

REPORT ON THE 1987 BENTHOS
AND SEDIMENT MONITORING PROGRAM

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SUMMARY

Bottom surface sediments and benthic organisms were collected from the Fraser River in January 1987. Sediments were collected at two types of sites: six replicate sites where ten replicate sediment samples were collected and benthic organisms were also obtained; and at five randomly selected sites in each of three Fraser River reaches, between the two replicate sites for that reach. The replicate sites had previously been sampled for benthos and sediments in 1985 at about the same time of year. Bottom surface sediments were also collected in November 1987 at twelve sites, eleven on systems tributary to the Fraser River. Tributaries sampled included Kanaka Creek, the Pitt River (and Alouette River), the Coquitlam River, and the Brunette River (and Still Creek).

Polychlorinated biphenyls and chlorophenols could not be detected at the replicate sites although these had been detected at three of six replicate sites in 1985. These substances were also not detected at the twelve sites sampled in November 1987.

Among the tributary sites, the lowest concentrations generally were found at one site in the Brunette River where the largest sized particles occurred, while the highest concentrations were found in sediments from the Pitt River where the smallest sized particles were encountered.

In the Fraser River, values generally were lowest in the Main Stem, higher in the North Arm, and highest in the Main Arm, both in this survey and that in 1985. This relationship corresponds to successively smaller sized particles among these reaches. Coarser sediments were encountered at the replicate sites in 1987 compared to 1985, which would likely lead to lower levels being measured in 1987 than in the sediments sampled in 1985. Statistically significant differences ($P=0.05$) between 1985 and 1987 for the same sites were observed most frequently at the Main Stem and Main Arm sites.

Some exceptions to these general relationships were found. Zinc was highest in sediments from the North Arm, likely due to inputs from storm-water or metal finishing plants. The highest concentrations of cadmium, copper, lead, mercury, tin, and zinc in the tributaries were in sediments from Still Creek.

It was determined statistically ($P=0.05$) that nearly 95% of the characteristics measured at the replicate sites were explained equally in terms of variability (F-test) and similarity of mean values (Students t-test) by three sediment samples as with ten. The remaining characteristics could be explained using four replicates or at most, five.

A comparison of upstream and downstream replicate sites on the Fraser River indicated significant variability ($P=0.05$) for several characteristics. Most of the remaining characteristics were determined to vary considerably when results from randomly selected sites were included.

It is thus concluded that in the Fraser River, intra-site variability seems to be less important than inter-site variability. In future surveys of sediment quality in the Fraser River, it is recommended that fewer replicate samples be collected at each site, and that a larger number of sites should be sampled. The exact number of replicates should be determined on the basis of the F-test and Students t-test results in this report for the characteristics of concern.

Benthic organisms were collected only at the six replicate sediment sites in the Fraser River. The same benthic organisms were not found at all six sites probably due to particle size differences of sediments among sites, and salinity differences which increased going downstream.

Ten taxonomic groups of benthic organisms were obtained from the sediments, although one (clam) was found in insufficient quantity for analysis. The other nine groups in which only chlorophenols were measured

included amphipods, chironomids, crustacea, diptera, lampreys, leeches, oligochaetes, pelecypods, and polychaetes. The organisms which provide the most information due to their presence at four of the six sites in sufficient numbers to permit analyses included chironomids, pelecypods, lampreys, and oligochaetes.

The highest chlorophenol levels were found in oligochaetes and lampreys in the Main Stem, in pelecypods in the Main Arm, and in polychaetes in the North Arm. High values were found in the North Arm in chironomids, pelecypods, lampreys, oligochaetes, and leeches.

These data imply that there is a considerable level of chlorophenol contamination in benthic organisms in the North Arm. This is not surprising since random sediment samples from sites in the North Arm had detectable chlorophenols, and there are a large number of wood protection facilities using chlorophenates located along the North Arm.

Chlorophenols (PCP and TCP) were measured in only a few organisms in the 1985 survey of the same sites. Values measured in chironomids in this survey at a site in the Main Stem have increased marginally from values measured at the same site in the same organism in 1985. Larger increases were seen for lampreys from the same site in the Main Stem and polychaetes from a site in the Main Arm. At a site in the North Arm, values were approximately the same or lower in polychaetes between 1985 and 1987. Thus, although values in benthic organisms appear to be increasing, insufficient numbers of organisms have been collected to draw a firm conclusion.

Information is also provided on which organisms were obtained during a the 1985 survey and which were found during this 1987 survey of the same sites. Chironomids, pelecypods, lampreys, oligochaetes, and polychaetes have been found in both surveys in sufficient numbers to allow laboratory analysis. Future surveys should prioritize analyses on these organisms to allow as thorough a comparison as possible prior to undertaking analyses of other benthic organisms.

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TABLE OF CONTENTS

	Page
SUMMARY.....	i
ACKNOWLEDGEMENTS.....	iv
TABLE OF CONTENTS.....	v
LIST OF TABLES.....	vii
LIST OF FIGURES.....	viii
1. INTRODUCTION.....	1
1.1 Site Selection.....	2
1.2 Provisional Water Quality Objectives.....	2
2. MATERIALS AND METHODS.....	4
3. RESULTS AND DISCUSSION.....	6
3.1 Fraser River Sediments.....	6
3.1.1 Particle Size Distribution.....	6
3.1.2 Polychlorinated Biphenyls.....	6
3.1.3 Chlorophenols.....	7
3.1.4 Metals.....	8
3.1.4.1 Aluminum.....	9
3.1.4.2 Barium.....	10
3.1.4.3 Cobalt.....	12
3.1.4.4 Chromium.....	13
3.1.4.5 Copper.....	15
3.1.4.6 Iron.....	16
3.1.4.7 Mercury.....	18
3.1.4.8 Manganese.....	20
3.1.4.9 Nickel.....	22
3.1.4.10 Lead.....	24
3.1.4.11 Strontium.....	25
3.1.4.12 Vanadium.....	26
3.1.4.13 Zinc.....	28

TABLE OF CONTENTS - (Continued)

	Page
3.1.5 Total Volatile Residue.....	30
3.1.6 Carbon.....	31
3.1.6.1 Total Carbon.....	31
3.1.6.2 Total Inorganic Carbon.....	33
3.1.7 Phosphorus.....	34
3.1.8 Conclusions.....	36
3.2 Fraser River Benthic Organisms.....	39
3.3 Sediments in Tributaries.....	41
3.3.1 Particle Size Distribution.....	41
3.3.2 Polychlorinated Biphenyls.....	42
3.3.3 Chlorophenols.....	42
3.3.4 Other Organic Compounds.....	42
3.3.5 Metals and Other Elements.....	43
3.3.5.1 Beryllium.....	43
3.3.5.2 Boron.....	44
3.3.5.3 Cadmium.....	44
3.3.5.4 Calcium.....	44
3.3.5.5 Copper.....	45
3.3.5.6 Lead.....	45
3.3.5.7 Manganese.....	45
3.3.5.8 Mercury.....	46
3.3.5.9 Molybdenum.....	46
3.3.5.10 Nickel.....	46
3.3.5.11 Tin.....	46
3.3.5.12 Titanium.....	47
3.3.5.13 Zinc.....	47
3.3.6 Total Volatile Residue and Organic Carbon.....	47
3.3.7 Conclusions.....	48
REFERENCES CITED.....	49
APPENDIX - Sample Preparation and Analysis, Can Test Ltd.	60

LIST OF TABLES

	Page
Summary of Sediment Analyses at the Ten Replicate Sites in the Fraser River.....	51
Levels of PCB's and Chlorophenols in Fraser River Sediments.....	54
A Comparison of Levels of Chlorophenols in Benthic Organisms from the Fraser River to 1985 Levels.....	55
Sediment Particle Size Distribution, Tributary Sites.....	56
Trace Organic Analyses For Sediments in Tributaries.....	57
Plasma Spectrographic Analyses For Sediments in Tributaries.....	58
Carbon Analyses For Tributary Sites.....	59

LIST OF FIGURES

FIGURE		Page
1	1987 Sediment and Benthic Organism Sampling Sites.....	50

1. INTRODUCTION

On April 1, 1986, a five-year agreement was concluded between the Fraser River Harbour Commission and the B.C. Ministry of Environment. The agreement related to carrying out monitoring in the Fraser River Estuary area, based on a report prepared by the Working Committee on Fraser River Estuary Monitoring (1984). The estuary area under study is from Kanaka Creek downstream.

Monitoring during 1987/1988 was directed towards determining the quality of sediments and invertebrates in the Fraser River Estuary system. Samples were collected in January 1987 from the riverine section of the Estuary. In November 1987, sediment samples were collected from four systems tributary to the Fraser River (see Figure 1).

The purpose of the monitoring was:

1. To determine levels of metals, chlorophenols and PCB's in sediments and benthic organisms in the riverine section of the Fraser River Estuary.
2. To determine, as possible, variability within sample sites.
3. To determine variability along the length of the Fraser River.
4. To determine levels of metals, chlorophenols, and PCB's in sediments from the major tributaries to the Fraser River Estuary.
5. To determine the degree to which values in sediments met provisional Water Quality Objectives for this section of the estuary (Swain and Holms 1985).

1.1 SITE SELECTION

Six sites, two in each of the Main Stem, Main Arm, and North Arm were used for the collection of ten replicate sediment samples and one benthos sample at each site in January 1987 (hereafter referred to as the replicate sites). These sites are MS-1 and MS-2, MA-1 and MA-2, and NA-1 and NA-2, respectively. The replicate sites were located as described in Swain (1986). In each of the three main river reaches, five additional sites between the two replicate sites were set up for the collection of single sediment samples. These are identified by MS-3 to MS-7, MA-3 to MA-7, and NA-3 to NA-7. All sites are shown on Figure 1.

Sediment samples (at least three grab samples were composited and then subsampled) were collected in November 1987 from four tributary systems (Still Creek/Brunette River, Coquitlam River, Pitt River, and Kanaka Creek) and from a site near the western tip of Barnston Island in the Main Stem of the Fraser River.

All sediment samples were from the surface of bottom sediments as opposed to core samples.

1.2 PROVISIONAL WATER QUALITY OBJECTIVES

The B.C. Ministry of Environment and Parks is currently establishing provisional Water Quality Objectives on a site-specific basis. One area where such Objectives have been prepared is the Fraser River from Kanaka Creek to the mouth. In preparation are Objectives for the Pitt River, Kanaka Creek, Coquitlam River, and the Brunette River systems.

Provisional Objectives which are applicable to the sediments examined in this survey are (Swain and Holms 1985):

Chlorophenols:	0.01 µg/g (dry weight) maximum in bottom surface sediments
PCB's	: 0.03 µg/g (dry weight) maximum in bottom surface sediments

Existing chlorophenol levels in certain bottom sediments were used in setting a provisional Objective at 0.01 µg/g (dry weight). Levels of this magnitude occur in relatively uncontaminated parts of the Fraser River and other rivers in Canada.

Polychlorinated biphenyls (PCB's) can enter the river channels through urban stormwater runoff, sewage discharges and have been associated with industries on the North Arm. Objectives were therefore proposed to limit a buildup of these substances. The Objective of 0.03 µg/g (dry-weight) in sediments was set to minimize the passage of PCB's along the food web. It is met generally in parts of the river which are relatively uncontaminated by PCB's (Swain and Holms 1985).

Both of these Objectives are partly empirical but also conservative. If achieved in the short-term, they are expected to prevent any harmful effects to aquatic life or uses of aquatic life.

2. MATERIALS AND METHODS

All sediment samples were collected using a Petersen grab. Samples from the Fraser River were collected during three consecutive days in January 1987. Samples from the tributaries were collected during two consecutive days in November 1987.

At the Fraser River replicate sites, the boat was anchored and ten replicate samples obtained. Sub-samples of these sediments were placed in either acid-washed plastic bottles for metals or amber glass bottles for PCB and chlorophenol analyses. Only the surface layer of sediments was used for analyses in order to obtain those most recently deposited sediments. Each sediment replicate analysis represents a separate grab sample. The remainder of the samples at the replicate sites were sieved to obtain benthic organisms. In order to get sufficient tissue mass for conducting the analyses, sampling was often conducted away from, but in close proximity to, the point at which sediment samples were collected.

Sediments were sieved through plastic buckets with ± 0.5 mm screens to collect benthic organisms for analyses. These samples contained wood, organic debris, as well as benthos. The containers were submitted to R.W. Kistritz and Associates for sorting and a taxonomic listing of the benthic organisms. Sorted samples were then submitted to the B.C. Ministry of Environment and Parks Environmental Laboratory in April 1987 for subsequent analyses.

Sediment samples from the Fraser River were analyzed by the B.C. Ministry of Environment and Parks Environmental Laboratory. Their procedures can be summarized as follows. For metals, the sediments were analyzed following drying and grinding. The sample was then digested in nitric/perchloric acid and analyzed by ICP. The ICP was replaced by a Heated Graphite Atomizer for analyses of cadmium. For mercury analyses, a nitric/sulphuric acid digestion was used prior to a manual cold vapour analysis.

Carbon analyses in sediments were done with the Leco Carbon analyzer, while total volatile residue was obtained using a graphite furnace at 550°C, following drying and grinding.

For organics, the following procedure was used. Samples of benthic organisms were initially homogenized while sediment samples were dried and ground. Sediment and benthic organism samples were then extracted, fluorosil added, and the samples analyzed for PCB's on the gas chromatograph with electron capture. Acidification, extraction, back extraction, methylation and fluorosilation were completed prior to analysis for chlorophenols on the gas chromatograph.

Details on the sample preparation and analysis by Can Test for sediment samples from the tributaries are in the Appendix.

3. RESULTS AND DISCUSSION

3.1 FRASER RIVER SEDIMENTS

3.1.1 PARTICLE SIZE DISTRIBUTION

A summary of particle size distribution for the collected sediment samples at the replicate sites is in Table 1. Based upon the percentage of sediment particles that passed the 400 mesh size (Tyler), the coarsest particles were associated with Main Stem sediments, and the finest were associated with sediments from the Main Arm. This was the same finding as the 1985 survey at the same sites (Swain 1986).

The sediments collected during the 1987 survey at the replicate sites were much coarser in texture than found in 1985. Only about 2% of the material passed the 400 mesh sieve at the Main Stem (Table 1) while about 40% passed in 1985 (Swain 1986). Comparable approximate percentages were 40% in 1987 and 65% in 1985 for the North Arm sites and 60% in 1987 and 90% in 1985 for the Main Arm sites. Particle size distributions were not determined for any of the sites between the replicate sites.

Particle size can be important with respect to contaminant concentrations of sediments, with finer materials having the potential to have higher contaminant levels, since fine grained particles have large surface areas to which contaminants are more easily sorbed.

3.1.2 POLYCHLORINATED BIPHENYLS

Total PCB's could not be detected (<0.02 $\mu\text{g/g}$ - wet-weight) at any of the replicate sites sampled during 1987. This compares to the finding during a 1985 survey (Swain 1986) where PCB's were detected at Barnston Island in the Main Stem (MS-1) and at both sites in the North Arm (NA-1 and NA-2).

At sites between replicate sites, a sample collected in the North Arm at NA-5 (Figure 1) near the eastern end of Mitchell Island towards the Fraser River's south shore had 0.10 $\mu\text{g/g}$ (wet-weight) of PCB 1254, or 0.18 $\mu\text{g/g}$ (dry-weight), which is far in excess of the Objective of 0.03 $\mu\text{g/g}$ maximum. This indicates that there are still PCB's in North Arm sediments. PCB's were not detected ($<0.02 \mu\text{g/g}$) at any other sites between replicate sites in the Fraser River. Thus, PCB's may be of decreasing concern in the Fraser River.

Swain (1983) has reported that "stormwater constitutes a diffuse source of PCB's at low levels to the river". Values for PCB's in stormwater sediments expressed on a dry-weight basis ranged from <0.02 to 0.19 $\mu\text{g/g}$ (Arochlor 1242) and from <0.02 to 0.45 $\mu\text{g/g}$ (Arochlor 1260). These maximum values in stormwater sediments exceed the maximum found in the North Arm. Swain (1985) indicated that there are a large number of stormwater outfalls to the North Arm, therefore this high sediment level may originate from stormwater.

3.1.3 CHLOROPHENOLS

Chlorophenols, measured individually as tri-(sum of 2,4,6- and 2,3,6), tetra-(predominantly 2,3,4,6), and penta-, could not be detected ($<0.005 \mu\text{g/g}$ - wet-weight) at any of the replicate sites in 1987. During the 1985 survey at the same sites, chlorophenols were measured as MS-1 (average of 0.038 $\mu\text{g/g}$), NA-1 (average of 0.050 $\mu\text{g/g}$), and NA-2 (average of 0.056 $\mu\text{g/g}$).

At sites between the replicates, only tetrachloropenol and pentachloropenol were measured. Most values were below detection ($<0.002 \mu\text{g/g}$ - wet-weight basis), except for those sites whose values have been converted from wet-(see Table 2) to dry-weight:

Site (Figure 1)	Chlorophenol Concentrations ($\mu\text{g/g}$, dry-weight)	
	Pentachlorophenol	Tetrachlorophenol
Main Stem (MS-3)	<0.003	0.003
(MS-4)	0.003	0.005
North Arm (NA-4)	<0.003	0.003
(NA-5)	0.004	0.005
(NA-6)	0.003	0.003
(NA-7)	0.003	0.003
Main Arm (MA-3)	<0.003	0.003

The total for all measurable chlorophenols at any one of these sites was <0.010 $\mu\text{g/g}$, the Water Quality Objective.

The generally lower levels of chlorophenols in 1987 compared to 1985 might be the result of degradation of those chlorophenols already in the sediments with only a minimal introduction of freshly deposited sediments which were contaminated. Alternatively, it could be due to less chlorophenols being present on coarser particles, due to a trend away from the use of dip tanks (with direct overflows and more dripping) to the use of spray booths which should have lesser quantities released.

3.1.4 METALS

Metal values in sediments are reported in Table 1 on a dry-weight basis. Only arsenic, cadmium, and molybdenum could not be detected (<30 $\mu\text{g/g}$, 0.3 $\mu\text{g/g}$, and <2 $\mu\text{g/g}$, respectively) at any of the sites, although selenium could only be detected (≥ 22 $\mu\text{g/g}$) at one site. The other metals detected are discussed in the following where values cited refer to mean values for replicate sites, unless otherwise stated. As well, statistical comparisons using the F- and Students t-tests are made with data collected in 1985 at the same sites (Swain 1986). It should be noted that only three replicate samples were collected at each of the replicate sites in 1985 (except NA-1 where five replicates were collected).

In the following discussion of metal levels, two measurements of variability of data are also made. The first will determine whether there is significant variability in data between the upstream and downstream replicate sites in each reach. The second will determine whether fewer than ten replicate samples from each replicate site can be taken in the future to describe the conditions with equal confidence. This latter measurement will also be confirmed by use of a two-tailed Students t-test.

3.1.4.1 Aluminum

Aluminum values in the Main Stem in 1987 were about 8 000 $\mu\text{g/g}$ (dry-weight), while values in the North Arm were about 10 500 $\mu\text{g/g}$ and 13 000 $\mu\text{g/g}$ (dry-weight) in the Main Arm. This pattern follows that observed in 1985 (Swain 1986), with areas of smaller particles having higher aluminum concentrations. There was no statistically significant difference ($P=0.05$) in mean values for the same sites (except Site MS-2) in the two years when F- and Students t-test procedures were applied.

Data in Table 1 for the replicate sites indicate standard deviations in aluminum concentrations for the Main Stem of 875 $\mu\text{g/g}$ (MS-1) and 461 $\mu\text{g/g}$ (MS-2), in the North Arm of 714 $\mu\text{g/g}$ (NA-1) and 1712 $\mu\text{g/g}$ (NA-2), and in the Main Arm of 1207 $\mu\text{g/g}$ (MA-1) and 578 $\mu\text{g/g}$ (MA-2). Using the statistical F-test ($P=0.05$) procedure, the standard deviations in each reach were determined not to be homogeneous (i.e. significant difference), therefore the variation between upstream and downstream sites in each reach was significant.

For individual samples collected between replicate sites, the following values were measured:

Site	Aluminum ($\mu\text{g/g}$, dry-weight)		
	Main Stem (MS)	North Arm (NA)	Main Arm (MA)
3	8 500	7 980	7 020
4	8 930	8 760	10 000
5	9 120	11 400	9 220
6	8 500	8 190	11 900
7	10 100	9 990	10 900

These values were often outside two standard deviations of mean values at the replicate sites and on occasion outside the range of values (Table 1) for the replicate sites in the same river reach. Thus, it is desirable that future surveys should, if possible, collect samples at more sites.

To determine if fewer replicate samples could be collected at each of the sites in future surveys, the standard deviation of the first three samples collected at each of the replicate sites (see below) was compared, using the statistical F-test (P=0.05) procedure, to that found using the ten replicates (Table 1):

Site (Figure 1)	Mean of 1st 3 Samples (dry-weight)	Standard Deviation	Calculated F	Calculated t
MS-1	6 763	525.4	2.77	2.22
MS-2	8 336	667.1	2.09	0.86
NA-1	10 700	529.2	1.82	0.30
NA-2	9 800	793.7	4.65	0.43
MA-1	13 600	721.1	2.80	2.06
MA-2	13 200	755	1.70	1.01

The calculated "F" values indicate that the variation between the sets of data are statistically similar. The calculated "t" values (P=0.05) indicate that the mean values for three and ten replicates were statistically similar.

3.1.4.2 Barium

Barium values in 1987 decreased in the Main Stem, North Arm, and Main Arm between the upstream and downstream replicate sites. In 1985, this same pattern was noticed in the Arms but not the Main Stem where an increase occurred (Swain 1986). At that time, it was noted that this apparent trend was not related to particle size distribution (Table 1) and may be related to tidal influences at the downstream sites in the North and Main Arms.

Comparing the 1985 and 1987 results for the same sites, there was no statistically significant ($P=0.05$) difference in mean values except at Site MS-2 (Sapperton Channel) when the F-test and Students t-test were applied.

Data in Table 1 for standard deviations in barium concentrations were from 5 (MS-2) to 11 $\mu\text{g/g}$ (MS-1) in the Main Stem, 8 (NA-1) to 14 $\mu\text{g/g}$ (NA-2) in the North Arm, and from 3 (MA-2) to 8 $\mu\text{g/g}$ (MA-1) in the Main Arm. Using the statistical F-test ($P=0.05$) procedure, the standard deviations in the North Arm were determined to be homogeneous (i.e., no significant difference), although this was not the case in either the Main Stem or Main Arm. Therefore the variation for barium between upstream and downstream sites in the Main Stem and Main Arm was significant.

For individual samples collected between replicate sites, the following values were measured:

Site	Barium ($\mu\text{g/g}$, dry-weight)		
	Main Stem (MS)	North Arm (NA)	Main Arm (MA)
3	66	66	48
4	84	79	84
5	77	75	61
6	78	53	68
7	98	49	77

Values in the Main Stem and Main Arm were occasionally outside the range or two standard deviations from the mean barium value for the replicate sites, however barium values in the North Arm were inside the range. Therefore, the noted trends in variation between replicate sites held for the random sites in each reach.

To determine if fewer than ten replicate samples could be collected at each of the sites in future surveys, the standard deviation of the first three samples collected at each of the replicate sites (see below) was compared using the statistical F-test ($P=0.05$) procedure, to that found using ten replicates (Table 1):

Site (Figure 1)	Mean of 1st 3 Samples (dry-weight)	Standard Deviation	Calculated F	Calculated t
MS-1	54.7	5.5	3.84	2.21
MS-2	69	7.5	2.27	1.39
NA-1	90.3	3.8	4.81	0.24
NA-2	50.7	3.2	19.9*	-
MA-1	112.7	6.7	1.43	1.92
MA-2	67.7	1.5	3.24	1.18

The calculated "F" values indicated that at all replicate sites except NA-2 (North Arm-McDonald Slough), the variation between the sets of data are statistically similar. The calculated "t" values (P=0.05) indicate that the mean values for three and ten replicates, except at site NA-2, were statistically similar. However, when the first four samples at NA-2 were compared, the calculated "F" value was reduced sufficiently for the data to be considered the same (statistically significant) as having ten replicates collected. For four samples, the "t" value was calculated to be 0.93 (P=0.05) so that the mean values for four and ten replicates were statistically similar.

3.1.4.3 Cobalt

Cobalt could not be detected (<10 µg/g, dry-weight) in sediments from replicate sites in the Main Stem, and were at the detection limit of 10 µg/g (dry-weight) in the North and Main Arms. These are slightly lower levels than found in the 1985 survey (Swain 1986), likely a reflection of the difference in particle size of the sediments.

For individual samples collected between replicate sites, the following values were measured:

Site	Cobalt ($\mu\text{g/g}$, dry-weight)		
	Main Stem (MS)	North Arm (NA)	Main Arm (MA)
3	<10	12	10
4	15	10	16
5	<10	<10	<10
6	<10	<10	15
7	10	16	19

Where it was possible to calculate a standard deviation at the replicate sites, it was 0.0. The single grab samples were on occasion outside the ranges of values for the replicate sites. Thus the two replicate sites selected in each of the reaches do not necessarily accurately reflect cobalt concentrations along the entire reach.

3.1.4.4 Chromium

Chromium values at the replicate sites were lowest in the Main Stem, higher in the North Arm, and highest in the Main Arm in 1987, reflecting the presence of progressively finer grained sediments in each of the reaches. Values were significantly lower in the Main Stem in the 1987 survey (mean values of 21 to 24 $\mu\text{g/g}$ dry-weight) compared to 1985 (≈ 31 $\mu\text{g/g}$) and at Sites NA-1 and MA-1 where values decreased from 36 to 29.6 $\mu\text{g/g}$, and 31.2 to 26.9 $\mu\text{g/g}$ dry-weight, respectively. Approximately the same values were found in the North Arm at Site NA-2 (mean value of 30.7 $\mu\text{g/g}$ dry-weight in 1985 and 29.7 $\mu\text{g/g}$ in 1987) and the Main Arm at Site MA-2 (mean value of 36.3 $\mu\text{g/g}$ dry-weight in 1985 and 34.8 $\mu\text{g/g}$ in 1987). These data were compared using the F-and Students t-tests ($P=0.05$).

Data in Table 1 for standard deviations of chromium concentrations were 1.75 (MS-2) to 1.95 $\mu\text{g/g}$ (MS-1) in the Main Stem, 1.45 (NA-1) to 6.4 $\mu\text{g/g}$ (NA-2) in the North Arm, and 1.69 (MA-2) to 2.37 $\mu\text{g/g}$ (MA-1) in the Main Arm. Using the statistical F-test ($P=0.05$) procedure, the standard deviations in the Main Stem and Main Arm were determined to be homogeneous (i.e., no significant difference), although this was not the case for the North Arm. Therefore, the variation for chromium between upstream and downstream sites in the North Arm was statistically significant.

For individual samples collected between replicate sites, the following values were measured:

Site	Chromium ($\mu\text{g/g}$, dry-weight)		
	Main Stem (MS)	North Arm (NA)	Main Arm (MA)
3	35	37	36
4	40	37	44
5	38	50	41
6	36	37	50
7	47	42	50

Chromium values in all three river reaches were often outside the range of values determined for the replicate sites. Thus, although the data for the replicate sites implied little variation between sites in the Main Stem and Main Arm, this was not confirmed by the random chromium samples collected in these reaches.

To determine if fewer than ten replicate chromium samples could be collected at each of the sites in future surveys, the standard deviation of the first three samples collected at each of the replicate sites (see below) was compared using the statistical F-test ($P=0.05$) procedure to that found using the ten replicates (Table 1):

Site (Figure 1)	Mean of 1st 3 Samples (dry-weight)	Standard Deviation	Calculated F	Calculated t
MS-1	18.3	1.53	1.63	1.93
MS-2	24.7	1.53	1.31	0.44
NA-1	26.7	1.53	1.11	0.21
NA-2	28.3	2.52	6.46	0.36
MA-1	31.	1.0	5.6	0.97
MA-2	34.	2.0	1.41	0.69

The calculated "F" values indicate that at all replicate sites, the variation in data for chromium provided is not significantly different.

The calculated "t" values (P=0.05) indicate that the mean values for three and ten replicates were statistically similar.

3.1.4.5 Copper

Copper values (dry-weight) decreased going downstream in both the Main Stem (17.0 µg/g to 14.6 µg/g) and the North Arm (27.5 µg/g to 26.0 µg/g) but increased in a downstream direction in the Main Arm (30.1 to 37.4 µg/g). The same trends were noted in 1985 for the North and Main Arms (Swain 1986). Mean copper values in 1987 were significantly lower than in 1985 at all sites except Site NA-2 (North Arm, McDonald Slough) when compared using the F-and Students t-tests (P=0.05). This is likely due to the smaller particle size in samples collected in 1985. Stancil (1980) reported 28.8 µg/g near Sapperton Channel, between 22.4 and 28.4 µg/g in the North Arm, and between 17 and 19.6 µg/g in the Main Arm. In comparison, values found in 1987 were lower in the Main Stem, about the same in the North Arm, and higher in the Main Arm.

Data in Table 1 for the standard deviations of copper concentrations were 1.70 (MS-1) to 2.17 µg/g (MS-2) in the Main Stem, 2.80 (NA-1) to 7.57 µg/g (NA-2) in the North Arm, and 2.28 (MA-1) to 2.37 µg/g (MA-2) in the Main Arm. Using the statistical F-test (P=0.05) procedure, the standard deviations for the Main Stem sites and the Main Arm sites were determined to be homogeneous (i.e., no significant difference), although this was not the case for the North Arm. Therefore, the variation in copper between upstream and downstream sites in the North Arm was statistically significant.

For individual samples collected between the replicate sites, the following values were measured:

Site	Copper (µg/g, dry-weight)		
	Main Stem (MS)	North Arm (NA)	Main Arm (MA)
3	23	20	15
4	28	26	26
5	24	38	24
6	24	25	38
7	33	33	31

Copper values in the Main Stem and Main Arm were often outside the range of values found for the replicate sites. Thus, although the data for the replicate sites implied little variation in copper values between Main Stem and Main Arm sites, this was not confirmed by random copper samples collected in these reaches.

To determine if fewer than ten replicate copper samples could be collected at each of the sites in future surveys, the standard deviation of the first three samples collected at each of the replicate sites was compared to that of the ten replicates (Table 1) using the statistical F-test procedure:

Site (Figure 1)	Mean of 1st 3 Samples (dry-weight)	Standard Deviation	Calculated F	Calculated t
MS-1	15.3	1.53	1.24	1.55
MS-2	16.3	3.51	2.62	1.05
NA-1	27.3	2.08	1.81	0.11
NA-2	24.0	3.61	4.41	0.71
MA-1	32.3	0.58	15.6	1.61
MA-2	37.7	3.79	2.56	0.17

The calculated "F" values indicate that at all replicate sites, the variation in information for copper is significantly ($P=0.05$) similar. The calculated "t" values ($P=0.05$) indicate that the mean values for three and ten replicates were statistically similar.

3.1.4.6 Iron

Iron values (dry-weight) decreased in a downstream direction in the Main Stem (17 050 to 16 350 $\mu\text{g/g}$) and in the North Arm (22 340 to 21 710 $\mu\text{g/g}$) but increased in the Main Arm (24 830 to 27 830 $\mu\text{g/g}$) at replicate sites (Table 1). Iron values for each reach corresponded to decreasing particle size. This trend was also found in 1985 (Swain 1986). Iron values in

sediments from the same sites in 1985 were significantly higher than these 1987 data except at Site NA-2 (McDonald Slough) in the North Arm, based on F- and Students t- ($P=0.05$) tests. Stancil (1980) reported values of about 23 000 $\mu\text{g/g}$ in the Main Stem, 18 350 to 20 450 $\mu\text{g/g}$ for the North Arm, and 16 820 to 20 000 $\mu\text{g/g}$ for the Main Arm, which were higher than the 1987 data in the Main Stem and Main Arm but lower than the values for the North Arm.

Data in Table 1 for the standard deviations of iron concentrations were 964 (MS-1) to 1 296 $\mu\text{g/g}$ (MS-2) in the Main Stem, 1 520 (NA-1) to 3 116 $\mu\text{g/g}$ (NA-2) in the North Arm, and from 959 (MA-2) to 2 008 $\mu\text{g/g}$ (MA-1) in the Main Arm. Using the statistical F-test ($P=0.05$) procedure, the standard deviations for the Main Stem were determined to be homogeneous (i.e., no significant difference), however this was not the case for the North Arm or Main Arm. Therefore, the variation in iron between upstream and downstream replicate sites in the North and Main Arms was statistically significant.

For individual samples collected between the replicate sites, the following values were measured:

Site	Iron ($\mu\text{g/g}$, dry-weight)		
	Main Stem (MS)	North Arm (NA)	Main Arm (MA)
3	19 400	18 600	16 300
4	22 000	21 500	23 600
5	20 800	26 900	21 200
6	20 300	20 400	27 100
7	25 900	24 000	24 500

Iron values in the Main Stem and Main Arm were often outside the range of values found at the replicate sites. Thus, although the data for the replicate sites implied little variation in iron values between sites in the Main Stem, this was not confirmed by random iron samples collected in this reach.

To determine if fewer than ten replicate samples for iron could be collected at each of the sites in future surveys, the standard deviation of the first three samples collected at each of the replicate sites (see below) was compared to that of the ten replicates (Table 1) using the statistical F-test procedure:

Site (Figure 1)	Mean of 1st 3 Samples (dry-weight)	Standard Deviation	Calculated F	Calculated t
MS-1	15 967	862	1.25	1.75
MS-2	17 667	1 861	2.06	1.41
NA-1	22 500	608	6.25	0.17
NA-2	20 900	1 308	5.68	0.43
MA-1	27 333	1 168	2.96	2.02
MA-2	27 133	1 060	8.65	1.08

The calculated "F" values indicate that at all replicate sites, the variation in information for iron is significantly ($P=0.05$) similar. The calculated "t" values ($P=0.05$) indicate that the mean values for three and ten replicates were statistically similar.

3.1.4.7 Mercury

Mercury values (dry-weight) in the 1985 survey were fairly consistent, at about 0.06 to 0.07 $\mu\text{g/g}$ (Swain 1985). This was also generally the case in the 1987 survey, although the downstream value in the Main Arm (MA-2) was 0.08 $\mu\text{g/g}$. Mercury was occasionally not detected in samples from Main Stem sites ($<0.05 \mu\text{g/g}$). At sites in the the North and Main Arms where mercury values were always detectable in 1987. There was no significant difference between mean values in 1985 and 1987 except at Site MA-1 (Annacis Channel) when the F and Students t tests were applied. At Site MA-1, mercury levels increased significantly from 0.06 to 0.071 $\mu\text{g/g}$. Stancil (1980) reported that mercury could not be detected (varying detection limits).

Data in Table 1 for the standard deviations of detectable mercury concentrations were from 0.0130 (MS-1) to 0.0299 $\mu\text{g/g}$ (MS-2) in the Main Stem, from 0.0082 (NA-1) to 0.0193 $\mu\text{g/g}$ (NA-2) in the North Arm, and from 0.0057 (MA-1) to 0.0094 $\mu\text{g/g}$ (MA-2) in the Main Arm. Using the statistical F-test ($P=0.05$) procedure, the standard deviations for the Main Arm were determined to be homogeneous (i.e., no significant difference), however this was not the case for the Main Stem or North Arm. Therefore, the variation in detectable mercury concentrations between upstream and downstream replicate sites in the Main Stem and North Arm was statistically significant.

Individual samples collected between the replicate sites were not analyzed for mercury. However, given the variation at those sites for the metals discussed in the preceding sections, it is likely that mercury values would be found along the reaches outside the ranges of values at the replicate sites.

To determine if fewer than ten replicate mercury samples could be collected at each of the sites in future surveys, the standard deviation for the first three samples collected at each of the replicate sites (see below) was compared to that of the ten replicates (Table 1) using the statistical F-test procedure:

Site (Figure 1)	Mean of 1st 3 Samples (dry-weight)	Standard Deviation	Calculated F	Calculated t
MS-1	<0.05	0.000	*	*
MS-2	0.05	*	*	*
NA-1	0.063	0.012	1.98	0.0
NA-2	0.073	0.012	2.79	0.75
MA-1	0.077	0.006	1.02	1.58
MA-2	0.08	0.010	1.13	0.0

* inadequate data

The calculated "F" values indicate that at the replicate sites in the North Arm and Main Arm where mercury levels could be detected in all samples, the variation in values for mercury was not significantly ($P=0.05$) different when the number of replicates increased from three to ten. The calculated "t" values ($P=0.05$) for the North and Main Arms indicate that the mean values for three and ten replicates were statistically similar. In the Main Stem, seven samples had to be collected at the upstream site (MS-1) before three detectable values (out of five) could be used for comparison, while four samples had to be collected at the downstream site (MS-2) before three detectable values (out of seven) could be used.

Mercury is associated with many geological faults which occur in the Fraser River watershed, the most well known of which is at Pinchi Lake, although some closer to the Lower Mainland are on the Harrison River. Sediment samples should be collected between the headwaters and the Lower Mainland area to determine the overall status of mercury in sediments of the Fraser River.

3.1.4.8 Manganese

Manganese (dry-weight) values decreased in a downstream direction in the Main Stem (from 368.7 to 362.3 $\mu\text{g/g}$) and in the North Arm (from 441.5 to 325.1 $\mu\text{g/g}$), but increased in the Main Arm (from 542.2 to 624.9 $\mu\text{g/g}$). In 1985, values ranged from 410 to 460 $\mu\text{g/g}$, 284 to 430 $\mu\text{g/g}$, and 520 to 590 $\mu\text{g/g}$, respectively (Swain 1986). Values were about the same in 1985 and 1987 except at Site MS-2 (Sapperton Channel) in the Main Stem and Site NA-2 (McDonald Slough) in the North Arm, where values were significantly lower in 1987 on the basis of F- and Students t-tests ($P=0.05$). Values reported by Stancil (1980) for the Main Stem (370 $\mu\text{g/g}$) were about the same as found in 1987, however values in the North and Main Arms were considerably higher in the 1985 and 1987 studies than those reported by Stancil (1980) of 213 to 320 $\mu\text{g/g}$ and 261 to 309 $\mu\text{g/g}$, respectively.

Data in Table 1 for the standard deviations of manganese values were from 32.3 (MS-2) to 40.7 $\mu\text{g/g}$ (MS-1) in the Main Stem, from 25.3 (NA-2) to

39.6 $\mu\text{g/g}$ (NA-1) in the North Arm, and from 27.2 (MA-1) to 72.8 $\mu\text{g/g}$ (MA-2) in the Main Arm. Using the statistical F-test ($P=0.05$) procedure, the standard deviations for the Main Stem and North Arm were found to be homogeneous (i.e., no significant difference), however this was not the case for the Main Arm. Therefore, the variation in manganese concentrations between upstream and downstream replicate sites in the Main Arm was statistically significant.

For individual samples collected between the replicate sites, the following values were found:

Site	Manganese ($\mu\text{g/g}$, dry-weight)		
	Main Stem (MS)	North Arm (NA)	Main Arm (MA)
3	311	334	307
4	450	440	425
5	400	469	366
6	403	342	501
7	530	398	389

Manganese values in all the reaches were occasionally outside the ranges of values found at the replicate sites. Thus, although the data for the replicate sites implied little variation in manganese values between sites in the Main Stem and the North Arm, this was not confirmed by random manganese samples collected in these reaches.

To determine if fewer than ten replicate manganese samples could be collected at each of the sites in future surveys, the standard deviation for the first three manganese samples collected at each of the replicate sites (see below) was compared to that of the ten replicates (Table 1) using the statistical F-test procedure:

Site (Figure 1)	Mean of 1st 3 Samples (dry-weight)	Standard Deviation	Calculated F	Calculated t
MS-1	358	52.0	1.63	0.38
MS-2	396	45.0	1.93	1.46
NA-1	442	40.6	1.05	0.02
NA-2	321.7	12.9	3.84	0.22
MA-1	558.7	45.7	2.81	0.80
MA-2	629	120.1	2.72	0.07

The calculated "F" values indicate that at all the replicate sites, the variation in information for manganese was significantly ($P=0.05$) similar when the number of replicates was increased from three to ten. The calculated "t" values ($P=0.05$) indicate that the mean values for three and ten replicates were statistically similar.

3.1.4.9 Nickel

Mean nickel (dry-weight) values (Table 1) were lowest in the Main Stem (30.9 to 32.3 $\mu\text{g/g}$), higher in the North Arm (35.9 to 36.0 $\mu\text{g/g}$), and highest in the Main Arm (37.8 to 40.6 $\mu\text{g/g}$). In 1985 values ranged from 34.7 (MS-1) to 40.3 $\mu\text{g/g}$ (MS-2), 38.6 (NA-1) to 38.7 $\mu\text{g/g}$ (NA-2), and from 41.3 (MA-2) to 43.3 $\mu\text{g/g}$ (MA-1), respectively (Swain 1986). Values were significantly lower in 1987 compared to 1985 at all sites except MA-2 (Ewen Slough) and NA-2 (McDonald Slough) when compared using the F- and Students t-tests ($P=0.05$). These differences are likely due to larger sized particles in the 1987 versus the 1985 survey. Variations in nickel values between stations in 1987 related to decreasing particle size in each reach.

Data in Table 1 for the standard deviations of nickel values were from 0.82 (MS-2) to 1.29 $\mu\text{g/g}$ (MS-1) in the Main Stem, from 1.45 (NA-1) to 4.14 (NA-2) in the North Arm, and from 0.84 (MA-2) to 2.04 $\mu\text{g/g}$ (MA-1) in the Main Arm. Using the statistical F-test ($P=0.05$) procedure, the standard deviations for the Main Stem were found to be homogeneous (i.e., no significant difference), however this was not the case for the North or Main Arms. Therefore, the variations in nickel concentrations between upstream and downstream replicate sites in the North and Main Arms were statistically significant.

For individual samples collected between replicate sites, the following values were measured:

Site	Nickel ($\mu\text{g/g}$, dry-weight)		
	Main Stem (MS)	North Arm (NA)	Main Arm (MA)
3	32	36	35
4	37	35	40
5	36	42	38
6	36	34	43
7	45	37	44

Nickel values at these Main Stem sites were usually outside the ranges of values for the Main Stem replicate sites, and in the Main Arm occasionally outside the ranges of values for the Main Arm replicate sites. Thus, although the data for the replicate sites implied little variation in nickel values between sites in the Main Stem, this was not confirmed by the random nickel samples collected in these reaches.

To determine if fewer than ten replicate nickel samples could be collected at each of the sites in future surveys, the standard deviation of the first three nickel samples collected at each of the replicate sites (see below) was compared to that of the ten replicates (Table 1) using the statistical F-test procedure:

Site (Figure 1)	Mean of 1st 3 Samples (dry-weight)	Standard Deviation	Calculated F	Calculated t
MS-1	30	2.0	2.42	0.95
MS-2	33	1.0	1.48	1.24
NA-1	35.3	1.15	1.57	0.65
NA-2	35	2.0	4.28	0.40
MA-1	39.3	0.58	12.5	1.22
MA-2	40	1.0	1.41	1.05

The calculated "F" values indicate that at all the replicate sites, the variation in information for nickel was significantly ($P=0.05$) similar when the number of replicates was increased from three to ten. The calculated "t" values ($P=0.05$) indicate that the mean values for three and ten replicates were statistically similar.

3.1.4.10 Lead

Although lead was often not detected ($<10 \mu\text{g/g}$ dry weight) in many of the samples collected at the replicate sites, those detected ranged as high as $30 \mu\text{g/g}$ (dry-weight). Stancil (1980) had reported undetectable ($<10 \mu\text{g/g}$) lead values in the sediments from the Main Arm and Main Stem, and values in the North Arm from 20 to $25 \mu\text{g/g}$. In 1985, lead values at the Main Arm and Main Stem sites were about $20 \mu\text{g/g}$, and from 20 to $25 \mu\text{g/g}$ at the North Arm sites (Swain 1986).

As many as seven of the ten replicate samples had undetectable levels of lead, therefore it is not realistic to attempt to estimate whether any variations between sites in each reach were statistically significant.

For individual samples collected between replicate sites, the following values were measured:

Site	Lead ($\mu\text{g/g}$, dry-weight)		
	Main Stem (MS)	North Arm (NA)	Main Arm (MA)
3	21	21	15
4	22	20	20
5	12	37	13
6	29	27	21
7	26	36	22

These data indicate that in the North Arm, lead values outside the ranges of values for the replicate sites occur. Thus there is greater variation in lead concentrations along the North Arm than is evidenced by data for the replicate sites. Swain (1983) reported lead values of $180 \mu\text{g/g}$ for sediments associated with stormwater. There are a considerable number of stormwater outfalls to the North Arm.

Given the large number of undetectable lead values in each reach (from 2 to 7), it is not practical to attempt to determine the minimum number of samples that could be collected to determine the variation in lead concentrations.

3.1.4.11 Strontium

Strontium values (dry-weight) decreased in a downstream direction in the Main Stem (from 28.6 to 25.0 $\mu\text{g/g}$) and in the North Arm (from 33.9 to 29.3 $\mu\text{g/g}$) but increased only slightly (from 40.8 to 41.3 $\mu\text{g/g}$) in the North Arm (Table 1). These values increase in relation to decreasing particle sizes between reaches. The application of the F- and Students t-tests ($P=0.05$) revealed that there was no statistically significant difference between mean values for 1985 and 1987 at Sites MS-1, MA-1, NA-1, or NA-2. Values in 1987 at Site MS-2 were significantly lower than in 1985, while values at MA-2 were significantly higher.

Data in Table 1 for the standard deviations of strontium values were from 3.27 (MS-2) to 4.12 $\mu\text{g/g}$ (MS-1) in the Main Stem, 3.09 (NA-2) to 3.35 $\mu\text{g/g}$ (NA-1) in the North Arm, and 2.49 (MA-1) to 2.50 $\mu\text{g/g}$ (MA-2) in the Main Arm. Using the statistical F-test ($P=0.05$) procedure, the standard deviations were homogeneous (i.e., no significant difference) in all three reaches, therefore the variation in strontium concentrations within each reach did not differ significantly.

For individual samples collected between replicate sites, the following values were measured:

Site	Strontium ($\mu\text{g/g}$, dry-weight)		
	Main Stem (MS)	North Arm (NA)	Main Arm (MA)
3	26	28	22
4	35	34	35
5	31	33	32
6	33	29	36
7	41	31	34

Strontium values in the Main Stem and Main Arm were often outside the ranges of values for replicate sites in their respective reaches. Thus, although the data for the replicate sites implied little variation in

strontium values between sites in the Main Stem and Main Arm, this was not confirmed by the random samples collected and analyzed for strontium in those reaches. Random samples collected in the North Arm did confirm (i.e., were within the ranges of values for replicate sites) that there was little variation.

To determine if fewer than ten replicate strontium samples could be collected at each of the sites in future surveys, the standard deviation of the first three strontium samples collected at each of the replicate sites (see below) was compared to that of the ten replicates (Table 1) using the statistical F-test procedure:

Site (Figure 1)	Mean of 1st 3 Samples (dry-weight)	Standard Deviation	Calculated F	Calculated t
MS-1	26.3	2.31	3.17	0.91
MS-2	28.3	4.51	1.91	1.44
NA-1	33.3	0.58	33.6	-
NA-2	29.3	2.52	1.51	0.0
MA-1	43.7	1.53	2.65	1.88
MA-2	41.0	4.36	3.05	0.16

The calculated "F" values indicate that at all the replicate sites except NA-1, the variation in information for strontium was significantly ($P=0.05$) similar when the number of replicates was increased from three to ten. The calculated "t" values ($P=0.05$) indicate that the mean values for three and ten replicates were statistically similar. At NA-1, when the number of replicates was increased to four, there also was no significant variation and the mean values for four and ten replicates were statistically similar.

3.1.4.12 Vanadium

Mean vanadium values (dry-weight) increased slightly in a downstream direction in the Main Stem (19.5 to 23.5 $\mu\text{g/g}$) and in the Main Arm (22.0 to

27.0 $\mu\text{g/g}$) but decreased in the North Arm (24.0 to 21.0 $\mu\text{g/g}$). Values in 1985 (Swain 1986) in the same reaches were higher (24.0 to 29.0 $\mu\text{g/g}$ in the Main Stem, 28.0 to 29.0 $\mu\text{g/g}$ in the Main Arm, and 33.0 to 34.0 $\mu\text{g/g}$ in the North Arm). These differences were found by means of the F- and Students t-tests to be statistically significant at MS-1, MA-1, MA-2, and NA-1. The differences between 1985 and 1987 are likely due to the smaller particle size sampled in 1985.

Data in Table 1 for the standard deviations of vanadium values were from 1.51 (MS-1) to 4.09 $\mu\text{g/g}$ (MS-2) in the Main Stem, 1.33 (NA-1) to 3.72 $\mu\text{g/g}$ (NA-2) in the North Arm, and 1.45 (MA-2) to 1.55 $\mu\text{g/g}$ (MA-1) in the Main Arm. Using the statistical F-test ($P=0.05$) procedure, the standard deviations in only the Main Arm were found to be homogeneous (i.e., no significant difference), therefore the variation in vanadium concentrations was statistically significant along the Main Stem and North Arm.

For individual samples collected between the replicate sites, the following values were measured:

Site	Vanadium ($\mu\text{g/g}$, dry-weight)		
	Main Stem (MS)	North Arm (NA)	Main Arm (MA)
3	25	24	24
4	26	24	26
5	25	30	26
6	23	23	30
7	26	28	28

Vanadium values at these sites in all three reaches were within the ranges of values for the replicate sites, therefore the previous conclusion that vanadium concentrations in the Main Arm do not vary significantly is unchanged.

To determine if fewer than ten replicate vanadium samples could be collected at each of the sites in future surveys, the standard deviation of the first three vanadium samples collected at each of the replicate sites (see below) was compared to that of the ten replicates (Table 1) using the statistical F-test procedure:

Site (Figure 1)	Mean of 1st 3 Samples (dry-weight)	Standard Deviation	Calculated F	Calculated t
MS-1	18.0	2.0	1.76	1.42
MS-2	26.7	7.23	3.13	1.01
NA-1	25.3	0.58	5.33	0.87
NA-2	24.0	2.0	3.46	0.61
MA-1	26.3	0.58	7.20	0.53
MA-2	29.3	1.53	1.11	0.21

The calculated "F" values indicate that at all the replicate sites, the variation in information for vanadium was significantly ($P=0.05$) similar when the number of replicates was increased from three to ten. The calculated "t" values indicate that the mean values for three and ten replicates were statistically similar.

3.1.4.13 Zinc

Mean zinc values (dry-weight) decreased slightly in a downstream direction in the Main Stem (38.8 to 37.4 $\mu\text{g/g}$) but increased in both the North Arm (69.7 to 76.4 $\mu\text{g/g}$) and the Main Arm (63.4 to 73.5 $\mu\text{g/g}$). Values in 1985 (Swain 1986) were 47 to 55 $\mu\text{g/g}$ in the Main Stem, 71 to 98 $\mu\text{g/g}$ in the North Arm, and about 70 $\mu\text{g/g}$ in the Main Arm. Application of the F- and Students t-tests determined that statistically, values in 1987 were significantly lower ($P=0.05$) than in 1985 at all sites except NA-2, likely due to the smaller particle size of the sediments collected in 1985. Stancil (1980) cited values even higher than those reported in 1985 for the Main Stem, about the same for the North Arm, but lower in the Main Arm.

Data in Table 1 for the standard deviations of zinc values were from 2.82 (MS-1) to 4.55 $\mu\text{g/g}$ (MS-2) in the Main Stem, 6.45 (NA-1) to 29.08 $\mu\text{g/g}$ (NA-2) in the North Arm, and 2.46 (MA-2) to 3.63 $\mu\text{g/g}$ (MA-1) in the Main Arm. Using the statistical F-test ($P=0.05$) procedure, the standard devia-

tions in the Main Stem and Main Arm were found to be homogeneous (i.e., no significant difference), therefore the variation in zinc concentrations was found to be statistically significant along the North Arm.

For individual samples collected between the replicate sites, the following values were measured:

Site	Zinc ($\mu\text{g/g}$, dry-weight)		
	Main Stem (MS)	North Arm (NA)	Main Arm (MA)
3	54	59	38
4	55	62	58
5	52	93	50
6	50	68	68
7	61	78	62

Zinc values in the Main Stem and the Main Arm were often outside the ranges of values for the replicate sites in those reaches. Thus, although the data for the replicate sites implied little variation in zinc values in the Main Stem and the Main Arm, this was not confined by the random site zinc values collected along those reaches.

To determine if fewer than ten replicate zinc samples could be collected at each of the sites in future surveys, the standard deviation of the first three zinc values collected at each of the replicate sites (see below) was compared to that of the ten replicates (Table 1) using the statistical F-test procedure:

Site (Figure 1)	Mean of 1st 3 Samples (dry-weight)	Standard Deviation	Calculated F	Calculated t
MS-1	36.3	3.21	1.30	1.31
MS-2	42.0	6.56	2.08	1.40
NA-1	72.3	6.43	1.01	0.61
NA-2	65.7	9.50	9.36	0.61
MA-1	65.7	3.06	1.41	0.99
MA-2	73.0	3.61	2.15	0.28

The calculated "F" values indicate that at all the replicate sites, the variation in information for zinc was significantly ($P=0.05$) similar when the number of replicates was increased from three to ten. The calculated "t" values ($P=0.05$) indicate that the mean values for three and ten replicates were statistically similar.

3.1.5 TOTAL VOLATILE RESIDUE

Volatile residue values provide an indication of the amount of organic material present in the sediments. Mean values (% on weight basis) in the Main Stem decreased in a downstream direction from 2.69% to 1.60%, but increased in the North Arm (3.76% to 4.15%) and the Main Arm (4.28% to 6.37%). This indicates that there is considerably more organic material in North and Main Arm sediments. These values are slightly lower than found in 1985 (Swain 1986) for the Main Stem (2.7% and 4.0%) and the North Arm (5.3% and 4.5%) but slightly higher for the Main Arm (4.8% to 5.5%). When tested by means of the F- and t-tests ($P=0.05$), significantly lower values were determined for Sites MS-2, NA-1, and NA-2, while no significant difference was found at Site NA-2. At Sites MS-1 and MA-2, the F-test results indicated significant ($P=0.05$) variability between 1985 and 1987.

Data in Table 1 for the standard deviations of volatile residue were from 0.411 (MS-2) to 0.935% (MS-1) in the Main Stem, from 0.528 (NA-1) to 1.260% (NA-2) in the North Arm, and from 0.371 (MA-1) to 1.0% (MA-2) in the Main Arm. Using the statistical F-test ($P=0.05$) procedure, the standard deviations in the three reaches were found not to be homogeneous (i.e., no significant difference), therefore the variation in volatile residue (and organic content) was significant along the reaches. Individual random sediment samples between the replicate sites were not analyzed for volatile residue.

To determine if fewer than ten replicate samples could be analyzed for volatile residue at each site, the standard deviation for the first three samples collected was compared to that of the ten replicates (Table 1) using the statistical F-test procedure:

Site (Figure 1)	Mean of 1st 3 Samples (% w/w)	Standard Deviation	Calculated F	Calculated t
MS-1	1.8	0.346	7.29	1.57
MS-2	1.7	0.300	1.88	0.39
NA-1	4.0	0.400	1.74	0.72
NA-2	3.5	0.656	3.69	0.84
MA-1	4.6	0.404	1.19	1.29
MA-2	6.7	1.71	2.91	0.43

The calculated "F" values indicate that at all the replicate sites, the variation in information for total volatile residue was significantly ($P=0.05$) similar when the number of replicates was increased from three to ten. The calculated "t" values ($P=0.05$) indicate that the mean values for three and ten replicates were statistically similar.

3.1.6 CARBON

Total carbon and total inorganic carbon values (dry-weight) were determined at all the replicate sites. Organic carbon is the difference between a sample's total and inorganic carbon values.

3.1.6.1 Total Carbon

Total carbon values were lowest in the Main Stem (4 346 to 7 174 $\mu\text{g/g}$), higher in the North Arm (10 462 to 10 805 $\mu\text{g/g}$), and highest in the Main Arm (10 944 to 16 050 $\mu\text{g/g}$). Thus higher levels were generally associated with smaller particle size. In the 1985 survey of the same sites (Swain 1986), values were from 9 847 to about 15 000 $\mu\text{g/g}$ in the Main Stem, from 10 547 to 17 460 $\mu\text{g/g}$ in the North Arm, and from 15 130 to 17 400 $\mu\text{g/g}$ in the Main Arm. Therefore total carbon levels in 1987 were generally considerably lower than found in 1985. The application of the F- and Students t-tests ($P=0.05$) found that there was a statistically significantly lower value at

only Site MA-1; and the differences at Sites MS-1 and NA-2 were not significantly different. At Sites MS-2, NA-1, and MA-2, the variability determined between 1985 and 1987 using the F-test ($P=0.05$) procedure was significant, therefore a comparison of mean values at those three sites may not be statistically meaningful.

Data in Table 1 for standard deviations of total carbon were from 1 390 (MS-2) to 3 898 $\mu\text{g/g}$ (MS-1) in the Main Stem, from 1 980 (NA-1) to 3 511 $\mu\text{g/g}$ (NA-2) in the North Arm, and from 1 383 (MA-1) to 3 919 $\mu\text{g/g}$ (MA-2) in the Main Arm. Using the statistical F-test ($P=0.05$) procedure, the standard deviations in only the North Arm were homogeneous (i.e., no significant difference). Therefore, the variations in total carbon concentrations were significant in the Main Stem and the Main Arm. The individual samples were not analyzed for total carbon, however it is speculated that variability in total carbon along the North Arm would have been considerable since the calculated "F" value for the North Arm (3.14) was very close to the 95% confidence level (3.18).

To determine if fewer than ten replicate samples could be analyzed for total carbon at each site in future surveys, the standard deviation of the first three total carbon samples collected at each of the replicate sites (see below) was compared to that of the ten replicates (Table 1) using the statistical F-test procedure:

Site (Figure 1)	Mean of 1st 3 Samples (dry-weight)	Standard Deviation	Calculated F	Calculated t
MS-1	3 703	453.9	73.8	-
MS-2	3 370	762.2	3.33	1.14
NA-1	11 733	1 930	1.05	0.98
NA-2	9 840	3 236	1.18	0.42
MA-1	11 800	1 559	1.27	0.92
MA-2	17 567	5 920	2.28	0.53

The calculated "F" values indicate that at all the replicate sites except MS-1, the variation in information for total carbon was significantly ($P=0.05$) similar when the number of replicates was increased from three to ten. The calculated "t" values ($P=0.05$) indicate that the mean values for three and ten replicates were statistically similar. At MS-1 (Barnston Island), the first four samples provided information with no significant variation to that of ten replicates, while the mean values were statistically similar.

3.1.6.2 Total Inorganic Carbon

Mean total inorganic carbon values (dry-weight) decreased in a downstream direction in the Main Stem (2 223 to 1 210 $\mu\text{g/g}$), the North Arm (2 245 to 1 466 $\mu\text{g/g}$), and the Main Arm (2 175 to 1 390 $\mu\text{g/g}$). Since total carbon values generally increased (Section 3.1.6.1), organic carbon levels increased. In 1985, values increased in the Main Stem (2 457 to 3 097 $\mu\text{g/g}$), but decreased in the North Arm (2 010 to 1 440 $\mu\text{g/g}$) and the Main Arm (2 410 to <500). The application of the F- and Students t-tests ($P=0.05$) determined that there were not statistically significant differences between mean values for 1985 and 1987 at Sites MS-1 (Barnston Island) and NA-1 (Upper North Arm). At Sites MS-2 (Sapperton Channel), NA-2 (McDonald Slough), and MA-1 (Annacis Channel), the variability between the data collected in the two years was determined to be significantly different ($P=0.05$) when the F-test procedure was applied.

Data in Table 1 for the standard deviations of total inorganic carbon values were from 339 (MS-2) to 646 $\mu\text{g/g}$ (MS-1) in the Main Stem, from 500 (NA-2) to 742 $\mu\text{g/g}$ (NA-1) in the North Arm, and from 505 (MA-1) to 802 $\mu\text{g/g}$ (MA-2) in the Main Arm. Using the F-test statistical procedure ($P=0.05$), the standard deviations were homogeneous (i.e. no significant difference) in the North Arm and Main Arm. The variation in total inorganic carbon values was found to be statistically significant only along the Main Stem. Individual samples collected between the replicate sites were not analyzed for total inorganic carbon. It is therefore not known if the previous

conclusion on variability in the North and Main Arms is confirmed by random samples.

To determine if fewer than ten replicate total inorganic carbon samples could be collected at each of the sites in future surveys, the standard deviation of the first three total inorganic carbon values collected at each of the replicate sites was compared to that of the ten replicates (Table 1) using the F-test statistical procedure:

Site (Figure 1)	Mean of 1st 3 Samples (wet-weight)	Standard Deviation	Calculated F	Calculated t
MS-1	2430	658.2	1.04	0.49
MS-2	1437	516.0	2.32	0.91
NA-1	1669	811.2	1.19	1.16
NA-2	2053	507.2	1.03	1.78
MA-1	2303	148.4	11.6	0.42
MA-2	1513	761.5	1.11	0.24

The calculated F values ($P=0.05$) indicate that at all the replicate sites, the variation in information for total inorganic carbon was not significantly ($P=0.05$) different when the number of replicates was increased from three to ten. The calculated "t" values ($P=0.05$) indicate that the mean values for three and ten replicates were statistically similar.

3.1.7 PHOSPHORUS

Mean phosphorus values (dry-weight) increased in a downstream direction in the Main Stem (436 to 518 $\mu\text{g/g}$) and the North Arm (565 to 667 $\mu\text{g/g}$) but decreased slightly in the Main Arm (723 to 715 $\mu\text{g/g}$). Thus, phosphorus concentrations generally increased as the particle size of the sediments decreased. In the 1985 survey of the same sites, mean values in the Main Stem increased from 567 to 636 $\mu\text{g/g}$, decreased in the North Arm from 672 to 630 $\mu\text{g/g}$, and increased in the Main Arm from 737 to 772 $\mu\text{g/g}$. Using the F-

and Students t-tests to compare 1985 and 1987 mean values at the same sites, statistically significant ($P=0.05$) lower values in 1987 were found at Sites MS-2 (Sapperton Channel), MA-2 (Ewen Slough), and NA-1 (Upper North Arm).

Data in Table 1 for the standard deviations of phosphorus values were from 42.0 (MS-1) to 55.3 $\mu\text{g/g}$ (MS-2) in the Main Stem, from 50.4 (NA-1) to 108.3 $\mu\text{g/g}$ (NA-2) in the North Arm, and from 19.6 (MA-2) to 142.1 $\mu\text{g/g}$ (MA-1) in the Main Arm. Using the statistical F-test procedure, the standard deviations in the Main Stem were determined to be homogeneous (i.e., no significant difference). Therefore the variation in phosphorus concentration was significant in both the North and Main Arms.

For individual samples collected between the replicate sites, the following values were measured:

Site	Phosphorus ($\mu\text{g/g}$, dry-weight)		
	Main Stem (MS)	North Arm (NA)	Main Arm (MA)
3	623	548	481
4	706	715	699
5	615	767	599
6	708	708	725
7	676	808	740

Phosphorus values for the individual samples in the Main Stem and Main Arm were often outside the ranges of values for the two replicate sites in these reaches. Although the data for the replicate sites in the Main Stem implied little variation in phosphorus levels, this was not confirmed by random sample phosphorus analyses along this reach.

To determine if fewer than ten replicate samples could be collected at each of the sites in future surveys, the standard deviation of the first three phosphorus values collected at each of the replicate sites (see below) was compared to that of the ten replicates (Table 1) using the statistical F-test procedure:

Site (Figure 1)	Mean of 1st 3 Samples (dry-weight)	Standard Deviation	Calculated F	Calculated t
MS-1	483	15.3	7.54	1.85
MS-2	560	95.4	2.97	0.99
NA-1	580	10.0	25.4	-
NA-2	807	35.1	9.51	2.15
MA-1	610	17.3	67.3	-
MA-2	720	17.3	1.28	0.40

The calculated "F" values indicate that at all the replicate sites except NA-1 and MA-1, the variation in information for phosphorus values was not significantly ($P=0.05$) different when the number of replicates was increased from three to ten. The calculated "t" values ($P=0.05$) indicate that the mean values for three and ten replicates were statistically similar. At NA-1 to obtain the same variation and statistically similar means ($P=0.05$), four samples were required, while at MA-1, five samples were required.

3.1.8 CONCLUSIONS

The data for sediments were examined by individual characteristics in order to:

- 1) determine trends among main river reaches;
- 2) compare values found in this 1987 survey to those found in a 1985 survey of the same sites;
- 3) determine if there was significant variation between sites where replicate samples were collected using a statistical procedure (F-test: $P=0.05$) or by a comparison of characteristics in individual grab samples collected concurrently in the same reach to the ranges of values for the replicate samples in the same reach;
- 4) determine by means of statistical procedures (F- and t-tests: $P=0.05$) if the intra-site data variability was reduced significantly by collecting fewer samples.

The last point (4) is crucial to examine initially since a comparison between data collected in 1985 and 1987 (point 2) could have no statistical

significance since generally only three replicate samples were collected in 1985 compared to ten in 1987. The samples in both surveys were collected at about the same time of year at about the same sites. It should also be remembered that in both 1985 and 1987, the boat was anchored at one location while the replicate samples were collected. Different results may be obtained if the samples were collected from a grid at a particular location.

The F- and t-test results indicated that the variability of the data collected by sampling at a fixed point did not change significantly ($P=0.05$) when the number of replicate samples was reduced from ten to three for aluminum, chromium, copper, iron, manganese, nickel, vanadium, zinc, total volatile residue, and total inorganic carbon. Four replicate samples were required to obtain the same significant ($P=0.05$) variability for barium at NA-2, strontium and phosphorus at NA-1, and total carbon at MS-1; otherwise three replicates for the same characteristics at the other replicate sites were sufficient, except phosphorus at MA-1 where five samples were required. When values of some of the replicates were below detection limits, such as for mercury and lead, it was not always possible to determine the required number of samples.

It therefore seems reasonable to compare data collected in 1987 to those collected from the same sites in 1985, since nearly 95% of the characteristics and sites examined were explained statistically by three samples.

During the 1987 survey, the largest-sized particles were found in the Main Stem, smaller particles in the North Arm, and the smallest particles in the Main Arm. This is the same general trend found among the reaches in 1985 (Swain 1986), although the particles in 1987 were coarser than in 1985. One would therefore expect lower concentrations in the 1987 survey than found in 1985.

Polychlorinated biphenyls could not be detected at the replicate sites, although PCB's were detected at three (MS-1, NA-1, NA-2) of these six sites

in 1985. This may be related to particle size or reduced PCB releases. At the 1987 random sites, PCB's could be detected at one site in the North Arm (NA-5), which was at a level which exceeded the Water Quality Objective. It is possible that these higher PCB levels could be a result of large volumes of stormwater entering the North Arm.

Chlorophenols were not detected in sediments from the replicate sites, although these had been measured at three (MS-1, NA-1, NA-2) of the six sites in 1985. This may be related to differences between 1985 and 1987 in sediment particle size. At the 1987 random sites, chlorophenols were detected at two sites (MS-3, MS-4) in the Main Stem, four sites (NA-4-7) in the North Arm, and at one site (MA-3) in the Main Arm, but at levels less than the Water Quality Objectives. Chlorophenols are likely present in stormwater discharges from wood protection sites. There are a large number of such sites along the North Arm of the river.

Values of other characteristics were generally lowest in the Main Stem, higher in the North Arm, and highest in the Main Arm. An exception to this was zinc which was highest in the North Arm. Zinc can enter the North Arm from stormwater or metal finishing plant discharges. The noted trends were also usually apparent in 1985. Characteristics measured in 1987 were usually at lower concentrations than when measured in 1985, likely due to the coarser- sized sediments encountered in the 1987 survey. Statistically significant differences ($P=0.05$) at the same sites between 1985 and 1987 were noted as follows based on F- and Students t-tests: for 6 of 14 characteristics at MS-1 (Barnston Island); for 10 of 14 characteristics at MS-2 (Sapperton Channel); for 7 of 15 characteristics at NA-1 (Upper North Arm); for one of 15 characteristics at NA-2 (McDonald Slough); for 9 of 15 characteristics at MA-1 (Annacis Channel); and for 6 of 15 characteristics at MA-2 (Ewen Slough).

The F-test results comparing upstream and downstream replicate sites indicated significant variation ($P=0.05$) within all reaches for aluminum and total volatile residue, for two of the three reaches for barium, iron,

mercury, nickel, vanadium, total carbon and phosphorus, and for one of the three reaches for chromium, copper, manganese, zinc, and total inorganic carbon. No significant variation ($P=0.05$) along the reaches was found for strontium. When results for random samples along each reach were compared to ranges of values at the two replicate sites in the same reach, significant variations (noted by being outside the replicate range or as determined by the results of the F-test) were noted in all three reaches for aluminum, cobalt, chromium, copper, iron, manganese, nickel, zinc, total volatile residue, and phosphorus.

Intra-site variability seems to be less important than inter-site variability. In future surveys of sediment quality, it is recommended that fewer replicate samples be collected at each site, and that a larger number of sites should be sampled. The F- and t-test results in this report for the characteristics of concern should assist in the determination of the exact number of replicates.

3.2 FRASER RIVER BENTHIC ORGANISMS

Benthic organisms were collected only at the six replicate sediment sites. The same benthic organisms were not found at all six sites due to particle size differences of sediments among sites, and salinity differences which increased going downstream.

Ten taxonomic groups of benthic organisms were obtained from the sediments, although one (clam) was found only at MS-1 in the Main Stem and in insufficient quantity for analysis. The other nine groups in which chlorophenols were measured included amphipods, chironomids, crustacea, diptera, lampreys, leeches, oligochaetes, pelecypods, and polychaetes. Chlorophenol results (penta (PCP), tetra (TTCP), and tri (TCP)) are in Table 3. The organisms which provide the most information due to their presence at four of the six sites in sufficient numbers to permit analyses included chironomids, pelecypods, lampreys, and oligochaetes.

In the following discussion, all values are expressed as $\mu\text{g/g}$ on a wet-weight basis. The highest chlorophenol levels were found in oligochaetes (4.2 $\mu\text{g/g}$ PCP, 3.0 $\mu\text{g/g}$ TTCP, 2.0 $\mu\text{g/g}$ TCP) and lampreys (3.2 $\mu\text{g/g}$ PCP, 0.5 $\mu\text{g/g}$ TTCP, TCP undetected) from site MS-1 in the Main Stem, in pelecypods (2.5 $\mu\text{g/g}$ PCP, 1.5 $\mu\text{g/g}$ TTCP, 0.4 $\mu\text{g/g}$ TCP) from site MA-1 in the Main Arm, and in polychaetes (1.0 $\mu\text{g/g}$ PCP, 1.0 $\mu\text{g/g}$ TTCP, 0.2 $\mu\text{g/g}$ TCP) from site NA-2 in the North Arm. High values were found at site NA-1 in the North Arm in chironomids (0.3 $\mu\text{g/g}$ PCP, 0.6 $\mu\text{g/g}$ TTCP, 0.06 $\mu\text{g/g}$ TCP), pelecypods (0.4 $\mu\text{g/g}$ PCP, 0.9 $\mu\text{g/g}$ TTCP, 0.08 $\mu\text{g/g}$ TCP), lampreys (0.3 $\mu\text{g/g}$ PCP, 0.2 $\mu\text{g/g}$ TTCP, 0.02 $\mu\text{g/g}$ TCP), oligochaetes (0.4 $\mu\text{g/g}$ PCP, 0.2 $\mu\text{g/g}$ TTCP, 0.07 $\mu\text{g/g}$ TCP), and leeches (0.8 $\mu\text{g/g}$ PCP, 0.5 $\mu\text{g/g}$ TTCP, 0.2 $\mu\text{g/g}$ TCP).

These data imply that there is a considerable level of chlorophenol contamination in benthic organisms in the North Arm. This is not surprising since random sediment samples from sites NA-4, NA-5, NA-6, and NA-7 in the North Arm had detectable chlorophenol levels, and there are a large number of wood protection facilities using chlorophenates located along the North Arm.

High chlorophenol levels were found at site MS-1 in the Main Stem in sediments during the 1985 survey (Swain 1986).

Chlorophenols (PCP and TCP) were measured in only a few organisms in a 1985 survey (Swain 1986) of the same sites. Values measured in chironomids in this survey (0.08 $\mu\text{g/g}$ PCP, 0.04 $\mu\text{g/g}$ TTCP, <0.02 $\mu\text{g/g}$ TCP) at site MS-1 in the Main Stem have increased marginally from values measured at the same site in the same organism (0.06 $\mu\text{g/g}$ PCP, 0.03 $\mu\text{g/g}$ TTCP). Larger increases were seen for lampreys (PCP increased from 0.5 to 3.2 $\mu\text{g/g}$, TTCP from <0.1 to 0.5 $\mu\text{g/g}$) from site MS-1 in the Main Stem and polychaetes (PCP increased from 0.04 to 0.2 $\mu\text{g/g}$, TTCP from 0.07 to 0.2 $\mu\text{g/g}$) from site MA-2 in the Main Arm. At site NA-2 in the North Arm, values were approximately the same or lower in polychaetes between 1985 and 1987 (PCP increased from 0.8 to 1.0 $\mu\text{g/g}$, TTCP decreased from 1.7 to 1.0 $\mu\text{g/g}$). Thus values in benthic organisms appear to be increasing, however insufficient numbers of organisms have been collected to draw a firm conclusion.

Table 3 also provides information on the organisms obtained during the 1985 and 1987 surveys of the same sites. Chironomids, pelecypods, lampreys, oligochaetes, and polychaetes have been found in both surveys in sufficient numbers to allow laboratory analysis. Future surveys should prioritize analyses on these organisms to allow as thorough a comparison as possible prior to undertaking analyses of other benthic organisms.

3.3 SEDIMENTS IN TRIBUTARIES

Sediments were collected from four sites on the Pitt River and one at the mouth of the Alouette River, two sites on each of the Brunette and Coquitlam Rivers, and one site on the Fraser River, and Still and Kanaka Creeks. The sediments from the tributaries and one site on the Fraser River at Barnston Island were collected in November 1987, compared to those cited earlier in this report which had been collected in January 1987. This difference in time of year does not permit scientifically-valid comparisons to be made between the two surveys.

Another difference between the two surveys was that the January 1987 Fraser River samples were analyzed by the B.C. Ministry of Environment and Parks (MoEP) Environmental Laboratory while those collected in January 1987 were analyzed by Can Test Ltd. This difference in the laboratory performing the analyses is another reason why scientifically-valid comparisons cannot be made between the two surveys.

3.3.1 PARTICLE SIZE DISTRIBUTION

Sediments made up of the largest sized (Table 4) particles (from largest to smaller) were from Site T-11 on the Brunette River, Site T-1 on Kanaka Creek, Site T-10 on Still Creek, and Site T-8 on the Coquitlam River (Figure 1). The smallest sized particles were associated with sediments from the Pitt River near its mouth (Site T-6) and the Pitt River (Site T-4) upstream from the Alouette River.

If the general relationship exists for these sediments wherein the smallest sized particles have the highest contamination levels due to larger surface areas, it is expected that Pitt River sediments should have the highest concentrations and those from Site T-11 on the Brunette River, the lowest.

3.3.2 POLYCHLORINATED BIPHENYLS

Whereas the MoEP Environmental Laboratory reports data for PCB isomers 1248, 1254, and 1260, Can Test Ltd. reported information on these and isomers 1016, 1221, 1232, and 1242. No PCB isomers were detected above the detection limit of 0.03 $\mu\text{g/g}$ dry-weight (Table 5).

3.3.3 CHLOROPHENOLS

As was the case for the MoEP Environmental Laboratory, values reported by Can Test for trichlorophenols were for isomers 2,3,6 and 2,4,6 and those for tetrachlorophenol were for the 2,3,4,6 isomer. Chlorophenols could not be detected (<0.005 $\mu\text{g/g}$, dry-weight) as penta- or tetra- or as tri- (<0.01 $\mu\text{g/g}$, dry-weight).

3.3.4 OTHER ORGANIC COMPOUNDS

Other organochlorinated pesticides are listed in Table 5. None of the eighteen pesticides were above varying detection limits (see Table 5) except dieldrin in sediments from near Barnston Island in the Fraser River (Site T-7). It is of interest to note that chlorophenols had been measured near this Site (T-7) at Site MS-1 in the 1985 survey (Section 3.1.3). This could indicate that there is a local source of these contaminants, or that contaminants from upstream sources are associated with larger particles and are settling out near this Site. The use of dieldrin was banned many years ago, in part, because of its persistence. It was very likely used in the Fraser Valley, so that this measured level may relate simply to past anthropogenic activity.

3.3.5 METALS AND OTHER ELEMENTS

All values cited in this Section are in terms of $\mu\text{g/g}$, dry-weight. Many of the elements listed in Table 6 could not be detected (varying detection limits, listed in Table 6) at any of the sites. These included antimony, arsenic, bismuth, and silver.

Others are ubiquitous and are not generally indicators of anthropogenic impacts. Such elements in general would be expected to vary in concentration according to the particle size of the sediments, as discussed in Section 3.3.1. Strictly speaking, if such a relationship exists, the highest values would be associated with sediments from the Pitt River Site T-6 (87.5% silt and clay particles) and the lowest from the Brunette River Site T-11 (10.9% silt and clay). This relationship is in fact found for aluminum (24 600 $\mu\text{g/g}$ at T-6 compared to 12 900 $\mu\text{g/g}$ at T-11), barium (180 $\mu\text{g/g}$ at T-6 compared to 63 $\mu\text{g/g}$ at T-11), chromium (51.1 $\mu\text{g/g}$ at T-6 compared to 14.7 $\mu\text{g/g}$ at T-11), cobalt (15.3 $\mu\text{g/g}$ at T-6 compared to 5.47 $\mu\text{g/g}$ at T-11), iron (35 900 $\mu\text{g/g}$ at T-6 compared to 14 800 $\mu\text{g/g}$ at T-11), magnesium (13 900 $\mu\text{g/g}$ at T-6 compared to 4 390 $\mu\text{g/g}$ at T-11), phosphorus (2 450 $\mu\text{g/g}$ at T-6 compared to 1 080 $\mu\text{g/g}$ at T-11), potassium (3 310 $\mu\text{g/g}$ at T-6 compared to 1 090 $\mu\text{g/g}$ at T-11), sodium (779 $\mu\text{g/g}$ at T-6 compared to 381 $\mu\text{g/g}$ at T-11), strontium (61.6 $\mu\text{g/g}$ at T-6 compared to 31.6 $\mu\text{g/g}$ at T-11), and vanadium (59.0 $\mu\text{g/g}$ at T-6 compared to 29.2 $\mu\text{g/g}$ at T-11). The remaining elements are discussed in the following sections.

3.3.5.1 Beryllium

The highest beryllium values (0.96 $\mu\text{g/g}$, dry-weight) was at Site T-6 on the Pitt River. At many other sites, values were not detectable (<0.75 $\mu\text{g/g}$, dry-weight), including Site T-11, where it had been predicted that the lowest level would be found.

3.3.5.2 Boron

The highest boron level (7.23 $\mu\text{g/g}$, dry-weight) was found in sediments from the Pitt River (Site T-4) while the lowest level (1.26 $\mu\text{g/g}$, dry-weight) was found in the Coquitlam River at Site T-8. Although strictly speaking, these levels do not correspond directly to particle size, the particle sizes of the sediments from these two sites were of the same magnitude as from Sites T-6 and T-11, respectively. Therefore, these boron levels likely reflect natural conditions (i.e., no anthropogenic effect).

3.3.5.3 Cadmium

Most cadmium values were less than the detection limit of 0.10 $\mu\text{g/g}$, dry-weight. Detectable levels were found at two Pitt River sites (T-4 and T-6), and due to the quantity of fine particles at these sites, these values likely reflect natural levels.

The highest cadmium level was in Still Creek (1.18 $\mu\text{g/g}$, dry-weight) at Site T-10. This is approximately twice the concentration of 0.6 $\mu\text{g/g}$, dry-weight allowed in solids to be dumped pursuant to regulations under the Ocean Dumping Control Act. This fact, in conjunction with the particle size distribution of the sediments, indicates that anthropogenic activities have impacted Still Creek sediments. Fortunately, this impact is not seen further downstream in the Brunette River.

3.3.5.4 Calcium

The general relationship between particle size distribution and concentration was evident for the lowest concentration of 4 120 $\mu\text{g/g}$ (dry-weight) being at Site T-11 on the Brunette River, and the second highest concentration of 11 600 $\mu\text{g/g}$ (dry-weight) being at Site T-6 in the Pitt River. However, the highest level of 11 700 $\mu\text{g/g}$ was found at Site T-7 in the Fraser River at Barnston Island. The reason for this higher value is not known, although a lime manufacturer is located just east from Barnston Island on the south shore. It is suspected that it may be erroneous since

no other Fraser River samples (Table 1) from the January 1987 survey were as high.

3.3.5.5 Copper

The lowest copper level in sediments was 17.3 $\mu\text{g/g}$ (dry-weight) in the Coquitlam River at Site T-8. The highest value was 122 $\mu\text{g/g}$ (dry-weight) in Still Creek at Site T-10. High values were not apparent at Sites T-11 and T-12 in the Brunette River. Of interest is the fact that sediments from Kanaka Creek and Still Creek were similar in size distribution, yet the copper levels in Still Creek sediments were over ten times those in Kanaka Creek. Stancil (1980) has reported that copper levels in sediments near the Iona STP of this magnitude corresponded to a zone of degradation due to human activity. Hall et al. (1976) had reported that copper, lead, and zinc were the most significant trace metal contaminants in the Brunette basin (including Still Creek).

3.3.5.6 Lead

Still Creek also had the highest lead levels (238 $\mu\text{g/g}$, dry-weight). Hall et al. (1976) had found that copper, lead and zinc were the most significant trace metal contaminants in the Brunette River basin (including Still Creek). Throughout the whole drainage system, high lead levels were found, with 52.9 $\mu\text{g/g}$ (dry-weight) at Site T-11 and 90.6 $\mu\text{g/g}$ (dry-weight) at Site T-12, both in the Brunette River. A large number of stormwater discharges occur to this drainage system.

Stormwater and/or atmospheric lead deposition are likely the sources of higher lead levels in Pitt River sediments at Site T-5 (15.1 $\mu\text{g/g}$, dry-weight) than at other Pitt River Sites.

3.3.5.7 Manganese

The highest manganese level of 558 $\mu\text{g/g}$ (dry weight) was found at Site T-6 in the Pitt River, as would be expected according to the sediment size

gradation. The lowest level was 299 $\mu\text{g/g}$ (dry-weight) in Still Creek which would not be expected from the sediment size gradation.

3.3.5.8 Mercury

Mercury contamination was apparent in Still Creek sediments, with a value of 0.12 $\mu\text{g/g}$ (dry-weight). This is about seven times greater than was found at Kanaka Creek (0.018 $\mu\text{g/g}$, dry-weight) where the gradation of particle sizes of the sediments was about the same as for Still Creek. Mercury is also present in Brunette River sediments at Site T-12, where a level of 0.066 $\mu\text{g/g}$ (dry-weight) was measured.

3.3.5.9 Molybdenum

Molybdenum could not be detected (<5 $\mu\text{g/g}$, dry-weight) at any sites except in Still Creek, where a level of 26 $\mu\text{g/g}$ (dry-weight) was found.

3.3.5.10 Nickel

As expected by an examination of the particle size distribution of sediments, the lowest nickel concentration (10.7 $\mu\text{g/g}$, dry-weight) was found in the Brunette River at Site T-11. The highest nickel level (69.6 $\mu\text{g/g}$, (dry-weight) was in Alouette River sediments. Although levels of nickel would be expected to be high in the Alouette River due to the small size of the sediments sampled, the level is about 20 $\mu\text{g/g}$ higher than in sediments from Site T-6 in the Pitt River. This could mean that there is a source of nickel to the Alouette River.

3.3.5.11 Tin

Tin could not be detected (<3 $\mu\text{g/g}$, dry weight) at any sites except in Still Creek, where a level of 5.31 $\mu\text{g/g}$ (dry-weight) was measured.

3.3.5.12 Titanium

The highest level of titanium (1 680 µg/g, dry-weight) was found at Site T-4 in the Pitt River, while the lowest (923 µg/g, dry-weight) was found at Site T-10 on Still Creek. The reason for this distribution of results is not known. However, it could be related to the analytical capability to measure this element. For two certified samples with known concentrations of 9 050 and 7 340 µg/g (dry-weight), Can Test Ltd. determined levels to be 685 and 603 µg/g (dry-weight), respectively.

3.3.5.13 Zinc

Sediments from Still Creek were also contaminated with zinc, at a level of 256 µg/g (dry-weight). This is between four and five times the level (45.2 µg/g) found in Kanaka Creek, a site with similar particle size gradation to Still Creek. The level found in Still Creek is as high as found in contaminated sediments adjacent to the outfall from the Iona STP.

Values were also high in the Brunette River at Site T-11 (83.1 µg/g, dry-weight) and at Site T-12 (128 µg/g, dry-weight). Hall et al. (1976) found that copper, lead, and zinc were the most significant trace metal contaminants in the Brunette basin (including Still Creek).

The lowest levels of zinc in sediments were from Site T-8 on the Coquitlam River (43.4 µg/g, dry-weight).

3.3.6 TOTAL VOLATILE RESIDUE AND ORGANIC CARBON

These provide measures of the amount of organic material present in the sediments. The largest percentage of volatile residue was in Still Creek sediments (11.5%) and the smallest percentage in the Pitt River at Site T-2. Percentages at most of the sites ranged from about 3% to 5%.

The largest organic carbon level was also in Still Creek sediments (37 300 µg/g, dry-weight) and the smallest in the Pitt River at Site T-2.

3.3.7 CONCLUSIONS

To note that sediments of smaller particle size sorb higher levels of contaminants compared to sediments of larger sized particles is useful when comparing sediments from different water bodies. When such relationships do not occur, areas of human impact can be suspected.

This concept was useful in examining the sediments from the tributaries since many sediment characteristics followed the predicted relationship. Characteristics for which this relationship indicated problems of contamination included cadmium, copper, lead, mercury, tin, and zinc in Still Creek sediments and lead, mercury, and zinc in Brunette River sediments.

With the exception of dieldrin measured in the Fraser River near Barnston Island, chlorophenols, PCB's and other organic compounds could not be detected in sediments from any of the tributary sites.

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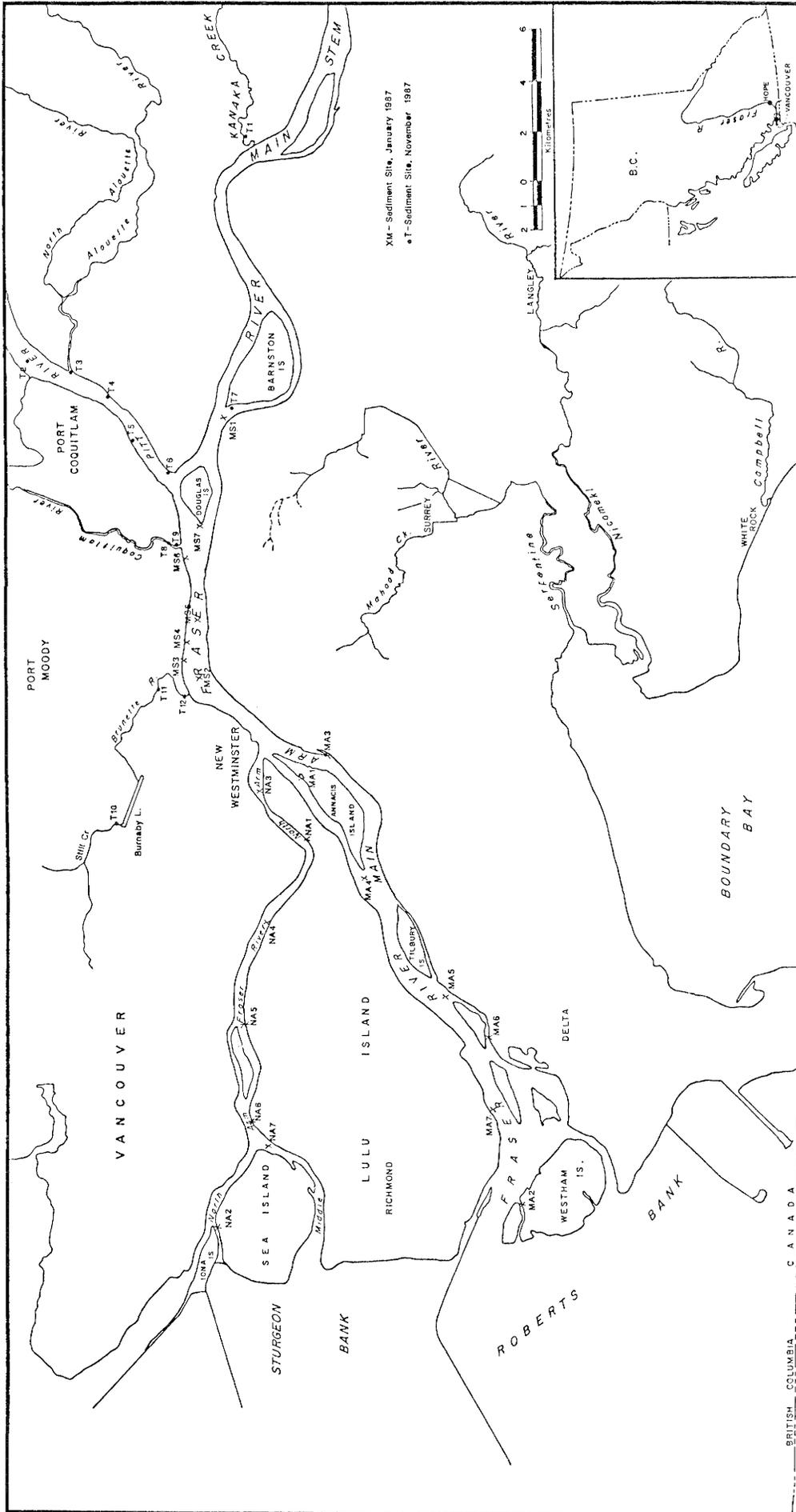


Figure 1: 1987 Sediment and Benthic Organism Sampling Sites

TABLE 1

**SUMMARY OF SEDIMENT ANALYSES AT THE TEN
REPLICATE SITES IN THE FRASER RIVER**
Site : E206965 - FRASER R AT BARNSTON ISLAND MS-1

Parameter	Unit	Maximum Observation	Minimum Observation	Mean	Standard Deviation	Date	No. Obs. (Tot)	No. Obs. (Used)
Moisture	%(W/W)	32.100	20.900	25.860	3.8945	87/01/13	10	10
Residue Tot.Volatile	%(W/W)	4.300	1.600	2.690	0.9351	87/01/13	10	10
Part. Size 16 Mesh	%(W/W)	3.800	0.100	0.800	1.1116	87/01/13	10	10
Part. Size 30 Mesh	%(W/W)	2.000	< 0.100	1.022	0.7530	87/01/13	10	9
Part. Size 50 Mesh	%(W/W)	10.800	0.800	5.600	3.4091	87/01/13	10	10
Part. Size 100 Mesh	%(W/W)	53.500	12.700	28.130	14.1267	87/01/13	10	10
Part. Size 140 Mesh	%(W/W)	50.700	24.400	37.440	9.0156	87/01/13	10	10
Part. Size 200 Mesh	%(W/W)	25.200	7.500	17.620	6.2778	87/01/13	10	10
Part. Size 270 Mesh	%(W/W)	5.700	1.000	4.160	1.7335	87/01/13	10	10
Part. Size 400 Mesh	%(W/W)	5.100	0.800	3.280	1.3506	87/01/13	10	10
Part. Size >400 Mesh	%(W/W)	4.100	0.400	2.020	1.1073	87/01/13	10	10
Carbon Tot Inorganic	ug/g	3270.000	1420.000	2223.000	646.0831	87/01/13	10	10
Aluminum	ug/g	8720.000	6370.000	7964.000	874.6085	87/01/13	10	10
Arsenic	ug/g	*****	*****	*****	*****	87/01/13	10	0
Barium	ug/g	80.000	51.000	69.300	10.8017	87/01/13	10	10
Carbon Total	ug/g	14000.000	3180.000	7174.000	3898.4248	87/01/13	10	10
Calcium	ug/g	6300.000	4630.000	5722.000	514.4533	87/01/13	10	10
Cobalt	ug/g	*****	*****	*****	*****	87/01/13	10	0
Chromium	ug/g	23.000	17.000	20.700	1.9465	87/01/13	10	10
Copper	ug/g	20.000	14.000	17.000	1.6997	87/01/13	10	10
Iron	ug/g	18400.000	15200.000	17050.000	964.0798	87/01/13	10	10
Mercury	ug/g	0.080	< 0.050	0.062	0.0130	87/01/13	10	5
Magnesium	ug/g	8190.000	7700.000	7951.000	143.8711	87/01/13	10	10
Manganese	ug/g	428.000	328.000	368.700	40.7241	87/01/13	10	10
Molybdenum	ug/g	*****	*****	*****	*****	87/01/13	10	0
Nickel	ug/g	32.000	28.000	30.900	1.2867	87/01/13	10	10
Phosphorus Total	ug/g	500.000	360.000	436.000	41.9524	87/01/13	10	10
Lead	ug/g	20.000	<10.000	12.500	5.0000	87/01/13	10	4
Selenium	ug/g	*****	*****	*****	*****	87/01/13	10	0
Strontium	ug/g	33.000	20.000	28.600	4.1150	87/01/13	10	10
Vanadium	ug/g	21.000	16.000	19.500	1.5092	87/01/13	10	10
Zinc	ug/g	43.000	34.000	38.800	2.8206	87/01/13	10	10

Site : E206966 - FRASER R AT SAPPERTON CHANNEL MS-2

Parameter	Unit	Maximum Observation	Minimum Observation	Mean	Standard Deviation	Date	No. Obs. (Tot)	No. Obs. (Used)
Moisture	%(W/W)	29.300	18.200	23.010	3.2064	87/01/13	10	10
Residue Tot.Volatile	%(W/W)	2.600	1.300	1.600	0.4110	87/01/13	10	10
Part. Size 16 Mesh	%(W/W)	0.200	< 0.100	0.150	*****	87/01/13	10	2
Part. Size 30 Mesh	%(W/W)	3.300	0.600	1.720	0.6746	87/01/13	10	10
Part. Size 50 Mesh	%(W/W)	42.800	4.900	30.920	11.9906	87/01/13	10	10
Part. Size 100 Mesh	%(W/W)	46.100	16.400	35.560	7.7380	87/01/13	10	10
Part. Size 140 Mesh	%(W/W)	25.900	12.200	18.000	4.7870	87/01/13	10	10
Part. Size 200 Mesh	%(W/W)	24.200	3.900	7.880	6.1800	87/01/13	10	10
Part. Size 270 Mesh	%(W/W)	9.900	0.600	2.330	2.8028	87/01/13	10	10
Part. Size 400 Mesh	%(W/W)	8.500	0.600	2.020	2.4376	87/01/13	10	10
Part. Size >400 Mesh	%(W/W)	6.900	0.300	1.510	2.0712	87/01/13	10	10
Carbon Tot Inorganic	ug/g	2020.000	<889.000	1210.222	339.0630	87/01/13	10	9
Aluminum	ug/g	8840.000	7530.000	8049.000	461.2657	87/01/13	10	10
Arsenic	ug/g	*****	*****	*****	*****	87/01/13	10	0
Barium	ug/g	76.000	60.000	63.900	5.0651	87/01/13	10	10
Carbon Total	ug/g	6430.000	1980.000	4346.000	1390.1174	87/01/13	10	10
Calcium	ug/g	6530.000	4060.000	4635.000	740.1238	87/01/13	10	10
Cobalt	ug/g	*****	*****	*****	*****	87/01/13	10	0
Chromium	ug/g	28.000	22.000	24.200	1.7512	87/01/13	10	10
Copper	ug/g	20.000	13.000	14.600	2.1705	87/01/13	10	10
Iron	ug/g	19400.000	15400.000	16350.000	1295.5057	87/01/13	10	10
Mercury	ug/g	0.130	< 0.050	0.064	0.0299	87/01/13	10	7
Magnesium	ug/g	8820.000	7140.000	7501.000	544.7415	87/01/13	10	10
Manganese	ug/g	430.000	330.000	362.300	32.3455	87/01/13	10	10
Molybdenum	ug/g	*****	*****	*****	*****	87/01/13	10	0
Nickel	ug/g	34.000	31.000	32.300	0.8233	87/01/13	10	10
Phosphorus Total	ug/g	660.000	470.000	518.000	55.3373	87/01/13	10	10
Lead	ug/g	30.000	<10.000	22.000	8.3666	87/01/13	10	5
Selenium	ug/g	28.000	<22.000	24.667	*****	87/01/13	10	3
Strontium	ug/g	33.000	22.000	25.000	3.2660	87/01/13	10	10
Vanadium	ug/g	35.000	21.000	23.500	4.0893	87/01/13	10	10
Zinc	ug/g	48.000	34.000	37.400	4.5509	87/01/13	10	10

TABLE 1 (CONTINUED)

Site : E206967 - Upper North Arm NA-1

Parameter	Unit	Maximum Observation	Minimum Observation	Mean	Standard Deviation	Date	No. Obs. (Tot)	No. Obs. (Used)
Moisture	%(W/W)	33.200	21.900	29.910	3.4446	87/01/14	10	10
Residue Tot.Volatile	%(W/W)	4.500	2.800	3.760	0.5275	87/01/14	10	10
Part. Size 16 Mesh	%(W/W)	0.300	0.100	0.140	0.0699	87/01/14	10	10
Part. Size 30 Mesh	%(W/W)	6.000	0.200	1.850	1.7309	87/01/14	10	10
Part. Size 50 Mesh	%(W/W)	38.500	1.000	20.020	13.2727	87/01/14	10	10
Part. Size 100 Mesh	%(W/W)	8.100	1.000	4.980	1.9770	87/01/14	10	10
Part. Size 140 Mesh	%(W/W)	10.800	0.800	5.310	3.2515	87/01/14	10	10
Part. Size 200 Mesh	%(W/W)	10.600	3.900	7.200	2.6068	87/01/14	10	10
Part. Size 270 Mesh	%(W/W)	8.900	4.000	6.200	1.5384	87/01/14	10	10
Part. Size 400 Mesh	%(W/W)	14.100	7.800	10.340	2.2555	87/01/14	10	10
Part. Size >400 Mesh	%(W/W)	72.600	25.600	43.940	13.0168	87/01/14	10	10
Carbon Tot Inorganic	ug/g	3180.000	868.000	2244.800	742.2753	87/01/14	10	10
Aluminum	ug/g	12100.000	9940.000	10834.000	713.9904	87/01/14	10	10
Arsenic	ug/g	*****	*****	*****	*****	87/01/14	10	0
Barium	ug/g	110.000	81.000	91.500	8.2899	87/01/14	10	10
Carbon Total	ug/g	13900.000	7660.000	10462.000	1979.7744	87/01/14	10	10
Calcium	ug/g	7730.000	5360.000	6541.000	661.3530	87/01/14	10	10
Cobalt	ug/g	10.000	<10.000	10.000	0.0000	87/01/14	10	7
Chromium	ug/g	28.000	24.000	26.900	1.4491	87/01/14	10	10
Copper	ug/g	32.000	23.000	27.500	2.7988	87/01/14	10	10
Iron	ug/g	25300.000	20000.000	22340.000	1520.3800	87/01/14	10	10
Mercury	ug/g	0.070	0.050	0.063	0.0082	87/01/14	10	10
Magnesium	ug/g	10100.000	7940.000	8992.000	599.4042	87/01/14	10	10
Manganese	ug/g	503.000	391.000	441.500	39.5706	87/01/14	10	10
Molybdenum	ug/g	*****	*****	*****	*****	87/01/14	10	0
Nickel	ug/g	38.000	34.000	35.900	1.4491	87/01/14	10	10
Phosphorus Total	ug/g	650.000	490.000	565.000	50.3874	87/01/14	10	10
Lead	ug/g	30.000	<10.000	18.000	8.3666	87/01/14	10	3
Selenium	ug/g	*****	*****	*****	*****	87/01/14	10	0
Strontium	ug/g	40.000	28.000	33.900	3.3483	87/01/14	10	10
Vanadium	ug/g	28.000	24.000	26.000	1.3333	87/01/14	10	10
Zinc	ug/g	81.000	61.000	69.700	6.4472	87/01/14	10	10

Site : E206968 - FRASER RIVER AT McDONALD SLOUGH NA-2

Parameter	Unit	Maximum Observation	Minimum Observation	Mean	Standard Deviation	Date	No. Obs. (Tot)	No. Obs. (Used)
Moisture	%(W/W)	35.800	25.200	29.390	3.6284	87/01/12	10	10
Residue Tot.Volatile	%(W/W)	6.500	2.800	4.150	1.2599	87/01/12	10	10
Part. Size 16 Mesh	%(W/W)	0.700	<0.100	0.289	0.2028	87/01/12	10	9
Part. Size 30 Mesh	%(W/W)	2.000	0.100	0.970	0.5208	87/01/12	10	10
Part. Size 50 Mesh	%(W/W)	14.800	2.500	6.480	3.5540	87/01/12	10	10
Part. Size 100 Mesh	%(W/W)	43.200	5.400	19.510	12.5586	87/01/12	10	10
Part. Size 140 Mesh	%(W/W)	17.500	4.300	10.620	4.1989	87/01/12	10	10
Part. Size 200 Mesh	%(W/W)	11.800	5.200	8.050	1.8549	87/01/12	10	10
Part. Size 270 Mesh	%(W/W)	7.300	3.600	5.390	1.2387	87/01/12	10	10
Part. Size 400 Mesh	%(W/W)	10.500	4.000	8.100	2.1644	87/01/12	10	10
Part. Size >400 Mesh	%(W/W)	65.700	13.300	40.580	17.6697	87/01/12	10	10
Carbon Tot Inorganic	ug/g	2390.000	960.000	1465.500	500.0136	87/01/12	10	10
Aluminum	ug/g	13400.000	7630.000	10251.000	1711.7339	87/01/12	10	10
Arsenic	ug/g	*****	*****	*****	*****	87/01/12	10	0
Barium	ug/g	92.000	45.000	58.400	14.3233	87/01/12	10	10
Carbon Total	ug/g	18500.000	6120.000	10805.000	3511.1040	87/01/12	10	10
Calcium	ug/g	5680.000	3440.000	4964.000	732.2750	87/01/12	10	10
Cobalt	ug/g	10.000	<10.000	10.000	*****	87/01/12	10	3
Chromium	ug/g	45.000	24.000	29.700	6.3953	87/01/12	10	10
Copper	ug/g	40.000	16.000	26.000	7.5719	87/01/12	10	10
Iron	ug/g	28300.000	17000.000	21710.000	3116.4258	87/01/12	10	10
Mercury	ug/g	0.120	0.050	0.082	0.0193	87/01/12	10	10
Magnesium	ug/g	10700.000	7290.000	9048.000	1029.7880	87/01/12	10	10
Manganese	ug/g	357.000	289.000	325.100	25.2650	87/01/12	10	10
Molybdenum	ug/g	*****	*****	*****	*****	87/01/12	10	0
Nickel	ug/g	44.000	32.000	36.000	4.1366	87/01/12	10	10
Phosphorus Total	ug/g	840.000	520.000	667.000	108.3256	87/01/12	10	10
Lead	ug/g	30.000	<10.000	17.500	7.0711	87/01/12	10	8
Selenium	ug/g	*****	*****	*****	*****	87/01/12	10	0
Strontium	ug/g	33.000	24.000	29.300	3.0930	87/01/12	10	10
Vanadium	ug/g	32.000	21.000	25.400	3.7178	87/01/12	10	10
Zinc	ug/g	143.000	51.000	76.400	29.0830	87/01/12	10	10

TABLE 1 (CONTINUED)

Site : E206963 - FRASER RIVER AT ANNACIS ISLAND MA-1

Parameter	Unit	Maximum Observation	Minimum Observation	Mean	Standard Deviation	Date	No. Obs. (Tot)	No. Obs. (Used)
Moisture	%(W/W)	33.600	23.700	29.160	3.4336	87/01/15	10	10
Residue Tot.Volatile	%(W/W)	5.000	3.800	4.280	0.3706	87/01/15	10	10
Part. Size 16 Mesh	%(W/W)	0.200	<0.100	0.111	0.0333	87/01/15	10	9
Part. Size 30 Mesh	%(W/W)	0.400	0.100	0.200	0.0943	87/01/15	10	10
Part. Size 50 Mesh	%(W/W)	2.200	0.200	0.680	0.6443	87/01/15	10	10
Part. Size 100 Mesh	%(W/W)	2.300	0.200	1.090	0.7264	87/01/15	10	10
Part. Size 140 Mesh	%(W/W)	11.500	0.900	5.120	3.4415	87/01/15	10	10
Part. Size 200 Mesh	%(W/W)	21.000	2.400	13.390	6.1531	87/01/15	10	10
Part. Size 270 Mesh	%(W/W)	14.500	4.400	11.110	3.4834	87/01/15	10	10
Part. Size 400 Mesh	%(W/W)	20.200	12.500	16.050	2.1900	87/01/15	10	10
Part. Size >400 Mesh	%(W/W)	78.900	39.200	52.300	14.2961	87/01/15	10	10
Carbon Tot Inorganic	ug/g	3270.000	1490.000	2175.000	504.9807	87/01/15	10	10
Aluminum	ug/g	14400.000	10800.000	12060.000	1207.5687	87/01/15	10	10
Arsenic	ug/g	*****	*****	*****	*****	87/01/15	10	0
Barium	ug/g	117.000	93.000	102.900	7.9645	87/01/15	10	10
Carbon Total	ug/g	12800.000	8640.000	10944.000	1383.1622	87/01/15	10	10
Calcium	ug/g	9320.000	7210.000	8354.000	706.3408	87/01/15	10	10
Cobalt	ug/g	10.000	10.000	10.000	0.0000	87/01/15	10	10
Chromium	ug/g	32.000	24.000	29.600	2.3664	87/01/15	10	10
Copper	ug/g	33.000	26.000	30.100	2.2828	87/01/15	10	10
Iron	ug/g	28600.000	22300.000	24830.000	2008.3424	87/01/15	10	10
Mercury	ug/g	0.080	0.060	0.071	0.0057	87/01/15	10	10
Magnesium	ug/g	10900.000	9420.000	10311.000	462.2762	87/01/15	10	10
Manganese	ug/g	587.000	506.000	542.200	27.2144	87/01/15	10	10
Molybdenum	ug/g	*****	*****	*****	*****	87/01/15	10	0
Nickel	ug/g	40.000	33.000	37.800	2.0440	87/01/15	10	10
Phosphorus Total	ug/g	900.000	590.000	723.000	142.1306	87/01/15	10	10
Lead	ug/g	20.000	<10.000	16.667	*****	87/01/15	10	3
Selenium	ug/g	*****	*****	*****	*****	87/01/15	10	0
Strontium	ug/g	45.000	37.000	40.800	2.4855	87/01/15	10	10
Vanadium	ug/g	27.000	22.000	25.800	1.5492	87/01/15	10	10
Zinc	ug/g	69.000	59.000	63.400	3.6271	87/01/15	10	10

Site : E206970 - FRASER RIVER AT EWEEN SLOUGH MA-2

Parameter	Unit	Maximum Observation	Minimum Observation	Mean	Standard Deviation	Date	No. Obs. (Tot)	No. Obs. (Used)
Moisture	%(W/W)	40.700	32.000	35.870	3.2097	87/01/12	10	10
Residue Tot.Volatile	%(W/W)	8.700	5.600	6.370	1.0023	87/01/12	10	10
Part. Size 16 Mesh	%(W/W)	0.900	0.100	0.420	0.2251	87/01/12	10	10
Part. Size 30 Mesh	%(W/W)	2.400	0.300	1.220	0.6909	87/01/12	10	10
Part. Size 50 Mesh	%(W/W)	7.000	0.400	3.240	2.3726	87/01/12	10	10
Part. Size 100 Mesh	%(W/W)	6.300	0.600	3.410	2.0936	87/01/12	10	10
Part. Size 140 Mesh	%(W/W)	5.500	1.700	3.330	1.4064	87/01/12	10	10
Part. Size 200 Mesh	%(W/W)	9.900	3.800	7.540	2.0538	87/01/12	10	10
Part. Size 270 Mesh	%(W/W)	8.900	4.900	6.850	1.3624	87/01/12	10	10
Part. Size 400 Mesh	%(W/W)	14.800	8.000	10.610	2.0701	87/01/12	10	10
Part. Size >400 Mesh	%(W/W)	75.500	54.200	63.390	7.5509	87/01/12	10	10
Carbon Tot Inorganic	ug/g	3010.000	691.000	1390.400	801.6564	87/01/12	10	10
Aluminum	ug/g	14500.000	12500.000	13610.000	578.2156	87/01/12	10	10
Arsenic	ug/g	*****	*****	*****	*****	87/01/12	10	0
Barium	ug/g	75.000	66.000	69.700	2.7508	87/01/12	10	10
Carbon Total	ug/g	24400.000	11600.000	16050.000	3919.8223	87/01/12	10	10
Calcium	ug/g	6540.000	6050.000	6294.000	175.3853	87/01/12	10	10
Cobalt	ug/g	10.000	10.000	10.000	0.0000	87/01/12	10	10
Chromium	ug/g	37.000	32.000	34.800	1.6865	87/01/12	10	10
Copper	ug/g	42.000	35.000	37.400	2.3664	87/01/12	10	10
Iron	ug/g	29100.000	26000.000	27830.000	959.2196	87/01/12	10	10
Mercury	ug/g	0.090	0.070	0.080	0.0094	87/01/12	10	10
Magnesium	ug/g	11900.000	11100.000	11660.000	250.3331	87/01/12	10	10
Manganese	ug/g	760.000	524.000	624.900	72.8216	87/01/12	10	10
Molybdenum	ug/g	*****	*****	*****	*****	87/01/12	10	0
Nickel	ug/g	42.000	39.000	40.600	0.8433	87/01/12	10	10
Phosphorus Total	ug/g	740.000	690.000	715.000	19.5789	87/01/12	10	10
Lead	ug/g	30.000	<10.000	17.143	7.5593	87/01/12	10	7
Selenium	ug/g	*****	*****	*****	*****	87/01/12	10	0
Strontium	ug/g	46.000	38.000	41.300	2.4967	87/01/12	10	10
Vanadium	ug/g	31.000	27.000	29.100	1.4491	87/01/12	10	10
Zinc	ug/g	77.000	69.000	73.500	2.4608	87/01/12	10	10

TABLE 2
LEVELS OF PCB'S AND CHLOROPHENOLS IN FRASER RIVER SEDIMENTS

River Reach	Site	CONCENTRATIONS ($\mu\text{g/g}$, wet-weight)			
		PCB's	PCP	TTCP	TCP
Main Stem	MS-1*	<0.02	<0.005	<0.005	<0.005
	MS-2*	<0.02	<0.005	<0.005	<0.005
	MS-3	<0.02	<0.002	0.002	-
	MS-4	<0.02	0.002	0.003	-
	MS-5	<0.02	<0.002	<0.002	-
	MS-6	<0.02	<0.002	<0.002	-
	MS-7	<0.02	<0.002	<0.002	-
North Arm	NA-1*	<0.02	<0.005	<0.005	<0.005
	NA-2*	<0.02	<0.005	<0.005	<0.005
	NA-3	<0.02	<0.002	<0.002	-
	NA-4	<0.02	<0.002	0.002	-
	NA-5**	0.10	0.002	0.003	-
	NA-6	<0.02	0.002	0.002	-
	NA-7	<0.02	0.002	0.002	-
Main Arm	MA-1*	<0.02	<0.005	<0.005	<0.005
	MA-2*	<0.02	<0.005	<0.005	<0.005
	MA-3	<0.02	<0.002	0.002	-
	MA-4	<0.02	<0.002	<0.002	-
	MA-5	<0.02	<0.002	<0.002	-
	MA-6	<0.02	<0.002	<0.002	-
	MA-7	<0.02	<0.002	<0.002	-

* Replicate Sites - all ten individual values below detection.

** PCB 1254

- Analysis not performed for trichlorophenol

TABLE 3
A COMPARISON OF LEVELS OF CHLOROPHENOLS ($\mu\text{g/g}$, wet-weight)
IN BENTHIC ORGANISMS FROM THE FRASER RIVER TO 1985 LEVELS

LOCATION	Amphipods			Crustacea			Chironomids					
	Organism Found in 1985	Chlorophenol*		Organism Found in 1985	Chlorophenol*		Organism Found in 1985	Chlorophenol*				
		Penta	Tetra		Tri	Penta		Tetra	Tri	Penta	Tetra	Tri
Barnston Is. (MS-1)	-	<0.02	<0.02	0.08	✓	0.05	<0.02	0.10	✓	0.08(0.06)	0.04(0.03)	<0.02
Sapperton Ch. (MS-2)	-	-	-	-	-	-	-	-	-	0.02	0.03	0.02
Upper N. Arm (NA-1)	-	-	-	-	-	IS	IS	IS	✓	0.30	0.60	0.06
McDonald Slough (NA-2)	✓	IS	IS	IS	-	IS	IS	IS	-	-	-	-
Annacis Ch. (MA-1)	-	IS	IS	IS	-	-	-	-	✓	0.10	0.10	0.06
Ewen Sl. (MA-2)	✓	IS(<0.01)	IS(<0.01)	IS	-	IS	IS	IS	-	IS	IS	IS

LOCATION	Pelecypods			Diptera			Lampreys					
	Organism Found in 1985	Chlorophenol*		Organism Found in 1985	Chlorophenol*		Organism Found in 1985	Chlorophenol*				
		Penta	Tetra		Tri	Penta		Tetra	Tri	Penta	Tetra	Tri
Barnston Is. (MS-1)	-	0.02	<0.02	0.04	-	IS	IS	IS	✓	3.2(0.05)	0.5(<0.01)	<0.02
Sapperton Ch. (MS-2)	-	-	-	-	✓	IS	IS	IS	✓	0.20	<0.02	0.08
Upper N. Arm (NA-1)	-	0.40	0.90	0.08	-	-	-	-	-	0.30	0.20	0.02
McDonald Slough (NA-2)	✓	IS(0.01)	IS(0.02)	IS	-	-	-	-	-	-	-	-
Annacis Ch. (MA-1)	✓	2.5	1.5	0.4	-	-	-	-	✓	0.10	0.02	<0.02
Ewen Sl. (MA-2)	-	0.02	0.02	0.10	-	-	-	-	-	-	-	-

LOCATION	Oligochaetes			Polychaetes			Leeches					
	Organism Found in 1985	Chlorophenol*		Organism Found in 1985	Chlorophenol*		Organism Found in 1985	Chlorophenol*				
		Penta	Tetra		Tri	Penta		Tetra	Tri	Penta	Tetra	Tri
Barnston Is. (MS-1)	✓	4.2	3.0	2.0	-	-	-	-	-	-	-	-
Sapperton Ch. (MS-2)	✓	0.03	0.20	0.06	-	-	-	-	-	-	-	-
Upper N. Arm (MA-1)	-	0.40	0.20	0.07	-	-	-	-	-	0.80	0.50	0.20
McDonald Slough (NA-2)	-	-	-	-	✓	1.0 (0.8)	1.0 (1.7)	0.2	-	-	-	-
Annacis Ch. (MA-1)	✓	0.07	0.50	0.20	-	-	-	-	✓	IS	IS	IS
Ewen Sl. (MA-2)	-	IS	IS	IS	✓	0.2+(0.04)	0.2+(0.07)	0.03+	-	-	-	-

* Values are from the 1987 survey except those in brackets which are from the 1985 survey (Swain 1986).

+ Replicate sample provided identical values.

- Not present, or no value.

IS Insufficient tissue mass for analysis in the 1987 survey.

✓ Indicates the organism was present in sufficient mass in the 1985 survey for measurements to be made of metals and/or PCB's and chlorophenols.

TABLE 4
SEDIMENT PARTICLE SIZE DISTRIBUTION
TRIBUTARY SITES

Site	Description (see Figure 1)	% Gravel	% Sand	% Silt	% Clay
		>2 mm	<2 mm >0.063 mm	<0.063 mm >0.004 mm	<0.004 mm
T- 1	Kanaka Creek	7.3	65.4	19.4	7.9
T- 2	Pitt R. u/s Alouette R.	-	60.0	31.3	8.7
T- 3	Alouette R. at Mouth	-	31.8	54.3	13.9
T- 4	Pitt R. d/s Alouette R.	-	23.1	63.7	13.2
T- 5	Pitt R. d/s Highway Bridge	-	35.8	51.2	13.0
T- 6	Pitt R. Near Mouth	-	12.5	70.7	16.8
T- 7	Fraser R. at Barnston Is.	-	51.1	37.0	11.9
T- 8	Coquitlam R. u/s Highway Bridge	-	70.4	22.0	7.6
T- 9	Coquitlam R. d/s Highway Bridge	-	43.6	44.2	12.2
T-10	Still Creek	-	72.1	17.1	10.8
T-11	Brunette R. d/s Landfill	3.1	86.0	6.2	4.7
T-12	Brunette R. Near Lamford Forest Products	-	59.5	27.4	13.1

TABLE 5
TRACE ORGANIC ANALYSES FOR SEDIMENTS IN TRIBUTARIES

Characteristic	Detection Limit	T-1 Kanaka Creek	T-2 Pitt R. u/s Alouette R	T-3 Alouette River at Mouth	T-4 Pitt R. d/s Alouette Bridge	T-5 Pitt R d/s Bridge	T-6 Pitt R Near Mouth	T-7 Fraser River Barnston Is.	T-8 Coquitlam River u/s Bridge	T-9 Coquitlam River d/s Bridge	T-10 Still Creek	T-11 Brunette River d/s Landfill	T-12 Brunette River near Lamford Forest
Aldrin	0.001	<	<	<	<	<	<	<	<	<	<	<	<
BHC, alpha	0.001	<	<	<	<	<	<	<	<	<	<	<	<
BHC, gamma	0.001	<	<	<	<	<	<	<	<	<	<	<	<
BHC, beta	0.001	<	<	<	<	<	<	<	<	<	<	<	<
BHC, delta	0.001	<	<	<	<	<	<	<	<	<	<	<	<
Chlordane	0.005	<	<	<	<	<	<	<	<	<	<	<	<
4,4'-DDE	0.003	<	<	<	<	<	<	<	<	<	<	<	<
4,4'-DDE	0.003	<	<	<	<	<	<	<	<	<	<	<	<
4,4'-DDT	0.003	<	<	<	<	<	<	<	<	<	<	<	<
4,4'-DDT	0.003	<	<	<	<	<	<	0.009	<	<	<	<	<
Dieldrin	0.003	<	<	<	<	<	<	<	<	<	<	<	<
Endosulfan I	0.01	<	<	<	<	<	<	<	<	<	<	<	<
Endosulfan II	0.01	<	<	<	<	<	<	<	<	<	<	<	<
Endosulfan sulfate	0.01	<	<	<	<	<	<	<	<	<	<	<	<
Endrin	0.01	<	<	<	<	<	<	<	<	<	<	<	<
Endrin aldehyde	0.01	<	<	<	<	<	<	<	<	<	<	<	<
Heptachlor	0.001	<	<	<	<	<	<	<	<	<	<	<	<
Heptachlor epoxide	0.001	<	<	<	<	<	<	<	<	<	<	<	<
Toxaphene	0.3	<	<	<	<	<	<	<	<	<	<	<	<
PCB-1016	0.03	<	<	<	<	<	<	<	<	<	<	<	<
PCB-1221	0.03	<	<	<	<	<	<	<	<	<	<	<	<
PCB-1232	0.03	<	<	<	<	<	<	<	<	<	<	<	<
PCB-1242	0.03	<	<	<	<	<	<	<	<	<	<	<	<
PCB-1248	0.03	<	<	<	<	<	<	<	<	<	<	<	<
PCB-1254	0.03	<	<	<	<	<	<	<	<	<	<	<	<
PCB-1260	0.03	<	<	<	<	<	<	<	<	<	<	<	<
Trichlorophenols (2,3,6 + 2,4,6)	0.01	<	<	<	<	<	<	<	<	<	<	<	<
Tetrachlorophenol (2,3,4,6)	0.005	<	<	<	<	<	<	<	<	<	<	<	<
Pentachlorophenol	0.005	<	<	<	<	<	<	<	<	<	<	<	<

All results expressed as micrograms per gram on a "dry weight" basis; < = less than

TABLE 6
PLASMA SPECTROGRAPHIC ANALYSES FOR SEDIMENTS IN TRIBUTARIES

Characteristic	Detection Limit	T-1 Kanaka Creek	T-2 Pitt R. w/s Alouette R	T-3 Alouette River at Mouth	T-4 Pitt R. d/s Alouette	T-5 Pitt R d/s Bridge	T-6 Pitt R Near Mouth	T-7 Fraser River Barnston Is.	T-8 Coquitlam River w/s Bridge	T-9 Coquitlam River d/s Bridge	T-10 Still Creek	T-11 Brunette River d/s Landfill	T-12 Brunette River near Lamford Forest Products
Moisture (105°C) xH ₂ O	0.01	31.5%	35.4%	42.8%	38.7%	41.6%	36.0%	39.0%	33.6%	42.9%	64.8%	39.3%	51.3%
Total Volatile Residue (550°C)	0.01	3.30%	2.30%	3.10%	2.90%	3.80%	3.20%	3.10%	2.40%	5.80%	11.5%	5.00%	7.10%
Aluminum	4.0	17900.	16900.	20100.	21200.	20300.	24600.	18600.	13500.	17600.	15700.	12900.	19900.
Antimony	4.0	<	<	<	<	<	<	<	<	<	<	<	<
Arsenic	10.0	<	<	<	<	<	<	<	<	<	<	<	<
Barium	0.025	87.6	126.	137.	151.	143.	180.	137.	75.9	105.	93.7	63.0	110.
Beryllium	0.75	<	<	0.78	0.86	0.76	0.9%	0.83	<	<	<	<	0.75
Bismuth	12.5	<	<	<	<	<	<	<	<	<	<	<	<
Boron	0.25	1.94	4.61	3.06	7.23	5.30	6.55	1.34	1.26	1.54	3.14	2.04	4.32
Cadmium	0.10	<	<	<	0.11	<	0.16	<	<	<	1.18	<	<
Calcium	0.25	6070.	8470.	8880.	10800.	9820.	11600.	11700.	5310.	7400.	8070.	4120.	6160.
Chromium	0.75	19.1	41.5	50.0	46.2	44.8	51.1	41.9	16.0	25.2	32.9	14.7	28.3
Cobalt	0.5	8.52	12.3	13.8	14.5	14.0	15.3	12.9	9.84	9.00	6.24	5.47	8.68
Copper	0.4	17.6	24.1	30.1	31.4	33.0	34.7	45.5	17.3	23.8	122.	20.8	37.6
Iron	0.75	21400.	28100.	31700.	32600.	32500.	35900.	31000.	18400.	24200.	20100.	14800.	26700.
Lead	2.0	3.93	4.34	6.44	6.02	15.1	6.40	4.67	7.23	12.6	238.	52.9	90.6
Magnesium	0.025	6720.	11100.	11600.	13100.	12300.	13900.	12600.	5900.	7230.	4770.	4390.	6650.
Manganese	0.075	381.	472.	485.	552.	508.	558.	496.	308.	358.	299.	362.	356.
Mercury	0.002	0.018	0.057	0.045	0.057	0.045	0.063	0.049	0.020	0.032	0.12	0.029	0.066
Molybdenum	5.0	<	<	<	<	<	<	<	<	<	<	<	<
Nickel	0.75	15.7	40.5	69.6	44.1	42.7	47.2	41.8	14.5	21.3	24.3	10.7	20.0
Phosphorus	10.	1260.	1930.	2340.	2280.	2160.	2450.	2000.	1290.	1740.	2310.	1080.	1940.
Potassium	0.25	1220.	2140.	2380.	2780.	2480.	3310.	2260.	1653.	2180.	1670.	1090.	2070.
Silver	0.75	<	<	<	<	<	<	<	<	<	<	<	<
Sodium	2.5	501.	530.	732.	643.	641.	779.	584.	543.	707.	645.	381.	716.
Strontium	0.025	52.6	48.4	51.9	54.2	52.3	61.6	56.7	36.2	49.5	47.9	31.6	47.5
Tin	3.0	<	<	<	<	<	<	<	<	<	5.31	<	<
Titanium	0.15	750.	980.	1140.	1680.	1130.	1310.	1060.	714.	996.	923.	930.	1020.
Vanadium	0.25	38.4	46.1	54.8	52.8	51.9	59.0	44.9	31.2	52.7	37.5	29.2	45.5
Zinc	0.4	45.2	59.9	76.2	71.9	75.2	78.6	68.8	43.4	57.4	256.	83.1	128

All results expressed as micrograms per gram on a "dry weight" basis; < = less than

TABLE 7
CARBON ANALYSES FOR TRIBUTARY SITES

Site	Description (see Figure 1)	Carbon ($\mu\text{g/g}$, dry-weight)		
		Total	Organic	Inorganic
T- 1	Kanaka Creek	8 900	6 500	2 400
T- 2	Pitt R. u/s Alouette R.	7 400	3 600	3 800
T- 3	Alouette R. at Mouth	10 300	5 600	4 700
T- 4	Pitt R. d/s Alouette R.	10 400	5 100	5 300
T- 5	Pitt R. d/s Highway Bridge	14 000	7 700	6 300
T- 6	Pitt R. near Mouth	10 700	5 800	4 900
T- 7	Fraser R. at Barnston Is.	10 300	5 900	4 400
T- 8	Coquitlam R. u/s Highway Bridge	19 800	12 200	7 600
T- 9	Coquitlam R. d/s Highway Bridge	8 300	4 400	3 900
T-10	Still Creek	52 600	37 300	15 300
T-11	Brunette R. d/s Landfill	15 200	9 500	5 700
T-12	Brunette R. Near Lamford Forest Products	27 900	16 500	11 400

APPENDIX

SAMPLE PREPARATION AND ANALYSIS
CAN TEST LTD.



can test ltd.

REPORT ON: Analysis of sediment samples for Trace Metals and Trace Organics

REPORTED TO: Province of British Columbia (Ministry of Environment and Parks)
15326 - 103A Avenue
Surrey, B.C.
V3R 7A2

Att'n: Mr. Doug Walton, Ph.D.

FILE NO: 5890G

DATE: February 1, 1988

cc + Invoice: Fraser River Harbour Commission
Suite 505, 713 Columbia St.
New Westminster, B.C. V3M 1B2



We have tested the sediment samples submitted by you on November 17, 1988 and report as follows:

SAMPLE IDENTIFICATION:

The samples were submitted in plastic and glass containers and were labelled as shown under the "Results of Testing".

METHOD OF TESTING:

Approach - As received (wet) samples were digested with nitric (NH_3) and perchloric (HClO_4) acids and analyzed the same day for mercury by Mercury Monitor, copper, lead, and zinc by Flame Atomic Absorption Spectrophotometry (AA), cadmium by Graphite Furnace (AA) and all other reported metals by Inductively Coupled Argon Plasma Spectroscopy. The polychlorinated biphenyls, chlorinated phenolics, organochlorinated pesticides and oil and grease analyses were determined on the samples "as received" using the recommended and accepted procedures.

The carbon analyses and volatile residue determinations were performed on a dried, crushed and homogenized sub-aliquot of each sample.

The moisture content of the samples was determined gravimetrically on separate aliquots, dried at 105°C overnight.

can test it.**Sample Dissolution, trace metal analysis**Nitric-Perchloric Acid Digestion of "as received" samples

The samples were digested for the trace metals analysis after representative duplicate subsamples were accurately weighed into Pyrex beaker, fitted with glass covers. Seven millilitres of concentrated Baker Instra Analysed Nitric Acid was added to each sample and this mixture digested for one hour. After cooling, five millilitres of Amachem Reagent Grade Perchloric Acid was added to each sample and this mixture digested until dense perchloric acid fumes were expelled. After cooling the samples were diluted to volume using distilled, de-ionized water. Acid reagent blanks and Certified Marine Sediment Reference Materials MESS-1 and BCSS-1 were digested and analyzed concurrently.

Trace Metals Analysisi) Mercury (Hg)

Analysis was performed on the "nitric-perchloric digestion" solutions by first calibrating the Mercury Monitor with a series of freshly-prepared mercury standard solutions. Analysis of digestion blanks, and sample solutions was then carried out in duplicate. Calibration was checked after every ten samples solutions.

Briefly, mercury analysis is carried out as follows:

- pipet standard or sample solution into reaction vessel, dilute to volume with ultra-pure water.
- add 10 drops 20 percent Stannous Chloride Solution.
- connect bubbling tube to reaction vessel, bubble nitrogen through solution until instrument recorder pen starts descending back towards baseline.
- calibration curve is prepared by plotting recorder peak height versus micrograms of mercury in standard solution.

ii) I.C.P. (Plasma) Analysis

Analysis was performed on the "Nitric Perchloric" digested solutions for the all other elements reported. The instrument used was a Jarrell Ash Model #975 Inductively Coupled Argon Plasma Spectrograph (ICAP), equipped with a Minipuls 2 Peristaltic Pump and an "All Glass" MAK High Pressure Nebulizer.

The Instrument was calibrated using standard solutions prepared from pure metals or pure metal salts obtained from Johnson Matthey or from Spex Industries. Calibration was checked after every ten solutions (blanks, Certified Standards, or sample solutions) were analyzed; the instrument was recalibrated if the deviation from the standard value was over two percent

For this study, the ICP Analysis was undertaken using a "General Purpose" ICP program which consists of thirty elements and their associated calibration standard solutions. This was done to ensure that computer corrections for spectral interferences caused by elements such as aluminum, magnesium and titanium could be carried out. This elemental array with calibration standards are used on a daily basis for analysis of water, biological tissues, geological materials, and alloys.

iii) Analysis by Atomic Absorption Spectrophotometry

Graphite Furnace Atomic Absorption Analysis - The element cadmium was determined Graphite Furnace Atomic Absorption Spectrophotometer on the $\text{HNO}_3/\text{HClO}_4$ digests of undried sample material.

can test ltd.Province of British Columbia
File No: 5890G

Instrumental Conditions were:

Cadmium

Wavelength	222.8	nm
Lamp current	6	mA
Slit width	0.7	nm
Volume Injected	50	microliters
Drying Cycle	100 ⁰	C for 30 sec, ramp 20 sec
Charring Cycle	400 ⁰	C for 30 sec, ramp 20 sec
Atomizing Cycle	1500 ⁰	C for 8 sec

The instrument was calibrated using standard solutions at levels of 0.001 mg/L, 0.005 mg/L, 0.010 mg/L, 0.030 mg/L and mg/L. These calibration standards were prepared, immediately prior analysis, by serial dilution of a 100 mg/L cadmium stock solution. The stock solution was prepared from pure cadmium metal.

Flame Atomic Absorption Analysis - The elements copper, lead and zinc were determined using Background Corrected Flame Atomic Absorption Spectrophotometry on the $\text{HNO}_3/\text{HClO}_4$ digests of the undried sample material.

The instrument was calibrated with standard solutions prepared from pure metals or pure metal salts. Calibration was checked after the analysis of every ten solutions.

Instrumental Conditions were:

	<u>Copper</u>	<u>Lead</u>	<u>Zinc</u>
Wavelength	324.7 nm	217.0 nm	213.9 nm
Lamp Current	5. mA	5. mA	5. mA
Slit Width	0.5 nm	0.5 nm	1. nm
Flame Condition	Oxidizing	Oxidizing	Oxidizing

Organic Analysesi) Chlorinated Phenols

Analysis of the sediments for chlorinated phenols was carried out in accordance with a procedure obtained from the British Columbia Ministry of Environment, Water Resources Laboratory.

Briefly, the procedure consists of extraction of an accurately weighed ten gram sample of undried sediment with a methanol-dichloromethane solvent mixture at an acidic pH, followed by extraction by acidic dichloromethane, derivatization (methylation), and analysis using Gas Liquid Chromatography using an Electron Capture Detector.

ii) Polychlorinated Biphenyls (PCB's)

The analysis was carried out in accordance with the methodology described in the "Procedure for the Analysis of Organochlorinated Pesticides and PCB's in Water, Sediment, and Fish", published by Inland Water Directorate, Water Quality Branch, Environment Canada, 1979.

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File No: 5890G

4

iii) Organochlorinated Pesticides

The organochlorinated pesticides were analysed in accordance with methodology described in "Test Methods for Evaluating Solid Wastes" SW-846, 2nd Edition, 1982, published by the United States Environment Protection Agency, Washington, D.C. 20460. The method #8080 was used to determine the chlorinated pesticides.

Carbon Analyses - The total carbon was determined on a dried and crushed portion of the samples using a Leco Induction Furnace. The total organic carbon was also determined by Leco Induction Furnace after a digestion with hydrochloric acid to remove carbonates. The inorganic carbon was calculated by difference of the total and organic carbons.

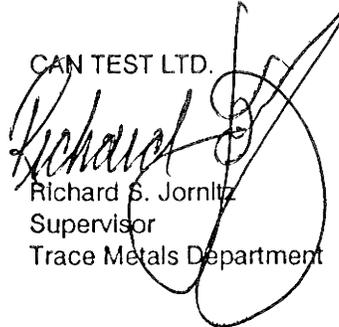
Particle Size Distribution - Analyzed for in accordance with procedures described in Ocean Dumping Report #1, "Methods for Sampling and Analysis of Marine Sediments and Dredged Materials", edited by A. Walton, Department of Fisheries and Environment, Ottawa, 1978.

Total Volatile Residue - The volatile residue was determined in accordance with procedures described in "Standard Methods for the Examination of Water and Wastewater (16th Edition)" published by the American Public Health Association, 1985, pages 97 and 98.

RESULTS OF TESTING:

NOTE: All results other than particle size, carbon, moisture and volatile residue have been reported as micrograms parameter per gram of sample on a "dry weight" basis, all others have been reported as percent "dry weight" basis.

See the following pages.

CAN TEST LTD.

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Supervisor
Trace Metals Department

RSJ/csd
D4:PROVBC

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Province of B.C.
 File No: 5890G
 Page No: 12

NATIONAL RESEARCH COUNCIL (NRC) - MESS-1

Plasma Spectrographic analysis made on Certified Reference Material

SAMPLE I.D.		CERTIFIED	ANALYSED DEC. 3, 1987
MAJOR COMPONENTS (Percent)			
Silica	SiO ₂	67.5	-
Alumina	Al ₂ O ₃	11.03	4.77
Iron	Fe ₂ O ₃	4.36	3.72
Calcium	CaO	0.674	0.43
Magnesium	MgO	1.44	1.29
Sodium	Na ₂ O	2.50	0.80
Potassium	K ₂ O	2.24	0.70
		0.72 as S	-
TRACE COMPONENTS (Microgram per Gram)			
Antimony	Sb	0.73	<8.0
Arsenic	As	10.6	<15.0
Barium	Ba	-	80.0
Beryllium	Be	1.9	1.13
Bismuth	Bi	-	<25.0
Boron	B	-	22.8
Cadmium	Cd	0.59	0.58
Chromium	Cr	71.0	32.5
Cobalt	Co	10.8	10.0
Copper	Cu	25.1	22.5
Lead	Pb	34.0	29.5
Manganese	Mn	513.	353.
Mercury	Hg	0.171	0.20
Molybdenum	Mo	2.2*	<2.0
Nickel	Ni	29.5	25.5
Phosphorus	P ₂ O ₅	2180.	1650.
Silver	Ag	-	<1.5
Strontium	Sr	89.0*	33.3
Tin	Sn	-	<1.5
Titanium	Ti	9050.	685.
Vanadium	V	72.4	44.7
Zinc	Zn	191.	175.

< = less than
 *Not Certified

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Province of B.C.

File No: 5890G

Page No: 13

NATIONAL RESEARCH COUNCIL (NRC) - BCSS-1

Plasma Spectrographic analysis made on Certified Reference Material

SAMPLE I.D.		CERTIFIED	ANALYSED DEC. 3, 1987
MAJOR COMPONENTS (Percent)			
Silica	SiO ₂	66.1	-
Alumina	Al ₂ O ₃	11.83	5.67
Iron	Fe ₂ O ₃	4.70	4.18
Calcium	CaO	0.76	0.67
Magnesium	MgO	2.44	2.30
Sodium	Na ₂ O	2.72	1.17
Potassium	K ₂ O	2.17	1.00
		0.36 as S	-
TRACE COMPONENTS (Microgram per Gram)			
Antimony	Sb	0.59	<8.0
Arsenic	As	11.1	<15.0
Barium	Ba	-	101.
Beryllium	Be	1.3	1.00
Bismuth	Bi	-	<25.0
Boron	B	-	36.5
Cadmium	Cd	0.25	0.20
Chromium	Cr	123.	65.0
Cobalt	Co	11.4	10.0
Copper	Cu	18.5	17.1
Lead	Pb	22.7	21.3
Manganese	Mn	229.	195.
Mercury	Hg	0.129	0.15
Molybdenum	Mo	1.9*	<2.0
Nickel	Ni	55.3	48.8
Phosphorus	P ₂ O ₅	2300.	1960.
Silver	Ag	-	<1.5
Strontium	Sr	96.0*	36.0
Tin	Sn	-	<1.5
Titanium	Ti	7340.	603.
Vanadium	V	93.4	51.0
Zinc	Zn	119.	107.

< = less than

*Not Certified