver concentrations of 0.024 µg/g, 0.032 µg/g, and 0.081 µg/g, respectively. Anthracene and benzo(a) anthracene were each detected in one northern squawfish with liver concentrations of 0.020 µg/g, and 0.035 µg/g respectively. Chrysene was detected in the hepatic tissue of peamouth chub with a maximum concentration of 0.077 µg/g and a median for four samples of 0.057 µg/g. Fluorene was detected in the livers of peamouth chub, staghorn sculpin and starry flounder in maximum concentrations of 0.024 µg/g, 0.067 µg/g, and 0.048 µg/g, respectively. Naphthalene was detected in the livers of all species. Maximum naphthalene concentrations in the Main Arm ranged from 0.074 µg/g in largescale sucker to 0.12 µg/g in starry flounder. Mean concentrations were statistically similar for all species and ranged in concentrations from 0.051 µg/g for four largescale suckers to 0.064 µg/g for four northern squawfish. Phenanthrene was detected in the livers of all species except largescale sucker. Maximum liver concentrations ranged from 0.023 µg/g in northern squawfish (n=4) to 0.071 µg/g in starry flounder (n=1). Pyrene was detected in the hepatic tissues of one (of four) peamouth chub (0.12 µg/g). All seven other PAHs were not detected (Swain and Walton, 1989).

Liver concentrations had detection limits five times higher than in muscle yet, more detectable concentrations were found. This strongly suggests that bioaccumulation is occurring in the liver. Detectable concentrations were found most often for fluorene, naphthalene and phenanthrene. PAHs may be a concern in Fraser River fish from the Main Arm.

To protect consumers of fish and shellfish, an objective is proposed as follows: the maximum concentrations of benzo (a) pyrene in edible tissues should not exceed 4 µg/kg for consumers of up to 50 grams per week, 2 µg/kg for consumers of up to 100 grams per week, and 1 µg/kg for consumers of up to 200 grams per week.

6.5.4.2.6 Organochloride Pesticides

In 1988, the organochloride pesticides tested for in fish muscle and their detection limits were as shown in the following Table:

Organochloride Pesticide	Detection Limit
aldrin	0.2 µg/g
alpha-chlordane	0.2 µg/g
gamma-chlordane	0.2 µg/g
dieldrin	0.2 µg/g
DDT	0.2 µg/g
DDD	0.2 µg/g
DDE	0.01 µg/g
Endrin	0.2 µg/g
endosulfan I	0.1 µg/g
endosulfan II	0.4 µg/g
endosulfan sulfate	2.0 µg/g
heptachlor	0.2 µg/g
heptachlor epoxide	2.0 µg/g
lindane	0.1 µg/g
methoxychlor	1.0 µg/g
toxaphene	10 µg/g

Alpha-and gamma-chlordane were detected in the muscle tissues of all species except largescale sucker. However, the mean concentration was reported for levels detected in starry flounder only: the mean concentrations of alpha-and gamma-chlordane were 0.55 µg/g and 0.6 µg/g, respectively. Dieldrin was detected in one sample each of largescale sucker and peamouth chub: muscle concentrations were 1.42 µg/g and 1.53 µg/g, respectively. Maximum DDT concentrations ranged from 0.356 µg/g in one of 12 northern squawfish to 2.59 µg/g in one of nine largescale suckers. DDD was detected in all species; only peamouth had enough measures (n=8) to calculate a mean (2.98 µg/g). DDE was the most common pesticide detected. Maximum DDE concentrations ranged from 2.26 µg/g in one of six staghorn sculpins to 8.28 µg/g in one of eight peamouth chub in the muscle tissues sampled. Within the Main Arm, largescale sucker, staghorn sculpin and starry flounder had similar mean concentrations of DDE of 1.51 µg/g, 1.64 µg/g and 1.89 µg/g, respectively. Northern squawfish and peamouth chub had substantially higher mean values at 3.74 µg/g and 4.61 µg/g. Endrin was not detected in the muscle tissues of Main Arm fish. Endosulfan I and Endosulfan II were each detected in one of 12 northern squawfish at 2.63 µg/g and 0.666 µg/g, respectively. Endosulfan sulfate was detected in the muscle tissue of one of six staghorn sculpins

(1.88 µg/g). Methoxychlor was detected at a muscle concentration of 3.38 µg/g in one of 12 northern squawfish. All other organochlorine pesticides were not detected in muscle tissue samples (Swain and Walton, 1989).

Detection limits were 20 times lower in liver samples than muscle tissue samples. Therefore, more detectable concentrations would be expected in livers. DDT was detected in the liver of one of three staghorn sculpins (0.021 µg/g) and the one starry flounder (0.042 µg/g) tested. DDD was detected in all species with maximum liver concentrations between 0.020 µg/g in one of four northern squawfish to 0.050 µg/g in one of four largescale suckers. DDE was detected in all species. The mean concentrations for largescale sucker and staghorn sculpin were similar (0.026 µg/g and 0.028 µg/g) but lower than the liver concentrations for the northern squawfish (0.044 µg/g) and the peamouth chub (0.067 µg/g). Mean liver concentrations of DDE in largescale sucker (n=4) in the Main Arm was 0.026 µg/g and 0.044 µg/g (n=4) for northern squawfish. Endosulfan I was detected in the livers of one of four northern squawfish (0.009 µg/g) and one of three staghorn sculpin (0.007 µg/g). All other values were below detection limits (Swain and Walton, 1989).

The most commonly detected pesticides in fish muscle were alpha- and gamma-chlordane, dieldrin, DDT, DDD, and DDE. The detection limit in liver was 20 times lower and yet concentrations were detected less often. Therefore, it can be concluded that organochloride pesticides are not bioaccumulating. They are not a concern in Fraser River fish from the Main Arm.

6.5.4.3 General Fish Health

A 1995 FREMP Monitoring Program Report measured the fish health of peamouth chub and starry flounder in the Fraser River Estuary (Roome, 1995). Fish were tested for gill, spleen, kidney, liver, and gut abnormalities, as well as parasitic infestations. For comparison, peamouth chub were tested in the Main Stem at Barnston Island, in the North and Main Arms, and at a reference site at Mission. Starry flounders were collected for testing only in the Main and North Arms.

In a gross examination, North and Main Arm sites had higher levels of abnormalities. Skin aberrations and fin erosion were found in 7% and 5% of peamouth from the Main Arm; this frequency is compared to 0% for both parameters at the Mission site. Hepatomas in the Main Arm were the highest of any reach at 97%. Only 74% of the Mission fish had a similar condition. However, abnormal gills were found in 9% of the peamouth chub in Mission but in the Main Arm, gill abnormalities were present in less than 5% of the peamouth chub and 2% of the starry flounder. Abnormal spleen conditions were also higher in the peamouth chub from the Mission site (7%) than those from the Main Arm (5%) (Roome, 1995).

In a histological analysis, the percentage of gill and spleen abnormalities of peamouth from the Main Arm were 34% and 98% respectively, while the same disorders were found in 100% of the reference fish from Mission. Spleen myxosporean and kidney hemorrhages were also found in 100% of the peamouth chub from Mission but only 98% and 94% respectively of peamouth chub from the Main Arm. Only gill protozoans, which were found in 10% of the Main Arm peamouth chub, were not found in any of the Mission peamouth chub (Roome, 1995).

If the visual and histological assessments are compared, the results are far from conclusive. Both assessments show the highest percentage of gill aberrations at the Mission site and the highest percentage of spleen disorders in the Main Stem. However, liver and kidney abnormalities, which were found in the highest percentage in North and Main Arms by visual assessment, were found in the highest percentages in the Main Stem and Mission sites by histological assessment (Roome, 1995).

Overall, the prevalence of melanosis and myxosporeans was high in several tissues at all sites including the reference location. This may indicate normal protozoan and pigmentation levels and not an anthropogenic increase. The presence of liver and spleen abnormalities and kidney hemorrhaging was high in all regions including the reference site. This may indicate high PCB concentrations or poor water quality and poor fish health in upstream stations as well as the Main Arm; high levels in the reference location hinder interpretation.

6.6 Sturgeon and Roberts Banks

6.6.1 Water Chemistry

The Fraser River discharges to the Strait of Georgia over the relatively shallow Sturgeon and Roberts Banks. Though this area is predominantly marine, it is influenced significantly by the freshwater outflow from the Fraser River. The North and Middle Arms of the river discharge over Sturgeon Banks and the Main Arm traverses Roberts Bank to the south. Water, sediment and fish tissue data were collected from a number of sources to assess the quality of this area.

Limited data concerning water and sediment quality were retrieved from the SEAM database for one provincial monitoring site on both Sturgeon and Roberts Banks (Sites E216048 and E206049, respectively), and are summarized in Tables 121, 122, 123, and 124. Sediment, benthic fish and invertebrate samples were collected on Sturgeon and Roberts Banks, as well as north and south of the Iona Jetty by Environment Canada (Harding *et al*., 1988). Water and sediment data were collected at three sites on Sturgeon and Roberts Banks (Figure 10) for a study of the toxic accumulation of chemicals in estuarine vascular plants by AIM Ecological Consultants (Moody, 1989). Sediment data were collected as part of the Fraser River Estuary Monitoring Program (FREMP) program on Roberts Bank in 1993 (Swain and Walton, 1994).

The Greater Vancouver Regional District (GVRD) periodically monitors a number of sites in the Fraser River. One of these sites (GVRD South 5, Figure 10) is located at the mouth of the Main Arm, south of the Main Arm Jetty on Roberts Bank. Data were collected at this site between February, 1991 and November, 1994 (Table 125). Dissolved oxygen and bacteriological monitoring was also conducted by the GVRD along the south face of the North Arm Jetty (GVRD Sites 4-14), and data from 1990 to 1992 are discussed (Tables 126, 127 and 128). Dissolved oxygen and bacteriological concentrations were monitored between 1989 and 1991 at GVRD sites 1-4, north of the North Arm Jetty (Figure 10, Table 129).

6.6.1.1 pH and Alkalinity

The pH of water in Sturgeon and Roberts Banks was slightly basic, with a mean pH at the three AIM sites ranging from 7.3 to 7.5, and a mean pH at GVRD South 5 of 7.5. In order to maintain these near-neutral conditions, a Water Quality Objective is proposed for pH. The objective, applicable to discrete samples collected from outside of provisional initial dilution zones of effluents, is that the pH in any discrete sample should not be outside the pH range of 6.5 to 8.5. Initial dilution zones of effluents are defined as extending from the bed to the surface, and in a radius no larger than 100 m. By restricting the upper limit of pH to 8.5 instead of 9.0, the percentage of un-ionized ammonia in aqueous ammonia solution will be about one-third that which would be available at pH 9.0 (Trussell, 1972).

6.6.1.2 Hardness and Metals

Hardness values have been calculated from calcium and magnesium concentrations collected at the GVRD monitoring site. The mean hardness at this site was 577 mg/L; values ranged from 69 mg/L to 2 293 mg/L. No criterion exists for hardness for the protection of marine aquatic life or recreation.

Concentrations of calcium at the GVRD sites ranged from 14.5 to 163 mg/L, with a mean value of 48.3 mg/L. No criterion exists for calcium for the protection of marine aquatic life.

The mean concentration of magnesium was 111 mg/L, with values ranging from 7.96 to 460 mg/L. No criterion exists for magnesium concentrations with regards to marine aquatic life.

Cadmium

Mean concentrations of cadmium at the three AIM sites ranged from 0.00057 mg/L to 0.00147 mg/L. All concentrations of cadmium measured at GVRD South 5 were <0.0005 mg/L. These concentrations are well below the water quality criterion of a four-day average of 0.009 mg/L for the protection of marine aquatic life (U.S. EPA, 1986). Therefore, cadmium does not appear to be a concern to water quality.

Chromium

All measurements of chromium at GVRD South 5 were below detection limits of 0.001 mg/L, and thus well below the 4-day average water quality criterion of 0.05 mg/L (Chromium VI) for the protection of marine aquatic life (U.S. EPA, 1986). Therefore, chromium is not a concern in this area.

Copper

The mean concentration of total copper was approximately 0.003 mg/L at the three AIM sites. This exceeds the 30-day average water quality criterion for the protection of marine and estuarine aquatic life for copper of ≤0.002 mg/L, and is equal to the maximum recommended concentration of 0.003 mg/L (Singleton, 1987). The mean concentration of copper measured at GVRD South 5 was 0.001 mg/L with a maximum value of 0.004 mg/L. These excursions over the criterion may be a concern to marine aquatic life. However, in Section 6.4.1.2, it was stated that copper concentrations in the Fraser River are naturally high and the range of copper measured on the Banks is well within the range measured in the North Arm as well as in the reach between Chilliwack and Kanaka Creek. As there are no known sources of copper to Sturgeon and Roberts Banks, no objective is proposed for copper in this area.

Lead

Concentrations of lead at the three AIM monitoring sites were generally quite low, with median values below detection limits of 0.001 mg/L at two of the sites and a mean value of just over 0.001 mg/L at the third site. All concentrations measured at GVRD South 5 were below detection limits of 0.001 mg/L. These values are below the water quality criterion for lead ≤0.002 mg/L for a 30-day average in marine and estuarine environments for the protection of aquatic life (U.S. EPA, 1986). Therefore, lead does not appear to be a concern.

Mercury

Concentrations of mercury were below detectable limits of 0.05 µg/L for all samples taken at the AIM sites on the Roberts and Sturgeon Banks. The water quality criterion for the 30-day average concentrations for mercury is 0.02 µg/L (Nagpal, 1989). Therefore, the detection limit is too high to make any assessment of possible impacts from mercury on marine aquatic life.

Zinc

Mean concentrations of zinc at the three AIM sites ranged from < 0.005 mg/L to 0.013 mg/L, well below the water quality criterion for zinc in marine environments of a 4-day average ≤0.086 mg/L (U.S. EPA, 1986). Concentrations were also low at GVRD South 5, with a median value of <0.001 mg/L and a maximum value of 0.002 mg/L. Therefore, zinc does not appear to be a concern to aquatic life.

6.6.1.3 Dissolved Oxygen and Oxygen-Consuming Materials

The mean concentration of dissolved oxygen measured at GVRD South 5 was 10.8 mg/L, with a minimum concentration of 9.2 mg/L. This value exceeds the water quality criterion of 9.0 mg/L (100% saturation at 28 parts per thousand salinity at all temperatures between 0 and 25 °C) which provides a high level of protection for anadromous marine species, including salmonids (Davis, 1975).

Mean concentrations of dissolved oxygen measured in 1990 at GVRD Sites 4-14 ranged from 8.1 to 8.6 mg/L, with a minimum concentration of 6.3 mg/L. This minimum value is only slightly below the water quality criterion of 6.5 mg/L (80% saturation at 28 parts per thousand salinity at temperatures between 0 and 15 °C) to provide a moderate level of protection for anadromous marine species (Davis, 1975). Mean concentrations at GVRD Sites 1-4 north of the North Arm jetty ranged from 9.4 to 9.8 mg/L, with a minimum value of 7.6 mg/L at Site 2. Therefore, dissolved oxygen concentrations are not a serious concern in this area; however, there are times when aquatic life might be under greater than normal levels of physiological stress. Consequently, a Water Quality Objective is proposed for dissolved oxygen. This objective states that the mean of at least five samples collected at the same site within a 30-day period should not have dissolved oxygen concentration less than the lower of 8.0 mg/L or 100% saturation, and the dissolved oxygen concentration of any discrete sample collected on Sturgeon or Roberts Banks should not be less than 5 mg/L, for the protection of anadromous species including salmonids. This objective applies outside of initial dilution zones as described in Section 6.6.1.

6.6.1.4 Nutrients

The mean concentration of total dissolved ammonia measured at the provincial monitoring sites on Roberts and Sturgeon Banks ranged from 0.034 to 0.092 mg/L, with a maximum value of 0.333 mg/L occurring at Roberts Bank. Mean concentrations at the three AIM sites ranged from 0.037 mg/L to 0.302 mg/L, with the maximum concentration of 0.64 mg/L occurring at the Reifel site. The mean concentration at GVRD South 5 was 0.08 mg/L, with a maximum concentration of 0.15 mg/L. The water quality criteria for maximum total ammonia at a salinity of about 30 g/kg, a pH of 8.0, and a temperature of 20° C is 7.3 mg/L and average five to 30-day concentration is 1.1 mg/L for the protection of saltwater aquatic life (Nordin, 1990). Therefore, all values are below the criteria and do not pose an immediate concern at present; however, the high maximum ammonia measured should be monitored in future to ensure that the criteria continue to be met.

Concentrations of total nitrate at the three AIM sites ranged from 0.06 mg/L to 1.04 mg/L, with a maximum concentration of 2.94 mg/L. This value was extremely high compared to the other two measurements taken at the site (0.07 and 0.1 mg/L). No water quality criterion has been proposed for the protection of marine aquatic life, but the maximum concentration recommended for recreation and aesthetics is 10 mg/L (Nordin, 1990). Therefore, it does not appear that nitrate is of concern.

Mean concentrations of nitrite at the three AIM sites ranged from 0.008 to 0.032 mg/L, well below the water quality criterion for recreation and aesthetics of 1 mg/L (Nordin, 1990). No criterion has yet been proposed for nitrite for the protection of marine aquatic life.

The mean concentration of total phosphorus measured at the three AIM sites ranged from 0.18 mg/L to 0.38 mg/L. The maximum concentration was 0.64 mg/L. Concentrations of ortho-phosphorus ranged from 0.058 to 0.074 mg/L, with a maximum concentration of 0.15 mg/L. No water quality criterion has been set for phosphorus concentrations in the marine environment.

Harrison (1985) discusses the effects of the outflow from the Iona plant at the south-east base of Iona Jetty to Sturgeon Banks before the deep-sea outflow was constructed. He found that concentrations of phosphorus and ammonium were high in the effluent channel close to the outfall (approximately 0.5 mg/L and 9 mg/L, respectively) but decreased by about two orders of magnitude about 2 km west beyond the jetty. Increases in phytoplankton concentrations were also reported near the jetty (Harrison, 1981). Concentrations of chlorophyll a measured along a transect on Sturgeon Banks in 1992 (Lucey *et al*., 1992) were generally higher closer to shore, and maximum values occurred at Sites A4, A5, and B8 (Figures 17, 18), approximately 1200 m from the original outflow site. These measurements were taken in late 1992, four years after the outflow was completed, and so reflect a partial recovery of the banks. In general, phytoplankton standing stock and primary productivity are depressed near the mouth of the Fraser River due to the turbidity of the river water, resulting in a light-limited, rather than nutrient limited, environment (Harrison, 1985),

6.6.1.5 Bacteriological Indicators

Concentrations of fecal coliforms measured at the provincial monitoring sites were much higher at Sturgeon Banks than at Roberts Bank, with geometric means of 263 CFU/cL (n=5) at Sturgeon Banks and 4 CFU/cL (n=5) at Roberts Bank. This is probably due to the greater influence of the Iona Island discharge and the Fraser River outflow on Sturgeon Bank. The maximum concentration of fecal coliforms measured at Sturgeon Banks was 640 CFU/cL, while at Roberts Bank the maximum value was 17 CFU/cL. Water quality data collected at a GVRD site (GVRD South 5) had a geometric mean of 4 165 MPN/100 mL during the winter months (November to March) and a geometric mean of 773 MPN/100 mL during the summer months (April to October, the period when recreation generally occurs). The water quality criterion applies to the summer months only. The most stringent water quality criterion for fecal coliforms in this area is for the protection of primary-contact recreation, with a maximum geometric mean of 200 CFU/cL (Warrington, 1988), and is exceeded both by the geometric mean of fecal coliforms at Sturgeon Banks, and at the GVRD Roberts Bank site. Therefore, fecal coliforms are of concern in this area.

Concentrations of fecal coliforms measured in the summers of 1990 - 1992 at GVRD Sites 4 - 14 were very low, with the majority of the sites having median concentrations < 20 MPN/100 mL. Concentrations were generally highest in the summer of 1991, with the maximum concentration of 2 300 MPN/100 mL occurring at Site 9 in that year. All geometric means were well below the water quality criterion for fecal coliforms. Fecal coliform geometric means in the winter at these sites ranged from 41 to 180 MPN/100 mL, with the highest concentrations occurring in the winter of 1990. The maximum concentration of 2 400 MPN/100 mL was measured at both Site 6 and Site 10 during that winter. Geometric means of concentrations of fecal coliforms measured at GVRD Sites 1-4, north of the North Arm jetty, ranged from 140 to 252 MPN/100 mL during the summer months. As it appears that fecal coliform concentrations between sites and over time can vary considerably, a Water Quality Objective is proposed for fecal coliform concentrations on Sturgeon and Roberts Banks for the protection of primary-contact recreation. This objective states that the geometric mean of fecal coliforms in at least five samples collected within a 30-day period between April and October should not exceed 200 CFU/100 mL, and applies outside of initial dilution zones as described in Section 1.0.

Concentrations of *E. coli* bacteria were also much higher at the provincial monitoring sites on Sturgeon Bank, with a geometric mean of 231 CFU/cL compared to the geometric mean of 3 CFU/cL at Roberts Bank. The maximum value measured at the Sturgeon Bank monitoring site was 580 CFU/cL. The water quality criterion for the protection of primary-contact recreation from E. coli is a geometric mean of ≤77 CFU/cL (Warrington, 1988). This value is exceeded by E. coli concentrations measured at the Sturgeon Bank monitoring site. Therefore, a Water Quality Objective for *E. coli* bacteria concentrations is proposed. This objective states that, outside of initial dilution zones as described in Section 6.4.1.1, the geometric mean of *E. coli* concentrations measured in at least five samples collected in a 30-day period between April and October should not exceed 77 CFU/ 100 mL for the protection of primary-contact recreation.

Concentrations of *Enterococci* were fairly low at both provincial monitoring sites. Geometric means of concentrations ranged from 3 CFU/cL to 18 CFU/cL at Roberts Bank and Sturgeon Bank, respectively, with a maximum concentration of 67 CFU/cL occurring at Sturgeon Bank. These geometric means are below the water quality criterion for the protection of primary-contact recreation of ≤20 CFU/cL (Warrington, 1988). The geometric mean of *Enterococci* in four samples taken at GVRD Site 5 was 26 CFU/cL, with a maximum value of 45 CFU/cL. This mean exceeded the criterion, but the sample size (n=4) was very small. Larger samples (n=35 at each site) taken from GVRD Sites 7 and 13 in 1992 had geometric means of 2 and 3 CFU/cL, respectively in the summer months, and 10 CFU/cL and 13 CFU/cL, respectively in the winter months; these values are well below the criterion. The maximum concentration measured at these sites was 70 CFU/cL at Site 7 during the winter months. The geometric mean at GVRD Site 1, north of the North Arm jetty, was 37 MPN/100 mL. Due to these occasional excursions over the criterion suggest, a Water Quality Objective for *Enterococci* bacteria concentrations is proposed for the Sturgeon/Roberts Banks area. This objective is that the geometric mean of *Enterococci* coliforms in at least five samples collected in a 30-day period not exceed 20 CFU/100 mL between April and October outside of initial dilution zones as described in Section 6.6.1, for the protection of primary-contact recreation.

Concentrations of *Pseudomonas aeruginosa* were below detection limits (<2 CFU/cL) at both the Roberts and Sturgeon Banks monitoring sites for all of the measurements taken. These values meet the water quality criterion for *Pseudomonas aeruginosa* for the protection of primary-contact recreation of a geometric mean ≤2 CFU/cL (Warrington, 1988). As there is a potential for the introduction of *Pseudomonas aeruginosa* from the Annacis Island or Lulu Island STPs, a water quality objective is proposed for *Pseudomonas aeruginosa* concentrations at Sturgeon and Roberts Banks for the protection of primary-contact recreation. This objective states that the geometric mean of *Pseudomonas aeruginosa* coliforms in at least five samples collected in a 30-day period between April and October should not exceed 2 CFU/100 mL, outside of initial dilution zones as described in Section 6.6.1.

6.6.1.6 Organics

Total PCBs, PCPs and TCPs were measured at each of the three AIM sites. The concentration of PCBs was below detection limits (0.001 mg/L) for all samples taken. The water quality criterion for maximum concentrations of total PCBs is 0.1 ng/L, much lower than the detection limits used in the AIM study. Therefore, no conclusion about the possible effects of PCB levels on marine aquatic life can be made.

The concentrations of PCPs in three of nine samples taken at the three AIM sites matched the detection limit of 0.002 mg/L; the remaining six samples were below detection limits of <0.002 mg/L). Values measured at this detection limit exceed the water quality criterion for PCPs of 0.0001 mg/L at a pH of between 6.9 and 7.9 (Warrington, 1993). Although PCP is the most environmentally persistent form of chlorinated phenols, and may be introduced into the estuary from any of 20 wood-treatment plants in the estuary area (Moody, 1989), it is being eliminated from use.

Therefore measuring its presence in the water column on the Banks is not particularly effective in determining whether there are problems. Therefore, no Water Quality Objective is proposed for this compound in the water column on Sturgeon and Roberts Banks..

Concentrations of TCPs at the three AIM sites were undetectable at detection limits of 0.002 mg/L. Even when detection limits were lowered to 0.0002 mg/L, all samples had undetectable levels of TCPs. The most restrictive water quality criterion for any of the forms of TCP is ≤0.06 µg/L for 2,3,6-TCP; because this criterion is greater than even the lower detection limit, it may be concluded that the criterion is met by all samples tested.

6.6.2 Sediment Chemistry

Sediment samples taken by Harding *et al.* (1988) in May, 1985 and January, 1986 were tested for a number of trace metals both north and south from the Iona Jetty (designated North Iona and South Iona, respectively), as well as on Sturgeon and Roberts Banks (referred to as the Environment Canada sites). Particle size composition of sediments was highly variable, but generally quite large, with the composition of silt and clay (particles <0.063 mm) in the sediment samples from the various sites ranging from 0.3 to 7.2% north of the Iona jetty, 0.7-20.2% south of the Iona Jetty, 0.0-25.9% on Sturgeon Banks, and 0.3-15.8% on Roberts Bank.

Dioxins, furans and chlorinated phenol levels in sediments were measured at six sites on Sturgeon and Roberts Banks in 1990 (Harding, 1990). Percent composition of sand and clay was not recorded; therefore analysis of the data based on relative particle sizes is not possible.

Prior to 1988 (when the Iona outfall was completed), treated sewage was discharged at the base of the south side of the Iona Jetty and allowed to flow through a drainage channel into Georgia Strait. However, the drainage channel was covered by seawater at high tide so the treated sewage was subject to tidal currents. A number of jetties (e.g. the Iona Jetty, the North Arm Jetty, and the Main Arm Jetty) functioned to channel water directly out into Georgia Strait and prevent cross-shore transport of effluent from both the Iona treatment plant and discharge from the Fraser River. Due to this channeling effect, the concentration of trace metals in sediment samples was greatest along the south side of the Iona Jetty, with concentrations decreasing both south, along Sturgeon and Roberts Banks, and north of the Iona Jetty. The concentrations of metals north from the Iona Jetty (North Iona) were generally intermediate between those at Sturgeon Bank and Roberts Bank. Concentrations of all metals were highest at the western end of Iona Jetty, and lowest midway between Iona Jetty and the North Arm Jetty. High concentrations near the end of the jetty are probably due to suspended metals from the discharge being carried around the jetty by tidal currents and precipitating into the sediments as the water approaches shore.

Sediment samples were also collected on Roberts Bank between the coal port jetty and the B.C. Ferry terminal as part of the 1993 sediment monitoring program (Swain and Walton, 1994). The mean composition of the sediment at this site was 59.9% sand (particle sizes of 2.00 mm - 0.063 mm in diameter) and 39.9% silt and clay (particle sizes <0.063 mm in diameter); the particles were smaller on average than those measured on Roberts Bank by Harding *et al.* in 1985-86.

6.6.2.1 Metals

Arsenic

Concentrations of arsenic were below detection limits of 8 µg/g at all of the Environment Canada sites in the sample areas, well below the minimum effects concentration of 33 µg/g based on the National Status and Trends Program Approach (NSTPA) (Long and Morgan, 1990). The maximum concentration measured at the Roberts Bank site in 1993 was 6.04 µg/g. All samples taken in 1986 were also below detection levels.

Cadmium

The concentration of cadmium was greatest directly south from the Iona Jetty, with a mean concentration of 1.4 µg/g and a maximum concentration of 4.68 µg/g. These values are below the lowest-effects concentration of 5.0 µg/g based on NSTPA in a marine environment (Long and Morgan, 1990) but above the draft interim marine TEL of 0.676 µg/g (Environment Canada, 1995). Concentrations decreased rapidly with distance from the discharge, with mean concentrations of 0.19 µg/g at Sturgeon Banks and 0.18µg/g north of the Iona Jetty. Little change occurred in cadmium concentrations in 1986. The maximum concentration of cadmium measured in 1993 at the Roberts Bank site was 0.18 µg/g

Chromium

Two of seven samples collected from South Iona in 1985 exceeded the minimum effects water quality criterion of 80 µg/g in a marine environment based on NSTPA (Long and Morgan, 1990). The maximum concentration measured was 102.0 µg/g. Concentrations measured in 1986 further increased at both South Iona and Sturgeon Banks while remaining constant or decreasing slightly at Roberts Bank and North Iona. Chromium concentrations measured in 1993 at Roberts Bank were also below the water quality criterion with a maximum concentration of 64.9 µg/g. The excursions over the criterion at South Iona and Sturgeon Banks indicate that the marine biota inhabiting these sites are not adequately protected from chromium toxicity; however, these higher levels are due to historic discharges.

Copper

The mean concentration of copper measured in 1985 was much higher at South Iona than at any of the other sites measured. This value of 88.7 µg/g exceeded the minimum effects water quality criterion of 70 µg/g copper in the marine environment based on NSTPA (Long and Morgan, 1990) and is well above the draft interim marine TEL of 18.7 µg/g (Environment Canada, 1995). The high mean value was due to extremely high concentrations at the two sites closest to the South Iona discharge. The remaining five sites in this area had a mean concentration of 26 µg/g. Concentrations at the other sampling areas were also well below the criterion. Copper concentrations increased along Roberts Bank in 1986 by 3 to 4 µg/g at each of three sites, increased by 25 µg/g at one of the South Iona sites, and remained fairly constant at the remaining sites. The maximum concentration of copper measured in 1993 at the Roberts Bank site was 28.8 µg/g. It is apparent that copper is of concern in sediment collected from the mouth of the Fraser River: All values collected exceed the draft interim marine TEL of 18.7 µg/g and some values exceed the more relaxed marine sediment quality criterion of 70 µg/g for the protection of aquatic life.

Lead

Concentrations of lead in 1985 were low, (mean values ranged from less than 3 to 5 µg/g) except at South Iona where the mean concentration was 44.4 µg/g and the maximum concentration was 166 µg/g. However, beyond the two sampling sites closest to the discharge, concentrations did not exceed 16 µg/g. The lowest-effects water quality criterion for lead in marine sediment is 35 µg/g based on NSTPA (Long and Morgan, 1990) and the draft interim marine TEL is 30.2 µg/g (Environment Canada, 1995). The concentration at which major biological effects are measured in the marine environment is 130 µg/g, based on the Sediment Quality Triad method (SQT) (Chapman, 1986). Lead concentrations increased by 15 µg/g at one of the Iona sites, and remained fairly consistent at the remaining sites in 1986. The maximum concentration measured in 1993 at the Roberts Bank site was 7.6 µg/g.

Mercury

In 1985, the mean concentration of mercury at South Iona (0.38µg/g) exceeded the lowest-effects water quality criterion of 0.15 µg/g based on NSTPA for the marine environment (Long and Morgan, 1990) and the draft interim marine TEL of 0.13 µg/g (Environment Canada, 1995). Again, this was due to very high concentrations at the two sampling sites closest to the Iona discharge. The mean concentration for the remaining five sites in this area was 0.14 µg/g. Values were below the criterion at all sites in the other sampling areas except at one site in the Roberts Bank area where the concentration was 0.17 µg/g. Concentrations of mercury measured in 1986 generally decreased at all sites surveyed. The maximum concentration in 1993 at the Roberts Bank site was 0.039 µg/g.

Molybdenum

Molybdenum concentrations were below detection limits (0.8 µg/g) at all Environment Canada sites. The maximum concentration of molybdenum in 1993 at the Roberts Bank site was 4.1 µg/g. No criterion exists for this metal in sediments.

Nickel

All concentrations of nickel were similar in the four areas sampled; mean values ranged from 35.3 µg/g to 40.6 µg/g in 1985. These values exceed the minimum effects water quality criterion for the marine environment of 30 µg/g based on NSTPA (Long and Morgan, 1990) and the draft interim marine TEL of 15.9 µg/g (Environment Canada, 1995). The maximum value at both North and South Iona was 50 µg/g which is the median effects threshold for nickel (Long and Morgan, 1990). Concentrations measured in 1986 were similar to those measured in 1985 in all sampling areas. The mean concentration of nickel measured in 1993 at the Roberts Bank site was 45.5 µg/g; the maximum concentration was 51.7 µg/g. The maximum value exceeded the median effects threshold for nickel (Long and Morgan, 1990).

Zinc

Mean concentrations of zinc in 1985 were well below the low range effects criterion of 120 µg/g based on NSTPA (Long and Morgan, 1990) in all areas except South Iona. At this site, the mean concentration was 125.4 µg/g due to the high concentration in sediments closest to the historic discharge. Concentrations at the five sites furthest from the discharge were all below 85 µg/g. There was a slight increase in zinc concentrations at all sites measured in the 1986 sampling period. The mean concentration measured in 1993 at the Roberts Bank site was 80.9 µg/g.

6.6.2.2 Organics

6.6.2.2.1 PCBs, Chlorophenols, and Pesticides

Mean concentrations of PCBs at the three AIM sites ranged from below detection limits (0.01 µg/g) to a maximum of 0.0127 µg/g. These values are below the water quality criterion for total PCBs of 0.02 µg/g for the protection of marine aquatic life, based on the equilibrium partitioning approach (Nagpal, 1992)(see 6.2.2).

Concentrations of PCPs, 3-chlorophenol and 4-chlorophenol were measured at both the Sturgeon Banks and Roberts Bank sites. PCPs were also measured at the three Environment Canada sites. Median concentrations of PCP were below detection limits of

0.005µg/g at Roberts and Sturgeon Banks, and the maximum concentration measured was 0.080 µg/g at Sturgeon Bank. Concentrations at the three AIM sites ranged from a median value of less than 0.002 µg/g to a mean of 0.0044 µg/g.

The median concentration of 3-monochlorophenol was less than 0.005 µg/g at both sites with the maximum concentration of 0.012 µg/g occurring at the Roberts Bank monitoring site. The limit of detection at the Sturgeon Banks site was lowered during the monitoring period, from 0.05 to 0.005 µg/g; it is possible that two of the values measured at this site before the reduction in detection limit exceeded this maximum concentration of 0.012 µg/g. No criterion exists for further evaluation of concentrations of this compound in sediments.

The high mean concentration of 4-monochlorophenol at Sturgeon Banks (0.366 µg/g) is due primarily to a single extreme value of 2.1 µg/g measured in early March, 1992. With the exclusion of this extreme value, the mean concentration of 4-monochlorophenol meets the interim aquatic life toxicity criterion of 0.70 µg/g 4-monochlorophenol. Measurements taken in subsequent years show a marked decrease in concentrations, with the mean of three values measured in March, 1993 being 0.149 µg/g, and the concentration measured in the sediment at this site in 1994 being less than detection limits of 0.005 µg/g for all three samples taken at that time.

Mean concentrations of total TCP ranged from 0.0038 to 0.0169 µg/g at the three AIM sites. No criterion exists for total TCP in sediment, so an interpretation of these values is not possible.

All chlorinated phenols, PCBs, organochlorine pesticides, and organophosphate pesticides tested for in 1993 at the Roberts Bank site were present in concentrations below detection limits. All detection limits are below existing sediment quality criteria except for the organochlorine pesticides endrin and heptachlor which had detection limits much higher than the existing criteria. Therefore, it is difficult to determine the potential impacts of these compounds.

6.6.2.2.2. Dioxins and Furans

Levels of dioxins and furans measured at the six sites (NA-1, SB-1, 23, SB-2, WI-3, and RB-2, Figure 10) on Sturgeon and Roberts Banks in 1990 (Harding, 1990) were generally very low. Only dioxin congeners with 6 or more chlorine atoms were detected. These congeners were detected at three of the six sites (SB-1, WI-3, and NA-1) and concentrations of dioxins were highest at site NA-1. Furans were detected only at Site NA-1, and only congeners with 7 or more chlorine atoms were present. The total TEQs at sites where dioxins and furans were detected ranged from 0.08 ng TEQ/kg at SB-1 to 1.25 ng TEQ/kg at NA-1. This maximum value was approximately five times the interim recommended guidelines of 0.25 pg/g for total PCDD/PCDF TEQs for the protection of marine and estuarine aquatic life (CCME, 1995). Therefore, a Sediment Quality Objective is proposed for dioxins and furans on Roberts and Sturgeon Banks. This Objective is that the total TEQ for PCDD/PCDF in any discrete sample collected on Sturgeon or Roberts Banks should not exceed 0.25 pg TEQ/g, outside of initial dilution zones as described in Section 6.1.1.

6.6.2.2.3 Polyaromatic Hydrocarbons

Of the sixteen PAHs measured in 1993 at the Roberts Bank site, only naphthalene was present in concentrations exceeding the sediment quality criterion of 0.01 µg/g (Nagpal, 1993 (b)). This high naphthalene concentration is possibly due to coal dust from the Roberts Bank Coal Port. The mean concentration was 0.049 µg/g, with a maximum concentration of 0.063 µg/g. A Sediment Quality Objective is therefore proposed for naphthalene on Sturgeon and Roberts Banks. The objective is that the concentration of naphthalene in any discrete sample should not exceed 0.01 µg/g.

All PAHs were present in concentrations below detection limits at the Environment Canada Sites. However, detection limits exceeded the existing sediment quality criteria for benzo(a)pyrene, dibenzo(a,h)anthracene, naphthalene and phenanthrene. Since the coal port could generate PAHs that could be deposited in sediments, the following PAHs and maximum concentrations (dry-weight, normalized to 1% organic carbon) are proposed for water quality objectives: acenaphthene, maximum of 0.15 µg/g; fluorene, maximum of 0.2 µg/g; chrysene, maximum of 0.2 µg/g; and benzo (a) pyrene, maximum of 0.06 µg/g.

Therefore, a discussion of possible impacts from these compounds is not possible.

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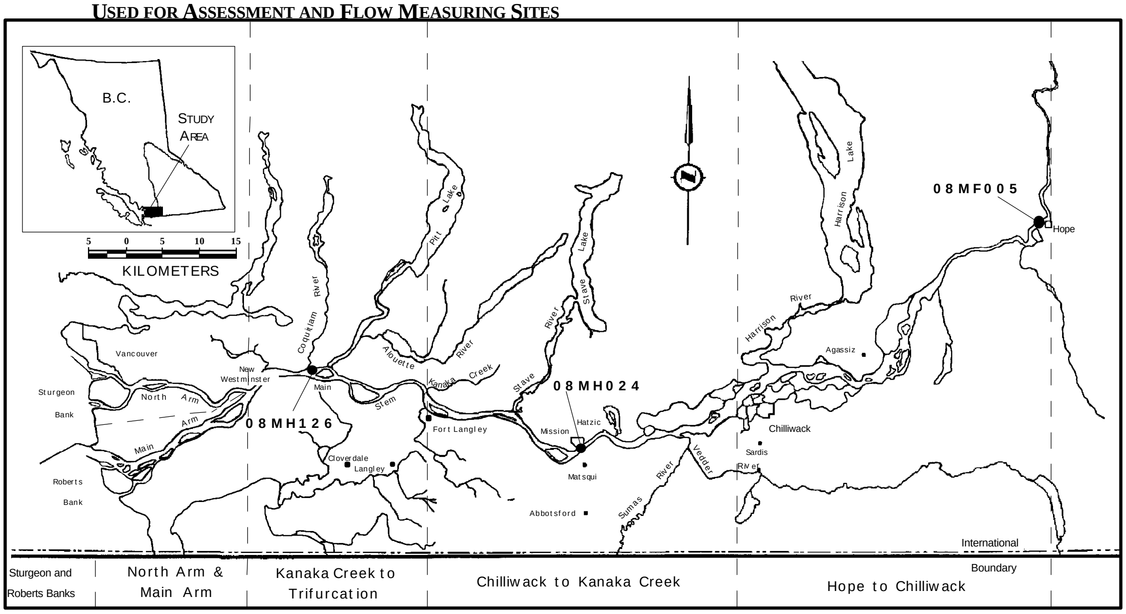
FIGURE 1: THE FRASER RIVER WATER BASIN

FIGURE 2. FRASER RIVER STUDY AREA: HOPE TO THE MOUTH - SUB-DIVISIONS USED FOR ASSESSMENT AND FLOW MEASURING SITES



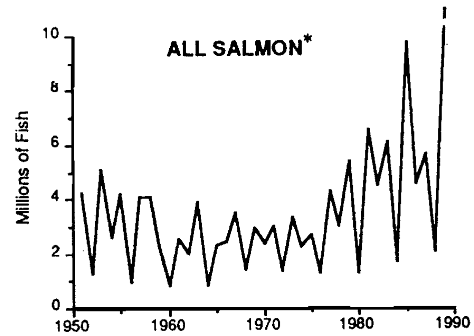


Figure 3. Average Annual Pacific Salmon Escapement to the Fraser River Basin, 1951 to 1989. Total Escapement (all salmon) includes interpolated values for pink salmon on even numbered years; (from Northcote and Burwash, 1991)

* 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).

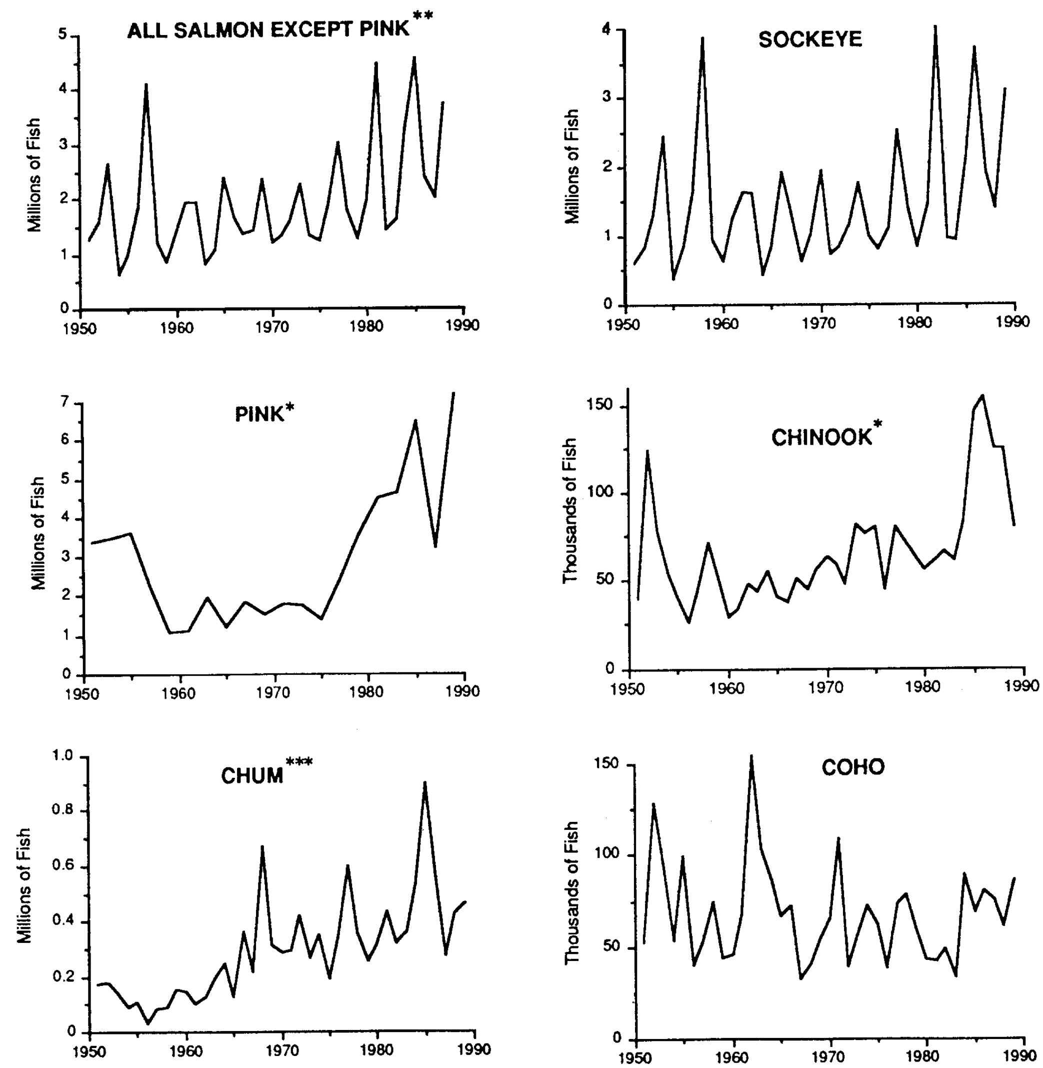


FIGURE 4: LOCATIONS OF LICENCED WATER WITHDRAWALS FROM THE FRASER RIVER BETWEEN HOPE AND CHILLIWACK

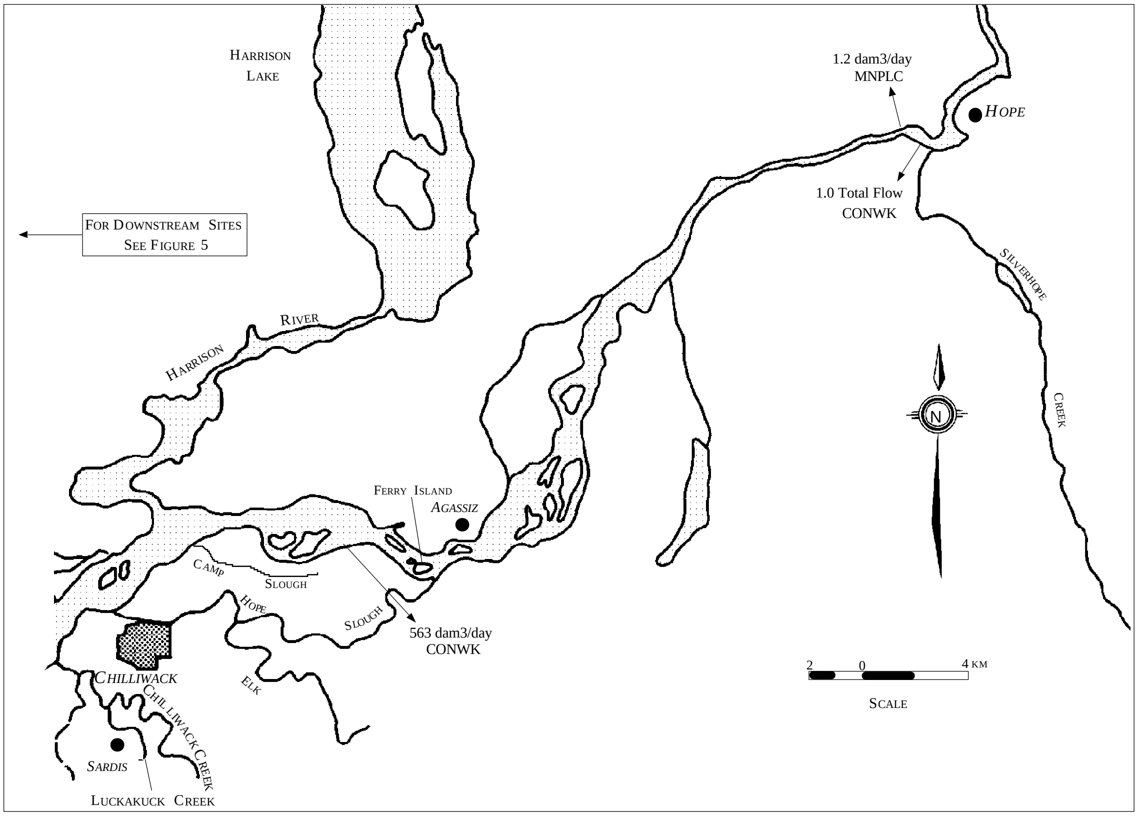


FIGURE 5. LOCATIONS OF LICENCED WATER WITHDRAWALS FROM THE FRASER RIVER BETWEEN CHILLIWACK AND KANAKA CREEK

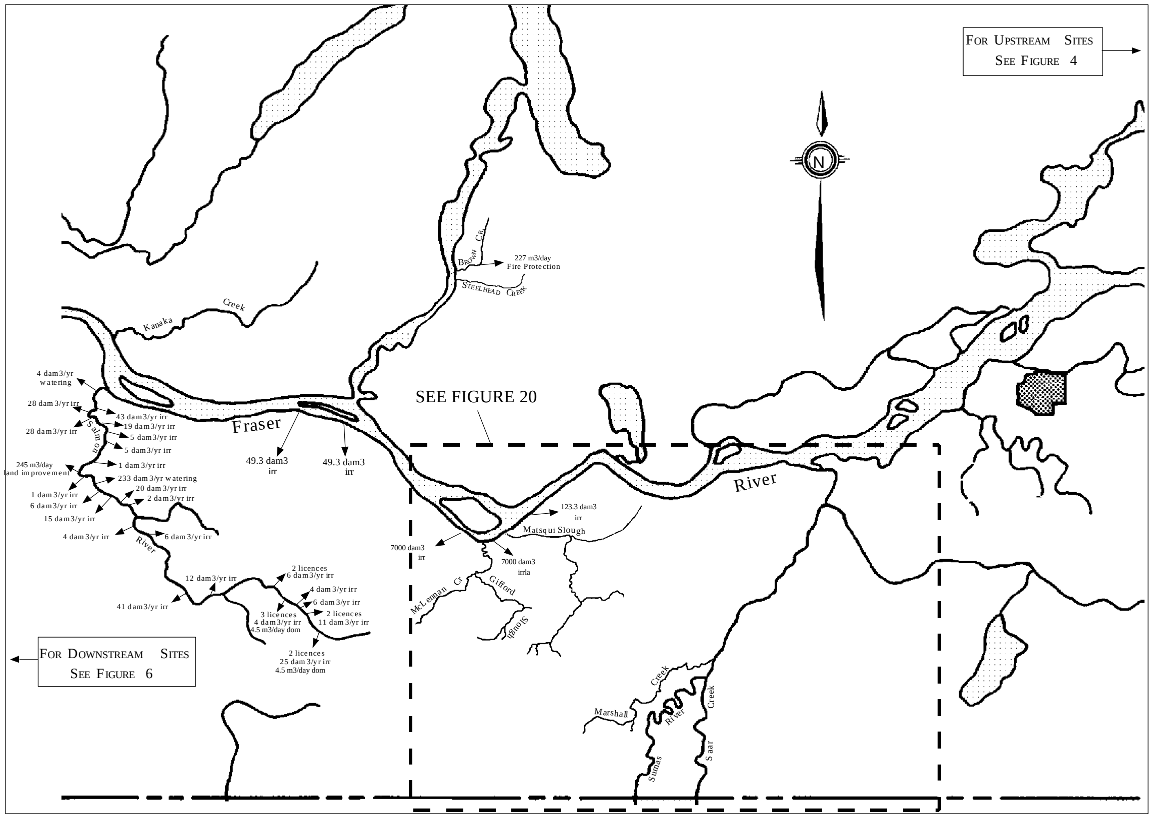


FIGURE 6: LOCATIONS OF LICENCED WATER WITHDRAWALS FROM THE FRASER RIVER BETWEEN KANAKA CREEK AND THE MOUTH

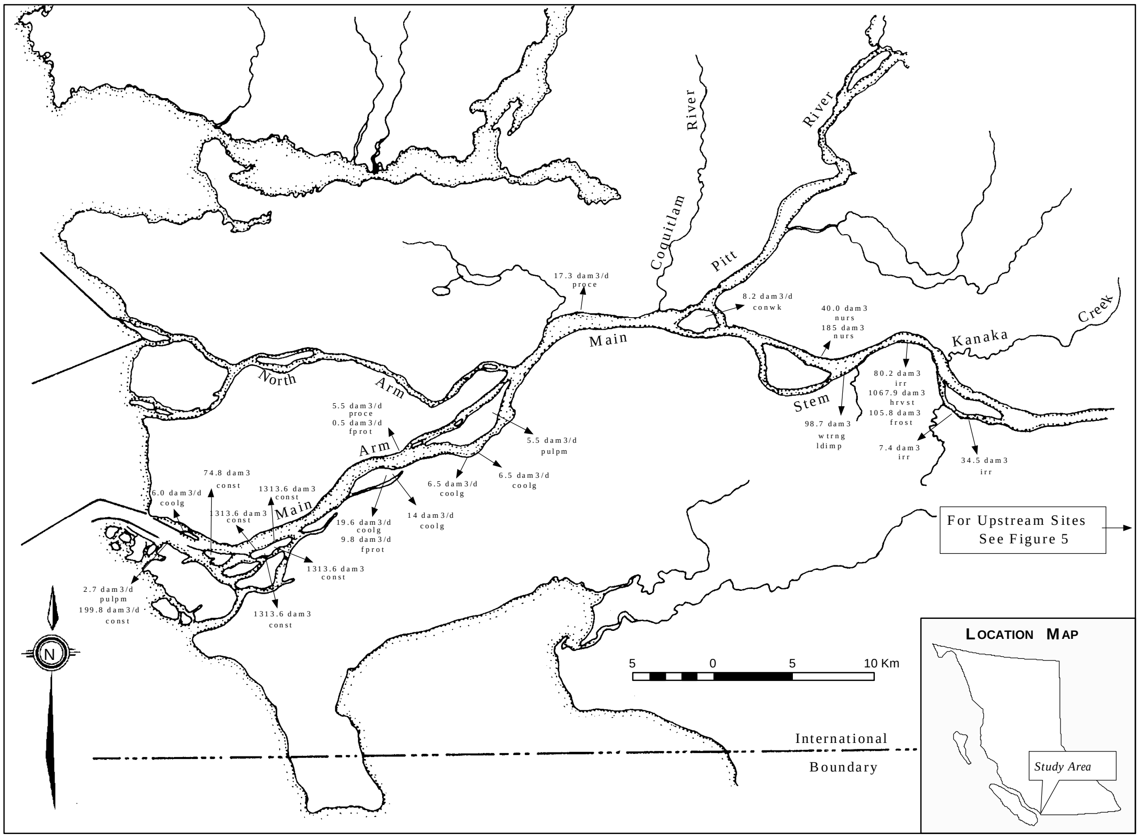


FIGURE 7: LOCATIONS OF AMBIENT MONITORING SITES AND SITES DISCHARGING EFFLUENTS FROM HOPE TO CHILLIWACK

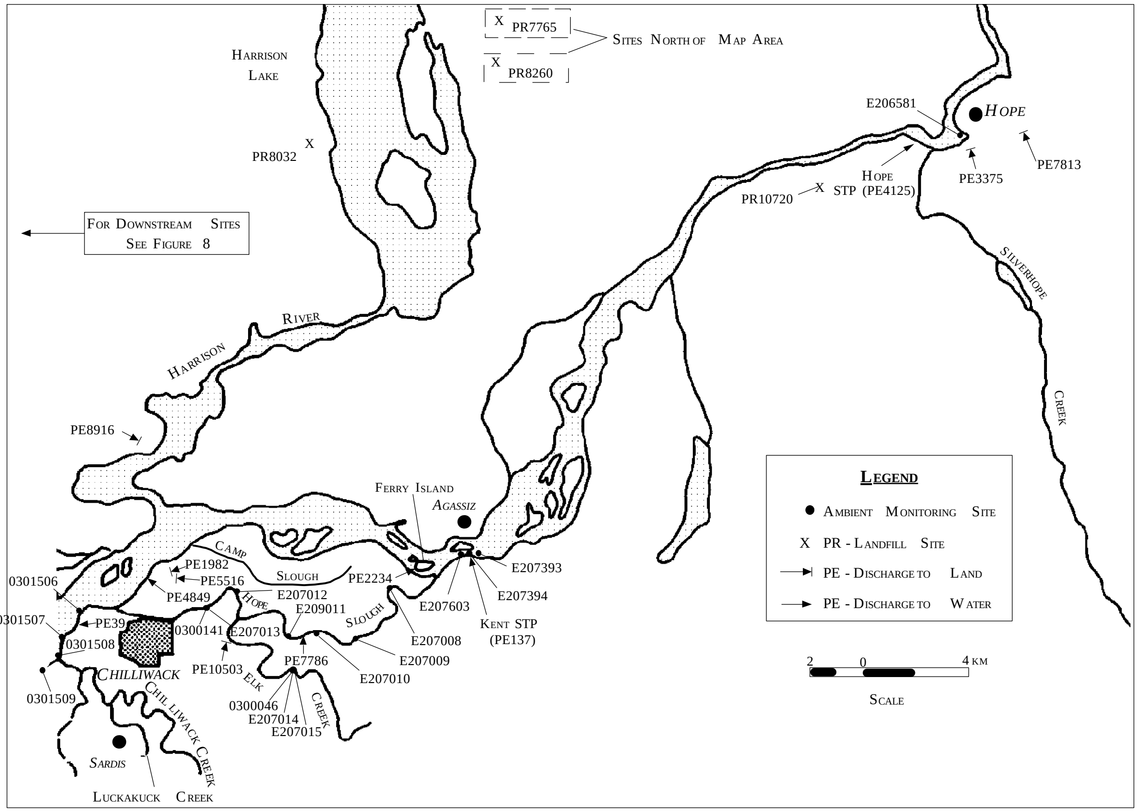


FIGURE 8: LOCATIONS OF AMBIENT MONITORING SITES AND SITES DISCHARGING EFFLUENTS FROM CHILLIWACK TO KANAKA CREEK

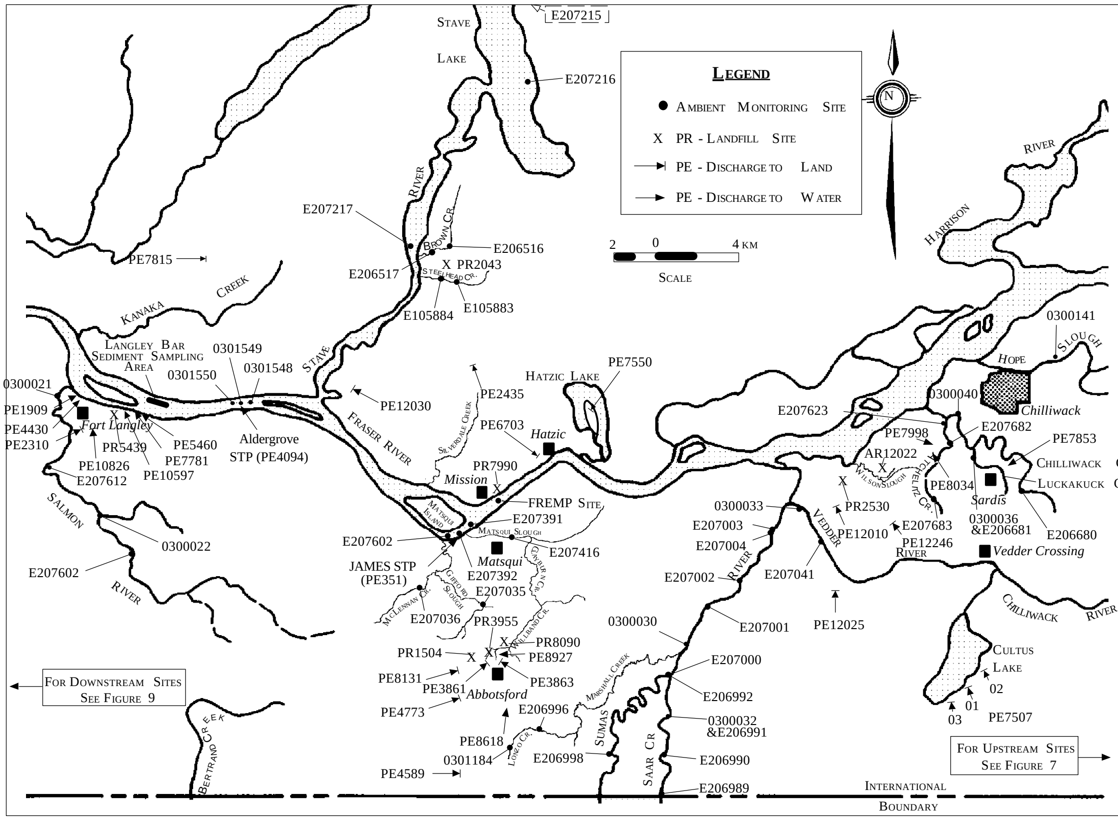


FIGURE 9. LOCATIONS OF AMBIENT MONITORING SITES AND SITES DISCHARGING EFFLUENT FROM KANAKA CREEK TO THE TRIFURCATION

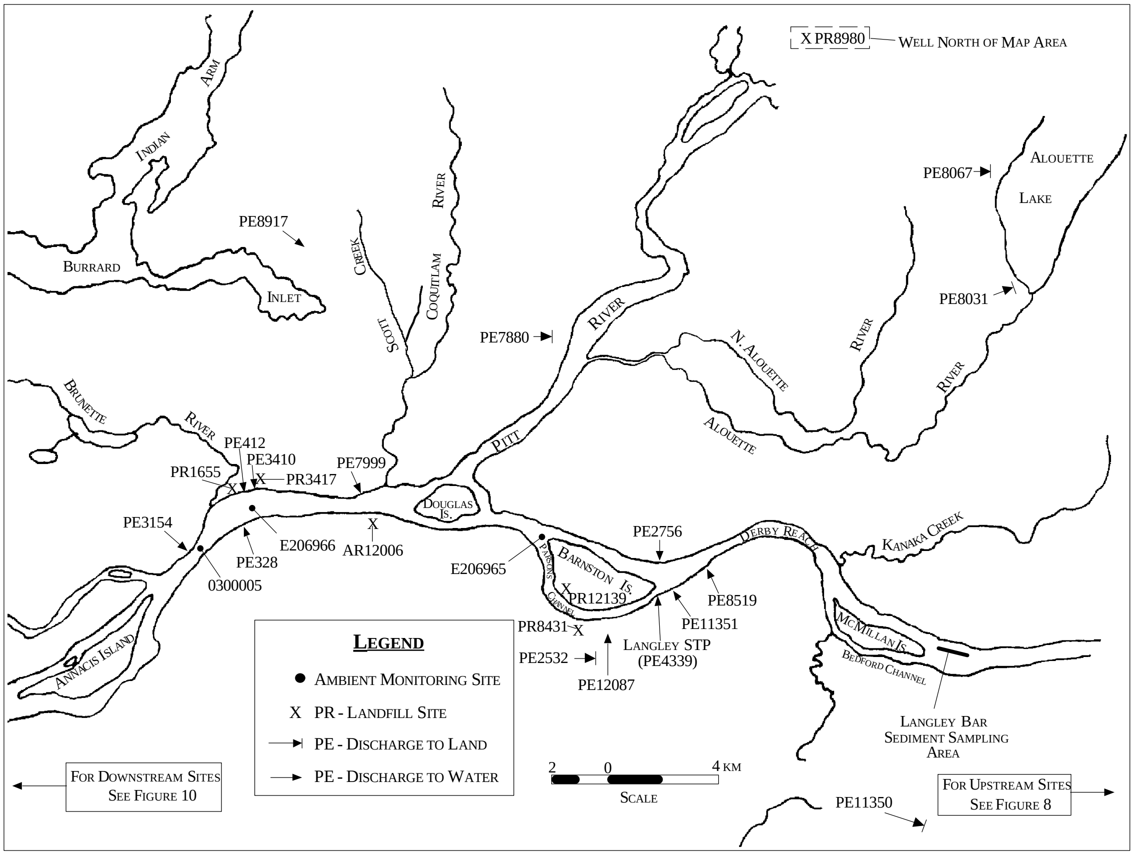


FIGURE 10. LOCATIONS OF AMBIENT MONITORING SITES AND SITES DISCHARGING EFFLUENT FROM THE TRIFURCATION TO THE MOUTH

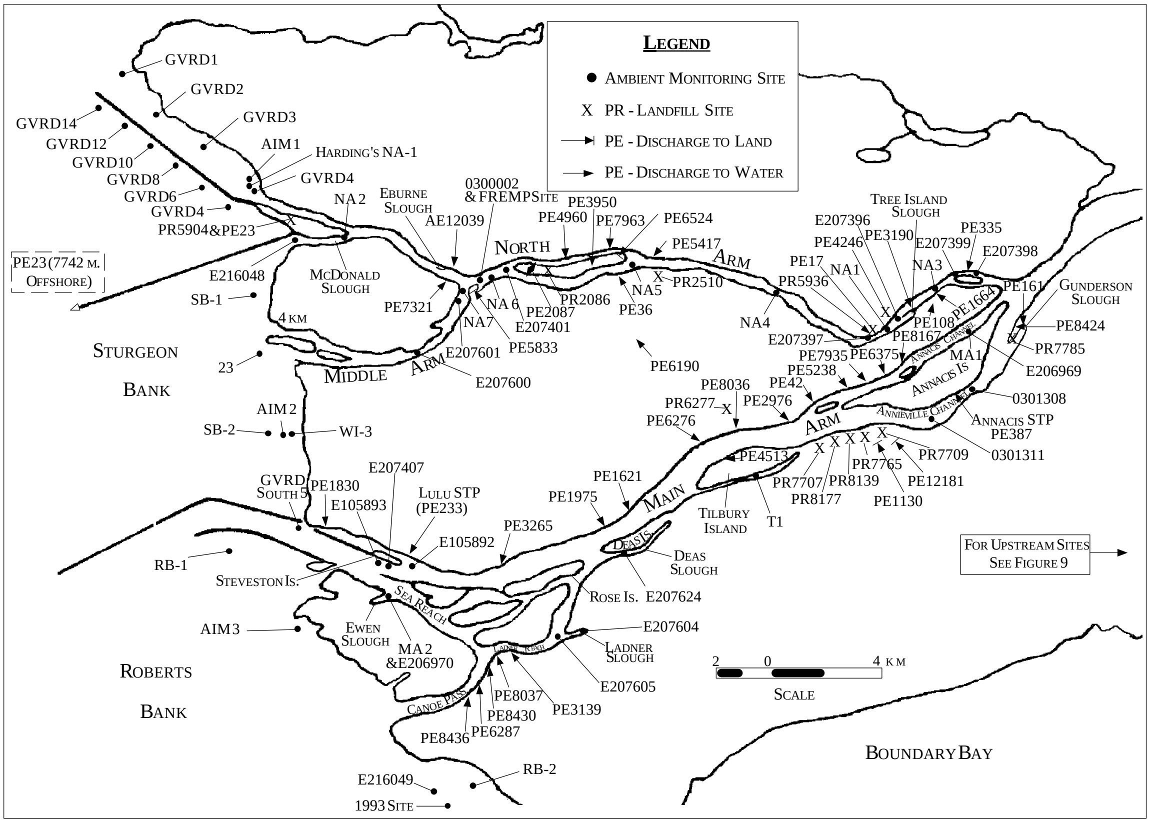


FIGURE 11. SEDIMENT COMPOSITION AND METAL CONCENTRATIONS AT SITE MS-1

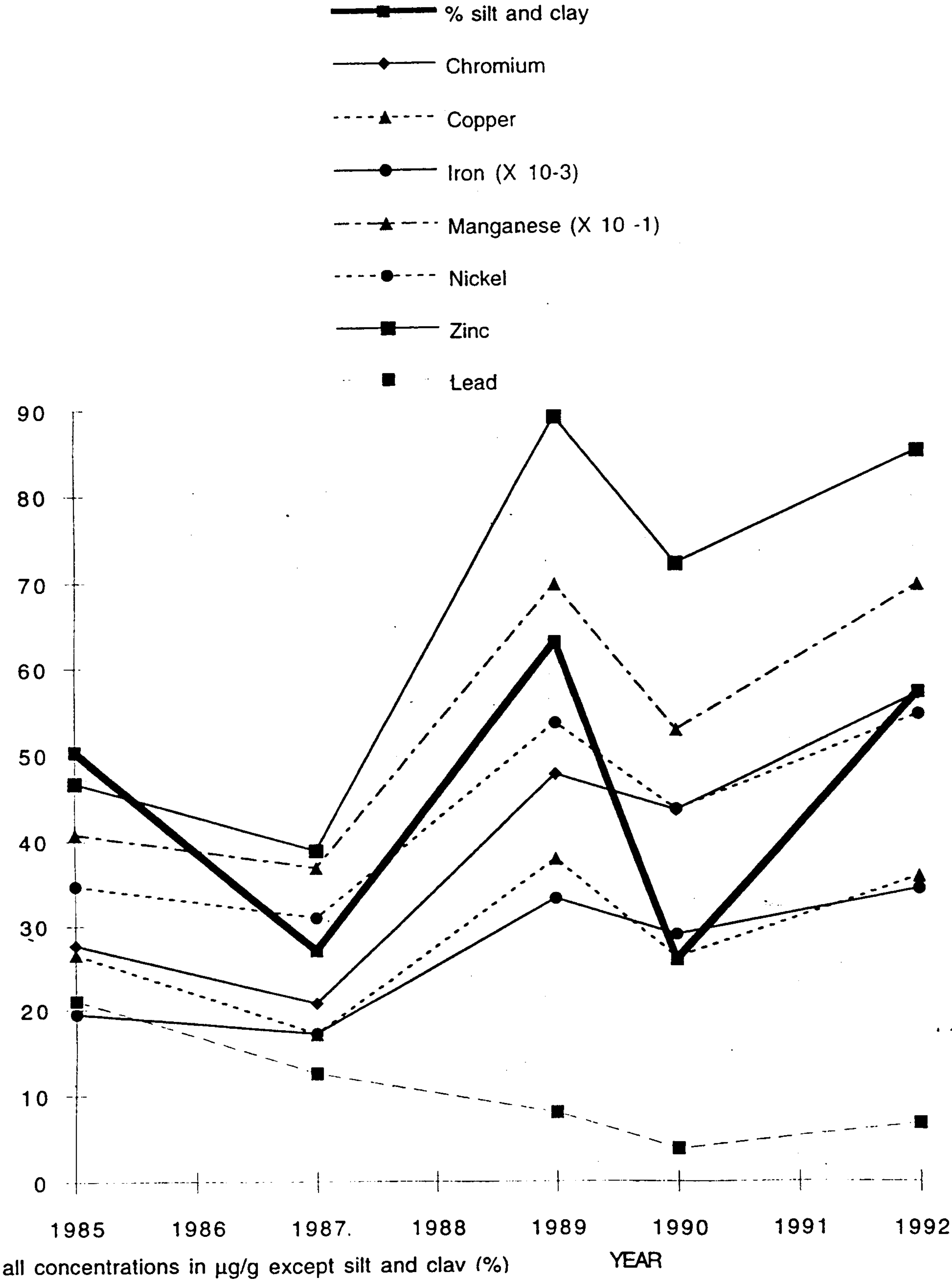
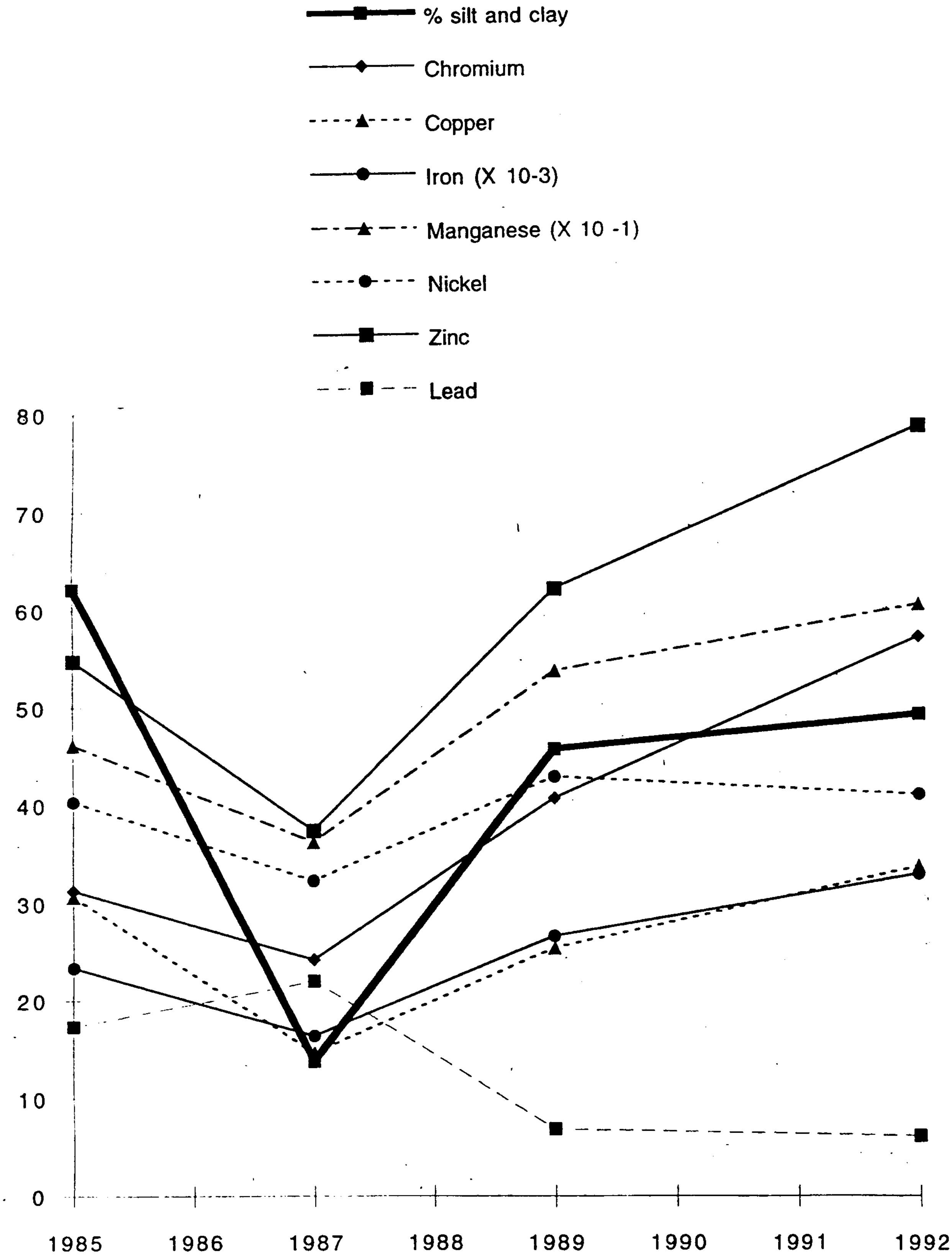


FIGURE 12. SEDIMENT COMPOSITION AND METAL CONCENTRATIONS AT SITE MS-2



*all concentrations in µg/g except silt and clay (%)

FIGURE 13. SEDIMENT COMPOSITION AND METAL CONCENTRATIONS AT SITE NA-1

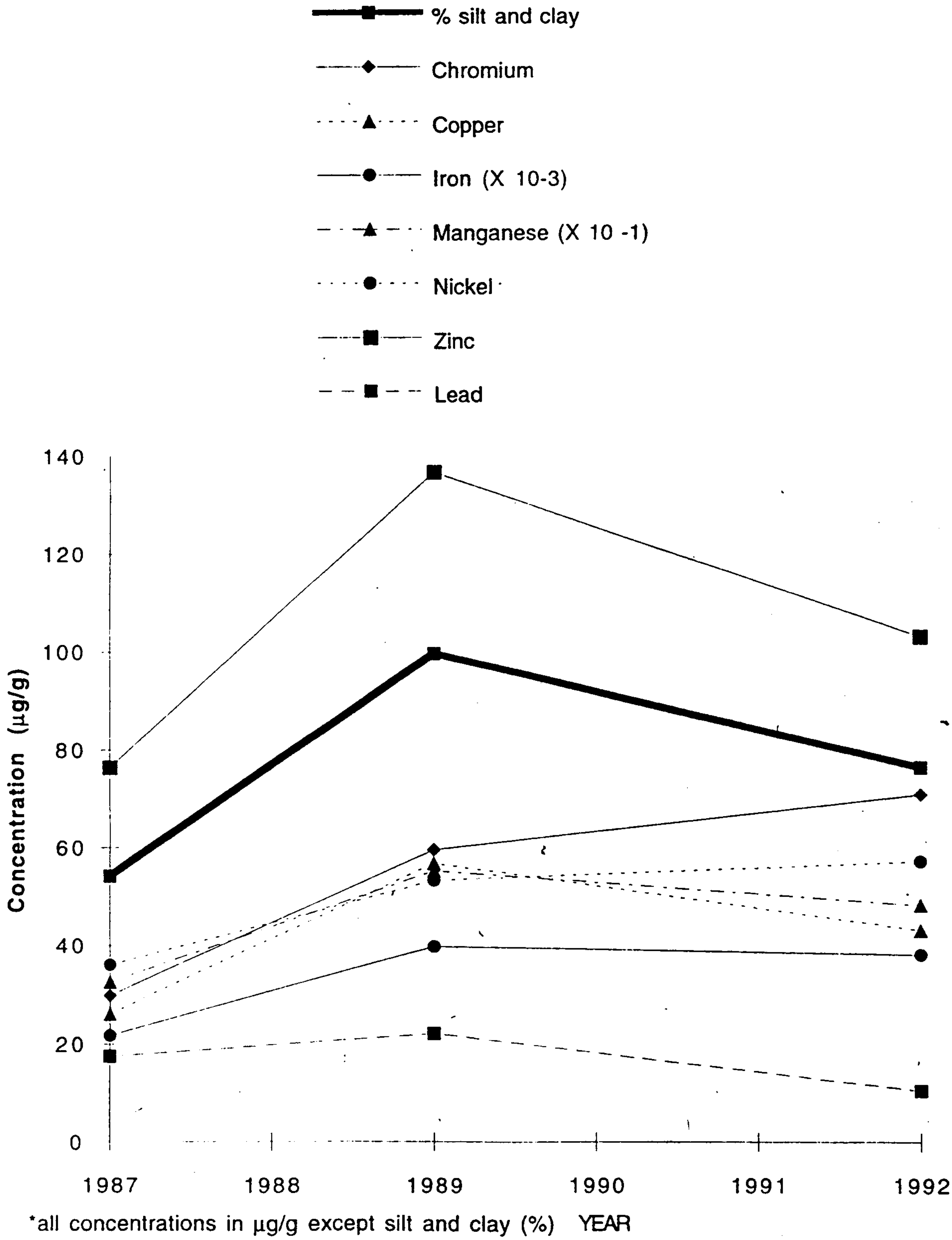
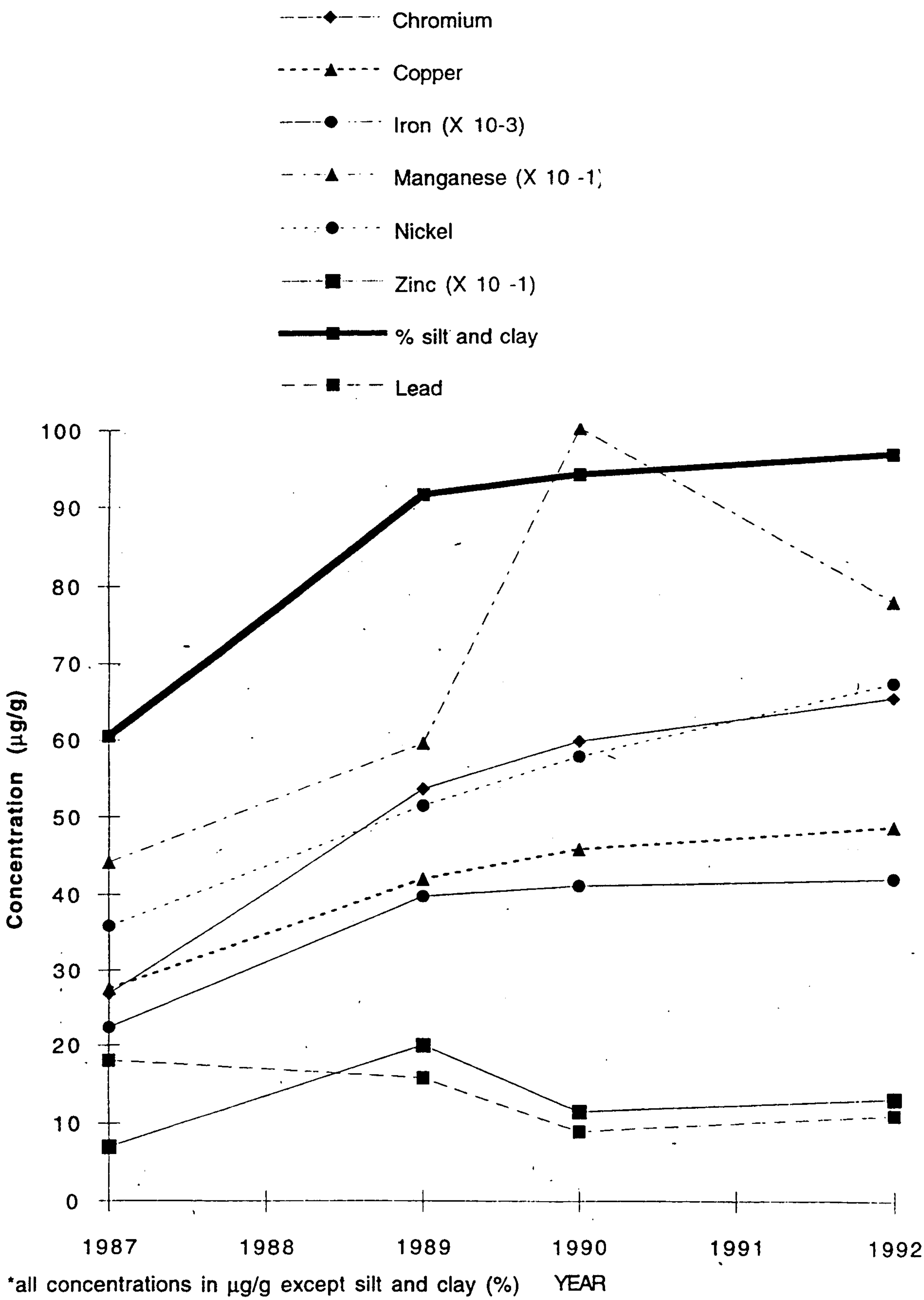


FIGURE 14. SEDIMENT COMPOSITION AND METAL CONCENTRATIONS AT SITE NA-2



*all concentrations in µg/g except silt and clay (%)

FIGURE 15. SEDIMENT COMPOSITION AND METAL CONCENTRATIONS AT SITE MA-1

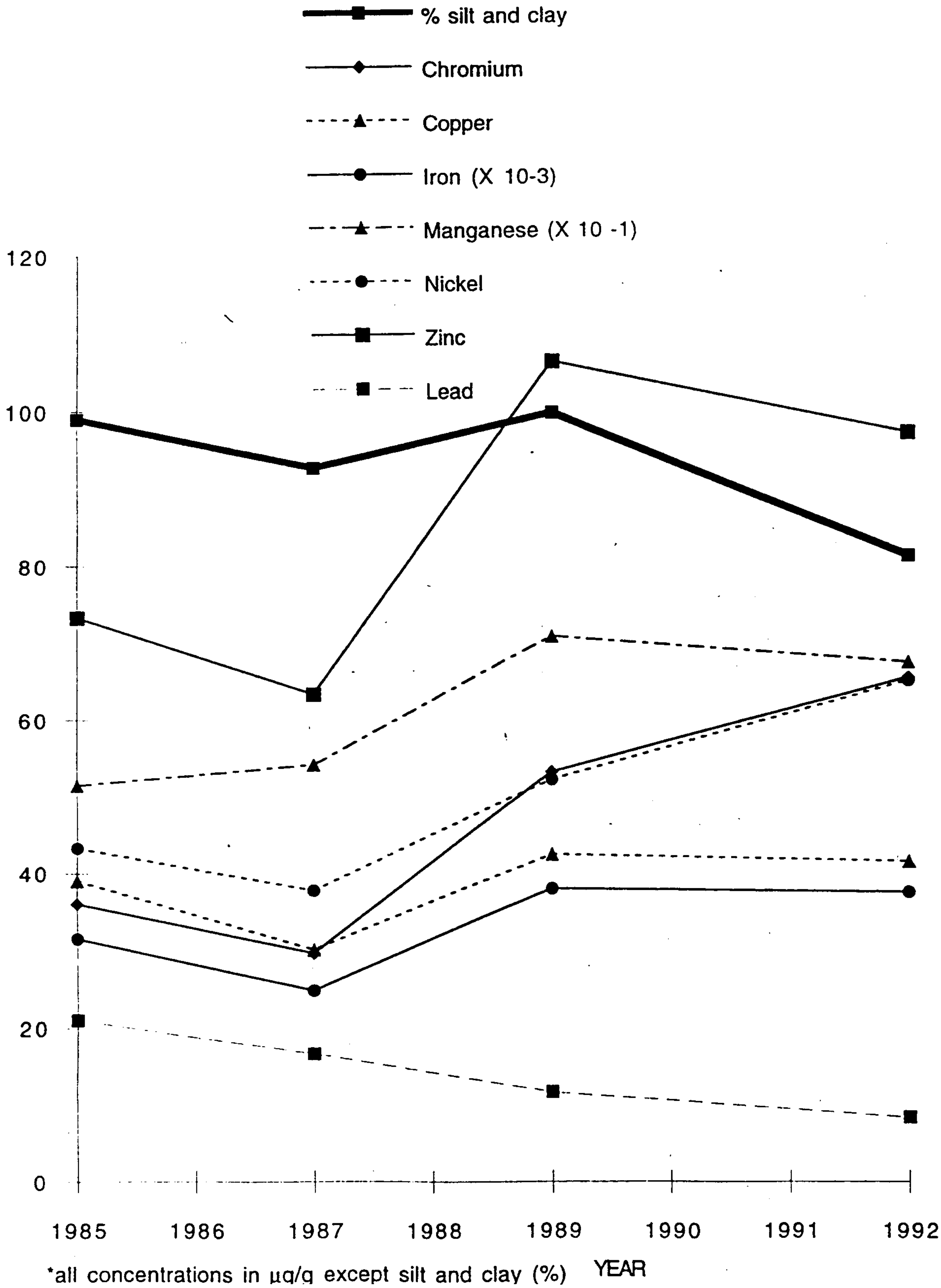
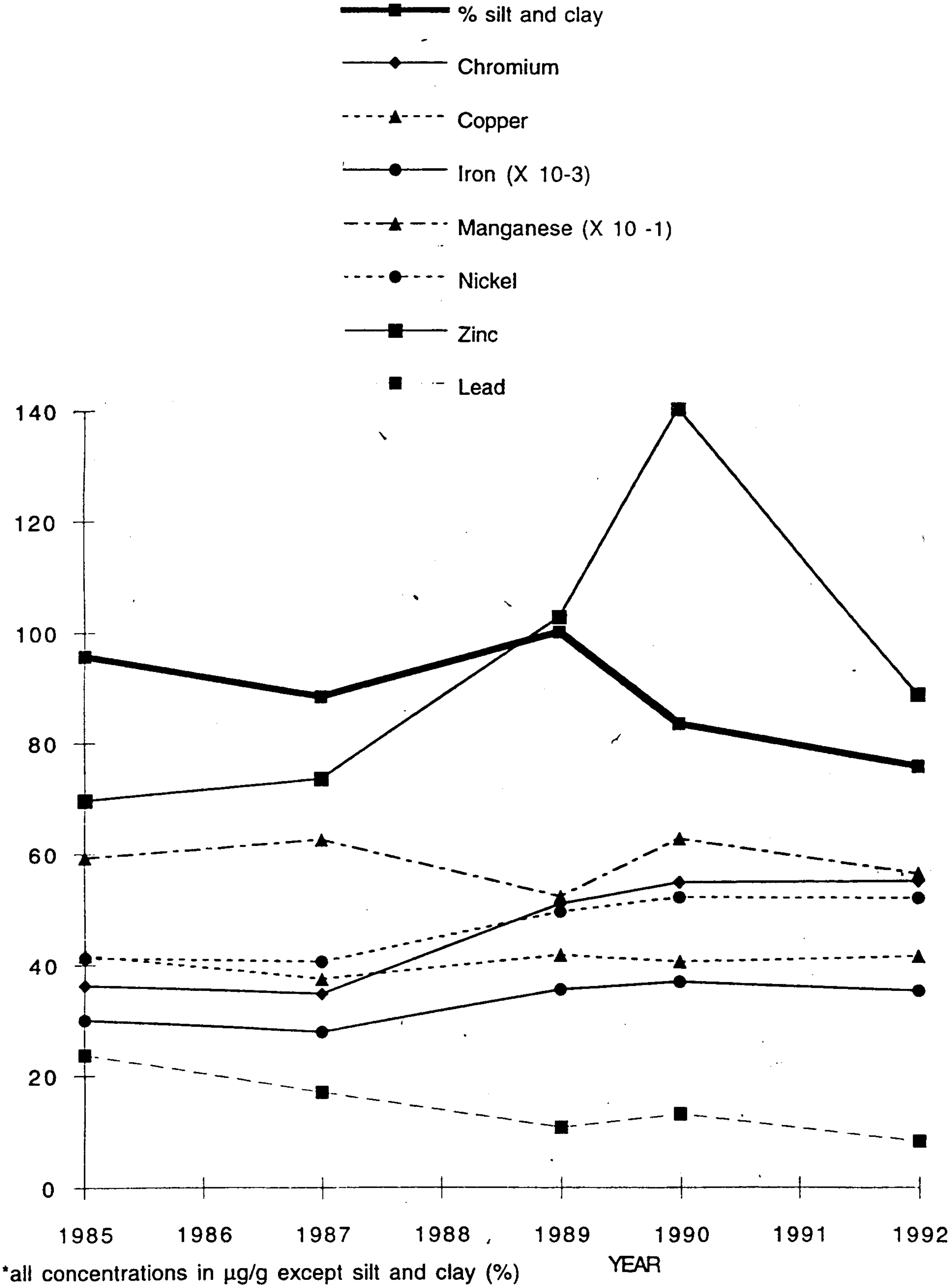


FIGURE 16. SEDIMENT COMPOSITION AND METAL CONCENTRATIONS AT SITE MA-2



*all concentrations in µg/g except silt and clay (%)

FIGURE 17. CONCENTRATION OF CHLOROPHYLL-A (MG/M²) ALONG A TRANSECT FROM THE OLD IONA OUTFALL

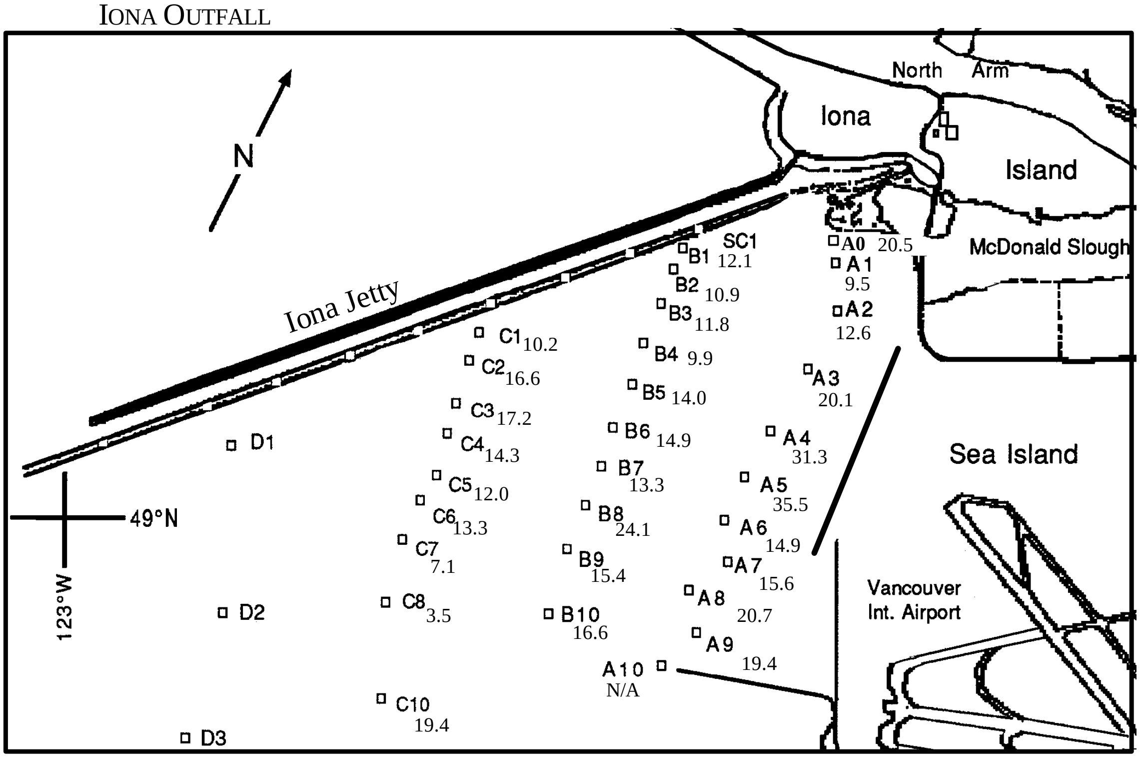


FIGURE 18. TOTAL VOLATILE RESIDUE (%) ALONG A TRANSECT FROM THE OLD IONA OUTFALL

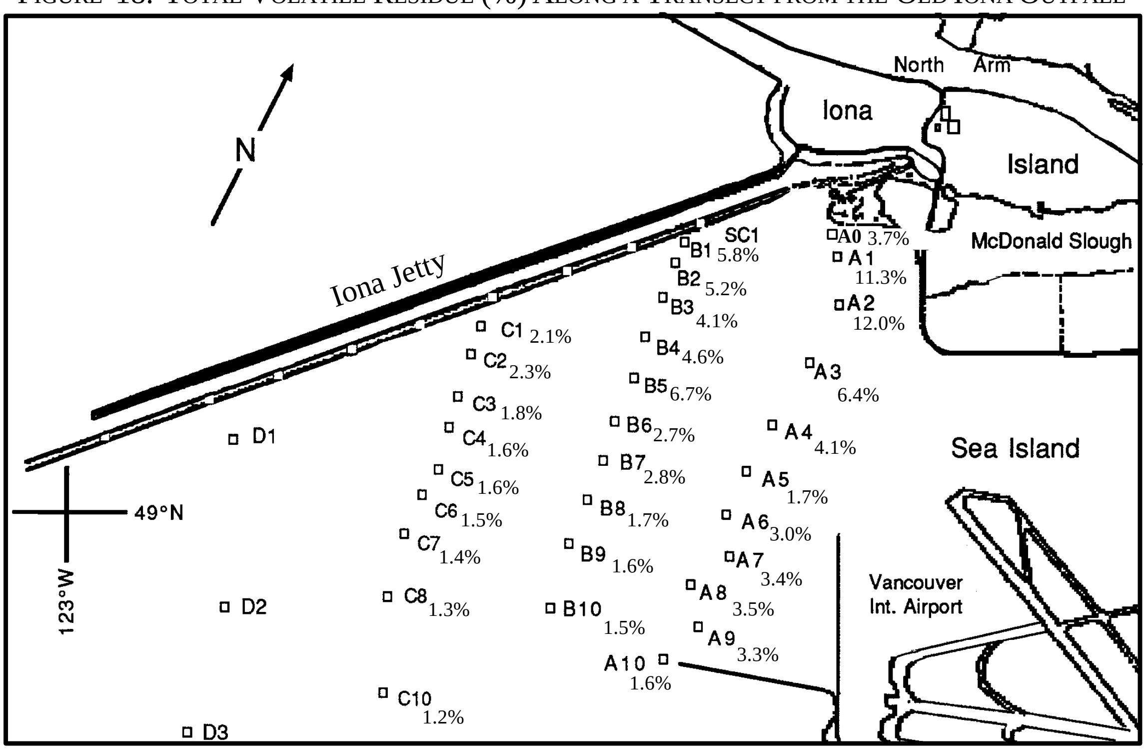


Table 1

Summary of Flows (m^3/s) for the Fraser River at Hope (1912 to 1993)

FLOW	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
10th %ile	656	633	610.2	923.2	3540	5734	4095	2742	1791	1340	995.6	747.5
Median	886	799	808.5	1730	4955	6870	5225	3455	2315	1910	1550	1040
90th %ile	1240	1180	1249	2446	6389	8426	7206	4487	3108	2686	2182	1583
Mean	930.5	876.2	859	1747	5284	6992	5528	3555	2392	1933	1576	1121

Table 2

Summary of Flows (m^3/s) for the Fraser River at Mission (1965 to 1992)

FLOW	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
10th %ile	1020	977.2	1082	1564	4426	6553	4903	3308	2127	1788	1619	1220
Median	1350	1360	1240	2480	5605	7785	6045	4115	2875	2370	2180	1590
90th %ile	1828	2000	2140	3034	6593	9747	8604	5114	3475	2925	3058	2003
Mean	1442	1400	1455	2366	5555	8040	6398	4218	2891	2356	2267	1641

Table 3

Summary of Flows (m^3/s) for the Fraser River at Port Mann (1965-1972, 1983-1992)

FLOW	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
10th %ile	1336	1178	1202	2312	4370	7212	5018	3434	2220	1838	1948	1424
Median	1780	1800	1860	2950	6000	8590	6850	3940	2690	2360	2450	1770
90th %ile	2190	2262	2618	3184	6740	10456	8314	4970	3436	3226	3522	2246
Mean	1748	1766	1862	2810	5749	8566	6585	4165	2826	2505	2642	1847

Table 4

Ratio of Flow Statistic at Mission to Hope on a monthly basis for the period 1965 to 1992

FLOW	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Avg
10th %ile	1.34	1.40	1.38	1.18	1.14	1.13	1.22	1.23	1.18	1.23	1.32	1.45	1.27
Median	1.38	1.45	1.30	1.21	1.09	1.16	1.17	1.20	1.26	1.22	1.36	1.49	1.27
90th %ile	1.50	1.54	1.57	1.20	1.11	1.12	1.19	1.18	1.17	1.19	1.47	1.35	1.30
Mean	1.45	1.44	1.39	1.19	1.11	1.14	1.17	1.20	1.22	1.24	1.38	1.46	1.28

Table 5

Ratio of Flow Statistic at Port Mann to Hope on a monthly basis for the period 1965-1972 and 1983-1992

FLOW	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Avg
10th %ile	1.75	1.68	1.49	1.53	1.17	1.21	1.27	1.27	1.23	1.27	1.59	1.76	1.44
Median	1.81	1.83	1.84	1.41	1.16	1.23	1.29	1.16	1.21	1.23	1.52	1.84	1.46
90th %ile	1.86	1.79	1.66	1.15	1.14	1.15	1.23	1.27	1.23	1.32	1.70	1.57	1.42
Mean	1.78	1.79	1.68	1.32	1.15	1.17	1.23	1.24	1.26	1.34	1.59	1.73	1.44

Table 6
Ratio of Flow Statistic at Port Mann to Mission on a monthly basis for the period 1965-1972 and 1983- 1992

FLOW	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Avg
10th %ile	1.31	1.12	1.11	1.33	1.06	1.05	1.08	1.10	1.04	1.04	1.16	1.24	1.14
Median	1.32	1.22	1.32	1.13	1.05	1.03	1.06	1.02	1.03	1.05	1.11	1.17	1.13
90th %ile	1.20	1.13	1.21	1.03	1.04	0.99	1.02	1.01	1.03	1.08	1.18	1.17	1.09
Mean	1.20	1.19	1.19	1.11	1.04	1.02	1.04	1.05	1.05	1.10	1.17	1.18	1.11

Table 7
Estimated Flow Statistics for Mission Using Ratios of Flows at Hope and Mission and Summary Statistics for Hope (1912 - 1993)

FLOW	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
10th %ile	876.4	884	844.8	1090	4029	6471	5014	3376	2112	1647	1317	1085
Median	1223	1160	1050	2093	5424	7988	6139	4133	2906	2327	2105	1545
90th %ile	1859	1821	1965	2943	7069	9428	8540	5288	3635	3205	3216	2142
Mean	1350	1266	1194	2072	5852	7964	6478	4273	2923	2395	2182	1640

Table 8
Estimated Flow Statistics for Port Mann Using Ratios of Flows at Hope and Port Mann and Summary Statistics for Hope (1912 - 1993)

FLOW	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
10th %ile	1147	1066	909.3	1415	4150	6962	5197	3482	2204	1707	1585	1313
Median	1599	1466	1485	2436	5734	8467	6740	4004	2805	2354	2351	1912
90th %ile	2311	2117	2068	2814	7295	9660	8851	5693	3822	3535	3704	2485
Mean	1660	1568	1440	2305	6100	8207	6803	4391	3023	2586	2502	1942

Table 9
Mean Annual Salmon Escapements To The Different Reaches of the Fraser River Since 1951

REACH 1 : HOPE TO LILLOOET

YEAR	CHINOOK	CHUM	COHO	PINK	SOCKEYE
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

Table 9

(Continued)

REACH 2 : LILLOOET TO PRINCE GEORGE

YEAR	CHINOOK	CHUM	COHO	PINK	SOCKEYE
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

YEAR	CHINOOK	CHUM	COHO	PINK	SOCKEYE
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

YEAR	CHINOOK	CHUM	COHO	PINK	SOCKEYE
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

YEAR	CHINOOK	CHUM	COHO	PINK	SOCKEYE
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

YEAR	CHINOOK	CHUM	COHO	PINK	SOCKEYE
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

Table 9

(Continued)

REACH 7 : FRASER RIVER AND TRIBUTARIES ABOVE PRINCE GEORGE

YEAR	CHINOOK	CHUM	COHO	PINK	SOCKEYE
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 10
Effluent Data Summary for City of Chilliwack and District of Chilliwack (PE 39)

Characteristics	No. of Values	Maximum	Minimum	Mean	Std Dev
BOD 5-day	19	80	10	39	24
Biomass	6	101	80	92	9
Biomass-fixed	6	62	52	59	4
Carbon, Organic	20	67	0	16	25
COD	6	207	74	155	48
Coliforms: fecal	1	28000	28000	28000	-
Total Suspended Solids	16	335	9	70	93
Specific Conductivity	18	670	460	590	60
Nitrogen: ammonia	9	27.8	17.3	23.6	3.7
nitrite	7	0.041	0.006	0.018	0.013
Kjeldahl	8	34.6	19.7	29.5	5.0
pH	18	7.6	7.1	7.3	0.2
Phosphorus-ortho (D)	6	5.04	3.58	4.50	0.58

*All values are in mg/L except coliforms (CFU/cL), conductivity (μS/cm) and pH.

Table 11

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. ^oC
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	l0.9	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 12

Average 30-day Nitrogen 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
6.5-7.1	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	0.45	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 11.
- each measured value is compared to the corresponding individual values in Table 11.

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 11.

Table 13
Criteria for Nitrate-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 14
Effluent Data Summary for Corporation of the District of Kent (PE 137)

Characteristics	No. Of Values	Maximum	Minimum	Mean	Std. Dev.
BOD 5-day	20	64	10	23	16
Coliform-fecal	14	240 000	2	47 765†	91614
Nitrogen: ammonia	14	31.000	0.585	15.613	9.461
nitrate/nitrite	8	4.75	0.20	1.76	1.59
nitrite	7	0.889	0.020	0.292	0.354
Kjeldahl(T)	4	26.10	3.49	14.09	10.27
Total suspended Solids	33	88	2	21	18
pH	19	7.6	6.8	7.3	0.2

*All values are in mg/L except coliform (MPN/100 mL) and pH.
† The median value is 1 050 MPN/100 mL.

Table 15
Effluent Data Summary for Westcoast Transmission Limited
Rosedale Station #9 (PE 2234)

Characteristics	No. Of Values	Maximum	Minimum	Mean	Std. Dev.
Oil and Grease	3	3	1	2	1

*All values are in mg/L.

Table 16
Effluent Data Summary for District of Hope (Fraser-Cheam) (PE 4125)

Characteristics	No. Of Values	Maximum	Minimum	Mean	Std. Dev.
BOD 5-day	19	80	10	39	24
Biomass	6	101	80	92	9
Biomass-fixed	6	62	52	59	4
Carbon, Organic	20	67	0	16	25
COD	6	207	74	155	48
Coliforms-fecal	1	28 000	28 000	28 000†	-
Total Suspended Solids	16	335	9	70	93
Specific Conductivity	18	670	460	590	60
Nitrogen: ammonia	9	27.8	17.3	23.6	3.7
nitrite	7	0.041	0.006	0.018	0.013
Kjeldahl	8	34.6	19.7	29.5	5.0
pH	18	7.6	7.1	7.3	0.2
Phosphorus-ortho (D)	6	5.04	3.58	4.50	0.58

*All values are in mg/L except coliform (CFU/cL) and pH (pH units).
† The median value is 1 050 CFU/cL.

Table 17
Effluent Data Summary for Cheam View Trout Farm (PE 7886)

Characteristics	No. Of Values	Maximum	Minimum	Mean	Std. Dev.
BOD 5-day	21	36	2	14	11
Nitrogen: ammonia	21	0.30	0.01	0.12	0.09
nitrate	21	0.4	0.05	0.19	0.14
Phosphorous	3	0.15	0.150	0.150	0.000
Phosphate	18	0.20	<.05	Median < 0.05	
Total Suspended Solids	18	122	1	22	36
pH	21	8.4	7.3	7.7	0.3

*All values are in mg/L except pH (pH units).

Table 18
Effluent Data Summary for Central Fraser Valley
Regional District (PE 351)
1985-1988

Characteristics	No. Of Values	Maximum	Minimum	Mean	Std. Dev
BOD	10	223	60	128	52
Coliform: fecal	1	350	350	350	-
Nitrogen: ammonia	2	35.2	21.4	28.3	9.8
nitrite	1	0.02	0.02	0.02	-
pH	10	7.5	6.4	7.0	0.4
Total Suspended Solids	10	113	14	69	27

*All values are in mg/L, except coliform (MPN/100 mL) and pH (pH units).

Table 19
Effluent Data Summary for Central Fraser Valley Regional District (PE 351) - 1994

Characteristics	No.Of Values	Maximum	Minimum	Mean	Std Dev
BOD	48	62	12	25	8
Coliform: fecal	48	210000	2	24883	45245
Nitrogen: ammonia	48	18	2.4	8.2	3.0
pH	48	7.51	6.61	7.1	0.2
Total Suspended Solids	48	36	7	16	7

*All values are in mg/L, except coliform (colonies/100 mL) and pH (pH units).

Table 20
Effluent Data Summary for Odyssey Holdings Limited (PE 1909)

Characteristics	No. Of Values	Maximum	Minimum	Mean	Std Dev
BOD	5	55	10	29	17
pH	5	7.4	7.1	7.2	0.2
Total Suspended Solids	6	88	12	35	28

*All values are in mg/L except pH (pH units).

Table 21
Effluent Data Summary for Corporation of the Township of Langley (PE 4094)

Characteristics	No. Of Values	Maximum	Minimum	Mean	Std Dev
BOD	18	64	10	25	14
Coliforms: fecal	10	240000	2	26862	75064
Metals: aluminum (D)	1.00	0.44	0.44	0.44	-
copper	3.00	0.02	0.01	0.01	0.01
Nitrogen: ammonia	15	34.800	0.094	24.066	9.319
nitrate/nitrite	11.00	20.40	0.02	2.79	5.97
nitrite	8.000	16.700	0.005	2.440	5.799
Kjeldahl	3.00	40.20	4.61	25.47	18.57
pH	15	7.8	6.9	7.5	0.3
Phosphorus-ortho (D)	2.00	6.32	5.74	6.03	0.41
Total Suspended Solids	17	109	2	47	27

*All values are in mg/L, except coliform (CFU/cL) and pH (pH units).

Table 22
Effluent Data Summary for Bedford House Limited (PE 4430)

Characteristics	No. of Values	Maximum	Minimum	Mean	Std Dev
BOD (mg/L)	8	149	10	59	49
Coliforms: fecal (CFU/cL)	1	111000	1	111000	-
pH	6	7.5	7.1	7.3	0.1
Total Suspended Solids (mg/L)	8	107	9	53	33

Table 23
Effluent Data Summary for Stella Jones Inc. (PE 3410)

Characteristics	No. of Values	Maximum	Minimum	Mean	Std Dev
Average Flow	24	191	92	136	33
Temperature	24	33	19	24	4
pH	24	7.70	5.56	6.43	0.52
Arsenic (total)	24	0.3	<0.001	median = 0.001	
Copper (total)	24	0.015	0.001	0.005	0.005
Chromium (total)	18	0.030	<0.001	median = 0.001	
Phenols (total)	18	0.010	0.001	0.002	0.002
Pentachlorophenols	18	0.05	0.05	0.05	0
Tetrachlorophenol	18	<0.05	<0.05	<0.05	0
Trichlorophenol	18	<0.1	<0.1	<0.1	0
Oil & Grease	18	4	2	2	1

*All values are in mg/L except flow (m^3/d), temperature (C), pH (pH units),PCP, TTCP and TCP (µg/L)

Table 24
Effluent Data Summary for Langley STP (PE 4339)

Characteristics	No. Of Values	Maximum	Minimum	Mean	Std Dev
BOD_5	22	109	19	52	25
Coliforms-fecal	14	240000	200	83521	109295
Total Suspended Solids	23	99	12	33	22
Nitrogen: ammonia	20	62	13.7	23.0	13.3
nitrite/nitrate	14	1.21	0.02	0.34	0.39
nitrite	13	0.449	0.005	0.087	0.121
Kjeldahl	8	66.10	17.20	28.24	15.67
Copper	8	0.13	0.03	0.07	0.03
Zinc	8	0.13	0.03	0.06	0.03
pH	22	8	7	7.4	0.2
Phosphorus-ortho (D)	2	5.0	4.9	5.0	0.1
Phosphorus (T)	8	12.50	4.78	7.07	2.75

All values are in mg/L except coliform (MPN/100 mL) and pH (pH units).

Table 25
Effluent Data Summary for GVRD Port Mann Landfill (AR 12006)

Characteristics (mg/L)	No. Of Values	Maximum	Minimum	Mean	Std Dev
Total Suspended Solids	6	49.0	3.0	23.5	17.5
Sulphate	6	38.0	10.4	22.1	10.7
Nitrogen: ammonia	6	2.09	0.15	0.87	0.78
nitrate/nitrite	6	1.46	0.48	1.00	0.43
Phosphate (total)	6	0.190	0.036	0.079	0.057
5-day BOD	6	21	10	13	4
Aluminum	6	1.34	0.15	0.42	0.52
Arsenic	6	0.008	0.001	0.004	0.003
Barium	6	0.240	0.018	0.070	0.087
Copper	6	0.021	0.001	0.007	0.007
Iron	6	17.10	0.41	4.92	6.21
Lead	6	0.007	0.002	0.005	0.002
Manganese	6	1.81	0.06	0.64	0.65
Zinc	6	0.03	0.01	0.02	0.008

Table 26
Effluent Data Summary for Crown Packaging (PE17)

Characteristics	No. of Values	Maximum	Minimum	Mean	Std Dev
BOD (mg/L)	7	676	250	422	141
Carbon: inorganic (mg/L)	1	13	13	13	-
Carbon (T) (mg/L)	1	360	360	360	-
Nitrogen: ammonia (mg/L)	1	0.263	0.263	0.263	-
pH	7	8.1	6	6.9	0.7
Total Suspended Solids (mg/L)	4	631	66	276	246

Table 27
Effluent Data Summary for MacMillan Bathhurst Ltd. (PE 108)

Characteristics (mg/L)	No. of Values	Maximum	Minimum	Mean	Std Dev
Barium	1	0.003	0.003	0.003	-
Calcium	1	1.180	1.180	1.180	-
Chromium	1	0.035	0.035	0.035	-
Copper	1	0.007	0.007	0.007	-
Iron	1	0.320	0.320	0.320	-
Magnesium	1	0.110	0.110	0.110	-
Manganese	1	0.016	0.016	0.016	-
Nickel	1	0.060	0.060	0.060	-
Silicon	1	1.000	1.000	1.000	-
Strontium	1	0.005	0.005	0.005	-
Zinc	1	0.120	0.120	0.120	-

Table 28
Effluent Data Summary for MacMillan Bloedel Limited (PE1664)
Discharge "01"

Characteristics	No. of Values	Maximum	Minimum	Mean	Std. Dev.
Flow	7	60	31	40	10
BOD	7	13	<10	Median 10	
Oil and Grease	7	4	1	2	1
pH	7	7.36	6.28	6.71	0.36
Temperature	7	27	14	21	6
Total Suspended Solids	7	210	4	51	75
Toxicity 96h LC50	5	>100	>100	>100	

All values are in mg/L, except oil and grease (ppm), pH (pH units), and toxicity (percent survival).

Table 29
Effluent Data Summary for MacMillan Bloedel Limited (PE1664)
Discharge "03"

Characteristics	**No. of Values**	**Maximum**	**Minimum**	**Mean**	**Std. Dev.**
Flow	7	198	118	161	26.38
Oil and Grease	7	3	1	1	1
Temperature	7	29	18	23	4

All values are in mg/L, except oil and grease (ppm).

Table 30
Effluent Data Summary for Western Steel
Ltd. (PR 2086, PE 2087)

Characteristics	**No. of Values**	**Maximum**	**Minimum**	**Mean**	**Std Dev**
Barium	9	0.10	0.01	0.04	0.03
Boron	9	0.09	0.01	0.03	0.03
Calcium	9	28.20	2.16	8.45	9.72
Copper	9	0.05	0.01	0.03	0.02
Iron	9	0.81	0.15	0.49	0.25
Magnesium	9	16.20	0.17	2.91	5.31
Manganese	9	0.39	0.01	0.16	0.12
Oil and Grease	8	19.00	1.00	8.00	6.99
pH	9	7.80	6.20	6.97	0.45
Suspended Solids	6	118.00	7.00	35.00	42.35
Zinc	9	0.06	0.01	0.03	0.02

All values are in mg/L, except pH (pH units).

Table 31
Effluent Data Summary for EOC Holdings Inc. (PR 2510)
1985-1987

Characteristics	No. of Values	Maximum	Minimum	Mean	Std Dev
Aluminum	10	0.10	0.02	0.05	0.02
Boron	10	1.56	0.01	0.49	0.63
Calcium	10	3.17	1.38	1.90	0.66
Iron	10	0.23	0.04	0.13	0.07
Lead	10	0.70	0.07	0.25	0.22
Magnesium	10	0.72	0.12	0.28	0.22
Manganese	10	0.03	0.01	0.01	0.01
Nitrogen: ammonia	1	0.008	0.008	0.008	-
NO2/NO3	1	0.06	0.06	0.06	-
nitrite	1	0.005	0.005	0.005	-
pH	10	7.80	4.40	6.62	0.96
Total Suspended Solids	5	2	1	2	1
Zinc	10	1.06	0.05	0.30	0.31

All values are in mg/L, except pH (pH units).

Table 32
Effluent Data Summary for EOC Holdings Inc. (PR 2510)
December 1993-December 1994, Groundwater Monitoring

Characteristics	No. of Values	Maximum	Minimum	Mean	Std. Dev.
Arsenic	22	1.0200	0.0004	0.0767	0.2341
Barium	22	0.755	0.010	0.179	0.190
Cadmium	22	0.0058	<0.0002	Median 0.0002	
Copper	22	0.015	<0.010	Median 0.010	
Lead	22	0.036	<0.001	Median 0.001	
Mercury	22	0.01100	<0.00005	Median 0.00005	
Molybdenum	22	30.100	<0.030	Median 0.123	
Nickel	22	0.159	<0.020	Median 0.020	
pH	23	10.50	6.08	7.48	1.40
Zinc	22	0.880	<0.005	Median 0.012	

All values are in mg/L, except pH (pH units).

Table 33
Effluent Data Summary for EOC Holdings Inc. (PR 2510)
December 1993-December 1994, Ditch Monitoring

Characteristics	No. of Values	Maximum	Minimum	Mean	Std. Dev.
Arsenic	7	0.0037	0.0009	0.0025	0.0013
Barium	7	0.190	0.025	0.061	0.060
Cadmium	7	0.0313	<0.0002	Median 0.0002	
Copper	7	0.024	<0.010	Median 0.010	
Lead	7	0.020	<0.002	Median 0.008	
Mercury	7	0.00005	<0.00005	Median 0.00005	
Molybdenum	7	0.157	<0.030	Median 0.030	
Nickel	7	0.065	<0.020	Median 0.020	
pH	7	7.58	4.78	6.23	1.14
Zinc	7	0.196	<0.005	Median 0.088	

*All values are in mg/L, except pH (pH units).

Table 34
Effluent Data Summary for Tree Island Industries (PE 3190)

Characteristic	No. of Values	Maximum	Minimum	Mean	Std. Dev.
Conductivity	52	37	8.8	14.09	4.89
Hardness	52	12	2.63	3.80	1.49
Lead (D)	52	0.1	<0.08	Median 0.08	
pH	52	7.92	3.1	6.61	0.68
Temperature	52	26	7	19.33	4.76
Zinc (D)	52	0.29	0.02	0.06	0.04

*All values are in mg/L, except conductivity (umhos/cm) and hardness (mg/L CaCO3).

Table 35
Effluent Data Summary for Greater Vancouver Sewerage and Drainage District, Iona WWTP
(PR 5904) Oily Sludge Biodegradation Beds (1987-1990)

Characteristic	No. of Values	Maximum	Minimum	Mean	Std. Dev.
Chromium	18	531	65	260	132
Copper	18	92.3	28.3	67.3	17.4
Lead	18	490	168	363	98
Nickel	18	65.2	26.2	38.9	11.6
Oil and Grease	18	220 000	12 500	72 983	54 622
PCBs	2	0.31	0.11	0.21	0.14
Vanadium	18	145.0	38.6	68.2	27.7
Zinc	18	331	121	193	44

*All values are in mg/kg dry-weight

Table 36
Effluent Data Summary for Greater Vancouver Sewerage and Drainage District, Iona WWTP (PR 5904) Oily Sludge Test Wells (1989-1990)

Characteristic	No. of Values	Maximum	Minimum	Mean	Std. Dev.
Ammonia	12	98	2	33	36
Carbon-organic	12	111	5	37	33
Chromium	12	0.05	<0.05	Median 0.05	
Copper	12	0.04	0.02	0.02	0.01
Lead	12	0.005	<0.005	Median 0.005	
Nickel	12	0.05	<0.05	Median 0.05	
Oil and Grease	12	5	5	Median 5	
pH	12	6.9	6.2	6.5	0.2
Vanadium	12	0.5	<0.5	Median 0.5	
Zinc	12	0.01	<0.01	Median 0.01	

*All values are mg/L, except pH (pH units)

Table 37
Effluent Data Summary for Lafarge Cement (PE 42)

Discharge "01"					
Characteristics	**No. Of Values**	**Maximum**	**Minimum**	**Mean**	**Std Dev**
Temperature	23	21	2	12	6
Oil & Grease	23	23.0	0.1	6.3	21.6
Suspended Solids	23	236.0	2.0	40.4	54.9
Flow	19	3715	1450	2337	576
Discharge "02"					
Temperature	23	29	6	17	6
Oil & Grease	23	3.6	0.1	1.4	1.1
Suspended Solids	23	358.5	4.0	50.3	75.6
Flow	17	2660	170	1144	778

All values are in mg/L except pH (pH units), flow (m^3/d) and temperature (^oC).

Table 38
Effluent Data Summary for Titan Steel and Wire Company Ltd. (PE 161)

Characteristics	No. Of Values	Maximum	Minimum	Mean	Std Dev
Flow Rate	6	1800	1200	1500	245
Temperature	21	26	14	20	3
Calcium	21	24	2.6	15	6
Copper	21	0.01	0.002	0.003	0.002
Iron	21	1.6	0.2	0.3	0.3
Potassium	21	6.8	0.2	3.9	1.9
Magnesium	21	5.8	0.2	3.3	1.5
Manganese	21	0.100	0.002	0.023	0.021
Molybdenum	19	0.026	0.002	0.02	0.01
Sodium	20	85	2.4	51.0	19.7
Nickel	21	0.004	0.002	0.003	0.001
Phosphorous	21	0.72	0.02	0.44	0.17
Lead	21	0.28	0.004	0.02	0.06
Strontium	21	0.13	0.01	0.08	0.03
Zinc	21	0.30	0.002	0.04	0.07

All values are for total metals in mg/L except flow (m^3/d) and temperature (^oC).

Table 39
Effluent Data Summary for Lulu STP (PE 233)

Characteristics	No. of Values	Maximum	Minimum	Mean	Std Dev
BOD 5-day	544	195	90	143	19
COD	970	383	162	280	2
Coliform: fecal	721	160000000	0	Median = 2,700,000	
Conductivity	1419	980	375	530	79
Chloride	1419	200	34	67	25
Daily Flow	1461	85	39	54	5
Dissolved Oxygen	993	6.6	0.4	2.4	0.9
pH	993	8.8	6.1	6.8	0.3
Temperature	993	23	11	18	2
Total Suspended Solids	1419	128	29	56	10
Volatile Suspended Solids	1321	107	23	46	8

All values are in mg/L except: pH, Temperature (^oC), Conductivity (µS/cm) and Coliforms (MPN/100mL).

Table 40
Effluent Data Summary for Lulu STP (PE 233)

Characteristic	No. of Values	Maximum	Minimum	Mean	Std. Dev.
Aluminum (diss.)	48	82	5	19	16
Aluminum (tot.)	48	582	30	77	85
Arsenic	48	< 0.07	0.05	median < 0.07	
Barium	36	4.8	1.7	2.2	0.6
BOD 5-day	544	11495	4535	7801	1113
Boron	36	14	6	9	2
Cadmium	48	0.18	0.03	0.05	0.03
Chromium	48	6.9	0.3	1.3	1.1
Cobalt	48	< 3	< 2	median < 2	
Copper	48	15	8	10	1
Cyanide	48	<2	<1	median <2	
Fluoride	48	20	5	13	4
Iron (diss.)	48	105	33	58	14
Iron (total)	48	160	75	107	19
Lead	48	3.2	0.4	0.9	0.6
M.B.A.S.	48	300	95	175	44
Manganese	44	300	95	176	45
Mercury	48	< 0.04	< 0.03	median < 0.03	
Molybdenum	48	<2	<1	median < 2	
Nitrogen: ammonia	48	1300	810	979	91
Kjeldahl	46	2000	1000	1600	234
nitrate/nitrite	48	100	1	33	20
Nickel	48	13.0	0.4	1.7	1.5
Oil & Grease	48	8350	750	1656	1059
Phenol	48	5.0	1.0	2.2	0.7
Phosphorous	48	320	180	242	31
Selenium	48	< 0.07	< 0.05	median < 0.06	
Silver	48	3.0	0.2	1.0	0.5
Sulphate	48	2800	950	1770	443
Sulphide	10	40	< 6	median <6	
Tin	47	< 40	< 6	median < 30	
Total Suspended Solids	1419	7962	1565	2991	602
Zinc	51	1600.0	0.6	40.2	223.8

All values are in kg/d, to represent loadings.

Table 41
Effluent Data Summary for Annacis Island STP (PE 387)

Characteristics	No. Of Values	Maximum	Minimum	Mean	Std Dev
BOD 5-day (mg/L)	554	205	60	136	23
COD (mg/L)	983	522	133	263	40
Coliform: fecal (MPN/100mL)	690	48000000	20	2519610	3694378
Conductivity (µS/cm)	1442	1080	300	495	65
Chloride (mg/L)	1443	275	26	53	15
Dissolved Oxygen (mg/L)	989	7.8	0.2	3.4	1.3
pH	992	8.9	6.0	6.9	0
Suspended Solids (mg/L)	1443	132	23	61	11
Temperature (^{o}C)	990	25	11	18	3
Volatile Susp. Solids (mg/L)	1336	88	23	52	9

Table 42
Effluent Data Summary for Annacis Island STP (PE 387)

Characteristic (kg/d)	No. of Values	Maximum	Minimum	Mean	Std. Dev.
Aluminum (total)	48	400	90	177	78
Arsenic	48	2.0	0.3	0.5	0.3
Barium	36	47	7	12	7
BOD 5-day	554	205	60	136	23
Boron	36	120	41	68	18
Cadmium	48	0.30	< 0.2	Median < 0.2	
Chromium	48	6	1	3	1
Cobalt	48	<30	<7	Median < 8	
Copper	48	76	30	50	10
Cyanide	48	<20	<7	median <7.5	
Fluoride	48	46	10	30	8
Iron (diss.)	48	741	200	448	134
Iron (total)	48	1470	354	838	254
Lead	48	9	2	4	2
M.B.A.S.	48	1500	470	961	229
Manganese	48	76	30	41	79
Mercury	48	< 0.3	< 0.2	Median < 0.2	
Molybdenum	48	< 20	< 7	Median < 7	
Nitrogen: Ammonia	48	8300	4000	5952	826
Kjeldahl	46	13000	6900	9287	1212
nitrate/nitrite	48	910	3	245	178
Nickel	48	16	1	5	3
Oil & Grease	48	12000	3000	8863	1855
Phenol	48	40	8	17	6
Phosphorous	47	1200	500	870	143
Selenium	48	0.60	< 0.3	Median <0.4	
Silver	48	2.0	0.4	1.3	0.5
Sulphate	48	17000	5600	10940	2734
Sulphide	10	< 60	< 40	Median < 40	
Tin	47	<300	<40	Median <200	
Total Suspended Solids	1442	55207	7320	22083	5896
Zinc	51	10000	1	246	1398

Table 43
Effluent Data Summary for B.C. Packers Limited (PE 1830)

Characteristics		No. Of Values	Maximum	Minimum	Mean	Std Dev
BOD 5-day		8	1500	10	546	482
Carbon		3	2500	340	1167	1166
Carbon, Inorganic		3	48	2	23	23
Total Suspended Solids		6	2240	49	641	804
Nitrogen:	ammonia	4	45	3.5	16.9	18.8
	nitrite	1	0.006	0.006	0.006	-
	Kjeldahl	3	328.0	50.0	185.0	139.2
Oil & Grease		5	119	17	54	44
pH		5	6.7	6.2	6.4	0.2
Phosphorous (total)		2	24	16.4	20.2	5.4
Sulphide		1	0.8	0.8	-	-
Specific Conductivity		5	1750	275	1025	668

All values are in mg/L except pH and Conductivity (µS/cm).

Table 44
Effluent Data Summary for Lions Gate Fisheries Limited (PE 3139)

Characteristic		No. Of Values	Maximum	Minimum	Mean	Std Dev
BOD 5-day		3	1500	591	1006	460
Total Suspended Solids		3	917	414	680	253
Nitrogen	ammonia	3	59	8.8	26.8	28.0
	nitrite/nitrate	1	0.02	0.02	0.02	-
	nitrite	1	0.005	0.005	0.005	-
	Kjeldahl	3	202.0	92.7	164.6	62.3
Oil & Grease		2	149	74	112	53
pH		3	7.7	6.8	7.3	0.5
Phosphorous-ortho (dissolved)		1	7.5	7.5	7.5	-
Specific Conductivity		3	1010	380	728	320

All units are in mg/L except pH and Conductivity (µS/cm).

Table 45
Effluent Data Summary for Tilbury Cement Limited (PE 4513)

Characteristic	No. Of Values	Maximum	Minimum	Mean	Std Dev
Total Suspended Solids	3	134	6	59	67
Oil and Grease	7	5	1	3	2
pH	4	7.8	7.7	7.8	0.05
Specific Conductivity	4	7.8	7.7	8	0.05

All values are in mg/L except pH and Conductivity (µS/cm).

Table 46
Effluent Data Summary for Tilbury Cement Limited (PE 4513)

Characteristic	No. Of Values	Maximum	Minimum	Mean	Std Dev
Intake Temperature	47	20	4	12	5
Discharge Temperature	47	26	9	17	5
Discharge minus Intake	47	8	3	6	0.9
Temp. Downstream of Discharge	47	19	2	10	5.6
Flow	45	12600	5640	7731	1930

All values are in ^{o}C except flow (m^3/d).

Table 47
Effluent Data Summary for Bella Coola Fisheries Limited (PE 5400)

Characteristics	No. Of Values	Maximum	Minimum	Mean	Std Dev
BOD 5-day	3	549	123	310	218
Total Suspended Solids	3	276	129	186	79
Nitrogen ammonia	3	17	0.8	7.4	8.6
nitrite/nitrate	3	0.04	0.02	0.03	0.01
nitrite	3	0.031	0.005	0.014	0.015
Kjeldahl	3	48.7	23.6	37.9	12.9
Oil & Grease	3	59	18	34	22
pH	3	6.5	6.4	6.5	-
Phosphorous	3	16.6	4.44	11.7	6.4
Phosphorus-ortho (dissolved)	3	13.2	2.6	9.3	5.8
Potassium	1	34.0	34.0	34.0	-
Sodium	2	212.0	16.2	114.1	138.5
Specific Conductivity	3	16500	139	6046	9079

All values are in mg/L except pH and Conductivity (µS/cm).

Table 48
Effluent Data Summary for Fraser River Harbour Commission (PE 6276)

Characteristics	No. Of Values	Maximum	Minimum	Mean	Std Dev
pH	7	8.3	7.4	7.9	0.3
Temperature	7	20.5	2.5	10.8	6.7
Dissolved Oxygen	7	12.2	6.3	8	2
Acidity pH 8.3	7	27.0	0.5	13.3	9.7
Total Suspended Solids	7	18	7	11	4
BOD 5-day	7	75	10	27	24
COD	7	87	49	68	12
Nitrogen: ammonia	7	7.60	0.95	4.02	2.47
nitrate	7	7.96	0.31	2.62	2.64
nitrite	7	0.940	0.041	0.283	0.306
Copper (total)	7	<0.05	<0.05	<0.05	0
Iron (total)	7	8.50	0.84	2.55	2.68
Manganese (total)	7	1.90	0.40	0.92	0.48
Aluminum (total)	7	<0.10	<0.10	<0.10	0
Sulfate (dissolved)	7	24.0	2.0	14.1	8.7
Phosphorous (total diss.)	7	0.280	0.002	0.055	0.100
Lead (total)	7	0.002	0.001	0.001	0.000
Zinc (total)	7	<0.05	<0.02	median = 0.04	
Resin Acids	7	<0.005	<0.005	<0.005	0
Fatty Acids	7	0.405	0.005	0.150	0.142

All values are in mg/L except pH, temperature (^{o}C) and acidity (mg CaCO3/L).

Table 49
Effluent Data Summary for Alpha Manufacturing Inc. (PR 7707)

Characteristics	No. of Values	Maximum	Minimum	Mean	Std. Dev.
Aluminum	1	0.15	0.15	0.15	-
Barium	1	0.04	0.04	0.04	-
Calcium	1	18.9	18.9	18.9	-
Cadmium	1	0.01	0.01	0.01	-
Iron	1	0.03	0.03	0.03	-
Magnesium	1	2.3	2.3	2.3	-
Manganese	1	1.66	1.66	1.66	-
Zinc	1	0.06	0.06	0.06	-

All values are in mg/L.

Table 50
Effluent Data Summary for Alpha Manufacturing Inc. (PR 7707)

Characteristics	No. Of Values	Maximum	Minimum	Mean	Std Dev
pH	16	8.5	6.7	7.6	0.7
Sulphate	16	53.2	6.9	25.3	15.4
COD	16	130	44	89	30
Phenols (total)	16	0.012	0.002	0.006	0.003
Iron (total)	16	29.5	0.9	12.2	7.5
Iron (dissolved)	16	2.14	0.03	0.67	0.72
Manganese (total)	16	3.71	0.19	2.04	1.00
Zinc (total)	16	0.17	0.02	0.06	0.04

All values are in mg/L except pH (pH units).

Table 51
Effluent Data Summary for 7437 Holdings Ltd. (PR 7709)

Characteristics	No. Of Values	Maximum	Minimum	Mean	Std Dev
pH	15	7.8	6.7	7.3	0.3
Sulphate	9	18.9	2.8	10.6	5
Cadmium (diss)	15	<0.0002	<0.0002	<0.0002	0
Calcium (diss)	15	157.0	9.6	67.1	39.9
Chromium (diss)	15	0.015	0.001	0.010	0.007
Copper (diss)	15	0.010	0.001	0.007	0.004
Iron (diss)	15	4.64	0.03	1.25	1.56
Lead (diss)	15	0.002	<0.001	median = 0.001	
Magnesium (diss)	15	34.6	2.1	16.1	8.2
Manganese (diss)	15	2.24	0.005	0.74	0.78
Zinc (diss)	15	0.498	0.008	0.138	0.2
Phenols (tot)	15	0.060	0.006	0.027	0.02
Tetrachlorophenol	17	<0.001	<0.001	<0.001	0
Pentachlorophenol	17	<0.001	<0.001	<0.001	0
Resin or Fatty Acids	17	<0.010	<0.002	median = 0.010	
COD	15	199	6	89	50

All values are in mg/L except pH (pH units).

Table 52
Effluent Data Summary for Robert Brown (PR 7765)

Characteristics	No. Of Values	Maximum	Minimum	Mean	Std Dev
pH	7	8.5	7.1	7.7	0.4
Dissolved Oxygen	7	15.2	7.4	9	3
Temperature	7	21.0	3.0	12.3	7.5
BOD 5-day	7	34	10	16	8
COD	7	182	36	117	56
Ammonia	7	1.1	<1	median = 1	
Sulphide (total)	7	<0.5	<0.04	median = 0.5	
Total Suspended Solids	7	80	2	35	29
Phenol	7	0.007	0.005	0.006	0.001
Pentachlorophenol	7	<0.005	<0.0005	median = 0.0005	
Tetrachlorophenol	7	<0.001	<0.001	<0.001	0
Mercury (total)	7	<0.00005	<0.00005	<0.00005	0
Aluminum (total)	7	1.90	0.10	1.02	0.58
Chromium (total)	7	<0.05	<0.05	<0.05	0
Lead (total)	7	<0.05	0.007	median = 0.05	
Cadmium(diss.)	7	<0.005	<0.002	median = 0.005	
Copper (diss.)	7	<0.05	<0.05	<0.05	0
Iron (diss.)	7	0.64	0.06	0.34	0.21
Manganese(diss.)	7	0.35	0.05	0.14	0.11
Zinc (diss.)	7	<0.02	<0.02	<0.02	0
Toxicity	6	100	90	98	4

All values are in mg/L except pH and toxicity (% survival).

Table 53
Effluent Data Summary for Shearer Seafood Products Ltd. (PE 7785)

Characteristics	No. Of Values	Maximum	Minimum	Mean	Std Dev
BOD 5-day	5	578	145	346	160
Chlorine, residual	5	<0.5	<0.2	Median = <0.2	
pH	3	6.93	6.25	6.5	0.39
Suspended Solids	5	322	74	186	89

All values are in mg/L except pH.

Table 54
Effluent Data Summary for Ecowaste Industries Ltd. (PE 8036)

Characteristics	No. Of Values	Maximum	Minimum	Mean	Std Dev
Flow Rate	2	1640	105	873	1085
pH	16	8.48	7.4	8	0.3
Total Suspended Solids	13	22	1	8	6
BOD 5-day	15	23	10	15.133	5.125
COD	12	214.0	128.0	185.8	25.3
Dissolved Oxygen	16	12.3	6.4	9.4	1.6
Total Sulfide	16	<0.5	<0.1	median = 0.1	
Ammonia nitrogen (tot)	16	8.500	0.170	4.057	2.371
Aluminum (tot)	7	<1.5	<0.1	median = 0.15	
Cadmium (diss)	7	<0.005	<0.0002	median = 0.0002	
Chromium(tot)	6	<0.05	<0.03	median = 0.03	
Copper (diss)	7	<0.05	<0.001	median = 0.01	
Lead (tot)	7	<0.08	<0.001	median = 0.003	
Manganese (diss)	10	0.57	0.004	0.22	0.18
Mercury (tot)	5	<0.00005	<0.00005	<0.00005	0
Zinc (diss)	9	<0.02	<0.015	median = <0.02	
Phenols	12	0.038	0.003	0.014	0.010
Pentachlorophenol	6	<0.0001	<0.00005	median = 0.0001	
Tetrachlorophenol	6	<0.0001	<0.00005	median = 0.0001	
Toxicity (96h LC20)	6	>100	>100	>100	-

All values are in mg/L except Flow (m^3/d), pH (pH units), and Toxicity (% survival).

Table 55
Effluent Data Summary for Meadowland Peat Ltd. (PR 8139)

Characteristics	No. Of Values	Maximum	Minimum	Mean	Std Dev
pH	12	7.6	6.5	7.0	0.3
COD	12	215	50	103	61
Phenols	12	0.037	0.007	0.014	0.012
Sulfide (tot)	12	0.053	0.005	0.019	0.015
Ammonia nitrogen (diss)	12	7.42	0.02	1.33	2.36
Sulfate	12	134.0	32.2	69.4	36.6
Aluminum (tot)	12	1.4	0.1	0.3	0.4
Calcium (tot)	8	102	34	71	22
Copper (tot)	12	0.008	0.002	0.004	0.002
Iron (tot)	12	32.9	3.1	11.2	8.1
Magnesium (tot)	5	26.4	15.7	21.7	4.3
Manganese (tot)	12	12.4	0.5	3.4	3.3
Zinc (tot)	12	0.19	0.01	0.07	0.05
Calcium (diss)	9	127	57	78	24
Copper (diss)	12	0.005	0.001	0.002	0.001
Iron (diss)	12	8.09	0.09	2.95	2.48
Magnesium (diss)	9	25.9	11.9	17.9	5.0
Manganese (diss)	12	4.560	0.002	1.176	1.517
Zinc (diss)	12	0.510	0.002	0.057	0.143

All values are in mg/L.

Table 56
Greater Vancouver Sewerage and Drainage District
Iona Island WWTP, Digester Supernatant Discharge (1993-1994)

Characteristic	No. of Values	Maximum	Minimum	Mean	Std. Dev.
Flow	26	765	288	453	138
Arsenic	26	2.600	0.051	0.206	0.489
Cadmium	26	0.17	0.05	0.11	0.03
Chromium	26	3.13	0.78	1.87	0.59
Copper	26	28.9	7.8	19.4	5.2
Iron	26	326	143	269	46
Lead	26	5.82	2.36	3.55	0.67
Manganese	26	7.98	3.13	5.26	1.07
Mercury	26	0.150	0.030	0.103	0.029
Nickel	26	0.962	0.410	0.703	0.139
Zinc	26	15.00	7.56	11.52	2.13

*All values are in mg/L.

Table 57
Greater Vancouver Sewerage and Drainage District
Iona Island WWTP
Digester Sludge and Digester Sludge Cleanout Discharge (Nov. 1993)

Characteristic	No. of Values	Maximum	Minimum	Mean	Std. Dev.
Cadmium	2	0.18	0.11	0.15	-
Chromium	2	2.08	1.62	1.85	-
Copper (T)	2	22.7	19.1	20.9	-
Iron	2	247	197	222	-
Lead	2	4.33	2.78	3.56	-
Manganese	2	4.33	3.64	3.99	-
Mercury	2	0.098	0.084	0.091	-
Nickel	2	0.77	0.53	0.65	-
Zinc (T)	2	13.3	10.8	12.1	-

*All values are in mg/L.

Table 58
Greater Vancouver Sewerage and Drainage District Iona Island WWTP
Sludge Lagoon Groundwater Monitoring Wells (1993-1994)

Characteristic	No. of Values	Maximum	Minimum	Mean	Std. Dev.
Cadmium	138	0.0121	0.0005	0.0012	0.0015
Chromium	66	0.04	0.01	Median 0.01	
Copper (T)	138	4.46	0.02	0.15	0.40
Iron	66	45.70	0.00	4.79	10.19
Lead	138	0.5200	0.0005	Median 0.005	
Manganese	66	58.70	0.02	7.96	14.42
Mercury	138	1.0600	0.0005	Median 0.0005	
Nickel	66	1.43	0.01	0.27	0.32
Zinc (T)	136	1.65	0.01	0.11	0.21

*All values are in mg/L.

Table 59
Ambient Water Quality 75 Metres Upstream from the Chilliwack Sewage Treatment Plant

Characteristic	No. Of Values	Maximum	Minimum	Mean	Std Dev
Coliforms: fecal CFU/cL	13	230	6	65	76
fecal MPN/cL	2	350	17	77	235
E. coli CFU/cL	4	110	11	33	45
Enterococci CFU/cL	4	36	2	9	15
Pseudomonas CFU/cL	4	4	<2	2	1
Nitrogen: ammonia	32	0.136	<0.005	0.016	0.023
nitrite/nitrate	2	0.12	0.12	0.12	0
nitrite	16	0.005	<0.005	med. <0.005	0
Kjeldahl	19	0.55	0.07	0.16	0.12
pH	26	8.2	7.7	7.9	0.1
Phosphorus-ortho (diss)	13	0.014	0.003	0.007	0.004
total	2	0.495	0.352	0.424	0.101
Oxygen: dissolved	4	10.3	9.5	10.0	0.3
Biomass	17	35	24	27	3

*all measurements in mg/L unless otherwise noted

Table 60
Ambient Water Quality 100 metres Downstream from the Chilliwack Sewage Treatment Plant

Characteristic	No. Of Values	Maximum	Minimum	Mean	Std Dev
Coliforms: fecal CFU/cL	13	41000	2	384	17040
E. coli CFU/cL	4	290	11	53	128
Enterococci CFU/cL	5	45	2	18	19
Pseudomonas CFU/cL	5	3	2	med.<2	0
Nitrogen: ammonia	31	3.84	<0.005	0.977	1.045
nitrite	15	0.132	<0.005	0.033	0.043
Kjeldahl	18	5.14	0.56	2.36	1.27
pH	26	8.1	7.2	7.7	0.3
Phosphorus-ortho diss	12	0.692	0.128	0.354	0.181
Oxygen dissolved	6	10.4	8.9	9.8	0.5
Biomass	18	78	28	38	11
Solids suspended	1	27	27	27	0

*all measurements in mg/L unless otherwise noted

Table 61
Ambient Water Quality 200m Downstream from the Chilliwack Sewage Treatment Plant

Characteristics	No. Of Values	Maximum	Minimum	Mean	Std Dev
Coliforms: fecal CFU/cL	2	140	40	75	71
Nitrogen: ammonia	2	0.238	0.137	0.188	0.071
nitrite/nitrate	2	0.13	0.12	0.13	0.01
nitrite	2	0.006	0.005	0.006	0.001
Kjeldahl	2	0.93	0.63	0.78	0.21
Phosphorus: dissolved	2	0.023	0.017	0.020	0.004
Oxygen: dissolved	1	11.6	11.6	11.6	0
Specific Conductivity	1	134	134	134	0
pH	1	8.2	8.2	8.2	0.0

*all measurements in mg/L unless otherwise noted

Table 62
Ambient Water Quality 300m Downstream from the Chilliwack STP

Characteristics	No. Of Values	Maximum	Minimum	Mean	Std Dev
Nitrogen: ammonia	17	2.08	0.135	0.8	0.6
nitrite	15	0.055	0.005	0.02	0.0
Kjeldahl	17	2.39	0.34	1.25	0.7
Phosphorus: dissolved	11	0.394	0.139	0.2	0.1
Oxygen: dissolved	1	11.1	11.1	11.1	0.0
Specific Conductivity	17	191	152	175.2	11.0
Biomass	17	38	24	31.2	3.7

*all measurements in mg/L unless otherwise noted

Table 63
Ambient Water Quality Upstream from the Kent Sewage Treatment Plant (Bridal Falls)

Characteristic	No. Of Values	Maximum	Minimum	Mean	Std Dev
Coliforms: fecal CFU/cL	13	1260	9	78	348
fecal MPN/cL	5	200	33	95	88
E. coli CFU/cL	4	58	14	22	21
Enterococci CFU/cL	4	47	8	15	19
Pseudomonas CFU/cL	4	5	2	med. <2	2
Nitrogen: ammonia	18	0.023	<0.005	0.008	0.005
nitrite/nitrate	1	0.05	0.05	0.05	0
nitrite	1	<0.005	<0.005	<0.005	0
pH	13	8.1	7.6	7.9	0.1
Phosphorus-ortho dissolved	12	0.692	0.128	0.354	0.181
total	5	0.02	0.017	0.019	0.001
Oxygen: dissolved	4	10.2	9.8	10.0	0.2
Solids: suspended	5	7	1	4	2

*all measurements in mg/L unless otherwise noted

Table 64
Ambient Water Quality at Kent Sewage Treatment Plant

Characteristic	No. Of Values	Maximum	Minimum	Mean	Std Dev
Coliforms: fecal MPN/cL	4	92000	170	3462	43758
Nitrogen: ammonia	4	14.1	0.475	6.136	6.770
pH	4	7.8	7.3	7.6	0.3
Phosphorus: total	4	5.07	0.124	2.077	2.390
Solids: dissolved	4	52	4	26	24
Specific Conductivity	4	550	184	335	181
Solids: suspended	4	52	4	26	24

*all measurements in mg/L unless otherwise noted

Table 65
Ambient Water Quality Downstream from the Kent Sewage Treatment Plant

Characteristics	No. Of Values	Maximum	Minimum	Mean	Std Dev
Coliforms: fecal CFU/cL	12	4200	5	85	1204
E. coli CFU/cL	3	58	2	11	30
Enterococci CFU/cL	4	35	6	13	13
Pseudomonas CFU/cL	4	26	2	med.<2	12
Nitrogen: ammonia	12	0.015	<0.005	med.<0.005	0.004
nitrite/nitrate	1	0.05	0.05	0.05	0
nitrite	1	<0.005	<0.005	<0.005	0
pH	7	8.1	7.9	8.0	0.1
Oxygen (dissolved)	4	10.1	9.9	10.0	0.1

*all measurements in mg/L unless otherwise noted

Table 66
Ambient Water Quality at Hope

Characteristic	No. Of Values	Maximum	Minimum	Mean	Std Dev
Alkalinity	2	62.7	61.1	61.9	1.1
Coliforms: fecal CFU/cL	29	210	11	37	45
MPN MPN/cL	28	540	2	61	117
Colour(TAC)	4	21	15	18	3
Hardness: calcium	44	29.6	10.6	18.5	2.7
magnesium	44	7.22	1.48	4.20	0.93
Metals: aluminum (total)	65	13.3	0.11	1.77	2.26
arsenic (total)	11	<0.3	<0.001		0.116
cadmium (total)	43	<0.01	<0.0005		0.0020
chromium (total)	44	0.02	<0.005	med.<0.01	0.003
copper (total)	44	0.89	<0.001	med.<0.01	0.133
iron (total)	44	14.1	0.17	1.79	2.51
mercury (total)	2	<0.00005	<0.00005	med. <0.00005	0
manganese (total	44	0.46	<0.006	0.049	0.074
molybdenum (total)	44	0.02	<0.01	med. <0.01	0.00
lead (total)	44	0.1	<0.001	med.<0.1	0.025
nickel (total)	44	0.08	<0.05	med.<0.05	0.00
zinc (total)	44	0.39	<0.005	0.024	0.058
Nitrogen: ammonia	72	0.021	0.005	0.007	0.003
nitrate/nitrate	2	0.12	0.1	0.1	0.0
Kjeldahl	2	0.2	0.09	0.15	0.08
pH	98	8.2	5.6	7.8	0.4
Phosphorus-ortho (diss)	71	8.2	5.6	7.8	0.4
dissolved	98	8.2	5.6	7.8	0.4
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
Chloride (diss)	3	6.8	3.5	4.9	1.7
Sulphate	3	12.9	9.7	11.0	1.7
Solids: dissolved	1	82	82	82	0
suspended	71	380	1	48	62
Specific Conductivity	73	207	84	136	23
Turbidity	3	25	2	10	13
Organic Halide: 1ChlPhen	50	<0.00005	<0.00005	med.<0.00005	
Organics: 2ChlPhen	50	<0.00005	<0.00005	med.<0.00005	
3ChlPhen	50	<0.00005	<0.00005	med.<0.00005	
4ChlPhen	48	<0.00005	<0.00005	med.<0.00005	
1Chlgua	50	<0.00005	<0.00005	med.<0.00005	
2Chlqua	50	<0.00005	<0.00005	med.<0.00005	
3Chlgua	45	<0.00005	<0.00005	med.<0.00005	
4Chlgua	46	<0.00005	<0.00005	med.<0.00005	
1Chlcat	50	<0.0001	<0.0001	med.<0.0001	
2Chlcat	50	<0.0001	<0.0001	med.<0.0001	

Table 66 (continued)
Ambient Water Quality at Hope

Characteristic	No. Of Values	Maximum	Minimum	Mean	Std Dev
3Chlcat	50	<0.0001	<0.0001	med.<0.0001	
4Chlcat	49	<0.0001	<0.0001	med.<0.0001	
2Chlvere	50	<0.0001	<0.0001	med.<0.0001	
3Chlvere	50	<0.0001	<0.0001	med.<0.0001	
1Chlvanl	50	<0.0001	<0.0001	med.<0.0001	
2Chlvanl	50	<0.0001	<0.0001	med.<0.0001	
3Chlsyr	50	<0.0001	<0.0001	med.<0.0001	
PCP's	47	<0.00005	<0.00005	med.<0.00005	

*all measurements in mg/L unless otherwise noted

Table 67
Ambient Water Quality Data Summary for Fraser River Upstream From JAMES Sewage Treatment Plant (Site E207391)

Characteristic	No. Of Values	Maximum	Minimum	Mean	Std Dev
Coliforms - fecal (MPN/100 mL) - winter	5	920	180	geo. mean = 313	
Coliforms-fecal (CFU/cL)	13	700	12	geo. mean = 74	
fecal (MPN/100 mL)	1	79	79	geo. mean = 79	
E. Coli (CFU/cL)	5	100	10	geo. mean = 27	
Enterococci (CFU/cL)	4	13	<1	geo. mean = 4	
Pseudomonas aeruginosa (CFU/cL)	3	3	<2	geo. mean = 2	
Nitrogen-ammonia	19	0.062	<0.005	0.020	0.019
nitrate/nitrite	1	0.05	0.05	0.05	0
nitrite	1	<0.005	<0.005	<0.005	0
pH	13	8.3	7.7	8.0	0.2

*all measurements in mg/L unless otherwise noted

Table 68
Ambient Water Quality Data Summary for Fraser River at Discharge of JAMES Sewage Treatment Plant (Site E207392)

Characteristics	No. Of Values	Maximum	Minimum	Mean	Std Dev
Coliforms-fecal (MPN/100 mL) - winter	5	1100	200	geo. mean = 420	
Nitrogen-ammonia	5	1.19	0.068	0.500	0.443
pH	5	7.8	7.6	7.7	0.1
Phosphorus-total	5	0.343	0.025	0.149	0.129

*all measurements in mg/L unless otherwise noted

Table 69
Ambient Water Quality Data Summary for Fraser River 100 metres Downstream from JAMES Sewage Treatment Plant (Site E207602)

Characteristics	No. Of Values	Maximum	Minimum	Mean	Std Dev
Coliforms-fecal (CFU/cL)	18	275	6	geo. mean = 53	
fecal (MPN)	1	70	70	geo. mean = 70	
E. Coli (CFU/cL)	4	320	11	geo. mean = 65	
Enterococci (CFU/cL)	4	16	6	geo. mean = 9	
Pseudomonas (CFU/cL)	4	3	<2	median <2	
Hardness-total	5	51.0	46.2	49.5	2.0
calcium	5	14.7	13.9	14.4	0.3
magnesium	5	3.55	2.8	3.31	0.30
Metals-aluminum(dissolved)	5	0.1	0.04	0.06	0.03
arsenic (total)	5	<0.04	<0.04	<0.04	0
iron (total)	5	2.57	0.92	1.83	0.75
iron (dissolved)	5	0.14	0.04	0.09	0.04
manganese (total)	5	0.07	0.03	0.06	0.02
nickel (total)	5	<0.01	<0.01	<0.01	0
zinc (total)	5	0.01	0	0.01	0.00
Nitrogen-ammonia	19	0.029	<0.005	0.010	0.007
nitrate/nitrite	1	0.05	0.05	0.05	-
nitrite	6	0.007	<0.005	median <0.005	
pH	13	8.2	7.7	8.0	0.1
Phosphorus-dissolved	5	<0.04	<0.04	<0.04	0
total	5	0.08	<0.04	0.06	0.02
Potassium	5	1	0.7	0.8	0.1
Sodium	5	2.25	1.68	1.92	0.24

*all measurements in mg/L unless otherwise noted

Table 70
Ambient Water Quality Data Summary for Fraser River, 50 m. Upstream from Aldergrove Sewage Treatment Plant (Site 0301548)

Characteristics	No. Of Values	Maximum	Minimum	Mean	Std Dev
Coliforms - fecal (MPN/100 mL) - winter	5	1100	170	geo. mean = 377	
Coliforms-fecal (CFU/cL)	13	9500	9	geo. mean = 296	
fecal (MPN/100 mL)	1	79	79	geo. mean = 79	
E. Coli (CFU/cL)	4	250	10	geo. mean = 48	
Enterococci (CFU/cL)	4	24	3	geo. mean = 11	
Pseudomonas aeruginosa (CFU/cL)	3	4	<2	geo. mean = 3	
Nitrogen-ammonia (mg/L)	18	0.138	<0.005	0.038	0.0
nitrate/nitrite (mg/L)	1	0.04	0.04	0.04	0
nitrite (mg/L)	1	<0.005	<0.005	<0.005	-
pH	12	8.2	7.5	7.9	0.2
Phosphorus-total (mg/L)	5	0.042	0.024	0.0332	0.007

Table 71
Ambient Water Quality Data Summary for Fraser River in Initial Dilution Zone of Aldergrove Sewage Treatment Plant (Site 0301549)

Characteristic	No. Of Values	Maximum	Minimum	Mean	Std Dev
Coliforms fecal (MPN) - winter	6	790	180	geo. mean = 278	
Nitrogen - ammonia (mg/L)	6	1.24	0.068	0.276	0.472
pH	6	7.7	7.4	7.6	0.2
Phosphorus - total (mg/L)	6	0.344	0.026	0.091	0.124
Solids - dissolved (mg/L)	6	8	3	6	2
Specific Conductivity (uS/cm)	6	178	139	152	14

Table 72
Ambient Water Quality Data Summary for Fraser River 100 m. Downstream from Aldergrove Sewage Treatment Plant (Site 0301550)

Characteristic	No. Of Values	Maximum	Minimum	Mean	Std Dev
Coliforms-fecal (CFU/cL)	12	2100	12	geo. mean = 147	
fecal (MPN)	1	140	140	geo. mean = 140	
E. Coli (CFU/cL)	4	140	7	geo. mean = 27	
Enterococci (CFU/cL)	4	14	2	geo. mean = 6	
Pseudomonas aeruginosa (CFU/cL)	4	2	<2	geo. mean <2	
Nitrogen-ammonia (mg/L)	13	0.016	<0.005	0.008	0.004
nitrate/nitrite (mg/L)	1	0.04	0.04	0.04	0
nitrite (mg/L)	1	<0.005	<0.005	<0.005	0
pH	7	8.3	8.0	8.1	0.1

Table 73
Ambient Water Quality Data Summary for Fraser River at Mission

Characteristic	No. of Values	Maximum	Minimum	Mean	Std. Dev.
Physical Tests:					
Dissolved Oxygen (mg/L)	29	13.8	8.8	11.1	1.5
Water Temp ° C	29	18.9	1	8.9	6.0
Air Temp ° C	29	22.1	-4	10.4	6.2
pH	30	7.91	7.18	7.55	0.16
Field pH	29	7.85	6.9	7.47	0.23
Specific Conductance (SC)	30	146	92.5	120.1	14.9
Field SC	29	3300	69	205	596
Suspended Solids (mg/L)	30	377	1	40	72
Dissolved Solids (mg/L)	30	91	45	71	14
Hardness Total (mg/L)	30	63.2	39.8	55.1	5.7
Anions:					
Alkalinity Total (mg/L)	30	58.4	38.3	48.2	5.0
Chloride Dissolved (mg/L)	30	2.6	<0.2	1.7	0.5
Fluoride Dissolved (mg/L)	30	0.06	<0.02	0.04	0.01
Sulphate (mg/L)	30	14.4	5.8	9.8	2.1
Nutrients:					
Nitrogen Ammonia (mg/L)	29	0.043	<0.005	0.019	0.010
Nitrogen Kjeldahl (mg/L)	30	0.75	<0.05	0.18	0.12
Nitrogen nitrate/nitrite (mg/L)	30	0.318	0.015	0.116	0.067
Phosphorus Dissolved (mg/L)	30	0.066	<0.001	0.015	0.014
Phosphorus Total (mg/L)	30	0.478	0.013	0.058	0.087
TOTAL METALS (mg/L)					
Aluminum	30	5.6	<0.02	0.59	1.21
Aluminum (w/out max. value)	29	1.94	0.07	0.41	0.44
Arsenic	30	0.0017	<0.0001	0.0005	0.0003
Barium	30	0.085	0.013	0.021	0.013
Cadmium	30	0.0011	<0.0002	median <0.0002	
Calcium	30	18.6	11.5	15.9	1.6
Chromium	30	0.011	<0.001	median <0.001	
Cobalt	30	<0.015	<0.015	<0.015	0.000
Copper	30	0.012	<0.001	0.003	0.003
Iron	29	9.22	0.054	0.739	1.690
Iron (w/out max. value)	28	2.34	0.054	0.436	0.449
Lead	30	0.003	<0.001	median <0.001	

Table 73 (continued)
Ambient Water Quality Data Summary for Fraser River at Mission.

Characteristic	No. of Values	Maximum	Minimum	Mean	Std. Dev.
TOTAL METALS (mg/L)					
Magnesium	30	5.09	2.69	3.73	0.55
Manganese	30	0.292	0.01	0.034	0.051
Mercury	30	<0.00005	<0.00005	<0.00005	0.00000
Molybdenum	30	0.001	<0.001	median <0.001	
Nickel	30	0.015	<0.001	0.002	-
Selenium	30	<0.0005	<0.0005	<0.0005	0.0000
Silver	30	0.0003	<0.0001	median <0.0001	
Sodium	30	4.3	<2	3.49	-
Tin	30	<0.3	<0.3	<0.3	0.0
Zinc	30	0.07	<0.001	0.007	-
Bacteriological: (MPN/100 mL)					
Fecal Coliform - Winter	15	800	30	geo. mean = 120	
Fecal Coliform- Summer	14	500	<2	geo. mean = 28	
ORGANIC PARAMETERS:					
Carbon Total Organic (mg/L)	30	5.08	1	2.60	0.79
AOX (mg/L)	16	0.04	<0.01	0.02	0.01
Chlorophenolics: (mg/L)					
Pentachlorophenol	16	0.000005	<0.000001	median <0.000001	
2,3,4,6+2,3,5,6-Tetrachlorophenol	16	0.000001	<0.000001	median <0.000001	
2,4,6-Trichlorophenol	16	0.000006	<0.000001	median <0.000001	
Tetrachloroguaiacol	16	0.000002	<0.000002	median <0.000002	
3,4,5-Trichloroguaiacol	16	0.000011	<0.000002	median <0.000002	
4,5,6-Trichloroguaiacol	16	0.000008	<0.000002	median <0.000002	
4,5-Dichloroguaiacol	16	0.000014	<0.000002	0.000004	0.000004
5-Chloroguaiacol	16	0.000008	<0.000002	median <0.000002	
Tetrachlorocatechol	16	0.000008	<0.000002	median <0.000002	
3,4,5-Trichlorocatechol	16	0.000012	<0.000002	median <0.000002	
4,5-Dichlorocatechol	16	0.000008	<0.000002	median <0.000002	
3,4,5-Trichloroveratrole	16	0.000006	<0.000002	median <0.000002	
5,6-Dichlorovanillin	16	0.000002	<0.000002	median <0.000002	
6-Chlorovanillin	16	0.000007	<0.000002	median <0.000002	
Nonylphenol	16	0.000006	<0.000002	median <0.000002	
Resin and Fatty Acids:					
Myristic Acid (mg/L)	4	0.0005	<0.0005	median<0.0005	
Palmitric Acid (mg/L)	4	0.0007	<0.0005	median<0.0005	

Table 74
Organic Parameters Measured at Mission Below Detectable Limits

Organic Parameters:	**Detection Limits (mg/L)**	**No. of Values**
Chlorophenolics:		
2,3,4,6+2,3,5,6-Tetrachlorophenol	0.000001	12
2,3,4,5-Tetrachlorophenol	"	12
3,4,5-Trichlorophenol	"	12
2,3,4-Trichlorophenol	"	12
2,3,5-Trichlorophenol	"	12
2,3,6-Trichlorophenol	"	12
2,4,5-Trichlorophenol	"	12
2,4-Dichlorophenol	"	12
2,6-Dichlorophenol	"	12
2,5-Dichlorophenol	"	12
3,5-Dichlorophenol	"	12
2,3-Dichlorophenol	"	12
3,4-Dichlorophenol	"	12
4-Chlorophenol	"	12
3,4,6-Trichloroguaiacol	0.000002	12
4,6-Dichloroguaiacol	"	12
4-Chloroguaiacol	"	12
6-Chloroguaiacol	"	12
3,4-Dichlorocatechol	"	12
3,5-Dichlorocatechol	"	12
4-Chlorocatechol	"	12
Tetrachloroveratrole	"	12
4,5-Dichloroveratrole	"	12
2,6-Dichlorosyringaldehyde	"	12
2-Chlorosyringaldehyde	"	12
3,4,5-Trichlorosyringol	"	12
Trichlorotrimethoxybenzene	"	12
Resin and Fatty Acids:		
Abietic Acid	0.0005	3
Arachidic Acid	0.0005	3
Behenic Acid	0.0005	3
Chlorodehydroabietic	0.0005	3
Dehydroabietic Acid	0.0005	3
Dichlorodehydroabietic	0.0005	3
Isopimaric Acid	0.0005	3
Lauric Acid	0.0005	3
Levo Pimaric Acid	0.0005	3
Lignoceric Acid	0.0005	3

Table 74 (continued)

Organic Parameters Measured at Mission Below Detectable Limits

Organic Parameters:	**Detectable Limits (mg/L)**	**No. of Values**
Linoleic Acid	0.0005	3
Linolenic Acid	0.0005	3
Neoabietic Acid	0.0005	3
Oleic Acid	0.0005	3
Palustric Acid	0.0005	3
Pimaric Acid	0.0005	3
Sandaraco Pimaric Acid	0.0005	3
Stearic Acid	0.0005	3
Antisapstain Compounds:		
TCMTB	0.005	3
Organochlorine Pesticides and PCB's		
Aldrin	0.000001	2
BHC alpha-	0.000001	2
BHC beta-	0.000001	2
BHC delta-	0.000001	2
Chlordane alpha-	0.000005	2
Chlordane gamma-	0.000005	2
DDE p p'-	0.000005	2
DDD p p'-	0.000005	2
DDT p p'-	0.000005	2
Dieldrin	0.000005	2
Endosulfan I	0.000005	2
Endosulfan II	0.000005	2
Endosulfan sulphate	0.00001	2
DDT o p'-	0.000005	2
Endrin	0.000005	2
Hexachlorobenzene	0.0000005	2
Heptachlor	0.000001	2
Heptachlor epoxide	0.000002	2
Lindane BHC gamma-	0.000001	2
Methoxychlor	0.00001	2
Mirex	0.00001	2
Nonachlor trans-	0.000005	2
Oxychlordane	0.000005	2
Toxaphene	0.00005	2
PCB's - Total	0.00002	2

Table 75
Ambient Sediment Quality Data Summary for Langley Bar Area (from Environmental Services, 1994)

Characteristic	No. of Values	Maximum	Minimum	Mean	Std. Dev
Total Metals					
Arsenic	6	3.66	2.40	2.97	0.52
Barium	6	78.9	59.4	72.0	7.5
Cadmium	6	0.14	<0.10	0.12	0.01
Chromium	6	42.4	20.9	32.1	8.2
Cobalt	6	10.2	8.7	9.4	0.7
Copper	6	15.9	14.0	14.9	0.8
Lead	6	3.3	<2.0	2.7	0.3
Mercury	6	0.036	0.022	0.027	0.005
Molybdenum	6	0	0	<4.0	0
Nickel	6	33.1	23.8	28.8	3.6
Selenium	6	<0.10	<0.10	<0.10	0
Silver	6	<2.0	<2.0	<2.0	0
Tin	6	<30	<30	<30	0
Zinc	6	44.9	39.9	42.0	2.0

*all measurements in µg/g unless otherwise noted

Table 76

Detection Limits of Organic Compounds Measured at Langley Bar

Characteristic	No. of Values	Detection Limits
Polyaromatic Hydrocarbons Low Molecular Weight PAH		
Naphthalene	7	<0.020
Acenaphthylene	7	<0.020
Acenaphthene	7	<0.020
Fluorene	7	<0.020
Phenanthrene	7	<0.020
Anthracene	7	<0.020
Low Molecular Weight PAH's	7	<0.020
High Molecular Weight PAH		
Fluoranthene	7	<0.020
Pyrene	7	<0.020
Benz(a)anthracene	7	<0.020
Chrysene	7	<0.020
Benzo(b)fluoranthene	7	<0.020
Benzo(k)fluoranthene	7	<0.020
Benzo(a)pyrene	7	<0.020
Indeno(1,2,3-cd)pyrene	7	<0.020
Dibenz(a,h)anthracene	7	<0.020
Benzo(ghi)perylene	7	<0.020
High Molecular Weight PAH's	7	<0.020
Total PAH's	7	<0.020
Chlorinated Phenols		
2,3,4-trichlorophenol	6	<0.020
2,3,5-trichlorophenol	6	<0.020
2,4,5-trichlorophenol	6	<0.020
2,4,6-trichlorophenol	6	<0.020
2,3,4,5-tetrachlorophenol	6	<0.020
2,3,4,6-tetrachlorophenol	6	<0.020
2,3,5,6-tetrachlorophenol	6	<0.020
pentachlorophenol	6	<0.020
Polychlorinated Biphenyls		
Total Polychlorinated Biphenyls	7	<0.050
Extractable		
Oil and Grease	7	<50

*all measurements in µg/g unless otherwise noted

Table 77
Ambient Water Quality Summary for Fraser River at Barnston Island

Characteristic	No Of Values	Minimum	Maximum	Mean	Std. Dev.
Organics: 4ChlPhen	9	0.0001	0.0004	0.0001	0.0001
3ChlPhen	8	0.0001	0.0001	0.0001	0.0000
PCP	9	0.0001	0.0004	0.0001	0.0001
pH	1	7.9	7.9	7.9	0

*all measurements in mg/L except pH (in pH units)

Table 78
Ambient Water Quality for Fraser River at Sapperton Channel

Characteristic (mg/L)	No Of Values	Minimum	Maximum	Mean	Std. Dev.
Organics: 4 ChlPhen	1	0.0001	0.0001	0.0001	-
3ChlPhen	1	0.0001	0.0001	0.0001	-
PCP	1	0.0001	0.0001	0.0001	-

Table 79
Ambient Water Quality Summary for Fraser River at Pattullo Bridge

Characteristic	No Of Values	Minimum	Maximum	Mean	Std. Dev
Coliforms: *E. coli*	5	27	56	37	11
Enterococci	5	9	26	16	7
Fecal coliform	29	20	3220	311	651
Hardness	1	51.8	51.8	51.8	0.0
calcium	10	12.5	16.5	14.4	1.5
magnesium	10	0.31	0.78	0.48	0.14
Metals (total): cadmium	10	0.01	0.01	0.01	0
cobalt	10	0.1	0.1	0.1	0.0
chromium	10	0.01	0.01	0.01	0
copper	10	0.001	0.05	0.009	0.016
iron	10	0.31	0.78	0.48	0.14
lead	10	0.001	0.1	0.031	0.047
manganese	10	0.02	0.03	0.02	0.00
molybdenum	10	0.01	0.01	0.01	0
nickel	10	0.05	0.06	0.05	0.00
Nitrogen: ammonia	3	0.041	0.093	0.060	0.028
pH	14	6.4	9.6	7.9	1.2
Solids (suspended)	10	1	14	7.2	3.8

*all measurements in mg/L unless otherwise noted except pH (pH units), coliforms (CFU/100 mL)

Table 80

Sediment Quality Summary for Fraser River at Barnston Island

Characteristic	No Of Values	Maximum	Minimum	Mean	Median
Metals: arsenic	15	30	4.18	21.58	30
cadmium	5	0.24	0.2	0.22	0.21
chromium	15	49.6	17	29.7	22
copper	15	39.2	14	23.9	18
iron	15	34600	15200	22420	17600
lead	15	20	6.55	10.01	10
manganese	15	728	328	478	413
mercury	15	0.08	0.044	0.054	0.05
nickel	15	55.1	28	38.4	32
selenium	10	10	10	10	10
PAH's: anthracene	5	0.005	0.005	0.005	0.005
benz[a]anthracene	5	0.12	0.01	0.046	0.01
benzo[a]pyrene	5	0.1	0.02	0.036	0.02
benzo-[g]-perylene	5	0.02	0.02	0.02	0.02
benzo-[k]-fluoranthene	5	0.02	0.02	0.02	0.02
chrysene	5	0.01	0.01	0.01	0.01
dibenzo[a,h]anthracene	5	0.089	0.02	0.048	0.05
indenopyrene	5	0.098	0.02	0.044	0.026
naphthalene	5	0.005	0.005	0.005	0.005
pyrene	5	0.01	0.01	0.01	0.01
PCB (total)	5	0.01	0.01	0.01	0.01
Pesticides: aldrin	5	0.001	0.001	0.001	0.001
chlordane alpha	5	0.001	0.001	0.001	0.001
chlordane gamma	5	0.001	0.001	0.001	0.001
Dieldrin	5	0.001	0.001	0.001	0.001
DDE	5	0.0005	0.0005	0.0005	0.0005
DDD	5	0.001	0.001	0.001	0.001
DDT	5	0.003	0.001	0.001	0.001
Endrin	5	0.0005	0.0005	0.0005	0.0005
heptachlor	5	0.0005	0.0005	0.0005	0.0005
heptachlor epoxide	5	0.01	0.01	0.01	0.01
Lindane	5	0.001	0.001	0.001	0.001
Methoxychlor	5	0.005	0.005	0.005	0.005
Phthalate esters (PTE)					
Bis(2ethylhexyl) PTE	5	1.44	0.11	0.454	0.14
diethyl PTE	5	0.1	0.1	0.1	0.1
dimethyl PTE	5	0.1	0.1	0.1	0.1
di-n-butyl PTE	5	0.1	0.01	0.082	0.1
di-n-octyl PTE	5	0.37	0.1	0.154	0.1

*all measurements in µg/g unless otherwise noted

Table 81
Sediment Quality Summary for Fraser River at Sapperton Channel

Characteristic	No Of Values	Maximum	Minimum	Mean	Median
Metals: arsenic	11	30	2.89	27.54	30
cadmium	1	0.21	0.21	0.21	0.21
chromium	11	40.7	22	25.7	24
copper	11	25.4	13	15.6	14
iron	11	26600	15400	17282	15900
lead	11	30	6.9	15.2	10
manganese	11	537	330	378	353
mercury	11	0.13	0.039	0.058	0.05
nickel	11	42.9	31	33.3	32
selenium	10	28	10	14.4	10
PAH's: benzo-[g]-perylene	1	0.02	0.02	0.02	0.02
benzo-[k]-fluoranthene	1	0.02	0.02	0.02	0.02
chrysene	1	0.01	0.01	0.01	0.01
dibenzo[a,h]anthracene	1	0.02	0.02	0.02	0.02
indenopyrene	1	0.02	0.02	0.02	0.02
pyrene	1	0.01	0.01	0.01	0.01
PCB (total)	1	0.01	0.01	0.01	0.01
Pesticides: aldrin	1	0.001	0.001	0.001	0.001
chlordane alpha	1	0.001	0.001	0.001	0.001
chlordane gamma	1	0.001	0.001	0.001	0.001
Dieldrin	1	0.001	0.001	0.001	0.001
DDE	1	0.0005	0.0005	0.0005	0.0005
DDD	1	0.001	0.001	0.001	0.001
DDT	1	0.001	0.001	0.001	0.001
Endrin	1	0.0005	0.0005	0.0005	0.0005
heptachlor	1	5E-04	5E-04	5E-04	0.0005
heptachlor epoxide	1	0.01	0.01	0.01	0.01
Lindane	1	0.001	0.001	0.001	0.001
Methoxychlor	1	0.005	0.005	0.005	0.005
Phthalate esters (PTE)					
Bis(2-ethylhexyl) PTE	1	0.19	0.19	0.19	0.19
diethyl PTE	1	0.1	0.1	0.1	0.1
dimethyl PTE	1	0.1	0.1	0.1	0.1
di-n-butyl PTE	1	0.1	0.1	0.1	0.1
di-n-octyl PTE	1	0.1	0.1	0.1	0.1

*all measurements in ug/g unless otherwise noted

Table 82
Ambient Water Quality Data Summary for the Fraser River at the Oak St. Bridge (0300002)

Characteristic	No. Of Values	Maximum	Minimum	Mean	Std. Dev.
Coliforms-fecal (CFU/cL)	26	2460	39	geo. mean = 205	
fecal (MPN/100 mL)	1	350	350	geo. mean = 350	
E. Coli (CFU/cL)	4	96	61	geo. mean = 78	
Enterococci (CFU/cL)	4	28	21	geo. mean = 25	
Hardness-total	55	1582	43	346	379
calcium	55	136	11.6	34.6	27.8
magnesium	55	303	3.43	63.21	75.85
Metals-aluminum(total)	47	2.12	0.15	0.51	0.46
arsenic (total)	41	0.12	<0.04	median <0.04	
cadmium (total)	50	<0.01	<0.002	median <0.002	
chromium(total)	50	0.01	<0.002	median <0.002	
copper (total)	55	0.007	<0.001	0.002	0.001
iron (total)	50	3.2	0.39	0.83	0.62
manganese (total)	50	0.09	0.017	0.031	0.014
molybdenum(total)	50	<0.01	<0.004	median <0.004	
lead(total)	55	0.014	<0.001	median <0.003	
nickel (total)	50	<0.05	<0.01	median <0.01	
zinc (total)	55	0.07	<0.005	0.013	0.011
Nitrogen-ammonia	55	0.062	<0.005	0.020	0.015
pH	48	9.5	6.3	7.6	0.6
Phosphorus-total	5	0.06	<0.04	0.05	0.01
Potassium	5	3.8	1.6	2.9	0.9
Sodium	5	87.6	15.5	56.4	29.5
Solids-dissolved	1	6000	6000	6000	-
Specific Conductivity	2	750	400	575	247
Dissolved Oxygen (mg/L)	10	13.2	6.9	10.3	2.6

*all measurements in mg/L unless otherwise noted

Table 83
Ambient Water Quality Data Summary for the Fraser River Upstream from Crown Packaging (Site E207396)

Characteristics	No. Of Values	Maximum	Minimum	Mean	Std. Dev.
Coliforms-fecal (CFU/cL)	13	415	32	geo. mean = 78	
fecal (MPN/100 mL)	1	350	350	geo. mean = 350	
E. Coli (CFU/cL)	4	78	33	geo. mean = 51	
Enterococci (CFU/cL)	5	37	16	geo. mean = 26	
Hardness-total	45	94	38	51	9
calcium	45	17.4	11.2	14.4	1.6
magnesium	45	12.3	2.49	3.53	1.48
Metals-aluminum(total)	38	1.65	0.1	0.45	0.39
arsenic (total)	35	<0.04	<0.04	<0.04	0
cadmium (total)	42	<0.01	<0.002	median <0.002	
chromium(total)	42	<0.01	<0.002	median <0.002	
copper (total)	45	0.011	<0.001	median <0.002	
iron (total)	42	2.56	0.24	0.70	0.53
manganese (total)	42	0.085	0.01	0.025	0.015
molybdenum(total)	42	<0.01	<0.004	<0.004	0
lead(total)	45	0.044	<0.001	median <0.003	
nickel (total)	42	<0.05	<0.01	median <0.01	
zinc (total)	45	0.07	<0.005	median <0.01	
Nitrogen-ammonia	44	0.056	0.005	0.014	0.014
pH	36	7.9	7.4	7.7	0.1
Phosphorus-total	0	0.06	<0.04	0.05	0.01
Specific Conductivity	1	65	65	65	-

*all measurements in mg/L unless otherwise noted

Table 84
Ambient Water Quality Data Summary for the Fraser River Downstream From Crown Packaging (Site E207397)

Characteristics	No. Of Values	Maximum	Minimum	Mean	Std. Dev.
Coliforms-fecal (CFU/cL)	13	375	30	geo. mean = 88	
fecal (MPN/100 mL)	1	220	220	geo. mean = 220	
E. Coli (CFU/cL)	5	71	49	geo. mean = 60	
Enterococci (CFU/cL)	5	33	15	geo. mean = 26	
Hardness-total	45	89	38	50	8
calcium	45	17.1	11.3	14.3	1.5
magnesium	45	11.2	2.49	3.49	1.32
Metals-aluminum(total)	38	2.08	0.15	0.45	0.41
arsenic (total)	35	<0.04	<0.04	<0.04	0
cadmium (total)	42	<0.01	<0.002	median <0.002	
chromium(total)	42	<0.01	<0.002	median <0.002	
copper (total)	45	0.01	<0.001	median <0.002	
iron (total)	42	3.3	0.29	0.73	0.57
manganese (total)	42	0.094	0.011	0.025	0.014
molybdenum(total)	42	<0.01	<0.004	median <0.004	
lead(total)	45	0.015	0.001	0.0036	0.002799
nickel (total)	42	<0.05	<0.01	median <0.01	
zinc (total)	45	0.06	<0.005	0.016	0.013
Nitrogen-ammonia	44	0.05	<0.005	0.014	0.014
pH	36	7.9	7.3	7.6	0.1
Specific Conductivity	1	70	70	70	-
PCP (mg/L)	9	0.0003	<0.0001	median <0.0001	
4ChlPhen (mg/L)	9	0.0004	<0.0001	median <0.0001	
3ChlPhen (mg/L)	8	<0.0001	<0.0001	<0.0001	0

*all measurements in mg/L unless otherwise noted

Table 85
Ambient Water Quality Data Summary for the Fraser River Upstream from Scott Paper (Site E207398)

Characteristic	No. Of Values	Maximum	Minimum	Mean	Std. Dev.
Coliforms-fecal (CFU/cL)	30	2900	26	geo. mean = 136	
fecal (MPN/100 mL)	1	540	540	geo. mean = 540	
E. Coli (CFU/cL)	5	110	34	geo. mean = 64	
Enterococci (CFU/cL)	5	49	18	geo. mean = 36	
Hardness-total	56	323	32	55	37
calcium	56	33	9.43	14.78	2.89
magnesium	56	58.7	2.1	4.4	7.4
Metals-aluminum(total)	49	2.31	0.12	0.54	0.48
arsenic (total)	41	<0.04	<0.04	<0.04	0
cadmium (total)	53	<0.01	<0.002	median <0.002	
chromium(total)	53	0.01	<0.002	median <0.002	
copper (total)	56	0.021	<0.001	0.003	0.003
iron (total)	53	3.62	0.28	0.82	0.65
manganese (total)	53	0.102	0.013	0.028	0.015
molybdenum(total)	53	0.01	<0.004	median <0.004	
lead(total)	56	0.015	<0.001	median <0.003	
nickel (total)	53	<0.05	<0.01	median <0.01	
zinc (total)	56	0.18	<0.005	0.018	0.026
Nitrogen-ammonia	54	0.104	<0.005	0.015	0.018
pH	49	9.6	6.5	7.7	0.6
Phosphorus-total	5	0.06	0.04	0.05	0.01
Potassium	5	1.1	0.7	0.9	0.1
Sodium	5	4.68	2.68	3.46	0.75
Specific Conductivity	1	65	65	65	0
Dissolved Oxygen (mg/L)	11	13.2	8.2	10.9	2.1

*all measurements in mg/L unless otherwise noted

Table 86
Ambient Water Quality Data Summary for the Fraser River Downstream From Scott Paper (Site E207399)

Characteristic	No. Of Values	Maximum	Minimum	Mean	Std. Dev.
Coliforms-fecal (CFU/cL)	9	305	40	geo. mean = 102	
fecal (MPN/100 mL)	1	540	540	geo. mean = 540	
Hardness-total (mg/L)	10	308	34	69	84
calcium (mg/L)	10	30.7	10.1	14.1	6.0
magnesium (mg/L)	10	56.4	2.21	8.27	16.92
Metals-aluminum(total) (mg/L)	3	0.23	0.16	0.19	0.04
cadmium (total) (mg/L)	7	<0.01	<0.01	<0.01	0
chromium(total) (mg/L)	7	<0.01	<0.01	<0.01	0
copper (total) (mg/L)	10	0.007	<0.001	0.003	0.002
iron (total) (mg/L)	7	0.55	0.28	0.43	0.09
manganese (total) (mg/L)	7	0.03	0.02	0.02	0.00
molybdenum(tot) (mg/L)	7	<0.01	<0.01	<0.01	0
lead(total) (mg/L)	10	0.002	<0.001	0.002	0.001
nickel (total) (mg/L)	7	<0.05	<0.05	<0.05	0
zinc (total) (mg/L)	10	0.009	<0.005	0.006	0.001
Nitrogen-ammonia (mg/L)	10	0.099	<0.005	0.033	0.029
pH	2	7.7	7.6	7.7	0.1
PCP (mg/L)	1	0.0001	0.0001	0.0001	-
4ChlPhen (mg/L)	1	<0.0001	<0.0001	<0.0001	0
3ChlPhen (mg/L)	1	<0.0001	<0.0001	<0.0001	0

Table 87
Ambient Water Quality Data Summary for the Fraser River Downstream from Mitchell Island (Site E207401)

Characteristic	No. Of Values	Maximum	Minimum	Mean	Std. Dev.
pH	1	7.8	7.8	7.8	0
Specific Conductivity (uS/cm)	1	300	300	300	0
PCP (mg/L)	8	0.0002	<0.0001	median <0.0001	
4ChlPhen (mg/L)	9	0.0001	<0.0001	<0.0001	0
3ChlPhen (mg/L)	9	<0.0001	<0.0001	<0.0001	0

Table 88
Ambient Water Quality Data Summary for the Fraser River Downstream from Richmond Recycle (Site E207403)

Characteristic	No. Of Values	Maximum	Minimum	Mean	Std. Dev.
PCP (mg/L)	1	<0.0001	<0.0001	<0.0001	-
4ChlPhen (mg/L)	1	0.0001	0.0001	0.0001	-

Table 89
Ambient Water Quality Data Summary for the Fraser River Near the Airport in the Middle Channel. (Airport #1, Site E207600)

Characteristic	No. Of Values	Maximum	Minimum	Mean	Std. Dev.
Coliforms-fecal (CFU/cL)	26	640	34	geo. mean = 140	
E. Coli (CFU/cL)	4	110	28	geo. mean = 58	
Enterococci (CFU/cL)	5	29	14	geo. mean = 21	
Hardness-total	19	1247	43	357	321
calcium	19	90.7	12.9	33.7	20.2
magnesium	19	249	2.55	66.63	65.94
Metals-aluminum(total)	10	1.2	0.28	0.65	0.36
arsenic (total)	5	0.05	<0.04	0.05	0.00
cadmium (total)	19	<0.01	<0.002	median <0.01	
chromium(total)	19	0.02	<0.002	median <0.01	
copper (total)	19	0.007	<0.001	0.002	0.001
iron (total)	19	1.99	0.37	0.86	0.41
manganese (total)	19	0.052	0.02	0.032	0.011
molybdenum(total)	19	0.03	<0.004	median <0.01	
lead(total)	19	0.005	<0.001	0.002	0.001
nickel (total)	19	<0.05	<0.01	median <0.05	
zinc (total)	19	0.08	<0.005	0.015	0.022
Nitrogen-ammonia	19	0.041	<0.005	0.016	0.011
nitrate/nitrite	4	0.05	0.04	0.04	0.01
nitrite	4	<0.005	<0.005	<0.005	0
pH	25	9.7	6.5	7.7	0.8
Specific Conductivity	4	3000	282	1149	1256
Dissolved Oxygen (mg/L)	11	12.6	7.9	10.2	2.0
PCP (mg/L)	5	<0.0001	<0.0001	<0.0001	0
4ChlPhen (mg/L)	5	<0.0001	<0.0001	<0.0001	0
3ChlPhen (mg/L)	5	<0.0001	<0.0001	<0.0001	0

*all measurements in mg/L unless otherwise noted

Table 90
Ambient Water Quality Data Summary for the Fraser River Near the Airport in the Middle Channel (Airport #2, Site E207601)

Characteristic	No. Of Values	Maximum	Minimum	Mean	Std. Dev.
Coliforms-fecal (CFU/cL)	28	950	29	geo. mean = 142	
E. Coli (CFU/cL)	5	97	30	geo. mean = 61	
Enterococci (CFU/cL)	5	24	18	geo. mean = 21	
Hardness-total	20	771	43	186	213
calcium	20	61	12.6	22.9	14.0
magnesium	20	151	2.52	31.38	43.40
Metals-aluminum(total)	11	1.92	0.2	0.95	0.66
arsenic (total)	6	0.13	<0.04	median <0.04	
cadmium (total)	20	<0.01	<0.002	median <0.01	
chromium(total)	20	0.02	<0.002	median <0.01	
copper (total)	20	0.008	<0.001	0.004	0.002
iron (total)	20	3.22	0.43	1.29	0.89
manganese (total)	20	0.084	0.02	0.042	0.018
molybdenum(total)	20	0.02	<0.004	median <0.01	
lead(total)	20	0.024	<0.001	0.003	0.005
nickel (total)	20	<0.05	<0.01	median <0.05	
zinc (total)	20	0.09	<0.005	0.013	0.020
Nitrogen-ammonia	20	0.05	<0.005	0.022	0.016
nitrate/nitrite	4	0.07	0.04	0.05	0.02
nitrite	4	<0.005	<0.005	<0.005	0
pH	21	9.5	6.4	7.7	0.7
Specific Conductivity	5	1600	114	807	528
Dissolved Oxygen (mg/L)	9	18.4	8.8	12.0	2.9

*all measurements in mg/L unless otherwise noted

Table 91
Ambient Sediment Quality Data Summary for the Fraser River Upstream from Crown Packaging (Site E207396)

Characteristic	No. Of Values	Maximum	Minimum	Mean	Std. Dev.
PCB (µg/g)	3	<0.02	<0.02	<0.02	0
PCP (µg/g)	3	0.005	<0.005	median <0.005	
4ChlPhen (µg/g)	3	0.005	<0.005	median <0.005	
3ChlPhen (µg/g)	3	<0.005	<0.005	<0.005	0

Table 92
Ambient Sediment Quality Data Summary for the Fraser River Downstream From Crown Packaging (Site E207397)

Characteristic	No. Of Values	Maximum	Minimum	Mean	Std. Dev.
PCB (µg/g)	13	<0.02	<0.02	<0.02	0
PCP (µg/g)	15	0.066	<0.005	0.018	0.021
4ChlPhen (µg/g)	1	0.0001	<0.0001	median <0.0001	
4ChlPhen (µg/g)	15	0.016	<0.005	median <0.005	
3ChlPhen (µg/g)	15	0.038	<0.005	median <0.005	

Table 93
Ambient Sediment Quality Data Summary for the Fraser River Upstream from Scott Paper (Site E207398)

Characteristic	No. Of Values	Maximum	Minimum	Mean	Std. Dev.
PCB (µg/g)	3	<0.02	<0.02	<0.02	0
PCP (µg/g)	3	0.012	0.005	0.008	0.004
4ChlPhen (µg/g)	3	0.022	<0.005	0.013	0.009
3ChlPhen (µg/g)	3	<0.005	<0.005	<0.005	0

Table 94
Ambient Sediment Quality Data Summary for the Fraser River Downstream From Scott Paper (Site E207399)

Characteristic	No. Of Values	Maximum	Minimum	Mean	Std. Dev.
PCB (µg/g)	6	<0.02	<0.02	<0.02	0
PCP (µg/g)	6	0.13	<0.005	0.038	0.046
4ChlPhen (µg/g)	6	0.022	<0.005	median <0.005	
3ChlPhen (µg/g)	6	<0.005	<0.005	<0.005	0

Table 95
Ambient Sediment Quality Data for the Fraser River Downstream from Mitchell Island (Site E207401)

Characteristic	No. Of Values	Maximum	Minimum	Mean	Std. Dev.
PCB (µg/g)	6	<0.02	<0.02	<0.02	0
PCP (µg/g)	6	0.036	<0.005	0.019	0.014
4ChlPhen (µg/g)	6	0.012	<0.005	0.006	0.003
3ChlPhen (µg/g)	6	0.008	<0.005	median <0.005	

Table 96
Ambient Sediment Quality Data Summary for the Fraser River Near the Airport in the Middle Channel (Airport #1, Site E207600)

Characteristics	No. Of Values	Maximum	Minimum	Mean	Std. Dev.
PCB (µg/g)	4	<0.02	<0.02	<0.02	0
PCP (µg/g)	6	0.013	<0.005	median <0.005	
4ChlPhen (µg/g)	6	<0.005	<0.005	<0.005	0
3ChlPhen (µg/g)	6	0.009	<0.005	median <0.005	

Table 97
Ambient Water Quality Data Summary for the Fraser River Near the Oak St. Bridge (FREMP Data)

Characteristic	No. of Values	Maximum	Minimum	Mean	Std. Dev.
Physical Tests:					
Dissolved Oxygen	32	12.4	8.4	10.2	1.1
Water Temp ° C	32	19	2.8	11.9	5.1
Air Temp ° C	32	22.5	1	13.6	5.9
pH	44	7.7	6.91	7.42	0.21
Field pH	32	7.65	7	7.36	0.16
Specific Conductance (SC)	44	6900	71	1335	2190
Field SC	32	3400	62	476	937
Suspended Solids (NFR)	44	224	5	32	35
Dissolved Solids (FR)	44	4080	43	764	1266
Hardness Total	44	700	39.9	166.7	210.0
Anions:					
Alkalinity Total @ pH 4.5	44	60	32.7	45.0	8.0
Chloride Dissolved	44	2000	1.1	373.6	660.1
Fluoride Dissolved	44	0.19	0.03	0.06	0.05
Sulfate	44	315	4.8	60.8	94.6
Nutrients:					
Nitrogen Ammonia	34	0.089	0.006	0.039	0.027
Nitrogen Kjeldahl	44	0.4	0.1	0.2	0.1
Nitrate/Nitrite	44	0.362	0.024	0.111	0.084
Phosphorus (Dissolved)	44	0.04	0.001	0.02	0.01
Phosphorus (Total)	44	0.23	0.017	0.06	0.04
TOTAL METALS					
Aluminum	44	3.37	0.1	0.41	-
Arsenic	44	0.0013	0.0003	0.0006	0.0002
Barium	44	0.051	0.011	0.017	0.006
Cadmium	44	0.0001	<0.0001	median <0.0002	
Calcium	44	57.5	11.3	22.5	14.6
Chromium	45	0.007	<0.001	median <0.001	
Cobalt	43	<0.015	<0.004	median <0.015	
Copper	44	0.008	<0.001	0.003	0.002
Iron	38	5.48	0.136	0.614	0.889
Lead	44	0.005	<0.001	median <0.001	
Magnesium	44	135	2.35	26.82	42.25
Manganese	44	0.17	0.014	0.033	0.023
Mercury	44	<0.00005	<0.00005	<0.00005	0
Molybdenum	44	0.002	<0.001	median <0.001	
Nickel	44	0.017	<0.001	0.003	-

Table 97 (continued)
Ambient Water Quality Data Summary for the Fraser River Near the Oak St. Bridge (FREMP Data)

Characteristic	No. of Values	Maximum	Minimum	Mean	Std. Dev.
Potassium	44	40	<2	9	-
Selenium	44	<0.0005	<0.0005	<0.0005	0
Silver	43	0.0002	<0.0001	median <0.0001	
Sodium	44	1090	2.1	110.4846	341.7184
Tin	44	<0.3	<0.02	median <0.3	
Zinc	44	0.09	<0.001	0.009	-
Bacteriological:					
Fecal Coliform (MPN/100 mL/100 mL)	23	17000	14	median = 360	
ORGANIC PARAMETERS:					
Carbon Total Organic	43	8	1.4	2.7	1.2
Adsorbable Org. Halides	12	0.04	<0.01	0.02	0.01
Chlorophenolics:					
Pentachlorophenol	14	0.000013	<0.000001	median <0.000001	
2,3,4,6+2,3,5,6-Tetrachlorophenol	14	0.000003	<0.000001	median <0.000001	
2,3,5-Trichlorophenol	14	0.000001	<0.000001	median <0.000001	
2,4,6-Trichlorophenol	14	0.000012	<0.000001	median <0.000001	
Tetrachloroguaiacol	14	0.000002	<0.000002	median <0.000002	
3,4,5-Trichloroguaiacol	14	0.00001	<0.000002	median <0.000002	
4,5,6-Trichloroguaiacol	14	0.000003	<0.000002	median <0.000002	
4,5-Dichloroguaiacol	14	0.000014	<0.000002	median <0.000002	
5-Chloroguaiacol	14	0.000006	<0.000002	median <0.000002	
Tetrachlorocatechol	14	0.000004	<0.000002	median <0.000002	
3,4,5-Trichlorocatechol	14	0.000012	<0.000002	median <0.000002	
4,5-Dichlorocatechol	14	0.000008	<0.000002	median <0.000002	
4-Chlorocatechol	14	0.000003	<0.000002	median <0.000002	
3,4,5-Trichloroveratrole	14	0.000004	<0.000002	median <0.000002	
5,6-Dichlorovanillin	14	0.000003	<0.000002	median <0.000002	
6-Chlorovanillin	14	0.000012	<0.000002	median <0.000002	
Nonylphenol	14	0.000003	<0.000002	median <0.000002	
Resin and Fatty Acids:					
Linoleic Acid	3	0.001	<0.0005	median <0.0005	
Antisapstain Compounds:					
TCMTB	3	0.007	<0.005	median <0.005	
Organochlorine Pesticides and PCB's					
DDD p p'-	3	0.000011	<0.000005	median <0.000005	
Hexachlorobenzene	3	0.000001	<0.0000005	median <0.0000005	

*all measurements in mg/L unless otherwise noted

Table 98
Ambient Water Quality Data Summary for the Fraser River Near the Oak St. Bridge (FREMP Data): Organics Below Detection Limits

ORGANIC PARAMETER:	No. of Values	Minimum Detection Limit (mg/L)
Chlorophenolics:		
2,3,4,5-Tetrachlorophenol	14	0.000001
3,4,5-Trichlorophenol	14	0.000001
2,3,4-Trichlorophenol	14	0.000001
2,3,6-Trichlorophenol	14	0.000001
2,4,5-Trichlorophenol	14	0.000001
2,4-Dichlorophenol	14	0.000001
2,6-Dichlorophenol	14	0.000001
2,5-Dichlorophenol	14	0.000001
3,5-Dichlorophenol	14	0.000001
2,3-Dichlorophenol	14	0.000001
3,4-Dichlorophenol	14	0.000001
4-Chlorophenol	14	0.000001
3,4,6-Trichloroguaiacol	14	0.000002
4,6-Dichloroguaiacol	14	0.000002
4-Chloroguaiacol	14	0.000002
6-Chloroguaiacol	14	0.000002
3,4-Dichlorocatechol	14	0.000002
3,5-Dichlorocatechol	14	0.000002
Tetrachloroveratrole	14	0.000002
4,5-Dichloroveratrole	14	0.000002
2,6-Dichlorosyringaldehyde	14	0.000002
2-Chlorosyringaldehyde	14	0.000002
3,4,5-Trichlorosyringol	14	0.000002
Trichlorotrimethoxybenzene	14	0.000002
Resin and Fatty Acids:		
Abietic Acid	3	0.0005
Arachidic Acid	3	0.0005
Behenic Acid	3	0.0005
Chlorodehydroabietic	3	0.0005
Dehydroabietic Acid	3	0.0005
Dichlorodehydroabietic	3	0.0005
Isopimaric Acid	3	0.0005
Lauric Acid	3	0.0005
Levo Pimaric Acid	3	0.0005
Lignoceric Acid	3	0.0005
Linolenic Acid	3	0.0005
Myristic Acid	3	0.0005

Table 98 (continued)
Ambient Water Quality Data Summary for the Fraser River Near the Oak St. Bridge (FREMP Data): Organics Below Detection Limits

ORGANIC PARAMETER:	No. of Values	Minimum Detection Limit (mg/L)
Neoabietic Acid	3	0.0005
Oleic Acid	3	0.0005
Palmitric Acid	3	0.0005
Palustric Acid	3	0.0005
Pimaric Acid	3	0.0005
Sandaraco Pimaric Acid	3	0.0005
Stearic Acid	3	0.0005
Organochlorine Pesticides and PCB's		
Aldrin	3	0.000001
BHC alpha	3	0.000001
BHC beta-	3	0.000001
BHC delta-	3	0.000001
Chlordane alpha-	3	0.000005
Chlordane gamma-	3	0.000005
DDE p p'-	3	0.000005
DDT p p'-	3	0.000005
Dieldrin	3	0.000005
Endosulfan I	3	0.000005
Endosulfan II	3	0.000005
Endosulfan sulphate	3	0.00001
DDT o p'-	3	0.00001
Endrin	3	0.00001
Heptachlor	3	0.000001
Heptachlor epoxide	3	0.000002
Lindane BHC gamma-	3	0.000001
Methoxychlor	3	0.00001
Mirex	3	0.00001
Nonachlor trans-	3	0.000005
Oxychlordane	3	0.000005
Toxaphene	3	0.00005
PCB's - Total	3	0.00002

Table 99
FREMP McDonald Slough Water Quality Data

Lab ID	Detection Limits			Zenon	Zenon	ASL/ Zenon	ASL/ Zenon
	Zenon	ASL/ Zenon					
			UNITS	Surface - 1m 1.0m	Bottom + 1m 6.0m	Surface - 1m 1.0 m	Bottom + 1m 5.5 m
Sampled On:				93-02-11	93-02-11	94-02-23	94-02-23
Latitude (N)				49 - 12.78	49 - 12.78	49 - 12.78	49 - 12.78
Longitude (W)				123 - 11.26	123 - 11.26	123 - 11.26	123 - 11.26
Physical Tests:							
Dissolved Oxygen			mg/L	10.6	10.4	10.5	10.2
Water Temp			° C	5	6.5	5.1	6.1
Air Temp			° C	2	2	1	1
pH				7.6	7.7	7.27	7.58
Field pH				7.2	7.35	7.85	7.8
Specific Conductivity	1	0.2	uS/cm	11600	28200	16000	46000
Field Specific Conductivity			uS/cm	8100	10000	9500	24000
Suspended Solids	4	1	mg/L	7	19	13	25
Dissolved Solids	4	1	mg/L	7820	19000	-	30300
Hardness Total		0.05	mg/L	1060	2780	-	5030
Anions:							
Alkalinity Total	0.5	0.5	mg/L	61.7	83.4	68.8	98.7
Chloride Dissolved	0.5	0.2	mg/L	4430	9800	4890	14000
Fluoride Dissolved	0.1	0.02	mg/L	0.28	0.56	0.34	0.66
Sulphate	1	0.5	mg/L	460	1730	657	1830
Nutrients:							
Nitrogen Ammonia	0.005	0.005	mg/L	0.061	0.049	-	0.01
Nitrogen Kjeldahl	0.04	0.05	mg/L	0.3	0.25	0.195	<0.050
Nitrogen nitrate/nitrite	0.02	0.005	mg/L	0.24	0.31	0.353	0.424
Phosphorus Dissolved	0.003	0.001	mg/L	0.021	0.044	0.037	0.061
Phosphorus Total	0.003	0.001	mg/L	0.035	0.062	0.042	0.069
Total Metals:							
Aluminum	0.06	0.20	mg/L	0.08	0.27	0.92	<2.0
Arsenic	0.001	0.0001	mg/L	<	0.001	0.0039	0.0013
Barium	0.001	0.01	mg/L	0.012	0.01	<0.030	<0.10
Cadmium	0.0001	0.0002	mg/L	0.0001	<	<0.001	<0.002
Calcium	0.05	0.05	mg/L	78.1	187	111	304
Chromium	0.005	0.001	mg/L	<	<	<0.001	0.001
Cobalt	0.004	0.015	mg/L	<	<	<0.045	<0.15
Copper	0.001	0.001	mg/L	0.002	0.002	<0.001	<0.001

Table 99 (continued)
FREMP McDonald Slough Water Quality Data

	Detection Limits						
Total Metals (cont'd)	Zenon	ASL/ Zenon		Zenon	Zenon	ASL/ Zenon	ASL/ Zenon
Iron	0.05	0.03	mg/L	0.29	0.5	2.74	2
Lead	0.003	0.001	mg/L	<	<	<0.010	<0.010
Magnesium	0.02	0.01	mg/L	210	561	350	1040
Manganese	0.002	0.005	mg/L	0.024	0.016	0.03	<0.05
Mercury	0.00005	0.00005	mg/L	<	<	<0.00005	<0.00005
Molybdenum	0.004	0.001	mg/L	<	<	0.003	0.006
Nickel	0.005	0.001	mg/L	0.008	0.005	0.013	0.016
Potassium	0.4	2	mg/L	57.5	160	104	303
Selenium	0.03	0.0005	mg/L	<	<	<0.0005	<0.0005
Silver	0.03	0.0001	mg/L	<	<	<0.001	<0.001
Sodium	0.4	2	mg/L	1730	4770	-	8190
Tin	0.02	0.30	mg/L	0.09	0.12	<0.90	<3.0
Zinc	0.01	0.001	"	<	<	0.004	<0.005
Bacteriological:							
Fecal Coliform			MPN /100mL	800		5000	1300
ORGANIC PARAMETERS:							
Carbon Total Organic	2	0.50	mg/L	3	3	<5	<10
Adsorb. Org Halide as Cl	0.01	0.01	mg/L	0.03	0.03	0.03	0.02
Chlorophenolics:							
3,4,5-Trichloroguaiacol	0. 002	0. 002	µg/L	0. 004	0. 002	<	<
4,5,6-Trichloroguaiacol	0. 002	0. 002	µg/L	0. 002	<	<	<
4,5-Dichloroguaiacol	0. 002	0. 002	µg/L	0. 005	0. 003	0. 003	<
5-Chloroguaiacol	0. 002	0. 002	µg/L	<	0. 009	<	<
Tetrachlorocatechol	0. 002	0. 002	µg/L	<	0. 006	<	<
3,4,5-Trichlorocatechol	0. 002	0. 002	µg/L	0. 006	0. 004	<	<
3,4,5-Trichloroveratrole	0. 002	0. 002	µg/L	0. 003	<	<	<
6-Chlorovanillin	0. 002	0. 002	µg/L	0. 007	0. 006	0. 005	0. 002
Resin and Fatty Acids:							
Myristic Acid	0.0005	0.0005	mg/L	<	<	<	0.0007
Palmitric Acid	0.0005	0.0005	mg/L	<	0.0009	0.0005	<
Stearic Acid	0.0005	0.0005	mg/L	<	<	0.0006	<
Total Resins and Fatty Acids				0.01	0.0104	0.0101	0.0102
Organochlorine Pesticides and PCB's							
Hexachlorobenzene	0. 0005	0. 0005	µg/L	<	0.001	<	<
Polyaromatic Hydrocarbons:							
Benz(a)anthracene	0.00001	0.00001	mg/L	<	<	0.00003	0.00002

Table 99 (continued)
FREMP McDonald Slough Water Quality Data

	Detection Limits						
	Zenon	ASL/ Zenon		Zenon	Zenon	ASL/ Zenon	ASL/ Zenon
Polyaromatic Hydrocarbons (cont'd):							
Pyrene	0.00001	0.00001	mg/L	0.00001	0.00001	<	<
Acenaphthene	0.00001	0.00001	mg/L	<	<	0.00001	<
Fluoranthene	0.00001	0.00001	mg/L	<	<	0.00001	<
Fluorene	0.00001	0.00001	mg/L	<	<	0.00001	<
Naphthalene	0.00001	0.00001	mg/L	0.00003	<	0.00009	0.00002
Phenanthrene	0.00001	0.00001	mg/L	0.00003	<	0.00004	0.00002
Total PAH's	0.00005	0.00005	mg/L	0.00007	<	0.00019	0.00006
Total low MW PAH's	0.00005	0.00005	mg/L	0.00006	<	0.00015	<

Table 100
FREMP McDonald Slough Water Quality Data: Parameters Less Than Detection Limits

Characteristic	Detection Limit (mg/L)	**Characteristic**	Detection Limit (mg/L)
ORGANIC PARAMETERS:		Tetrachloroveratrole	0.000002
Chlorophenolics:		4,5-Dichloroveratrole	0.000002
Pentachlorophenol	0.000001	2,6-Dichlorosyringaldehyde	0.000002
2,3,4,6+2,3,5,6-Tetrachlorophenol	0.000001	2-Chlorosyringaldehyde	0.000002
2,3,4,5-Tetrachlorophenol	0.000001	3,4,5-Trichlorosyringol	0.000002
3,4,5-Trichlorophenol	0.000001	Trichlorotrimethoxybenzene	0.000002
2,3,4-Trichlorophenol	0.000001	5,6-Dichlorovanillin	0.000002
2,3,5-Trichlorophenol	0.000001	Nonylphenol	0.00002
2,3,6-Trichlorophenol	0.000001	**Resin and Fatty Acids:**	
2,4,5-Trichlorophenol	0.000001	Abietic Acid	0.0005
2,4,6-Trichlorophenol	0.000001	Arachidic Acid	0.0005
2,4-Dichlorophenol	0.000001	Behenic Acid	0.0005
2,6-Dichlorophenol	0.000001	Chlorodehydroabietic	0.0005
2,5-Dichlorophenol	0.000001	Dehydroabietic Acid	0.0005
3,5-Dichlorophenol	0.000001	Dichlorodehydroabietic	0.0005
2,3-Dichlorophenol	0.000001	Isopimaric Acid	0.0005
3,4-Dichlorophenol	0.000001	Lauric Acid	0.0005
4-Chlorophenol	0.000001	Levo Pimaric Acid	0.0005
Tetrachloroguaiacol	0.000002	Lignoceric Acid	0.0005
3,4,6-Trichloroguaiacol	0.000002	Linoleic Acid	0.0005
4,6-Dichloroguaiacol	0.000002	Linolenic Acid	0.0005
4-chloroguaiacol	0.000002	Neoabietic Acid	0.0005
6-Chloroguaiacol	0.000002	Oleic Acid	0.0005
3,4-Dichlorocatechol	0.000002	Palustric Acid	0.0005
3,5-Dichlorocatechol	0.000002	Pimaric Acid	0.0005
4,5-Dichlorocatechol	0.000002	Sandaraco Pimaric Acid	0.0005
4-Chlorocatechol	0.000002		

Table 100 (continued)
FREMP McDonald Slough Water Quality Data: Parameters Less Than Detection Limits

Characteristic	Detection Limit (mg/L)	Characteristic	Detection Limit (mg/L)
Antisapstain Compounds:		**Polyaromatic Hydrocarbons:**	
TCMTB	0.005	7 12-Dimethylbenz(a)anthracene	0.00005
		Dibenz(a h)anthracene	0.00001
Organochlorine Pesticides and PCB's		Chrysene	0.00001
Aldrin	0.000001	Benzo(b+k)fluoranthene	0.00001
BHC alpha-	0.000001	3-Methylcholanthrene	0.00002
BHC beta-	0.000001	Benzo(j)fluoranthene	0.00001
BHC delta-	0.000001	Benzo(g h i)perylene	0.00002
Chlordane alpha-	0.000005	Benzo(c)phenanthrene	0.00001
Chlordane gamma-	0.000005	Benzo(a)pyrene	0.00001
DDE p p'-	0.000005	Dibenzo(a h)pyrene	0.00005
DDD p p'-	0.000005	Dibenzo(a i)pyrene	0.00005
DDT p p'-	0.000005	Dibenzo(a l)pyrene	0.00005
Dieldrin	0.000005	Indeno (1 2 3-c d) pyrene	0.00001
Endosulfan I	0.000005	Acenaphthylene	0.00001
Endosulfan II	0.000005	Anthracene	0.00001
Endosulfan sulphate	0.00001	Total high MW PAH's	0.00005
DDT o p'-	0.000005		
Endrin	0.000005		
Heptachlor	0.000001		
Heptachlor epoxide	0.000002		
Lindane BHC gamma-	0.000001		
Methoxychlor	0.00001		
Mirex	0.00001		
Nonachlor trans-	0.000005		
Oxychlordane	0.000005		
Toxaphene	0.00005		
PCB's - Total	0.00002		

Table 101
FREMP Eburne Slough Water Quality Data

Lab ID	Detection Limits Zenon	Detection Limits ASL/		Zenon	Zenon	ASL/ Zenon	ASL/ Zenon
Sampled On:			UNITS	Surface - 1m 1.0m 93-02-11	Bottom + 1m 4.0m 93-02-11	Surface - 1m 1.0 m 94-02-23	Bottom + 1m 3.5 m 94-02-23
Latitude (N)				49 - 12.16	49 - 12.16	49 - 12.16	49 - 12.16
Longitude (W)				123 - 8.58	123 - 8.58	123 - 8.58	123 - 8.58
Physical Tests:							
Dissolved Oxygen			mg/L	11.2	10.8	10.9	11
Water Temp			^{o}C	5.5	7	4.5	4.9
Air Temp			^{o}C	2	2	1	1
pH				7.7	7.6	7.38	7.32
Field pH				7.3	7.45	7.65	7.7
Specific Conductance	1	0.2	uS/cm	20800	30500	12000	17400
Field SC			uS/cm	17500	21000	7000	10500
Suspended Solids	4	1	mg/L	252	17	8	12
Dissolved Solids	4	1	mg/L	13500	20900	8250	12400
Hardness Total		0.05	mg/L	1740	2770	1300	1960
Anions:							
Alkalinity Total	0.5	0.5	mg/L	73.3	85.1	59.4	71.6
Chloride Dissolved	0.5	0.2	mg/L	11800	11200	3950	5860
Fluoride Dissolved	0.1	0.02	mg/L	0.44	0.6	0.34	0.34
Sulfate	1	0.5	mg/L	901	1660	515	756
Nutrients:							
Nitrogen Ammonia	0.005	0.005	mg/L	0.037	0.017	0.054	0.051
Nitrogen Kjeldahl	0.04	0.05	mg/L	0.23	0.21	0.19	0.185
Nitrogen nitrate/nitrite	0.02	0.005	mg/L	0.29	0.34	0.374	0.373
Phosphorus Dissolved	0.003	0.001	mg/L	0.033	0.048	0.037	0.04
Phosphorus Total	0.003	0.001	mg/L	0.053	0.061	0.048	0.049
Total Metals:							
Aluminum	0.06	0.20	mg/L	0.14	0.09	<0.60	<0.60
Arsenic	0.001	0.0001	mg/L	0.001	0.001	0.0008	0.0009
Barium	0.001	0.01	mg/L	0.011	0.009	<0.030	<0.030
Cadmium	0.0001	0.0002	mg/L	<	<	<0.001	<0.001
Calcium	0.05	0.05	mg/L	121	186	86	126
Chromium	0.005	0.001	mg/L	<	<	<0.001	<0.001
Cobalt	0.004	0.015	mg/L	<	<	<0.045	<0.045
Copper	0.001	0.001	mg/L	0.001	0.003	<0.001	<0.001
Iron	0.05	0.03	mg/L	0.34	0.23	0.696	0.944
Lead	0.003	0.001	mg/L	<	<	<0.010	<0.010
Magnesium	0.02	0.01	mg/L	348	559	263	399

Table 101 (continued)
FREMP Eburne Slough Water Quality Data

Lab ID	Detection Limits Zenon	ASL/		Zenon	Zenon	ASL/ Zenon	ASL/ Zenon
Sampled On:			UNITS	Surface - 1m 1.0m 93-02-11	Bottom + 1m 4.0m 93-02-11	Surface - 1m 1.0 m 94-02-23	Bottom + 1m 3.5 m 94-02-23
Total Metals: (cont'd)							
Manganese	0.002	0.005	mg/L	0.018	0.008	0.01	<0.01
Mercury	0.00005	5E-05	mg/L	<	<	<0.00005	<0.00005
Molybdenum	0.004	0.001	mg/L	<	<	0.002	0.003
Nickel	0.005	0.001	mg/L	<	<	0.013	0.014
Potassium	0.4	2	mg/L	96.9	160	74.4	119
Selenium	0.03	0.0005	mg/L	<	<	<0.0005	<0.0005
Silver	0.03	0.0001	mg/L	<	<	<0.001	<0.001
Sodium	0.4	2	mg/L	2880	4820	2060	3120
Tin	0.02	0.30	mg/L	0.13	0.1	<0.90	<0.90
Zinc	0.01	0.001	mg/L	<	<	0.004	0.003
Bacteriological:							
Fecal Coliform			MPN /100mL	1300		5000	3000
ORGANIC PARAMETERS:							
Carbon Total Organic	2	0.50	mg/L	1	2	<5	<5
Absorbable Org Halide as Cl	0.01	0.01	mg/L	0.03	0.04	0.02	0.03
Chlorophenolics:							
2,3,4,6+2,3,5,6-TTCP	0.001	0.001	µg/L	<	<	<	0.0021
2,4,6-Trichlorophenol				<	<	0.002	0.002
3,4,5-Trichloroguaiacol	0.002	0.002	µg/L	0.003	<	<	<
4,5-Dichloroguaiacol	0.002	0.002	µg/L	<	<	0.0004	0.003
5-Chloroguaiacol	0.002	0.002	µg/L	0.007	<	<	<
3,4,5-Trichlorocatechol	0.002	0.002	µg/L	0.005	<	<	<
4,5-Dichlorocatechol	0.002	0.002	µg/L	<	<	<	0.003
3,4,5-Trichloroveratrole	0.002	0.002	µg/L	0.002	<	<	<
6-Chlorovanillin	0.002	0.002	µg/L	0.007	<	0.006	0.004
Resin and Fatty Acids:							
Linoleic Acid	0.0005	0.0005	mg/L	<	<	0.0008	<
Myristic Acid	0.0005	0.0005	mg/L	<	<	0.0007	<
Oleic Acid	0.0005	0.0005	mg/L	0.0012	<	0.0018	0.0009
Palmitric Acid	0.0005	0.0005	mg/L	<	<	0.0008	0.0008
Stearic Acid	0.0005	0.0005	mg/L	<	<	0.001	0.001
Total Resins and Fatty Acids				0.0107	0.01	0.0126	0.0112

Table 101 (continued)
FREMP Eburne Slough Water Quality Data

Lab ID	Detection Limits Zenon	ASL/		Zenon	Zenon	ASL/ Zenon	ASL/ Zenon
Sampled On:			UNITS	Surface - 1m 1.0m 93-02-11	Bottom + 1m 4.0m 93-02-11	Surface - 1m 1.0 m 94-02-23	Bottom + 1m 3.5 m 94-02-23
Polyaromatic Hydrocarbons:							
Benz(a)anthracene	0.00001	0.00001	mg/L	<	<	0.00002	0.00003
Chrysene	0.00001	0.00001	mg/L	<	<	0.00001	<
Pyrene	0.00001	0.00001	mg/L	0.00001	0.00001	0.00002	<
Acenaphthene	0.00001	0.00001	mg/L	0.00001	<	0.00003	0.00002
Fluoranthene	0.00001	0.00001	mg/L	0.00001	<	0.00003	<
Fluorene	0.00001	0.00001	mg/L	<	<	0.00002	0.00002
Naphthalene	0.00001	0.00001	mg/L	0.00004	<	0.00014	0.00014
Phenanthrene	0.00001	0.00001	mg/L	0.00007	0.0001	0.00004	0.00004
Total PAH's	0.00005	0.00005	mg/L	0.00014	0.00011	0.00031	0.00025
Total low MW PAH's	0.00005	0.00005	mg/L	0.00012	0.0001	0.00023	0.00022
Total high MW PAH's	0.00005	0.00005	mg/L	<	<	0.00008	<

Table 102
FREMP Eburne Slough Water Quality Data: Parameters Below Detection Limits

Characteristic	Detection Limit (mg/L)	Characteristic	Detection Limit (mg/L)
ORGANIC PARAMETERS:		Isopimaric Acid	0.0005
Chlorophenolics:		Lauric Acid	0.0005
Pentachlorophenol	0.000001	Levo Pimaric Acid	0.0005
2,3,4,5-Tetrachlorophenol	0.000001	Lignoceric Acid	0.0005
3,4,5-Trichlorophenol	0.000001	Linolenic Acid	0.0005
2,3,4-Trichlorophenol	0.000001	Neoabietic Acid	0.0005
2,3,5-Trichlorophenol	0.000001	Palustric Acid	0.0005
2,3,6-Trichlorophenol	0.000001	Pimaric Acid	0.0005
2,4,5-Trichlorophenol	0.000001	Sandaraco Pimaric Acid	0.0005
2,4-Dichlorophenol	0.000001	**Antisapstain Compounds:**	
2,6-Dichlorophenol	0.000001	TCMTB	0.005
2,5-Dichlorophenol	0.000001	**Organochlorine Pesticides and PCB's**	
3,5-Dichlorophenol	0.000001	Aldrin	0.000001
2,3-Dichlorophenol	0.000001	BHC alpha-	0.000001
3,4-Dichlorophenol	0.000001	BHC beta-	0.000001
4-Chlorophenol	0.000001	BHC delta-	0.000001
Tetrachloroguaiacol	0.000002	Chlordane alpha-	0.000005
3,4,6-Trichloroguaiacol	0.000002	Chlordane gamma-	0.000005
4,5,6-Trichloroguaiacol	0.000002	DDE p p'-	0.000005
4,6-Dichloroguaiacol	0.000002	DDD p p'-	0.000005
4-chloroguaiacol	0.000002	DDT p p'-	0.000005
6-Chloroguaiacol	0.000002	Dieldrin	0.000005
Tetrachlorocatechol	0.000002	Endosulfan I	0.000005
3,4-Dichlorocatechol	0.000002	Endosulfan II	0.000005
3,5-Dichlorocatechol	0.000002	Endosulfan sulphate	0.00001
4-Chlorocatechol	0.000002	DDT o p'-	0.000005
Tetrachloroveratrole	0.000002	Endrin	0.000005
4,5-Dichloroveratrole	0.000002	Hexachlorobenzene	0.0000005
2,6-Dichlorosyringaldehyde	0.000002	Heptachlor	0.000001
2-Chlorosyringaldehyde	0.000002	Heptachlor epoxide	0.000002
3,4,5-Trichlorosyringol	0.000002	Lindane BHC gamma-	0.000001
Trichlorotrimethoxybenzene	"	Methoxychlor	0.00001
5,6-Dichlorovanillin	"	Mirex	0.00001
Nonylphenol	0.00002	Nonachlor trans-	0.000005
Resin and Fatty Acids:		Oxychlordane	0.000005
Abietic Acid	0.0005	Toxaphene	0.00005
Arachidic Acid	0.0005	PCB's - Total	0.00002
Behenic Acid	0.0005	**Polyaromatic Hydrocarbons:**	
Chlorodehydroabietic	0.0005	Benz(a)anthracene	0.00001
Dehydroabietic Acid	0.0005	Chrysene	0.00001
Dichlorodehydroabietic	0.0005	Pyrene	0.00001
		Acenaphthene	0.00001

Table 102 (continued)
FREMP Eburne Slough Water Quality Data: Parameters Below Detection Limits

Characteristic	Detection Limit
PAH's (cont'd)	
Fluoranthene	0.00001
Fluorene	0.00001
Naphthalene	0.00001
Phenanthrene	0.00001
Total PAH's	0.00005
Total low MW PAH's	0.00005
Total high MW PAH's	0.00005

Table 103
FREMP Tree Island Slough Water Quality Data

Lab ID	Detection Limits Zenon	ASL/ Zenon		Zenon	Zenon	ASL/ Zenon	ASL/ Zenon
				Surface - 1m	Bottom + 1m	Surface - 1m	Bottom + 1m
			UNITS	1.0m	3.0m	1.0 m	3.0 m
Sampled On:				93-02-10	93-02-10	94-02-22	94-02-22
Latitude (N)				49 - 11.08	49 - 11.08	49 - 11.08	49 - 11.08
Longitude (W)				122 - 57.70	122 - 57.70	122 - 57.70	122 - 57.70
Physical Tests:							
Dissolved Oxygen			mg/L	13.6	13.2	11.6	11.8
Water Temperature			^{o} C	4	4	3.8	3.8
Air Temperature			^{o} C	11.5	11.5	6	6
pH				7.7	7.7	7.47	7.44
Field pH				7.25	7.15	7.65	7.6
Specific Conductivity	1	0.2	uS/cm	142	172	660	1290
Field Specific Conductivity			uS/cm	90	155	450	900
Suspended Solids	4	1	mg/L	5	5	7	5
Dissolved Solids	4	1	mg/L	87	102	330	842
Hardness Total		0.05	mg/L	50.3	51.9	78.1	160
Anions:							
Alkalinity Total @ pH 4.5	0.5	0.5	mg/L	45.9	45.7	40.1	41.7
Chloride Dissolved	0.5	0.2	mg/L	8.4	17	125	360
Fluoride Dissolved	0.1	0.02	mg/L	<	<	0.04	0.05
Sulphate	1	0.5	mg/L	11.2	10.5	29.5	55
Nutrients:							
Nitrogen Ammonia	0.005	0.005	mg/L	0.04	0.054	0.051	0.069
Nitrogen Kjeldahl	0.04	0.05	mg/L	0.2	0.2	0.22	0.28
Nitrogen nitrate/nitrite	0.02	0.005	mg/L	0.2	0.21	0.252	0.26
Phosphorus Dissolved	0.003	0.001	mg/L	0.014	0.008	0.024	0.026
Phosphorus Total	0.003	0.001	mg/L	0.022	0.017	0.038	0.038

Table 103 (continued)
FREMP Tree Island Slough Water Quality Data

	Detection Limits						
Lab ID	Zenon	ASL/ Zenon		Zenon	Zenon	ASL/ Zenon	ASL/ Zenon
				Surface - 1m	Bottom + 1m	Surface - 1m	Bottom + 1m
			UNITS	1.0m	3.0m	1.0 m	3.0 m
Sampled On:				93-02-10	93-02-10	94-02-22	94-02-22
Total Metals:							
Aluminum	0.06	0.2	mg/L	0.14	0.14	0.3	0.25
Arsenic	0.001	0.0001	mg/L	<	<	0.0004	0.0008
Barium	0.001	0.01	mg/L	0.014	0.014	0.018	0.017
Cadmium	0.0001	0.0002	mg/L	<	<	<0.0002	<0.0002
Calcium	0.05	0.05	mg/L	14.4	14.6	14.4	19.3
Chromium	0.005	0.001	mg/L	<	<	<0.001	<0.001
Cobalt	0.004	0.015	mg/L	<	<	<0.015	<0.015
Copper	0.001	0.001	mg/L	0.002	0.001	0.002	0.002
Iron	0.05	0.03	mg/L	0.35	0.37	0.386	0.373
Lead	0.003	0.001	mg/L	<	<	<0.001	<0.001
Magnesium	0.02	0.01	mg/L	3.49	3.74	10.3	27.2
Manganese	0.002	0.005	mg/L	0.023	0.027	0.03	0.025
Mercury	0.00005	0.00005	mg/L	<	<	<0.00005	<0.00005
Molybdenum	0.004	0.001	mg/L	<	<	0.001	0.001
Nickel	0.005	0.001	mg/L	<	<	<0.001	<0.001
Potassium	0.4	2	mg/L	0.9	1.1	3	8.1
Selenium	0.03	0.0005	mg/L	<	<	<0.0005	<0.0005
Silver	0.03	0.0001	mg/L	<	<	<0.0001	<0.0001
Sodium	0.4	2	mg/L	6.5	9.4	64.5	202
Tin	0.02	0.3	mg/L	<	<	<0.30	<0.30
Zinc	0.01	0.001	mg/L	<	<	0.003	0.002
Bacteriological:							
Fecal Coliform			MPN /100mL	1100		1700	5000
Organic Parameters:							
Carbon Total Organic	2	0.5	mg /L	2	2	2.2	2.7
Absorbable Org Halide as Cl	0.01	0.01	mg /L	0.03	0.02	0.02	0.03
Chlorophenolics:							
2,4,6-Trichlorophenol	0.001	0.001	µg/L	<	<	0.000002	<
3,4,5-Trichloroguaiacol	0.001	0.001	µg/L	0.005	0.007	0.003	0.002
3,4,6-Trichloroguaiacol	0.001	0.001	µg/L	<	<	<	<
4,5,6-Trichloroguaiacol	0.001	0.001	µg/L	0.004	0.005	0.002	0.002
4,5-Dichloroguaiacol	0.001	0.001	µg/L	<	0.018	0.005	0.004
5-Chloroguaiacol	0.001	0.001	µg/L	<	0.007	<	<
3,4,5-Trichlorocatechol	0.001	0.001	µg/L	0.009	<	<	<
4,5-Dichlorocatechol	0.001	0.001	µg/L	<	<	0.003	<
5,6-Dichlorovanillin	0.001	0.001	µg/L	<	0.007	<	<
6-Chlorovanillin	0.001	0.001	µg/L	0.000009	0.007	0.006	0.008

Table 103 (continued)
FREMP Tree Island Slough Water Quality Data

	Detection Limits						
Lab ID	Zenon	ASL/ Zenon		Zenon	Zenon	ASL/ Zenon	ASL/ Zenon
				Surface - 1m	Bottom + 1m	Surface - 1m	Bottom + 1m
			UNITS	1.0m	3.0m	1.0 m	3.0 m
Sampled On:				93-02-10	93-02-10	94-02-22	94-02-22
Resin and Fatty Acids:							
Myristic Acid	0.0005	0.0005	mg/L	<	<	0.0005	0.0007
Oleic Acid	0.0005	0.0005	mg/L	<	<	0.0011	<
Palmitric Acid	0.0005	0.0005	mg/L	<	0.0007	0.001	0.0016
Stearic Acid	0.0005	0.0005	mg/L	<	<	0.0009	0.0017
Total Resins and Fatty Acids				0.01	0.0102	0.0115	0.0125
Polyaromatic Hydrocarbons:							
Benz(a)anthracene	0.00001	0.00001	mg/L	<	<	0.00002	0.00002
Chrysene	0.00001	0.00001	mg/L	<	<	0.00001	0.00001
Benzo(b+k)fluoranthene	0.00001	0.00001	mg/L	<	<	0.00001	0.00001
Pyrene	0.00001	0.00001	mg/L	<	<	0.00003	0.00002
Acenaphthene	0.00001	0.00001	mg/L	0.00003	0.00002	<	<
Fluoranthene	0.00001	0.00001	mg/L	<	<	<	0.00002
Fluorene	0.00001	0.00001	mg/L	0.00002	0.00002	<	<
Naphthalene	0.00001	0.00001	mg/L	0.00008	0.00009	<	0.00003
Phenanthrene	0.00001	0.00001	mg/L	<	<	0.00003	0.00003
Total PAH's	0.00005	0.00005	mg/L	0.00013	0.00013	0.0001	0.00014
Total low MW PAH's	0.00005	0.00005	mg/L	0.00013	0.00013	<	0.00006
Total high MW PAH's	0.00005	0.00005	mg/L	<	<	0.00007	0.00008

Table 104
FREMP Tree Island Slough Water Quality Data: Characteristics Below Detection Limits

Characteristic	Detection Limit mg/L	Characteristic	Detection Limit mg/L
Organic Parameters:		Anthracene	0.00001
Chlorophenolics:		**Resin and Fatty Acids:**	
Pentachlorophenol	0.000001	Abietic Acid	0.0005
2,3,4,6+2,3,5,6-Tetrachlorophenol	0.000001	Arachidic Acid	0.0005
2,3,4,5-Tetrachlorophenol	0.000001	Behenic Acid	0.0005
3,4,5-Trichlorophenol	0.000001	Chlorodehydroabietic	0.0005
2,3,4-Trichlorophenol	0.000001	Dehydroabietic Acid	0.0005
2,3,5-Trichlorophenol	0.000001	Dichlorodehydroabietic	0.0005
2,3,6-Trichlorophenol	0.000001	Isopimaric Acid	0.0005
2,4,5-Trichlorophenol	0.000001	Lauric Acid	0.0005
2,4-Dichlorophenol	0.000001	Levo Pimaric Acid	0.0005
2,6-Dichlorophenol	0.000001	Lignoceric Acid	0.0005
2,5-Dichlorophenol	0.000001	Linoleic Acid	0.0005
3,5-Dichlorophenol	0.000001	Linolenic Acid	0.0005
2,3-Dichlorophenol	0.000001	Neoabietic Acid	0.0005
3,4-Dichlorophenol	0.000001	Palustric Acid	0.0005
4-Chlorophenol	0.000001	Pimaric Acid	0.0005
Tetrachloroguaiacol	0.000002	Sandaraco Pimaric Acid	0.0005
3,4,6-Trichloroguaiacol	0.000002	**Antisapstain Compounds**:	
4,6-Dichloroguaiacol	0.000002	TCMTB	0.005
4-chloroguaiacol	0.000002	**Organochlorine Pesticides and PCB's**	
6-Chloroguaiacol	0.000002	Aldrin	0.000001
Tetrachlorocatechol	0.000002	BHC alpha-	0.000001
3,4-Dichlorocatechol	0.000002	BHC beta-	0.000001
3,5-Dichlorocatechol	0.000002	BHC delta-	0.000001
4-Chlorocatechol	0.000002	Chlordane alpha-	0.000005
Tetrachloroveratrole	0.000002	Chlordane gamma-	0.000005
3,4,5-Trichloroveratrole	0.000002	DDE p p'-	0.000005
4,5-Dichloroveratrole	0.000002	DDD p p'-	0.000005
2,6-Dichlorosyringaldehyde	0.000002	DDT p p'-	0.000005
2-Chlorosyringaldehyde	0.000002	Dieldrin	0.000005
3,4,5-Trichlorosyringol	0.000002	Endosulfan I	0.000005
Trichlorotrimethoxybenzene	0.000002	Endosulfan II	0.000005
Nonylphenol	0.00002	Endosulfan sulphate	0.00001
Polyaromatic Hydrocarbons:		DDT o p'-	0.000005
7 12-Dimethylbenz(a)anthracene	0.00005	Endrin	0.000005
Dibenz(a h)anthracene	0.00001	Hexachlorobenzene	0.0000005
3-Methylcholanthrene	0.00002	Heptachlor	0.000001
Benzo(j)fluoranthene	0.00001	Heptachlor epoxide	0.000002
Benzo(g h i)perylene	0.00002	Lindane BHC gamma-	0.000001
Benzo(c)phenanthrene	0.00001	Methoxychlor	0.00001
Benzo(a)pyrene	0.00001	Mirex	0.00001
Dibenzo(a h)pyrene	0.00005	Nonachlor trans-	0.000005
Dibenzo(a i)pyrene	0.00005	Oxychlordane	0.000005
Dibenzo(a l)pyrene	0.00005	Toxaphene	0.00005
Indeno(1 2 3-c d)pyrene	0.00001	PCB's - Total	0.00002
Acenaphthylene	0.00001		

Table 105
Beak North Arm Slough Dissolved Oxygen Concentrations

Slough	No. of Values	Maximum	Minimum	Average	Std. Dev.
McDonald Slough - surface:	4	10.0	8.4	9.0	0.7
bottom:	4	8.0	3.0	5.3	2.1
Eburne Slough - surface:	4	9.4	8.8	9.1	0.3
bottom:	4	8.6	2.0	6.4	3.0
Tree Island Slough - surface:	4	10.2	8.4	9.5	0.8
bottom:	4	9.0	5.0	7.2	1.7

*all concentrations in mg/L

Table 106
GVRD Water Quality Data

North Arm Site 5	**No. of Values**	**Maximum**	**Minimum**	**Average**	**St. Dev.**
Dissolved Oxygen (mg/L)	7	11	8.5	9.9	1.0
Fecal Coliforms (MPN/100 mL)	19	1300	40	181.4	348.3
North Arm Site 6	**No. of Values**	**Maximum**	**Minimum**	**Average**	**St. Dev.**
Dissolved Oxygen (mg/L)	8	11.2	8.6	10.1	1.1
Fecal Coliforms (MPN/100 mL)	19	3000	20	163.4	707.8
North Arm Site 7	**No. of Values**	**Maximum**	**Minimum**	**Average**	**St. Dev.**
Dissolved Oxygen (mg/L)	8	11	8.5	10.2	1.0
Fecal Coliforms (MPN/100 mL)	19	1300	20	154.8	398.7
Enterococci (MPN/100 mL)	9	140	20	55.9	40.3
North Arm Site 8	**No. of Values**	**Maximum**	**Minimum**	**Average**	**St. Dev.**
Dissolved Oxygen (mg/L)	4	10.5	8.7	9.4	0.9
Fecal Coliforms (MPN/100 mL)	19	800	<20	87.5	193.1
N.A. Site 9	**No. of Values**	**Maximum**	**Minimum**	**Average**	**St. Dev.**
Dissolved Oxygen (mg/L)	7	11.2	8.8	10.2	0.9
Fecal Coliforms (MPN/100 mL)	19	230	20	91.2	52.2
N.A. Site 10	**No. of Values**	**Maximum**	**Minimum**	**Average**	**St. Dev.**
Dissolved Oxygen (mg/L)	7	11.5	8.7	10.2	1.0
Fecal Coliforms (MPN/100 mL)	19	230	<20	75.2	50.0
N.A. Site 11	**No. of Values**	**Maximum**	**Minimum**	**Average**	**St. Dev.**
Dissolved Oxygen (mg/L)	7	11.1	8.9	10.2	0.9
Fecal Coliforms (MPN/100 mL)	18	140	<20	50.3	43.3

Table 107
Ambient Water Quality Summary for the Fraser River Upstream from the Annacis Sewage Treatment Plant

Characteristic	No. of Values	Maximum	Minimum	Mean	Median	Std Dev.
Coliforms (CFU/cL): *E.coli*	5	71	30	43	41	16
Enterococci	5	21	9	14	15	5
fecal coliform	29	40600	13	195	142	7618
Hardness: calcium	27	40.3	11.4	17.0	15.5	5.8
magnesium	27	41	2.61	7.28	4.54	8.13
Metals: aluminum	20	2.52	0.1	1.06	0.92	0.73
arsenic	10	<0.04	<0.04	<0.04	<0.04	-
boron	10	0.22	<0.01	0.06	0.04	0.06
barium	18	0.039	0.01	0.022	0.020	0.007
beryllium	10	<0.001	<0.001	<0.001	<0.001	0.000
bismuth	10	<0.02	<0.02	<0.02	<0.02	0.00
cadmium	24	<0.01	<0.01	<0.01	<0.01	0.00
chromium	24	0.02	0.002	0.01	<0.01	0.00
cobalt	24	<0.1	0.0	<0.1	<0.1	0.0
copper	27	0.020	0.000	0.003	0.002	0.004
iron	24	4.02	0.17	1.24	0.95	1.01
manganese	24	0.132	0.02	0.043	0.040	0.030
molybdenum	24	0.04	0	<0.01	<0.01	0.01
nickel	24	0.09	<0.008	na	<0.05	0.023
silver	10	<0.03	<0.01	<0.02	<0.02	0.01
Nitrogen: ammonia	26	0.196	<0.005	0.042	0.027	0.042
Oxygen: dissolved	10	13.6	8.7	11.1	11.2	2.1
pH	22	9.5	6.6	7.9	7.8	0.9
Phosphorus	4	0.08	0.05	0.07	0.07	0.01
Salts: sodium	4	9.25	3.59	5.94	5.46	2.76
potassium	4	1.6	0.9	1.1	1.0	0.3
Solids: suspended	10	70	5	29	25	22
Temperature ° C	10	18.9	2	10.1	9.7	8.0

*all measurements in mg/L unless otherwise noted

Table 108
Ambient Water Quality Summary for the Fraser River Downstream from the Annacis Sewage Treatment Plant

Characteristic	No. of Values	Maximum	Minimum	Mean	Median	Std. Dev
Coliforms (CFU/cL)	5	71	25	48	51	18
E. coli						
Enterococci	6	24	10	18	21	6
fecal coliform	28	19700	22	265	43	4605
Hardness: calcium	28	32	12.6	16.7	15.6	5.0
magnesium	28	52.2	2.76	9.55	4.24	13.93
Metals: aluminum	21	2.27	0.07	0.97	0.87	0.66
arsenic	11	<0.04	<0.04	<0.04	<0.04	<0.04
boron	11	0.16	<0.01	0.06	0.04	0.05
barium	19	0.036	0.01	0.021	0.020	0.007
beryllium	11	<0.001	0	<0.001	<0.001	0.001
bismuth	11	<0.02	<0.02	<0.02	<0.02	0.00
cadmium	25	<0.01	0	<0.01	<0.01	0.00
chromium	25	0.01	0	<0.01	<0.01	0.00
cobalt	25	0.1	0.0	<0.1	<0.1	0.0
copper	28	0.010	0.000	0.003	0.002	0.002
iron	25	3.55	0.22	1.14	0.91	0.91
manganese	25	0.108	0.019	0.037	0.030	0.021
molybdenum	25	<0.01	0	<0.01	<0.01	0.00
nickel	25	0.05	<0.008	0.032	<0.05	0.020
silver	11	<0.03	<0.01	0.02	<0.03	0.01
Nitrogen: ammonia	27	0.14	<0.005	0.042	0.030	0.035
Organics: PCP	1	0.0001	0.0001	0.0001	0.0001	0
Oxygen: dissolved	10	13.4	8.4	11.0	11.1	2.2
pH	22	9.5	6.4	7.8	7.8	0.9
Phosphorus	5	0.08	<0.04	0.06	0.06	0.02
Salts: sodium	5	362	3.21	75.20	3.61	160.33
potassium	5	14.4	0.7	3.7	1.1	6.0
Solids: suspended	12	61	4	20	17	17
Temp ° C	10	18.9	0.5	9.8	9.7	8.4

*all measurements in mg/L unless otherwise noted

Table 109
Ambient Water Quality Summary for the Fraser River Upstream from the Lulu Sewage Treatment Plant

Characteristic	No. of Values	Maximum	Minimum	Mean	Median	St. Dev.
Coliforms (CFU/cL)	3	190	46	93	92	74
E. coli						
Enterococci	5	100	13	30	25	35
fecal coliform	12	800	33	152	143	234
Hardness: calcium	17	164	14.7	54.1	34.1	47.0
magnesium	17	405	9.69	126.13	63.80	134.6
Metals: aluminum	10	2.01	<0.1	0.82	0.75	0.57
arsenic	5	0.05	<0.04	<0.04	<0.04	0.00
boron	5	0.26	<0.04	0.16	0.21	0.11
barium	8	0.029	0.01	0.020	0.020	0.005
beryllium	5	<0.001	<0.001	<0.001	<0.001	0.000
bismuth	5	<0.02	<0.02	<0.02	<0.02	0.00
cadmium	14	<0.01	<0.002	<0.01	<0.01	0.00
chromium	14	0.01	<0.002	0.01	<0.01	0.00
cobalt	14	<0.1	0.0	<0.1	<0.1	0.0
copper	17	0.009	<0.001	0.004	0.003	0.002
iron	14	3.25	0.16	0.95	0.57	0.88
manganese	14	0.097	0.02	0.033	0.020	0.022
molybdenum	14	<0.01	<0.004	<0.01	<0.01	0.00
nickel	14	<0.05	<0.01	0.036	<0.05	0.020
silver	5	<0.03	<0.03	<0.03	<0.03	0.00
Nitrogen: ammonia	16	0.095	0.011	0.055	0.055	0.019
pH	6	7.9	7.6	7.7	7.7	0.1

*all measurements in mg/L unless otherwise noted

Table 110
Ambient Water Quality Summary for the Fraser River Downstream from the Lulu Sewage Treatment Plant

Characteristic	No. of Values	Maximum	Minimum	Mean	Median	Std Dev.
Coliforms (CFU/cL) fecal coliform	9	3600	60	283	230	1127
Hardness: calcium	11	143	14.5	59.8	63.4	43.5
magnesium	11	143	14.5	59.83	63.40	43.5
Metals: aluminum	5	1.67	0.12	0.97	0.83	0.61
barium	3	0.05	0.02	0.030	0.020	0.017
cadmium	8	<0.01	<0.01	<0.01	<0.01	0.00
chromium	8	0.09	<0.01	0.02	<0.01	0.03
cobalt	8	<0.1	<0.1	<0.1	<0.1	0.0
copper	11	0.01	<0.001	0.003	0.001	0.003
iron	8	1.52	0.2	0.67	0.46	0.54
manganese	8	0.05	0.02	0.026	0.020	0.012
molybdenum	8	<0.01	<0.01	<0.01	<0.01	-
nickel	8	<0.05	<0.05	<0.05	<0.05	-
Nitrogen: ammonia	10	0.097	0.014	0.060	0.062	0.023
Organics: PCP	1	0.0001	-	-	-	-
pH	1	7.9	-	-	-	-

*all measurements in mg/L unless otherwise noted

Table 111
Ambient Water Quality Summary for the Fraser River Downstream from the Lulu Sewage Treatment Plant

Characteristic	No. of Values	Maximum	Minimum	Mean	Median	Std Dev.
Coliforms (CFU/cL)	3	92	55	72	75	19
E. Coli						
Enterococci	5	59	16	27	27	17
fecal coliform	3	130	55	81	73	39
Hardness: calcium	5	41.8	18.3	31.5	35.3	9.6
magnesium	5	90.3	3.01	50.12	67.80	38.01
Metals: aluminum	5	1.18	0.07	0.68	0.73	0.41
arsenic	5	<0.04	<0.04	<0.04	<0.04	-
boron	5	0.39	<0.04	0.19	0.25	0.15
barium	5	0.021	0.015	0.018	0.019	0.002
beryllium	5	<0.001	<0.001	<0.001	<0.001	-
bismuth	5	0.02	<0.02	<0.02	<0.02	-
cadmium	5	<0.002	<0.002	<0.002	<0.002	-
chromium	5	0.002	<0.002	0.002	<0.002	-
cobalt	5	<0.004	<0.004	<0.004	<0.004	-
copper	5	0.005	<0.002	0.003	0.004	0.001
iron	5	2.04	0.14	1.16	1.14	0.69
manganese	5	0.053	0.023	0.039	0.041	0.013
molybdenum	5	<0.004	<0.004	<0.004	<0.004	-
nickel	5	<0.01	<0.01	<0.01	<0.01	-
silver	5	<0.03	<0.03	<0.03	<0.03	-
Nitrogen: ammonia	5	0.062	0.036	0.052	0.056	0.011
pH	5	7.8	7.4	7.6	7.6	0.1

*all measurements in mg/L unless otherwise noted

Table 112
Ambient Water Quality at Ladner Slough

Characteristic	No. of Values	Maximum	Minimum	Mean	Median	Std Dev.
Coliforms (CFU/cL): fecal coliforms	4	770	90	233	224	310
Hardness: calcium	4	34.8	19.6	25.9	24.6	7.2
magnesium	4	60.2	17.9	35.65	32.25	20.34
Metals: cadmium	4	<0.01	<0.01	<0.01	<0.01	-
chromium	4	0.01	<0.01	<0.01	<0.01	-
cobalt	4	<0.1	<0.1	<0.1	<0.1	-
copper	4	0.002	0.001	0.001	0.001	-
iron	4	1.07	0.6	0.79	0.75	0.20
manganese	4	0.1	0.04	0.075	0.080	0.026
molybdenum	4	0.03	0.01	0.02	0.02	0.01
nickel	4	<0.05	<0.05	<0.05	<0.05	-
Nitrogen: ammonia	4	0.047	0.014	0.027	0.024	0.014
nitrate/nitrite	4	0.05	<0.02	0.0325	0.03	0.015
nitrite	4	<0.005	<0.005	<0.005	<0.005	-
pH	4	8	7.5	7.7	7.7	0.2

*all measurements in (mg/L) unless otherwise noted

Table 113
Ambient Water Quality at Ladner Slough Mouth

Characteristic	No. of Values	Maximum	Minimum	Mean	Median	Std Dev.
Coliform : fecal coliforms	3	430	136	211	160	163
Hardness: calcium	4	20.2	16.2	18.5	18.8	1.9
magnesium	4	20.9	7.87	15.22	16.05	5.41

*all measurements in mg/L except fecal coliforms (CFU/cL)

Table 114
Sediment Data Upstream from Annacis Sewage Treatment Plant

Characteristic	No Of Values	Maximum	Minimum	Mean	Median
PCB (total) (ug/g)	3	<0.02	<0.02	<0.02	0.02
PCP (ug/g)	3	0.051	0.029	0.041	0.042

Table 115
Sediment Data Downstream from Annacis Sewage Treatment Plant

Characteristics ug/g	No Of Values	Maximum	Minimum	Mean	Median
Carbon: organic	3	1400	800	1000	800
total	3	13000	9000	10667	10000
PCB (total)	6	<0.2	<0.2	<0.2	<0.2
PCP	6	0.064	0.016	0.0345	0.0335

Table 116
Sediment Data Upstream from Lulu Sewage Treatment Plant

Characteristic	No Of Values	Maximum	Minimum	Mean	Median
PCB (total)	3	<0.2	<0.2	<0.2	<0.2
PCP	3	0.031	0.007	0.0207	0.024

*all measurements in ug/g unless otherwise noted

Table 117
Sediment Data Downstream from Lulu Sewage Treatment Plant

Characteristic	No Of Values	Maximum	Minimum	Mean	Median
PCB (total)	7	<0.2	<0.2	<0.2	<0.2
PCP	7	0.07	<0.005	0.027	0.007
Carbon: inorganic	4	900	500	725	750
total	4	17000	9000	13750	14500

*all measurements in ug/g unless otherwise noted

Table 118
Sediment Quality Summary for Annacis Channel

Characteristic	No Of Values	Maximum	Minimum	Mean	Median
PCP	4	<0.005	<0.005	<0.005	<0.005
Carbon: organic	3	7000	6600	6767	6700
inorganic	14	5100	1490	2818	2320
Metals: aluminum	10	14400	10800	12060	11700
arsenic	14	8.21	<30	na	<30
barium	10	117	93	103	100.5
cadmium	4	0.37	0.26	0.30	0.285
calcium	10	9320	7210	8354	8480
chromium	14	55	24	36	31
cobalt	10	10	10	10	10
copper	14	42.9	26	33.6	32
iron	14	39100	22300	28600	25800
magnesium	14	14100	9420	11186	10500
manganese	14	794	506	590	553
mercury	14	0.08	0.052	0.067	0.07
molybdenum	14	<2	<1	<2	<2
nickel	14	54.6	33	41.9	39
PAH's: asnapene	4	<0.005	<0.005	<0.005	<0.005
asnapyre	4	<0.005	<0.005	<0.005	<0.005
anthracene	4	<0.005	<0.005	<0.005	<0.005
benzoanthracene	4	<0.01	<0.01	<0.01	<0.01
benzoperylene	4	<0.02	<0.02	<0.02	<0.02
benzo[b]fluoranthene	4	0.051	<0.02	0.036	0.0365
benzo[g]perylene	4	<0.02	<0.02	<0.02	<0.02
benzo[k]fluoranthene	4	0.06	<0.02	0.03	0.02
chrysene	4	<0.01	<0.01	<0.01	<0.01
dibenzoanthracene	4	<0.02	<0.02	<0.02	<0.02
fluorene	4	<0.005	<0.005	<0.005	<0.005
fluoranthene	4	0.036	<0.01	0.017	<0.01
indenopyrene	4	0.17	<0.02	0.06	<0.02
naphthalene	4	<0.005	<0.005	<0.005	<0.005
Pesticides: chlordane [a]	4	<0.001	<0.001	<0.001	<0.001
chlordane [g]	4	<0.001	<0.001	<0.001	<0.001
DDD	4	<0.001	<0.001	<0.001	<0.001
DDE	4	<0.0005	<0.0005	<0.0005	<0.0005
DDT	4	<0.001	<0.001	<0.001	<0.001
Dieldrin	4	<0.001	<0.001	<0.001	<0.001
heptachlor	4	<0.0005	<0.0005	<0.0005	<0.0005
heptachlor epoxide	3	<0.01	<0.01	<0.01	<0.01
Lindane	4	<0.001	<0.001	<0.001	<0.001
Methoxychlor	4	<0.005	<0.005	<0.005	<0.005
Phosphorus	10	900	590	723	625
Phthalate (PE): Bis(2ethylhexyl)PE	4	0.63	0.11	0.41	0.46
diethyl PE	4	<0.1	<0.1	<0.1	<0.1
dimethyl PE	4	<0.1	<0.1	<0.1	<0.1
di-n-butyl PE	4	<0.1	<0.1	<0.1	<0.1
di-n-octyl PE	4	<0.1	<0.1	<0.1	<0.1

*all measurements in ug/g unless otherwise noted

Table 119
Sediment Data Summary for Ewen Slough

Characteristic	No Of Values	Maximum	Minimum	Mean	Median
PCP	5	<0.005	<0.005	<0.005	<0.005
PCB	5	<0.01	<0.01	<0.01	<0.01
Carbon: organic	5	9000	5700	7800	8300
inorganic	15	5200	691	2494	1940
total	10	24400	11600	16050	14200
Metals: aluminum	10	14500	12500	13610	13700
arsenic	15	8.06	<30	na	<30
barium	10	75	66	70	69.5
cadmium	5	0.32	0.2	0.26	0.27
calcium	10	6540	6050	6294	6285
chromium	15	54.4	32	40.2	36
cobalt	10	10	10	10	10
copper	15	44.2	35	38.8	38
iron	15	37100	26000	30373	28600
magnesium	15	14000	11100	12220	11800
manganese	15	760	476	591	583
mercury	15	0.09	0.056	0.074	0.07
molybdenum	15	2	<1	<2	<2
nickel	15	51.8	39	43.6	41
PAH's: asnapene	5	<0.005	<0.005	<0.005	<0.005
asnapyre	5	<0.005	<0.005	<0.005	<0.005
anthracene	5	<0.005	<0.005	<0.005	<0.005
benzoanthracene	5	<0.01	<0.01	<0.01	<0.01
benzoperylene	5	0.098	<0.02	0.036	<0.02
benzo[b]fluoranthene	5	0.069	<0.02	0.030	<0.02
benzo[g]perylene	5	<0.02	<0.02	<0.02	<0.02
benzo[k]fluoranthene	5	0.15	<0.02	0.08	0.07
chrysene	5	<0.01	<0.01	<0.01	<0.01
dibenzoanthracene	5	0.37	<0.02	0.09	<0.02
fluorene	5	<0.005	<0.005	<0.005	<0.005
fluoranthene	5	0.085	<0.01	0.025	<0.01
indenopyrene	5	0.32	<0.02	0.08	<0.02
naphthalene	5	0.13	<0.005	0.03	<0.005
Pesticides: Aldrin	5	<0.001	<0.001	<0.001	<0.001
chlordane [a]	5	<0.001	<0.001	<0.001	<0.001
chlordane [g]	5	<0.001	<0.001	<0.001	<0.001
DDD	5	<0.001	<0.001	<0.001	<0.001
DDE	5	<0.0005	<0.0005	<0.0005	<0.0005
DDT	5	<0.001	<0.001	<0.001	<0.001
Dieldrin	5	<0.001	<0.001	<0.001	<0.001
Endrin	5	<0.0005	<0.0005	<0.0005	<0.0005
heptachlor	5	<0.0005	<0.0005	<0.0005	<0.0005
heptachlor epoxide	5	<0.01	<0.01	<0.01	<0.01
Lindane	5	<0.001	<0.001	<0.001	<0.001
Methoxychlor	5	<0.005	<0.005	<0.005	<0.005

Table 119 (continued)
Sediment Data Summary for Ewen Slough

Characteristic	No Of Values	Maximum	Minimum	Mean	Median
Phthalate (PE)	10	740	690	715	710
Bis(2ethylhexyl) PE	5	1.22	0.34	0.69	0.62
diethyl PE	5	0.12	<0.1	0.11	<0.1
dimethyl PE	5	<0.1	<0.1	<0.1	<0.1
di-n-butyl PE	5	0.15	<0.1	0.11	<0.1
di-n-octyl PE	5	0.23	<0.1	0.13	<0.1

*all measurements in µg/g unless otherwise noted

Table 120
Sediment Data Summary for Deas Slough

Characteristic	No Of Values	Maximum	Minimum	Mean	Median
PCP	10	<0.02	<0.02	<0.02	<0.02
PCB	12	0.038	<0.005	0.0125	0.009
Carbon: inorganic	12	2700	<500	1305	1000
total	12	15100	8000	12267	12150

*all measurements in µg/g

Table 121

Ambient Water Quality Summary for Sturgeon Bank (Site E216048)

Characteristic	No. Of Values	Maximum	Minimum	Mean	Std. Dev.
Coliforms-fecal (CFU/cL)	5	640	160	geo. mean = 263	
E. Coli (CFU/cL)	4	580	160	geo. mean = 231	
Enterococci (CFU/cL)	5	67	2	geo. mean = 18	
Pseudomonas aeruginosa (CFU/cL)	4	<2	<2	<2	0
Nitrogen-ammonia (mg/L)	10	0.074	<0.005	0.034	0.028

Table 122
Ambient Water Quality Summary for Roberts Bank (Site E216049)

Characteristics	No. Of Values	Maximum	Minimum	Mean	Std. Dev.
Coliforms-fecal (CFU/cL)	5	17	2	geo. mean = 4	
E. Coli (CFU/cL)	5	14	<1	geo. mean = 3	
Enterococci (CFU/cL)	5	29	1	geo. mean = 3	
Pseudomonas aeruginosa (CFU/cL)	5	<2	<2	<2	0
Nitrogen-ammonia (mg/L)	7	0.333	0.01	0.092	0.109

Table 123
Ambient Sediment Quality Summary for Sturgeon Bank (Site E216048)

Characteristics	No. Of Values	Maximum	Minimum	Mean	Std. Dev.
PCP(µg/g)	7	0.08	<0.005	median <0.005	-
4ChlPhen (µg/g)	7	2.1	<0.005	0.366	0.770
3ChlPhen (µg/g)	7	<0.05	<0.005	median <0.005	-

Table 124

Ambient Sediment Quality Summary for Roberts Bank (Site E216049)

Characteristics	No. Of Values	Maximum	Minimum	Mean	Std. Dev.
PCP(µg/g)	9	0.011	<0.005	median <0.005	-
4ChlPhen (µg/g)	9	0.037	<0.005	median <0.005	-
3ChlPhen (µg/g)	9	0.012	<0.005	median <0.005	-

Table 125
Ambient Water Quality Summary for GVRD South 5

Characteristics	No. Of Values	Maximum	Minimum	Mean	Std Dev
Coliforms-fecal MPN (winter)	8	8000	1100	geo. mean = 4165	
fecal - MPN (summer)	20	30000	20	geo. mean = 773	
Enterococci (/100 mL)	4	45	20	geo. mean = 26	
Hardness-total	24	2293	69	577	558
calcium	24	163	14.5	48.3	37.3
magnesium	24	460	7.96	111.45	113.61
Metals - cadmium (dissolved)	24	<0.0005	<0.0005	<0.0005	0
chromium (dissolved)	24	<0.001	<0.001	<0.001	0
copper (dissolved)	24	0.004	<0.001	0.001	0.001
iron (dissolved)	24	0.13	<0.02	0.06	0.03
lead (dissolved)	24	<0.001	<0.001	<0.001	-
zinc (dissolved)	24	0.002	<0.001	median <0.001	-
Nitrogen-ammonia	24	0.15	0.03	0.08	0.03
pH	24	7.9	6.9	7.5	0.2
Sodium	24	3560	45	893	917
Solids - suspended	24	91	<5	24	25
Specific Conductivity	24	21300	361	5537	5295
Dissolved Oxygen	23	12.1	9.2	10.8	0.9

all values in mg/L except for coliforms (CFU/cL), pH)pH units), conductivity (μS/cm)

Table 126
1990 Dissolved Oxygen Concentrations and Bacteriological Indicators at GVRD Sites 4-14

Dissolved Oxygen (mg/L) - 1990					
	No. of Values	**Maximum**	**Minimum**	**Average**	**Std. Dev.**
Site 4	7	10.6	6.6	8.4	1.4
Site 5	11	10.4	6.8	8.2	1.1
Site 6	7	11.2	6.8	8.5	1.5
Site 7	10	10.1	7.1	8.1	0.9
Site 8	8	10.7	6.7	8.6	1.3
Site 9	18	10.3	6.9	8.4	1.0
Site 10	8	10.3	6.9	8.5	1.2
Site 11	10	10.8	7.7	8.6	0.9
Site 12	8	10.1	6.4	8.5	1.2
Site 13	10	10.2	6.9	8.4	0.9
Site 14	8	10.1	6.3	8.5	1.3
Fecal Coliforms (MPN/100 mL) - summer 1990					
	No. of Values	**Maximum**	**Minimum**	**Geo. Mean**	**St. Dev.**
Site 4	28	300	20	median < 20	-
Site 5	28	170	20	median < 20	-
Site 6	28	230	20	median < 20	-
Site 7	28	500	20	median < 20	-
Site 8	28	300	20	median < 20	-
Site 9	28	170	20	median < 20	-
Site 10	28	300	20	median < 20	-
Site 11	28	300	20	median < 20	-
Site 12	28	300	20	median < 20	-
Site 13	28	300	20	28	67
Site 14	28	300	20	median < 20	-
Fecal Coliforms (MPN/100 mL) - winter 1990					
	No. of Values	**Maximum**	**Minimum**	**Geo. Mean**	**St. Dev.**
Site 4	8	800	40	122	250
Site 5	8	800	40	84	261
Site 6	8	2400	20	115	815
Site 7	8	800	20	149	335
Site 8	8	500	20	80	163
Site 9	8	700	20	101	222
Site 10	8	2400	20	129	814
Site 11	8	1100	20	76	368
Site 12	8	2200	40	161	734
Site 13	8	1100	20	103	361
Site 14	8	700	20	100	230

Table 127
Bacteriological Indicators Summary for 1991 GVRD Sites 4-14

Fecal Coliforms (MPN/100 mL) - summer 1991					
	No. of Values	**Maximum**	**Minimum**	**Geo. Mean**	**St. Dev.**
Site 4	33	1300	20	30	224
Site 5	34	500	20	31	91
Site 6	34	500	20	33	91
Site 7	34	1300	20	median < 20	-
Site 8	34	1300	20	median < 20	-
Site 9	35	2300	20	31	385
Site 10	35	500	20	27	113
Site 11	35	600	20	median < 20	-
Site 12	36	2200	20	median < 20	-
Site 13	36	1700	20	median < 20	-
Site 14	36	1300	20	median < 20	-
Fecal Coliforms (MPN/100 mL) winter 1991					
	No. of Values	**Maximum**	**Minimum**	**Geo. Mean**	**St. Dev.**
Site 4	21	230	20	41	68
Site 5	21	300	20	52	95
Site 6	21	230	20	42	61
Site 7	21	500	20	52	122
Site 8	21	500	20	75	149
Site 9	21	500	20	50	135
Site 10	21	500	20	60	119
Site 11	21	800	20	54	182
Site 12	21	500	20	51	108
Site 13	21	500	20	50	116
Site 14	21	230	20	45	62

Table 128
Bacteriological Indicators Summary for 1992 GVRD Sites 4-14

Fecal coliforms (MPN/100 mL) - summer 1992					
	No. of Values	**Maximum**	**Minimum**	**Geo. Mean**	**St. Dev.**
Site 4	34	130	< 20	27	24
Site 5	34	170	< 20	median < 20	-
Site 6	34	110	< 20	median < 20	-
Site 7	35	170	< 20	median < 20	-
Site 8	35	170	< 20	median < 20	-
Site 9	35	110	< 20	median < 20	-
Site 10	35	80	< 20	median < 20	-
Site 11	35	230	< 20	median < 20	-
Site 12	35	70	< 20	median < 20	-
Site 13	35	110	< 20	median < 20	-
Site 14	35	300	< 20	median < 20	-
Fecal coliforms (MPN/100 mL) - winter 1992					
	No. of Values	**Maximum**	**Minimum**	**Geo. Mean**	**St. Dev.**
Site 4	21	230	< 20	47	67
Site 5	23	300	< 20	48	78
Site 6	23	230	< 20	41	74
Site 7	23	300	< 20	51	87
Site 8	23	260	< 20	52	83
Site 9	23	500	< 20	61	118
Site 10	23	800	< 20	65	180
Site 11	23	700	< 20	57	152
Site 12	23	500	< 20	63	147
Site 13	23	300	< 20	49	80
Site 14	23	230	< 20	54	65
***Enterococci* (CFU/100 mL) - summer 1992**					
	No. of Values	**Maximum**	**Minimum**	**Geo. Mean**	**St. Dev.**
Site 7	35	25	<1	2	6
Site 13	35	44	<1	3	8
***Enterococci* (CFU/100 mL) - winter 1992**					
	No. of Values	**Maximum**	**Minimum**	**Geo. Mean**	**St. Dev.**
Site 7	23	70	<1	10	21
Site 13	22	64	<1	13	19

Table 129
Dissolved Oxygen Concentration and Bacteriological Indicators Summary for GVRD Sites 1-4

Dissolved Oxygen (mg/L)					
	No. of Values	**Maximum**	**Minimum**	**Mean**	**Std. Dev.**
Site 1	7	10.4	8.1	9.4	0.9
Site 2	8	10.6	7.6	9.5	1.2
Site 3	7	10.7	8	9.6	1.1
Site 4	8	10.7	8	9.8	1.1
Fecal Coliforms (MPN/100 mL)					
	No. of Values	**Maximum**	**Minimum**	**Geo. Mean**	**Std. Dev.**
Site 1	23	500	<20	140	132
Site 2	23	700	<20	187	194
Site 3	19	800	<20	181	207
Site 4	23	1100	<20	252	256
***Enterococci* (MPN/100 mL)**					
	No. of Values	**Maximum**	**Minimum**	**Geo. Mean**	**Std. Dev.**
Site 1	9	110	3	37	33

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**)
Acclimation	To accustom test organisms to different environmental conditions as part of an experiment or analytical procedure. (cf. **Acclimatization**)
Acclimatization	The process by which an organism, through increased **tolerance** or physiological **adaptation**, adjusts to changes in its environment. (cf. **Acclimation**)
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**)
Adaptation	The ability of an organism to cope with its environment.
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**)
Anion	A negatively charged **ion**.
Anoxic	Oxygen depletion or deficiency; **anaerobic**.
Antagonism	Reduction or elimination of individual (separate) toxic effects when two or more substances are combined and act together. It is the opposite of **synergism**.
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.
Assimilate	To absorb, transform and incorporate substances or changes into an organism or **ecosystem**. In the case of water, its ability to accept wastes without impairing **water uses**.
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.
Carrying Capacity	The number of organisms and amount of exploitation that an **ecosystem** can support without damage or loss.
Cation	A positively charged **ion**.
Characteristic	A distinguishing trait, quality or property. (cf. **Constituent**, **Property**, **Variable**)
Chlorinated Hydrocarbons	Chemicals containing chlorine, hydrogen and carbon. Examples include pesticides such as DDT, aldrin, and dieldrin.
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 Exposure	Long-term exposure to a substance.
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**
Combined sewer	A sewage collection system containing both domestic sewage and stormwater.
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**)
Constituent	An essential part (physical, chemical or biological) of something. For example, pH is a chemical constituent of water. (cf. **Variable**, **Property**, **Characteristic**)
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 judgment 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.
Diffuse Source Pollution	see **Non-point Source Pollution**
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.
Dose	The quantifiable amount of a substance that enters an organism by ingestion or injection. Not the same as **concentration**.
Drainage Basin	An area of land drained by a river and its tributaries. A **watershed.**
Ecology	Study of living organisms and their relationships to one another and the environment.
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**)
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.
Flush	A sudden rush of water down a stream, as occurs during a **freshet**. Also, a rinsing or cleansing with a flush of water, as occurs at high tide.
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.
Guideline	Directing principle for action. (see **Water Quality Guideline**)

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.
Instream	Within the natural stream channel.
Instream Use	Use of water for fish and wildlife, recreation, power generation, navigation or other purposes without its removal from a water body. **Minimum flows**, water levels and quantities may be required to support instream uses.
Invertebrate	Animals without backbones.
Ion	Electrically charged particle. Positively charged ions are called **cations**; negatively charged ions are called **anions**.
Isomer	One of two or more chemical substances having the same molecular weight and percentage elementary composition but differing in structure and properties such as **toxicity**.
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.
Micro-organisms	Organisms too small to be seen without the aid of a microscope. Usually taken to mean bacteria and viruses, but also includes certain moulds and algae.
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 stream flows 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.
Mollusc	A large class of mostly aquatic animals which are soft bodied and usually enclosed in a single or double calcareous shell. Examples are clams, snails and octopus. (cf. **Shellfish**)
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.
Nearshore	The zone extending out from the shore to a distance where the **water column** is no longer influenced by conditions on or drainage from the land.
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.
Objective	A standard against which environmental quality at a particular location can be measured. Often used to guide environmental management decisions and practices to protect users, **designated uses** and the environment. see **Water Quality Objective**
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. Inter-changeable with **chlorinated organics**.
Organotins	Organic chemicals containing tin. Uses include marine antifouling paints, preservatives and lubricants. Highly toxic to marine organisms.
Outfall	The outlet of a sanitary sewer or stormwater discharge to a body of receiving water.
Oxidize, Oxidation	The chemical reaction or combination of oxygen with a substance.
PAH	A group of chemical compounds (**polycyclic aromatic hydrocarbons**) containing benzene molecules, released into the environment from atmospheric emissions, 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**)
Pathogen	An organism (usually a **micro-organism**) that causes disease or death.
Pathogenic	Causing or resulting in disease or death.
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.
Pesticide	A chemical substance used to kill pests. Includes herbicides, insecticides, algacides, fungicides, and others.

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.
Photosynthesis	The process by which the **chlorophyll-**bearing cells of green plants use sunlight to make their food from carbon dioxide and water, and give off oxygen.
Physiology	The study of the processes which go on in living organisms.
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**
Precision	The degree of agreement among replicate analyses or measurements of a sample. (cf. **Accuracy**)
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**.
Productivity	The rate of replacement or increase in organic matter by biological processes such as **photosynthesis**. It represents the amount or **biomass** of food potentially available to consumers within an ecosystem.
Public Water Supply	A source and distribution system of domestic water for a community or group of individuals.
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**)
Riparian	Refers to land bordering a water body.
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.
Side channel	A branch of a river with both ends connected to the **main stem** .
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 **main stem** .
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.
Smolt	A juvenile **salmonid** when it first enters salt water.
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**)
Stream flow	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 fibers 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.
Sustainable Development	A vision of economic and social development where growth and expansion is within the limits required to sustain long-term environmental well-being. The intent is to ensure that the use of resources and environment today does not damage prospects for their use in the future.
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**.
Thermocline	A well-defined vertical temperature change or boundary; often associated with **stratification** in lakes.

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.
Tolerance	The ability of an organism to withstand adverse environmental conditions.
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**)
Toxicology	The study of the adverse health effects of chemicals on living organisms.
Toxin	A toxic or poisonous substance capable of producing an adverse response in an organism, injuring, impairing or killing it.
Trophic, Trophic Level	Relating to processes of energy and nutrient transfer from one or more organisms to others in an ecosystem. (cf. **Food Chain**, **Food Web**)
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.
Wastewater	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 Quality Standard	A **Water Quality Objective** that is recognized in enforceable environmental protection laws of a level of government.
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.
Watershed Boundary	The imaginary line or divide separating **headwaters** which flow to different **drainage basins**.
Wetland	An area of land such as a marsh or swamp that is continually or periodically inundated by water, usually two metres deep or less. Organic **productivity** may be very high.
Zooplankton	Microscopic floating or drifting animals. (see **Phytoplankton**)

Appendix 1
Fraser River Water Quality and Recreational Use Public Survey

Summary of Fraser River Water Quality and Recreational Use Public Survey				
Number of respondents:		156	100%	
Number of respondents from FREMP/FBMP:		134	86%	
Number of respondents from FBMP:		10	6%	
Number of Respondents from Richmond News:		2	1%	
Number of Respondents from Fish & Game Mag.:		10	6%	
Interest in condition of the Fraser River (Avg. years):		22.62		
Most common Activity:	Hiking/walking	often-45/occassionally.-80	125/156	80%
2nd Most Common Activity:	Nature study/Bird watching	often-28/occassionally-70	98/156	63%
3rd Most Common Activity:	Shoreline Activities	often-30/occassionally-59	89/156	57%
4th Most Common Activity:	Crabbing/Fishing	often-18/occassionally-23	54/156	33%
5th Most Common Activity:	Power Boating	often-14/occassionally-25	39/156	25%
6th Most Common Activity:	Kayaking, canoeing, rowing	often-11/occassionally-23	34/156	22%
7th Most Common Activity:	Swimming	often-4/occassionally-15	19/156	12%
8th Most Common Activity:	Sailing	often-0/occassionally-6	6/156	4%
9th Most Common Activity:	Water/jet Skiing	often-2/occassionally-2	4/156	5%
10th Most Common Activity:	Wind Surfing	often-0/occassionally-3	3/156	2%
Most Valued Characteristic:		Natural Beauty	106/156	68%
2nd Most Valued:		Diversity of plant/animal life	90/156	58%
3rd Most Valued:		Greenspaces/parks	85/156	54%
4th Most Valued:		Trails along dykes	52/156	3%
5th Most Valued:		Non-comm. fishing	27/156	17%
6th Most Valued:		Cult. and Spiritual	27/156	17%
7th Most Valued:		Access and Views	21/156	13%
8th Most Valued:		Diversity of Rec. Activities	18/156	12%
9th Most Valued:		Marinas	18/156	10%
10th Most Valued Characteristic:		Other	0/156	0%
Valued Characteristic Most Sensitive to Change:		Diversity of plant/animal life	67/156	43%
2nd Valued Characteristic Most Sensitive to Change:		Natural Beauty	34/156	22%
3rd Valued Characteristic Most Sensitive to Change:		Non-comm. fishing	22/156	14%
4th Valued Characteristic Most Sensitive to Change:		Greenspaces/parks	18/156	12%
5th Valued Characteristic Most Sensitive to Change:		Cult. and Spiritual	11/156	7%
6th Valued Characteristic Most Sensitive to Change:		Access and Views	7/156	4%
7th Valued Characteristic Most Sensitive to Change:		Diversity of Rec. Activities	4/156	3%
8th Valued Characteristic Most Sensitive to Change:		Marinas	3/156	2%
9th Valued Characteristic Most Sensitive to Change:		Trails along dykes	0/156	0%
Respondent's Home Community:		Abbotsford	21/156	13%
		Chilliwack	19/156	12%
		Surrey	17/156	11%
		Langley	14/156	9%
		Vancouver	11/156	7%
		Burnaby	9/156	6%
		Mission	8/156	5%
		Richmond	4/156	3%

Public Responses to Questions from the Fraser River Water Quality and Recreational Use Survey.

	What changes have you experienced in your use of the river?
1	Beach surfing has reduced, walks, parks, public access GVRD parks have all increased
2	More garbage in it.
3	Increased traffic. Less wood debris but more land based garbage. Increase in minor diesel and oil contamination.
4	From general knowledge of it to first-hand use (I work at Fraser Surrey Docks).
5	Poor WQ, (oil & fuel discharges on surface increasing), loss of public access to waterfront in N.A., marshes continue to be degraded, air quality-very poor in vicinity of STP and commercial activities.
6	less fishing
7	polluted water
8	Recognizing the many stewards of the river doing their job-First Nation Police-RCMP-Port Authority-local police-Children Adopt a Stream-BC Rivers Day-GVRD-Park Staff all want to participate.
9	Since my time-line does not go back to far, I'd have to say the at the transformations being effected by FREMP on local beaches constitute the greatest changes I've seen.
10	Major deterioration of WQ, more marine use (commercial and recreational).
11	loss of habitat, woodlands, marshes etc.
13	more boat traffic
14	nothing in particular
15	Less Dolly, Rainbow and Cutthroat Trout, duck's, Chinook and frogs.
16	it's getting more polluted
17	increased regulations - appears to be cleaner
18	more pleasure craft - more noisy jet boats
19	Increased usage by recreational users. Introduction of jet-skiing in Deas Slough. Fishing not as good as it used to be.
20	Since park opened at Kanaka Creek., have gone there often.
21	I spend less time on the river than when I was younger.
22	none
23	more activity in and around - more people
24	no changes
25	Increase in development, more parks
26	none
27	diminished ease of access
28	When working the N. Arm on river tugs in early sixties and then experiencing working again in late seventies one could notice the change to the better regarding pollution on some regards-it used to be dirty work especially in the highly industrialized area in and around Lulu Isl.
30	more intensive use by sports fishermen, higher use by aboriginal fishers, WQ appears to have improved
32	more people
33	more use(s)
34	increased use as municipalities and regional districts gradually increase public access to the river
35	it smells more now when I play golf
36	Increase in the use of the river for recreational and tourist projects. Building up of housing along the river, golf courses silting up the river.
37	increasingly uncomfortable with the pollution
38	natural silting, many changes towards the estuary caused by commercial and residential developments
39	seems to be dirtier than 10-15 years ago

40	not much change visually, but raised concern about what is said, read or heard
41	More people using dykes for walks, log booms are cluttering foreshore and posing safety issues, need for more public access to adjacent FR through constructed public trails and walkways
42	less dangerous because the log booms are tied and don't disturb the shoreline, more protection from industries along the river, parks and trails along the river, secondary treatment
43	In the Central Fraser Valley more people are looking for recreational opportunities.
44	The beaches of Barnston Is. used to be lovely. Now the north-eastern tip, at one time a lovely sandy beach, is obliterated with dredges and motorcyclists.
45	More cautious as to what gets into streams and creeks that end up in the FR.
46	I am a pensioner now and retired. The only use I have of the river is what I put down on paper. I have done research and talk to some of the early pioneers about the FR.
47	I have moved from strictly on-shore activities to being on small water craft on the river itself.
48	Higher pollution, increased boat traffic, increased noise, higher shoreline usage
49	Hopefully reduced agricultural discharge into the river since implementation of Agricultural. Waste Guidelines, promotion sustainable farming practices(including waste handling, reduced chemical fertilizers etc.)
50	More pollution, too much driftwood.
51	Many more pleasure boats, erosion of the banks, decline in wildlife, birds, and fish(especially), larger mills, less trees!
52	The lack of good charts due to moving sand bars and floating debris floating on the water have prevented us from boating on the river.
53	fewer fish
54	usage has remained about the same
55	more crowded
56	Increased use by dog walkers who do not "scoop".
57	Increased algae growth in Hope Slough and garbage; garbage along rural drainage canals; Promontory area-dirt runoff a major problem since development started in environmentally sensitive areas-creeks containing Pacific Giant Salamanders washed out
58	less waterfowl present
59	more people/crowding
60	just becoming more aware of all the "stuff" in the river
61	Reduced number of fish of all types since 1980's (especially cut throat trout in spite of catch and release). Very substantial increase in number of sport fishers through out the year.
62	less aquatic life in the river; recreational use (i.e. power boating, jet skiing) has increased
63	place of residence makes use of river infrequent, though considered worthwhile/enjoyable when visited
64	log booms diminish access options and pose safety risks, more people using foreshore
66	Appears to be more discharge of pollutants from industry and in particular sewage.
67	More restricted access(gates and fences), more garbage in the water, more people making more noise and mess.
68	dirtier water, more silt.
69	none
70	More people using trails and fishing.
71	It is more polluted and it has less fish every year.
72	Increase in residential development and loss of access. Loss of natural settings.
73	less fishing time, no swimming now
74	There will be an increased demand for foreshore use as the population spreads up the FV. The river is a measure of how we are doing.
75	Sturgeon are scarce. Water is less lively, used to be tiny organisms in it when we swam. Is dirtier, smellier. Oolichans are less, salmon are less, stocks seem depleted.

76	Pollution has increased, there is a sign at Gary Pt. in Steveston "Fraser River unsafe for bathing" which confirms official recognition and acceptance of this.
77	Construction along shores-setback, commercial tours Langley-west, dyke improvements-parks along foreshore.
78	none
79	degradation of shoreline, garbage lying around. Lots of debris.
80	The trails alongside and tables for picnics
81	less industrial-recreation advances
82	silting, lower tides on low water, clearer water in spring months.
83	Indians restrict access to river over their land
84	Smell of the water
85	Never used it much because of the negative information available about pollution.
86	As a youngster I used to fish the river more frequently.
87	It seems to be under some pressure from development, industrial and primary sewage dumping.
88	none
89	Over fishing by natives, more and more pollution.
90	decrease of fishing opportunity. Less fish more pressure from fishermen.
92	Loss of shoreline and access
93	Great increase in water skiing and personal water craft use.
94	not clean enough yet.
95	The river is cloudier. More marine traffic. It's harder to find a place on it that's quiet. Surrey's portion of the river has been spoiled by poor planning.
96	None-more time on streams
97	Increased number of jet skiing. Fishing pressure greatly increasing
98	Much more recreational boating with lack of knowledge of river. More passive shoreline watchers. Much more varied bird life in recent 10 years. Jet ski users out of control.
99	Less access to it, more activity on the river, dirtier banks.
100	Water quality decrease. Much harder to catch fish. More garbage on shoreline.
101	More public access and parks have been developed.
102	none
103	Water too dirty. Too much traffic to canoe safely.
104	Very little as there is not much to do anyway. It is very difficult for the public to experience the river as most of it is lost to industrial use.
105	More pollution from industry, housing.
106	Boating (canoe), skating (1960's), fishing, bird watching and some animal life.
107	More pollution of the water itself-better control of floating debris. Better flood and erosion control.
108	Sturgeons are found dead on the shore.
110	It is getting more polluted. Garbage is thrown on shorelines. Erosion of the banks of the river.
111	It has become commercialized heavily in the Delta area, i.e. Surrey Docks
112	Lessening
113	none
115	Muddier.
119	Increased erosion and commercial usage (gravel pits, etc.). Pollution.
121	none
122	It would appear to be more polluted and thus curtail the activities stated previously.
123	Don't go as often, find it dirty. Swam in Hope River as a child and would not allow my teens to do so.
125	none
128	Moved into area where we can reach the FR occasionally-about 1 1/2 years ago.

130	As a new comer I am just becoming aware there might be/is a problem.
131	As a young person I swam and fished in the FR. My children and I would picnic along its banks. Now I seldom go along it.
132	Garbage along shoreline. More people, more damage to park bench, loss of government money in upkeep.
133	I use to swim in the Fraser but no longer.
135	I would not like to eat fish caught in the FR.
136	none
140	none
142	none
144	The fishing has declined.
146	I do not use the river for recreation but I'm concerned about WQ especially for fish stocks.
148	It appears dirty.
149	None
150	? changes-allowable fishing.
151	We are new to the area so we appreciate its beauty from a distance.
154	Much more traffic, debris, septic waste including toilet paper.
155	I have used it more since moving closer to it in 1987.
156	decreased access personally, increased urban population pressure.

	Have these changes affected how you use the river?
1	I go out with the family bike riding, dog walking, etc. more often.
2	No.
3	no
5	do not continue recreational activities in North Arm, access-no longer use portion of shoreline, marshes-noted less bird life, viewing of floating contaminates (sewage, etc.) during discharge events, Air quality-do not hike in adjacent recreational areas.
6	visit river less
7	I don't swim here. I boil my water before I drink it sometimes, but don't know if I need to.
8	Yes, I recognize a problem like oil or see dumping going on or other illegal practices there is someone to phone to report
10	no-but have concerns as to future of fish spawning and loss of tourism
11	loss of wildlife and waterfowl
13	less peaceful
15	stay home, get drunk, watch TV
16	no
17	regulations for simple maintenance of long time barge berths are now a problem
18	no- still enjoy kayaking - tow boats are courteous and slow down
19	power boaters effect the paddle sports that I enjoy
21	no
23	no
25	Diminished access in general, but improved access where parks have been established.
30	concerned some salmonid stocks may be over harvested by both sports and native fishermen
32	no
33	more people have found this recreational resource and are now using it
34	increased use as stated
36	I would not, knowingly, eat fish from the river. I would not want river water to get directly on my body.
37	won't eat fish from the river, don't care for children swimming in it

38	no
39	Am somewhat concerned of the pollution to fish and it's affects on the food chain, especially human consumption
40	no, I still appreciate and am in awe of all that it is
41	full potential of passive public use of FR and foreshore is becoming more difficult
42	great improvements, safer to boat, shores are alive with life
43	not yet
44	Yes, since I do not land there any more with my canoe, nor do so the geese.
46	I would not want to see my grandchildren swim or drink the river water, like I did.
48	Try to plan river visits during early morning in the summer or during bad weather
49	no
50	Much less water activities involving body contact with water.
51	The amount of people and industries who's presence has ultimately invaded our river systems; access to the river has been made very easy via roads, marinas, parks etc. "mowing over and moving in!"
53	Yes, I don't fish the Fraser anymore.
54	no
56	no
57	I'd enjoy canoeing trips more if less garbage. What are we leaving for our kids?
58	yes, not as good for birding as in past.
59	Don't use it as much.
60	It certainly is not as enjoyable being by the river when you are aware of all the "junk" in it.
61	Fishing method 98% fly for 12 years
62	The noise from power boat and jet ski is a disturbance to a quiet outdoor activity.
64	not as natural as it once was, seek out other areas besides Fraser River to recreationalize.
66	Yes- don't go near areas directly downstream from sewage outfalls.
67	If we can't get down there, we don't go. Because of the pollution and garbage left by others it is becoming a less desirable place to go.
68	Yes, if the water is dirty, fishing is poor.
71	The fishing is half as good as it was 4 years ago.
72	Change in location of hikes. some good trails formed in the last 6 years.
73	Family's last swim in 1965 brought on a very annoying rash
74	Human impact must be minimal
75	Yes we know the difference between erosion, silt and characteristics of a young river and almost polluted. If it didn't move so fast we would be in trouble. Heavy contaminants forced us to fish and recreate in other older rivers.
76	We have to be careful of out children's contact with water.
77	Yes, walking/hiking, parks nice to visit. New West area built up more. Has agricultural pollution diminished?
78	no
79	People don't like to walk beside the river with all the debris and garbage around, very unsightly in places.
80	Yes, it's a nice place to have lunch or dinner
81	less industry/less marine activity
82	Channels have changed from silting.
83	Yes, it restricts where I can go.
84	Yes, we no longer let our children play in the water.
85	Tend to avoid the river.
87	No
88	No

89	I spend about 1/2 hour every time out picking up garbage (i.e. bottles, plastic bags)
90	I fish less often. Spend less money going fishing and buying supplies.
92	Access for kayaking is more restricted.
93	They have made it more difficult to find quiet, peaceful anchorage.
94	I will not swim until clean. I do love swimming.
95	I don't use Surrey's portion anymore. Coquitlam's portion has been spoiled by putting a highway through it.
97	Indians won't allow access to some areas, claim it's Indian land
98	More caution in normal navigation. Many more "good samaritan" towing of broken down recreational boaters.
99	There are places where I can not go anymore and places where I wouldn't go anyway.
100	When camping, I used to boil water from FR, now it is so bad I bring water.
101	Yes, easy access to the river
102	no
103	Don't swim in it anymore. Unsafe to canoe.
104	Cannot enjoy the river due to limited access.
105	No
106	No but we are sensitive to the environment, birds and fish.
107	I wouldn't swim in it now
108	We suspect that it's deadly polluted. It stinks in Surrey, New West, and Steveston.
110	It is not pleasant to walk along river banks with pampers and beer bottles on the ground.
111	Access is not as easy.
113	no
115	no
119	Pollution is strong concern for water quality
121	no
122	It has affected my family-fewer outings.
123	Less activity.
124	no
132	Not so that I have stopped hiking with kids but it is not a natural beauty anymore.
133	Yes it stinks and is filthy.
135	no
136	no
140	no
144	Yes, don't fish as much.
146	The build up of industry-affects hiking trails, bird life, etc.
150	no
154	Very large tug and large traffic cautions our use of small run-abouts on the North Arm.
155	All the uses I have listed previously have been since 1987. They include most of the members of our household of 10.
156	Yes, the river and valley are absorbing more of my pollution. But personally I don't go there as much as before.

	What are your thoughts about the current water quality (WQ) of the Fraser River (FR) at this time?
1	I would consider the WQ to be poor, and getting worse. Sewage outfalls and storm water/sewage pipes are a real concern. So too is "accidental spills" into urban creeks - domestic disposal of paints, toxics etc.
3	Visually, the WQ appears to be quite good,
4	WQ is generally good.

5	N & Middle Arms are still visibly polluted-sewage overflows, oil and fuel on surface, commercial pollution, air quality problems contributing to water degradation.
7	I don't believe the WQ is good due to pollution from WWTP and industrial (including transportation) pollution.
8	The current WQ hasn't changed for the better since 1985, it's worse. Management. resource people are more afraid of losing their jobs to fiscal problems. Fish are now endangered more since 1985. 9 years going on 10 and the problem is worse.
9	I realize the condition of the Fraser is considerably better than that of the Hudson or Delaware, but I believe that BC has the public support and ability to be a world leader in environmental issues.
16	It needs to be improved
17	The WQ of the FR seems to be improving and we should continue working for more improvement.
18	WQ seems okay
19	WQ improved, at least to the point where swimming could be considered safe in protected water ways.
22	WQ is generally good at the present time. One could question why, during this time of fiscal restraint, are hundreds of millions of dollars being spent on upgrading Annacis. and Lulu when there is no demonstrated effect from them in the estuary. Can our society afford this?
24	generally good. some concern about levels of Fecal Coliforms in river during certain times of the year.
25	Not as bad as many other industrial rivers. Believe progress is being made in protecting and perhaps improving WQ. I applaud current efforts to restore the FR (FRAP, FREMP etc.)
26	WQ is gradually deteriorating. The river has always appeared dirty because of the amount of silt in it. It is the unseen pollutants (municipal, industrial and agricultural wastes) which concern one.
28	I believe the natural flow of the water with natures own pollutants tolerable because that is natural. It is the carefree and illegal pollutants that run and seep into the river.
29	generally good, with 'hot spots' in sloughs and areas with low flushing of water.
30	WQ has improved lately.
33	WQ between Hope and Chilliwack is all right and improving.
34	My main concern for Fraser Valley WQ relates to underground WQ rather than surface WQ. Leaking old gasoline & oil storage tanks pose a real threat to underground WQ. Fraser Cheam Regional District area, Canyon to Chilliwack, contributes relatively little to surface water degradation.
35	Wouldn't drink FR water, that's sad.
36	We are killing this river-sturgeon are dying-bottom fish are polluted. Too many unrestricted industries use this body of water.
37	Fish are the 'canaries in the mines', if their numbers are depleting, we are in danger. Although, because of the recent clean ups it is improving, but the river is still far too polluted.
38	I would like to restrict commercial uses which infringe on the river. I do not believe the river should be used for waste disposal and have concerns when residential developments change drainage patterns.
39	Any effluent from human activities should be limited to the natural WQ of the river
40	It bothers me, I wonder about contaminants, disease, cancer related diseases, general health of all species related to the river.
41	WQ seems questionable for drinking, swimming, etc. but the river is still a 'draw' for a range of other recreational opportunities.
42	poor now
43	The use by salmon, not the use by humans for recreation, should determine the quality of water to be maintained.
44	In spite of your positive image report on WQ in the FR, I still feel the water is far from clean. While I do have my occasional dip into the 'brew', particularly if my boat capsizes, I would not recommend it to be used for cooking or drinking untreated
45	WQ probably not as good as it should be, but we have to accept the fact that with the increased population and activities in the valley it never will be perfect.
46	The James STP (at Matsqui) and the Aldergrove STP (at Glen Valley) are the only place in the FR that the current seems slowest. The elevation between Haney and Sumas is almost level, which makes both outfalls

	going into stagnant water.
48	Water quality is dropping annually.
49	from information provided, appears the River is in pretty good shape.
51	Large mills and industries will be the death of our river as we know and love it! Regulations, legislation, and laws are made to help protect our innocent waters.
52	For 25 years my family has grown rainbow trout and arctic char in two watershed areas of the Fraser. Development in one of these watersheds (Silver Creek) has caused the water quality to decrease so much that we feel that there is limited time left to farm
53	I believe the way we treat the river is disgusting, there is more to life than market economics.
54	Seems to be extremely poor
55	Industrial pollution causing pollution.
56	WQ is under siege by intense agricultural drainage and runoff and by increased sewage production by expanding housing.
57	I believe the FR is being used as a dumping ground for partially treated sewage and effluent from municipalities and commercial operations. While the drinking water we receive from Elk Lake may be satisfactory, I'm not so sure about that coming from wells in the area. These may be affected by leachate from our landfill, farms and households. What is really known about the interactions of various chemicals used by industry and the consumer?
59	River is fairly good at this time
60	It's probably a lot better than the water quality of many of the worlds rivers, but we need to do our utmost to reduce the loading of pollutants
61	My knowledge of the water 'quality' is limited to visual, to this degree, during the 90's, it appears to have improved.
62	The current water quality is extremely poor. I suppose this will improve once the Lulu Island and Annacis Island secondary treatment plants are in operation.
63	Literature would suggest in general that water quality is continually improving but in the writers opinion the implementation of improved municipal sewage discharges it too slow (though now in a long process)
64	Water quality seems to be more silty &murky.
65	Current WQ not good due to Municipal and District Sewage dumping of effluent, treatment generally primary-governed by financial restraints & so river WQ suffers.
66	It appears today that the water supply system to the lower mainland for human usage is stretched to its limits during the years of low precipitation. In years to come, as population density increases, water shortages, particularly in summer will increase
67	I worry about the number of industries and housing developments along the shore and the pollution flowing into the water.
69	The river is severely polluted and of poor quality for most recreational activities.
70	I believe the water is polluted by sewage and industrial contaminants.
71	I think it is getting dirty each year. It is beginning to look like nobody cares.
72	Important to enforce the dumping of heavy metals organochlorides & often toxic waste at all cost. Biodegradable material and bacterial conc. should be kept w/in reasonable limits but to completely eliminate it would cost alot ,money better spent elsewhere.
73	The river is cleaner and there is more bird activity than 25 years ago. No DDT and less bark and raw sewage are found.
74	Log booms are far too extensive.
75	The FR is relatively clean, young and wild.
76	Apparent official acceptance of deteriorating water quality (industrial pollution, mill effluent , sewage, mining wastes, etc.) worries me.
77	Sewage: expensive-remove all 1 &2ary treated sewage, all our wastes should be as pure as possible. Stormwater runoff-could this be run through a cyclone filter before river discharge-don't have to be expensive just sufficient to handle storm flows.

78	Careful control of human activities & development is the single most important aspect of the river we must allow the river to sustain its ecosystem and act accordingly-No new foreshore development
79	It's not very good. There is too much being pumped into the river. We must decide whether we want anything to live in the water.
80	It seems dirty sometimes.
81	Deplorable amount of untreated sewage and/or permitted to leach in the river system from source, creating a vast sewer of an unpolluted system.
82	I don't like the rising water temp. I don't like untreated sewage dumped in the river and leaching from Van. City dump and landfills in N. Delta.
83	Sedimentation on lower FR is heavy, and pollution compounds the adverse impact on wildlife.
85	Believe the FR is polluted & even dangerous for any in-water activities.
87	WQ is very poor. I would like to see FR brought back to more sustainable water quality.
88	It is terrible, always has been and always will be. Just leave it alone.
89	The water condition is poor.
91	Better now than 15 years ago.
92	I have long wanted to kayak Hope ->NewWest. but information is very limited & the debris trap may be a hazard.
94	Still not clean enough.
96	Been led to believe there's too much pollution. There's not much point in salmon enhancement if we're releasing them into a hostile environment.
98	Present WQ is reasonable but will soon deteriorate unless sewage treatment at places like Annacis Island are upgraded.
99	The river below Hope is a septic sewer.
102	Good quality. Protect it by good planning of any type of development
103	New Annacis water treatment plant will help.
104	FR WQ is satisfactory.
105	At present I think the foreshore could be vulnerable due to pollution from industry along th FR. I am sure that big housing developments in Richmond & New West. will be a major contributor to the pollution.
107	Man's ability to pollute are astounding. In 1967 there were 60 outlets running into the river 4" to 3'. Today there are still 53 outlets doing the same thing.
108	We have to stop using chemical detergents or at least use some system to purify the sewage.
109	To concentrate on what flows or goes into the river from boats, houseboats, industry (sawmills), etc.
110	The river is very dirty. Waste is being pumped into the river and people are not being censored for dumping.
111	There have been promises that the FR could be cleaned & pollution from industry (i.e. leachate from landfills) stopped. There has not been much evidence. Even the sewage plant hasn't been upgraded.
112	I don't know how the river can be protected in the future, but it is a shame to allow the continued pollution of the water.
114	They are good compared to other populated areas.
115	Too much soil erosion above Hope, new forestry practices leaving the border.
119	Increased population along shoreline has increased need for proper disposal of sewage so that septic tank systems need to be replaced by proper sewage treatment so pollution does not increase along with population
120	Pollution is most evident.
121	Dirty
122	What happens in the next 10 years. Will we see swimming without problems; will the spiritual quality improve? It can if something is done about it now.
124	less pollution
125	The water under the Pattullo Bridge looks like sludge.
126	I don't know enough about the river to comment.
128	Need to upgrade and diligently maintain waste disposal treatment.

129	Pollution
130	I have appreciated that the FR is a "working" river & I have enjoyed seeing all the traffic. I would hope that this could continue- safely and with as little damage as possible to the ecosystems.
131	All of our waterways and natural resources are in jeopardy. We need to re-think our values in relation to these.
133	It is very polluted and should be forcefully cleaned up.
134	Keep the pollution out of the river. Don't remove the trees from along the river. Cut down on erosion.
135	I feel the river is terribly contaminated!
136	Concerns about pollution and fishing rights.
138	People canoeing on the river need to feel the river is minimally contaminated.
145	We must protect our water. I have just returned from Istanbul and the sea is very polluted, old gas cans, logs, raw sewage- all do not make for a pleasant experience. This too could happen to the FR if we do not look after it.
146	With increased urbanization I would imagine that WQ is decreasing.
148	They have cleaned up the Thames in London and the Hudson in New York, maybe we can do the same with the mighty FR.
151	I do not know what measures are being undertaken to clean up the river and preserve the natural beauty and natural habitat.
154	Having moved to Surrey from Kamloops I find it inexcusable that the GVRD is only now upgrading its sewage treatment on Annacis Island to Secondary. I am willing to pay my share.
155	I hope the WQ could be improved significantly. Working to clean the river up IS DO-ABLE.

	What changes would you like to see?
5	Monitoring of all discharges into river, oil & fuel discharges controlled (regulations and fines), Air quality-dusts, wood chips etc. reported and fined.
6	less industries and have their sites cleaned and greened up, reduction in pleasure boating using fossil fuels, reduction of marinas, better protection of all watersheds feeding Fraser i.e. less housing, urban sprawl.
7	Everyone must promote pride in their environment and understand better how individuals and corporations' actions impact WQ.
8	priorities must be made for water export, groundwater management., water pricing, regulating activities in and about streams and protection bylaws that jail offenders of safe drinking water regulations.
9	Both the public and industry ought to be expected to clean up their habits when it comes to messing around with something that ultimately does not belong to us.
10	More awareness in the public sector as to the significance of the FR (and it's reliant contiguous lands) on the future of BC and Canada.
11	much tighter enforcement of existing discharge and dumping regulations, much tighter zoning controls to protect remaining green habitat zones and river estuary fish habitats.
12	I went out to volunteer with FREMP for a habitat restoration workshop on Lulu Isl. The event was very well organized but I was very angry about its purpose. We gathered to pick up the woody debris and logs from the shoreline of which there was huge amounts. It really seemed crazy to me that FREMP, a publicly funded organization was calling on volunteers to clean up woody debris that was the result of log booms breaking loose. Why isn’t the forest industry out there cleaning up their own mess! (Cont’d on next question)
13	Save shoreline from massive housing developments, save unique areas-Surrey Bend, etc., save green space
14	Do no (more) harm.
15	1)more flood lands made 2)100 ft. green on all creeks 3)park land with own gates 4)no commercial fishing 5)log storage & sorting in half 6)wood clean up improved 7)cut fish hatchery production 8)don't promote rec. activity. on FR LEAVE IT ALONE!
18	would like to see log salvagers take all loose, square cut logs, not be so selective!
20	need to control forest industry sediment, escaped logs, bark etc. also human litter and industrial waste
21	I would like to see the prohibition of dumping of any potentially harmful substances including human waste.

24	I feel closer monitoring of sewage treatment very important. Also closer monitoring of all harmful contaminates should continue on the river.
26	Society is awakening to how we are polluting our environment, including the FR.
28	People have to change first before our river returns to being a river other than a 'sewage and garbage outlet'. More control needs to take place.
29	storm sewer discharges treated before entering the FR, especially combined sewer discharges during periods of wet weather.
31	the river dredged and deepened along the Agassiz/Harrison River stretch and the river banks better protected from erosion.
33	steps should be taken to see these initiatives followed further down the river
34	Worry about issues such as fertilizer, hormones, wood preservatives (at mill in Boston Bar), nitrates from agriculture. and the potential for toxic spills from road, rail or pipeline transport.
35	see salmon remain in the river and the water level remain high.
36	1) no logging for at least 3 miles up the tributaries, 2) closer control over industry using the river as a dumping ground. 3) limit the proliferation of marinas along the river.
38	I would welcome the building of another bridge but would hope that careful consideration be made to the ways in which this would affect the river.
40	I would like to see stiff fines on Polluters and abusers, and laws produced and put into effect about cleaning the river and areas up.
41	Limit control, decrease amount of industrial and public pollution. More recreational enhancement of river will help educate public of benefits of river and need to protect it.
42	hope to see my grandchildren swimming in the river, the fish healthy, no toxic chemicals from the shores, production plants that would return tested composted human feces to the soil
45	We need to do the best we can to keep pollution to a minimum.
46	There are only 4 months/yr. that there is a flushing action and the other 8 months the tide floods, so that it takes days before it reaches the sea. In between time the sediment has settled to the bottom. We wonder why our sturgeon are dying.
47	Important changes would include green-space along shore-lines that ensured a wider ecosystem was not impacted.
48	Every community that discharges sewage or garbage directly or indirectly into the Fraser should have treatment plants. Logging companies and mills should clean up the wood debris.
49	Would like to see greater enforcement of agricultural. waste regulations to reduce inputs of agricultural contaminants-mainly in sloughs, channels, canals and tributary ditches.
50	The water could be protected from log debris. The logging companies should be held responsible for some of this debris. Also sewage is a major concern because alot of boats and houseboats still dump raw sewage into the River though it is not permitted.
51	Zero tolerance, fines; people and companies should be held accountable for careless chemical dumping, no more slaps on the wrist, prosecution for protection phasing out chlorophenols and other chemicals.
52	Storm sewers and contaminated water are 2 areas of concern. Silver Creek flows into F.R. 2 km from our farm. 2nd farm in Hatzic Valley, we draw pure water from artesian springs to feed the farm. Proposed quarry 1.5 km away makes us aware we are vulnerable.
55	Stricter control necessary for pollutants caused by industry and development.
56	Inc. education for households to save &reduce water, fertilizer, lawns less & convert large lawn areas to ground cover, educate farmers in care of stored manure, monitor and enforce regulations., charge and penalize the guilty, fine ships for dumping & industry for toxic w.
57	from wells in the area. These may be affected by leachate from our landfill, farms and households. What is really known about the interactions of various chemicals used by industry and the consumer?
58	Stop dumping of municipal sewage; enhancement of trails; restriction/regulation of power boating; elimination of water/jet skiing.
59	stop all untreated and primary sewage discharge-secondary treated only. Work harder at removing wood debris from up river.

61	I have read Item 7(WQ Management). I would like to see the Water Act applied. I would like to see fish have a legal right to 'quality' water under that Act. I particularly like the quote of the West Least Environmental. Law Assoc. on page 8 of item 7.
62	Industrial discharge should be monitored and regulated more closely. Sanitary discharge from boats and boat houses should be banned completely.
64	MOE & DF0 should take proactive approach to educate public of ecology, history & future of F.R. through signage, interpretive displays and park land supervision.
65	Changes necessary would require more stringent monitoring of dumping & tighter evaluation of quality allowed to be emptied into the FR.
66	It’s incredible to think that Canada’s largest FW river can not be accessed for human consumption because of industrial, animal and human pollution. We need to address this situation now to provide safe water for children of the future.
68	No more raw sewage
70	I would like to see restoration to as natural state as possible- legally enforced.
71	I would like to see it become filled with fish more often from the fisheries.
72	Maintain forest cover around tributaries to prevent periods of massive runoff. Plan green spaces between development that large size. Encourage local communities to build access trails & river walls along the river.
74	There must be at least 50 feet for the FR along its banks with no development allowed, only! Exception is when absolutely proved that a particular interest needs foreshore. This does not include housing.
75	To keep it as close as possible to natural, a cradle to grave system of monitoring commercial, industrial activities and discharges is relatively simple. Including recreational riverside activities.
76	As a commercial fisher, salmon marketer, father and recreational canoeist, I am concerned and disgusted with what is happening to the FR. I would like to see already existing laws (e.g. DFO) enforced.
77	Agriculture Wastes: Waste handling practices should be enforced. Manure still running freely-only small % of farming community is guilty of inattention
78	Restoration of lost floodplain & marshlands. Removal of dykes, access roads. & humans in certain areas key for salmonid & bird habitats. Untreated Municipal waste discharge must be stopped. 2ary treatment or better should be priority.
79	Buffer zones for shading on in streams or tributaries. going into the FR so that they will be silt free. Farmers are directing all their drainage off the land into creeks and streams which ultimately end up in the river.
80	Keep industry off the banks more parks alongside would protect.
81	In, 1936 potable water from the River was usable, though untested. It would be hazardous to use current water flow for that purpose. How injurious is this condition to fish stocks?
82	Alcan should not control water flows. There should not be anymore floating homes moored in the river.
84	Stop dumping sewage and commercial effluent
85	Quit using it as a liquid garbage dump. We need to have respect for the life of the river not just see it as a tool serving human wants.
86	We must ensure that strong anti-pollution measures are taken and policed adequately.
89	They must stop industrial pollution.
92	Log booms destroy shoreline, river bed, and access should be limited and old piles removed.
93	I think more needs to be done to remove debris from the river. Move to re-claim sunken commercial logs.
94	Any polluters to be closed down now!!
95	The BC Gov. should pass a law requiring all land owners to allow 50 m of green space along every section of the FR west of Hope, so that people can hike along the whole river where it is safe to do so. The 50 m strips of land should be replanted with(cont’d)
96	It's vital to protect existing riparian corridor and restore it.
97	Treatment-sewage/industrial waste.
98	There must be recognition that the economic viability of the working river community is being eroded due to inappropriate taxation and land use restrictions along the river.
101	Stringent monitoring program to monitor pesticide and fecal contamination in the farmlands along the river.

	More monitoring programs in sloughs, side channels & tributaries. Urge GVRD to install 2ary sewage treat. to minimize municipal waste contamination con's
103	Need water treatment for every town.
104	2ary treatment or improved treatment of sewage throughout Fraser Basin. Storm WQ improvements, upland source control of pollutants. Require lumber mills to restore river banks and protect habitat. Houseboats/float homes sewage control.
105	I think more effort should be placed on 2ary sewage systems. I would like to see more money spent in building treatment plants all over the lower mainland.
107	When will the GVRD and other gutless government bodies going to take positive action.
110	The river banks have to be policed.
113	Proper upstream sewage treatment must be instituted & maintained in order for even any sustainable commercial fishery to be maintained let alone any of the previously mentioned characteristics.
119	Pollution will also affect natural ecosystems & animal/fish conservation. Fine balance needs to be maintained to protect environment & natural beauty.
120	Need to "clean up" the water of garbage etc.
121	More regulation of toxic flow.
122	Look at the Thames and Londoners, look at the Hudson and New Yorkers. It can be done.
129	More control at what is being pumped into the river by drain outlets and smaller creeks.
132	A cleaner river less traffic use (boats).
135	No more landfill sites on the banks of the river!
144	Less pollution
146	Need strong regulations re: urban/industrial build-up and protection.
150	I would like to see all of the sewage, pollutants, etc. cleaned up and cleaned out of the FR.
151	Education and awareness and more public pressure to protect the FR.
153	Would definitely like to see the WQ improved and the use of it by industry lessened (in other words-industry must be forced to clean up their act).
156	Water Act to include all instream users & fish. Modify land law to promote stewardship of land & water. Endangered species legislation. Recognize sloughs, ponds & sm. lakes as water as a biophysical resource. Provide incentive to local governments wishing...

	How could these water uses be protected in the future?
2	local stewardshp of streams and tributaries feeding Fraser, storm water management programs for municipalities, public ed. of where wastewater goes, historical review and publication, perhaps dedication, of important history, industry sponsorship of public access.
3	Pressure to reduce the discharge of untreated and primary treated sewage should be kept on govt. until all sewage undergoes 2 treat. Tighter monitoring of Steveston. fishing harbour is required to prevent diesel spills from the harbour facilities and vessels.
4	Stormwater drainage and CSO's mapped and monitored, Development controlled- with precedence to marine dependent industries, fisheries managed more effectively.
5	Harbour Commissions are not doing their jobs. Regulate, monitor, enforcement, fines.
8	Laws must protect workers in these resource management. areas. Fines can and will support extra enforcement and First Nations have got to play a major role.
9	Begin factoring the real cost of pollutants into their 'market value'. Industry should be expected to deal with effluent & shoulder clean-up costs. Public could be made aware of, & encouraged to use, composting toilets etc. in aid of high fecal col. count
10	We must take better care of this stream/tributaries for quality and less pollution.
12	Why if industry needs volunteers organize the public participation event themselves! Not to mention that there was 20-25 of us out working for 4 hours and our clean-up was really minimal. I definitely think that major improvements need to be made in government handling of this issue. Are we concerned about loss of eelgrass beds, important salmon habitat? Let's do something really effective about it!

14	a). industrial discharges should be stopped (PCB, chlorophenols, chlorine, and other man made compounds have no place in the river; other options of disposal or better still a more environmental industrial process should be pursued) b). All municipal sewage discharge should be at least secondarily treated. c) All human activities, especially development and industrial operations should be restricted on the waterfront. d). All inland watercourses draining into the FR should also be monitored and controlled against human impact (increase in flow, sedimentation/erosion/industrial-municipal contaminant discharge, etc.
18	Phone number for people to report things about degradation to the river should be more available somehow! Also, to encourage more rec. activities. of lower FR, a boat launching area near Westminster Quay for canoes, kayaks etc.
23	The river should be protected from untreated sewage. Tighter regulation of outfalls and education campaigns.
25	Constant vigilance is needed against pressure for development, improvement, etc. by human manipulation of the river through industries, etc. Waterways are one of our most vital resources, not a place to dump garbage or 'hide' industrial operations.
26	Need to focus on and tackle the chief causes of pollution. (sure studies show which causes should be top priority)
27	Increased protection from discharges is a priority.
30	STP's should be upgraded to meet the needs of increasing urban pop'n. Pulp mill effluent should be monitored more closely. The use of chloramine in water treatment should be discouraged.
35	Fish could be protected by ensuring that discharges are not toxic to fish. Water shouldn't be diverted to produce electricity.
37	Surrounding industries need to be forced to be more responsible.
43	License industry to take make-up process water only out of the river, no discharges. Sewerage - Tertiary treatment. Storm sewerage - Primary at least. Tributaries - to be cleaned up!
48	The MOE should have more power. Sewage holding tanks on ALL boats. The DFO should learn how to count.
50	There should be floating pump stations too pump out raw sewage from boats, such a design is in effect in lakes in the interior(Ex. Shuswap Lake).
51	Boats that are 20 ft or larger should all be made to have holding facility sewage tanks. Pump stations should be made available.
52	Legislation must recognize groundwater as a valuable source of water for the province and rivers. Protection must be #1 priority. Province must be committed to good management as a long term goal.
53	An improvement in technologies to reduce waste and a moratorium on development in the Fraser Valley are two possibilities after all more people means more pressure on the river.
54	Reduce the amounts of effluents being dumped into the river. Utilize settling ponds or other means of eliminating certain wastes from commercial/residential use so as to provide a cleaner product re-entering the river.
56	Equal or increased monitoring of WQ. Enforcement of present regulations. More and greater penalties for spills, toxic effluent, runoff, etc.
57	Levels of pesticides, herbicides and food additives and their break down prod. are not tested for routinely by municipalities. I do not believe we know how good the WQ of the FR is but I strongly suspect many chemicals there are detrimental to environment & us.
63	Enforcement (voluntary and regulated) would continue to improve state of river.
64	monitor septic effluent, industrial pollution discharges. Foreshore trails should be enhanced and public/community/school/service groups should 'Adopt-a-foreshore trail' & supervise its integrity to provide a safe, litter-free, natural outdoor experience.
65	Time to apply the laws meant to protect river from pollution commit violators to heavy fines and direct them to clean up their operations to acceptable, non-polluting standards rather than excuses!
66	Consumers and dischargers into the FR drainage system should be made more accountable (morally and financially) to ensure safe & consumable water for users (animal and human) who are downstream.
68	Mills closely watched.

69	The quality of all wastes entering the river must be improved before it enters the river rather than relying on pollution dispersal. This includes sewage, storm water, industrial effluents and pulp wasted/wood bark and debris.
72	Develop a river front tax on developers as a compensation to the people of BC for future loss of river front greenspace which can be used to develop/buy/upgrade river front parks. 1-2% of selling price of completed project..
73	Constant monitoring against industrial and urban pollution must be done to guard against chemical pollution that can't be recognized w/out scientific tests i.e. chorines and metals etc.
75	Monitoring transient activities within an active perimeter of runoff draining feeder creeks, rivers and underground aquifers leading to the FR. Ex. personal mining, milling, resorts, etc.
78	The natural ecosystem of the FR and its tributaries must take precedence over human activities. Lost habitat must be restored. Responsible municipal planning must be enforced.
79	We still can do something with the river so we must work at it to protect aquatic life and wildlife and view.
81	Barnston Isl. residents draw their potable water from the FR directly downstream from untreated sewage from Langley, according to recent reports.
83	Better monitoring & enforcement of standards is required.
85	Perhaps we should start a Friends of the Fraser organization to promote awareness of the values of this resource.
86	I would also like to see the river tested at a number of locations every 2-4 weeks and the results to be published a.s.a.p. to create and awareness of the need to be vigilant with regards to clean water.
87	Secondary sewage treatment could help and more fines for polluters, industrial or whatever sectors are responsible for polluting the river.
89	We must have more patrols by fisheries officers on weekends. I would suggest an auxiliary fishery officer program. There must be something done about natives fishing when there is not an opening or native fisheries guardians contributing to poaching.
90	Absolutely no untreated wastes dumped into the river. Step up enforcement of environmental laws. No commercial fishing in the FR or w/in 50 NM of the mouth.
92	Drains into the FR should be monitored & limited. Old stream channels should be restored.
93	We are long overdue for secondary and tertiary sewage treatment plants
94	Fine dumpers 'til they are broke so they will not pollute again in their activity.
95	trees, plants and trails. Trees should be planted on a regular basis like the Van. Park's Board does in every community west of Hope. Taxes should fund this.
96	Zero tolerance for pollution-companies should be compelled to return "used" water at least as pure as at intake-No untreated sewage. We need to stop further pollution and clean up existing pollution to make our rivers and streams coho-friendly
97	Native control of fishery resources must be stopped. This resource must be managed for conservation then = access by all Canadians regardless of race/origin.
99	Stop all towns, cities, and industrial sites from using the FR as their sewer pipe for waste.
100	Get all the towns from Vancouver to Prince George to stop pumping raw sewage into the river. Stop all the Indian reserves from putting all their garbage on the shore every spring so the freshet takes it away.
101	Educate the workers & owners etc. of the heavy industry along the N. Arm in regards to the impact of heavy metals to biota and health of FR. Promote conservation of water from aquifers, reduce contamination.
104	Require DFO/MoE to take greater enforcement action on foreshore issuers e.g. salvage co., lumber mills, gravel/sand/cement operators, etc. & riparian habitat destruction. No more river front expansion for industry. The FR has been compromised enough.
114	A higher control of foreign additives into the water (runoffs and dumpage)
120	Monitor these waters. Education programs, visual presentations now and then.
132	The WQ can be protected by tighter guidelines by the Government. Stiffer penalties for abuse.
135	Less traffic on the river and less industry along the river could help protect the water.
147	Unfiltered sewage should not flow into the river.
149	No dumping of any kind into the river from land or from boats (inc. sewage, junk from mills, etc.)

156	acquire land for conservation & recreation; encourage green zoning. Tax formula to exclude marshes from assessment taxes if left wild. Legislate to preserve corridors or buffers adjacent to creeks, rivers, marshes, & lakes. Waste discharge section of MoE be expanded to include storm discharge management.

	Other thoughts?
1	Need a dog-only park, say in Burnaby foreshore park, for water dogs to retrieve, etc.
2	Community forums sponsored by B.C. Hydro seeking public input in regards to hydro-dam operations
3	WQ is a global problem but if everyone does their bit and acts responsibly it will slowly improve.
5	The North Arm has become a river where any water contact is considered risky. 1). Why is this river continued to be a disposal water site? 2). Who is responsible for these conditions continuing: FREMP, DFO, MoE, HARBOUR COMMISSIONS
6	too many fishing boats on river, reduce for sustainability
7	Waterloo District (funded by Province of Ontario) has promoted low flush toilets and other water-saving devices-continue to be one of lowest consumption rates in Canada-maybe should look into similar program here.
8	Limit development on floodplains. Ban mineral extraction 3 miles from the Fraser, support the BC Cattlemen with money for groundwater enforcement. Continue to improve fish habitat.
9	refer. to bar graph (“W.Q. Status Report", pg. 2), catchy but didn’t tell anything. Objectives reached, but what were they? Meeting 'objectives' means nothing if the 'objectives' themselves are low!
10	Your survey covers personal pleasure activities. I would hope you are doing a separate survey of those who use the river commercially (tourism, shipping, towing and transportation etc.)
12	Hope previously stated issue gets considered because other volunteers felt the same way.
14	Natural open space and public access to Fraser shores are important: a). to allow passive, 'low impact' rec. activities (nature/bird watching, etc.) b). to promote public appreciation of beauty and ecological value of FR c).to foster a sense of “public domain”/”public ownership”, hence public concern for the well being of FR
17	Water access for commercial activities is what Van. and other communities along the FR were built on. We cannot lose site of the importance of industry.
18	Why would BC Environment approve more houseboats on the river, there would seem to be lots of land! Big money lobby?? (floating homes wont help sensitive characteristics) Nice work on the Nechako though!
20	I appreciate increased access to the FR at such places as Westminster Quay, Port Haney wharf, Kanaka Creek. Park.
21	The provision of more green space and trails that are accessible would be worthwhile.
25	I am elated with the BC gov't accomplishments in setting aside parks, etc. (Except Clayoquot Sound -stop logging it!) Boundary Bay is a world-class habitat treasure-when are it, and lands around it, going to be protected from development and hunting?
26	Public education is important to keep the awareness level up on these kind of issues. The health of the river depends on the responsible action of all those who live in the watershed.
27	As an anthropologist, I am quite concerned about the loss of heritage values (e.g. archaeological sites) along the river.
28	Although I have moved from the immediate FR area, I have worked on tugs and flown off the river in the past, and will always be concerned about the FR well being.
30	Do away with commercial gill-netting below Mission, install fish traps instead. Limit development and stop destruction of estuarine areas.
35	I'm willing to accept the drop in standard of living that comes with lower industrial activity around the FR.
41	The FR amidst all the residential and population growth represents a tremendous natural and recreational resource. The continued passive public use of the river (ie. walks, canoeing, etc.) should not be jeopardized, rather enhanced.
42	the FR is the life of our area, this life belongs to us and generations to come
43	Start rehabilitation of tributary streams.
44	The Pitt river, Pitt Lake., Douglas Is., Barnston Is., Fort Langley river portion with the Kanaka Creek. area

	is great for small craft boating.
45	For me, being in agriculture, drainage is very important.
46	Now is the time to correct this situation. If they are going to change the Aldergrove STP to the Matsqui STP they will be taking it the wrong way. Now is the time to run both the outfalls to the Annacis STP, where it only takes < 6 hours to reach the sea.
48	The river belongs to the future generations, those who are responsible for its deterioration must pay for its rehabilitation. 50% of all $ made from or through the river should be returned to the river.
49	Societies link to the river needs to be illuminated, with regards to commerce but as well to agriculture. The Lower F.V. and its lowland soils created by the river is a critically valuable resource not to be thoughtlessly put at risk by urban expansion.
51	Most if not all boats with washrooms pump raw sewage into our river. This includes large tug companies that have holding tanks then they pump out into Georgia Strait-This happens every day!
56	I would like to see groups of volunteers recruited to undertake care of trails, parks, picnic areas, to aid parks personnel, to help monitor the use and abuse of specific areas.
57	[The respondent is also very concerned about deforestation, development and soil erosion and quotes solutions expressed in Mark Roseland's book ÔToward Sustainable Communities’]
59	Industrial uses were not included in this survey. How can you get a fair picture if you eliminate one important stakeholder group entirely.
61	I am told the Thames in England has been cleaned up to the degree that salmon have returned after almost 300 years. Have we obtained any information from there that might help? What action can be taken regarding the use of chloramine before we have a major spill?
64	The FR represents a tremendous environmental and recreational resource; its future use should not be jeopardized at the expense of industrial activities or other detrimental impacts.
65	Potable water is not available from the FR (w/out boiling or treatment) and this has occurred w/in 50 years--time to take care of this precious life-giving liquid with bold protective action.
66	I am concerned about the contamination of groundwater wells from inappropriate disposal of manure. There is some urgency to start ASAP to ensure farmers and in particular hobby farmers & horse people are using proper disposal techniques & proper holding facilities.
68	Dredging the FR would be good. Farmers losing prime land because water needs to directed different ways. Fish stocks should be built up more.
69	It is important to try and restore some areas to their natural condition rather than building everything right to the waters edge. Existing facilities have a lot of work to do and no one seems to want to do more than symbolic gestures
70	Rapidly increasing population growth makes it imperative to proceed as quickly as possible.
71	No
73	This river is important to all BC, economically, recreationally and aesthetically. I doubt one could ever drink this water again but its a nice thought.
74	Source control in all spheres must be the key message to all since our home and business effluent eventually effects the FR. People must be first encouraged and then forced to realize the impact of our human activities.
75	Use some people without a bunch of classroom degrees to use what was naturally given to us. Common sense, brains, historical environmental logic.
78	Empower the GVRD such that it can enforce upon the municipalities its livable region strategies. Establish greenbelts around existing municipalities to contain urban sprawl. Establish an "ecological" land reserve - not parks for humans.
79	We still can do something with the river so we must work at it to protect aquatic life, wildlife and view
80	More parks alongside the river, greenspace around Mission and Hatzic areas
81	Perhaps our Capital City Fathers of Victoria should have a closer look at the raw sewage dumping into Juan de FICA.
82	I don't like to see so many condos & residential buildings on the lower river. I would like to see the lower river for light industry and moorage facilities
83	This is a great river & people should be able to enjoy it in many ways & not interfere with the wildlife

	habitat. Pollution standards & enforcement is a prime factor.
86	When publishing test results of WQ, the findings should be shown with the results from 1,5,& 10 years ago so people can understand the significance of trends etc.
87	I would like to see more designated camping spots on the FR and more access for horse riding trails
88	Organized pollution criminals such as the GVRD should be checked into before the poor land farmer & loggers are further harassed
90	Sport fishing brings in 90% of revenue from renewable resource of fisheries & oceans. Anglers amount for about 1% of mortality of salmonids. Common sense dictates that sport fishing opportunities should be increased & a ban on welfare industry of commercial /fishing!
91	Please don't take the mud out of the FR, Thomson River seems too clean, and fish hide in it
92	Recognizing the commercial uses of the river, a clean up of riverside(many non-active) areas should be required.
93	I love this river and hope it can be cleaned up and at the same time preserve some of the tranquil areas.
94	Unless you have radical punishment we will never solve the pollution.
95	If we must have high-rises along the FR, do the development like the developers in the Westminster Quay area and the Sullivan Heights area of Burnaby west of Lougheed Mall
96	Coho are very particular and if they can thrive, so can the sockeye, chum, pink, chinook, cutthroat, steelhead, etc. We must keep the main river friendly for fish or lose all the tributary salmonid runs.
99	Politicians must have the courage now to turn things around for the FR or it will be too late for fish and plant life.
100	Would be nice to reduce the number of drunk Indians cruising the river at high speeds checking nets, shooting seals, and pestering everyone to buy fish.
101	FR is one of the majestic rivers in BC. Preservation of this important feature is the utmost priority.
104	There is very little public access to the river, esp. to enjoy natural settings in the GVRD. Planning over the decades has given this almost exclusively to industry. NO MORE!! Time to restore/protect. GIVE IT BACK!!!
105	I personally am a gill netter who has caught everything in my nets from toilet paper to dead bodies.
108	In late 1980's Kamloops-Okanagan Presbytery wrote letters protesting against dumping of Van. garbage in their backyard. They missed recognizing that they are polluting FR. We need a wider world-view.
109	Concern about leachate into the waterways from sawdust/hogfuel being spread on the ground along the river. Some of the wood refuse is then covered with gravel to hide it.
111	The Thames and the Hudson Rivers have been cleaned why not the Fraser.
112	How soon will improvements be visible?
114	Maintain good flows to obtain proper river levels.
116	It is important to keep the water clean so fish can live in it and to keep the river accessible to everyone & to make it easier to enjoy than it is now.
120	If other major waterways can be "cleaned up" e.g. Thames, why not the FR.
122	What about agriculture?
129	Some way to control the sand and soil being washed down from upper riverbank erosion
130	I would like old industries and no longer active industries to leave the river beds and edges in good condition.
132	The time is now to do something to abusers.
146	Thanks for this-please take it seriously
149	Fishing should be eliminated until stocks are built up and then tightly and accurately monitored and regulated.
150	A few more walking trails by the river might be provided.