Fraser River Action Plan

Recommended Guidelines for Wastewater Characterization in the Fraser River Basin

Volume I Development Document

CANADA'S GREEN PLAN
LE PLAN VERT DU CANADA

Canada

DOE FRAP 1993-10

Environment Canada Environnement Canada

RECOMMENDED GUIDELINES FOR WASTEWATER CHARACTERIZATION IN THE FRASER RIVER BASIN

VOLUME I
DEVELOPMENT DOCUMENT

DOE FRAP 1993-10

Prepared for:

Environment Canada
Environmental Protection
Fraser Pollution Abatement Office
224 West Esplanade
North Vancouver, B.C.
V7M 3H7

Prepared by:

NORECOL ENVIRONMENTAL CONSULTANTS LTD.
Richmond, B.C.

June 1993

PREFACE

This consultant's report contains the results of a project conducted under contract to Environment Canada. Comments regarding this report are welcomed and should be addressed to:

Ms. Lisa Walls
Senior Engineer
Fraser Pollution Abatement Office
Environment Canada
224 West Esplanade
North Vancouver, British Columbia
V7M 3H7

EXECUTIVE SUMMARY

The Fraser River Action Plan, an initiative under Canada's Green Plan, includes a cooperative pollution abatement program with specific targets to:

- reduce by 30% the total discharge of environmentally disruptive effluents entering waters of the Fraser River Basin by the year 1997; and

- reduce the release of persistent toxic substances entering the waters of the basin, to the extent attainable by best practicable technology.

The Fraser Pollution Abatement Office (FPAO) has the responsibility to determine strategies for meeting these targets. The first step toward devising strategies is to identify the contaminant sources and the loadings of specific contaminants by characterizing wastewater releases to the Fraser River and its tributaries.

It is envisaged that wastewater characterization will be conducted jointly by FPAO, other government agencies, crown corporations, first nations, industries, and/or consultants. In order to ensure comparability of data generated at different sites and by different agencies, a consistent set of field sampling protocols and analytical procedures must be established. Therefore, FPAO contracted Norecol Environmental Consultants Ltd. to prepare documents describing the parameters to be measured, the protocols for field sampling and the preferred analytical methods to be used in the quantitative assessment of wastewater discharges within the Fraser River Basin.

The purposes of this Development Document are to define the parameters to be measured in the wastewater characterization program and to explain the rationale for parameter selection. Volume II of this series, the Methods Manual, outlines sampling and analytical protocols.

The Development Document identifies core parameters to be measured at all sites and source-specific parameters to be monitored at specific industrial, agricultural or urban (eg. sewage treatment plant) sites. Developing the parameters list involved:

1) development of an initial list of parameters to be evaluated;

2) evaluation of the parameters with emphasis on tentatively selecting those persistent and/or toxic substances that could have significant impacts on aquatic organisms; and

3) final parameter selection based on probable presence in Fraser Basin effluents and the ability to obtain accurate, routine analytical results.

The selection process resulted in the identification of 9 core and 35 industry specific parameters or parameter groups. The industry specific parameters include a variety of parameters that have been identified in sediments and fish tissues in the Fraser Basin: chlorophenols, chlorinated dioxins and furans, polycyclic aromatic hydrocarbons (PAH), and several metals. They also include chlorinated and non-chlorinated organic compounds selected from the Priority Substances List of the Canadian Environmental Protection Act. These substances are potentially of concern because of their toxicity or because they have been found in the tissues of aquatic organisms from other basins.

The document identifies industry specific parameters for 10 industry groups. It also recommends development of or testing to confirm the validity of analytical methods for parameters potentially of concern but for which reliable methods do not exist or have only recently been developed.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

INTRODUCTION

1.1 Background

The Fraser River Action Plan, an initiative under Canada's Green Plan, has a key goal to implement a cooperative pollution abatement program to reverse the trend of environmental degradation in the Fraser River ecosystem. The specific targets of the pollution abatement program are to:

- reduce by 30% the total discharge of environmentally disruptive effluents entering waters of the Fraser River Basin by the year 1997; and

- reduce the release of persistent toxic substances entering the waters of the Basin, to the extent attainable by best practicable technology.

Persistent toxic substances are defined by the Priority Substances List and Toxic Substances List (PSL) and the Toxic Substances List (TSL) of the Canadian Environmental Protection Act (CEPA).

The Fraser Pollution Abatement Office (FPAO) has been formed to coordinate action toward these pollution abatement targets. In order to determine strategies for meeting the targets, it is first necessary to identify the contaminant sources and the loadings of specific contaminants produced by each source. Therefore, an immediate priority of FPAO is to characterize the wastewater releases that contribute to contaminant loadings to the Fraser River and its tributaries.

It is envisaged that wastewater characterization will be conducted jointly by FPAO, other government agencies, crown corporations, first nations, industries, and/or consultants. In order to ensure comparability of data generated at different sites and by different agencies, a consistent set of field sampling protocols and analytical procedures must be established. Therefore, FPAO contracted Norecol Environmental Consultants Ltd. to prepare documents describing the parameters to be measured, the protocols for field sampling and the preferred analytical methods to be used in the quantitative assessment of wastewater discharges within the Fraser River Basin.

The study focuses on "end of pipe" measurements on stationary source effluent discharges to surface water courses and to ground. The effluents addressed include process and cooling water discharges. Storm water is included if it discharges directly to the receiving environment through a pipe or ditch (point source) and does not discharge to the municipal storm, sanitary, or combined sewer system.

1.2 Objectives

In order to provide methods for conducting valid wastewater characterization studies, FPAO initiated a two-phase project to develop guideline documents. The overall objectives of the project were:

- to identify the list of parameters that will be used to characterize wastewater discharges in the Fraser River Basin;
- to develop guidelines on field sampling procedures and quality assurance measures to generate reliable and comparable data on parameter concentrations and loadings; and
- to prepare technical specifications on sample collection, preservation, processing, and transportation procedures, and to identify preferred and alternate analytical methods that can be appended as terms of reference to future statements of work for wastewater characterization.

The project is divided into two phases. The first phase, reported in this volume, identifies the parameters to be used in wastewater characterization. Volume II, the Methods Manual, describes the protocols for collecting and analyzing the samples.

The specific objectives of the Development Document are to determine:

- core parameters to be measured at all sites, and
- source-specific parameters to be monitored at specific industrial, agricultural or urban (eg. sewage treatment plant) sites.

Development of the list of characterization parameters included identifying candidate parameters to be evaluated, determining the criteria for evaluation, and applying the selection criteria to derive the final parameter list.

The Development Document describes the development and application of the selection criteria and identifies the recommended monitoring parameters for each major industry group within the Fraser Basin. It is FPAO's hope that comments on the contents of this report will enable FPAO to improve the recommended list of parameters for wastewater characterization in the basin.

PARAMETER SELECTION METHODOLOGY

This section outlines the process and criteria used to develop the list of parameters for wastewater characterization. Sections 3 and 4 describe the selection of parameters to evaluate, application of the selection criteria, and the information used for parameter selection. Section 5 presents the recommended core and industry-specific parameter lists.

2.1 Overview of Selection Process

The parameter selection process was designed primarily to identify persistent toxic substances present (or likely to occur in) Fraser Basin effluents but also to identify supporting parameters that would aid in data interpretation. The process involved the following three steps:

1) development of an initial list of parameters to be evaluated;

2) evaluation of the parameters with emphasis on tentatively selecting those persistent and/or toxic substances which could have significant impacts on aquatic organisms; and

3) final selection based on probable presence in Fraser Basin effluents and the ability to obtain accurate, routine analytical results.

Figure 2-1 outlines the selection process.

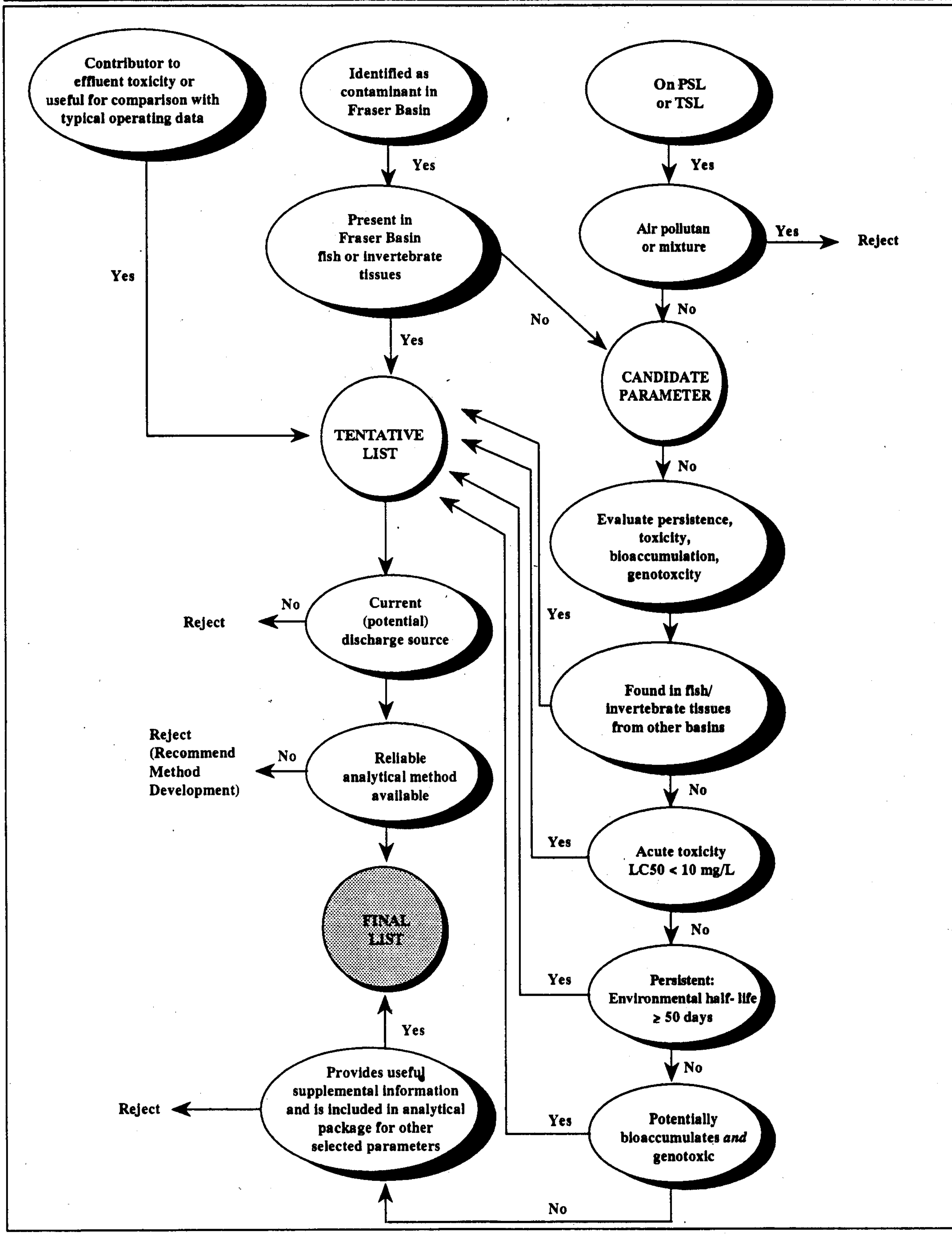
2.2 Identification of Parameters for Evaluation

The following initial selection criteria were used to identify parameters for further evaluation:

1) The substance has been identified as a contaminant of concern in effluent, water, sediments, or fish of the Fraser River Basin.

2) The substance is included on the Priority Substances List (PSL) or Toxic Substances List (TSL) of the Canadian Environmental Protection Act (CEPA).

FIGURE 2-1 **PARAMETER SELECTION PROCESS**



3) The parameter could provide useful supporting data to explain effluent toxicity, flag potential problems not identified by the other analyses, or provide a degree of confidence that samples were collected under typical operating conditions for the particular plant.

To identify contaminants of concern in the Fraser Basin, Norecol reviewed published and unpublished technical literature related to monitoring of effluents, water, sediments, and biota within the Fraser Basin and the Fraser Estuary. Substances which had been detected in the tissues of aquatic organisms were placed on a "tentative" parameters list. The rationale for promoting these substances directly to the tentative parameters list was as follows. Any substance that bioaccumulates has the potential to harm the organism in which it occurs as well as any other organism (including human) that eats it. Although not all bioaccumulated substances may be harmful, they at least merit monitoring.

Substances that had not been detected in aquatic organisms but had been identified as being present and potentially of concern in effluents or receiving waters were considered "candidate parameters". These substances were evaluated further with respect to the criteria listed in Section 2.3.

Norecol also screened the CEPA PSL and TSL lists. Parameters on the TSL list which were only of concern with respect to air pollution were eliminated. Mixtures of substances which are not specifically identified were also eliminated because nonspecific parameters could not be evaluated and cannot be analyzed. The remaining PSL and TSL compounds were placed on the list of candidate parameters and subjected to the continuing selection process.

A third group of parameters was identified during the initial selection process. These parameters were not necessarily persistent or toxic substances but were selected because they could provide useful supplemental information on wastewater characteristics. Parameters in the third group were selected based on the following criteria:

1) The parameter could help to explain the results of effluent toxicity tests because it is a known contributor to effluent toxicity (eg. ammonia, residual chlorine) or is a known modifier of toxicant effects (eg. pH, dissolved oxygen).

2) The parameter could help to explain adverse environmental effects or to flag potential problems not identified by the other analyses (eg. dissolved organic carbon, biochemical oxygen demand).

3) The parameter could be compared with routine monitoring data to indicate whether a discharge sampled on a single day represented typical effluent conditions (eg. AOX in pulp mill effluents).

Many of the parameters considered in the supplemental category were "conventional parameters" monitored under the province of Ontario's Municipal-Industrial Strategy for Abatement (MISA) program. Norecol reviewed the rationale for monitoring these parameters given in the MISA development documents (eg. OMOE 1989) and selected parameters for which the rationale was consistent with the selection criteria for the Fraser Basin program. Supplemental parameters were promoted directly to the tentative parameters list.

2.3 Detailed Evaluation of Candidate Parameters

2.3.1 Factors Considered

Candidate parameters were promoted to the tentative parameters list if they were deemed to be persistent or toxic substances. The definition of a persistent or toxic substance was based on the following factors:

1) Demonstrated or inferred potential to bioaccumulate;

2) Persistence in the environment;

3) Acute toxicity to aquatic organisms at low concentrations; and

4) Demonstrated or probable genotoxicity.

Some definitions of these factors are necessary prior to explaining how they were applied.

Bioaccumulation. The potential for a substance to bioaccumulate can be measured directly in the laboratory, based on field measurements, or inferred from the substance's octanol/water coefficient. When an organism is exposed in the laboratory or field to a chemical present in water, bioaccumulation is expressed as the bioconcentration factor (BCF), which is the ratio of the concentration of the chemical in the organism to its concentration in the water. The octanol/water partition coefficient measures the relative amounts of a chemical which dissolve in an organic solvent (octanol) and water. Use of this ratio assumes that a compound which dissolves more readily in octanol than in water is likely to have an affinity for fat and therefore will bioaccumulate. The log of the octanol/water partition coefficient has been shown to be proportional to the log of the BCF.

Another indicator of bioaccumulation is the half-life of a substance in fish (or other aquatic organisms), which measures the potential for the tissue contamination to persist after the animal is no longer exposed to the substance. In general, the greater the half-life, the greater the potential for the chemical to bioaccumulate.

Persistence. Environmental persistence is measured by half-life, or the time it takes for 50% of the initial concentration to disappear. Substances are removed from the aquatic environment by a number of mechanisms, including volatilization, hydrolysis, and biodegradation. The cumulative effects of all these processes will determine the half-life of a substance in the aquatic environment.

Acute Toxicity. Acute lethality is measured by the LC50, which is the concentration of a chemical that kills 50% of the test animals in a specified time period. Sublethal effects, such as loss of equilibrium in fish or immobilization of *Daphnia*, are measured by the EC50, or concentration that produces the specified response in 50% of the test animals. The time period for measuring acute LC50 or EC50 is $\leq$96 hours (usually 96 hours for fish and 48 hours for invertebrates).

Genotoxicity. Genotoxicity is the ability of a chemical to produce any of three effects. The separate abilities to produce these effects are defined as follows:

- *Carcinogenicity*, the ability of a substance to cause cancer as estimated from tests with experimental animals (rats, mice) or from actual human exposure data;
- *Teratogenicity*, the ability to cause abnormal development of a fetus (without causing hereditary changes), estimated by tests with experimental animals; and
- *Mutagenicity*, the ability to cause hereditary changes in cells, estimated by various experimental procedures ranging from tests on bacteria or isolated cells to tests on whole animals (mice, rats);

The tests for carcinogens, teratogens, and mutagens generally are done to address concerns for human health. Humans are unlikely to be exposed directly to contaminants in the Fraser Basin ecosystem, unless they consume fish which have concentrated these substances. However, potential for carcinogenicity, teratogenicity, or mutagenicity may signal a potential for adverse impacts to aquatic organisms.

2.3.2 *Selection Criteria to Evaluate Candidate Parameters*

The four key factors were applied by defining a set of rules or specific numeric limits that, if met, would result in parameter selection. The numeric limits were those used by the Ontario Ministry of Environment to screen parameters for inclusion in the

MISA monitoring program (OMOE 1987a). If a candidate parameter met any of the following criteria, it was promoted to the tentative parameters list:

1) The substance has been detected in the tissues of aquatic organisms from locations other than the Fraser Basin. (Substances detected in organisms from the Fraser Basin had already been promoted to the tentative parameters list as described in Section 2.2).

2) The substance is acutely lethal or sublethal to fish or invertebrates as indicated by an LC50 or EC50 $\leq$10 mg/L.

3) The substance has a half-life in aquatic systems $\geq$50 days. Because of the variety of methods for estimating half-life, this criterion was applied only to data determined in natural systems or mesocosms (which closely simulate natural systems). Half-lives estimated from bench-scale laboratory determinations were not considered sufficient to promote a substance, unless data addressing several types of loss (eg. volatilization, hydrolysis, biodegradation) all supported a long half-life.

4) The inferred potential to bioaccumulate or genotoxicity alone were not considered sufficient to promote a substance to the tentative parameters list. However, a substance was promoted if it met *both* of the following criteria:

    a) The substance has a BCF in aquatic organisms $\geq$700 or a log(octanol/water partition coefficient) $\geq$4.5; and

    b) The substance is a known or suspected carcinogen, teratogen or mutagen.

2.3.3 Data Used to Evaluate Candidate Parameters

In order to evaluate each of the candidate parameters against these criteria, Norecol reviewed a range of documents which summarize environmental fate and toxicity data for a large number of compounds. Key documents included:

- the development document for the MISA priority pollutants list (OMOE 1987a), which summarizes screening data and methodologies used by the Niagara River Toxics Committee and the Michigan Critical Materials Register Advisory Committee;

- Canadian Council of Resource and Environment Ministers/Canadian Council of Ministers of Environment's *Canadian Water Quality Guidelines* (CCREM 1987);

- the two-volume *Handbook of Environmental Fate and Exposure Data for Organic Chemicals* (Howard 1989, 1990);
- an unpublished review of biological half-lives of various compounds in fish tissues (Nimi, undated); and
- an environmental risk assessment of landfill leachates which summarizes information on carcinogenicity, mutagenicity, and teratogenicity for numerous compounds (Brown and Donnelley 1988).

Norecol also referred to reviews of specific compounds and primary research publications when the information was necessary and available.

Substances which, based on the literature review, met the criteria for persistence and toxicity were placed on the tentative parameters list. Substances that clearly failed to meet these criteria usually were not considered further, although some substances that could automatically be analyzed with the selected parameters were reconsidered during the final selection process (Section 2.4.1).

In some cases, the available information was insufficient to determine whether a parameter met the selection criteria. In these cases, Norecol reviewed the U.S. Environmental Protection Agency (U.S. EPA) Treatability Database (U.S. EPA 1983) and determined whether the substance had undergone full scale treatability tests. If such tests had been completed, the parameter was assumed to have been of concern to the U.S. EPA and was promoted to the tentative parameters list. If full scale treatability tests had not been done, the parameter was not considered further.

2.4 Final Parameter Selection

2.4.1 Final Selection Criteria

Norecol evaluated parameters on the tentative list with respect to two additional criteria. Tentative parameters were selected for the final monitoring list if they met *both* of the following criteria:

1) There are data to indicate or a high probability (based on monitoring data from similar industries in the USA or Ontario) that the substance is currently being discharged in the Fraser River Basin.

2) There is a defensible analytical method routinely available for the parameter.

Since parameters that already appeared on the tentative parameters list were removed if they failed to meet these criteria, the final parameter selection was primarily a deselection process. However, a few substances were returned to the monitoring list at the final selection stage. Specifically, candidate parameters which had not met the selection criteria for promotion to the tentative parameters list were added to the final monitoring list if they met the following criterion:

- The parameter provides useful additional information at little or no incremental cost because it is part of an analytical package which measures other parameters already selected.

2.4.2 *Identification of Contaminants Currently Discharged*

The probability that a contaminant is currently being discharged to the Fraser Basin was determined as follows. Tentative parameters identified through the literature review of contaminants in the Fraser Basin clearly had been discharged to the basin at some time. The literature was reviewed to identify the sources of these substances and to determine whether the sources still exist. Parameters no longer being discharged were removed from the monitoring list.

To determine whether tentative parameters selected from the evaluation of PSL and TSL substances were likely to be discharged in the Fraser Basin, Norecol

- identified the specific industries, municipal, and agricultural sectors discharging to the Fraser River Basin; and

- identified the contaminants likely to be present in the effluents from each source.

To identify the types of industries present in the Fraser Basin, Norecol obtained the Fraser Basin Point Source Inventory (Westwater Research 1993) from Environment Canada. This computerized inventory includes British Columbia Ministry of Environment, Lands, and Parks (MELP) discharge permits and federal effluent sources (eg. airports, military bases, Indian reserves) that do not require MELP permits. The database classifies effluent sources by industry type.

To identify contaminants associated with the specific types of industries in the Fraser Basin, Norecol first referred to published monitoring data for Fraser Basin industrial effluents. Next, the probability that substances not currently identified might be discharged in Fraser basin effluents was determined by comparing the list of industries present in the basin with the industries identified as discharging persistent, toxic (PSL or TSL) substances in other areas such as Ontario or the U.S.A. This comparison was based on a review of the following documents:

- the development document for the priority pollutants list (OMOE 1987a) and status reports for industry-specific monitoring prepared under Ontario's MISA (OMOE 1987b, 1990, 1991);

- the U.S. Environmental Protection Agency effluent treatability database, which identifies the industrial sources of priority pollutants (U.S. EPA 1983);

- an unpublished list provided by Environment Canada, which identifies industrial sources of PSL contaminants;

- a two-volume review of fate and exposure data for organic chemicals (Howard 1989-90) and

- the report of the Fraser Basin pilot effluent characterization study (Environmental Management Associates and Hydroqual Laboratories 1993).

Any substance that had never been identified in the types of industries present in the Fraser Basin was removed from the monitoring list.

2.4.3 Identification of Reliable Analytical Methodologies

Published analytical methodologies were reviewed for all tentative parameters. The review included evaluation of method performance data and identification of problems (if any) commonly encountered in the analyses. A method was considered acceptable based on:

- availability of acceptable method performance data;

- lack of frequent, significant problems with the analysis; and

- ability of commercial laboratories to perform the analysis on a routine basis.

Parameters that failed to meet the all of the analytical reliability criteria were not recommended for routine inclusion in the wastewater characterization program. However, Norecol recommended development of reliable methods, where appropriate. In cases where apparently effective methodologies had only recently been developed, the recommendations involved inclusion of the parameter in the monitoring program on an experimental basis to develop method reliability data.

DERIVATION OF TENTATIVE PARAMETERS LIST

This chapter describes the derivation of the tentative parameters list. Section 3.1 documents the process by which parameters were directly selected for the tentative parameters list or identified as candidates for further evaluation. Section 3.2 provides the environmental fate and toxicity data used to evaluate the candidate parameters and identifies those parameters promoted to the tentative parameters list.

3.1 Identification of Parameters for Evaluation

3.1.1 Identification of Contaminants in the Fraser Basin

Recent reviews have identified contaminants detected in Fraser River water, sediments, and biota (Standing Committee on the Fraser River Estuary Water Quality Plan 1990, Hall et al. 1991, Swain 1993). The most frequently identified contaminants include anti-sapstain/wood preservative chemicals (especially chlorophenols), chlorinated organic constituents of pulp mill effluents (especially chlorinated phenolics, dioxins and furans), polycyclic aromatic hydrocarbons (PAH), phthalate esters, polychlorinated biphenyls (PCB), chlorinated hydrocarbon pesticides (such as DDT and DDE), and various metals (Tables 3.1-1 and 3.1-2).

The impacts of anti-sapstain/wood preservative chemicals have been of significant concern over the past decade. Hall (1985) cited high levels of tetra- and pentachlorophenol in fish from the Fraser Estuary and noted that these compounds were commonly used as anti-sapstains. Subsequently Krahn and Shrimpton (1988) identified high concentrations of chlorophenols in runoff from treated wood storage yards at lumber mills in the lower Fraser Basin (Table 3.1-3).

As a result of concerns raised by these and other studies, lumber mills began to switch to different anti-sapstain chemicals. One of the initial replacements for chlorophenols, 2-(thiocyanomethylthio) benzothiazole (TCMTB) was quickly identified as a concern for toxicity to fish (Standing Committee on the Fraser River Estuary Water Quality Plan 1990) and worker health and safety. By 1992, TCMTB, chlorophenols, and other anti-sapstain chemicals had been almost entirely replaced by didecyl dimethyl ammonium chloride (DDAC) used alone or combined with 3-iodo-2-propynyl butyl carbamate (IPBC) (Envirochem 1992a). Potential toxicity problems related to runoff containing DDAC and/or IPBC have already been identified (Envirochem 1992a).

TABLE 3.1-1

CONTAMINANTS MEASURED IN SEDIMENTS OF THE FRASER RIVER BASIN

PARAMETER	LOCATION	MIN.	MAX.	MEAN	REFERENCE
Metals					
Aluminum	Near steel plant	7800 ug/g	14200 ug/g	-	Envirochem 1989
Arsenic	Near steel plant	33 ug/g	63 ug/g		Envirochem 1989
Cadmium	Near recycling plant		11 ug/g		MOE 1990
Chromium	Near steel plant	40 ug/g	117 ug/g		Envirochem 1989
Copper	Near steel plant	15 ug/g	369 ug/g		Envirochem 1989
Copper	Main Stem (Barnston Island)			46 ug/g	Swain and Walton 1988
Copper	North Arm	23 ug/g	32 ug/g		Swain and Walton 1988
Copper	Brunette River			38 ug/g	Swain and Walton 1988
Copper	Still Creek			122ug/g	Swain and Walton 1988
Lead	Near steel plant	17 ug/g	100 ug/g		Envirochem 1989
Lead	Near recycling plant		71 ug/g		MOE 1990
Lead	Main Stem (Barnston Island)			5 ug/g	Swain and Walton 1988
Lead	North Arm	<10 ug/g	30 ug/g		Swain and Walton 1988
Lead	Brunette River			91 ug/g	Swain and Walton 1988
Lead	Still Creek			238 ug/g	Swain and Walton 1988
Zinc	Near steel plant	71 ug/g	187 ug/g		Envirochem 1989
Zinc	Main Stem (Barnston Island)			69 ug/g	Swain and Walton 1988
Zinc	North Arm	61 ug/g	81 ug/g		Swain and Walton 1988
Zinc	Brunette River			128 ug/g	Swain and Walton 1988
Zinc	Still Creek			256 ug/g	Swain and Walton 1988
Mercury	Lower Fraser	<0.05 ug/g	1.15 ug/g		Beatty 1983
Phenolics					
Phenol	Fraser Estuary	7000 ng/g	56000 ng/g		Hall et al. 1986
Pentachlorophenol	Iona Island		10 ng/g		Rogers & Hall 1987
Tetrachlorophenol	Iona Island		13 ng/g		Rogers & Hall 1987
Pentachlorophenol	Near wood preserving plant		107 ng/g		Garrett and Shrimpton 1988
Tetrachlorophenol	Near wood preserving plant		63 ng/g		Garrett and Shrimpton 1988
Tetrachlorocatechol	Fraser Estuary	1 ng/g	300 ng/g		Swain 1993
3,4,5-trichlorocatechol	Fraser Estuary	1 ng/g	300 ng/g		Swain 1993
2.4.6-trichlorophenol	Prince George/Quesnel		<1 ng/g		Dwernychuk 1990
2,4,5-trichlorophenol	Prince George/Quesnel		<1 ng/g		Dwernychuk 1990
2,3,4-trichlorophenol	Prince George/Quesnel		<1 ng/g		Dwernychuk 1990
2,3,5-trichlorophenol	Prince George/Quesnel		<1 ng/g		Dwernychuk 1990
2,3,4,6-tetrachlorophenol	Prince George/Quesnel		<1 ng/g		Dwernychuk 1990
2,3,5,6-tetrachlorophenol	Prince George/Quesnel		<1 ng/g		Dwernychuk 1990
2,3,4,5-tetrachlorophenol	Prince George/Quesnel		<1 ng/g		Dwernychuk 1990
3,4,5 trichloroguäiacol	Prince George/Quesnel	<1 ng/g	19 ng/g		Dwernychuk 1990
Pentachlorophenol	Prince George/Quesnel		<1 ng/g		Dwernychuk 1990
3,4,5-trichlorocatecol	Prince George/Quesnel	<1 ng/g	1.9 ng/g		Dwernychuk 1990
Tetrachloroguaiacol	Prince George/Quesnel	<1 ng/g	14 ng/g		Dwernychuk 1990
Tetrachlorocatecol	Prince George/Quesnel	<1 ng/g	3 ng/g		Dwernychuk 1990
3,4,5-trichloroveratrol	Prince George/Quesnel		<1 ng/g		Dwernychuk 1990
Tetrachloroveratrol	Prince George/Quesnel		<1 ng/g		Dwernychuk 1990

TABLE 3.1-1

CONTAMINANTS MEASURED IN SEDIMENTS OF THE FRASER RIVER BASIN

PARAMETER	LOCATION	MIN.	MAX.	MEAN	REFERENCE
Dioxins/furans					
2,3,7,8 TCDD	Prince George/Quesnel/Kamloops		<15 pg/g		Mah et al. 1989
Total T4CDD	Prince George/Quesnel/Kamloops		<15 pg/g		Mah et al. 1989
Total P5CDD	Prince George/Quesnel/Kamloops		<20 pg/g		Mah et al. 1989
Total H6CDD	Prince George/Quesnel/Kamloops		<30 pg/g		Mah et al. 1989
Total O8CDD	Prince George/Quesnel/Kamloops	<75 pg/g	572 pg/g		Mah et al. 1989
2,3,7,8 TCDF	Prince George/Quesnel/Kamloops	<10 pg/g	3168 pg/g		Mah et al. 1989
Total T4CDF	Prince George/Quesnel/Kamloops	<10 pg/g	3459 pg/g		Mah et al. 1989
Total P5CDF	Prince George/Quesnel/Kamloops		<15 pg/g		Mah et al. 1989
Total H6CDF	Prince George/Quesnel/Kamloops		<25 pg/g		Mah et al. 1989
Total H7CDF	Prince George/Quesnel/Kamloops		<40 pg/g		Mah et al. 1989
Total O8CDF	Prince George/Quesnel/Kamloops		<75 pg/g		Mah et al. 1989
2,3,7,8 TCDD	Lower Fraser	<6 pg/g	<19 pg/g		Tuominen and Sekela 1992
Total T4CDD	Lower Fraser	<6 pg/g	<19 pg/g		Tuominen and Sekela 1992
Total P5CDD	Lower Fraser	<12 pg/g	<46 pg/g		Tuominen and Sekela 1992
Total H6CDD	Lower Fraser	<16 pg/g	200 pg/g		Tuominen and Sekela 1992
Total O8CDD	Lower Fraser	255 pg/g	546 pg/g		Tuominen and Sekela 1992
2,3,7,8 TCDF	Lower Fraser	<7 pg/g	24 pg/g		Tuominen and Sekela 1992
Total T4CDF	Lower Fraser	<7 pg/g	24 pg/g		Tuominen and Sekela 1992
Total P5CDF	Lower Fraser	<12 pg/g	<46 pg/g		Tuominen and Sekela 1992
Total H6CDF	Lower Fraser	<16 pg/g	<58 pg/g		Tuominen and Sekela 1992
Total H7CDF	Lower Fraser	<9 pg/g	<110 pg/g		Tuominen and Sekela 1992
Total O8CDF	Lower Fraser	<10 pg/g	<60 pg/g		Tuominen and Sekela 1992
Polycyclic Aromatic Hydrocarbons					
Acenaphthene	Lower Fraser		30 ng/g		Swain 1993
Acenaphthene	Fraser Estuary	ND	trace		Hall et al. 1986
Acenaphthene	Lower Fraser, Near STP			ND	Rogers & Hall 1987
Acenaphthylene	Lower Fraser		11 ng/g		Swain 1993
Acenaphthylene	Lower Fraser, Near STP			<15 ng/g	Rogers & Hall 1987
Anthracene	Fraser Estuary	ND	3 ug/g		Hall et al. 1986
Anthracene	Lower Fraser		46 ng/g		Swain 1993
Anthracene	Lower Fraser, Near STP			ND	Rogers & Hall 1987
Benzo(a)anthracene	Fraser Estuary	ND	18 ug/g		Hall et al. 1986
Benzo(a)anthracene	Lower Fraser, Near STP			ND	Rogers & Hall 1987
Chrysene	Fraser Estuary	ND	4 ug//g		Hall et al. 1986
Chrysene	Lower Fraser, Near STP			ND	Rogers & Hall 1987
Fluoranthene	Lower Fraser		300 ng/g		Swain 1993
Fluoranthene	Fraser Estuary	trace	139 ug/g		Hall et al. 1986
Fluoranthene	Lower Fraser, Near STP			115 ng/g	Rogers & Hall 1987
Fluorene	Lower Fraser		52 ng/g		Swain 1993
Fluorene	Fraser Estuary		98 ug/g		Hall et al. 1986
Fluorene	Lower Fraser, Near STP			ND	Rogers & Hall 1987
Naphthalene	Lower Fraser		35 ng/g		Swain 1993
Naphthalene	Lower Fraser, Near STP			<15 ng/g	Rogers & Hall 1987
Naphthalene	Fraser Estuary	trace			Hall et al. 1986
Phenanthrene	Lower Fraser		260 ng/g		Swain 1993
Phenanthrene	Fraser Estuary	trace	75 ug/g		Hall et al. 1986

TABLE 3.1-1

CONTAMINANTS MEASURED IN SEDIMENTS OF THE FRASER RIVER BASIN

PARAMETER	LOCATION	MIN.	MAX.	MEAN	REFERENCE
Phenanthrene	Lower Fraser, Near STP			44 ng/g	Rogers & Hall 1987
Pyrene	Lower Fraser		230 ng/g		Swain 1993
Pyrene	Fraser Estuary	trace	335 ug/g		Hall et al. 1986
Pyrene	Lower Fraser, Near STP			45 ng/g	Rogers & Hall 1987
Phthalate Esters					
Benzyllbutylphthalate	Lower Fraser, Near STP			<30 ng/g	Rogers & Hall 1987
Bis(2-ethylhexyl)phthalate	Fraser Estuary	ND	595 ug/g		Hall et al. 1986
Bis(2-ethylhexyl)phthalate	Lower Fraser, Near STP			844 ng/g	Rogers & Hall 1987
Butybenzyl phthalate	Fraser Estuary	ND	196 ug/g		Hall et al. 1986
Di-n-butyl phthalate	Fraser Estuary	ND	300 ug/g		Hall et al. 1986
Di-n-butylphthalate	Lower Fraser, Near STP			204 ng/g	Rogers & Hall 1987
Di-n-octylphthalate	Lower Fraser, Near STP			94 ng/g	Rogers & Hall 1987
Diethylphthalate	Fraser Estuary	ND	160 ug/g		Hall et al. 1986
Diethylphthalate	Lower Fraser, Near STP			190 ng/g	Rogers & Hall 1987
Resin and Fatty Acids					
Fatty Acids	Lower Fraser	trace			Swain 1993
Abietic acid	Lower Fraser		1.68 ug/g		Swain 1993
Chlorodehydroabietic acid	Lower Fraser		0.404 ug/g		Swain 1993
Pimaric acid	Lower Fraser		0.55 ug/g		Swain 1993
Organotin Compounds					
Butyl tin	Fraser Estuary	ND	0.01 ug/g		Maguire et al. 1985
Dibutyl tin	Fraser Estuary	ND	0.06 ug/g		Maguire et al. 1985
Tributyl tin	Fraser Estuary	ND	0.04 ug/g		Maguire et al. 1985
Tin	Fraser Estuary	ND	0.08 ug/g		Maguire et al. 1985
Polychlorinated Biphenyls (PCB)					
Total PCBs	Brunette River	37 ng/g	780 ng/g		Hall 1985
Total PCBs	Fraser Estuary	<5 ng/g	1300 ng/g		Hall 1985
Total PCBs	Iona Island			30 ng/g	Rogers and Hall 1987
Total PCBs	Lower Fraser		ND		Swain 1993
Organochloride Pesticides					
DDT	Brunette River	4 ng/g	90 ng/g		Hall 1985
DDE	Brunette River	5 ng/g	6 ng/g		Hall 1985
P,P'-DDE	Iona Island			20 ng/g	Rogers and Hall 1987
Chlordane	Brunette River	3 ng/g	44 ng/g		Hall 1985
Chlordane	Iona Island			trace	Rogers and Hall 1987
Aldrin	Iona Island			trace	Rogers and Hall 1987
Heptachlor epoxide	Iona Island			trace	Rogers and Hall 1987
Heptachlor epoxide	Lower Fraser	trace			Hagen 1990
Endosulfan	Lower Fraser	trace			Hagen 1990
Organochloride pesticides	Lower Fraser	ND			Swain 1993

ND - Not detectable

TABLE 3.1-2

CONTAMINANT CONCENTRATIONS MEASURED IN FRASER BASIN FISH TISSUES

PARAMETER	LOCATION	SPECIES	ORGAN	MIN.	MAX.	MEAN	REFERENCE
Metals							
Cadmium	Fraser Estuary	4 species	Liver	ND	2.61 ug/g		Singleton 1983
Chromium	Fraser Estuary	Largescale sucker	Muscle		0.42 ug/g		Singleton 1983
Copper	Fraser Estuary	Largescale sucker	Muscle	ND	0.78 ug/g	0.31 ug/g	Singleton 1983
Copper	Fraser Estuary	Northern squawfish	Muscle	ND	3.46 ug/g	0.36 ug/g	Singleton 1983
Copper	North Thompson	Rainbow trout	Muscle			<1 ug/g	Hall et al. 1991
Copper	North Thompson	Rainbow trout	Liver			44 ug/g	Hall et al. 1991
Lead	Fraser Estuary	4 species	Liver	ND	0.36 ug/g		Singleton 1983
Zinc	Fraser Estuary	Northern squawfish	Muscle	ND	8.56 ug/g	4.64 ug/g	Singleton 1983
Zinc	Fraser Estuary	Peamouth	Muscle	3.59 ug/g	33.0 ug/g	6.81 ug/g	Singleton 1983
Zinc	North Thompson	Rainbow trout	Muscle			7 ug/g	Hall et al. 1991
Zinc	North Thompson	Rainbow trout	Liver			34 ug/g	Hall et al. 1991
Mercury	Fraser Estuary	Rainbow trout	Muscle	ND	0.14 ug/g	0.09 ug/g	Singleton 1983
Mercury	Fraser Estuary	Northern squawfish	Muscle	0.11 ug/g	1.23 ug/g	0.39 ug/g	Singleton 1983
Mercury	North Thompson	Rainbow trout	Muscle			0.04 ug/g	Hall et al. 1991
Mercury	North Thompson	Rainbow trout	Liver			0.07 ug/g	Hall et al. 1991
Arsenic	Boundary Bay, Fraser Estuary	Fish, crabs	Tissue	All met Food and Drug criteria			Swain and Walton 1990b
Phenolics							
Phenol	Fraser Estuary	Fish	Tissue	4 ng/g	320 ng/g		Hall 1985
2-chlorophenol	Fraser Estuary	Fish	Tissue	ND	123 ng/g		Hall 1985
2,4-dichlorophenol	Fraser Estuary	Fish	Tissue	ND	337 ng/g		Hall 1985
Trichlorophenol	Fraser Estuary	Largescale suckers	Tissue	<20 ng/g	60 ng/g	<20 ng/g	Singleton 1983
2,4,6-trichlorophenol	Fraser Estuary	Starry flounder	Tissue	<3 ng/g	1442 ng/g		Hall 1985
2,3,4-trichlorophenol	Prince George/Quesnel	Fish	Muscle		<1 ng/g		Dwernychuk 1990
2,3,5-trichlorophenol	Prince George/Quesnel	Fish	Muscle		<1 ng/g		Dwernychuk 1990
2.4.6-trichlorophenol	Prince George/Quesnel	Fish	Liver	<5 ng/g	81.4 ng/g		Dwernychuk 1990
2,4,5-trichlorophenol	Prince George/Quesnel	Fish	Liver		<5 ng/g		Dwernychuk 1990
2,3,4-trichlorophenol	Prince George/Quesnel	Fish	Liver		<5 ng/g		Dwernychuk 1990
2,3,5-trichlorophenol	Prince George/Quesnel	Fish	Liver		<5 ng/g		Dwernychuk 1990
Tetrachlorophenol	Fraser Estuary	Starry flounder	Tissue	<3 ng/g	2522 ng/g		Hall 1985

TABLE 3.1-2

CONTAMINANT CONCENTRATIONS MEASURED IN FRASER BASIN FISH TISSUES

PARAMETER	LOCATION	SPECIES	ORGAN	MIN.	MAX.	MEAN	REFERENCE
Tetrachlorophenol	Fraser Estuary	Fish	Tissue	ND	62 ng/g		Hall 1985
Tetrachlorophenol	Fraser Estuary	Largescale suckers	Tissue	<10 ng/g	250 ng/g		Singleton 1983
Tetrachlorophenol		Juvenile chinook	Livers	500 ng/g	13000 ng/g	~3000 ng/g	Birtwell et al. 1985
Tetrachlorophenol (2,3,4,6)	Near wood preserving facilities	Starry flounder	Muscle	ND	47.8 ng/g	4.7 ng/g	Rogers & Hall 1987
Tetrachlorophenol (2,3,4,6)	Near wood preserving facilities	Starry flounder	Liver	ND	118.9 ng/g	26.0 ng/g	Rogers & Hall 1987
Tetrachlorophenol (2,3,4,6)	Near wood preserving facilities	Starry flounder	Bone	ND	16.7 ng/g	6.9 ng/g	Rogers & Hall 1987
Tetrachlorophenol (2,3,4,6)	Quesnel	Juvenile chinook	Tissue	2.7 ng/g	3.7 ng/g	3.3 ng/g	Hall et al. 1991
Tetrachlorophenol (2,3,4,6)	Prince George	Juvenile chinook	Tissue	5.0 ng/g	6.0 ng/g	5.6 ng/g	Hall et al. 1991
2,3,4,6-tetrachlorophenol	Prince George/Quesnel	Fish	Muscle		<1 ng/g		Dwernychuk 1990
2,3,5,6-tetrachlorophenol	Prince George/Quesnel	Fish	Muscle		<1 ng/g		Dwernychuk 1990
2,3,4,5-tetrachlorophenol	Prince George/Quesnel	Fish	Muscle		<1 ng/g		Dwernychuk 1990
2,3,4,6-tetrachlorophenol	Prince George/Quesnel	Fish	Liver	<5 ng/g	8.4 ng/g		Dwernychuk 1990
2,3,5,6-tetrachlorophenol	Prince George/Quesnel	Fish	Liver		<5 ng/g		Dwernychuk 1990
2,3,4,5-tetrachlorophenol	Prince George/Quesnel	Fish	Liver		<5 ng/g		Dwernychuk 1990
Pentachlorophenol	Fraser Estuary	Largescale suckers	Tissue	<10 ng/g	190 ng/g	35 ng/g	Singleton 1983
Pentachlorophenol	Fraser Estuary	Starry flounder	Tissue	<3 ng/g	2768 ng/g	1116 ng/g	Hall 1985
Pentachlorophenol		Juvenile chinook	Livers	1000 ng/g	17000 ng/g	~4000 ng/g	Birtwell et al. 1985
Pentachlorophenol	Near wood preserving facilities	Starry flounder	Muscle	0.8 ng/g	15.8 ng/g	6.1 ng/g	Rogers & Hall 1987
Pentachlorophenol	Near wood preserving facilities	Starry flounder	Liver	14.7 ng/g	496.6 ng/g	114.6 ng/g	Rogers & Hall 1987
Pentachlorophenol	Near wood preserving facilities	Starry flounder	Bone	1.1 ng/g	19.9 ng/g	11.4 ng/g	Rogers & Hall 1987
Pentachlorophenol	Quesnel	Juvenile chinook	Tissue	2.8 ng/g	5.0 ng/g	4.2 ng/g	Hall et al. 1991
Pentachlorophenol	Prince George	Juvenile chinook	Tissue	3.7 ng/g	12.7 ng/g	6.8 ng/g	Hall et al. 1991
Pentachlorophenol	Prince George/Quesnel	Fish	Liver	<5 ng/g	37.7 ng/g		Dwernychuk 1990
3,4,5 trichloroguaiacol	Prince George/Quesnel	Fish	Muscle	<1 ng/g	29.8 ng/g		Dwernychuk 1990
Tetrachloroguaiacol	Prince George/Quesnel	Fish	Muscle	<1 ng/g	29.8 ng/g		Dwernychuk 1990
Pentachlorophenol	Prince George/Quesnel	Fish	Muscle	<1 ng/g	7.9 ng/g		Dwernychuk 1990
3,4,5-trichlorocatecol	Prince George/Quesnel	Fish	Muscle		<1 ng/g		Dwernychuk 1990
3,4,5 trichloroguaiacol	Prince George/Quesnel	Fish	Liver	<5 ng/g	471 ng/g		Dwernychuk 1990
Tetrachloroguaiacol	Prince George/Quesnel	Fish	Liver	<5 ng/g	371 ng/g		Dwernychuk 1990
3,4,5-trichlorocatecol	Prince George/Quesnel	Fish	Liver		<5 ng/g		Dwernychuk 1990

TABLE 3.1-2

CONTAMINANT CONCENTRATIONS MEASURED IN FRASER BASIN FISH TISSUES

PARAMETER	LOCATION	SPECIES	ORGAN	MIN.	MAX.	MEAN	REFERENCE
Tetrachlorocatecol	Prince George/Quesnel	Fish	Muscle		<1 ng/g		Dwernychuk 1990
Tetrachlorocatecol	Prince George/Quesnel	Fish	Liver		<5 ng/g		Dwernychuk 1990
Dioxins/furans							
2,3,7,8 TCDD	Prince George/Quesnel/Kamloops	Various species	Muscle	<2 pg/g	137 pg/g		Mah et al. 1989
Total T4CDD	Prince George/Quesnel/Kamloops	Various species	Muscle	<2 pg/g	137 pg/g		Mah et al. 1989
Total P5CDD	Prince George/Quesnel/Kamloops	Various species	Muscle	<3 pg/g	4.2 pg/g		Mah et al. 1989
Total H6CDD	Prince George/Quesnel/Kamloops	Various species	Muscle	<5 pg/g	40.8 pg/g		Mah et al. 1989
Total O8CDD	Prince George/Quesnel/Kamloops	Various species	Muscle		<15 pg/g		Mah et al. 1989
2,3,7,8 TCDF	Prince George/Quesnel/Kamloops	Various species	Muscle	<2 pg/g	1185 pg/g		Mah et al. 1989
Total T4CDF	Prince George/Quesnel/Kamloops	Various species	Muscle	<2 pg/g	1185 pg/g		Mah et al. 1989
Total P5CDF	Prince George/Quesnel/Kamloops	Various species	Muscle	<3 pg/g	25.1 pg/g		Mah et al. 1989
Total H6CDF	Prince George/Quesnel/Kamloops	Various species	Muscle		<5 pg/g		Mah et al. 1989
Total H7CDF	Prince George/Quesnel/Kamloops	Various species	Muscle		<10 pg/g		Mah et al. 1989
Total O8CDF	Prince George/Quesnel/Kamloops	Various species	Muscle		<15 pg/g		Mah et al. 1989
2,3,7,8 TCDD	Lower Fraser	Fish	Muscle	<1 pg/g	<2 pg/g		Tuominen and Sekela 1992
Total T4CDD	Lower Fraser	Fish	Muscle	<1 pg/g	<2 pg/g		Tuominen and Sekela 1992
Total P5CDD	Lower Fraser	Fish	Muscle	<2 pg/g	<11 pg/g		Tuominen and Sekela 1992
Total H6CDD	Lower Fraser	Fish	Muscle	<3 pg/g	<5 pg/g		Tuominen and Sekela 1992
Total O8CDD	Lower Fraser	Fish	Muscle	<5pg/g	<16 pg/g		Tuominen and Sekela 1992
2,3,7,8 TCDF	Lower Fraser	Fish	Muscle	<1 pg/g	19 pg/g		Tuominen and Sekela 1992
Total T4CDF	Lower Fraser	Fish	Muscle	<1 pg/g	19 pg/g		Tuominen and Sekela 1992
Total P5CDF	Lower Fraser	Fish	Muscle	<2 pg/g	<11 pg/g		Tuominen and Sekela 1992
Total H6CDF	Lower Fraser	Fish	Muscle	<3 pg/g	<5 pg/g		Tuominen and Sekela 1992
Total H7CDF	Lower Fraser	Fish	Muscle	<5 pg/g	<16 pg/g		Tuominen and Sekela 1992
Total O8CDF	Lower Fraser	Fish	Muscle	<5 pg/g	<16 pg/g		Tuominen and Sekela 1992
Polycyclic Aromatic Hydrocarbons							
Anthracene	Fraser Estuary	Starry flounder	Tissue	ND	0.143 ug/g		Hall et al. 1986
Benzo (g,h,i) perylene	Fraser Estuary	Starry flounder	Tissue	ND	trace		Hall et al. 1986
Benzo (g,h,i) perylene	Fraser Estuary	Peamouth	Whole Fish		0.058 ug/g		Hall et al. 1986
Benzo(a) pyrene	Fraser Estuary	Starry flounder	Tissue	ND	0.135 ug/g		Hall et al. 1986

TABLE 3.1-2

CONTAMINANT CONCENTRATIONS MEASURED IN FRASER BASIN FISH TISSUES

PARAMETER	LOCATION	SPECIES	ORGAN	MIN.	MAX.	MEAN	REFERENCE
Benzo(a) pyrene	Fraser Estuary	Peamouth	Whole Fish		0.027 ug/g		Hall et al. 1986
Chrysene	Fraser Estuary	Starry flounder	Tissue	ND	0.302 ug/g		Hall et al. 1986
Chrysene	Fraser Estuary	Peamouth	Whole Fish		0.008 ug/g		Hall et al. 1986
Fluoranthene	Fraser Estuary	Starry flounder	Tissue	ND	0.204 ug/g		Hall et al. 1986
Fluoranthene	Fraser Estuary	Peamouth	Whole Fish		0.005 ug/g		Hall et al. 1986
Fluorene	Fraser Estuary	Peamouth	Whole Fish		0.012 ug/g		Hall et al. 1986
Naphthalene	Fraser Estuary	Starry flounder	Tissue	ND	0.109 ug/g		Hall et al. 1986
Naphthalene	Fraser Estuary	Peamouth	Whole Fish		0.034 ug/g		Hall et al. 1986
Phenanthrene	Fraser Estuary	Starry flounder	Tissue	ND	0.003 ug/g		Hall et al. 1986
Phenanthrene	Fraser Estuary	Peamouth	Whole Fish		0.010 ug/g		Hall et al. 1986
Pyrene	Fraser Estuary	Starry flounder	Tissue	ND	0.008 ug/g		Hall et al. 1986
Pyrene	Fraser Estuary	Peamouth	Whole Fish		0.017 ug/g		Hall et al. 1986
Phthalate Esters							
Bis (2-ethylhexyl) phthalate	Fraser Estuary	Starry flounder	Tissue	0.008 ug/g	1.057 ug/g		Hall et al. 1986
Benzylbutyl phthalate	Fraser Estuary	Largescale sucker	Tissue	0.029 ug/g	0.054 ug/g	0.038 ug/g	Singleton 1983
Benzylbutyl phthalate	Fraser Estuary	Starry flounder	Tissue	<0.008 ug/g	0.316 ug/g	0.054 ug/g	Hall et al. 1986
Butyl benzyl phthalate	Fraser Estuary	Largescale sucker	Muscle	0.020 ug/g	0.100 ug/g	~0.030 ug/g	Hall et al. 1986
Butyl isodecyl phthalate	Fraser Estuary	Largescale sucker	Muscle	0.01 ug/g	2.0 ug/g	~0.5 ug/g	Hall et al. 1986
Di-n-butyl phthalate	Fraser Estuary	Starry flounder	Tissue	ND	0.622 ug/g		Hall et al. 1986
Di-n-octalphthalate	Fraser Estuary	Fish	Muscle/Liver		Elevated		Swain & Walton 1990
Di-n-octyl phthalate	Fraser Estuary	Largescale sucker	Muscle	5 ug/g	25 ug/g	~12 ug/g	Hall et al. 1986
Diethyl phthalate	Fraser Estuary	Starry flounder	Tissue	trace	0.313 ug/g		Hall et al. 1986
Dimethyl phthalate	Fraser Estuary	Starry flounder	Tissue	ND	0.074ug/g		Hall et al. 1986
Dimethyl phthalate	Fraser Estuary	Peamouth	Whole Fish		0.014 ug/g		Hall et al. 1986
Chlorinated Benzenes							
1,4-Dichlorobenzene	Fraser Estuary	Starry flounder	Tissue	ND	32 ng/g		Hall et al. 1986
1,2-Dichlorobenzene	Fraser Estuary	Starry flounder	Tissue	ND	101 ng/g		Hall et al. 1986
Hexachlorobenzene	Fraser Estuary	Fish	Tissue	trace	19 ng/g		Hall 1985

TABLE 3.1-2

CONTAMINANT CONCENTRATIONS MEASURED IN FRASER BASIN FISH TISSUES

PARAMETER	LOCATION	SPECIES	ORGAN	MIN.	MAX.	MEAN	REFERENCE
Polychlorinated Biphenyls (PCB)							
Aroclor 1254	Sturgeon and Roberts Banks	Crabs	Tissue	154 ng/g	2100 ng/g		Hall 1985
Total PCBs	Iona Island	Starry flounder	Muscle	4.8 ng/g	39.7 ng/g	16.2 ng/g	Rogers and Hall 1987
Total PCBs	Iona Island	Starry flounder	Liver	ND	584.1 ng/g	173.4 ng/g	Rogers and Hall 1987
Chlorinated hydrocarbon pesticides							
DDT	Iona Island	Starry flounder	Muscle	1.9 ng/g	9.2 ng/g	4.0 ng/g	Rogers and Hall 1987
DDT	Iona Island	Starry flounder	Liver	ND	172.6 ng/g	43.3 ng/g	Rogers and Hall 1987
DDD	Iona Island	Starry flounder	Muscle	ND	8.7 ng/g	3.7 ng/g	Rogers and Hall 1987
DDD	Iona Island	Starry flounder	Liver	ND	329.7 ng/g	68.4 ng/g	Rogers and Hall 1987
P,P'- DDE	Sturgeon and Roberts Banks	Crabs	Tissue	4 ng/g	295 ng/g		Hall 1985
Heptachlor epoxide	Sturgeon and Roberts Banks	Crabs	Tissue	4 ng/g	22 ng/g		Hall 1985

ND - Not detectable

TABLE 3.1-3

CONCENTRATIONS OF CONTAMINANTS REPORTED IN FRASER RIVER BASIN EFFLUENTS

SOURCE	LOCATION	TYPE	PARAMETER	MINIMUM	MAXIMUM	MEAN/ MEDIAN	REFERENCE
STP	Kent	Effluent	Chlorine, residual	<0.1 mg/L	2 mg/L	0.6 mg/L	Swain & Holms 1985
STP	Kent	Effluent	Total ammonia, as N	5.96 mg/L	15.8 mg/L	12.2 mg/L	Swain & Holms 1985
STP	Chilliwack	Effluent	Chlorine, residual	ND	>3 mg/L	0.44 mg/L	Swain & Holms 1985
STP	Chilliwack	Effluent	BOD	8 mg/L	375 mg/L	40.2 mg/L	Swain & Holms 1985
STP	Chilliwack	Effluent	Fecal Coliforms	<200 MPN	>240,000 MPN	20,000 MPN	Swain & Holms 1985
STP	Chilliwack	Effluent	Total ammonia, as N	10.7 mg/L	30.6 mg/L	20.9 mg/L	Swain & Holms 1985
STP	Chilliwack	Effluent	Copper, total		0.3 mg/L		Swain & Holms 1985
STP	Chilliwack	Effluent	Lead, total		0.1 mg/L		Swain & Holms 1985
STP	Chilliwack	Effluent	Zinc, total		0.27 mg/L		Swain & Holms 1985
STP	Iona Island	Sewage & sludge	Dimethyl phthalate			Detected	Rogers et al. 1986
STP	Iona Island	Sewage & sludge	Diethyl phthalate	38 ug/L	289 ug/L		Rogers et al. 1986
STP	Iona Island	Sewage & sludge	Dibutyl phthalate			Detected	Rogers et al. 1986
STP	Iona Island	Sewage & sludge	Butylbenzyl phthalate			Detected	Rogers et al. 1986
STP	Iona Island	Sewage & sludge	Bis 2-ethylhexyl phthalate	ND	59 ug/L		Rogers et al. 1986
STP	Iona Island	Sewage & sludge	Phenanthrene			Detected	Rogers et al. 1986
STP	Iona Island	Sewage & sludge	Pyrene			Detected	Rogers et al. 1986
STP	Iona Island	Sewage & sludge	Tetrachlorophenol	0.6 ug/L	7.8 ug/L		Rogers et al. 1986
STP	Iona Island	Sewage & sludge	Pentachlorophenol	0.4 ug/L	13.2 ug/L		Rogers et al. 1986
STP	Iona Island	Sewage & sludge	Naphthalene			Detected	Birtwell et al. 1985
STP	Iona Island	Wastewater	Dehydroabietic acid			Detected	Birtwell et al. 1985
STP	Annacis Island	Effluent	Dichlorobenzene			73 g/day	Supervisory Coordinating Committee 1987
STP	Annacis Island	Effluent	Nonylphenol			9074 g/day	Supervisory Coordinating Committee 1987
STP	Annacis Island	Effluent, sludge	Hexachlorobenzene			ND	Supervisory Coordinating Committee 1987
STP	Annacis Island	Effluent, sludge	Pentachlorophenol			ND	Supervisory Coordinating Committee 1987
STP	Lulu Island	Effluent	Dichlorobenzene		2.34 ug/L		Supervisory Coordinating Committee 1987
STP	Lulu Island	Effluent	Nonyphenol			670 g/day	Supervisory Coordinating Committee 1987
STP	Lulu Island	Effluent	Hexachlorobenzene			ND	Supervisory Coordinating Committee 1987
STP	Lulu Island	Effluent	Pentachlorophenol			ND	Supervisory Coordinating Committee 1987
STP	Iona Island	Sludge	Dimethylphenanthrenes			260 ug/g	Supervisory Coordinating Committee 1987
Metal Fabrication	Lower Fraser	All effluents	Phosphorus	2.89 kg/week	3.78 kg/week		Supervisory Coordinating Committee 1987
Metal Fabrication	Lower Fraser	All effluents	Boron		8.52 kg/week		Supervisory Coordinating Committee 1987
Metal Fabrication	Lower Fraser	All effluents	Iron	4.26 kg/week	16.17 kg/week		Supervisory Coordinating Committee 1987
Metal Fabrication	Lower Fraser	All effluents	Zinc	2.94 kg/week	9.85 kg/week		Supervisory Coordinating Committee 1987
Metal Fabrication	Lower Fraser	Cooling water	Zinc, dissolved	0.17 mg/L	0.51 mg/L		Supervisory Coordinating Committee 1987
Metal Fabrication	Lower Fraser	Combined effluent	Total ammonia, as N	0.032 mg/L	0.056 mg/L	0.045 mg/L	Swain and Walton 1992
Metal Fabrication	Lower Fraser	Combined effluent	Phosphorus, dissolved	0.085 mg/L	0.224 mg/L	0.137 mg/L	Swain and Walton 1992
Metal Fabrication	Lower Fraser	Combined effluent	Arsenic, total	0.0010 mg/L	0.0020 mg/L	0.0015 mg/L	Swain and Walton 1992
Metal Fabrication	Lower Fraser	Combined effluent	Iron, total	0.145 mg/L	0.241 mg/L	0.178 mg/L	Swain and Walton 1992

TABLE 3.1-3

CONCENTRATIONS OF CONTAMINANTS REPORTED IN FRASER RIVER BASIN EFFLUENTS

SOURCE	LOCATION	TYPE	PARAMETER	MINIMUM	MAXIMUM	MEAN/ MEDIAN	REFERENCE
Metal Fabrication	Lower Fraser	Combined effluent	Zinc, total	<0.005 mg/L	0.014 mg/L	0.009 mg/L	Swain and Walton 1992
Metal Fabrication	Annacis Island	Furnace roof runoff	Copper			1.0 mg/L	Supervisory Coordinating Committee 1987
Metal Fabrication	Annacis Island	Furnace roof runoff	Zinc			19.5 mg/L	Supervisory Coordinating Committee 1987
Metal Fabrication	Mitchell Island	Exfiltration	Iron			13 kg/day	Supervisory Coordinating Committee 1987
Metal Fabrication	Mitchell Island	Pond overflow	Iron			6 kg/day	Supervisory Coordinating Committee 1987
Metal Fabrication	Mitchell Island	Outfall	Lead, dissolved			0.5 mg/L	Supervisory Coordinating Committee 1987
Metal Fabrication	Mitchell Island	Outfall	Zinc, dissolved			0.24 mg/L	Supervisory Coordinating Committee 1987
Metal Fabrication	Mitchell Island	Outfall	Oil and grease	3 mg/L	14 mg/L	.	Supervisory Coordinating Committee 1987
Metal Fabrication	Annieville Channel	Cooling water	Temperature	18 C	24 C	21.2 C	Envirochem 1989
Metal Fabrication	Annieville Channel	Cooling water	pH	6.5	7.6		Envirochem 1989
Metal Fabrication	Annieville Channel	Cooling water	Copper	0.002 mg/L	0.023 mg/L	0.008 mg/L	Envirochem 1989
Metal Fabrication	Annieville Channel	Cooling water	Lead	0.002 mg/L	0.100 mg/L	0.022 mg/L	Envirochem 1989
Metal Fabrication	Annieville Channel	Cooling water	Zinc	0.008 mg/L	1.15 mg/L	0.151 mg/L	Envirochem 1989
Metal Fabrication	Lulu Island	Lagoon discharge	Lead	0.05 mg/L	0.15 mg/L	0.13 mg/L	Envirochem 1989
Metal Fabrication	Lulu Island	Lagoon discharge	Zinc	0.02 mg/L	0.87 mg/L	0.15 mg/L	Envirochem 1989
Metal Fabrication	Lulu Island	Lagoon discharge	Chromium	0.01 mg/L	0.05 mg/L	0.02 mg/L	Envirochem 1989
Metal Fabrication	Lulu Island	Lagoon discharge	Iron	0.03 mg/L	0.20 mg/L	0.10 mg/L	Envirochem 1989
Metal Fabrication	Lulu Island	Lagoon discharge	Manganese	0.01 mg/L	0.29 mg/L	0.10 mg/L	Envirochem 1989
Metal Fabrication	Lulu Island	Lagoon discharge	Un-ionized NH3, as N		29 mg/L		Envirochem 1989
Metal Fabrication	Lulu Island	Lagoon discharge	Nitrate		19.6 mg/L		Envirochem 1989
Metal Fabrication	Lulu Island	Lagoon discharge	Nitrite		117 mg/L		Envirochem 1989
Metal Fabrication	Annieville Channel	Cooling/storm water	Oil/Grease	1 mg/L	15 mg/L	3.1 mg/L	Envirochem 1989
Metal Fabrication	Annieville Channel	Cooling/storm water	Chlorine	1 mg/L	2 mg/L		Envirochem 1989
Metal Fabrication	Annieville Channel	Cooling/storm water	Cyanide	0.005 mg/L	0.1 mg/L	0.005 mg/L	Envirochem 1989
Metal Fabrication	Annieville Channel	Cooling/storm water	Cadmium	<0.001 mg/L	0.100 mg/L	0.01 mg/L	Envirochem 1989
Metal Fabrication	Annieville Channel	Cooling/storm water	Copper	0.03 mg/L	0.113 mg/L	0.072 mg/L	Envirochem 1989
Metal Fabrication	Annieville Channel	Cooling/storm water	Iron	0.050 mg/L	0.310 mg/L	0.158 mg/L	Envirochem 1989
Metal Fabrication	Annieville Channel	Cooling/storm water	Zinc	0.030 mg/L	0.240 mg/L	0.105 mg/L	Envirochem 1989
Cement	Main Arm	Surface runoff	pH			11	Supervisory Coordinating Committee 1987
Cement	Main Arm	Surface runoff	Aluminum, dissolved			0.22 mg/L	Supervisory Coordinating Committee 1987
Cement	Main Arm	Effluent	Aluminum, total	0.50 mg/L	0.70 mg/L		Supervisory Coordinating Committee 1987
Gravel washing	Chilliwack	Washwater after 0.5 h settling	Copper, total		0.07 mg/L		Swain and Holms 1985
Gravel washing	Chilliwack	Washwater after 0.5 h settling	Iron, total		37 mg/L		Swain and Holms 1985
Gravel washing	Chilliwack	Washwater after 0.5 h settling	Zinc, total		0.1 mg/L		Swain and Holms 1985
Pulp & Paper	North Arm (Scott)	Mill effluents	Aluminum, total			73.52 kg/day	Supervisory Coordinating Committee 1987
Pulp & Paper	North Arm (Scott)	Mill effluents	Iron, total			29.05 kg/d	Supervisory Coordinating Committee 1987
Pulp & Paper	North Arm (Belkin)	Mill effluent	BOD	252 mg/L	461 mg/L		Supervisory Coordinating Committee 1987
Pulp & Paper	North Arm (Belkin)	Mill effluent	COD	660 mg/L	1620 mg/L		Supervisory Coordinating Committee 1987

TABLE 3.1-3

CONCENTRATIONS OF CONTAMINANTS REPORTED IN FRASER RIVER BASIN EFFLUENTS

SOURCE	LOCATION	TYPE	PARAMETER	MINIMUM	MAXIMUM	MEAN/ MEDIAN	REFERENCE
Pulp & Paper	North Arm (Belkin)	Mill effluent	Diethylphthalate			765 g/day	Supervisory Coordinating Committee 1987
Pulp & Paper	North Arm (Belkin)	Mill effluent	Pentachlorophenol	0.6 ug/L	1.7 ug/L		Supervisory Coordinating Committee 1987
Pulp & Paper	North Arm (Belkin)	Mill effluent	Tetrachlorophenol	0.3 ug/L	0.5 ug/L		Supervisory Coordinating Committee 1987
Pulp & Paper	North Arm (Belkin)	Mill effluent	Aluminum	26.9 kg/d	42.6 kg/d		Supervisory Coordinating Committee 1987
Pulp & Paper	North Arm (Belkin)	Mill effluent	Zinc	1.71 kg/d	3.19 kg/d		Supervisory Coordinating Committee 1987
Pulp & Paper	North Arm (Paperboard)	Mill effluent	Phthalate esters		ND		Swain and Walton 1992
Pulp & Paper	North Arm (Paperboard)	Mill effluent	Chlorophenols (tri, tetra, penta)		<0.001 mg/L		Swain and Walton 1992
Pulp & Paper	North Arm (Paperboard)	Mill effluent	Resin acids		<0.010 mg/L		Swain and Walton 1992
Pulp & Paper	North Arm (Paperboard)	Mill effluent	PAHs		<0.001 mg/L		Swain and Walton 1992
Pulp & Paper	North Arm (Paperboard)	Mill effluent	MAHs and chlorinated benzenes		ND		Swain and Walton 1992
Pulp & Paper	North Arm (Paperboard)	Mill effluent	H7CDD, total	<55 pg/L	150 pg/L	64 pg/L	Swain and Walton 1992
Pulp & Paper	North Arm (Paperboard)	Mill effluent	1,2,3,4,6,7,8 H7CDD	<55 pg/L	98 pg/L	64 pg/L	Swain and Walton 1992
Pulp & Paper	North Arm (Paperboard)	Mill effluent	O8CDD	780 pg/L	1200 pg/L	970 pg/L	Swain and Walton 1992
Pulp & Paper	North Arm (Paperboard)	Mill effluent	Other dioxins/furans		ND		Swain and Walton 1992
Pulp & Paper	North Arm (Paperboard)	Mill effluent	Aluminum, total	3.34 mg/L	7.39 mg/L	4.98 mg/L	Swain and Walton 1992
Pulp & Paper	North Arm (Paperboard)	Mill effluent	Zinc, total	0.136 mg/L	0.265 mg/L	0.185 mg/L	Swain and Walton 1992
Pulp & Paper	Prince George/Quesnel	Process effluent	2,4,6-trichlorophenol	0.1 ug/L	0.3 ug/l		Dwernychuk 1990
Pulp & Paper	Prince George/Quesnel	Process effluent	2,3,4,6-tetrachlorophenol	0.3 ug/l	2.7 ug/l		Dwernychuk 1990
Pulp & Paper	Prince George/Quesnel	Process effluent	2,3,4,5-tetrachlorophenol	0.7 ug/l	3.0 ug/l		Dwernychuk 1990
Pulp & Paper	Prince George/Quesnel	Process effluent	3,4,5-trichlorophenol	12 ug/l	30 ug/l		Dwernychuk 1990
Pulp & Paper	Prince George/Quesnel	Process effluent	Pentachlorophenol	0.1 ug/l	0.6 ug/l		Dwernychuk 1990
Pulp & Paper	Prince George/Quesnel	Process effluent	3.4.5-trichlorocatecol	2.9 ug/l	22 ug/l		Dwernychuk 1990
Pulp & Paper	Prince George/Quesnel	Process effluent	Tetrachloroguaiacol	14 ug/l	56 ug/l		Dwernychuk 1990
Pulp & Paper	Prince George/Quesnel	Process effluent	Tetrachlorocatecol	5.1 ug/l	38 ug/l		Dwernychuk 1990
Pulp & Paper	Prince George/Quesnel	Process effluent	Chloroform	8.2 mg/L	33.9 mg/L		Dwernychuk 1990
Pulp & Paper	Prince George/Quesnel	Process effluent	AOX	21 mg/L	36 mg/L		Dwernychuk 1990
Pulp & Paper	Prince George/Quesnel	Process effluent	Pimaric acid	<5 mg/L	150 mg/L		Dwernychuk 1990
Pulp & Paper	Prince George/Quesnel	Process effluent	Sandracopimaric acid	23mg/L	120 mg/L		Dwernychuk 1990
Pulp & Paper	Prince George/Quesnel	Process effluent	Isopimaric acid	<5 mg/L	32 mg/L		Dwernychuk 1990
Pulp & Paper	Prince George/Quesnel	Process effluent	Levopimaric acid	11 mg/L	37 mg/L		Dwernychuk 1990
Pulp & Paper	Prince George/Quesnel	Process effluent	Dehydroabietic acid	<5 mg/L	427 mg/L		Dwernychuk 1990
Pulp & Paper	Prince George/Quesnel	Process effluent	Abietic acid	21 mg/L	132 mg/L		Dwernychuk 1990
Pulp & Paper	Prince George/Quesnel	Process effluent	Neoabietic acid	<5 mg/L	32 mg/L		Dwernychuk 1990
Pulp & Paper	Prince George/Quesnel	Process effluent	Dichlorodehydroabietic acid	<5 mg/L	168 mg/L		Dwernychuk 1990
Forest Products	North Arm	Runoff from planer mill	Trichlorophenol	11.8 ug/L	95.0 ug/l		Supervisory Coordinating Committee 1987
Forest Products	North Arm	Runoff from planer mill	Tetrachlorophenol	146 ug/L	485 ug/L		Supervisory Coordinating Committee 1987
Forest Products	North Arm	Runoff from planer mill	Pentachlorophenol	4420 ug/L	107,000 ug/L		Supervisory Coordinating Committee 1987
Forest Products	North Arm	Outfall	Pentachlorophenol			160 ug/L	Supervisory Coordinating Committee 1987

TABLE 3.1-3

CONCENTRATIONS OF CONTAMINANTS REPORTED IN FRASER RIVER BASIN EFFLUENTS

SOURCE	LOCATION	TYPE	PARAMETER	MINIMUM	MAXIMUM	MEAN/ MEDIAN	REFERENCE
Forest Products	Main Stem, E. Barnston I.		BOD			460kg/d	Swain & Holmes 1985
Forest Products	Main Stem, E. Barnston I.		Suspended Solids			3390 kg/d	Swain & Holmes 1985
Forest Products	Main Stem, South Shore	Domestic sewage	TSS			<40 mg/L	Swain & Holmes 1985
Forest Products	Main Stem, South Shore	Fire deluge water	TSS			<40 mg/L	Swain & Holmes 1985
Forest Products	Main Stem, South Shore	Domestic sewage	BOD			<50 mg/L	Swain & Holmes 1985
Forest Products	Main Stem, South Shore	Fire deluge water	BOD			<50 mg/L	Swain & Holmes 1985
Forest Products	Main Stem, South Shore	Sewage	BOD			22 mg/L	Swain & Holmes 1985
Forest Products	Main Stem, South Shore	Sewage	TSS			22 mg/L	Swain & Holmes 1985
Forest Products	Lower Fraser	Stormwater	DDAC	<10 ug/L	1500 ug/L		Envirochem 1992a
Forest Products	Lower Fraser	Stormwater	IPBC	<10 ug/L	370 ug/L		Envirochem 1992a
Forest Products	Lower Fraser	Yard runoff	Total Chlorophenols	322 ug/L	27,542 ug/L		Krahn and Shrimpton 1986
Wood Preservation	Lower Fraser	Stormwater	Total Chlorophenol	11 ug/L	167 ug/L		Envirochem 1992b
Wood Preservation	Lower Fraser	Stormwater	Total PAH	1.7 ug/L	130 ug/L		Envirochem 1992b
Wood Preservation	Lower Fraser	Stormwater	Copper	0.023 mg/L	87.8 mg/L		Envirochem 1992b
Wood Preservation	Lower Fraser	Stormwater	Chromium	<0.002 mg/L	82.7 mg/L		Envirochem 1992b
Wood Preservation	Lower Fraser	Stormwater	Arsenic	<0.001 mg/L	84.2 mg/L		Envirochem 1992b
Wood Preservation	Lower Fraser	Stormwater	TOC	< 3 mg/L	276 mg/L		Envirochem 1992b
Wood Preservation	Lower Fraser	Water from adjacent ditch	Total ammonia, as N	0.380 mg/L	0.820 mg/L	0.617 mg/L	Swain and Walton 1992
Wood Preservation	Lower Fraser	Water from adjacent ditch	Arsenic, total	0.450 mg/L	0.660 mg/L	0.527 mg/L	Swain and Walton 1992
Wood Preservation	Lower Fraser	Water from adjacent ditch	Chromium, total	0.056 mg/L	0.139 mg/L	0.084 mg/L	Swain and Walton 1992
Wood Preservation	Lower Fraser	Water from adjacent ditch	Copper, total	0.022 mg/L	0.071 mg/L	0.042 mg/L	Swain and Walton 1992
Wood Preservation	Lower Fraser	Water from adjacent ditch	Mercury, total	<0.05 ug/L	0.11 ug/L	0.08 ug/L	Swain and Walton 1992
Wood Preservation	Lower Fraser	Water from adjacent ditch	Zinc, total	0.053 mg/L	0.133 mg/L	0.087 mg/L	Swain and Walton 1992
Petrochemical	Main Arm	Equalization lagoon	Cobalt			16.1 mg/L	Supervisory Coordinating Committee 1987
Petrochemical	Main Arm	Effluent	Cobalt			2.18 kg/day	Supervisory Coordinating Committee 1987
Petrochemical	Main Arm	Combined effluent	Aluminum, total	<0.20 mg/L	0.23 mg/L	0.22 mg/L	Swain and Walton 1992
Petrochemical	Main Arm	Combined effluent	Arsenic, total	0.0003 mg/L	0.0005 mg/L	0.0004 mg/L	Swain and Walton 1992
Petrochemical	Main Arm	Combined effluent	Cadmium, total	<0.0002 mg/L	0.0056 mg/L	<0.0002 mg/L	Swain and Walton 1992
Petrochemical	Main Arm	Combined effluent	Cobalt, total	<0.015 mg/L	<0.015 mg/L	<0.015 mg/L	Swain and Walton 1992
Petrochemical	Main Arm	Combined effluent	Iron, total	0.272 mg/L	0.395 mg/L	0.331 mg/L	Swain and Walton 1992
Petrochemical	Main Arm	Combined effluent	Zinc, total	<0.005 mg/L	<0.005 mg/L	<0.005 mg/L	Swain and Walton 1992
Petrochemical	Main Arm	Combined effluent	PAHs		<0.001 mg/L		Swain and Walton 1992
Petrochemical	Main Arm	Combined effluent	MAHs and chlorinated benzenes		ND		Swain and Walton 1992
Petrochemical	Main Arm	Combined effluent	P5CDF, total	120 pg/L	270 pg/L	173.3 pg/L	Swain and Walton 1992
Petrochemical	Main Arm	Combined effluent	H6CDF, total	270 pg/L	1000 pg/L	546.7 pg/L	Swain and Walton 1992
Petrochemical	Main Arm	Combined effluent	H7CDF, total	76 pg/L	690 pg/L	282.7 pg/L	Swain and Walton 1992
Petrochemical	Main Arm	Combined effluent	1,2,3,4,6,7,8 H7CDF	76 pg/L	300 pg/L	158.7 pg/L	Swain and Walton 1992
Petrochemical	Main Arm	Combined effluent	Other dioxins/furans		ND		Swain and Walton 1992

TABLE 3.1-3

CONCENTRATIONS OF CONTAMINANTS REPORTED IN FRASER RIVER BASIN EFFLUENTS

SOURCE	LOCATION	TYPE	PARAMETER	MINIMUM	MAXIMUM	MEAN/ MEDIAN	REFERENCE
Agriculture	Lower Fraser	Silage runoff	BOD			90,000 mg/L	Hagen 1990
Agriculture	Lower Fraser	Milk parlor effluent	BOD			200 mg/L	Hagen 1990
Egg production	Mainstem near Matsqui Is.	Discharge by spray irrigation	Total ammonia, as N	4.2 mg/L	115 mg/L	62.7 mg/L	Swain and Holms 1985
Egg production	Mainstem near Matsqui Is.	Discharge by spray irrigation	Nitrate+nitrite, as N	0.02 mg/L	109 mg/L	0.107 mg/L	Swain and Holms 1985
Egg production	Mainstem near Matsqui Is.	Discharge by spray irrigation	BOD	56 mg/L	3096 mg/L	956 mg/L	Swain and Holms 1985
Confined hog rearing	Mainstem near Matsqui Is.	Lagoon effluent	Total ammonia, as N	22 mg/L	1160 mg/L	470 mg/L	Swain and Holms 1985
Confined hog rearing	Mainstem near Matsqui Is.	Lagoon effluent	BOD	24 mg/L	728 mg/L	273.3 mg/L	Swain and Holms 1985
Confined hog rearing	Mainstem near Matsqui Is.	Lagoon effluent	COD	262 mg/L	8960 mg/L	2589 mg/L	Swain and Holms 1985
Confined hog rearing	Mainstem near Matsqui Is.	Lagoon effluent	Copper, total	0.04 mg/L	2.5 mg/L	0.52 mg/L	Swain and Holms 1985
Confined hog rearing	Mainstem near Matsqui Is.	Lagoon effluent	Zinc, total	<0.1 mg/L	26 mg/L	2.6 mg/L	Swain and Holms 1985
Vegetable processing	Mission	Combined effluent	Total ammonia, as N		0.062 mg/L		Swain and Holms 1985
Vegetable processing	Mission	Combined effluent	Nitrate+nitrite, as N	0.03 mg/L	0.39 mg/L		Swain and Holms 1985
Vegetable processing	Mission	Combined effluent	BOD	<5 mg/L	906 mg/L	124 mg/L	Swain and Holms 1985

ND - Not detected

Wood preservative plants, which treat wood for long-term use in exposed situations (patio decks, railroad ties, marine pilings) currently may use pentachlorophenol. They may also use creosote, chromated copper arsenate (CCA), and/or ammonaical copper arsenate (ACA). Effluent toxicity and loadings of pentachlorophenol, AHs, chromium, copper, and arsenic have been associated with runoff from these facilities (Envirochem 1992b).

Chlorinated compounds in pulp mill effluents have been another major environmental concern over last five years. Dioxins, furans, and chlorinated phenols, guaiacols, and catechols have been identified in effluents and have accumulated in sediments and fish tissues (Mah et al. 1989, Dwernychuk 1990, Schreier et al. 1991, Tuominen and Sekela 1992). These substances are primarily discharged by pulp and paper mills in Kamloops, Prince George and Quesnel, although there are also sources of the higher chlorinated dioxin/furan congeners in the Fraser Estuary (Table 3.1-3).

Other compounds identified as particular concerns include PAHs and phthalate esters. Both of these groups of compounds have been detected regularly in sediments and fish tissues from the Lower Fraser (Singleton 1983, Standing Committee 1990, Swain and Walton 1990a,b). The presence of PAHs in sediments and fish tissues is widespread and has been identified as a concern with respect to fish health (Rogers et al. 1986). However, there is some question of the extent to which detection of phthalate esters represents environmental contamination as opposed to sample contamination (Singleton 1983, Swain and Walton 1990a,b). Both PAHs and phthalate esters have been identified as constituents of sewage effluent (Rogers et al. 1986).

Various other organic substances have been reported in effluents, sediments and fish tissues monitored in the Fraser Basin. Polychlorinated biphenyls (PCB) and organochlorine pesticides have been monitored regularly over the past decade. The pesticides DDT, DDE and heptachlor epoxide were detected in crabs and/or starry flounders from Sturgeon and Roberts Banks and Boundary Bay (Singleton 1983, Hall 1985, Hall et al. 1991). PCBs have been widely detected in fish, crabs, and clams from the Fraser Estuary (Singleton 1983, Hall 1985, Swain and Walton 1990b, Hall et al. 1991). Chlorinated hydrocarbon pesticides and PCBs have also been detected in sediments (Table 3.2-1), but levels found in recent studies have been low or non-detectable (Standing Committee 1990, Swain 1993).

Metals are discharged in numerous effluents, and their presence in sediments and fish tissues has also been identified as a concern. Various metals are ubiquitous in sediments and fish (Table 3.1-1). Metals detected in sediments and fish tissues include cadmium, copper, chromium, lead, mercury, nickel and zinc. However, levels of some metals, notably lead, appear to be decreasing (Swain 1993).

Several other compounds of potential concern have been detected in effluents, sediments, or biota of the Fraser Basin. Chlorinated benzenes have occasionally been found in sediments and/or fish (Hall 1985). Organotins (tributyl, dibutyl, and butyl) are present in sediments (Maguire et al. 1985) and are a concern because of the toxicity of tributyl tin to aquatic organisms (CCREM 1987, Salazar and Salazar 1991). Other substances of potential concern are chloroform (detected in pulp mill effluents), nonylphenol (detected in sewage treatment plant effluent) and resin acids [constituents of pulp mill effluents and woodwaste leachate (Hagan 1990)]. The toxicity of these chemicals may also be of concern.

Based on the foregoing review of contaminants in the Fraser Basin, substances detected in fish tissues (Table 3.1-2) were promoted to the tentative parameters list. Substances detected in effluents and/or sediments and potentially toxic were considered candidate parameters and subjected to further review (Section 3.2). Table 3.1-4 summarizes the identification of tentative and candidate parameters.

3.1.2 Screening of PSL and TSL

The CEPA PSL and TSL were screened to remove air pollutants and mixtures of substances which could not be evaluated or analyzed because they are not specifically identified. The mixtures of substances removed in this screening included:

- waste crank case oils;
- chlorinated wastewater effluents;
- creosote-impregnated waste materials;
- inorganic fluorides;
- chlorinated paraffin waxes; and
- mineral fibres.

The remaining potential PSL and TSL water pollutants were considered candidates for further evaluation (Section 3.2). These substances are listed in Table 3.1-5.

3.1.3 Identification of Supporting Parameters

Supporting parameters were identified through knowledge of toxic "conventional" parameters present in Fraser Basin effluents (Table 3.1-3), knowledge of parameters that can modify effluent toxicity (eg. McLeay et al. 1986), and review of the rationales for monitoring conventional parameters provided in MISA documents (OMOE 1989). Table 3.1-6 lists the supporting parameters identified and provides the rationale for each selection. Because the selection criteria applied in Section 3.2 generally are not applicable to these parameters, the supporting parameters were promoted directly to the tentative parameters list.

TABLE 3.1-4

PARAMETERS SELECTED FOR EVALUATION BASED ON PRESENCE IN FRASER BASIN EFFLUENTS, SEDIMENTS, OR BIOTA

Tentative parameters identified based on presence in fish tissues
Metals:
Cadmium (1)
Chromium (1)
Copper
Lead (1)
Nickel (1)
Zinc
Mercury (1)
Arsenic (1)
Chlorophenols
Chloroguaiacols
Dibenzo-para-dioxin (Dioxin) (1) (2)
Dibenzofuran (Furan) (1) (2)
Polycyclic aromatic hydrocarbons (PAH) (1) (2)
Phthalate esters (1) (2)
1,2-Dichlorobenzene (1)
1,4-Dichlorobenzene (1)
Hexachlorobenzene (1)
Polychlorinated biphenyls (PCB)
Chlorinated hydrocarbon pesticides:
DDT
DDE
Heptachlor epoxide
Candidate parameters identified based on presence in effluents or sediment
Chlorocatechols
Chloroform
Nonylphenol
Resin acids
Organotins
Butyl tin
Dibutyl tin
Tributyl tin
Didecyl dimethyl ammonium chloride (DDAC)
3-iodo-2-propynyl butyl carbamate (IPBC)

(1) Parameter included on the TSL or PSL of CEPA
(2) See Appendix I for list of individual compounds

TABLE 3.1-5 **PARAMETERS FOR EVALUATION SELECTED FROM THE CANADIAN ENVIRONMENTAL PROTECTION ACT LISTS OF TOXIC AND PRIORITY SUBSTANCES**
Canadian Environmental Protection Act, Toxic Substances List (TSL)
Vinyl chloride
Canadian Environmental Protection Act, Priority Substances List (PSL)
Benzene
Methyl tertiary-butyl ether
1,2-Dichloroethane
Dichloromethane
Pentachlorobenzene
Styrene
Tetrachlorobenzenes
1,1,2,2-Tetrachloroethane
Tetrachloroethylene
Toluene
Trichlorobenzenes
1,1,1-Trichloroethane
Trichloroethylene
Xylenes
Analine
Benzidine
bis(2-Chloroethyl) ether
bis(Chloromethyl) ether
Chloromethyl methyl ether
3,3'-Dichlorobenzidine
3,5-Dimethylaniline
Methyl methcrylate
TSL and PSL parameters already identified as Fraser Basin Contaminants
Metals:
Cadmium
Chromium
Lead
Nickel
Mercury
Arsenic
Dibenzo-para-dioxin (Dioxin)
Dibenzofuran (Furan)
Polycyclic aromatic hydrocarbons (PAH)
Dibutyl phthalate [phthlate ester]
Di-n-octyl phthalate [phthalate ester]
bis(2-Ethylhexyl) phthalate [phthalate ester]
1,2-Dichlorobenzene
1,4-Dichlorobenzene
Hexachlorobenzene

TABLE 3.1-6

TENTATIVE PARAMETERS SELECTED BECAUSE THEY ARE TOXIC OR AID IN DATA INTERPRETATION

PARAMETER	RATIONALE
pH	Can affect chemical speciation and toxicity
Alkalinity	Potential modifier of toxicity; related to pH and hardness
Temperature (field measurement)	Can affect toxicity; high temperatures alone can impact aquatic organisms
Dissolved oxygen (field measurement)	Can affect toxicity; low oxygen alone can impact aquatic organisms
Conductivity (Specific conductance)	Indicator of presence of dissolved inorganic salts which can impact aquatic organisms
Total suspended solids (TSS)	May be a substrate for toxic contaminants; can have a direct impact on aquatic organisms
Dissolved organic carbon (DOC)	More likely to reflect trace organics than TOC, BOD5, or COD
Chemical oxygen demand (COD)	Measures oxygen demand of inorganic substances (eg. sulphides, sulphites) as well as organic substances
Biochemical oxygen demand (BOD5)	Measures oxygen demand of organic substances; simulates effect the waste will have on dissolved oxygen in the receiving environment
Adsorbable organic halogen (AOX)	Regularly monitored at pulp mills; useful for comparing with typical operating data
Cyanide	Toxic constituent of some mining and metal finishing effluents
Ammonia	Toxic constituent of numerous types of effluents
Nitrite	Toxic partial oxidation product of ammonia
Residual chlorine	Toxic constituent of STP effluent and some cooling waters

3.2 Detailed Evaluation of Candidate Parameters

Candidate parameters were evaluated with respect to toxicity and environmental fate as described in Section 2.3. Table 3.2-1 summarizes the toxicity and environmental fate data used to evaluate the parameters. The table provides the following information:

Presence in Other Basins: Notes detection and/or concentrations, primarily in sediments and aquatic organisms, of compounds identified in areas other than the Fraser River Basin;

Persistence; Identifies major pathway(s) of removal from the water column and half-life; note that if removal is by adsorption to sediments, the substance may still persist in the ecosystem;

Aquatic Toxicity: Gives measures of acute toxicity (LC50 or EC50);

Bioaccumulation: Evaluates the potential for a substance to accumulate in organisms based on bioconcentration factor (BCF), octanol/water partition coefficient, and/or half-life in fish; and

Genotoxicity: Indicates whether a substance has been identified as a carcinogen, teratogen, or mutagen.

Based on the data in Table 3.2-1, the following parameters failed to meet the selection criteria established in Section 2.3: 1,2-dichloroethane, bis(2-chloroethyl) ether, bis(chloromethyl) ether, chloromethyl methyl ether, methyl tertiary-butyl ether, vinyl chloride, aniline, methyl methacrylate, and chloroform. The available data were insufficient to determine whether chloromethyl methyl ether, 3,5-dimethyl aniline, and 3,3'- dichlorobenzidine met the selection criteria. The first two of these substances were not reviewed by MISA, and no data on them were present in the U.S. EPA Effluent Treatability Database. However, the U.S. EPA had undertaken full-scale testing on the treatability of 3,3'-dichlorobenzidine. Therefore, 3,3'-dichlorobenzidine was considered a potential concern and placed on the tentative parameters list.

The remaining parameters, except xylene and styrene, met the selection criteria for promotion to the tentative parameters list. Table 3.2-2 lists these parameters and identifies the reason for their selection. There was limited evidence that styrene and the xylenes might bioaccumulate, but the available information was considered insufficient for selection.

TABLE 3.2-1

ENVIRONMENTAL FATE OF CANADIAN ENVIRONMENTAL PROTECTION ACT LIST OF PRIORITY SUBSTANCES (PSL) AND SELECTED TOXIC SUBSTANCES AND OTHER POTENTIAL CONTAMINANTS OF THE FRASER RIVER

PARAMETER	PRESENCE IN OTHER BASINS	PERSISTENCE	AQUATIC TOXICITY	BIOACCUMULATION	GENOTOXICITY
Monocyclic aromatic hydrocarbons					
Benzene	Detected in 9% of 355 sediment samples (U.S. EPA database), median conc. <5 ug/kg; detected in bivalves from New Orleans	Rapid volatilization, half life in water 2.7 to 5.23 h; will not adsorb to soil	LC50: 5.3 mg/L (rainbow trout)	Not expected to accumulate based on bioconcentration factors <5 and octanol/water partition coefficient	Human carcinogen
Toluene	Detected in 17% of 397 data points for sediments, median concentration 5.0 ug/kg dry wt. (U.S. EPA); detected in fish from petroleum-contaminated harbor in Japan at 5 ug/g; also found in bivalves from Louisiana (3.4-18 ug/kg wet weight)	Lost by volatilization and biodegradation; half-life from days to several weeks	LC50: 5.46 mg/L (coho salmon); 240 mg/L (channel catfish)	Bioconcentration factors 1.67 to 380 (fish, invertebrates, algae); half-life 0.5 d	Mutagen, carcinogen
Styrene	Detected in water from U.S. and Europe; only two quantified values (1 and 4.2 ug/kg); detected in sediment from Tennessee and Saskatchewan (4.2 ug/kg)	Volatile; half life in water 3-23.8 h	LC50: 32-74.8 mg/L various spp..	Accumulates and produces tainting in fish	Possible animal carcinogen; weak mutagen in sea urchin egg test
Xylenes	Xylenes detected in fish from Colorado River (study was for analytical method development; significance unclear)	Volatile, half-life 1-5.5 d	No data	Bioconcentration factors for 3 xylenes <1 to 2; not expected to bioaccumulate	
Chlorinated benzenes	General presence in lake sediments (Ontario)			Some bioaccumulation potential for all chlorinated benzenes, increasing with increasing chlorination	

TABLE 3.2-1

ENVIRONMENTAL FATE OF CANADIAN ENVIRONMENTAL PROTECTION ACT LIST OF PRIORITY SUBSTANCES (PSL) AND SELECTED TOXIC SUBSTANCES AND OTHER POTENTIAL CONTAMINANTS OF THE FRASER RIVER

PARAMETER	PRESENCE IN OTHER BASINS	PERSISTENCE	AQUATIC TOXICITY	BIOACCUMULATION	GENOTOXICITY
Chlorobenzene	Not detected in Canadian raw drinking water; not detected in sediments from Lake Ontario(<1.5 ug/g), industrial river, or the Lower Hudson River (New York); not detected in fish from Great Lakes or Japan	Half-life est. at 1-12 h in rapidly-flowing stream; measured half-life in estuary 75 d	96-h LC50: 4.7-7.46 mg/L (rainbow trout); 48-h LC50: 5.8-25.8 mg/L (Daphnia)	Little or no bioconcentration expected based on laboratory tests	Mutagen; possible human carcinogen
1,2 Dichlorobenzene	0.3-1 ug/kg in trout from Great Lakes; up to 31 ug/kg in fish from California coast	Volatile; lost in 4 h in aerated water; adsorption to sediment is major environmental fate; core data indicate it has persisted in Lake Ontario sediment since before 1940	LC50: 15.8 mg/L (rainbow trout)	Experimentally determined bioconcentration factors in rainbow trout average 270-560	Mutagen
1,4 Dichlorobenzene	Present in Lake Ontario sediments	Volatile; half-life 4.3 h in model river; has persisted in Lake Ontario sediments since before 1940	LC50: 1.2-27 mg/L other spp. (position of Cl made no difference)	Experimentally determined bioconcentration factors in rainbow trout 100-1400 (highest at hatching stage)	Mutagen, probable human carcinogen
Trichlorobenzenes	Present in >90% of sediment samples from Great Lakes; 100% of trout from 5 sites in Great Lakes (0.5-5 ug/kg)	Volatile; persists 4 h in aerated and 3 d in unaerated distilled water; adsorbs to sediments	LC50: 3.4-21 mg/L (various fish); 0.5 mg/L (shrimp); 96-h LC50 for 1,2,4-trichlorobenzene: 2.9 mg/L (fathead minnow)	Bioconcentration factors in laboratory tests with various fish species ranged from 51-1300 for 1,2,4-T; 760-13,000 for 1,2,5-T	
Tetrachlorobenzenes	No data	No data	LC50: 1,2,3,5-Te: 3.4 - 37 mg/L (fish); 0.3 mg/L (shrimp); 1,2,4,5-Te: 0.8 - 1.6 mg/L (fish); 1.5 mg/L (shrimp); 1,2,3,4-Te: 1.1 mg/L (fathead minnow)	Bioconcentration factor 1800	

TABLE 3.2-1

ENVIRONMENTAL FATE OF CANADIAN ENVIRONMENTAL PROTECTION ACT LIST OF PRIORITY SUBSTANCES (PSL) AND SELECTED TOXIC SUBSTANCES AND OTHER POTENTIAL CONTAMINANTS OF THE FRASER RIVER

PARAMETER	PRESENCE IN OTHER BASINS	PERSISTENCE	AQUATIC TOXICITY	BIOACCUMULATION	GENOTOXICITY
Pentachlorobenzene	No data	Persistent in soil	LC50: 0.258 mg/L (rainbow trout); 0.2 mg/L (shrimp)	Bioconcentration factor 3400; biological half-life >7 d	Teratogen, possible animal carcinogen
Hexachlorobenzene	Average concentrations in sediments from Great Lakes range from 0.2 ug/kg in Lake Huron to 97 ug/kg in Lake Ontario; detected in numerous fish and shellfish from U.S.	Half life 1-3 days in experimental pond; adsorbs to sediments	Acute toxicity apparently above solubility limit	Biological half life >170 d (Nimi), 6-7 d (Moore & Ramamoorthy)	Teratogen, possible animal carcinogen
Chlorinated ethanes					
1,2 Dichloroethane	None detected in 40 soil/sediment samples in U.S. EPA database; not detected in livers of 5 fish spp; crab digestive gland, shrimps, or sediment	Volatile; half life 48 h in fresh water; adsorption to sediment not expected	LC50: 225 mg/L (rainbow trout); 106-550 mg/L other spp.; frog egg survival reduced by exposure to 0.99 mg/L	Bioconcentration not expected based on water solubility; all chloroethanes had half-life of <2 d in bluegills	Animal carcinogen, mutagen
1,1,1-Trichloroethane	Concentrations in sediment upstream and downstream of user industry were 0.039-2.6 ug/kg; in marine and estuarine fish and invertebrates from Great Britain and Ireland (0-34 ug/kg); also found in grey seal blubber, marine and freshwater birds and eggs	Primary loss by evaporation; half-life in mesocosm simulating Narragansett Bay were 11-24 d	LC50: 18-105 mg/L (various fish), >530 mg/L (Daphnia); 48-h LC50: 7.5 mg/L (barnacle nauplii)	Biological half-life < 1 d	Mutagen
1,1,2,2,-Tetrachloroethane	Present in sediments from Love Canal	Volatile; half life may be <1 d to weeks depending upon water body; adsorption to sediment not significant	LC50: 2.4-37 mg/L (fish); 9.3-62 mg/L (Daphnia)	Half life in fish <2 days	Known/suspected carcinogen

TABLE 3.2-1

ENVIRONMENTAL FATE OF CANADIAN ENVIRONMENTAL PROTECTION ACT LIST OF PRIORITY SUBSTANCES (PSL) AND SELECTED TOXIC SUBSTANCES AND OTHER POTENTIAL CONTAMINANTS OF THE FRASER RIVER

PARAMETER	PRESENCE IN OTHER BASINS	PERSISTENCE	AQUATIC TOXICITY	BIOACCUMULATION	GENOTOXICITY
Chlorinated ethylenes					
Trichloroethylene	U.S. EPA database: 6% of 338 sediment data points had detectable concentrations; detected in sediment from Liverpool Bay 9.9 ug/kg; detected in marine fish and bivalves 0.8 ug/kg-1.1 ug/g	Volatile but can stay in solution; half life <4 d	LC50: 16-213 mg/L (various fish), 18 mg/L (Daphnia), 8 mg/L (algae); 48-h LC50: 20 mg/L (barnacle nauplii)	Half life in fish <1 d	1,1,2-trichloroethylene is known/suspected carcinogen
Tetrachloroethylene	Present in 7% of 359 data points for sediment in U.S. EPA database (<0.050 ug/kg median); present in marine and freshwater fish from U.S. and Europe (0.3-1050 ug/kg); also found in grey seal blubber and marine and freshwater birds	Half life in a mesocosm experiment ranged from 11 to 25 d; in a natural pond was 5 to 36 days at low (25 ppm) and high (250 ppm) doses	LC50: 4.8-5.8 mg/L (rainbow trout); 4.8-30.0 mg/L (2 fish+3 invertebrate species)	Experimental bioconcentration factors of 38.9-49; not expected to accumulate significantly	Carcinogen
Dichloromethane	Detected in 20% of 338 data points listed in U.S. EPA database with median concentration 13.0 ug/kg; detected in bottom fish from Tacoma, WA (0.53 ug/g); also in shellfish near New Orleans	Evaporation to atmosphere should occur within several hours; adsorbs strongly to peat moss, likely not to adsorb to sediment with low organic content	LC50: 220-331 mg/L (various fish), 220 mg/L (Daphnia)	Not expected to bioaccumulate due to low octanol/water partition coefficient	Mutagen, probable human carcinogen

TABLE 3.2-1

ENVIRONMENTAL FATE OF CANADIAN ENVIRONMENTAL PROTECTION ACT LIST OF PRIORITY SUBSTANCES (PSL) AND SELECTED TOXIC SUBSTANCES AND OTHER POTENTIAL CONTAMINANTS OF THE FRASER RIVER

PARAMETER	PRESENCE IN OTHER BASINS	PERSISTENCE	AQUATIC TOXICITY	BIOACCUMULATION	GENOTOXICITY
bis(2-Chloroethyl) ether	Present in sediment from Love Canal	Hydrolysis half-life 40 d at pH 7: volatilization half-life est. as ranging from 3.5 d in streams to 180.5 d in lakes	Chloroalkyl ethers (general) are toxic to freshwater life at concentrations as low as 238 mg/L (USEPA water quality criteria)	Not expected to bioaccumulate based on laboratory tests with bluegills	Possible carcinogen
bis(Chloromethyl) ether	213 data points in U.S. EPA database: none detected in soils or sediments	In water, hydrolysis occurs with half-life of 10-38 sec	Highly unlikely due to short half-life in water	Short half-life in water precludes bioconcentration	
Chloromethyl methyl ether	No data	No data	Chloroalkyl ethers (general) are toxic to freshwater life at concentrations as low as 238 mg/L (USEPA water quality criteria)	No data	Suspected human carcinogen
Methyl tertiary-butyl ether	Not found in 21 samples of Nova Scotia shellfish (<0.01 ug/g)	Half-life for volatilization estimated to be 9 h; for aerobic biodegradation 28 to 180 d; for anaerobic degradation in deep water 12 to 72 d	96-h LC50 672 mg/L (fathead minnow); >10,000 mg/L (copepod)	BCF for carp: 1.1; fish eliminated almost all residue within 3 d	No data
Vinyl chloride	Detected in surface water from 7.6% of 105 U.S. cities (0.2 to 5.1 ug/L)	Rapid volatilization; est. half-life in river 0.8 h; not expected to adsorb to sediment	No data	Lack of appreciable bioconcentration reported in an ecosystem study	Human carcinogen
Aniline	Not detected in sediment of 2 U.S. rivers	Half life 6 d in eutrophic pond;75-90% loss in 21 d in oligotrophic lake	EC50 >10 - 100mg/L (Michigan Critical Materials Register: Score 2)	Does not bioconcentrate in fish based on laboratory tests	Possible animal carcinogen

TABLE 3.2-1

ENVIRONMENTAL FATE OF CANADIAN ENVIRONMENTAL PROTECTION ACT LIST OF PRIORITY SUBSTANCES (PSL) AND SELECTED TOXIC SUBSTANCES AND OTHER POTENTIAL CONTAMINANTS OF THE FRASER RIVER

PARAMETER	PRESENCE IN OTHER BASINS	PERSISTENCE	AQUATIC TOXICITY	BIOACCUMULATION	GENOTOXICITY
Benzidine	Not detected in downstream sediments following a discharge (New York); all 3240 records in U.S. EPA database showed benzidine nondetectable in sediment; also not detectable in 110 fish samples	Half-life in water approximately 1 d	EC50 >1 - 10 mg/L (Michigan Critical Materials Register: Score 3); acutely toxic to freshwater life at concentrations as low as 2.5 mg/L (USEPA water quality criteria)	Half life in bluegills about 7 d	Human carcinogen
3,3'-Dichlorobenzidine	No data	No data	BCF = 300-699 (Michigan Critical Materials Register: Score 1)	No data	Animal carcinogen
3,5-Dimethylaniline	No data	No data	No data	No data	Not designated a carcinogen by IARC, NCI, or USEPA
Methyl methacrylate	Detected in water in 2 of 195 U.S. sites (10 ug/L)	Half-life 6.3 h for typical river; no appreciable adsorption to sediment	No data	Not expected to occur based on octanol/water partition coefficient	Not designated a carcinogen by IARC, NCI, or USEPA
Resin acids	Dehydroabietic acid (DHA) detected in a longnose sucker collected 3 km from a pulp mill in Lake Superior	Aerated lagoons with retention time of 3-5 d remove 90% of resin acids; DHA more persistent than other resin acids	LC50 for DHA: 0.5-2.1 mg/L; other resin acid LC50s range from 0.2-1.5 mg/L in various species	Expected to occur based on octanol/water partition coefficient; accumulation of DHA 20-30 times surrounding water	Neoabietic acid mutagenic
Chloroform	Not detected in fish collected <2.5 km from pulp mill	No data (data not sought extensively)	96-h LC50: 18.2 mg/L (rainbow trout and bluegill); 48-h LC50: 29 mg/L (Daphnia)	BCF = 6 in fish exposed to pulp mill effluent	Teratogenic to frogs at 0.018 mg/L; animal carcinogen
Nonylphenol	Found in mussels exposed under field conditions	Relatively persistent; experimental biodegradation half-life 58 d	96-h LC50s: 0.13 to 0.16 mg/L (Atlantic salmon), 0.30 mg/L (shrimp)	BCF = 280 (Atlantic salmon); 1300 (sticklebacks); 3400 (mussels)	No data (not extensively sought)

TABLE 3.2-1

ENVIRONMENTAL FATE OF CANADIAN ENVIRONMENTAL PROTECTION ACT LIST OF PRIORITY SUBSTANCES (PSL) AND SELECTED TOXIC SUBSTANCES AND OTHER POTENTIAL CONTAMINANTS OF THE FRASER RIVER

PARAMETER	PRESENCE IN OTHER BASINS	PERSISTENCE	AQUATIC TOXICITY	BIOACCUMULATION	GENOTOXICITY
Organotins (butyl tins)	Detected in fish from Vancouver Harbour: Tributyl tin 0.58 ug/g, dibutyl tin 0.098 ug/g, monobutyl tin 0.090 ug/.g	Expected to adsorb to sediments; degradation products of tributyl tin include di- and monobutyl tins	96-h LC50: tributyl tin 0.0026 to 0.127 mg/L (various fish); 24-h EC50s: dibutyl tin 0.690 mg/L (Daphnia); monobutyl tin 30.4 mg/L (Daphnia); half-life for metabolism by freshwater algae is 25 d	No data (not extensively sought)	No data (not extensively sought)
Didecyl dimethyl ammonium chloride (DDAC)	No data (not extensively sought)	Appears to biodegrade; further studies in progress	96-h LC50: 0.70 mg/L (salmonids)	Not expected based on octanol/water partition coefficient (log Kow=0)	No data (not extensively sought)
3-Iodo-2-propynyl butyl carbamate(IPBC)	No data (not extensively sought)	Preliminary studies show half-life for biodegradation about 1 week	96-h LC50: 0.12 mg/L (salmonids)	Not expected: BCF=4	No data (not extensively sought)

Sources:

MISA (1987)	USEPA (1986)	Sittig (1985)	Rogers et al. (1986)	Ekelund et al. (1990)
Howard (1989, 1990)	Brown and Donnelly (1988)	Ferrario et al. (1985)	Envirochem (1992a)	Ekelund et al. (1993)
CCREM/CCME (1987-92)	Environment Canada (1984)	Dickson and Riley (1976)		
Taylor et al. (1988)	Nimi (undated)	Pearson and McConnell (1975)		
Moore and Ramamoorthy (1984)	McLeay et al. (1986)	Environment Canada + Health and Welfare Canada (1992a,b,c)		

TABLE 3.2-2

CANDIDATE PARAMETERS PROMOTED TO THE TENTATIVE PARAMETERS LIST BASED ON TOXICITY AND PERSISTENCE

PARAMETER	RATIONALE
Benzene	Toxicity; detection in bivalves from New Orleans
Toluene	Detection in fish from two locations; toxicity
Trichlorobenzenes	Characteristics similar to dichloro- and hexachlorobenzenes
Tetrachlorobenzenes	Characteristics similar to dichloro- and hexachlorobenzenes
Pentachlorobenzene	Characteristics similar to dichloro- and hexachlorobenzenes
1,1,1-Trichloroethane	Detected in biota from other areas
1,1,2,2-Tetrachloroethane	Acute toxicity
Trichloroethylene	Detected in biota from other areas
Tetrachloroethylene	Detected in biota from other areas; acute toxicity
Dichloromethane	Detected in biota from other areas
Benzidine	Acute toxicity
3,3'-Dichlorobenzidine	Lack of data but U.S. EPA completed full-scale treatability test
Organotins (butyl tins)	Detected in fish from Vancouver Harbour; toxicity
Resin acids	Detected in fish from other basins; toxicity
Nonylphenol	Toxicity
Didecyl dimethyl ammonium chloride (DDAC)	Toxicity
3-Iodo-2-propynyl butyl carbamate(IPBC)	Toxicity

FINAL PARAMETER SELECTION

This section describes the final evaluation of parameters on the tentative parameters list. Section 4.1 provides the information used to determine whether a substance is currently being discharged or is likely being discharged to the Fraser Basin. Section 4.2 summarizes the status of analytical method availability and reliability for parameters remaining on the tentative list. Section 4.3 describes the final addition of useful parameters that can be monitored at little or no additional cost because they are part of an analytical package that measures other parameters selected.

4.1 Identification of Potential Presence in Fraser Basin Effluents

4.1.1 Identification of Parameters No Longer Being Discharged

Substances identified as contaminants in the Fraser Basin (Section 3.1.1) have been discharged to the basin at some time. However, it was recognized that some persistent substances might no longer be discharged. Therefore, they would not meet the selection criterion of having a current known or probable discharge source.

From the literature review on Fraser Basin contaminants and discussions with Environment Canada personnel, Norecol identified several substances whose discharges have diminished because of changes in legislation or use patterns. The organochlorine pesticides DDT (including its decomposition product, DDE) and heptachlor are no longer registered for use in Canada. The handling of PCBs is strictly controlled, and under normal circumstances they are not expected to be present in effluents. The continued presence of these chemicals in Fraser Estuary biota and sediments apparently reflects their persistence rather than the existence of any current discharge source (Swain and Walton 1990a).

The major uses of lead, organotins, hexachlorobenzene, and pentachlorophenol have been curtailed, but there is still some potential for them to be present in effluents. The primary release source of lead was leaded gasoline. With the conversion to unleaded gasoline, lead levels in the Fraser Estuary have decreased (Swain 1993). However, there is potential for lead to be present in mining and metal processing effluents. The major use of organotins (tributyl tin) was as a biocide in antifouling paint. This use is no longer permitted, but tributyl tin is still used as a slimicide in cooling water, and dibutyl tins are used as catalysts in various chemical manufacturing processes. Hexachlorobenzene apparently has been used as a pesticide, although it is not currently registered for this purpose. It is also produced as a waste product in chemical manufacturing (CCREM 1987). Pentachlorophenol, which has been used extensively to treat wood, is no longer used by lumber mills as an anti-sapstain, but it is still used in long term preservation of wood for use outdoors (Envirochem 1992a,b). It may also be present in pulp mill effluents.

On the basis of this review, the chlorinated hydrocarbon pesticides and PCBs were removed from the monitoring list. The organotins, hexachlorobenzene, and pentachlorophenol remained on the tentative parameters list and were evaluated with respect to the remaining selection criteria.

4.1.2 Identification of Industries in the Fraser Basin

In order to determine possible sources of the remaining tentative parameters, Norecol identified the types of industries present in the basin and then identified the types of contaminants potentially discharged by these industries. The industries present were identified using the Fraser Basin Point Source Inventory. The inventory contains over 40 different categories of industries. In order to make the development of industry-specific monitoring parameters manageable, groups were combined to reduce the number of categories to 17 (Table 4.1-1).

The majority (240) of effluent sources in the Fraser Basin are sewage discharges associated with private residences, hotels, campgrounds, Indian reserves, and the like. These facilities are not considered a high priority for monitoring. Collectively the food production and food processing industries (food processing industries, aquaculture, fish packing, and agriculture-related) represent 62 effluents permits. Other important sources are municipal sewage treatment plants (50 discharges), forest products and wood preservative plants (together representing 37 permits) and concrete and industrial minerals (together representing 30 permits).

4.1.3 Identification of Types of Contaminants Present in Effluents

Norecol tabulated the available information on types of contaminants associated with particular industries, as determined from the MISA, U.S. EPA, and PSL information. Because of limited distinctions in the available literature between certain of the industries listed in Table 4.1-1, some categories were combined. Thus, in the tabulation of contaminants in specific industrial effluents, forest products includes forest products and wood preservation plants. The concrete and industrial minerals categories have also been combined.

Table 4.1-2 indicates the contaminants that have been detected in effluents from the different industry groups. Some of the contaminants (heavy metals, dioxins/furans,

TABLE 4.1-1

SUMMARY OF EFFLUENT TYPES IN THE FRASER RIVER BASIN

SOURCE	OUTFALLS
Private Sewage	240
Municipal Sewage	50
Food Industries (1)	29
Fish Packing (1)	23
Concrete Industries (2)	21
Forest Products (3)	21
Mining & Refining	18
Wood Preservative (3)	16
Petroleum Industry	13
Pulp & Paper	10
Industrial Minerals (2)	9
Chemical Products	8
Agriculture-Related (1)	7
Metal Fabricating	6
Pipelines	4
Aquaculture (1)	3
Plastics Industry	3

(1) Shown in Table 5.2-1 as Food Production/Food Processing
(2) Shown in Tables 4.1-2 and 5.2-1 as Concrete/ Industrial Minerals
(3) Shown in Tables 4.1-2 and 5.2-1 as Forest Products

TABLE 4.1-2
POTENTIAL PRESENCE OF PERSISTENT/TOXIC SUBSTANCES IN EFFLUENTS OF THE FRASER BASIN

CHEMICAL NAME	MUNICIPAL WWTP	PRIVATE SEWAGE	AGRICULTURE INDUSTRY	AQUACULTURE INDUSTRY	FOOD PROCESSING	FISH PACKING	CONCRETE/ IND. MINERALS*
Metals	P,E,Pi		X		P (canning)		X
Mercury	P,E,Pi						
Arsenic	P,E,Pi						
Chromium	M,P						
Chlorophenols	M						
Chloroguaiacols							
Nonylphenol	X						
Dioxins/Furans	M,Pi						
Polycyclic Aromatic Hydrocarbons	M,E						
Phthalate esters	M,P,E,H,Pi						
1,2-Dichlorobenzene	M,P,E,H						
1,4-Dichlorobenzene	M,P,E						
Trichlorobenzenes	M,P,E,H						
Tetrachlorobenzenes	P						
Pentachlorobenzene	M,P						
Hexachlorobenzene	M,P,E,H						
1,1,1-Trichloroethane	P,E,H						
1,1,2,2-Tetrachloroethane	M,P,E,H						
Dichloromethane							H**
Trichloroethylene	M,P,Pi						
Tetrachloroethylene	M,P,E						
Benzene	P,M						
Toluene	M,H,Pi						
Benzidine	M,E						
3,3'-Dichlorobenzidine	M,E						
Organotins	P,X						
Resin Acids	M						
DDAC							
IPBC							
Cyanide	M						
Ammonia	X,Pi	X	X	X	X	X	
Nitrite	X,Pi	X	X	X	X	X	
Chlorine, residual	X					X	

Legend

E: Listed on the United States Environmental Protection Agency Treatability Data Base

H: Identified as source by Howard (1989, 1990)

M: Listed on the Ontario Effluent Monitoring Priority Pollutants List

P: Information from the Canadian Environmental Protection Act Priority Substances List

Pi: Detected in effluent in the Environment Canada Fraser Basin wastewater characterization pilot study

X: Occur in effluents of the industries indicated based on Fraser Basin monitoring data

* Includes concrete and industrial minerals from Table 4.1-1

** "nonferrous minerals"

WWTP - Wastewater Treatment Plant

TABLE 4.1-2

POTENTIAL PRESENCE OF PERSISTENT/TOXIC SUBSTANCES IN EFFLUENTS OF THE FRASER BASIN

CHEMICAL NAME	FOREST PRODUCTS*	PULP AND PAPER	CHEMICAL PRODUCTS	PLASTICS INDUSTRY	PETROLEUM INDUSTRY	METAL FINISHING	MINING & REFINING
Metals	P	M,Pi	M,E	P	M,P	P,E	P,X
Mercury		M	M		M		X
Chromium	P	M	M	P	M		P
Arsenic	P,X	M,Pi	P		M	P,E,X	P,X
Chlorophenols	X	M,H,Pi,X	M		M	H (Trichloro)	
Chloroguaiacols		M,Pi,X					
Nonylphenol							
Dioxins/Furans		M,Pi,X					
Polycyclic Aromatic Hydrocarbons		M	M,E		M	E	
Phthalate esters		M,H	M,P,E	P,H	M,H	H	P
1,2-Dichlorobenzene		M,P	M,P	P	M,P		
1,4-Dichlorobenzene		M,P	M,P,E	P	M		
Trichlorobenzenes		M	H,M	H	M,P	P	
Tetrachlorobenzenes		M,P	M,P	P	M,P	H	
Pentachlorobenzene		M,P	M,P	P	M,P		
Hexachlorobenzene		M,P,Pi	M,P,E	P	M,P	H***	
1,1,1-Trichloroethane		M,P,Pi	M,P,E	P	M,P		
1,1,2,2-Tetrachloroethane		M	M,P,H	P	M,P		M
Dichloromethane			P	P			
Trichloroethylene		M	M,P	P	M,P		
Tetrachloroethylene	H**		P,E,H	P,H	P,H	H	H
Benzene	H**	M	M		P,H	H	
Toluene		M	M,P,E	P,H	M,P		
Benzidine			P	P	M,H	H	M
3,3'-Dichlorobenzidine		P	M,P	P	M,P		P
Organotins		C	P				
Resin Acids	X	M,Pi,X	M				
DDAC	X						
IPBC	X						
Cyanide		M				X	X
Ammonia							X
Nitrite		Pi					X

Legend

C: Identified as source by CCREM (1987)

E: Listed on the United States Environmental Protection Agency Treatability Data Base

H: Identified as source by Howard (1989, 1990)

M: Listed on the Ontario Efflulent Monitoring Priority Pollutants List

P: Information from the Canadian Environmental Protection Act Priority Substances List

Pi: Detected in effluent in the Environment Canada Fraser Basin wastewater characterization pilot study

X: Occur in effluents of the industries indicated based on Fraser Basin monitoring data

* Includes Forest Products and Wood Preservation Plants from Table 4.1-1

** Howard's "forest products" may include pulp mills

*** "nonferrous minerals"

PAHs) tabulated in Table 4.1-2 are summarized as classes rather than as individual substances. This summary was done for two reasons:

- because it simplifies the table; and
- because the groups represent individual analytical packages (see Section 4.3).

Appendix I lists specific metals, dioxins and furans, and PAHs typically included in the analytical packages.

Table 4.2-1 indicates that all of the parameters remaining on the tentative parameters list have been detected in effluents of at least one industry group represented in the Fraser Basin. Thus, all remained on the tentative parameters list .

4.2 *Identification of Analytical Method Availability and Reliability*

Analytical methods for all of the remaining tentative parameters were identified based on common practice and standard methodologies employed by government and commercial laboratories throughout North America. Table 4.2-1 summarizes these methods along with information on their reliability and/or any problems associated with them.

Analytical methods are available for all parameters remaining on the tentative parameters list; however, there are significant problems with several of the analyses. The widespread occurrence of phthalate esters makes sample contamination likely and reduces the reliability of analytical results. Analyses for benzidines have a record of poor chromatographic performance and inconsistent results. Available analytical methods for residual chlorine may not be appropriate for the wastewater characterization program. Because it is unstable, this parameter should be analyzed almost immediately. Field kits are available, but they utilize a colorimetric technique which is adversely affected by coloured effluents. Therefore, phthalate esters, benzidine, and 3,3'-dichlorobenzidine, were removed from the monitoring list. Residual chlorine was removed as a quantitative measurement, but field testing using a chlorine Hach (or similar) kit is still recommended for chlorinated wastewater discharges as a screening for acute toxicity.

Analyses for some other parameters are not routine at most laboratories. Parameters in this category include chlorinated dioxins/furans and organotins. While dioxin/furan analyses are not widely available, methods are well established and routinely available at several laboratories. Adequate analytical techniques for organotins have been developed, but analyses are available at only a few specialized laboratories and cannot be obtained routinely.

TABLE 4.2-1

RELIABILITY AND PRACTICALITY OF ANALYTICAL METHODS FOR PARAMETERS TENTATIVELY SELECTED FOR FRASER BASIN WASTEWATER CHARACTERIZATION PROGRAM

ANALYTICAL TEST GROUP	TEST METHOD	COMMENTS
Total Metals*	ICP or AA	Widely used - no problems.
Hydrides(As,Sb,Se)	Hydride Generation/AA or ICP	Widely used - no problems
Mercury	Cold Vapour AA	Widely used - no problems
Chromium (VI)	Colourimetry or AA	Less commonly available but no method problems
Chlorophenols*/ Chloroguaiacols*/ Chlorocatechols*/ Nonylphenol	GC/MS	Less commonly available but no problems with close adherence to method
Chlorinated Dioxins and Furans*	GC/High Resolution MS	Less commonly available. Method requires both very expensive instrumentation and extensive experience.
Polycyclic Aromatic Hydrocarbons (PAHs)*	GC/MS	Widely used - no problems
Phthalate Esters	GC/MS	Problems with high and inconsistent method blanks due to widespread occurrence of compounds in laboratory and field sampling equipment.
Chlorobenzenes	GC/ECD or MS	Less commonly available - no problems
Volatiles, Halogenated (Chlorinated ethanes, ethylenes, methanes; may also include di- and trichlorobenzenes)	Purge & Trap with GC/MS or ELCD; Headspace GC/MS	Widely used - no problems
Volatiles, Non-halogenated (Benzene, Toluene, Styrene, Xylene)	Purge & Trap with GC/MS or PID; Headspace GC/MS	Widely used - no problems
Benzidine and 3,3'-Dichlorobenzidine	GC/MS	Poor chromatographic performance. Also may be unstable in effluents and solvents. Very difficult to obtain consistent results.
Organotins	GC/MS or GC/AA	Only a few laboratories with experience in this analysis. No problems for experienced laboratories
Resin Acids	GC/MS	Widely used - no problems.
Didecyl dimethyl Ammonium Chloride (DDAC)	GC/NPD	Methods only recently developed; only available at a few laboratories; performance data limited

TABLE 4.2-1

RELIABILITY AND PRACTICALITY OF ANALYTICAL METHODS FOR PARAMETERS TENTATIVELY SELECTED FOR FRASER BASIN WASTEWATER CHARACTERIZATION PROGRAM

ANALYTICAL TEST GROUP	TEST METHOD	COMMENTS
3-Iodo-2-propynyl butyl carbamate (IPBC)	GC/NPD	Methods only recently developed; only available at a few laboratories; performance data limited
Cyanide, Total	Colourimetry	Widely used - no problems
Cyanide, WAD	Colourimetry	Widely used - no problems
Ammonia	Colourimetry	Widely used - no problems
Nitrite	Colourimetry	Widely used - no problems
Chlorine Residual	Amperometric Titration or Field Test Kit (Colourimetry)	Should be analyzed on site or within hours of collection because of continuing chlorine reactions with the effluent. Instruments not widely available in commercial labs due to limited demand. Coloured effluents interfere with field colourimetric tests.
Adsorbable Organic Halide (AOX)	Carbon Adsorption/ Pyrolysis/ Titration	Less commonly available - no problems
Biological Oxygen Demand (BOD)	Oxygen Probe	Widely used - no problems
Chemical Oxygen Demand (COD)	Titration	Widely used - no problems
Dissolved Organic Carbon (DOC)	Conversion to CO2 with IR detection	Widely used - no problems
Hydrogen ion (pH)	Meter	Widely used - no problems
Alkalinity	Titration	Widely used - no problems
Conductivity	Meter	Widely used - no problems
Total Suspended Solids	Gravimetric	Widely used - no problems

* See Appendix I for complete list of parameters in these groups

The available analytical methods for DDAC and IPBC have only recently been developed. Problems initially present have been solved, and the methods appear to be reliable (Envirochem 1992a). However, because the techniques are new, the method performance data are limited. In addition, these analyses are not routinely available from most laboratories.

Because they are not available routinely and because of limited method performance data, organotins, DDAC, and IPBC are not recommended for inclusion as routine parameters in the wastewater characterization program. However, if, as Envirochem (1992a) has suggested, DDAC and IPBC become virtually the only anti-sapstain chemicals used in British Columbia, these chemicals should be monitored in runoff from lumber mills. Therefore, inclusion of these chemicals on an experimental basis is recommended. The information obtained will strengthen the method performance database and may help to characterize the levels of these chemicals in stormwater discharges from lumber mills. In addition, experimental monitoring of organotins should be considered at sites (if any) where they are known to be used as catalysts or slimicides in cooling towers and paper making (CCREM 1987).

The remaining parameters on the tentative list (including dioxins/furans) meet the selection criterion of method availability and reliability. Therefore, they form the final monitoring list.

4.3 Selection of Additional Parameters

Several parameters on the PSL or identified as occurring in Fraser Basin effluents failed to meet the selection criteria related to toxicity and persistence. However, these chemicals normally are measured as part of analytical packages used for parameters that did meet the selection criteria. Chlorocatechols are analyzed in the package that includes chlorophenols and chloroguaiacols. Chloroform, 1,2-dichloroethane, xylene, and styrene are included in the volatiles analyses (chlorinated or non-chlorinated volatiles).

Chloroform initially was recommended for environmental effects monitoring at pulp mills. The data review indicated some potential for environmental concerns associated with 1,2-dichloroethane, xylene, and styrene (Table 3.2-1). Because these parameters can provide potentially useful information on wastewater characteristics at little or no incremental analytical cost or sampling effort, they were added to the final monitoring list.

RECOMMENDED MONITORING PARAMETERS

The parameters selected for the final monitoring list have been divided into two groups: core parameters, which should be analyzed in all effluents, and industry-specific parameters, which should only be analyzed at the industries that are likely to discharge them.

This section summarizes the core and industry-specific parameters. It also identifies the industrial sectors and subsectors for which each industry-specific parameter should be measured.

5.1 Core Parameters

Table 5.1-1 lists the core parameters. These parameters should be measured in all effluents sampled as part of the Fraser Basin wastewater characterization program.

5.2 Industry Specific Parameters

Table 5.2-1 lists the industry-specific parameters, indicating the industries to which they apply. To simplify this table, several of the industries listed in Table 4.1-2 that have similar effluent characteristics were combined. Thus, the category food production/food processing includes food processing industries, aquaculture, fish packing, and agriculture-related. The forest products and wood preservative industries and the concrete and industrial minerals industries shown in Table 4.1-1 had already been combined in Table 4.1-2. Thus, several of the industries listed in this Table 5.2-1 encompass several subsectors. Not all of the parameters suggested for the major industry group apply to all of the subsectors. The following sections discuss parameters recommended for the subsectors of these industries.

For most of the parameters shown in Table 5.2-1, the preparation and analytical techniques provide only one type of measurement, the total amount of the substance in the sample. For metals, however, the preparation (filtration or no filtration) determines whether total or dissolved metals are measured. In most cases, total metals should be measured because a primary objective of the wastewater characterization program is to characterize contaminant loadings. However, in specific instances the objective may be to pinpoint the cause of effluent toxicity. In these cases, dissolved metals should be measured because they more closely

TABLE 5.1-1 CORE PARAMETERS FOR FRASER BASIN WASTEWATER CHARACTERIZATION (TO BE MEASURED FOR ALL OUTFALLS)
Temperature (field measurement)
Dissolved oxygen (field measurement)
pH (field and laboratory measurement)
Alkalinity
Conductivity (Specific conductance)
Total suspended solids (TSS)
Dissolved organic carbon (DOC)
Chemical oxygen demand (COD)

TABLE 5.2-1

INDUSTRY SPECIFIC MONITORING PARAMETERS FOR WASTEWATER CHARACTERIZATION IN THE FRASER BASIN

PARAMETER	MUNICIPAL WWTP	FOOD PROD. PROCESSING	CONCRETE/ INDUST. MIN	FOREST PRODUCTS	PULP AND PAPER	CHEMICAL PRODUCTS	PLASTICS INDUSTRY	PETROLEUM INDUSTRY	METAL FINISHING	MINING & REFINING
Ammonia	X	X							X	X
Nitrite	X	X		X		X	X		X	X
Cyanide					X				X	
Metals*	X	X (1)	X	X (3)	X	X	X	X	X (5)	X (5)
Chromium**	X			X (3)	X	X	X	X	X (5)	X (5)
Arsenic	X			X (3)	X	X	X	X	X (5)	X (5)
Mercury	X				X	X	X	X		X
Chlorophenols*	X			X (3)	X		X			
Chloroguaiacols*					X					
Chlorocatechols*					X					
Chloroform					X					
Nonylphenol	X									
Dioxins/furans*	X				X					
Polycyclic aromatic hydrocarbons*	X			X (3)	X	X		X	X	
Trichlorobenzenes	X				X	X	X	X		
Tetrachlorobenzenes	X				X	X	X	X		
Pentachlorobenzene	X				X	X	X	X		
Hexachlorobenzene	X				X	X	X	X	X	
1,4-Dichlorobenzene	X				X	X	X	X		
1,2-Dichlorobenzene	X				X	X	X	X		
1,2-Dichloroethane	X				X	X	X	X		X
1,1,1-Trichloroethane	X				X	X	X	X		
1,1,2,2-Tetrachloroethane	X				X	X	X	X		X
Dichloromethane	X					X	X			
Trichloroethylene	X				X	X	X	X		
Tetrachloroethylene	X				X	X	X	X		
Benzene	X				X	X	X	X	X	
Toluene	X					X	X	X	X	X
Styrene						X	X			
Xylene	X				X	X	X	X	X	
Resin acids	X	X (2)		X	X	X				
Adsorbable organic halogens (AOX)					X					
Didecyl dimethyl ammonium chloride (DDAC)				X (3)						
3-Iodo-2-propynyl butyl carbamate (IPBC)				X (3)						
Biochemical oxygen demand (BOD5)	X	X	X	X (4)	X					
Chlorine, residual (field measurement)	X	X (6)								

WWTP - Wastewater Treatment Plant

* See Appendix I for complete listings
In general "Metals" refers to total metals; dissolved metals should be measured where indicated or to identify unknown toxicant

** Cr(VI) can also be measured to idenfity unknown toxicant

Notes:

(1) Where metals used (canning)
(2) Where woodwaste is used
(3) Where specific wood preservatives/ anti-sapstain chemicals used (DDAC and IPBC measured on experimental basis only)
(4) Where oil and grease are expected in effluent
(5) Measure both total and dissolved metals
(6) If wastewater is chlorinated

approximate the toxic fraction. In addition, where chromium toxicity is suspected, the analyses should include a special analysis for Cr(VI), the most toxic form of the metal. The following sections indicate the industries for which analyses for dissolved metals and/or Cr(VI) should automatically be included. For other industries, these analyses should be done only if required to help identify of the source of effluent toxicity.

5.2.2 *Food Production/Food Processing*

The food production and food processing industries include farm operations (where point source discharges exist), fish farms and hatcheries, and various types of food processing plants. In most cases there are common concerns related to their discharges. The common parameters include biochemical oxygen demand (BOD5), and toxic nitrogen compounds (ammonia and nitrite). However, some subsector may discharge other substances of concern. For example, some farm operations use large quantities of woodwaste (chips, bark mulch, sawdust) which may leach toxic resin acids. Also, food canning industries and breweries use metals (eg. aluminum) which may appear in the effluent. Table 5.2-2 indicates the industry-specific parameters associated with specific food production/food processing subsectors.

5.2.3 *Concrete and Industrial Minerals*

The concrete and industrial minerals sector consists primarily of cement and concrete operations (ready-mix concrete and cast concrete products) and sand and gravel operations. Effluents from the cement and concrete sectors may include cooling water and cement truck wash water, either of which may contain oil and grease, which can exert a biochemical oxygen demand. The effluents from sand and gravel operations usually consist only of sand/gravel wash water, which may be high in suspended solids. Therefore, BOD5 should be monitored in the cement and concrete subsector only (Table 5.2-3). Metals should be monitored in both subsectors, as there is potential for metals to be present in either effluent type. Metals are most likely to be present in particulate form. Total metals should be measured to reflect loadings, but the particulate fraction is unlikely to be an environmental concern. If toxicity is suspected, dissolved metals should be measured because they more closely reflect the toxic component.

5.2.4 *Forest Products*

Forest products industries include lumber mills, producers of specialty wood products (veneer, particle board), and wood preservative plants. In general, the concerns associated with the lumber mills and specialty wood products are similar, and the major differences among sites will depend upon the specific anti-sapstain products used. Most lumber mills currently use DDAC-based anti-sapstains. Some

TABLE 5.2-2 INDUSTRY SPECIFIC MONITORING PARAMETERS FOR FOOD PRODUCTION/FOOD PROCESSING INDUSTRIES IN THE FRASER BASIN						
TYPE	RESIN ACIDS	BOD5	AMMONIA	NITRITE	TOTAL METALS**	CHLORINE, RESIDUAL
Livestock Production	X*	X	X	X		
Meat/Poultry Production	X*	X	X	X		
Egg Production	X*	X	X	X		
Fish Farms/Hatcheries		X	X	X		
Fish Processing		X	X	X	X	X***
Canned Fruits and Vegetables		X	X	X	X	
Dairy/Fluid Milk	X*	X	X	X		
Feed Industry	X*	X	X	X		
Brewery		X	X	X	X	
Farms/Nurseries	X*	X	X	X		

* Where effluent includes runoff from woodwaste used as bedding, mulch, etc.

** Measure metals where canning process used; measure dissolved metals only if necessary to investigate source of effluent toxicity

*** Where effluent is chlorinated

TABLE 5.2-3 INDUSTRY SPECIFIC MONITORING PARAMETERS FOR CONCRETE AND INDUSTRIAL MINERALS INDUSTRIES IN THE FRASER BASIN		
TYPE	BOD5	TOTAL METALS*
Cement and Concrete	X	X
Sand and Gravel		X
Non-metallic minerals		X

* Measure dissolved metals to investigate source of effluent toxicity

formulations also contain IPBC. DDAC and IPBC are recommended for monitoring on an experimental basis only at sites where they known to be in use. The other parameters indicated in Table 5.2-1 should be measured at all sites.

Plants specializing in thermal or pressure treatment of wood that requires long-term protection for outside use (eg. hydro poles, railroad ties, marine pilings) may use one or more preservative chemicals which are different from the anti-sapstains used at lumber mills. Monitoring requirements for wood preservative chemicals should be determined on a site-specific basis. Table 5.2-4 indicates the monitoring parameters required for specific wood preservatives.

5.2.5 *Pulp and Paper*

The pulp and paper industry includes plants that employ chlorine bleaching and plants that use no chlorine. Chlorinated phenols, guaiacols, catechols, dioxins and furans all are associated with chlorine bleaching. However, chlorinated phenols, dioxins and furans may also be present in effluents from mills that use no chlorine but have used chlorophenol-treated wood chips. Although many mills are now refusing to take wood chips that have been treated with chlorophenols, it is valuable to determine the prevalence of these contaminants within the industry. Thus, the initial wastewater characterization studies for pulp mills should include all of the parameters indicated in Table 5.2-1, regardless of whether the mill uses chlorine bleaching. AOX is a routine monitoring parameter for all pulp mills using chlorine bleaching. Therefore, AOX is included on the basis that it will provide data needed for the comparison of discrete sample results with typical effluent quality.

5.2.6 *Chemical Products and Plastics Industries*

The industrial chemicals, organic chemicals, and plastics industries are a diverse group of companies which use different processes to produce different products. Where possible, the most appropriate monitoring parameters should be determined for each site by conducting an audit or survey of chemical use. Where it is not possible to obtain this information, wastewater characterization should include all of the parameters indicated in Table 5.2-1.

5.2.7 *Petroleum Industry*

The petroleum sector is also a diverse group whose subsectors range from refineries to pipelines to wholesalers of petroleum products. The industry-specific parameters listed in Table 5.2-1 are appropriate for petroleum refineries. The monitoring parameters for other petroleum industry subsectors should be determined based on audits or interviews with on-site staff.

TABLE 5.2-4

INDUSTRY SPECIFIC MONITORING PARAMETERS FOR FOREST PRODUCTS INDUSTRIES IN THE FRASER BASIN

ANTISAPSTAIN OR WOOD PRESERVATIVE USED	CHLORO-PHENOLS	PAH	METALS*	ARSENIC*	CR(VI)	DDAC (2)	IPBC (2)	BOD5	RESIN ACIDS	AMMONIA	NITRIT
DDAC-Based Products						X		X	X	X	X
NP-1 (DDAC+IPBC)						X	X	X	X	X	X
Pentachlorophenol	X							X	X	X	X
Creosote		X						X	X	X	X
Chromated Copper Arsenate			X	X	X (1)			X (3)	X	X	X
Ammoniacal Copper Arsenate			X	X				X (3)	X	X	X

* Measure both total and dissolved metals (if using AA, focus on copper and chromium); also total and dissolved arsenic

Notes:

(1) Optional Cr(VI) analysis to investigate source of effluent toxicity
(2) Recommended on experimental basis until method performance confirmed
(3) Measure where woodwaste leachate is present

5.2.8 Municipal and Private Sewage Discharges

The "sewage treatment" category listed in Table 5.2-1 represents monitoring parameters for municipal wastewater treatment plants and is not intended for private sewage effluents associated with hotels, campgrounds, Indian reserves and the like. The parameters indicated in Table 5.2-1 should be monitored at all large-scale municipal wastewater treatment plants whose inflow includes industrial waste and/or urban runoff.

Private sewage discharges are unlikely to contain most of the contaminants present in municipal wastewater treatment plants, which often treat industrial effluents as well as well as domestic sewage. In most cases monitoring of private sewage discharges should be restricted to BOD5, ammonia, and nitrite. However, the Fraser Point Source Inventory indicates that some of the private sewage sources represent laundromats. Some laundromats may have dry cleaning facilities associated with them. Because effluents from dry cleaning facilities may contain trichloroethylene and/or tetrachloroethylene (unpublished summary of PSL sources), effluents associated with laundromats/dry cleaners should be analyzed for these compounds (Table 5.2-5).

5.2.9 Metal Finishing and Mining Industries

There are likely to be some site-specific differences in the effluents from metal finishing plants and mines. However, the differences are not expected to be great enough to warrant sub-sector or site-specific parameters lists. Because dissolved metals are usually the major contributors to toxicity in effluents from these industries, characterization of metal finishing and mining effluents should include measurement of both total and dissolved metals.

TABLE 5.2-5

INDUSTRY SPECIFIC MONITORING PARAMETERS FOR DOMESTIC SEWAGE EFFLUENTS IN THE FRASER BASIN

TYPE	BOD5	AMMONIA	NITRITE	CHLORINATED VOLATILES*
Municipal Wastewater (WWTP)	Measure all parameters listed in Table 2-2			
Laundromats with Dry Cleaning Facilities	X	X	X	X
Private Domestic Sewage Discharges	X	X	X	
Industry Sanitary Effluent	X	X	X	

* Trichloroethylene and tetrachloroethylene

CONCLUSIONS AND RECOMMENDATIONS

The monitoring parameters established in Section 5 are the first step toward the FPAO's objective of identifying persistent, toxic chemicals in effluents of the Fraser Basin. The Guideline Document (Volume II) which accompanies this Development Document provides the specific field and laboratory protocols for carrying out the wastewater characterization program.

To complete the characterization of Fraser Basin effluents, some development of analytical methods is recommended. Reliable methods are available to measure most of the parameters that are potentially of concern in the basin; however, method performance data for benzidine and 3,3'-dichlorobenzidine are poor. Methods for measuring DDAC and IPBC are new, and although they appear to be reliable, the performance data are very limited.

Some research effort should be directed toward techniques for measuring benzidines. These substances appear on the PSL of CEPA. They are also identified as priority pollutants for effluent monitoring in Ontario, although this program gives them secondary status (OMOE 1987a). However, benzidines are not expected to be major pollutants in the Fraser Basin, and research into method development is considered low priority.

It appears that DDAC and IPBC will be the major anti-sapstain chemicals used in the Fraser Basin in the foreseeable future. Therefore, acquisition of method performance data should be given high priority. Analytical techniques and/or laboratory capabilities should be improved, if warranted by the performance data and actual use of these chemicals.

REFERENCES

Beatty, J. 1983. Fraser River Sewage Treatment Plants Environmental Impact Assessment 1983 Report. British Columbia Ministry of Environment.

Birtwell, I.K., G. Kruzynski, and I.H. Rogers. 1985. Identification of toxic compounds in municipal wastewater from the Iona Island Sewage Treatment Plant, Vancouver, and effects of exposure on juvenile chinook salmon (*Oncorhynchus tshawytscha*): a brief project overview, pp. 756-772 *in* New Directions and Research in Waste Treatment and Residuals Managements, Volume 2. Proceedings of a conference held at the University of British Columbia, Vancouver, British Columbia.

Brown, K.W. and K.C. Donnelly. 1988. An estimation of the risk associated with the organic constituents of hazardous and municipal waste landfill leachates. Hazardous Waste & Hazardous Materials, 5(1):1-30.

Canadian Council of Resource and Environment Ministers [CCREM]. 1987. Canadian Water Quality Guidelines. Inland Waters Directorate, Water Quality Branch, Ottawa, Ontario. With Appendices (1989-92) by Canadian Council of Ministers of Environment [CCME].

Dickson, A.G. and J.P. Riley. 1976. The distribution of short-chain halogenated aliphatic hydrocarbons in some marine organisms. Mar. Pollut. Bull. 7:167-169.

Dwernychuk, L.W. 1990. The Receiving Environment of the Upper Fraser River: A Pilot Environmental Effects Monitoring Program Examining Physical/Chemical/Biological Elements of the System Related to Pulp Mill Effluents 1989. Prepared by Hatfield Consultants Ltd., West Vancouver, British Columbia.

Ekelund, R., A. Bergman, A. Granmo, and M. Berggren. 1990. Bioaccumulation of 4-nonylphenol in marine animals-- a re-evaluation. Environmental Pollut. 64:107-120.

Ekelund, R., A. Granmo, K. Magnusson, and M. Berggren. 1993. Biodegradation of 4-nonylphenol in seawater and sediment. Environmental Pollut. 79:59-61.

Envirochem Services. 1989. Assessment of Metal Finishing Wastes: Consolidated Report. Prepared for British Columbia Ministry of Environment, Lower Mainland Region, Surrey, British Columbia.

Envirochem Special Projects Inc. 1992a. Lower Mainland Region Anti-Sapstain Facilities: Assessment of Operational Practices and Environmental Discharges Study Volume One. Prepared for British Columbia Ministry of Environment, Lands and Parks, Surrey, British Columbia.

Envirochem Special Projects Inc. 1992b. Lower Mainland Region Wood Preservation Facilities: Assessment of Operational Practices and Environmental Discharges Study General Report. Prepared for British Columbia Ministry of Environment, Lands and Parks and Environment Canada, North Vancouver, British Columbia.

Environmental Management Associates and Hydroqual Laboratories. 1993. Chemistry and Toxicity of Three Wastewaters. Prepared for Fraser Pollution Abatement Office, Vancouver, British Columbia.

Environment Canada. 1984. Styrene. Enviro Technical Information for Problem Spills. Technical Services Branch, Environmental Protection Service, Ottawa, Ontario.

Environment Canada and Health and Welfare Canada. 1992a. Chlorobenzene. Canadian Environmental Protection Act, Priority Substances List Assessment Report No. 3, Ottawa.

Environment Canada and Health and Welfare Canada. 1992b. Toluene. Canadian Environmental Protection Act, Priority Substances List Assessment Report No. 4, Ottawa.

Environment Canada and Health and Welfare Canada. 1992c. Methyl *tertiary*-butyl Ether. Canadian Environmental Protection Act, Priority Substances List Assessment Report No. 5, Ottawa.

Ferrario, J.B., G.C. Lawler, I.R. DeLeon, and J.L. Laseter. 1985. Volatile organic pollutants in biota and sediments of Lake Pontchartrain. Bull. Environ. Contam. Toxicol. 34:246-255.

Garrett, C.L. and J.A. Shrimpton. 1988. Chemicals in the Environment Pacific and Yukon Region. V. Chlorophenols. Environment Canada, Conservation and Protection, Pacific and Yukon Region, Vancouver, British Columbia.

Hagan, M.E. 1990. Agricultural Runoff Contamination in the Fraser River Estuary. Fraser River Estuary Management Program, Waste Management Activity Program Discussion Paper, New Westminster, British Columbia.

Hall, K.J. 1985. A review of toxic substances in the Fraser River Estuary. pp. 1-46 *in* Environment Canada, Pacific and Yukon Region, Regional Toxic Chemicals Committee, Ed. Toxic Chemicals Research Needs in the Lower Fraser River. Proceedings of a Workshop held at the University of British Columbia, Vancouver, June 19, 1985.

Hall, K.J., V. K. Gujral, P. Parkinson, and T. Ma. 1986, pp. 202-217 *in* G.H. Geen and K.L. Woodward, eds., Selected Organic Contaminants in Fish and Sediments from the Fraser River Estuary. Can. Tech. Rep. Fish. Aquat. Sci. No. 1480.

Hall, K.J., H. Schreier, and S.J. Brown. 1991. Water quality in the Fraser River Basin, pp. 41-76 *in* A. H.J. Dorcey and J.R. Griggs, eds. Water in Sustainable Development. Westwater Research Centre, University of British Columbia, Vancouver, B.C.

Howard, P.H. 1989-90. Handbook of Environmental Fate and Exposure Data for Organic Chemicals, 2 Vol. Lewis Publishers, Cheleas, Michigan.

Krahn, P.K. and J.A. Shrimpton. 1988. Stormwater related chlorophenol releases from seven wood protection facilities in British Columbia. Water Poll. Research J. Canada 23:46-54.

Maguire, R.J., R.J. Tkacz, Y.K. Chau, G.A. Bengert, and P.T.S. Wong. 1985. Occurrence of Organotin Compounds in Water and Sediment in Canada. CCIW Contribution No. 85-78, Canada Centre for Inland Waters, Burlington, Ontario.

Mah, F.T.S., D.D. MacDonald, S.W. Sheehan, T.M. Tuominen, and D. Valiela. 1989. Dioxins and Furans in Sediment and Fish from the Vicinity of Ten Inland Pulp Mills in British Columbia. Environment Canada, Inland Waters, Pacific and Yukon Region, Vancouver, British Columbia.

McLeay, D.J., A.B. McKague, and C.C. Walton. 1986. Aquatic Toxicity of Pulp and Paper Mill Effluent: A Review. Prepared for Environment Canada, Fisheries and Oceans Canada, Canadian Pulp and Paper Association, and Ontario Ministry of Environment by D.J. McLeay and Associates, Vancouver, British Columbia.

Ministry of Environment [MOE]. 1990. Metalex Receiving Environment Survey 1989. Waste Management Program, Lower Mainland Region, Surrey, British Columbia.

Moore, J.W. and S. Ramamoorthy. 1984. Organic Chemicals in Natural Waters. Springer-Verlag, New York.

Nimi, A.J. Undated. Biological half-lives of Chemicals in Fishes. Great Lakes Fisheries Research Branch, Canada Centre for Inland Waters, Burlington, Ontario.

Ontario Minsitry of Environment [OMOE], MISA Priority Pollutants Task Force. 1987a. Effluent Monitoring Priority Pollutants List (Draft). Municipal/Industrial Strategy for Abatement, Ontario Ministry of the Environment, Toronto, Ontario.

Ontario Minsitry of Environment [OMOE]. 1987b. Environmental Contaminants in Petroleum Refinery Waste Waters: An Assessment of Current Information and a Monitoring Approach. Municipal/Industrial Strategy for Abatement, Ontario Ministry of the Environment, Toronto, Ontario.

Ontario Minsitry of Environment [OMOE]. 1989. The Development Document for the Draft Effluent Monitoring Regulation for the Organic Chemicals Sector. Municipal/Industrial Strategy for Abatement, Ontario Ministry of the Environment, Toronto, Ontario.

Ontario Minsitry of Environment [OMOE]. 1990. Second Report on the Monitoring Data for the Petroleum Refining Sector. Municipal/Industrial Strategy for Abatement, Ontario Ministry of the Environment, Toronto, Ontario.

Ontario Ministry of Environment [OMOE]. 1991. Preliminary Report on the First Six Months of Process Effluent Monitoring in the MISA Pulp and Paper Sector. Municipal/Industrial Strategy for Abatement, Ontario Ministry of the Environment, Toronto, Ontario.

Pearson, C.R. and G. McConnell. 1975. Chlorinated C_1 and C_2 hydrocarbons in the marine environment. Proc. R. Soc. Lond. B 189:305-332.

Rogers, I.H., I.K. Birtwell, and G.M. Kruzynski. 1986. Organic Extractables in Primary-treated Municipal Wastewater and Uptake in Exposed Juvenile Chinook Salmon. A Preliminary Study at Iona Island Sewage Treatment Plant, Vancouver, B.C. Can. Tech. Rep. Fish. Aquat. Sci. No. 1433.

Rogers, I.H. and K.J. Hall. 1987. Chlorophenols and chlorinated hydrocarbons in starry flounder (*Platichthys stellatus*) and contaminants in estuarine sediments near a large municipal outfall. Water Poll. Res. J. Canada 22:197-210.

Salazar, M.H. and S.M. Salazar. 1991. Mussels as bioindicators: a case study of tributyltin effects in San Diego Bay, pp. 47-69 *in* P. Chapman et al., eds. Proceedings of the Seventeenth Annual Aquatic Toxicity Workshop: November 5-7, 1990, Vancouver, British Columbia.

Schreier, H., S.J. Brown, and K.J. Hall. 1991. The land-water interface in the Fraser River Basin, pp. 77-116 *in* A. H.J. Dorcey and J.R. Griggs, eds. Water in Sustainable Development. Westwater Research Centre, University of British Columbia, Vancouver, B.C.

Singleton, H.J. 1983. Trace Metals and Selected Organic Contaminants in Fraser River Fish. Water Management Branch, B.C. Ministry of Environment, Victoria, British Columbia.

Sittig, M. 1985. Handbook of Toxic and Hazardous Chemicals and Carcinogens. Second Edition. Noyes Publications, Park Ridge, New Jersey.

Standing Committee on the Fraser River Water Quality Plan, 1990. Status Report on Water Quality in the Fraser River Estuary, 1990. Fraser River Estuary Management Program, New Westminster, British Columbia.

Supervisory Coordinating Committee. 1987. Summary Report of the 1986 Effluent Monitoring Program. Fraser River Harbour Commission and British Columbia Ministry of Environment, Surrey, British Columbia.

Swain, L.G. 1993. Fraser River Estuary Sediment Chemistry and Toxicity. Presented at the FREMP Environmental Quality Workshop, New Westminster, British Columbia, February 23, 1993.

Swain, L.G. and G.B. Holms. 1985. Fraser-Delta Area, Fraser River Sub-basin from Hope to Kanaka Creek Water Quality Assessment and Objectives, Technical Appendix. British Columbia Ministry of Environment, Resource Quality Section, Water Management Branch, Victoria, British Columbia.

Swain, L.G. and D.G. Walton. 1988. Fraser River Estuary Monitoring, Report on the 1987 Benthos and Sediment Monitoring Program. Environmental Protection Branch, B.C. Environment, Victoria, British Columbia.

Swain, L.G. and D.G. Walton. 1990a. Report on the 1989 Sediment Monitoring Program. Environmental Protection Branch, B.C. Environment, Victoria, British Columbia.

Swain, L.G. and D.G. Walton. 1990b. Report on the 1989 Boundary Bay Monitoring Program. Environmental Protection Branch, B.C. Environment, Victoria, British Columbia.

Swain, L.G. and D.G. Walton. 1992. Report on the 1991 Effluent Discharge Monitoring Program. Fraser River Estuary Monitoring, New Westminster, British Columbia.

Taylor, B.R., K.L Yeager, S.G. Abernethy, and G.F. Westlake. 1988. Scientific Criteria Document for Development of Provincial Water Quality Objectives and Guidelines. Resin Acids. Ontario Ministry of Environment, Water Resources Branch, Willowdale, Ontario.

Tuominen, T.M. and M.A. Sekela. 1992. Dioxins and Furans in Sediment and Fish from the Vicinity of Four Inland Pulp and/or Paper Mills and One Petroleum Refinery in British Columbia. Environment Canada, Environmental Conservation, Pacific and Yukon Region, Vancouver, British Columbia.

U. S. Environmental Protection Agency [U.S. EPA]. 1983. Treatability Manual, Volume I. Treatability Data. Office of Research and Development, Washington, D.C.

U. S. Environmental Protection Agency [U.S. EPA]. 1986. Quality Criteria for Water 1986. Office of Water Regulations and Standards, Washington, D.C.

Vittozzi, L. and G. De Angelis. 1991. A critical review of comparative acute toxicity data on freshwater fish. Aquatic Toxicol. 19:167-204.

Westwater Research Centre. 1993. Users Manual. Fraser Point Source Inventory of Pollutants. Prepared for Fraser Pollution Abatement Office, North Vancouver, British Columbia.

Appendix I

Individual Parameters Included in Analytical Group Parameters

APPENDIX

INDIVIDUAL PARAMETERS INCLUDED IN ANALYTICAL GROUPS

Analytical Test Group	**Parameter**
Cyanide	Strong Acid Dissociable Cyanide Weak Acid Dissociable Cyanide
Metals, Total or Dissolved	Aluminum Beryllium Boron Cadmium Chromium Cobalt Copper Iron Lead Molybdenum Nickel Silver Strontium Thallium Tin Vanadium Zinc
Chlorophenols	Chlorophenol, penta- Chlorophenol, (2,3,4,6+2,3,5,6) Chlorophenol, 2,3,4,5-tetra- Chlorophenol, 2,3,4-tri- Chlorophenol, 2,3,5-tri- Chlorophenol, 2,3,6-tri- Chlorophenol, 2,4,5-tri- Chlorophenol, 2,4,6-tri- Chlorophenol, 2,4-di- Chlorophenol, 2,6-di-
Chloroguaiacols	Chloroguaiacol, tetra- Chloroguaiacol, 3,4,5-tri- Chloroguaiacol, 3,4,6-tri- Chloroguaiacol, 4,5,6-tri- Chloroguaiacol, 4,5-di- Chloroguaiacol, 4,6-di- Chloroguaiacol, 5- Chloroguaiacol, 6-
Chlorocatechols	Chlorocatechol, tetra- Chlorocatechol, 3,4,5-tri- Chlorocatechol, 3,4-di- Chlorocatechol, 3,5-di- Chlorocatechol, 4,5-di- Chlorocatechol, 4-

APPENDIX

INDIVIDUAL PARAMETERS INCLUDED IN ANALYTICAL GROUPS

Analytical Test Group	Parameter
Dioxins/Furans:	2,3,7,8-T4CDD
Chlorinated Dibenzo-p-dioxins	1,2,3,7,8-P5CDD
	1,2,3,4,7,8-H6CDD
	1,2,3,6,7,8-H6CDD
	1,2,3,7,8,9-H6CDD
	1,2,3,4,6,7,8-H7CDD
	OCDD
Chlorinated Dibenzofurans	2,3,7,8-T4CDF
	1,2,3,7,8-P5CDF
	2,3,4,7,8-P5CDF
	1,2,3,4,7,8-H6CDF
	1,2,3,6,7,8-H6CDF
	2,3,4,6,7,8-H6CDF
	1,2,3,7,8,9-H6CDF
	1,2,3,4,6,7,8-H7CDF
	1,2,3,4,7,8,9-H7CDF
	OCDF
Polycyclic Aromatic Hydrocarbons	Acenaphthene
(PAHs)	Acenaphthylene
	Anthracene
	Benz(a)anthracene
	Benzo(a)pyrene
	Benzo(b+k)fluoranthene
	Benzo(ghi)perylene
	Chrysene
	Dibenz(ah)anthracene
	Fluoranthene
	Fluorene
	Indeno(123-cd)pyrene
	Naphthalene
	Phenanthrene
	Pyrene
Xylenes	o-xylene
	m-xylene and p-xylene
Resin Acids	Abietic Acid
	Chlorodehydroabietic Acid
	Dehydroabietic Acid
	Isopimaric Acid
	Levopimaric Acid
	Neoabietic Acid
	Sandaracopimaric Acid
	Dichlorodehydroabietic Acid