Fraser River Estuary Study
Water Quality

Toxic Organic Contaminants

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PREFACE

The Fraser River Estuary Study was set up by the Federal and Provincial Governments to develop a management plan for the area.

The area under study is the Fraser River downstream from Kanaka Creek to Roberts Bank and Sturgeon Bank. The Banks are included between Point Grey and the U.S. Border. Boundary Bay and Semiahmoo Bay are also included but Burrard Inlet is not in the study area.

The study examined land use, recreation, habitat and water quality, and reports were issued on each of these subjects.

Since the water quality report was preliminary, a more detailed analysis of the information was undertaken by members of the water quality work group. As a result, eleven background technical reports, of which this report is one, are being published. The background reports are entitled as follows:

- Municipal effluents.
- Industrial effluents.
- Storm water discharges.
- Impact of landfills.
- Acute toxicity of effluents.
- Trace organic constituents in discharges.
- Toxic organic contaminants.
- Water chemistry; 1970-1978.
- Microbial water quality, 1970-1977
- Aquatic biota and sediments.
- Boundary Bay.

Each of the background reports contains conclusions and recommendations based on the technical findings in the report. The recommendations do not necessarily reflect the policy of government agencies funding the work. Copies of these reports will be available at all main branches of the public libraries in the lower mainland.

Five auxiliary reports are also being published in further support of the study. These cover the following subjects:

- Site registry of storm water outfalls.
- Dry weather storm sewer discharges.
- Data report on water quality.
- Survey of fecal coliforms in 1978.
- Survey of dissolved oxygen in 1978.

Copies of these reports will be available from the Ministry of Environment, Parliament Buildings, Victoria, B.C.

To bring this work together the water quality work group has published a summary report. This document summarizes the background reports, analyzes their main findings and presents final recommendations. Some of the recommendations from the background reports may be omitted or modified in the summary report, due to the effect of integrating conclusions on related topics. Copies of the summary report are in public libraries, and extra copies will be available to interested parties from the Ministry of Environment in Victoria.

ABSTRACT

This report is a compilation of available data pertaining to the contamination of the Fraser River and its estuary by toxic organic contaminants. The main objectives were to: document localized areas of high contamination; identify known and potential sources of release to the environment; and make recommendations with regard to the need for further investigation.

Existing data relating to use patterns, sources of release and environmental levels of these compounds in the Fraser River system are confined primarily to PCBs and the organochlorine pesticides. Much of this information was collected in the early 1970's and information on current levels of contamination is limited.

Levels of organochlorine pesticides are generally low and are thought to reflect background concentrations. It is apparent, however, that industrial and sewage treatment plant discharges into the Fraser River system have contributed to localized elevated PCB levels in sediments and biota. Despite recent restrictions on industrial uses of these compounds, certain facilities continue to discharge significant quantities. Limited monitoring within the past two years has also indicated the presence of such compounds as chlorinated phenols, phthalate esters, hexachlorobenzene and polycyclic aromatic hydrocarbons in the effluents and/or receiving environments of certain industrial and sewage treatment facilities.

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CONCLUSIONS

Many industrially important organic compounds have recently been identified by Health and Welfare Canada (HWC) and Environment Canada as priority contaminants requiring further study. With the exception of PCBs, few of these compounds have been investigated to determine the possible sources of release and environmental levels in the Fraser River and its estuary. Data on such compounds as polybrominated biphenyls (PBBs), chlorinated phenols, chlorinated benzenes, mirex, phthalate esters and polycyclic aromatic hydrocarbons (PAHs) are extremely limited while information on local use patterns, sources of contamination and environmental levels of other contaminants, including triaryl phosphates and organotins, is non-existent. Existing data relating to organic contaminant levels in the Fraser River system are confined primarily to PCBs and organochlorine pesticides.

PCBs have been detected in low but measurable quantities in the sediments of almost all industrially active areas of the Fraser River and Estuary downstream from the Port Mann Bridge. Elevated concentrations were detected in localized areas in the vicinity of some industrial operations on the Fraser River and also the Brunette River, which flows into the Fraser. This contamination has been largely attributed to effluent discharges from these facilities and to surface runoff.

Industrial activity has also influenced contaminant levels in biota of the Fraser River and Estuary. PCB tissue concentrations were most elevated in fish from the urban/industrialized lower reaches. A similar trend was identified for chlorinated phenols. Information on organic contaminant levels in fish is limited to data obtained during a 1973 survey; no recent monitoring has been conducted in this area. The available data indicate that, in all species of Fraser River fish, PCBs were present in higher concentrations than were any other organic contaminants. Although mean concentrations did not exceed HWC guidelines for edible tissues (2 ppm), certain coarse species contained significant concentrations. Elevated PCB concentrations have also been detected in biota from the estuary region off Sturgeon and Roberts Banks.

In contrast, organochlorine pesticide levels are low in sediments and biota from the Fraser River and are thought to reflect general background concentrations resulting primarily from the pre-1970 application of pesticides in the area. Although data on organochlorine pesticides in Fraser River sediments are very limited, these compounds do not appear to be present in measurable amounts. Sediments from the Brunette River system contained detectable concentrations of DDT and its derivatives, and chlordane. However, these organochlorine pesticides were present in much lower concentrations than were PCBs. DDE and HCB were the most commonly detected pesticides in Fraser River fish. While present in most samples, however, mean concentrations of DDE were well below the HWC guideline of 5 ppm. Although HWC guidelines for HCB levels in fish tissue have not been established, mean concentrations in all species from the Fraser River were very low.

Data relating to organic contaminant levels in bird tissues were obtained in, or prior to, 1970 with the exception of 1978 data on heron eggs from the University of British Columbia. Residue levels of both PCBs and the organochlorine pesticides were low except in isolated instances. For example, the heron eggs from U.B.C. and shorebirds collected near the Vancouver Airport contained surprisingly elevated concentrations of PCB.

Limited monitoring of industrial and municipal discharges in B.C. indicate that certain facilities release significant amounts of organic contaminants to the receiving waters of the Fraser River. Elevated concentrations of PCBs have been detected in the effluent discharges and sediments at the Belkin Paperboard Ltd. paper recycling plant. This contamination has been attributed to the discharge of large quantities of sludge containing high levels of PCB. Low levels of PCB were also present in the final settling pond effluent at the Roberts Bank Coal Superport. Sampling of selected industrial effluents for phenols indicated that pentachlorophenol and 2,3,4,6-tetrachlorophenol were present most frequently, although other phenolic compounds were detected in the wastes of some facilities. The highest concentrations were detected in drainage ditch runoff from Coast Laminated Timber, a wood laminating plant, and Later Chemicals Ltd., a pesticide formulating company which was, until recently, located on Sea Island. Penta- and tetrachlorophenol have been

detected in the sediments, water and biota near certain wood product plants on the Fraser River and also off Later Chemicals.

Extremely high concentrations of several organochlorine pesticides have also been detected in the soils, sediments and drainage water from the old Later Chemicals yard and this contamination has been attributed to poor "housekeeping practices". This site may be a significant source of contamination to the Fraser River through surface runoff and action is currently being taken to curb environmental releases.

Waste disposal systems, such as sewage treatment plants, landfills, incinerators and sewers, are probably an important route of organic contaminant entry into the environment. A major contributing factor to this problem is the current lack of regulations governing the use and disposal of most of these compounds. In a recent survey, a total of 57 trace organic compounds were detected in the effluents of the Annacis Island, Iona Island and Lulu Island sewage treatment plants. Among other compounds, these plants discharge low but measurable amounts of PCBs, HCB, chlorinated phenols and phthalate esters. PCBs were detected most frequently and at the highest concentrations.

There are indications that the Iona Island sewage treatment plant may also contribute benzo(a)pyrene and possibly other PAHs to the tidal flats area of the Fraser estuary. Benzo(a)pyrene concentrations in sediment samples collected in the vicinity of the plant increased with proximity to the outfall. Other PAHs have been detected in clams from Sturgeon and Roberts Banks and it is likely that atmospheric fallout from oil-fired burners and home heating units in the Greater Vancouver area contributes to the PAH loading in this region. It is not known whether PAHs enter the estuary region in either runoff or dustfall from the Roberts Bank Coal Superport. However, as these compounds are normally released from coal only during combustion processes, such contributions would probably not be significant.

Phthalate esters have also been detected in the sediments and biota from the vicinity of the Iona Island facility.

The chlorination of sewage effluents may be of environmental concern. Several researchers have demonstrated that this practice can result in the formation of certain chlorinated organic compounds and increase the concentration of such compounds already present. Contaminants are present at much higher concentrations in sewage sludges than in liquid effluents. Current methods of sludge disposal, including incineration, landfilling and agricultural applications, may result in the release of certain organic contaminants (and metals) into the environment. Due to the potential for uptake into certain species of vegetation, the use of heavily contaminated sludges on crops intended for human consumption requires further investigation.

Sampling of sanitary and storm sewers and street surface sediments in the Greater Vancouver area indicate that sewer systems and street surface runoff also contribute measurable amounts of PCBs and other organic contaminants to the Fraser River system.

Although the low solubility of many organic contaminants impedes their transport in groundwater and landfill leachates, it is likely that land disposal sites contribute measurable amounts of certain organic contaminants to the environment. The large volume of consumer products and other domestic and industrial wastes disposed of in these facilities contain a variety of persistent chemicals. PCBs and chlorinated phenols have been detected in leachate from local landfills. No information on landfill releases of the widely used plasticizing compounds was available; however, the fact that researchers from other areas have reported the presence of phthalate esters in groundwaters near landfills indicates the need for such monitoring.

Although little information is available on current levels of contaminants in the Fraser River Estuary region, data collected in the early 1970's indicate the early stages of a developing problem. Unless more positive controls are introduced in the near future, the estuarine ecosystem will undoubtedly become more seriously contaminated. It is important that early preventative measures be taken to ensure that residue levels in the food chain do not increase to a magnitude capable of causing irreversible damage to the ecosystem.

RECOMMENDATIONS

1. With the recent identification of priority contaminants by Health and Welfare Canada and Environment Canada, more information on environmental levels of these substances will be required. It is essential, however, that preliminary groundwork be done and background information obtained prior to the initiation of sampling programs. It is strongly recommended that additional information and expertise be obtained in the following areas:
   a) Use Patterns - attempts should be made to establish regional use patterns for these contaminants and to identify existing and potential sources of release into the environment.
   b) Analytical Techniques - greater analytical capabilities must be developed to ensure the reliable identification and quantification of trace organic compounds. Currently, severe limitations are placed on attempts at screening environmental samples due to the problems associated with the identification and quantification of these compounds in the low ppb and ppt range. In the past, too little attention has been paid to the analysis of blank and spiked samples to demonstrate quality control. Intercalibration between regional laboratories is also necessary to ensure the consistency and reliability of analytical results.
   c) Environmental Dynamics and Toxicity - the biological effects and ultimate fate of many of these compounds when released into the environment have been virtually unexplored. More information relating to their bioaccumulation potential, toxicity to aquatic biota, and persistence in the environment is required in order to determine whether their release to the environment constitutes a significant concern.

2. Industries and other facilities which have been identified or are suspected to be potential sources of contamination should be monitored to determine the amount and source of contaminants released into the environment. Investigations should focus on operations using these compounds in manufacturing or formulating processes, as well as

waste disposal facilities. Local receiving environments at these sites should also be monitored to assess impacts on the environment. For example:

a) although it is likely that the major source of PAHs to the Fraser River estuary region is through atmospheric fallout, further sampling should be conducted in the Fraser River estuary region in order to evaluate the relative input of PAHs from the Iona Island sewage treatment plant and the possibility of release in dustfall and runoff from the Roberts Bank Coal Superport, and to assess the significance of existing contamination.

b) the receiving environment around wood treatment plants utilizing creosote should be examined due to evidence of PAH accumulation in biota collected near creosote-treated pilings.

c) effluent releases from plastic formulators and landfill leachate should be sampled to determine the magnitude of release of organic compounds such as plasticizing agents including; organotins, triaryl phosphates and the extensively used phthalate esters.

3. PCB discharges to the Fraser River/Estuary must be reduced, particularly at the Belkin Paperboard Ltd. paper recycling plant, which is the major industrial source identified to date. The release of PCBs from Belkin plant should be terminated or greatly reduced due to evidence of substantial contamination in offshore bottom sediments. At some facilities, such as Belkin, significant reductions in the discharge of contaminants may be achieved by additional sludge removal through more effective effluent clarification.

In addition, measures must be taken to ensure that industries utilizing or handling electrical equipment containing PCBs employ adequate measures to prevent the escape of PCBs to the environment during routine maintenance or as a result of equipment malfunctions. This could be accomplished through industry education programs and plant inspections. Guidelines for the proper disposal of PCB contaminated materials should be strictly enforced.

4. Wood products industries utilizing chlorinated phenols for wood preservation should be inspected to determine the sources and magnitude of penta- and tetrachlorophenol releases. Better "housekeeping practices" at these facilities should be established to reduce losses to the environment.

5. It is necessary to further evaluate the effect of sewage waste chlorination with respect to the possible formation of chlorinated organic contaminants. The relative contribution of chlorinated versus non-chlorinated sewage treatment plant discharges to contaminant concentrations in local receiving environments should be assessed. More information on the effects of de-chlorination is also required.

6. Due to the high concentrations of contaminants in sewage sludges, current methods of sludge disposal should be reviewed and the potential for the release of contaminants to the environment should be assessed. The use of contaminated sludges as fertilizers for food crops should also be investigated due to possible health effects.

7. The effluent control system should specify certain allowable limits on the discharge of known contaminants as the most positive control must be achieved at the source. Although many discharges are routed through local sewage treatment plants, these facilities do not provide adequate contaminant control. Present pollution control standards ignore the discharge of most organic contaminants into the Fraser River/Estuary.

8. Monitoring of Fraser River fish species, similar to that conducted by the Westwater Research Centre in 1973, should be repeated in order to identify any changes in organochlorine pesticide, PCB and chlorinated phenol levels since that time, and to obtain data on environmental levels of contaminants for which no information is currently available.

9. Annual piecemeal sampling programs conducted by various agencies have contributed little to the understanding of trends in local levels of contamination. A comprehensive environmental survey should be conducted once every five years and should focus on contaminant levels in fish, shellfish and bottom sediments. Less emphasis should be placed on water column monitoring.

10. Due to the ever-increasing problems associated with long term storage or transport of contaminated materials across provincial and international borders, possible sites for the construction of a suitable disposal facility within the province should be investigated.

1 INTRODUCTION

1.1 Scope and Objectives

This document has been prepared as part of the joint federal-provincial Fraser River Estuary Water Quality Report series. The primary objective of this report series is to assess the current status of environmental quality in the receiving waters of the Fraser River and estuary region. These studies will provide background information for policy development and program planning which may affect future development and resource utilization in this area.

The lower reaches of the Fraser River and the estuary region receive industrial and sewage discharges and urban and agricultural runoff from the Vancouver area and outlying districts. The potential for contamination of the receiving environment from these sources is significant. Although very little information exists regarding inputs of contaminants to the system, several potential sources of release exist due to the extensive urbanization in some regions.

This report will be concerned exclusively with the sources and levels of organic contaminants in the Fraser River receiving environment. Data relating to trace metal contamination has been compiled and discussed in a separate report (1). All available information on levels of organic contaminants in the Fraser River estuary as of January 1st, 1980 has been compiled herein in order to determine levels of contamination, identify sources of input, and assess the potential for environmental impacts.

1.2 Organic Contaminants; Their Uses and Sources of Environmental Contamination

The potential for contamination of aquatic systems has increased significantly in recent decades. Extensive urbanization and industrial development has led to the ever-increasing utilization of receiving waters for the disposal of sewage and industrial wastes. Similarly, the development and widespread use of synthetic pesticides such as the organochlorines, organophosphates and carbamates following the Second World War have resulted in increased environmental loadings of such agricultural compounds.

Many of the compounds entering water systems do not constitute an environmental concern as they are relatively non-toxic or are rapidly degraded by natural mechanisms. However, many man-made organic compounds are not readily broken down in the environment, including industrial chemicals and biocides which exhibit both high toxicity and extreme stability, and are highly dispersible. These compounds are collectively known as the organic contaminants and their release to the environment is of great concern.

Upon entering the receiving environment, contaminants may escape to the atmosphere through volatilization or they may undergo degradation due to photochemical, chemical and/or biological reactions. As a result, the parent compound may be altered to compounds of less, or in some cases, greater environmental concern. The stability and environmental persistence of these contaminants vary significantly from a few hours to several decades and are influenced largely by their chemical structure. Chlorinated hydrocarbons are particularly long-lasting and their stability and toxicity usually increase with relative chlorination (2,3,4).

The receiving environments and/or effluents of certain industrial and municipal facilities along the Fraser River have been monitored for a variety of organic contaminants and the data are discussed in subsequent sections. The locations of these facilities are shown in Figure 1.

1.2.1 Pesticides. The class of substances which has received the most attention with respect to environmental impact and persistence, is the organochlorine pesticides group. These compounds have been used widely in post-war years and many, especially DDT and its metabolite DDE, have been implicated in reproductive failures, declines in animal populations, and other adverse biological effects in numerous aquatic and terrestrial organisms. The organochlorine pesticides exhibit a very low solubility in water, but are highly lipophilic and hence readily accumulate in body tissues. They are not easily metabolized and the biological half-life of many of these compounds is long (5,6,7,8). Consequently, they are magnified through the food chain and predators in the upper trophic levels are sometimes exposed to excessive levels of contamination. The majority

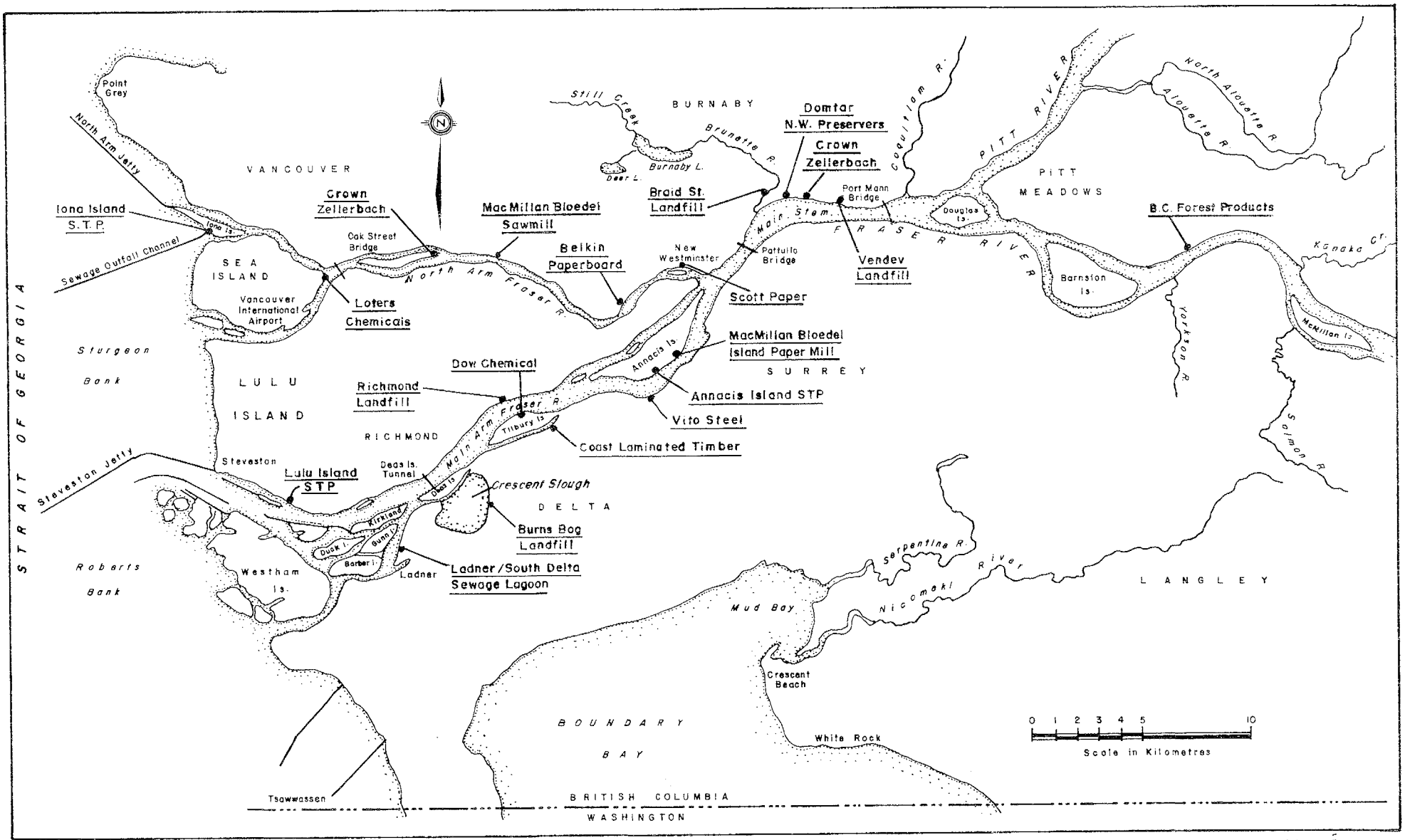

FIGURE 1 THE LOCATIONS OF INDUSTRIAL FACILITIES WHOSE EFFLUENTS / RECEIVING ENVIRONMENTS HAVE BEEN SAMPLED FOR ORGANIC CONTAMINANTS

of these compounds were banned for general use in Canada in the early 1970s and their presence in environmental samples collected since that time can be attributed mainly to historical applications.

The more water soluble carbamate and organophosphate pesticides are more rapidly metabolized and excreted and do not normally biomagnify through the food chain. Although many of these compounds have shown high acute toxicity, they are less persistent in the environment than are the organochlorines and rarely accumulate to environmentally unacceptable concentrations when applied correctly. For this reason the environmental impact of the carbamates and organophosphates tends to be more immediate and relatively short-lived in comparison to some of the more persistent organochlorines which may present a threat to the environment for many years after their release (9).

1.2.2 Industrial Contaminants. Industrial progress has resulted in the development and utilization of a wide variety of new industrial chemicals whose long-range environmental impact has not been studied in depth. The similarity in chemical structure of many of these compounds to some of the more well- known persistent and/or toxic biocides, implies the potential for adverse environmental impact and dictates the need for obtaining further information on their environmental persistence, toxicity and bioaccumulative tendencies.

Environment Canada and Health & Welfare Canada (HWC) have compiled a list of "priority" inorganic and organic chemicals for which more information is necessary and whose releases to the environment are thought to warrant concern. Included in this list are such organic contaminants as polychlorinated biphenyls (PCBs), polybrominated biphenyls (PBBs), polychlorinated terphenyls (PCTs), chlorinated benzenes, chlorinated phenols, phthalate esters, triaryl phosphates, organotins, and the polycyclic aromatic hydrocarbons (PAHs) (10).

PCBs are widely recognized as one of the most ubiquitous and environmentally persistent substances currently in use. Elevated concentrations of PCBs have been detected in aquatic systems throughout the world. These compounds have been used extensively in such products as dielectric, heat transfer, and hydraulic fluids; paints; plastics; printers' ink; carbonless copy paper; synthetic rubber; and brake linings (11). Many uses of PCBs were terminated in North America in the early

1970s and Environment Canada recently developed legislation under the Environmental Contaminants Act to provide further restrictions on their use, manufacture and importation. PBBs and PCTs closely resemble PCBs in chemical structure and pose similar threats to the environment. PBBs are widely used as flame retardants (12) while PCTs are used as plasticizers, flame retardants, and adhesives (13). The use, manufacture and importation of PBBs and PCTs has recently been banned in Canada.

Various chlorinated benzenes, including the lower chlorinated forms, have been detected in the environment and in industrial discharges, but in most instances, only the more persistent hexachlorobenzene (HCB) has been found in high concentrations. HCB was used as an agricultural compound due to its fungicidal properties until restrictions were placed on such uses in 1971. It also occurs as a contaminant in certain other pesticides. At this time no pest control products registered for use in Canada contain HCB as an active ingredient. Current applications of HCB include the production of nitroso- and styrene rubbers for tires and porosity control in graphite anodes. HCB may also be released to the environment when formed as a by-product during the production of chlorinated solvents and from electrolytic chlorine production facilities when the process involves the utilization of graphite anodes (14).

Chlorinated phenols are used as wood preservatives, slimicides in paper production, germicides, mildewcides, insecticides, and herbicides. Within this group of compounds, the most environmentally persistent form is pentachlorophenol (PCP). Chlorinated phenols are of particular concern due to their high toxicities and because some formulations have been found to contain significant levels of toxic impurities such as dioxins and dibenzofurans (15). Approximately 1000 tons of chlorinated phenols are used annually in B.C. for wood protection and preservation (16)[1].

National use patterns are currently being developed for phthalate esters, organotins and triaryl phosphates. While detailed information on applications and sources in this region are not yet available, the major uses of these compounds have been identified. Phthalate esters are used in very large quanitities as commercial plasticizers and the ultimate disposal

1. This figure was extrapolated from U.S. use patterns and 1974 B.C. wood preservation industry production rates.

of products containing these compounds makes their release into the environment inevitable. A large number of phthalate esters are manufactured but only a few of these appear to be of significant environmental concern. These include: diethylphthalate (DEP), dibutylphthalate (DBP), butyloctylphthalate (BOP), butylisohexylphthalate (BIHP), di-2-ethylhexylphthalate (DEHP), diisooctylphthalate (DIOP) and diisononylphthalate. These compounds have been detected in environmental samples and have been demonstrated to exert toxic effects on some organisms, although they are more readily degraded in the environment than are the more persistent organochlorine compounds (17). Organotins are used in the preservation of paper, wood, textiles and leather, in antifouling paints, electroplating, and as plasticizers. Triaryl phosphates are used as hydraulic fluids, synthetic lubricants, heat exchange media, fire retardants, and as additives in plastics, paints, rubber, and oil. Information on the potential environmental impacts of these three groups of compounds is very limited.

Polycyclic aromatic hydrocarbons are also considered to be important environmental contaminants. PAHs are not normally used in industrial processes and enter the environment primarily through the combustion of fossil fuels. Petroleum refineries and coking operations are thought to be major sources of release (18, 19). These compounds accumulate in the tissues of aquatic and terrestrial organisms and, although information on toxicity to fish and aquatic invertebrates is limited, there are indications that they are toxic at low concentrations (20, 21, 22). Some PAH compounds, particularly benzo(a)pyrene, have been shown to be carcinogenic in mammals (23, 24).

1.3 Toxicity and Biological Effects

1.3.1 Fish and Aquatic Invertebrates. While many of the compounds used in both agricultural and industrial applications display a relatively high acute toxicity to certain species, it is the long term or chronic effects which are normally of the greatest concern. In the natural environment, acute toxic effects are more easily identified than are long-term effects

as they may be manifested in the form of fish kills following such events as pesticide misuse or the accidental release of industrial chemicals. Chronic effects may interfere with such critical functions as reproduction, respiration, osmoregulation, behaviour, feeding, and general physiology. However, as disturbances occur gradually over a long period of time, in many instances, these effects may go unnoticed initially and become apparent in later years through diminishing population sizes.

Acute toxicities of several of the more common organochlorine pesticides and industrial compounds to various species of fish and aquatic invertebrates, as determined by 96 hr LC_{50} and longer term toxicity tests, have been listed in Appendix 1;A. Many compounds exert delayed toxic effects on aquatic biota and bioassays performed over several weeks or months indicate that the shorter term acute toxicity tests may underestimate the lethal concentrations of some contaminants (25).

There is considerable interspecific variation in the toxicity of these compounds to aquatic organisms. Several factors including rate and method of uptake, propensity for accumulation in specific body organs, distribution and persistence in the tissues, and metabolic and excretory processes account for this variation. Toxic actions within a species may be affected by age, size, lipid content, sex, nutrition and overall health of the organisms (26) as well as the length and level of exposure. For instance, in most species, larval and juvenile stages of development are more sensitive to the effects of environmental contaminants than are adult organisms (27).

While levels of persistent toxicants in most environments rarely reach acutely lethal concentrations, chronic exposure to sublethal levels may result in adverse effects on localized aquatic ecosystems. DDT and other chlorinated hydrocarbons, including PCBs, have been shown to cause reproductive impairment in the form of reduced ova production (28) and decreased hatchability of eggs and survival of alevins (29, 30). Other toxic effects, which have been demonstrated at ambient water concentrations in the ppb range, include decreased growth rates (29), disorientation and behavioural disturbances (31), increased susceptibility to disease (32), decreased ability to cope with environmental stresses and impaired osmoregulatory functions (33). Some aquatic invertebrates exhibit even

greater sensitivities to these compounds. Water concentrations of 0.1 ppb aldrin inhibited shell deposition in oyster by 11% while at higher concentrations oyster and clam egg development and larval survival was reduced (34). Shell deposition of oysters was also inhibited by exposure to concentrations equal or greater than 4.0 ppb heptachlor for 96 hours, and similar observations have been made with respect to chlordane, aldrin (35) and PCBs (36). Sublethal concentrations of various organic chemicals and their effects on aquatic organisms are listed in Appendix 1;B.

Toxic actions of environmental contaminants are often enhanced by suboptimal environmental conditions including increases in temperature and salinity. Silbergeld (37) has suggested that the decreased ability of fish to adapt to thermal stress following exposure to dieldrin indicates that the organisms' ability to acclimate to external changes has been affected. These facts combined with the demonstrated ability of many compounds to disrupt osmoregulative processes, suggest that sublethal exposure of aquatic organisms in estuarine habitats may be especially stressful as tidal action and freshwater infiltration cause repeated and sudden changes in salinity and temperature. The presence of other environmental contaminants in ambient waters can also increase the toxicity of various organochlorine compounds through possible synergistic effects. It has been shown that the toxicity of DDT may be increased in the presence of both PCB and dieldrin (38).

Water quality criteria objectives for the protection of aquatic life have been prepared by the United States Environmental Protection Agency (39). The objectives pertaining to organic contaminants have been listed in Table 1.

1.3.2 Birds. Since the 1950's, reproductive failures and population declines in avian populations in Europe and North America have been attributed to rising levels of organic contaminants in the environment. While these effects have been linked primarily to DDE and other DDT analogues; the cyclodienes, some organophosphate pesticides, and PCBs are also suspect.

TABLE 1 EPA WATER QUALITY OBJECTIVES FOR ORGANIC CONTAMINANTS (39)

Compound	For the protection of: Freshwater Species (ppb)	Marine Species (ppb)
Aldrin/Dieldrin	0.003	0.003
Chlordane	0.01	0.004
DDT	0.001	0.001
Endosulfan	0.003	0.001
Endrin	0.004	0.004
Heptachlor	0.001	0.001
Lindane	0.01	0.004
Methoxychlor	0.03	0.03
Mirex	0.001	0.001
Toxaphene	0.005	0.005
Phthalate esters	3	No objective as yet
PCBs	0.001	0.001

In the natural environment predatory birds such as raptors and fish-eating species are the most commonly affected due to their higher level in the food chain and consequent greater incidence of exposure (40). However, adverse effects have been induced experimentally in a wide range of species.

Reproductive failures are normally characterized by decreased hatchability of eggs, eggshell thinning and breakage, smaller clutch size, decreased survival of hatchlings (41, 42, 43, 44) and behavioural abnormalities in nesting adults (45). Jeffries (46) reported that p,p'-DDT, and possibly other organochlorine compounds, exert an inhibitory effect on the gonads of finches and so delay ovulation.

Reproductive impairment has been noted in avian species from the highly contaminated Great Lakes region. The productivity of Lake Ontario Herring gulls is markedly lower than that of colonies from nearby less contaminated areas. Mean total DDT and PCB levels of Herring gull eggs from Lake Ontario were 22.3 and 134.3 ppm wet weight, respectively. Morphological abnormalities in embryos from Lake Ontario colonies have also been reported (46). Similarly, deformities such as loss of flight feathers, stunted extremities, twisted mandibles and additional appendages discovered among tern colonies on Great Gull Island in Long Island Sound were attributed to a high level of PCB contamination (47).

Incidence of eggshell thinning has been correlated with contamination by some cyclodienes (48, 49) and especially DDT and its metabolites (41, 42, 43). While there is substantial evidence that PCBs impair reproductive processes, these compounds have not been as convincingly linked to eggshell thinning as have the organochlorine pesticides.

Di-n-butylphthalate (DNBP), a widely used plasticizer has also been demonstrated to cause eggshell thinning in Ring doves. In contrast di-2-ethylhexylphthalate had no significant effect. Phthalate esters are more readily metabolized than are the organochlorine compounds and Peakall (50) noted that the recovery of Ring Doves following ingestion of DNBP was relatively rapid. It was concluded that DNBP would contribute to eggshell thinning in wild bird populations only if continually available in the food source.

Faber and Hickey (42) report that 9 of 13 species of fish-eating birds from the Upper Great Lakes displayed eggshell thinning and that incidence and degree of thinning was positively correlated with chlorinated hydrocarbon concentrations. DDE was thought to be the major contributing factor among most species, however, dieldrin and PCB levels were assumed to be important factors in some species. Mean concentrations of DDE, dieldrin and PCBs in eggs from Great Lakes area birds were 339.5, 339.7 and 5.5 ppm lipid weight, respectively. Samples commonly contain elevated concentrations of more than one organochlorine and, therefore, it is often difficult to attribute eggshell thinning to any one compound.

2 RESULTS AND DISCUSSION

2.1 Levels in the Environment

2.1.1 Water. Environmental contamination by industrial chemicals such as PCBs, PBBs, PCTs, chlorinated phenols and chlorinated benzenes originates from the manufacture, use and degradation of products containing these compounds. They enter aquatic systems by a variety of modes including industrial and municipal discharges, urban runoff and atmospheric deposition. Contamination by pesticides may occur via these routes and also through surface run-off from agricultural areas and as a result of application to water systems. Upon entering aquatic systems these compounds can be dispersed by diffusion, tidal action, water currents, sediment redistribution and by aquatic organisms.

The solubility of pesticides and other contaminants in water varies significantly (Table 2). Solubility is an important consideration in determining the potential impacts of a chemical on the environment. Highly soluble compounds enter water systems in both industrial and municipal discharges and through surface runoff and drainage systems and are more likely to permeate surface soils and contaminate groundwater than are the more insoluble substances. Additionally, compounds dissolved in the water column are readily available for uptake and concentration by aquatic biota. Soluble compounds are more easily dispersed in aquatic systems, however, and are normally less persistent in the environment than are insoluble forms (8).

Many of the chlorinated hydrocarbon compounds are examples of highly persistent environmental contaminants, having very low solubilities in water. These compounds are rapidly bound to suspended organic matter in the water column and are ultimately deposited in the bottom sediments. Consequently, only very small amounts remain in solution for any length of time. Analyses of water samples for various organic contaminants typically reveal that very low concentrations are present in solution, with the bulk of the compounds being associated with particulate matter. Even in known areas of high contamination, surface water concentrations may be below or near the limits of detection. Except in unusual circumstances, such as a chemical spill or immediately following a pesticide application,

TABLE 2 SOLUBILITY OF PESTICIDES IN WATER (ppm)(8)

Chlorinated Hydrocarbons	
DDT	0.0012
Aldrin	0.01
Heptachlor	0.056
Methoxychlor	0.10
Dieldrin	0.18
Endrin	0.23
Toxaphene	0.40
Lindane	7.0
Organophosphates	
Parathion	24
Disulfoton	25
Azinphosmethyl	30
Diazinon	40
Phorate	50
Chlorfenvinphos	145
Malathion	145
Demeton methyl	330
Thionazin	1140
Dimethoate	2500

levels of organic contaminants in surface waters are normally in the parts per trillion (ppt) to parts per billion (ppb) range. Concentrations of DDE in streams from southern Ontario for instance, ranged from 0.003 ppb to 0.019 ppb, while PCBs were less than 1 ppb in all samples. Despite the relatively high input of organophosphates to the watershed, only diazinon was detected in measurable quantities (6). Other researchers report that the mean DDT concentration in Lake Erie over a period of six months was 0.005 ppb (7).

Chlorinated hydrocarbons are more soluble in oil than in water and may, therefore, accumulate to higher concentrations in the thin oil layer which is sometimes found at the air/water interface (51).

In 1973, a Westwater Research Centre study (52) demonstrated that levels of many organic contaminants in surface waters of the Fraser River were below the limits of detection. Samples were analyzed for the following compounds: PCBs, DDT and its metabolites, chlordane, heptachlor and its epoxide, aldrin, dieldrin, endrin, methoxychlor, and endosulphan. Subsequent sampling for these parameters by the Inland Waters Directorate (IWD) of Environment Canada in 1974 also indicated that concentrations in the Fraser River were below detection limits. Similarly, 2,4-D, 2,4,5-T, 2,4-DB, Silvex, and phenolic compounds were not detected in surface water samples collected by IWD in 1978 (53).

In 1979, chlorinated phenols were detected in water samples taken from the Fraser River near Later Chemicals Ltd. and three lumber mills using pentachlorophenol (PCP) as a wood preservative (54). Tetrachlorophenol (TCP) was present in higher concentrations than PCP probably due to its presence in commercial PCP formulations and its greater solubility in water. Low levels of pentachloroanisole, a degradation product of PCP, were also detected. However, chlorinated benzenes, which are often found as contaminants in PCP preparations (depending on the production method), were not detected in any samples (Appendix 2.3).

Surveys measuring contaminant levels in surface waters exclusively are inconclusive in determining environmental levels of contaminants due to the low solubility of many contaminants and the

variability of detected concentrations. For example, surface water concentrations fluctuate depending on such factors as precipitation, wind velocity, water turbidity and local precipitation. Quantification attempts may be further complicated by the analytical problems associated with accurately determining low concentrations of contaminants which may be strongly adsorbed to suspended solids.

It has been demonstrated that chemicals emitted or volatilized into the atmosphere can be transported over long distances by wind currents and ultimately contribute to contaminant loading in aquatic systems through aerial fallout and precipitation. Aerial transport is thought to account for the presence of chlorinated hydrocarbons in arctic and sub-arctic environments far removed from urbanization (55, 56).

Due to the very high temperatures required for total destruction of many of the more stable chlorinated hydrocarbons (in excess of 1000°C for PCBs), municipal incinerators and other relatively low temperature combustion processes may volatilize and release these compounds to the atmosphere. Atmospheric sampling conducted in Eastern Canada in 1974 and 1975 revealed much higher PCB concentrations in the atmosphere downwind from a municipal incinerator than in a research community or in a heavily industrialized area (57).

Rainwater samples collected at the Vancouver International Airport between 1977 and 1979 were analyzed for PCBs and a variety of pesticides (53). PCBs were detected in only one sample at a concentration of 20 ppt. Although the data are too limited to provide a good comparison with other areas, it appears that PCB levels in rainwater from the Vancouver area are lower than in Ontario where rainwater collected in agricultural areas ranged from 10 to 100 ppt (57).

The concentrations of most pesticides in the samples from the Vancouver Airport did not exceed the detection limit of 1 ppt, however, alpha-BHC was detected with regularity at levels of up to 130 ppt. Methoxychlor, p,p'-DDT, p,p'-DDE, alpha- and beta-endosulfan, and lindane were detected in some samples at very low concentrations. Other pesticides including heptachlor, heptachlor epoxide, alpha- and gamma-chlordane, p,p'-TDE, o,p'-DDT, aldrin, endrin, dieldrin, HCB and mirex were not detected (53).

2.1.2 Sediments. Sediments typically contain much higher concentrations of contaminants than do surface waters and may serve as environmental reservoirs for chlorinated hydrocarbons and other persistent chemicals. Contaminants adsorbed to suspended matter in the water column may settle out to the bottom sediments at the site of entry or may be transported to other areas by water currents. Particularly high concentrations of contaminants have been noted in estuarine sediments. Contaminants adhere to fine particulates and are carried downstream and deposited at the mouths of rivers due to the natural forces of sedimentation or to chemical reactions which occur at freshwater/saltwater boundaries.

High organic matter and humic content increase the adsorption tendencies and binding capacities of bottom sediments. The chemical characteristics of compounds, such as degree of polarity, also influence their tendency to bind to the bottom sediments. Adsorption of PCBs on soils of various compositions has been shown to increase with increasing chlorination of the PCB molecule (5).

Contaminants in the bottom sediments may be released to the water column, accumulated by aquatic biota, degraded or altered by micro-organisms, or buried by sedimentation processes. Some researchers have shown that there is a continuous interchange of contaminants between the sediments and overlying waters. For example, Frank et al (58) have shown that both DDT and dieldrin are released to the water from the bottom sediments, although in very small amounts. Resuspension of contaminants into the water column is influenced by water currents and tidal activity, disturbance of the bottom sediments and sediment consistency. Subsequent dissolution will depend on the solubility of the compound, water temperature, salinity, and the concentration of the compound in the surface sediment layer.

While adsorption of contaminants to the bottom sediments decreases the likelihood for direct uptake in some species of aquatic organisms, residue levels in bottom-feeding fish and invertebrates are greatly dependent upon local sediment levels. Young and Heesen (59) report that PCB and DDT levels in mussels and Dover sole from the Southern California Bight remained elevated despite drastic reductions in the release of these chemicals to the receiving waters. The authors concluded

that residue levels in these organisms were dependent upon the local levels of sediment contamination which also remained elevated. Median DDT and PCB levels in sediments were 12.0 ppm and 0.81 ppm, respectively.

Contaminants may be degraded, to some extent, while suspended in the water column but degradation processes occur more rapidly in the sediments due to the greater occurrence of microorganisms. Some compounds are readily broken down while others, like PCBs and some of the more persistent organochlorine pesticides, can remain in the environment for many years. Some of these substances may be partially degraded or altered to form stable compounds which are of even greater concern environmentally than are the parent compounds. For instance, DDT is degraded to the toxic DDE in the natural environment while aldrin and heptachlor are readily converted to their epoxides, dieldrin and heptachlor epoxide. Degradation products may vary with physical characteristics of the receiving environment. Researchers have shown that DDE is the main degradation product of DDT under aerobic conditions while DDD is favoured in anaerobic environments (58, 60).

Brunette River/Still Creek Drainage System

Hall et al (48) reported significantly elevated levels of PCB (as Arochlor 1254) in the sediments of the urban/industrial Brunette River basin (Appendix 2.1;Figure 2), which discharges into the Fraser River. Concentrations of up to 780 ppb (dry weight) were detected in Still Creek, which is the main tributary to the Brunette River system. Large quantities of storm water and urban runoff from a highly industrialized area drain directly into Still Creek and possible sources of PCB contamination included numerous local industrial facilities and a transformer storage yard.

Sediment samples were also analyzed for a wide range of organochlorine pesticides including p,p'-DDT, o,p'-DDT, p,p'-DDE, p,p'-DDD, DDMU, aldrin, dieldrin, endrin, lindane, heptachlor, heptachlor epoxide, p,p'-methoxychlor, alpha- and beta-endosulphan, and alpha- and gamma-chlordane. Only p,p'-DDT, p,p'-DDE, p,p'-DDD, and alpha- and gamma-chlordane were present in measurable concentrations. Total DDT levels did not exceed 189 ppb and the presence of DDT and its metabolites were noted

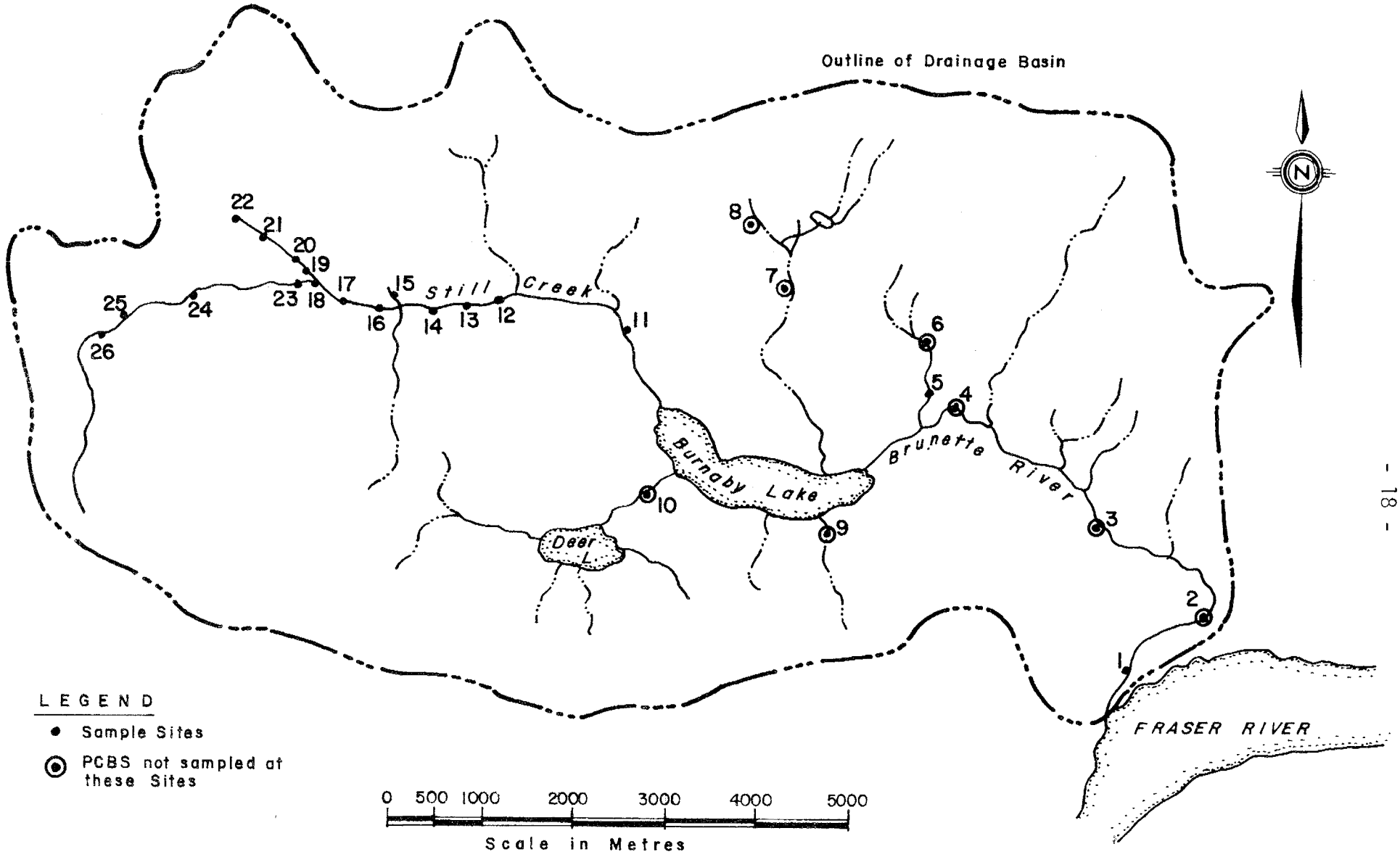

FIGURE 2 WESTWATER RESEARCH SEDIMENT SAMPLING SITES IN THE BRUNETTE RIVER DRAINAGE SYSTEM, BURNABY, B.C. (Adapted from Hall et al (61) (Refer to Appendix 2-1)

in almost all areas sampled. Chlordane was detected less frequently and at lower concentrations, not exceeding 87 ppb of alpha- and gamma-chlordane combined.

Fraser River

Despite the potential for substantial inputs of PCB from the Brunette system to the Fraser River the analyses of Fraser River sediments have demonstrated that chlorinated hydrocarbon concentrations are low at almost all sample locations (Appendix 2.2;Figure 3).

Data collected by the IWD in 1977 indicate that PCB concentrations ranged from less than 4 ppb to 108 ppb in sediments near the Oak Street bridge but were not detected in samples from New Westminster, Tilbury Island and Steveston (53). These samples were also analyzed for PBBs and various organochlorine pesticides including DDT and its metabolites, aldrin, dieldrin, endrin, lindane, heptachlor and its epoxide, methoxychlor, alpha- and beta-endosulphan, and alpha- and gamma-chlordane; however, these compounds were not present in measurable amounts in any sample.

PCB concentrations in dredge spoils collected at various locations in the Fraser River, from the Port Mann bridge to the mouth, ranged from less than 10 to 430 ppb. The highest concentrations (230 ppb and 430 ppb) were detected in samples collected offshore from the Rayonier sawmill in New Westminster and TPL Industries wood preserving plant in Burnaby, respectively (62). Sediment and soil samples from various stations in the Richmond landfill and along adjacent portions of the Fraser River have been collected and analyzed for PCB residues. Although the results did not indicate a major source of contamination in this area, detectable concentrations were found at several stations. Soil samples ranged from less than 10 to 30 ppb while sediment samples contained between less than 10 and 190 ppb (63).

In 1976, the Environmental Protection Service (EPS) collected sediment samples offshore from three paper mills on the Fraser River. Concentrations of up to 1000 ppb of PCBs were detected in sediments collected near the discharge site at Belkin Paperboard Ltd. while PCBs were not detected in the sediments near Island Paper Mills and Scott Paper Ltd.

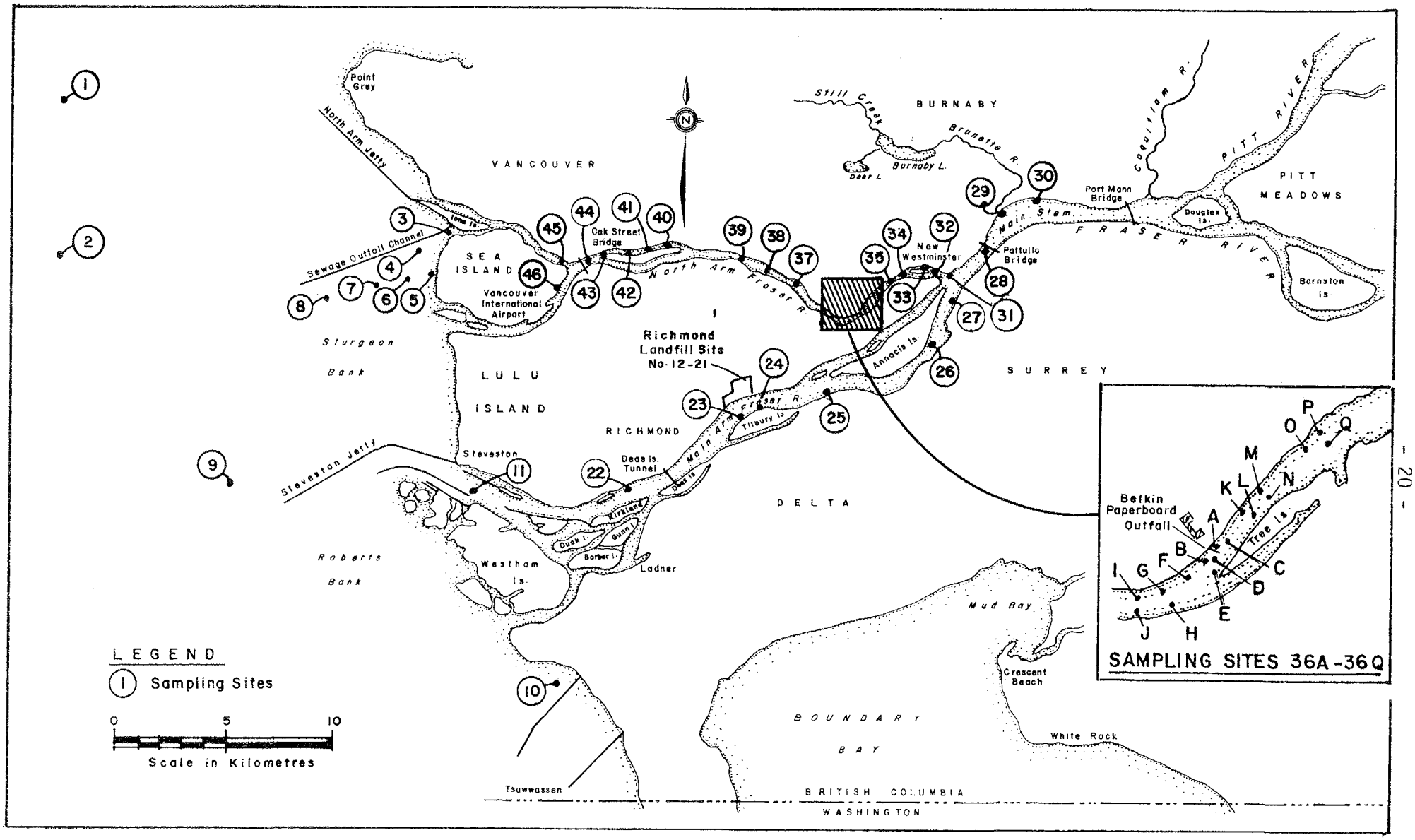

FIGURE 3 SEDIMENT SAMPLING SITES IN THE LOWER FRASER RIVER/ESTUARY
(Refer to Appendices 2.2 and 2.3)

Additional sediment sampling conducted by EPS around the Belkin plant in 1979 confirmed the presence of high levels of contamination (1500 ppb) in the area immediately adjacent the effluent outfall. This contamination is attributed primarily to the large amounts of PCB contaminated sludges discharged daily (see Section 2.2.1.4). Elevated concentrations (up to 1300 ppb) were also detected in sediments upstream from the plant. The source of this contamination has not been positively established. However, the sludge plume from the Belkin plant, observed during tide reversal, extended over 1/2 mile upstream of the point of discharge. This fact, combined with the absence of other known local sources of PCB discharge, indicates that the upstream contamination probably orginates from the Belkin plant.

Similar levels have been detected in sediments from the upper Great Lakes. The two highest PCB concentrations (1300 ppb and 90 ppb) were detected in Lake Superior sediments, however, concentrations in other nearby areas ranged from trace levels to 20 ppb. Organochlorine pesticide residue levels were much lower. The highest total DDT concentration detected was 22 ppb while dieldrin was present in only trace amounts. The concentrations of all other organochlorine pesticides were below the analytical limits of detection (64).

Monitoring by EPS and Pesticide Control Branch at the recently abandoned site of the Later Chemicals manufacturing plant in Richmond demonstrated that soils and drainage ditches in this area contained very high levels of chlorinated hydrocarbons (Appendix 2.4). Particularly high concentrations of several organochlorine pesticides were detected. Soil samples from the plant yard contained 2100 ppm DDT, 1100 ppm DDD, 650 ppm gamma-chlordane, 420 ppm alpha-chlordane, 130 ppm aldrin, 110 ppm heptachlor, 90 ppm methoxychlor and 66 ppm dieldrin. Residue levels of these compounds in drainage ditch sediments were 1900 ppm, 940 ppm, 630 ppm, 390 ppm, 120 ppm, 110 ppm, 15 ppm, and 21 ppm, respectively. Lindane, trichlorophenols and tetrachlorophenols were also detected at concentrations of 13 ppm, 0.18 ppm and 2.0 ppm, respectively in soils and 13 ppm, 0.09 ppm and 0.36 ppm in ditch sediments (62). Additional sampling by the provincial B.C. Pesticide Control Branch (Appendix 2.4) showed that

these compounds had penetrated to a depth of at least 40 inches in some areas, but that the highest levels were confined to the top 20 inches (65).

A study to assess environmental levels of pentachlorophenol in selected coastal areas was conducted in 1979 under contract to the Environmental Protection Service (54). In addition, samples were analyzed for lower chlorinated phenols and chlorinated benzenes which are often present in commercial PCP formulations. Lower chlorinated phenols may also occur as a product of PCP degradation in the environment. Pentachloroanisole, another degradation product of PCP, was also studied.

The receiving environments of several facilities utilizing PCP for wood preservation purposes were sampled. Some of the plants included in the survey discharge into the Fraser River. These include the Canadian White Pine, Domtar and Crown Zellerbach lumber mills and Later's Chemicals pesticide formulating plant. Sediment samples from all sites contained significant concentrations of tetra- and pentachlorophenol, however, trichlorophenol was detected only in samples from Domtar. The samples also contained very low concentrations of hexachlorobenzene but the lower chlorinated benzenes were not detected. Similarly, pentachloroanisole was present in low concentrations at all sites with the exception of Canadian White Pine, where concentrations of up to 100 ppb were reported (Appendix 2.3;Figure 3).

Preliminary sampling by the Waste Management Branch has indicated high levels of tetrachlorophenol (up to 90 ppm), pentachlorophenol (up to 525 ppm), oils and greases in the sediments off Koppers International pole treating facility. As a result, the Waste Management Branch has ordered the termination of discharge and the removal of highly contaminated sediments adjacent to the Koppers facility. Koppers utilizes both creosote and pentachlorophenol based wood preservatives for the treatment of poles. Future monitoring will attempt to identify the extent of contamination by chlorinated phenols and creosote in preparation for cleanup measures. Due to the likelihood of PAH release in areas of creosote contamination (66,67) sediments will also be analyzed for PAHs.

Estuary Region

Dunn and Stich (66) reported that sediment concentrations of the carcinogenic polycyclic aromatic hydrocarbon, benzo(a)pyrene, increased with proximity to the Iona Island sewage treatment plant (Appendix 2.2; Figure 3). Dry weight concentrations ranged from 0.4 ppb near the end of the breakwater to 121 ppb near the effluent outfall. No information on benzopyrene levels in other areas of the Fraser River is available but previous work by Dunn and others has indicated that elevated levels occur in sediments and biota near creosoted wood pilings (66, 67).

A sediment sample collected in the Sturgeon Bank area as part of the DOE study on organic contaminants in the estuary region contained 214 ppb PCB as well as equally significant levels of phthalate esters and lower concentrations of 1,2-dichlorobenzene and naphthalene (68).

2.1.3 Fish. Most of the available information on organic contaminant levels in Fraser River fish species was obtained from a Westwater Research Centre fish sampling program conducted in 1972 and 1973 (Appendix 3;Figure 4). A total of 265 fish from 12 resident species were sampled. Samples were collected at 14 stations along the lower Fraser between Hope and the mouth. The majority of the samples were analyzed in 1973, to determine muscle tissue levels of environmental contaminants such as; aldrin, dieldrin, alpha- and gamma-chlordane, heptachlor, heptachlor epoxide, p,p'-DDT, p,p'-DDE, p,p'-DDD, lindane and PCBs (as Aroclor 1254). The results of these analyses have been discussed in depth by Johnston et al (69). The remainder of the samples were frozen for future analysis. In 1978, additional funding became available through the Environmental Contaminants Contract Fund and representative samples were analyzed for a wide range of industrial and agricultural organic contaminants including those listed above and, in addition, hexachlorobenzene (HCB), Mirex, polychlorinated biphenyls (PCBs), polychlorinated terphenyls (PCTs), polybrominated biphenyls (PBBs), and chlorinated phenols. For the purposes of analysis the river was divided into five sections; North Arm, South Arm, Upper Estuary, Chilliwack Area, and Hope Area. All samples collected within each section were analyzed collectively.

PBBs, PCTs and Mirex were not detected in any samples. PCBs were detected with greater frequency and at higher concentrations than were any other contaminants but exceeded the HWC guideline of 2000 ppb (2 ppm wet weight) in only one sample. Residue levels were highest in coarse fish species such as largescale suckers (up to 3694.9 ppb) and northern squawfish (up to 1894.0 ppb). The mean concentrations of 174.1 and 214.3 ppb, however, were much lower than those reported for these species from the Columbia River system in the U.S. (1040.0 and 1190.0 ppb, respectively) (70). Most species from the Fraser River contained PCB tissue concentrations between 100.0 and 900.0 ppb. Mean residue levels and incidence of occurrence in several species were higher in the more industrially developed estuarine portions of the river than further upstream, indicating that past and current industrial activity in this vicinity has contributed to significant PCB contamination in the Fraser River.

Similarly, chlorinated phenol compounds were identified with greater frequency and at higher concentrations in fish from the industrially developed lower reaches of the Fraser. Pentachlorophenol (PCP) was the most consistently detected phenolic compound and tetrachlorophenol (TCP) was also detected in some samples. PCP and TCP concentrations did not exceed 125.0 ppb and 62.0 ppb wet weight, respectively.

Hexachlorobenzene (HCB) was present in all species sampled. Mean concentrations were less than 10.0 ppb in all instances and the maximum concentration detected was 19.0 ppb. There was no apparent variation in HCB residues with location and no significant source of contamination has been identified. Sources of HCB are difficult to identify as contamination may originate from either agricultural or industrial applications. It is assumed that the levels of HCB present in fish from the Fraser River represent local background concentrations and originate from minor inputs from both industrial and agricultural sources. Johnson et al (71) reported that mean HCB concentrations in various fish species throughout the United States ranged from less than 10.0 ppb to 130.0 ppb. One carp was reported to contain 62.0 ppm, but this extreme level of contamination was attributed to runoff from an industrial chemical storage area. Mean HCB residues in

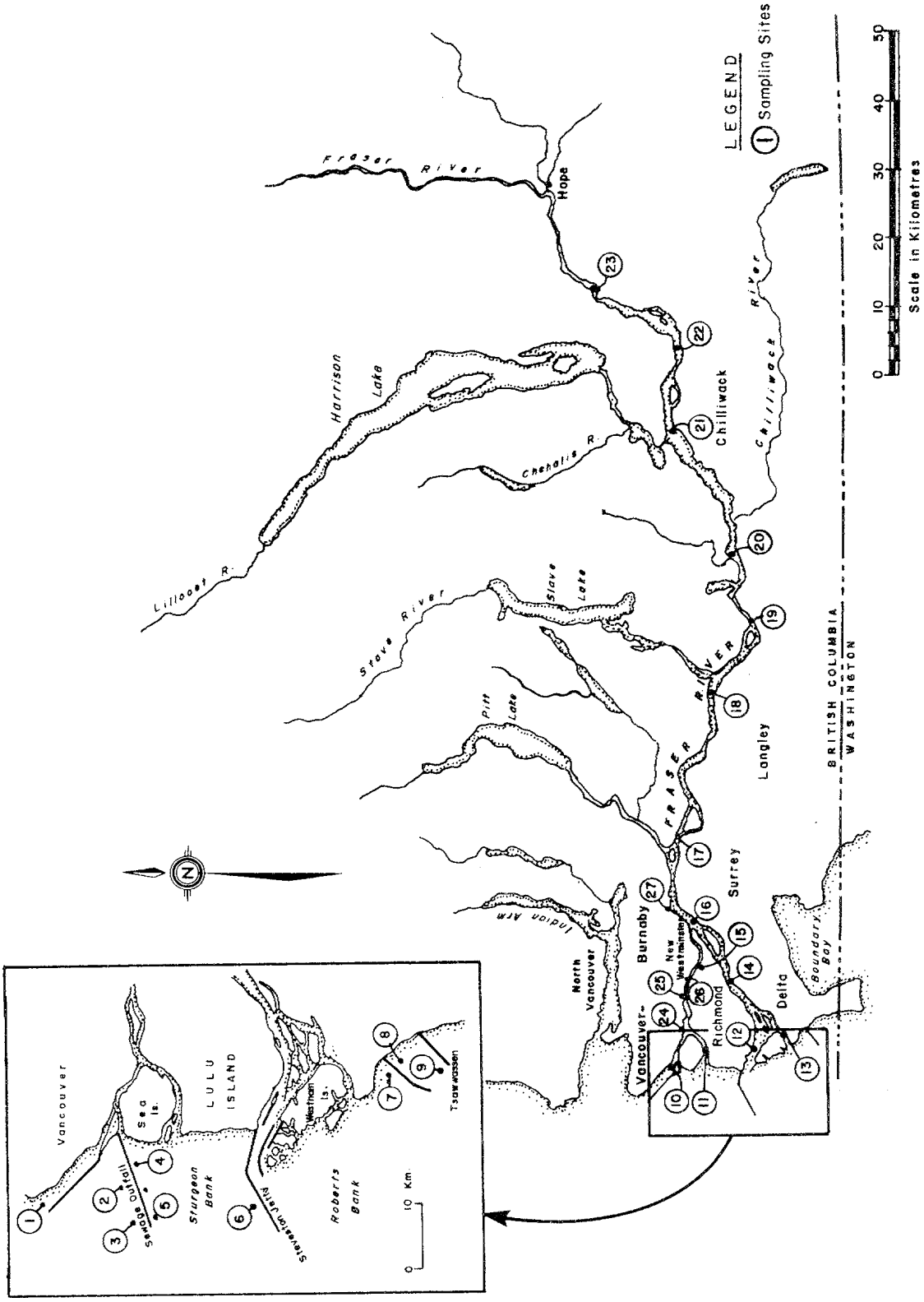

FIGURE 4 SAMPLING SITES FOR FISH AND AQUATIC INVERTEBRATES FROM THE LOWER FRASER RIVER / ESTUARY (Adapted from Johnston et al (56))
(Refer to Appendices 2.3, 3 and 4)

various freshwater and marine species in the Atlantic provinces ranged from 1.0 to 12.0 ppb (72).

Sculpins collected in 1978, near Later Chemicals and three lumber mills utilizing PCP in wood preservation techniques, contained elevated concentrations of both TCP and PCP. Muscle levels ranged from trace concentrations to 40 ppb for PCP and from trace concentrations to 100 ppb for TCP. Liver concentrations were significantly higher; trace-600 ppb for PCP and 74-480 ppb for TCP. HCB, however, was present in only one liver sample at a concentration of 8 ppb while the lower chlorinated forms were not detected in any sample. Similarly, pentachloroanisole did not exceed trace concentrations. Concentrations of all of these compounds in crayfish tissues were too low to permit quantification (54) (Appendix 2.3).

Various organochlorine pesticides were also detected in most species of Fraser River fish. The DDT breakdown product p,p'-DDE was detected in almost all samples. While elevated concentrations were detected in some individuals (1739.6 ppb in a carp from the North Arm) mean residue levels for all species were well below the HWC guideline of 5.0 ppm for DDT and its breakdown products. DDD and DDT concentrations were much lower and did not exceed 130.0 ppb and 190.0 ppb, respectively. Unlike DDE, residue levels of these contaminants were below the limits of detection in a large proportion of samples.

Heptachlor was not detected in any samples probably because it is readily converted to its degradation product, heptachlor epoxide, in the environment. While heptachlor epoxide was present in several species mean levels were less than 5.0 ppb, in most instances, and concentrations did not exceed 86.6 ppb.

Lindane, alpha- and gamma-chlordane and aldrin were not detected in the 1973 analyses, however, very low levels were reported for several samples analyzed in 1978. Improved methodology and consequent lowering of the detection limits may have allowed the quantification of lower residue levels. Dieldrin, the epoxide degradation product of aldrin, was present in trace amounts in the upper estuary region in 1973 but subsequent analyses in 1978 did not detect dieldrin residues in any samples. This was

unexpected considering the presence of the parent compound aldrin and the fact that it degrades rapidly to dieldrin in the receiving environment. A similar finding was reported by Parjeko et al (73) who detected aldrin in 60% of Lake Superior Lake trout at concentrations ranging from 80.0 to 220.0 ppb. Dieldrin, which is one of the most persistent organochlorine compounds and is commonly detected in water systems throughout the world, was not detected. This compound occurs more frequently than any other pesticide in river basins of the United States (34). Monitoring of channel catfish in Iowa showed that dieldrin levels in fish from extensively agricultural regions far exceeded the U.S. Food and Drug Administration allowable level of 300.0 ppb, while fish from non-agricultural areas contained acceptable concentrations (74). Fish collected from marine waters off Long Island, New York contained between 12.0 and 130.0 ppb of dieldrin (75). In England, concentrations of up to 232.0 ppb were detected in fish from Lower Medway Estuary in Kent (76), while concentrations in trout and perch from a dieldrin contaminated loch in Scotland ranged from 60.0 to 920.0 ppb and from 80.0 to 1610.0 ppb, respectively (72).

The presence of lindane in some fish probably indicates a low but current input into the receiving waters of the Fraser, since the half-life of lindane in fish is short (approximately 2 days). Additionally, lindane is more readily metabolized by microorganisms in the sediment than are other organochlorine insecticides (78).

Unlike the contaminants of urban-industrial origin, pesticide residue levels did not vary significantly with sample location and point sources of contamination have not been identified. Low inputs probably occur primarily as a result of runoff from agricultural regions and atmospheric fallout. Organochlorine insecticide levels in the Fraser River reflect low background concentrations when compared to more contaminated areas of the world such as the Great Lakes region, where organochlorine contamination has been a widely recognized problem for several years. Reinert and Bergman (79) report that lake trout from Lake Superior and Lake Michigan contained DDT and its metabolites at mean concentrations ranging from 1.0 to 6.4 ppm and 0.8 to 18.1 ppm, respectively, depending on fish

size. Concentrations in Lake Erie and Lake Michigan coho salmon also varied according to age and mean levels in various age groups ranged from 1.3 to 2.2 ppm and from 1.8 to 14.0 ppm for the two lakes, respectively. The South California Bight is one of the most highly contaminated water systems in the world, and has received discharges from a DDT manufacturing plant. Dover sole collected from this vicinity several years after DDT releases to the area had ceased, displayed elevated mean muscle concentrations of 1.0 ppm (59).

An extensive survey designed to obtain information on organic contaminant levels in aquatic biota in the Iona Island mudflats region, is being conducted under the direction of the Department of Fisheries and Oceans (DFO), West Vancouver Laboratory (formerly the Pacific Environment Institute). Preliminary results for PCBs demonstrate that concentrations in flounder ranged from non-detectable to 650.0 ppb while a salmon contained 44.0 ppb. Phthalate esters were detected in all samples with bis(2-ethylhexyl) phthalate being present in higher concentrations (up to 696.0 ppb). Although it is unlikely, contamination may have occurred as biotic samples had been wrapped in aluminum foil and then in plastic for shipment to the laboratory. The presence of low levels of phthalate esters in the blank samples indicate that some contamination may also have originated from the blender apparatus during sample preparation. Low concentrations of naphthalene, phenol and pentachlorophenol were also detected in some samples. Other phenolic compounds were present in trace amounts but they were neither identified nor quantified (68).

2.1.4 Aquatic Invertebrates. Information on chlorinated residues in aquatic invertebrates from the Fraser River estuary (Appendix 4;Figure 4) is very limited and is confined to data obtained by Westwater Research Centre (80) in 1972 and by limited Environment Canada sampling in 1978. Values from the Westwater study were reported on a dry weight basis and are not readily comparable to those from the Environment Canada survey or to levels reported for Fraser River fish species.

The Westwater Research Centre study showed that elevated PCB concentrations occurred most frequently in Dungeness crab. Residue levels

in this species ranged from 154.3 to 2100.3 ppb and were not dependent upon proximity to the Iona Island sewage treatment plant outfall. The mean PCB concentration for crabs collected in the vicinity of the outfall was 840.0 ppb while mean levels for specimens collected slightly south, at the Steveston jetty and Roberts Bank were 740.0 and 560.0 ppb, respectively. Several researchers have identified sewage discharges to be significant sources of chlorinated hydrocarbons to aquatic biota and PCB levels in crabs taken near sewage outfalls in coastal southern California contained concentrations of up to 4.9 ppm wet weight (81).

Elevated PCB concentrations were also detected in an oyster and a clam from the vicinity of the Westshore Terminal coal superport at Roberts Bank. These species contained 2.7 ppm and 1.8 ppm, respectively. Possible sources of contamination in this area include runoff and washings from the coal terminal, ferry docks, and contributions of PCB-contaminated particulate material which may be carried from the Fraser River and deposited in other areas by tidal movement and water currents.

Biota collected in the Fraser River mudflats area as part of a DFO survey of organic contaminants in aquatic biota, also indicate that PCB levels in crabs from the Iona Island sewage treatment plant outfall area ($\bar{x}$ = 134.5 ppb) are consistently higher than those in crabs from Roberts Bank ($\bar{x}$ = 7.0 ppb). Insufficient tissue was available to reliably quantify PCB residues in clams from the vicinity of the outfall.

Clams and crabs from both Sturgeon and Roberts banks contained significant levels of phthalate esters. As was the case with fish tissues bis(2-ethylhexyl)phthalate was present in the highest concentrations (up to 1600 ppb) and, similarly, the possibility of sample contamination cannot be discounted. Detectable concentrations of PAHs were also present in clams from this area. Concentrations were slightly more elevated in the Roberts Bank region (68) indicating that the Iona Island sewage treatment plant may not be the major source of release in this vicinity.

Atmospheric fallout from oil-fired burners and home heating units (82) in the Greater Vancouver area probably contribute even greater amounts of PAHs to the estuary region. Automobile emissions have also been found

to make significant contributions to atmospheric PAH levels (83). Although several PAH compounds have been detected in coal and coal dust (84,85) it is not known whether the Roberts Bank Coal Superport would release PAHs to the estuary region in coal dust or surface runoff. Several researchers, however, have reported that PAHs are released from coal only during combustion processes (85). It is, therefore, unlikely that the environmental impacts of any coal-related PAH discharges from the Roberts Bank facility are significant.

While mussels are normally considered to be excellent indicators of local levels of contamination, data on chlorinated hydrocarbons in mussels from the Fraser estuary region were too limited to provide any reliable information.

Organochlorine insecticides such as DDT and its metabolites, dieldrin and heptachlor epoxide were also detected in some species of invertebrates from the Fraser River estuary during the Westwater survey but residue levels were much lower than those reported for PCB (80). DDE was the most frequently detected compound and, like PCBs, the highest concentrations were detected in Dungeness crab from the vicinity of the Iona sewage treatment plant outfall ($\bar{x}$ = 101.4 ppb). All other contaminants, when present, were detected in very low or trace concentrations.

2.1.5 Birds. Limited information on organic contaminant levels in avian species (Appendix 5) obtained from the Canadian Wildlife Service (86) was confined primarily to the Fraser River delta region. Virtually all samples were collected prior to 1970 and so reflect past levels of contamination. With the exception of data on heron eggs collected from the U.B.C. Endowment Lands in 1978, no information on current levels of contamination was available. It may be speculated, however, that residue levels of some substances may have decreased to some extent in past years due to the curtailment or reduction in the use of many of the organochlorine pesticides.

Large interspecific variations in environmental contaminant residue levels are influenced by feeding habits and trophic level. Fish-eating and raptorial species at the top of the food chain commonly

contain particularly high concentrations of chlorinated hydrocarbons and other environmental contaminants. While information on residue levels in birds collected in the Fraser River/Estuary is far too limited to establish such trends, information on organochlorine levels in birds from British Columbia, in general, indicate that PCB and DDE were highest in fish-eating birds and raptorial species (87). This finding is consistent with observations reported by researchers throughout the world. Due to the lipophilic properties of these contaminants the highest residues are typically found in the liver, kidney and eggs.

Residue levels in birds from the Fraser River estuary region were generally low, however, very high concentrations of PCB were detected in heron eggs collected in the University Endowment Lands in 1978. Concentrations ranged from 6.92 to 50.20 ppm PCB with a mean value of 21.40 ppm. DDE levels in these samples were also elevated, ranging from 0.80 to 5.84 ppm ($\bar{x}$= 2.82 ppm), and although several other organochlorine pesticides were detected, they were present at much lower concentrations (86). No information was available on other fish-eating species such as eagles, osprey, cormorants, grebes, and gulls although these species from other areas of B.C. have been shown to contain elevated concentrations of PCBs (87) and DDE (86). Concentrations of total DDT, PCBs, dieldrin and heptachlor epoxide in the eggs of Red-tailed hawks from the Fraser delta region were 5.79 ppm, 0.37 ppm, 0.26 ppm, and 0.11 ppm, respectively. Elevated muscle concentrations of DDT analogues (up to 3.02 ppm) were also detected in Short-eared owls but residue levels of other organic contaminants were low.

Dunlin, a species of shorebird, would not normally be expected to contain significant concentrations of organochlorine compounds, however, Dunlin collected from the vicinity of the Vancouver International Airport on Sea Island contained surprisingly high levels of PCB and DDT metabolites. PCB levels ranged from 0.78 - 3.19 ppm while total DDT concentrations ranged between 0.26 and 1.39 ppm. Killdeer, another species of shorebird, from Sea Island also contained elevated concentrations of DDT and its metabolites while PCBs were not detectable. PCB and DDT concentrations in shorebirds from other regions of the province were very

low (86, 87). While the source of contamination has not been established it should be noted that the Iona Island sewage treatment plant which serves a large part of the greater Vancouver region is also located in this general vicinity.

Some species of birds from the agriculturally developed Westham and Reifel Islands also contained elevated concentrations of organochlorine insecticides. Maximum total DDT and dieldrin concentrations in Sora rail and Robin were 19.54 ppm and 1.68 ppm, and 3.60 and 0.10 ppm, respectively. Other species from these areas contained much lower levels of contamination.

In most instances, hexachlorobenzene and heptachlor epoxide levels were below the analytical limits of detection and did not exceed 0.03 ppm and 0.11 ppm, respectively, in any samples.

2.2 Sources of Contamination

2.2.1 Municipal Discharges

2.2.1.1 Sewage treatment plants. A study by Cain et al (88) to determine the presence of trace organic compounds in wastewaters from the Greater Vancouver region indicates that effluents from the Annacis Island, Iona Island, and Lulu Island primary sewage treatment plants which discharge into the Fraser River/Estuary, contain low but quantifiable concentrations of chlorinated phenols, polychlorinated biphenyls, phthalate esters and hexachlorobenzene (Appendix 6.1;A, Figure 1). A total of 57 trace organic compounds were detected in the wastewaters of the three plants, however, the identification of many of these compounds has not been confirmed. Compounds which were quantified were present in the low ppt to ppb range with the exception of fatty acids and steroids which were present in somewhat higher concentrations.

Phthalate ester compounds were identified in the effluent from all three sewage treatment plants in concentrations ranging from 2.0-50.0 ppb. Diethylphthalate was detected consistently and dimethyl-, dimethyliso-, diethyl-, and dibutylphthalate were found less frequently in quantifiable concentrations. A phthalate diester was tentatively identified as dioctylphthalate but was not quantified. Due to the ubiquity

of these compounds, however, the possibility of sample contamination has not been ruled out. Unfortunately no sample blanks were analyzed.

Similar concentrations of tetrachlorophenol (TCP) and pentachlorophenol (PCP) were identified in the wastewaters from the three plants. Tetrachlorophenol concentrations ranged from 1.0-30.0 ppb while PCP levels were somewhat lower at 6.0-9.0 ppb. Whereas PCP levels are very similar at all plants sampled, the concentration of TCP was much higher at the Iona Island plant than at either the Annacis Island or Lulu Island plants. Additional monitoring for phenolic compounds by Cain et al (88), however, indicated that PCP and TCP levels were highest at Annacis Island and lowest at Iona Island. Mean concentrations of PCP in sewage samples from Annacis, Iona and Lulu were 2.9-9.9, 1.3-1.7 and 2.1-3.7 ppb, respectively while TCP levels were 9.8-20.7, 0.9-1.3 and 1.2-5.3 ppb, respectively. P-cresol was identified in Lulu Island plant effluents but was not quantified.

These results compare favourably with a study by Buhler et al (89) on chlorinated phenol levels in the wastewater of three secondary sewage treatment facilities in Oregon. Concentrations of pentachlorophenol and hexachlorophene [2,2-methylene bis (3,4,6-trichlorophenol)] in Buhler's study range from 1.0-4.0 ppb and 6.0-12.0 ppb, respectively, in the effluent. Efficiency of removal during treatment at the three plants ranged from 60-72% for HCP and 4-29% for PCP. Subsequent monitoring of 24 hour composites for a seven day period at one of the plants, however, showed an average removal rate of 73% for HCP and 59% for PCP. Concentrations fluctuate with the time of day due to variations in the removal efficiency which is influenced by such factors as flow rate; the source and relative input of industrial waste, which determines the chemical composition of the wastewater; and the degree of treatment. Koch et al (90) detected phenolic compounds at a concentration of 12.5 ppb in Iona Island sewage treatment plant discharges, but specific compounds were not identified. Hexachlorobenzene and polychlorinated biphenyls were also detected in all wastewater samples. Hexachlorobenzene residues ranged from 4.0-6.0 ppt. The fact that the lower chlorinated benzene compounds were not detected in any samples is surprising in that Young and Heesen (59) found that the lower chlorinated benzenes such as p-DCB, o-DCB, and

1,2,4-TCB were present in concentrations at least one order of magnitude higher than was HCB. 1,3,5-TCB was also present but in lesser amounts. Chlorinated benzene concentrations were much higher than either DDT or PCB levels and total chlorinated benzene concentrations ranged from less than 0.4 to 800.0 ppb with contributions by HCB being relatively modest; less than 0.01-6.8 ppb. It is interesting to note that, although low, HCB concentrations in California facilities were up to three orders of magnitude higher than levels detected in wastewaters from British Columbia plants. The absence of lower chlorinated benzenes in local wastewaters may have been due, at least in part, to the higher volatility of these compounds.

Rogers (68) sampled the Lulu Island and Annacis Island sewage treatment plants between 1977 and 1979. Samples were screened for a wide range of organic compounds and those present were identified but not quantified. Samples of high chlorination effluent were also analyzed. Rogers confirmed the presence of many of the organic compounds identified by Cain et al (88) including certain phthalates, chlorinated phenols, terpenes, chlolesterol, coprostanol, caffeine and a wide range of fatty acids (Appendix 6.1;B). Rogers (68) did not attempt to detect PCBs or chlorinated benzenes, however, he did identify certain PAH compounds (anthracene and phenanthrene) and resin acids not reported by Cain et al (88).

Polychlorinated biphenyl levels in Vancouver area sewage discharges were normally two orders of magnitude higher than HCB concentrations and ranged from 130-300 ppt (Appendix 6.2). The Lulu Island plant services a largely residential area, while Iona and Annacis both have large industrial inputs. As would be expected, PCB concentrations in Lulu Island effluents were somewhat lower than the levels in discharges from the other two plants. Aroclor 1260, one of the most highly chlorinated and persistent of the biphenyl formulations, was the only PCB compound detected. Sampling conducted over a four day period in 1976 by the Environmental Protection Service determined mean PCB concentrations in the chlorinated effluent of Iona Island sewage treatment plant to be 0.08 ppb, while Annacis Island sewage treatment plant dechlorinated effluent contained an average of 0.03 ppb. Mean influent concentrations for these two plants

were 0.143 ppb and 0.059 ppb, respectively, reflecting a removal efficiency of approximately 43% and 42%, respectively. A sample of digester sludge from the Iona Island plant contained 1100.0 ppb PCB (62).

Dube et al (91) reported that mean PCB levels in seven of eleven sewage treatment plants sampled in Wisconsin were between less than 0.05 and 0.17 ppb. Three other plants contained mean levels between 0.73 and 2.5 ppb and one plant contained a mean concentration of 37.3 ppb. A more intensive study at one of the plants indicated that approximately 70% of the PCBs were removed during the secondary treatment. PCB concentrations in digester sludges from two of the plants were 2200.0 ppb and 5250.0 ppb.

Much higher concentrations of PCBs have been detected in the raw influent at certain plants in southern Ontario. The results of a study by Lawrence and Tosine (92) demonstrate that four out of six sewage treatment plants sampled contained PCB levels greater than 2.0 ppb with the highest mean concentration of 10.8 ppb occurring in the Hamilton plant discharges. Both Aroclor 1254 and 1260 were identified. Sludges from several plants contained between 92.0 and 192.0 ppb PCB but Lawrence and Tosine report that other researchers have found concentrations of up to 2085.0 ppb in digester sludges from Hamilton.

Several researchers have reported that contaminant concentrations in sewage vary significantly throughout the day. The highest inputs of industrial compounds, such as pentachlorophenol and polychlorinated biphenyls, to sewage facilities normally occur during the daytime and correspond to the periods of maximum industrial activity (89, 92). While no such information is available for sewage treatment plants sampled in the Vancouver area, it is logical to assume that a similar situation would exist.

The detection of high concentrations of PCBs and other toxic contaminants in sewage sludges demonstrates the importance of controlling the ultimate disposal of this material. The temperature of typical municipal incinerators is not adequate to degrade stable compounds such as PCBs. The use of sludges for application on agricultural land should also be reviewed as it has been shown that PCBs accumulated to significant concentrations in crops grown on sludge-treated land (92).

The chlorination of industrial and sewage effluent discharges for disinfection, odor control and to improve sedimentation and filtration processes, has become a common practice. The possible formation of organochlorines during the chlorination of wastewaters containing large amounts of organic compounds has been a subject of concern to several researchers. Glaze and Henderson (93) report that the 'superchlorination' of effluent from a secondary sewage treatment plant with chlorine gas resulted in the formation of 36 identifiable chlorinated organic compounds. Most of the compounds identified were aromatic derivatives and were present in the ppb range. Some of the compounds identified after chlorination include chlorinated phenols, chlorinated phthalates, and chlorinated benzenes. Similar results have been documented from the chlorination of primary effluents from a sewage treatment plant in North Vancouver. New compounds were produced as a result of chlorination and the concentrations of some compounds already present were increased. Three new compounds were identified; chlorobenzene, 1,3-dichlorobenzene, and alpha-chlorotoluene. All organic compounds were present in the ppt to ppb range (94). Approximately 0.01% of the chlorine applied became associated with volatile organics. Using a radioactive tracer, Jolley et al (95) determined that 0.5 to 3.1% of the chlorine added to cooling water and sewage effluents combined with non-volatile organic compounds. Studies conducted by other researchers have indicated that the chlorination of wastes containing aromatic hydrocarbons can result in the production of such compounds as PCBs, chlorinated phenols and chlorinated napthalenes. The chlorine substitution process was found to increase with decreasing pH (96, 97).

Cain et al (88) also reported the presence of various other types of trace organic compounds in the effluents of Vancouver area sewage treatment plants including; terpenes, fatty acids, steroids, caffeine and nicotine. Terpenoids occur naturally in plant material and are utilized in the perfume and cosmetics industry as well as in a variety of other industrial applications. Although several terpenoids were identified in effluent samples none were quantified. Analysis of Fraser River hardboard plant effluents by Rogers (98,99) indicated that the lumber industry in the Vancouver region may be a source of terpenoids to the Fraser River and to local sewage treatment plants. The steroids, coprostanol and cholesterol, were consistently detected and effluent concentrations ranged from 70-450

ppb and from 70-400 ppb, respectively. The major source of these compounds is human waste and coprostanol has often been used as an indicator of fecal contamination. Cholesterol is also present in various food products, oils, greases, etc.

Fatty acids occur ubiquitously in the environment and are present in oils, greases, soaps, foods, cosmetics, etc. They were present in higher concentrations than were any of the other trace organics. Stearic and palmitic acids were detected and the highest concentrations, up to 3000 ppb and 5000 ppb, respectively, occurred in Lulu Island effluents. These high concentrations of fatty acids have been tentatively attributed to the fact that large quantities of fats from local canneries probably enter the Lulu Island sewage treatment plant. Three fatty acid methyl esters were also identified but concentrations were not determined (88).

Caffeine was detected in all effluent samples in concentrations between 10 and 60 ppb. Nicotine was present in Lulu Island sewage treatment plant discharges, but was not quantified.

2.2.1.2 Sewers and urban runoff. Sewers and storm water collection systems receive inputs from households, industries, urban runoff and rainwater. Due to indications that street surface runoff or sewer systems may contribute significant amounts of contaminants to the receiving environment, samples from sanitary and storm sewers and street surface sediments in industrial, residential, agricultural, and combination-type land use areas thoughout the Greater Vancouver district, have been collected and analyzed for PCBs and various other organic contaminants. The results confirm that sewer systems and street surface runoff contribute measurable amounts of these compounds to the aquatic environment.

Street surface sediments (Appendix 6.3) sampled in various land-use areas (residential, industrial, commercial, green space) throughout the Brunette River basin area contained detectable concentrations of p,p'-DDT, p,p'-DDE, p,p'-DDD, PCBs, alpha- and gamma-chlordane (61). PCBs were detected more frequently and at higher concentrations than were any of the other compounds. Mean PCB residue levels were highest in commercial areas (141 ppb) although they were

present in all land-use areas, including green space regions (53 ppb). DDT and its metabolites were also prevalent in all areas, but residential zones contained the highest concentrations ($\bar{x}$ =18 ppb, p,p'-DDT) possibly as a result of the past use of this product by householders. In contrast, chlordane concentrations were higher in commercial regions than in the other land-use areas. Contaminants are deposited on street surfaces by atmospheric fallout, precipitation, vehicles (exhaust, tires, etc.), oils and greases from machinery and equipment, and releases from tar and asphalt road surfaces, and may enter aquatic systems in urban runoff, particularly via storm water drainage sewers. Storm sewers sampled by the Environmental Protection Service in the summer of 1976 (62) contained PCB concentrations between 0.10 ppb and 0.69 ppb (Appendix 6.2). Two of the sewers (Byrne Road and Kaymar Ravine) discharge directly into the Fraser River while the remainder discharge indirectly to the Fraser by way of Still Creek, Burnaby Lake and the Brunette River. These samples were not analyzed for other organic contaminants.

Still Creek in Burnaby receives large amounts of urban runoff from industrial areas and has been shown to be highly contaminated. Samples from Still Creek were collected at various stations in dry and wet weather flow conditions and analyzed for hydrocarbons and phenols (Appendix 6.4). While concentrations were much lower than those detected in the sewer wastewater samples described below, mean levels during periods of storm runoff (100-2400 ppb hydrocarbons; 0.5-8.5 ppb phenols) were often much higher than in dry weather conditions (100-800 ppb hydrocarbons; 1.6-10.0 ppb phenols) (90).

Similarly, Young and Heesen determined that storm water constitutes the major urban runoff contribution of HCB, DDT, PCB and dieldrin to the southern California Bight (100, 101). However, these authors also noted that while measurable amounts of chlorinated benzenes were present in storm runoff, this source made relatively insignificant contributions to the aquatic system (101).

In order to estimate the degree of organic contamination in wastewater, Westwater Research Centre (90) collected samples of sanitary and storm water from the Vancouver area and analyzed for hydrocarbons (as isooctane and benzene), phenols, and surfactants (as MBAS) (Appendix 6.4).

The mean concentrations of hydrocarbons in sewers from residential areas were 13.8-23.0 ppm and probably originate from the oils and greases contained in foodstuffs and cooking products. Burnaby Central and Burnaby Slope sewers contained the highest proportion of industrial wastes and hydrocarbon concentrations were slightly more than 27.0 ppm in both cases, indicating contributions from local industrial facilities. The lowest concentrations were detected in UBC sewers (mean concentrations of 6.0-15.0 ppm) and the Iona Island sewage treatment plant (10.2 ppm). Surfactant concentrations were slightly higher in residential drainage systems (720-790 ppb as compared to 540-630 ppb in industrial areas) probably due to the household use of detergents. Lower levels in Iona Island sewage treatment plant wastewaters (500 ppb) may be due, at least in part, to the rapid microbial degradation of these compounds (90) and to the dilution by groundwater, stormwater and cleaner industrial wastes such as cooling water entering the sewerage system.

Phenolic compounds were present in much lower concentrations. Residential sewer wastewater contained between 3.0 and 6.8 ppb while those from more industrial areas ranged from 0.5-21.6 ppb. The higher levels occurring in UBC sewers (18.0-43.0 ppb) may be due to the use of phenolic compounds in laboratories (90).

2.2.1.3 Landfills. The land disposal of waste materials containing toxic compounds may result in the release of these substances to the environment through the contamination of surface runoff and groundwater.

At present there is very limited legislation controlling the disposal of hazardous substances. The Ocean Dumping Control Act limits the concentrations of certain contaminants in materials for ocean disposal (102). EPS has also developed guidelines for the collection, storage and disposal of PCBs and electrical equipment and wastes containing PCBs at concentrations exceeding 100 ppm (103, 104, 105). Increasing industry's awareness of the hazards of PCBs and the proper handling and disposal methods for highly contaminated wastes has done much to decrease the amount of PCBs deposited in landfills. However, materials containing low levels of PCB (100 ppm) and numerous other chemicals still enter landfills in large quantities. The gradual decomposition of consumer products and

industrial, domestic and agricultural wastes results in the release of toxic and/or persistent chemical compounds to the soil. Depending on the solubility and persistence of these compounds, they may be dissolved in surface runoff and groundwater or become bound to soil particulates. Highly water soluble compounds are of greater environmental concern as they travel more quickly through the soils than do insoluble compounds such as PCBs which bind to the organic matter in the soil and are not readily leached into groundwaters. The dispersion of contaminants in landfills is influenced by a number of factors including, the chemical structure and level of contaminant present, soil composition and particle size, groundwater flow rate, rainfall and landfill construction.

Sampling of the groundwaters in the vicinity of a landfill in Oklahoma demonstrated the presence of at least five phthalate ester compounds in ppb concentrations. PCBs were not present in measurable concentrations (106). Limited monitoring by the Environmental Protection Service, however, indicated that leachate samples from drainage ditches in the Richmond landfill contained up to 20 ppb PCB (87). This value is surprisingly high considering that PCB levels in Ontario landfills are reported to range from ND to 1.2 ppb (57). Significant concentrations of di-, tri-, tetra- and especially pentachlorophenol, have also been detected in leachate samples from certain landfills in the Greater Vancouver area (88).

2.2.1.4 Industrial discharges. The effluent discharges of various industrial facilities located along the Fraser River have been analyzed for phenolic compounds (Appendix 6.5;Figure 1) as part of recent study (88). Of the 17 compounds identified, pentachlorophenol and 2,3,4,6-tetrachlorophenol were detected most frequently although elevated concentrations of several other compounds were also present in the effluents of certain facilities. The highest reported PCP level of 6000 ppb occurred in drainage ditch water from Coast Laminated Timber in Delta. Other high PCP concentrations (1125 and 2520 ppb) were detected in surface runoff collected from ditches draining the area around the old Later Chemical Ltd. pesticide formulating plant in Richmond. These drainage ditches also contained elevated concentrations of 2,3,4,6-tetrachloro-

phenol; 2100 ppb at Coast Laminated Timber and 166 ppb at Later Chemicals. The southwest drainage ditch at Later Chemicals contained elevated levels of numerous other phenolic compounds including 2,4,6-trimethylphenol (1000 ppb). Analytical results indicated the presence of several other organic compounds, although they were neither identified or quantified during this study.

The high concentrations of chlorinated phenols detected in the drainage ditches at Coast Laminated Timber were unexpected. The phenolic based glue and other products used at the plant do not contain chlorinated phenolics; therefore, it is likely that the contamination originated at another source. A specialty wood preserving plant operated next door to Coast Laminated Timber at the time of sampling, but has since closed down. The formulation of the preserving compound used at this facility is not known. Re-sampling of the 1978 stations would be extremely difficult due to site alteration during recent construction and expansion.

In late 1978, Later Chemicals moved to a new location and the original plant was demolished. Monitoring by the Environmental Protection Service, subsequent to plant closure, demonstrated that drainage ditches contained extremely high levels of chlorinated hydrocarbons (Appendix 2.4). The compounds present at the highest concentrations in drainage water were alpha-chlordane (5900 ppb), gamma-chlordane (3600 ppb), methoxychlor (4500 ppb), and DDD (3500 ppb). DDT, dieldrin, aldrin, heptachlor, lindane and HCB were also present in concentrations ranging from 120 ppb HCB to 1800 ppb dieldrin. Tri-and tetrachlorophenol were also elevated and were detected at concentrations of 150 and 300 ppb, respectively (62). The concentrations of many of these compounds far exceed their normal solubility in water indicating that they were associated primarily with suspended solids. Contamination from this facility undoubtedly has entered and continues to enter the Fraser River through surface drainage ditches and erosion processes. Due to the high degree of contamination and the extreme environmental persistence of certain compounds, this site could exist as a continuing source of contamination for several years. For this reason, the municipality of Richmond, in conjunction with federal and

provincial pollution control agencies, has initiated clean-up measures to prevent further contamination.

A limited number of industries along the Fraser River have been sampled to determine PCB content in their effluent discharges (Appendix 6.2). Due to the past use of PCBs in printing inks and paper coatings, the paper recycling industry has been identified as a potential source of contamination to the receiving environment (107).

Analyses of effluents from three paper plants on the Fraser River in 1976 indicated that, while PCB levels were below the limits of detection in two plants, discharges from Belkin Paperboard Ltd., contained 0.45 ppb (87). Subsequent sampling of the Belkin Paperboard clarifier overflow system in 1978 and the final discharge in 1979 indicated mean concentrations of 0.25 ppb and 2.4 ppb, respectively. The overflow system did not contain sludge solids at the time of sampling which probably accounts for the lower PCB concentrations in this sample. The great majority of the PCBs are associated with settleable paper solids which were combined with wastewaters prior to discharge. Concentrations of up to 70 ppm were detected in clarifier underflow from the Belkin plant. It should also be noted that one sample of clarifier effluent discharge contained uncharacteristically low levels of PCB. This finding has been attributed to the fact that, at the time of sampling, sludges were being recycled rather than discharged. As of September, 1979 sludges were being continually recycled, however, due to clarifier limitations large amounts of sludge are discharged in the overflow. Elevated PCB levels (up to 1500 ppb) were also detected in Fraser River sediments adjacent to the Belkin plant, while sediments in the vicinity of the other two paper plants contained much lower levels. It is likely that the contamination at the Belkin plant was due primarily to their almost total reliance on recycled paper which often contained significant levels of PCBs. Paper production at the other Vancouver area plants incorporated a large proportion of new material which was virtually devoid of contamination. It is expected that, as reserves of PCB-containing paper are depleted, effluent concentrations will decrease and the potential for environmental contamination from this source will greatly reduced. However, considering that the use of PCBs in carbonless

copy paper and printing inks was terminated in 1971, associated releases to the environment have continued for a surprising length of time. It is likely that the continual recycling of contaminated products also makes significant contributions to this release.

Effluent discharges from a chemical manufacturing plant and a wood preserving plant contained non-detectable concentrations of PCBs, as did a sample from the runoff collection pond at Westshore Terminals coal superport at Roberts Bank. A sample from the final settling pond at the coal superport, however, contained 2.98 ppb (62).

The toxic organic substances that have been found most frequently in British Columbia kraft pulp mill effluents are the resin acids (108, 109). The toxicity of these compounds was first reported in the 1930's (110) but it was not until much later that the specific compounds and their individual toxicities were identified. The most predominant resin acids are abietic, dehydroabietic, isopimaric, and palustric (111) and their 96 hr LC_{50}s as determined by static bioassays are 0.7, 1.1, 0.5 and 0.4 ppm, respectively (112). Fatty acids are also present in kraft mill effluents but only the long chain unsaturated forms are toxic to fish (110). Other potentially toxic compounds present in kraft mill effluents include mixtures of terpene alcohols and aldehydes. All of these substances occur naturally in the wood extractives of conifers but the concentration and type of compounds present depend on the wood species composition used in the pulping process (113).

A reduction in resin acid concentrations in pulp mill effluents appears to be directly related to reduced toxicity to fish. The biological treatment procedures employed by pulp mills in B.C. appear to be effective in reducing the resin acids to levels below acute lethal concentrations (114, 115, 116). However, due to the high toxicity of many of these substances and to the fact that there are currently five kraft mill operations discharging into the Fraser River system upstream of the study area, it is important to ensure that the release of such compounds is kept to a minimum.

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APPENDIX 1A ACUTE TOXICITIES OF VARIOUS ORGANOCHLORINE COMPOUNDS TO AQUATIC ORGANISMS AS DETERMINED BY LC_{50} TOXICITY TESTS

(a) Fish

(b) Aquatic Invertebrates

APPENDIX 1B SUBLETHAL TOXICITIES OF VARIOUS ORGANIC CONTAMINANTS TO AQUATIC ORGANISMS

(a) Fish

(b) Invertebrates

APPENDIX 1A ACUTE TOXICITIES OF VARIOUS ORGANOCHLORINE COMPOUNDS TO AQUATIC ORGANISMS AS DETERMINED BY LC_{50} TOXICITY TESTS
(a) Fish

Compound	Species	96 Hr. LC_{50} (ppb)	Reference
DDT	Rainbow trout (0.4 g)	1.7	117
	(3.2 g)	42.0	118
	Brook trout	7.4-11.9	117
	Cutthroat trout	1.37	117
	Coho Salmon (0.5-1.65 g)	11.3-18.5	117
	14 day LC_{50} (2.7-4.1 g)	44.0	118
	(0.43-0.88 g)	0.80	29
	Chinook salmon	11.5	118
	Fathead minnow	32.0	118
	Bluegill	16.0	118
	Goldfish	27.0	118
	Guppy	43.0	118
Dieldrin	Rainbow trout	9.9	118
	Coho salmon	10.8	118
	Chinook salmon	6.1	118
	Fathead minnow	16.0	118
	Bluegill	7.9	118
	Goldfish	37.0	118
	Guppy	22.0	118
Aldrin	Rainbow trout	17.7	118
	Coho salmon	45.9	118
	Chinook salmon	7.5	118
	Fathead minnow	33.0	118
	Bluegill	13.0	118
	Goldfish	28.0	118
	Guppy	33.0	118
Lindane	Rainbow trout	38.0	118
		60.0	
	Coho salmon	50.0	118
	Chinook salmon	40.0	118
	Fathead minnow	62.0	118
	Bluegill	77.0	118
	Goldfish	62.0	118
		152.0	
	Guppy	138.0	118
	Sheepshead minnow	104.0	119
	Pinfish	30.6	119

APPENDIX 1A ACUTE TOXICITIES OF VARIOUS ORGANOCHLORINE COMPOUNDS TO AQUATIC ORGANISMS AS DETERMINED BY LC_{50} TOXICITY TESTS (Continued)
(a) Fish

Compound	Species	96 Hr. LC_{50} (ppb)	Reference
Methoxychlor	Rainbow trout	62.6	118
		20.0	
	Coho salmon	66.2	118
	Chinook salmon	27.9	118
	Fathead minnow	64.0	118
	Bluegill	7.5	118
		62.0	
	Goldfish	62.0	118
		56.0	
	Guppy	120.0	118
	Yellow perch	20.0	120
Heptachlor	Rainbow trout	19.4	118
	Coho salmon	59.0	118
	Chinook salmon	17.3	118
	Fathead minnow	94.0	118
	Bluegill	19.0	118
	Goldfish	230.0	118
	Guppy	107.0	118
	Sheepshead minnow	3.68	35
	Pinfish	3.77	35
	Spot	0.85	35
Chlordane	Rainbow trout	44.0	118
	Coho salmon	56.0	118
	Chinook salmon	57.0	118
	Fathead minnow	52.0	118
	Bluegill	22.0	118
	Goldfish	82.0	118
	Guppy	190.0	118
Endrin	Rainbow trout	0.58	118
	Coho salmon	0.40	118
		0.51	
	Chinook salmon	0.76	118
		1.2	
	Fathead minnow	1.0	118
	Bluegill	0.6	118
	Goldfish	1.9	118
	Guppy	1.5	118
	Brook trout (1.2-2.0 g)	0.36-0.59	117
	Cutthroat trout (1.3 g)	0.19	117

APPENDIX 1A ACUTE TOXICITIES OF VARIOUS ORGANOCHLORINE COMPOUNDS TO AQUATIC ORGANISMS AS DETERMINED BY LC_{50} TOXICITY TESTS (Continued)
(a) Fish

Compound	Species	96 Hr. LC_{50} (ppb)	Reference
Pentachlorophenol (PCP)	Sheepshead minnow		
	fry - 1 day	329.0	121
	2 weeks	392.0	121
	4 weeks	240.0	121
	6 weeks	223.0	121
	Fathead minnows	210.0	122
	Goldfish	220.0	122
Sodium Penta-chlorophenate (Na - PCP)	Rainbow trout	230.0	123
	Zebra fish	1 130.0	123
	Flag fish	1 740.0	123
	Pinfish - (adult)	53.2	124
	Pinfish - (48 hr. prolarvae)	38.0	121
	Pinfish	66.0	121
	Striped mullet	112.0	124
Dowicide G 79% NO-PCP	Sheepshead minnow		
	fry - 2 weeks	516.0	121
Polychlorinated Biphenyls (PCBs)			
Arochlor			
1221	Cutthroat trout	1 170.0	125
1232		2 500.0	125
1242		5 430.0	125
1248		5 750.0	125
1254		42 500.0	125
1260		60 900.0	125
1262		50 000.0	125
1268		50 000.0	125
1254	Coho salmon (alevins)		
	72 day LC_{50}	<15.4	24
1248	Channel catfish	6 000.0	125
1254		12 000.0	125
1248	Bluegill	280.0	125
1254		12 000.0	125
1248	Fathead minnows		
	newly hatched	15.0	126
1254		7.7	126
1242	3 mos. old	300.0	126
1254	Pinfish		
	12 day LC_{50}	5.0	32
1254	Spot		
	18 day LC_{50}	5.0	32

APPENDIX 1A ACUTE TOXICITIES OF VARIOUS ORGANOCHLORINE COMPOUNDS TO AQUATIC ORGANISMS AS DETERMINED BY LC_{50} TOXICITY TESTS (Continued)
(b) Aquatic Invertebrates

Compound	Species	96 Hr. LC_{50} (ppb)	Reference
p,p'-DDT	Sand shrimp	0.6	126
	Grass shrimp	2.0	126
	Hermit crab	6.0	126
Dieldrin	Sand shrimp	7.0	126
	Grass shrimp	50.0	126
	Hermit crab	18.0	126
Aldrin	Sand shrimp	8.0	126
	Grass shrimp	10.0	126
	Hermit crab	33.0	126
Lindane	Sand shrimp	5.0	126
	Grass shrimp	10.0	126
		4.4	119
	Pink shrimp	0.17	119
	Mysid	6.3	119
	Hermit crab	5.0	127
BHC	Pink shrimp	0.34	119
Methoxychlor	Sand shrimp	4.0	127
	Grass shrimp	12.0	127
	Hermit crab	7.0	127
Heptachlor	Sand shrimp	8.0	127
	Grass shrimp	440.0	127
		1.06	35
	Pink shrimp	0.11	35
	American oyster	1.5	35
	Hermit crab	55.0	127
Endrin	Sand shrimp	1.7	127
	Grass shrimp	1.8	127
	Hermit crab	12.0	127
Sodium Penta-Chlorophenate (Na-PCP)	Grass shrimp	>515.0	126
	24 hr. larvae	649.0	126
	Brown shrimp	>195.0	126
	C. crangon - adult	2000.0	128
	1st insar larvae	100.0	128

APPENDIX 1A ACUTE TOXICITIES OF VARIOUS ORGANOCHLORINE COMPOUNDS TO AQUATIC ORGANISMS AS DETERMINED BY LC_{50} TOXICITY TESTS (Continued)
(b) Aquatic Invertebrates

Compound	Species	96 Hr. LC_{50} (ppb)	Reference
Polychlorinated Biphenyls (PCBs)	Daphnia magna		
	*14 day LC	24.0	33
	Grass shrimp		
Arochlor			
1016	Oyster	10	131
1016	Brown Shrimp	10	131
1016	Grass Shrimp	10	131
1254	Crayfish	80	129
1254	Grass Shrimp	41-86	132
1016	Brown Shrimp	10.5	133
1016	Grass Shrimp	12.5	133
1254	Daphnia magna		
	14 day LC_{50}	24.0	38
1254	Grass Shrimp		
	7 day LC_{50}	3.0	129
	16 day LC_{50}	4.0	130
1254	Pink Shrimp (juvenile)		
	15 day LC_{50}	0.94	130
1254	Pink Shrimp (adult)		
	35 day LC_{50}	3.5	130
1254	Crayfish		
	7 day LC_{50}	30.0-100.0	130

APPENDIX 1B SUBLETHAL TOXICITIES OF VARIOUS ORGANIC CONTAMINANTS TO AQUATIC ORGANISMS
a) Fish

Compound	Concentration (ppb)	Species	Effect	Ref.
DDT	5.0	Gambusia	behavioural abnormalities	139
	2.09 mg/kg in diet	Brook trout	reduced ova production	28
	$\geq$ 1.0 mg/kg in diet		increased mortality of sac fry	28
Dieldrin	1.7	Pumpkinseed sunfish	reduced swimming rate and increased oxygen consumption	140
	0.12	Rainbow trout	reduced growth rate	141
	0.75	Sailfin molly	inhibits growth rate and reproduction	142
	1.35	Mullet	degenerative changes in gills and visceral tissue	143
Methoxychlor	0.125	Fathead minnow (eggs)	reduced hatchability	147
	2.0	Fathead minnow (eggs)	inhibition of spawning	147

APPENDIX 1B SUBLETHAL TOXICITIES OF VARIOUS ORGANIC CONTAMINANTS TO AQUATIC ORGANISMS (Continued)
a) Fish

Compound	Concentration (ppb)	Species	Effect	Ref.
Sodium Pentachlorophenate Na-PCP	40.0	Steelhead trout (alevins)	-increased oxygen consumption -disrupt energy metabolism -reduce yolk utilization, efficiency and growth	149
	40.0	Steelhead trout eggs (exposed from fertilization to yolk absorption)	100% mortality	149
Polychlorinated Biphenyls				
Arochlor				
1016	32.0	Pinfish	liver and pancreatic alterations	131
1242	>10.0	Fathead minnow	decreased survival of newly hatched fry	126
1248	$\geq$ 2.2	Fathead minnow	inhibits growth	126
1254	1.8	Fathead minnow	decreased spawning	126
1254	56.4	Coho salmon	-reduced hatchability by 30% -reduced yolk sac utilization	29

APPENDIX 1B SUBLETHAL TOXICITIES OF VARIOUS ORGANIC CONTAMINANTS TO AQUATIC ORGANISMS (Continued)
a) Fish

Compound	Concentration (ppb)	Species	Effect	Ref.
Polychlorinated Biphenyls				
Arochlor 1254	≥ 4.4	Coho salmon	-premature hatching -reduced alevin survival	29
	≥ 15	Coho salmon	decreased length and weight of alevins	29
	≥ 0.05	Atlantic salmon (eggs exposed from gastrulation to hatching)	retarded behavioural development and impaired balance	31
	≥ 0.48 in diet	Coho salmon	thyroid stimulation	153
	5.0	Spot	fatty degeneration of the liver	154

APPENDIX 1B SUBLETHAL TOXICITIES OF VARIOUS ORGANIC CONTAMINANTS TO AQUATIC ORGANISMS (Continued)
b) Invertebrates

Compound	Concentration (ppb)	Species	Effect	Ref.
DDT	1000.0	Eastern oyster	depressed growth rate	134
	0.10	Eastern oyster	inhibit shell deposition by 80%	135
	50.0	Marine diatoms	inhibit photo-synthesis	136
Dieldrin	0.5-1.0	Marine crab	delayed develop-ment	144
Aldrin	1.0	Clam (eggs)	inhibit rate of development	134
Heptachlor	0.01	Eastern oyster	inhibit shell deposition	137
Chlordane	10.0	Eastern oyster	depressed growth rate	145
	6.2	Eastern oyster	inhibit shell deposition	146
	0.01	Eastern oyster	inhibit shell deposition	137
Toxaphene	0.1	Eastern oyster	reduced shell deposition by 30%	134
	1.0	Eastern oyster	depressed growth rate	134
	1.0	Clam (eggs)	inhibit rate of development	134

APPENDIX 1B SUBLETHAL TOXICITIES OF VARIOUS ORGANIC CONTAMINANTS TO AQUATIC ORGANISMS (Continued)
b) Invertebrates

Compound	Concentration (ppb)	Species	Effect	Ref.
Carbaryl	1.0	Clam (eggs)	inhibit rate of development	134
	400.0	Cockle clam	depressed larval growth rate	138
Sodium Pentachlorophenate (Na-PCP)	40.0	Eastern oyster	abnormal embryo development	121
	$\geq$ 34.0	Eastern oyster	inhibit shell deposition	124
	15.8-161.0	Molluscs, arthropods and annelids in macrobenthic community	decrease the number of individuals and the species diversity	150
	> 300.0	Grass shrimp	delay in the initiation and progress of limb regeneration	151
Polychlorinated Biphenyls Arochlor 1254	100.0	Eastern oyster	inhibit shell growth	131
	10.0	Eastern oyster	inhibit shell growth by 41%	131
	4.0	Eastern oyster	depressed growth rate	131
	5.0	Eastern oyster	tissue alterations in digestive system	131

APPENDIX 1B SUBLETHAL TOXICITIES OF VARIOUS ORGANIC CONTAMINANTS TO AQUATIC ORGANISMS (Continued)
b) Invertebrates

Compound	Concentration (ppb)	Species	Effect	Ref.
Polychlorinated Biphenyls				
Arochlor 1254	5.0	Easter oyster	radical internal tissue alterations	154
	3.0	Shrimp	crystalloid formation in hepatopancreas	154
Phthalate esters				
Di-2-ethylhexyl phthalate	3.0-30.0	Daphnia magna	decreased production of young by 60-83%	148
Dimethyl phthalate	100,000	Grass shrimp	desynchronized molting in comparison with controls	152
	1,000	Grass shrimp	desynchronized molting in comparison with controls	152

APPENDIX 2

2.1 LEVELS OF ORGANIC CONTAMINANTS IN SEDIMENTS FROM THE BRUNETTE RIVER - STILL CREEK SYSTEM

2.2 LEVELS OF ORGANIC CONTAMINANTS IN SEDIMENTS FROM THE FRASER RIVER/ESTUARY

2.3 LEVELS OF CHLORINATED PHENOLS AND CHLORINATED BENZENES AT SELECTED SITES IN THE FRASER RIVER/ESTUARY

2.4 LEVELS OF ORGANIC CONTAMINANTS IN THE SOILS, SEDIMENTS AND DRAINAGE WATER FROM LATER CHEMICALS' YARD AREA

APPENDIX 2.1 LEVELS OF ORGANIC CONTAMINANTS IN SEDIMENTS FROM THE BRUNETTE RIVER - STILL CREEK SYSTEM (ppb dry weight) (61) (refer to Figure 1)

Sample Station	Date	No. of Samples	p,p'-DDT	p,p'-DDE	p,p'-DDD	Alpha-Chlordane	Gamma-Chlordane	PCB's
1	Feb/74	1	6.0	ND	ND	ND	ND	ND
5	Feb/74	1	4.0	ND	ND	ND	ND	ND
11	Feb/74	1	13.0	6.0	14.0	ND	ND	75.0
12	Feb/74	1	ND	ND	ND	ND	ND	64.0
	Jun/74	1	ND	ND	ND	ND	ND	380.0
13	Jun/74	1	ND	ND	ND	ND	ND	400.0
14	Jun/74	1	ND	ND	ND	ND	ND	310.0
15	Jun/74	1	22.0	ND	14.0	ND	ND	540.0
16	Feb/74	1	18.0	ND	10.0	ND	ND	150.0
	Jun/74	1	11.0	ND	33.0	11.0	6.5	320.0
17	Jun/74	1	90.0	ND	40.0	23.0	28.0	780.0
18	Jun/74	1	5.4	ND	5.0	ND	ND	710.0
19	Jun/74	1	ND	ND	ND	ND	ND	120.0
20	Jun/74	1	ND	ND	ND	ND	ND	37.0
21	Feb/74	1	7.0	5.0	15.0	ND	ND	230.0
	Jun/74	1	ND	ND	ND	ND	ND	200.0
22	Jun/74	1	ND	ND	ND	ND	ND	120.0
23	Jun/74	1	135.0	ND	54.0	43.0	44.0	640.0
24	Jun/74	1	19.0	ND	6.8	2.8	ND	49.0
25	Feb/74	1	9.0	ND	ND	ND	ND	L10.0
	Jun/74	1	ND	ND	ND	ND	ND	55.0
26	Jun/74	1	8.0	ND	ND	ND	ND	44.0

ND = Not Detectable
L = Less Than

APPENDIX 2.2 LEVELS OF ORGANIC CONTAMINANTS IN SEDIMENTS FROM THE FRASER RIVER/ESTUARY (ppb dry weight) (refer to Figure 2)

Station No.	Location	Date	No. of Samples	PCB Concentration	Other Contaminants Mean ± S.D. (Range)		Data Source Reference
1	Point Grey Ocean Dump Site	Mar/76	1 (c)				62
	0-4 cm			1050	DDT	ND	
	4-8 cm			980		ND	
	12-14 cm			730		ND	
	20-24 cm			410		ND	
	40-44 cm			230		ND	
	70-74 cm			90		ND	
2	Sturgeon Bank	Mar/76	1 (c)				62
	0-4 cm			ND	DDT	ND	
	20-24 cm			ND		ND	
	60-64 cm			ND		ND	
	Sturgeon Bank - near Iona Is. STP outfall						
3		1975-76	3	-	benzo(a)-pyrene	79 ± 54 (19 - 121)	66
4		1975-76	6	-		11 ± 4 (3 - 15)	66
		Aug/78	1	ND			
		Nov/78	1	214	Diethyl-phthalate	48	68
					Di-n-butyl-phthalate	16	68
					Bis (2-ethylhexyl) phthalate	209	68

APPENDIX 2.2 (CONT'D) LEVELS OF ORGANIC CONTAMINANTS IN SEDIMENTS FROM THE FRASER RIVER/ESTUARY (ppb dry weight) (refer to Figure 2)

Station No.	Location	Date	No. of Samples	PCB Concentration (ppb)	Other Contaminants Mean ± S.D. (Range)	Data Source Reference
					Di-n-octyl- phthalate 178	68
					1,2-Dichlo- robenzene 70	68
					Naphthalene 22	68
					Fluoranthene, anthracene, pyrene, phenol & pentachlorophenol were not detected	
5		1975-76	7	-	benzo(a)-pyrene 15 ± 9 (4 - 31)	66
6		1975-76	3	-	4 ± 1 (3 - 5)	66
7		1975-76	9	-	3 ± 3 (0.8 - 10)	66
8		1975-76	3	-	0.6 ± 0.2 (0.4 - 0.7)	66
		Nov/78	1	0.05*		68
9	Sand Heads	Mar/76	1 (c)			62
	0-4 cm			ND	DDT ND	
	20-24 cm			ND	ND	
	66-74 cm			ND	ND	

APPENDIX 2.2 (CONT'D) LEVELS OF ORGANIC CONTAMINANTS IN SEDIMENTS FROM THE FRASER RIVER/ESTUARY (ppb dry weight) (refer to Figure 2)

Station No.	Location	Date	No. of Samples	PCB Concentration (ppb)	Other Contaminants Mean ± S.D. (Range)	Data Source Reference
10	Roberts Bank	Nov/78	1	10*		68
11	Fraser River - at Steveston	Mar/77	12	ND (ND-ND)	Lindane, heptachlor, heptachlor epoxide, aldrin, dieldrin, DDT and its metabolites, endrin, p,p'-methoxychlor, endosulphan, chlordane, and PBBs were not detected.	53
	- at Richmond Landfill					
12		Feb/76	1	30		87
13		Feb/76	1	20		87
14		Apr/77	1	10		62
15		Apr/77	1	ND		62
16		Apr/77	1	30		62
17		Apr/77	1	ND		62
18		Apr/77	1	20		62
19		Apr/77	1	ND		62

APPENDIX 2.2 (CONT'D) LEVELS OF ORGANIC CONTAMINANTS IN SEDIMENTS FROM THE FRASER RIVER/ESTUARY (ppb dry weight) (refer to Figure 2)

Station No.	Location	Date	No. of Samples	PCB Concentration (ppb)	Other Contaminants Mean ± S.D. (Range)	Data Source Reference
20	Main Arm	Apr/77	1	70		62
21		Apr/77	1	190		62
22		Jul/76	1	50		62
23		Jul/76	1	10		62
24		May/77	12	ND (ND-ND)	same as Station 11	53
25		Jul/76	1	10		62
26	(off Island Paper Mill)	Feb/76	2	215 ± 21 (200 - 230)		83
		Apr/76	2	ND (ND-ND)		83
27		Jul/76	1	40		62
28		Feb/76	2	ND (ND-ND)		62
		Apr/76	2	ND (ND-ND)		62
		Jul/76	1	10		62
		May/77	12	ND (ND-ND)	same as Station 11	53

APPENDIX 2.2 (CONT'D) LEVELS OF ORGANIC CONTAMINANTS IN SEDIMENTS FROM THE FRASER RIVER/ESTUARY (ppb dry weight) (refer to Figure 2)

Station No.	Location	Date	No. of Samples	PCB Concentration (ppb)	Other Contaminants Mean ± S.D. (Range)	Data Source Reference
29		Jul/76	1	30		62
30		Jul/76	1	30		62
31	(at Railway bridge)	Mar/79	1	L5		62
32	(off Rayonier Ltd.)	Jul/76	1	230		62
33	(u/s Scott Paper)	Feb/76	2	ND (ND-ND)		87
		Apr/76	1	ND		87
	(d/s Scott Paper)	Feb/76	2	ND (ND-ND)		87
		Apr/76	1	ND		87
	North Arm					
34		Jul/76	1	ND		62
35		Jul/76	1	30		62
36	(vicinity Belkin Paperboard Ltd.) i) adjacent plant outfalls					
A		Feb/76	2	773+325 (543-1002)		83

APPENDIX 2.2 (CONT'D) LEVELS OF ORGANIC CONTAMINANTS IN SEDIMENTS FROM THE FRASER RIVER/ESTUARY (ppb dry weight) (refer to Figure 2)

Station No.	Location	Date	No. of Samples	PCB Concentration (ppb)	Other Contaminants Mean ± S.D. (Range)	Data Source Reference
36 (contd.)		Apr/76	1	704		95
		Mar/79	1	1500		62
B		Mar/79	1	46		62
C		Mar/79	1	10		62
D		Mar/79	1	L5		62
E		Mar/79	1	L5		62
	ii) d/s plant					
F		Apr/76	1	50		87
G		Mar/79	1	L5		62
H		Mar/79	1	L5		62
I		Mar/79	1	L5		62
J		Mar/79	1	L5		62
	iii) u/s plant					
K		Mar/79	1	L5		87
L		Mar/79	1	L5		87
M		Mar/79	1	560		87
N		Mar/79	1	L5		87
O		Jul/76	1	430		62
P		Mar/79	1	1300		92
Q		Mar/79	1	L5		87
37		Jul/76	1	20		62
38		Jul/76	1	60		62

APPENDIX 2.2 (CONT'D) LEVELS OF ORGANIC CONTAMINANTS IN SEDIMENTS FROM THE FRASER RIVER/ESTUARY (ppb dry weight) (refer to Figure 2)

Station No.	Location	Date	No. of Samples	PCB Concentration (ppb)	Other Contaminants Mean ± S.D. (Range)	Data Source Reference
39	(off MacMillan Bloedel White Pine Division)	Jul/76	1	20		62
		May/77	2	475 ± 106 (400-550)		62
40	(off Crown Zellerbach mill)	Jul/76	1	20		62
41		Jul/76	1	60		62
42		Jul/76	1	30		62
43		Jul/76	1	60		62
44		Jul/76	1	70		62
	- (at Oak St. bridge)	May/77	12	32 ± 41 (ND - 112)	same as Station 11	53
45		Jul/76	1	50		62

* = values below the limit of confident quantification.
(c) = core samples
ND = not detectable
\- = not analyzed for
L = less than

APPENDIX 2.3 LEVELS OF CHLORINATED PHENOLS AND CHLORINATED BENZENES AT SELECTED SITES IN THE FRASER RIVER/ESTUARY[1] (54) [Mean ± S.D. (Range)]

Location	Media	Chlorophenols			Chlorobenzenes			Pentachloro-anisole
		Penta-	Tetra-	Tri-	Hexa-	Penta-	Tetra-	
off Crown Zellerbach Mill Site No. 40 Figure 1	Sediment	35±23 (10-70)	28±14 (10-60)	ND (ND-ND)	ND (ND-ND)	ND (ND-ND)	ND (ND-ND)	TR (ND-TR)
	Water	0.28	0.10	ND	ND	ND	ND	TR
Site No. 25 Figure 2	Biota:							
	Crayfish (muscle)	ND	ND	ND	ND	ND	ND	ND
	Prickly sculpin (muscle)	40	100	ND	ND	ND	ND	ND
	(liver)	140	89	ND	8	ND	ND	TR
off Domtar Site No. 30 Figure 1	Sediment	10±10 (ND-30)	27±24 (6-80)	TR (ND-10)	ND (ND-TR)	ND (ND-ND)	ND (ND-ND)	2±3 (ND-9)
	Water	0.25	1.0	ND	ND	ND	ND	ND
Site No. 27 Figure 2	Biota:							
	Crayfish (muscle)	ND	TR	ND	TR	ND	ND	ND
	Prickly sculpin (muscle)	14	80	ND	ND	ND	ND	TR
	(liver)	600	320	ND	ND	ND	ND	TR

APPENDIX 2.3 (CONT'D) LEVELS OF CHLORINATED PHENOLS AND CHLORINATED BENZENES AT SELECTED SITES IN THE FRASER RIVER/ESTUARY[1] (54) [Mean ± S.D. (Range)]

Location	Media	Chlorophenols			Chlorobenzenes			Pentachloro-anisole
		Penta-	Tetra-	Tri-	Hexa-	Penta-	Tetra-	
off MacMillan Bloedel White Pine Site No. 39 Figure 1	Sediment	17+29 (ND-90)	21+25 (TR-90)	ND (ND-ND)	0.7+0.7 (ND-1.9)	ND (ND-ND)	ND (ND-ND)	30+31 (TR-100)
	Water	TR	0.3	ND	ND	ND	ND	ND
Site No. 26 Figure 2	Biota:							
	Crayfish (muscle)	TR	TR	ND	ND	ND	ND	ND
	Staghorn sculpin							
	(muscle)	TR	TR	ND	ND	ND	ND	ND
	(liver)	100	74	ND	ND	ND	ND	ND
	Prickly sculpin							
	(muscle)	74	10	ND	ND	ND	ND	ND
	(liver)	300	96	ND	ND	ND	ND	ND
off Later's Chemicals Site No. 46 Figure 1	Sediment	TR (TR-TR)	10+4 (TR-15)	ND (ND-ND)	ND (ND-TR)	ND (ND-ND)	ND (ND-ND)	ND (ND-TR)
	Water	TR	0.2	ND	ND	ND	ND	0.006
Site No. 27 Figure 2	Biota:							
	Staghorn sculpin							
	(muscle)	5	8	ND	ND	ND	ND	ND
	(liver)	470	480	ND	ND	ND	ND	ND
	Prickly sculpin							
	(muscle)	12	5	ND	ND	ND	ND	ND
	(liver)	TR	82	ND	ND	ND	ND	TR

1 = sediment and tissue concentrations reported as ppb dry weight and ppb wet weight, respectively
ND = not detectable
TR = trace concentration

APPENDIX 2.4 LEVELS OF ORGANIC CONTAMINANTS IN THE SOILS, SEDIMENTS AND DRAINAGE WATER FROM LATER CHEMICALS' YARD AREA (62)

TABLE A

	Soils/Sediments (ppm dry weight)		Water (ppb)	
	Yard Area	Ditches	Yard Area	Ditches
PCB's	L0.005	L0.005	L0.05	L0.05
HCB	L0.005	L0.005	4.2	120.0
Lindane	13.0	13.0	77.0	560.0
Heptachlor	110.0	110.0	6.5	300.0
Aldrin	130.0	120.0	4.2	820.0
Alpha-Chlordane	420.0	390.0	11.0	5900.0
Gamma-Chlordane	650.0	630.0	5.3	3600.0
Dieldrin	66.0	21.0	5.8	1800.0
DDD	1100.0	940.0	TR	3500.0
DDT	2100.0	1900.0	25.0	1700.0
Methoxyclor	90.0	15.0	13.0	4500.0
Pentachlorophenol	L0.05	L0.05	L0.05	L0.05
Tetrachlorophenols	2.0	0.36	120.0	300.0
Trichlorophenols	0.18	0.09	190.0	150.0
2,4-D	1000.0	21.0	630.0	5400.0
Picloram	99.0	L0.2	430.0	4100.0

TR = trace
L = "less than"
NOTE:- The following organochloride pesticides were not detected: DDE, Mirex, Endrin and Alpha and Beta Endosulfan.
- The following herbicides were not detected: 2,4,5-T and Silvex.

APPENDIX 2.4 (CONT'D)

LEVELS OF ORGANIC CONTAMINANTS IN THE SOILS, SEDIMENTS AND DRAINAGE WATER FROM LATER CHEMICALS' YARD AREA (65)

TABLE B - Sediments (ppm dry weight)

	Testhole 1			Testhole 2				Testhole 3				
	0-10"	10-20"	20-30"	0-10"	10-20"	20-30"	30-40"	0-8"	8-14"	14-20"	20-30"	30-40"
Methoxychlor	ND	ND	ND	0.23	ND	ND	ND	54.00	20.60	6.40	0.05	0.01
Lindane	ND	0.38	ND	0.40	0.02	0.23	ND	84.84	30.00	15.00	0.05	0.02
Chlordane	2.63	12.11	ND	1.59	0.15	1.58	0.40	193.60	54.90	19.00	0.10	0.05
Heptachlor	0.52	ND	ND	0.19	ND	ND	ND	ND	ND	ND	ND	ND
Aldrin	2.41	0.56	0.01	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dieldrin	ND	0.40	ND	1.07	ND	ND	ND	5.00	1.20	1.40	ND	ND
o,p'-DDT	ND	ND	ND	0.25	ND	ND	ND	10.20	3.00	1.00	ND	ND
p,p'-DDT	2.97	6.61	0.02	1.02	0.05	0.10	0.02	41.30	5.30	1.80	ND	ND
DDE	ND	0.90	ND	0.13	ND	ND	ND	8.60	1.70	1.60	ND	ND
DDD	ND	2.10	0.01	0.11	ND	0.05	ND	17.30	4.50	1.60	ND	ND

ND = not detectable

APPENDIX 3

LEVELS OF ORGANIC CONTAMINANTS IN FISH FROM THE FRASER RIVER/ESTUARY

a) Pesticides

b) Industrial Contaminants

APPENDIX 3 LEVELS OF ORGANIC CONTAMINANTS IN FISH FROM THE FRASER RIVER/ESTUARY (refer to Figure 3)
a) Pesticides (ppb wet weight) [Mean ± S.D.(Range)]

Location	No. of Samples	Species	p,p-DDT	p,p-DDE	p,p-DDD	Aldrin	Dieldrin	Alpha-Chlordane	Gamma-Chlordane	Heptachlor Epoxide	Lindane
Fraser River - North Arm											
Stn. 10	1	Peamouth Chub	ND	85.9	ND	-	ND	-	-	ND	-
Stn. 11	3	Rainbow Trout	ND (ND-ND)	34.5+28.5 (TR-54.9)	ND (ND-ND)	-	ND (ND-ND)	-	-	4.9+6.7 (ND-12.6)	-
Stn. 15	4	Largescale sucker	4.2+5.8 (ND-12.9)	7.2+6.6 (TR-16.9)	ND (ND-ND)	-	ND (ND-ND)	-	-	ND (ND-ND)	-
	1	Dolly varden	ND	17.5	ND	-	ND	-	-	ND	-
	2	White sturgeon	ND (ND-ND)	22.9+27.5 (3.4+42.3)	ND (ND-ND)	-	ND (ND-ND)	-	-	4.6+5.2 (ND-8.3)	-
	2	Rainbow trout	TR (TR-TR)	7.4+0.8 (6.8-8.0)	1.5+0.7 (ND-TR)	-	ND (ND-TR)	-	-	3.7+3.9 (ND-6.5)	-
	2	Northern squawfish	ND (ND-ND)	238.3+281.1 (39.5-437.1)	1.5+0.7 (ND-TR)	-	ND (ND-ND)	-	-	4.8+5.4 (ND-8.6)	-
	1	Carp	ND	1739.6	TR	-	ND	-	-	ND	-
Fraser River - North Arm (Stations 10, 11, 15)	2	Staghorn sculpin	ND (ND-ND)	1.5+1.8 (ND-2.8)	1.7+0.2 (1.5-1.8)	ND (ND-ND)	ND (ND-ND)	ND (ND-ND)	TR (TR-TR)	ND (ND-ND)	TR (TR-TR)
	2	Northern squawfish	7.1+9.7 (ND-14.0)	42.0+7.1 (37.0-47.0)	11.5+2.1 (10.0-13.0)	1.8+2.2 (ND-3.4)	ND (ND-ND)	0.6+0.5 (ND-1.0)	ND (ND-ND)	ND (ND-ND)	0.7+0.6 (ND-1.1)
	3	Dolly varden	19.7+17.8 (ND-35.0)	0.9+1.2 (ND-2.3)	22.7+17.5 (4.2-39.0)	0.5+0.5 (ND-1.1)	ND (ND-ND)	4.5+3.7 (ND-7.0)	5.4+4.5 (ND-8.1)	ND (ND-ND)	7.2+12.0 (ND-21.0)
	2	Largescale sucker	8.1+5.5 (4.2-12.0)	6.0+1.3 (5.0-6.9)	6.0+1.7 (4.8-7.2)	ND (ND-ND)	ND (ND-ND)	0.4+0.2 (ND-TR)	ND (ND-ND)	ND (ND-ND)	TR (TR-TR)
	2	Peamouth chub	ND (ND-ND)	37.0+25.5 (19.0-55.0)	13.3+5.3 (9.5-17.0)	ND (ND-ND)	ND (ND-ND)	2.0+1.3 (1.1-3.0)	4.5+4.0 (1.6-7.3)	ND (ND-ND)	0.8+0.8 (ND-1.4)
	2	White sturgeon	ND (ND-ND)	51.0+4.2 (48.0-54.0)	4.3+5.7 (ND-8.3)	ND (ND-ND)	ND (ND-ND)	ND (ND-ND)	ND (ND-ND)	1.6+0.21 (1.4-1.7)	TR (TR-TR)
	2	Cutthroat trout	ND (ND-ND)	25.0+26.9 (6.0-44.0)	4.7+6.3 (ND-9.2)	ND (ND-ND)	ND (ND-ND)	0.6+0.5 (ND-1.0)	ND (ND-ND)	1.2+1.0 (TR-1.9)	0.44+0.1 (0.37-0.50)
	5	Black crappie	2.8+4.5 (ND-10.6)	7.6+7.4 (ND-20.0)	6.8+9.6 (ND-23.5)	ND (ND-ND)	ND (ND-ND)	0.6+0.4 (ND-1.2)	0.7+0.6 (ND-1.8)	0.4+0.1 (ND-TR)	0.4+0.1 (ND-TR)
Fraser River - South Arm											
Stn. 12	9	White sturgeon	1.3+0.5 (ND-TR)	15.1+15.0 (ND-47.4)	1.3+0.5 (ND-TR)	-	1.1+0.3 (ND-TR)	-	-	4.5+5.7 (ND-14.9)	-
	3	Largescale sucker	ND (ND-ND)	12.8+20.5 (ND-36.5)	ND (ND-ND)	-	ND (ND-ND)	-	-	ND (ND-ND)	-

APPENDIX 3 (CONT'D)

LEVELS OF ORGANIC CONTAMINANTS IN FISH FROM THE FRASER RIVER/ESTUARY (refer to Figure 3)
a) Pesticides (ppb wet weight) [Mean ± S.D.(Range)]

Location	No. of Samples	Species	p,p-DDT	p,p-DDE	p,p-DDD	Aldrin	Dieldrin	Alpha-Chlordane	Gamma-Chlordane	Heptachlor Epoxide	Lindane
Fraser River - South Arm											
Stn. 12	2	Northern squawfish	ND (ND-ND)	73.3+31.0 (51.4-95.2)	TR (TR-TR)	-	ND (ND-ND)	-	-	47.0-56.0 (7.4-86.6)	-
	2	Chinook salmon	1.5+0.7 (ND-TR)	12.3+4.6 (9.0-15.5)	ND (ND-ND)	-	ND (ND-ND)	-	-	2.6+2.3 (ND-4.3)	-
	5	Sockeye salmon	ND (ND-ND)	ND (ND-ND)	ND (ND-ND)	-	ND (ND-ND)	-	-	ND (ND-ND)	-
	2	Cutthroat trout	1.5+0.7 (ND-TR)	25.3+5.9 (21.1-29.4)	1.5+0.7 (ND-TR)	-	ND (ND-ND)	-	-	5.0+5.7 (ND-9.0)	-
	2	Peamouth chub	ND (ND-ND)	36.0+48.0 (TR-69.9)	ND (ND-ND)	-	ND (ND-ND)	-	-	ND (ND-ND)	-
Stn. 13	4	Northern squawfish	ND (ND-ND)	36.4+43.4 (3.8-99.9)	ND (ND-ND)	-	ND (ND-ND)	-	-	ND (ND-ND)	-
	1	Rainbow trout	ND	20.0	ND	-	ND	-	-	ND	-
Stn. 14	3	Largescale sucker	1.3+0.6 (ND-TR)	ND (ND-ND)	ND (ND-ND)	-	ND (ND-ND)	-	-	ND (ND-ND)	-
	5	Northern squawfish	1.2+0.4 (ND-TR)	85.0+56.7 (8.8-151.7)	ND (ND-ND)	-	ND (ND-ND)	-	-	ND (ND-ND)	-
	2	White sturgeon	ND (ND-ND)	12.2+15.9 (ND-23.5)	ND (ND-ND)	-	ND (ND-ND)	-	-	ND (ND-ND)	-
Fraser River - South Arm (Stations 12, 13, 14)	5	Staghorn sculpin	4.7+6.1 (ND-11.8)	0.8+0.5 (ND-1.4)	3.1+3.8 (ND-9.2)	ND (ND-ND)	ND (ND-ND)	1.8+2.5 (ND-5.9)	ND (ND-ND)	ND (ND-ND)	1.0+0.8 (TR-2.4)
	4	Northern squawfish	ND (ND-ND)	192.5+138.9 (110.0-400.0)	28.1+12.4 (14.0-39.0)	1.8+1.9 (ND-4.0)	ND. (ND-ND)	ND (ND-ND)	ND (ND-ND)	ND (ND-ND)	0.5+0.4 (ND-1.1)
	3	Dolly varden	45.3+32.0 (19.0-81.0)	29.9+24.6 (8.8-57.0)	30.7+11.6 (23.0-44.0)	ND (ND-ND)	ND (ND-ND)	4.6+4.2 (ND-8.7)	4.8+1.9 (2.8-6.5)	ND (ND-ND)	0.7+0.7 (ND-1.5)
	2	Largescale sucker	3.0+1.3 (2.0-3.9)	76.5+89.8 (13.0-140.0)	12.8+8.8 (6.5-19.0)	ND (ND-ND)	ND (ND-ND)	0.4+0.2 (ND-TR)	0.4+0.2 (ND-TR)	ND (ND-ND)	0.9+0.6 (TR-1.3)
	2	Peamouth chub	ND (ND-ND)	68.5+3.5 (66.0-71.0)	27.0+2.8 (25.0-29.0)	ND (ND-ND)	ND (ND-ND)	3.3+0.7 (2.8-3.8)	4.6+1.1 (3.8-5.3)	ND (ND-ND)	ND (ND-ND)
	2	White sturgeon	ND (ND-ND)	71.0+55.1 (32.0-110.0)	4.2+4.0 (1.3-7.0)	ND (ND-ND)	ND (ND-ND)	0.4+0.2 (ND-TR)	ND (ND-ND)	ND (ND-ND)	TR (TR-TR)
	2	Rainbow trout	3.6+4.7 (ND-8.9)	14.5+4.9 (11.0-18.0)	1.7+1.6 (TR-2.8)	ND (ND-ND)	ND (ND-ND)	0.4+0.2 (ND-TR)	0.4+0.2 (ND-ND)	ND (ND-ND)	TR (TR-TR)

APPENDIX 3 (CONT'D)

LEVELS OF ORGANIC CONTAMINANTS IN FISH FROM THE FRASER RIVER/ESTUARY (refer to Figure 3)
a) Pesticides (ppb wet weight) [Mean ± S.D.(Range)]

Location	No. of Samples	Species	p,p-DDT	p,p-DDE	p,p-DDD	Aldrin	Dieldrin	Alpha-Chlordane	Gamma-Chlordane	Heptachlor Epoxide	Lindane
Fraser River - Upper Estuary											
Stn. 16	1	White sturgeon	ND	10.6	ND	-	ND	-	-	ND	-
	1	Peamouth chub	ND	33.4	ND	-	ND	-	-	ND	-
	5	Rainbow trout	1.4+0.5 (ND-TR)	25.1+20.7 (ND-39.8)	1.4+0.5 (ND-TR)	-	ND (ND-ND)	-	-	12.7+21.5 (ND-44.9)	-
	4	Cutthroat trout	1.7+0.5 (ND-TR)	20.1+19.1 (ND-43.5)	1.7+0.5 (ND-TR)	-	1.5+0.6 (ND-TR)	-	-	5.1+6.0 (ND-13.7)	-
Stn. 17	1	Mountain whitefish	ND	TR	ND	-	ND	-	-	ND	-
	1	White sturgeon	ND	21.8	ND	-	ND	-	-	ND	-
	1	Largescale sucker	ND	ND	ND	-	ND	-	-	ND	-
	1	Northern squawfish	ND	329.3	ND	-	ND	-	-	ND	-
	1	Peamouth chub	ND	34.7	ND	-	ND	-	-	ND	-
Fraser River - Upper Estuary (Stns. 16 & 17)	2	Northern squawfish	ND (ND-ND)	38.5+29.0 (18.0-59.0)	8.7+1.1 (7.9-9.4)	ND (ND-ND)	ND (ND-ND)	ND (ND-ND)	ND (ND-ND)	ND (ND-ND)	0.4+0.2 (ND-TR)
	2	Largescale sucker	22.5+21.9 (7.0-38.0)	52.0+2.8 (50.0-54.0)	30.5+16.3 (19.0-42.0)	ND (ND-ND)	ND (ND-ND)	3.3+1.1 (2.5-4.0)	4.3+2.0 (2.9-5.7)	ND (ND-ND)	2.4+0.7 (1.9-2.9)
	2	Peamouth chub	ND (ND-ND)	45.0+29.7 (24.0-66.0)	10.4+14.3 (ND-20.5)	ND (ND-ND)	ND (ND-ND)	2.1+2.6 (ND-3.9)	5.1+6.9 (ND-10.0)	ND (ND-ND)	ND (ND-ND)
	3	White sturgeon	0.3+0.1 (ND-TR)	8.9+10.8 (ND-21.0)	3.7+3.9 (1.4-8.2)	ND (ND-ND)	ND (ND-ND)	0.8+0.9 (ND-1.8)	0.6+0.7 (ND-1.4)	0.9+0.7 (0.4-1.7)	0.7+0.4 (0.4-1.1)
Chilliwack Area											
Stn. 18	3	Rainbow trout	ND (ND-ND)	9.2+7.2 (ND-14.5)	ND (ND-ND)	-	ND (ND-ND)	-	-	ND (ND-ND)	-
	1	Largescale sucker	ND	ND	ND	-	ND	-	-	ND	-
	1	Peamouth chub	ND	37.3	ND	-	ND	-	-	ND	-
Stn. 19	2	Northern squawfish	ND (ND-ND)	36.4+35.2 (11.5-61.3)	ND (ND-ND)	-	ND (ND-ND)	-	-	ND (ND-ND)	-
		Rainbow trout	1.3+0.5 (ND-TR)	5.8+3.4 (ND-9.9)	1.5+0.5 (ND-TR)	-	ND (ND-ND)	-	-	3.5+4.1 (ND-10.7)	-
	1	White sturgeon	ND	ND	ND	-	ND	-	-	ND	-
	2	Largescale sucker	ND (ND-ND)	7.9+9.8 (ND-14.9)	ND (ND-ND)	-	ND (ND-ND)	-	-	5.0+5.7 (ND-9.1)	-

APPENDIX 3 LEVELS OF ORGANIC CONTAMINANTS IN FISH FROM THE FRASER RIVER/ESTUARY (refer to Figure 3)
a) Pesticides (ppb wet weight) [Mean ± S.D.(Range)]

Location	No. of Samples	Species	p,p-DDT	p,p-DDE	p,p-DDD	Aldrin	Dieldrin	Alpha-Chlordane	Gamma-Chlordane	Heptachlor Epoxide	Lindane
Chilliwack Area											
Stn. 19	1	Dolly varden	ND	19.5	ND	-	ND	-	-	ND	-
Stn. 20	1	Largescale sucker	ND	ND	ND	-	ND	-	-	ND	-
	2	Northern squawfish	ND (ND-ND)	37.2+31.5 (14.9-59.4)	ND (ND-ND)	-	ND (ND-ND)	-	-	ND (ND-ND)	-
	4	Rainbow trout	ND (ND-ND)	32.1+25.4 (6.9-59.5)	ND (ND-ND)	-	ND (ND-ND)	-	-	ND (ND-ND)	-
	1	Cutthroat trout	ND	14.4	ND	-	ND	-	-	ND	-
	1	Mountain whitefish	ND	20.3	ND	-	ND	-	-	ND	-
	2	Peamouth chub	ND (ND-ND)	32.1+14.1 (22.1-42.1)	ND (ND-ND)	-	ND (ND-ND)	-	-	ND (ND-ND)	-
Fraser River - Chilliwack Area Stns. 18, 19 & 20)	1	Staghorn sculpin	2.4	7.6	6.2	ND	ND	ND	ND	ND	2.0
	2	Northern squawfish	ND (ND-ND)	1.8+2.2 (ND-3.4)	0.7+0.6 (ND-1.1)	ND (ND-ND)	ND (ND-ND)	ND (ND-ND)	ND (ND-ND)	0.3+3.1 (ND-0.4)	0.4+0.2 (ND-TR)
	3	Dolly varden	7.6+6.6 (ND-13.0)	25.2+21.9 (1.7-45.0)	14.9+9.6 (9.1-26.0)	ND (ND-ND)	ND (ND-ND)	2.8+4.5 (ND-8.0)	ND (ND-ND)	ND (ND-ND)	1.1+0.8 (ND-1.8)
	2	Largescale sucker	32.1+45.1 (ND-64.0)	13.6+14.7 (3.2-24.0)	36.1+43.8 (5.1-67.0)	ND (ND-ND)	ND (ND-ND)	ND (ND-ND)	ND (ND-ND)	ND (ND-ND)	0.4+0.2 (ND-TR)
	2	Peamouth chub	ND (ND-ND)	75.0+26.9 (56.0-94.0)	6.1+8.3 (ND-12.0)	ND (ND-ND)	ND (ND-ND)	ND (ND-ND)	5.6+7.6 (ND-11.0)	ND (ND-ND)	ND (ND-ND)
	4	Cutthroat trout	ND (ND-ND)	26.5+22.3 (6.1-51.5)	6.5+5.2 (1.3-13.0)	ND (ND-ND)	ND (ND-ND)	0.6+0.4 (ND-1.1)	ND (ND-ND)	1.1+0.9 (TR-2.4)	0.8+0.6 (TR-1.6)
	3	White sturgeon	ND (ND-ND)	51.3+21.5 (30.0-73.0)	8.1+9.7 (ND-19.0)	ND (ND-ND)	ND (ND-ND)	1.5+1.7 (TR-3.5)	2.2+3.3 (ND-6.0)	0.6+0.4 (ND-1.0)	TR (TR-TR)
	1	Black crappie	ND	3.8	2.7	ND	ND	TR	ND	TR	1.9
	2	Rainbow trout	0.3+0.1 (ND-0.4)	0.3+0.1 (ND-0.4)	3.8+0.4 (3.5-4.0)	ND (ND-ND)	ND (ND-ND)	TR (TR-TR)	0.7+0.7 (ND-1.2)	ND (ND-ND)	0.8+0.6 (0.4-1.2)
Fraser River - Hope Area Stn. 21	6	Northern squawfish	ND (ND-ND)	48.4+59.1 (ND-149.7)	ND (ND-ND)	-	ND (ND-ND)	-	-	ND (ND-ND)	-
	1	Largescale sucker	ND	ND	ND	-	ND	-	-	ND	-
	2	Mountain whitefish	ND (ND-ND)	28.9+2.0 (27.5-30.3)	ND (ND-ND)	-	ND (ND-ND)	-	-	ND (ND-ND)	-

APPENDIX 3 (CONT'D)

LEVELS OF ORGANIC CONTAMINANTS IN FISH FROM THE FRASER RIVER/ESTUARY (refer to Figure 3)
a) Pesticides (ppb wet weight) [Mean ± S.D.(Range)]

Location	No. of Samples	Species	p,p-DDT	p,p-DDE	p,p-DDD	Aldrin	Dieldrin	Alpha-Chlordane	Gamma-Chlordan	Heptachlor Epoxide	Lindane
Fraser River - Hope Area											
Stn. 21	1	Peamouth chub	ND	49.6	ND	-	ND	-	-	ND	-
	3	White sturgeon	ND (ND-ND)	18.1+4.2 (15.0-22.9)	ND (ND-ND)	-	ND (ND-ND)	-	-	ND (ND-ND)	-
Stn. 22	3	Northern squawfish	ND (ND-ND)	9.9+7.8 (TR-17.6)	ND (ND-ND)	-	ND (ND-ND)	-	-	2.3+2.3 (ND-5.0)	-
	1	Largescale sucker	ND	9.6	ND	-	ND	-	-	ND	-
	1	Brown bullhead	ND	3.3	ND	-	ND	-	-	ND	-
	1	Carp	ND	53.5	ND	-	ND	-	-	ND	-
	8	Rainbow trout	1.1+0.4 (ND-TR)	20.6+18.0 (ND-48.8)	ND (ND-ND)	-	ND (ND-ND)	-	-	ND (ND-ND)	-
	3	Peamouth chub	ND (ND-ND)	44.4+18.1 (26.7-62.8)	ND (ND-ND)	-	ND (ND-ND)	-	-	ND (ND-ND)	-
Stn. 23	17	Northern squawfish	ND (ND-ND)	56.2+47.2 (TR-164.3)	ND (ND-ND)	-	ND (ND-ND)	-	-	ND (ND-ND)	-
	16	Largescale sucker	1.1+0.3 (ND-TR)	11.1+15.1 (ND-55.3)	1.2+0.4 (ND-TR)	-	1.1+0.3 (ND-TR)	-	-	4.8+7.2 (ND-26.5)	-
	2	Rainbow trout	ND (ND-ND)	6.3+7.6 (ND-11.7)	ND (ND-ND)	-	ND (ND-ND)	-	-	ND (ND-ND)	-
	1	Cutthroat trout	ND	ND	ND	-	ND	-	-	ND	-
	4	Mountain whitefish	ND (ND-ND)	56.3+48.9 (7.0-100.3)	ND (ND-ND)	-	ND (ND-ND)	-	-	ND (ND-ND)	-
	2	Peamouth chub	ND (ND-ND)	106.0+68.5 (57.5-154.4)	ND (ND-ND)	-	ND (ND-ND)	-	-	ND (ND-ND)	-
	4	White sturgeon	ND (ND-ND)	37.6+3.8 (31.9-40.0)	ND (ND-ND)	-	ND (ND-ND)	-	-	ND (ND-ND)	-
Stns. 21, 22 & 23	2	Northern squawfish	15.1+21.0 (ND-30.0)	65.1+91.7 (ND-130.0)	34.6+48.6 (ND-69.0)	ND (ND-ND)	ND (ND-ND)	ND (ND-ND)	ND (ND-ND)	ND (ND-ND)	ND (ND-ND)
	1	Dolly varden	39.0	54.0	52.0	ND	ND	11.0	ND	ND	2.2
	2	Largescale sucker	100.0+127.3 (10.0-190.0)	65.8+56.2 (26.0-105.5)	70.5+84.1 (11.0-130.0)	ND (ND-ND)	ND (ND-ND)	1.3+1.4 (ND-2.3)	1.7+0.5 (1.3-2.0)	ND (ND-ND)	6.9+9.4 (ND-13.5)
	2	Peamouth chub	ND (ND-ND)	22.8+5.3 (19.0-26.5)	11.4+15.7 (ND-22.5)	ND (ND-ND)	ND (ND-ND)	0.3+0.1 (ND-0.41)	ND (ND-ND)	ND (ND-ND)	ND (ND-ND)
	4	Cutthroat trout	53.+7.9 (ND-17.0)	14.4+5.2 (8.5-21.0)	8.9+5.3 (2.1-14.0)	ND (ND-ND)	ND (ND-ND)	1.4+0.9 (ND-2.3)	1.6+1.1 (ND-2.7)	0.6+0.3 (TR-1.0)	0.8+0.6 (ND-1.6)
	2	Rainbow trout	ND (ND-ND)	10.5+0.7 (10.0-11.0)	1.5+0.1 (1.4-1.6)	ND (ND-ND)	ND (ND-ND)	TR (TR-TR)	ND (ND-ND)	TR (TR-TR)	04+0.2 (ND-TR)
Sturgeon Bank											
Stn. 2	compo-site	Speckled sanddab	ND	TR	ND	-	ND	-	-	ND	-

APPENDIX 3 LEVELS OF ORGANIC CONTAMINANTS IN FISH FROM THE FRASER RIVER/ESTUARY (refer to Figure 3)

b) Industrial Contaminants (ppb wet weight) [Mean ± S.D. (Range)]

Location	No. of Samples	Species	PCBs	HCB	Chlorinated Phenols	
					Tetra-	Penta-
Fraser River - North Arm[1]						
Stn. 10	1	Peamouth chub	527.3	-	-	-
Stn. 11	3	Rainbow trout	116.5±171.8 (TR-314.1)	-	-	-
Stn. 15	4	Largescale sucker	90.8±104.2 (ND-198.7)	-	-	-
	1	Dolly varden	ND	-	-	-
	2	White sturgeon	167.3±43.1 (136.9-197.8)	-	-	-
	2	Rainbow trout	128.9±90.6 (64.8-192.9)	-	-	-
	2	Northern squawfish	1039.8±867.1 (426.7-1652.9)	-	-	-
	1	Carp	933.9	-	-	-

APPENDIX 3 (CONT'D)

LEVELS OF ORGANIC CONTAMINANTS IN FISH FROM THE FRASER RIVER/ESTUARY (refer to Figure 3)

b) Industrial Contaminants (ppb wet weight) [Mean ± S.D. (Range)]

Location	No. of Samples	Species	PCBs	HCB	Chlorinated Phenols	
					Tetra-	Penta-
Fraser River - North Arm[2] Stns. 10, 11, & 15	2	Staghorn sculpin	54.5+9.2 (48.0-61.0)	8.0+7.1 (3.0-13.0)	45.0+24.0 (28.0-62.0)	48.8+15.9 (37.5-60.0)
	2	Northern squawfish	404.0+519.0 (37.0-771.0)	4.5+2.4 (2.9-6.3)	10.5+9.9 (ND-18.0)	10.8+13.1 (1.5-20.0)
	3	Dolly varden	68.3 +55.5 (11.0-122.0)	5.2+2.8 (2.0-6.9)	ND (ND-ND)	38.0+16.5 (22.0-55.0)
	2	Largescale sucker	44.0 + 31.1 (22.0-66.0)	2.0+0.6 (1.6-2.4)	ND (ND-ND)	43.0+18.4 (30.0-56.0)
	2	Peamouth chub	123.0+111.7 (44.0-202.0)	1.6+1.5 (TR-2.6)	ND (ND-ND)	ND (ND-ND)
	2	White sturgeon	162.0+42.4 (132.0-192.0)	8.3+3.8 (5.6-11.0)	ND (ND-ND)	ND (ND-ND)
	2	Cutthroat trout	468.5+392.4 (191.0-746.0)	9.9+10.0 (2.8-17.0)	ND (ND-ND)	ND (ND-ND)

APPENDIX 3 (CONT'D)

LEVELS OF ORGANIC CONTAMINANTS IN FISH FROM THE FRASER RIVER/ESTUARY (refer to Figure 3)

b) Industrial Contaminants (ppb wet weight) [Mean ± S.D. (Range)]

Location	No. of Samples	Species	PCBs	HCB	Chlorinated Phenols	
					Tetra-	Penta-
Fraser River - North Arm[2] Stns. 10, 11, & 15	5	Black crappie	13.4+12.7 (ND-31.1)	3.3+2.4 (1.3-7.4)	ND (ND-ND)	2.7+0.5 (ND-TR)
Fraser River - South Arm[1] Stn. 12	9	White sturgeon	165.6+111.6 (ND-317.7)	-	-	-
	3	Largescale sucker	162.7+111.2 (ND-250.6)	-	-	-
	2	Northern squawfish	755.4+209.0 (607.6-903.2)	-	-	-
	2	Chinook salmon	(83.5-90.1)	-	-	-
	5	Sockeye salmon	ND (ND-ND)	-	-	-
	2	Cutthroat trout	118.6+23.8 (101.7-135.4)	-	-	-

APPENDIX 3 (CONT'D)

LEVELS OF ORGANIC CONTAMINANTS IN FISH FROM THE FRASER RIVER/ESTUARY (refer to Figure 3)

b) Industrial Contaminants (ppb wet weight) [Mean ± S.D. (Range)]

Location	No. of Samples	Species	PCBs	HCB	Chlorinated Phenols	
					Tetra-	Penta-
Stn. 12	3	Peamouth chub	91.5+156.7 (ND-272.4)	-	-	-
Stn. 13	4	Northern squawfish	122.0+240.8 (ND-483.2)	-	-	-
	1	Rainbow trout	138.8	-	-	-
Stn. 14	3	Largescale sucker	171.5+147.7 (ND-259.4)	-	-	-
	5	Northern squawfish	748.4+666.7 (204.1-1894.4)	-	-	-
	1	White Sturgeon	143.8 (ND-286.7)	-	-	-
Fraser River - South Arm[2] Stns. 12, 13 & 14	5	Staghorn sculpin	171.4+189.7 (22.0-495.0)	3.6+1.2 (2.4-4.8)	16.8+14.5 (TR-37.0)	70.9+34.9 (39.0-125.0)
	4	Northern squawfish	153.0+155.0 (40.0-382.0)	7.9+3.5 (4.9-13.0)	ND (ND-ND)	22.8+6.8 (15.0-29.0)

APPENDIX 3 (CONT'D)

LEVELS OF ORGANIC CONTAMINANTS IN FISH FROM THE FRASER RIVER/ESTUARY (refer to Figure 3)

b) Industrial Contaminants (ppb wet weight) [Mean ± S.D. (Range)]

Location	No. of Samples	Species	PCBs	HCB	Chlorinated Phenols	
					Tetra-	Penta-
Stns. 12, 13 & 14	3	Dolly varden	127.6+128.4 (26.0-272.0)	6.1+1.1 (4.8-6.9)	ND (ND-ND)	31.7+6.7 (26.0-39.0)
	2	Largescale sucker	166.5+177.5 (41.0-292.0)	1.9+1.9 (TR-3.2)	ND (ND-ND)	ND (ND-ND)
	2	Peamouth chub	132.0 (132.0-132.0)	6.2+2.1 (4.7-7.7)	ND (ND-ND)	ND (ND-ND)
	2	White sturgeon	372.0+212.1 (222.0-522.0)	7.2+5.4 (3.4-11.0)	ND (ND-ND)	ND (ND-ND)
	2	Rainbow trout	72.3+93.0 (9.5-141.0)	1.4+0.4 (1.1-1.7)	ND (ND-ND)	3.1+0.8 (ND-3.7)
Fraser River - Upper Estuary[1] Stn. 16	1	White sturgeon	ND	-	-	-
	1	Peamouth chub	ND	-	-	-
	5	Rainbow trout	143.4+93.4 (58.2-192.8)	-	-	-
	4	Cutthroat trout	128.2+56.9 (77.1-208.5)	-	-	-

APPENDIX 3 (CONT'D)

LEVELS OF ORGANIC CONTAMINANTS IN FISH FROM THE FRASER RIVER/ESTUARY (refer to Figure 3)

b) Industrial Contaminants (ppb wet weight) [Mean ± S.D. (Range)]

Location	No. of Samples	Species	PCBs	HCB	Chlorinated Phenols	
					Tetra-	Penta-
Stn. 17	1	Mountain whitefish	ND	-	-	-
	1	White sturgeon	ND	-	-	-
	1	Largescale sucker	623.4	-	-	-
	1	Northern squawfish	ND	-	-	-
	1	Peamouth chub	ND	-	-	-
Fraser River - Upper Estuary[2] Stns. 16 & 17	2	Northern squawfish	227.0+213.5 (76.0-378.0)	3.3+0.1 (3.2-3.3)	ND (ND-ND)	27.0+1.4 (26.0-28.0)
	2	Largescale sucker	150.0+87.7 (88.0-212.0)	5.5+1.8 (4.2-6.8)	ND (ND-ND)	3.7+1.8 (ND-TR)
	2	Peamouth chub	297.0+154.1 (188.0-406.0)	1.6 +1.6 (TR-2.7)	ND (ND-ND)	5.5+4.2 (ND-8.5)
	3	White sturgeon	58.0+14.0 (42.0-68.0)	4.4+2.4 (1.9-6.6)	ND (ND-ND)	ND (ND-ND)

APPENDIX 3 (CONT'D)

LEVELS OF ORGANIC CONTAMINANTS IN FISH FROM THE FRASER RIVER/ESTUARY (refer to Figure 3)

b) Industrial Contaminants (ppb wet weight) [Mean ± S.D. (Range)]

Location	No. of Samples	Species	PCBs	HCB	Chlorinated Phenols	
					Tetra-	Penta-
Fraser River - Chilliwack Area[1]						
Stn. 18	3	Rainbow trout	ND (ND-ND)	-	-	-
	1	Largescale sucker	3694.9	-	-	-
	1	Peamouth chub	ND	-	-	-
Stn. 19	2	Northern squawfish	84.2±117.7 (ND-167.5)	-	-	-
	11	Rainbow trout	67.5±37.3 (ND-106.2)	-	-	-
	1	White sturgeon	ND	-	-	-
	2	Largescale sucker	147.5±207.2 (ND-294.0)	-	-	-
	1	Dolly varden	164.3	-	-	-
Stn. 20	1	Largescale sucker	ND	-	-	-
	2	Northern squawfish	ND (ND-ND)	-	-	-

APPENDIX 3 (CONT'D)

LEVELS OF ORGANIC CONTAMINANTS IN FISH FROM THE FRASER RIVER/ESTUARY (refer to Figure 3)

b) Industrial Contaminants (ppb wet weight) [Mean ± S.D. (Range)]

Location	No. of Samples	Species	PCBs	HCB	Chlorinated Phenols	
					Tetra-	Penta-
Stn. 20	4	Rainbow trout	TR (ND-TR)	-	-	-
	1	Cutthroat trout	ND	-	-	-
	1	Mountain whitefish	ND	-	-	-
	2	Peamouth chub	ND (ND-ND)	-	-	-
Fraser River - Chilliwack Area[2] Stns. 18, 19 and 20	2	Peamouth chub	267.0+79.2 (211.0-323.0)	4.5+2.7 (2.6-6.4)	ND (ND-ND)	ND (ND-ND)
	4	Cutthroat trout	131.3+111.8 (4.0-276.0)	6.0+3.4 (2.3-9.0)	ND (ND-ND)	ND (ND-ND)
	3	White sturgeon	126.0+25.5 (108.0-144.0)	9.1+8.6 (3.1-19.0)	ND (ND-ND)	ND (ND-ND)
	1	Black crappie	11.9	5.5	ND	ND

APPENDIX 3 (CONT'D)

LEVELS OF ORGANIC CONTAMINANTS IN FISH FROM THE FRASER RIVER/ESTUARY (refer to Figure 3)

b) Industrial Contaminants (ppb wet weight) [Mean ± S.D. (Range)]

Location	No. of Samples	Species	PCBs	HCB	Chlorinated Phenols	
					Tetra-	Penta-
	2	Rainbow trout	181.5+19.1 (168.0-195.0)	1.9+0.2 (1.7-2.0)	ND (ND-ND)	ND (ND-ND
	1	Staghorn sculpin	ND	4.8	22.0	82.0
	2	Northern squawfish	153.5+187.4 (21.0-286.0)	2.6+0.4 (2.3-2.8)	ND (ND-ND)	17.5+4.9 (14.0-21.0)
	3	Dolly varden	27.0-20.8 (15.0-51.0)	3.9+3.5 (1.4-7.9)	ND (ND-ND)	32.7+14.4 (20.5-48.5)
	2	Largescale sucker	36.5+48.8 (TR-71.0)	3.1+2.5 (1.3-4.9)	ND (ND-ND)	2.7+0.5 (ND-TR)
Fraser River - Hope Area[1] Stn. 21	6	Northern squawfish	TR (ND-TR)	-	-	-
	1	Largescale sucker	ND	-	-	-
	2	Mountain whitefish	ND (ND-ND)	-	-	-

APPENDIX 3 (CONT'D)

LEVELS OF ORGANIC CONTAMINANTS IN FISH FROM THE FRASER RIVER/ESTUARY (refer to Figure 3)

b) Industrial Contaminants (ppb wet weight) [Mean ± S.D. (Range)]

Location	No. of Samples	Species	PCBs	HCB	Chlorinated Phenols	
					Tetra-	Penta-
Fraser River - Hope Area [1]						
Stn. 21	1	Peamouth chub	ND	-	-	-
	3	White sturgeon	TR (ND-TR)	-	-	-
Stn. 22	3	Northern squawfish	204.5+282.2 (ND-526.7)	-	-	-
	1	Largescale sucker	349.8	-	-	-
	1	Brown bullhead	235.3	-	-	-
	1	Carp	ND	-	-	-
	8	Rainbow trout	59.0+90.9 (ND-170.8)	-	-	-
	3	Peamouth chub	ND (ND-ND)	-	-	-
Stn. 23	17	Northern squawfish	33.1+62.8 (ND-234.7)	-	-	-

APPENDIX 3 (CONT'D)

LEVELS OF ORGANIC CONTAMINANTS IN FISH FROM THE FRASER RIVER/ESTUARY (refer to Figure 3)

b) Industrial Contaminants (ppb wet weight) [Mean ± S.D. (Range)]

Location	No. of Samples	Species	PCBs	HCB	Chlorinated Phenols	
					Tetra-	Penta-
Fraser River - Hope Area [1] Stn. 23	16	Largescale sucker	137.4±195.9 (ND-589.7)	-	-	-
	2	Rainbow trout	37.2±49.8 (TR-72.4)	-	-	-
	1	Cutthroat trout	TR	-	-	-
	4	Mountain whitefish	ND (ND-ND)	-	-	-
	2	Peamouth chub	ND (ND-ND)	-	-	-
	4	White sturgeon	42.2±81.7 (ND-164.7)	-	-	-
Fraser River - Hope Area [2] Stns. 21, 22 & 23	2	Northern squawfish	171.5±132.2 (78.0-265.0)	1.4±0.3 (1.2-1.6)	ND (ND-ND)	14.5±2.1 (13.0-16.0)

APPENDIX 3 (CONT'D)

LEVELS OF ORGANIC CONTAMINANTS IN FISH FROM THE FRASER RIVER/ESTUARY (refer to Figure 3)

b) Industrial Contaminants (ppb wet weight) [Mean ± S.D. (Range)]

Location	No. of Samples	Species	PCBs	HCB	Chlorinated Phenols	
					Tetra-	Penta-
Fraser River - Hope Area [2] Stns. 21,22 & 23	1	Dolly varden	61.0	17.0	ND	33.0
	2	Largescale sucker	114.5+95.5 (47.0-182.0)	4.5+4.9 (1.0-7.9)	ND (ND-ND)	3.1+0.8 (ND-3.7)
	2	Peamouth chub	254.0+2.8 (252.0-256.0)	2.4+0.1 (2.3-2.5)	ND (ND-ND)	ND (ND-ND)
	4	Cutthroat trout	51.6+14.4 (39.0-65.0)	4.1+2.5 (2.3-5.8)	ND (ND-ND)	ND (ND-ND)
	2	Rainbow trout	26.0+1.4 (25.0-27.0)	2.2+0.3 (2.0-2.4)	ND (ND-ND)	ND (ND-ND)

APPENDIX 3 (CONT'D)

LEVELS OF ORGANIC CONTAMINANTS IN FISH FROM THE FRASER RIVER/ESTUARY (refer to Figure 3)

b) Industrial Contaminants (ppb wet weight) [Mean ± S.D. (Range)]

Location	No. of Samples	Species	PCB	Diethyl phthalate	Di-n-butyl phthalate	Bis (2-ethyl-hexyl) phthalate	Di-n-octyl phthalate	Naph-thalene	Phenol	Penta-chloro-phenol
Sturgeon Bank										
Stn. 2[3]	composite	Speckled sanddab	214.0	-	-	-	-	-	-	-
Stn. 4[4]	1	Flounder (methylated acid fraction only)	-	ND	15.4	24.0	298.0	ND	ND	ND
	1	Flounder (Aug.)	640.0	-	-	-	-	-	-	-
	1	Flounder (Nov.)	167.0	ND	ND	356.0	ND	ND	60.0	26.0
Stn. 5[4]	1	Salmon	44.0	132.0	31.2	696.0	4.8	3.6	ND	ND
	1	Flounder	650.0	-	-	-	-	-	-	-
			ND	-	-	-	-			
Roberts Bank[4]										
Stn. 7		Flounder	2.0*	-	-	-	-	-	-	-
			1.0*	-	-	-	-	-	-	-

1 Data obtained from 1978 analysis of samples collected by Westwater Research Centre in 1973.
2 Data obtained from Johnston et al (69).
3 Data obtained from Bawden et al (80).
4 Data obtained from 1978 Environment Canada study (68).

* = Values below the limit of confident quantification.

ND = not detectable

APPENDIX 4

LEVELS OF ORGANIC CONTAMINANTS IN AQUATIC INVERTEBRATES FROM THE FRASER RIVER/ESTUARY

a) Pesticides

b) Industrial Contaminants

APPENDIX 4 LEVELS OF ORGANIC CONTAMINANTS IN AQUATIC INVERTEBRATES FROM THE FRASER RIVER/ESTUARY

a) Pesticides[1] (ppb dry weight) [Mean ± S.D. (Range)]

Location	No. of Samples	Species	p,p'-DDT	p,p'-DDE	p,p'-DDD	Dieldrin	Heptachlor Epoxide
Fraser River - North Arm							
Stn. 1	1	Dungeness crab	ND	82.0	ND	ND	ND
Sturgeon Bank							
Stn. 2	composite	Blue mussel	ND	ND	ND	ND	ND
	composite	Ghost shrimp	ND	32.0	ND	ND	23.0
Stn. 3	1	Pacific oyster	TR	TR	ND	ND	ND
	5	Dungeness crab	ND (ND-ND)	101.4+58.1 (23.1-176.9)	ND (ND-ND)	1.2+0.4 (ND-TR)	4.2+4.6 (ND-11.4)
Stn.6	5	Dungeness crab	ND (ND-ND)	95.6+113.1 (23.0-295.8)	ND (ND-ND)	1.2+0.4 (ND-TR)	7.3+9.4 (ND-22.0)
Roberts Bank							
Stn. 8	1	Pacific oyster	ND	TR	ND	ND	ND
	1	Ghost shrimp	ND	ND	ND	ND	ND
Stn. 9	1	Basket cockle	ND	ND	ND	ND	ND
	5	Dungeness crab	ND (ND-ND)	42.7+57.3 (ND-141.1)	1.2+0.4 (ND-TR)	ND (ND-ND)	5.2+7.8 (ND-18.9)
	2	Red crab	ND (ND-ND)	22.3 (21.1-23.6)	1.5+0.7 (ND-TR)	ND (ND-ND)	ND (ND-ND)

APPENDIX 4 LEVELS OF ORGANIC CONTAMINANTS IN AQUATIC INVERTEBRATES FROM THE FRASER RIVER/ESTUARY
b) Industrial Contaminants [2] [Mean ± S.D. (Range)]

Location	Date	No. of Samples	Species	PCBs	Diethyl phthalate	Di-n-butyl phthalate	Bis (2-ethyl-hexyl phthalate	Di-n-octyl phthalate	Naphthalene	Fluoranthene	Phenanthracene or Anthracene	Pyrene
Fraser River - North Arm												
Stn. 1	1972	1	Dungeness crab	1052.5	-	-	-	-	-	-	-	-
Sturgeon Bank												
Stn. 2	1972	composite	Blue mussel	TR	-	-	-	-	-	-	-	-
		composite	Ghost shrimp	295	-	-	-	-	-	-	-	-
Stn. 3	1972	1	Pacific oyster	322.3	-	-	-	-	-	-	-	-
		5	Dungeness crab	839.7+559.6 (154.3-1607.1)	-	-	-	-	-	-	-	-
Stn. 4	Aug/78	composite	Clam	ND	-	-	-	-	-	-	-	-
	Nov/78	composite	Clam	0.05*	-	37	158	47	15	3.6	-	12
Stn. 5	Aug/78	composite	Clam	ND	-	-	-	-	-	-	-	-
	Nov/78	composite	Clam	0.3*	44	89	717	620	80	-	-	18
	Aug/78	1	Crab	56	-	-	-	-	-	-	-	-
	Nov/78	1	Crab	213	36	52	1600	-	-	-	-	-
Stn. 6	1972	5	Dungeness crab	781.8+748.0 (234.2-2100.3)	-	-	-	-	-	-	-	-
Roberts Bank												
Stn. 7	Aug/78	composite	Clam	ND	-	-	-	-	-	-	-	-
	Nov/78	composite	Clam	76	39	187	788	427	112	6.5	1.0	10
	Aug/78	1	Crab	14*	-	-	-	-	-	-	-	-
	Nov/78	1	Crab	ND	-	-	-	-	-	-	-	-

1 Data obtained from Bawden et al (80).
2 Data obtained from 1978 DOE study (68) with exception of 1972 PCB data which was obtained from Bawden et al (80). DOE data was reported on ppb wet weight basis while data from Bawden et al was reported as ppb dry weight.

* = Values below limit of confident quantification.
TR = trace
ND = not detectable

APPENDIX 5

LEVELS OF ORGANIC CONTAMINANTS IN BIRDS FROM THE FRASER RIVER/ESTUARY

APPENDIX 5 LEVELS OF ORGANIC CONTAMINANTS IN BIRDS FROM THE FRASER RIVER/ESTUARY (ppb wet weight) [Mean ± S.D. (Range)] (86)

Location	Date	No. of Samples	Species	Tissue	p,p'-DDT	p,p'-DDE	p,p'-DDD	o,p'-DDT	Dieldrin	Heptachlor Epoxide	HCB	PCB
Westham Is.	Jul/69	5	Ring-necked pheasant	muscle	5+6 (ND-ND)	9+8 (ND-17)	4+4 (ND-10)	-	3+3 (ND-7)	ND (ND-ND)	ND (ND-ND)	-
	Aug/69	1	Sora rail	muscle	4	16 500	2630	-	1680	188	-	151
Reifel Refuge	Dec/69	1	Coot	muscle	4	27	12	-	8	ND	ND	-
	Jan/70	1	Canvasback	muscle	ND	45	ND	-	ND	ND	ND	-
	Jan/70	1	Scaup	muscle	30	90	39	-	ND	ND	ND	-
	Jan/70	1	Pintail	muscle	8	27	12	-	ND	ND	ND	-
	Jan/70	4	Mallard	muscle	4+3 (ND-6)	28+24 (ND-59)	7+4 (ND-11)	-	ND (ND-ND)	ND (ND-ND)	ND (ND-ND)	-
	-	1	Sandpiper	muscle	30	114	32	-	9	ND	ND	-
	Mar/68	9	Robin	muscle	41+47 (5-152)	204+261 (46-269)	28+26 (12-94)	2+4 (ND-14)	14+10 (3-27)	-	-	8+13 (ND-32)
				brain	116+171 (22-568)	657+991 (61-2980)	26+30 (2-96)	2+2 (ND-7)	34+36 (TR-98)	-	-	ND (ND-ND)
Reifel Is.	Mar/68	1	Greater scaup	muscle	TR	19	TR	ND	2	-	-	ND
				brain	2	17	2	ND	4	-	-	ND
	Mar/68	1	Green-winged teal	muscle	162	97	64	19	TR	-	-	ND
				brain	117	84	30	ND	2	-	-	ND
Ladner Marsh	Dec/69	1	Mallard	muscle	6	31	8	-	9	ND	ND	-
Sea Island	Mar/68	4	Snow goose	muscle	22+19 (ND-44)	11+3 (8-15)	7+5 (ND-13)	4+3 (ND-8)	3+2 (ND-5)	-	-	ND (ND-ND)
				brain	2+1 (TR-3)	7+5 (1-13)	2+1 (1-2)	ND (ND-ND)	1 (ND-1)	-	-	-
	Mar/68	10	Dunlin	muscle	124+68 (39-262)	411+249 (103-727)	42+24 (13-90)	ND (ND-ND)	27+15 (8-53)	-	-	10+14 (ND-38)
				brain	90+36 (37-151)	193+69 (90-276)	30+16 (9-58)	3+5 (ND-16)	31+16 (16-63)	-	-	ND (ND-ND)
	Mar/68	4	Killdeer	muscle	181+166 (44-396)	366+197 (131-590)	67+65 (15-161)	ND (ND-ND)	33+24 (2-59)	-	-	ND (ND-ND)
				brain	159+150 (48-377)	214+64 (143-288)	21+14 (6-36)	13+23 (ND-47)	31+27 (4-68)	-	-	ND (ND-ND)
	Mar/68	2	Green-winged teal	muscle	65+42 (35-95)	52+15 (41-62)	24+21 (9-39)	ND (ND-ND)	3+1 (2-4)	-	-	ND (ND-ND)
				brain	94+27 (75-113)	55+12 (46-63)	21+5 (17-24)	ND (ND-ND)	7+4 (4-9)	-	-	ND (ND-ND)
Sea Island & Reifel Is.	Mar/68	3	Killdeer	muscle	20+30 (8-72)	150+46 (101-191)	24+15 (7-37)	ND (ND-ND)	60+55 (9-118)	-	-	26+8 (21-35)
				brain	40+6 (33-45)	112+60 (73-181)	11+11 (TR-22)	27+30 (ND-59)	55+56 (14-119)	-	-	ND (ND-ND)

APPENDIX 5 (CONT'D) LEVELS OF ORGANIC CONTAMINANTS IN BIRDS FROM THE FRASER RIVER/ESTUARY (ppb wet weight) [Mean ± S.D. (Range)] (86)

Location	Date	No. of Samples	Species	Tissue	p,p'-DDT	p,p'-DDE	p,p'-DDD	o,p'-DDT	Dieldrin	Heptachlor Epoxide	HCB	PCB
Vancouver Int'l. Airport, Sea Island	-	12	Dunlin	muscle	168+118 (30-389)	318+151 (118-593)	169+117 (53-403)	-	32+32 (ND-100)	11+22 (ND-58)	6+9 (ND-30)	1544+798 (780-3190)
Richmond	Jul/69	1	Ring-necked pheasant.	muscle	10	22	15	-	6	ND	ND	-
	-	1	Snow goose	muscle	ND	ND	ND	-	ND	ND	ND	-
Fraser River Delta	Apr/69	1	Red-tailed hawk	egg	435	4720	639	-	262	111	-	374
	-	1	Chick	brain	2	75	6	-	37	8	-	24
	-	3	Short-eared owl	muscle	100+111 (20-252)	944+1512 (38-2690)	46.0+53 (ND-104)	3+3 (ND-6)	17+13 (7-32)	-	-	7+10 (ND-19)
	-	3		brain	33+39 (20-77)	161+230 (11-426)	15+17 (2-34)	ND (ND-ND)	7+9 (1-17)	-	-	5+8) (ND-14)
UBC Endowment Lands	Feb/78	12	Great blue heron	egg	78+45 (20-160)	2821+1767 (830-5840)	133+131 (40-530)	-	90+95 (30-340)	69+29 (30-130)	23+13 (10-50)	21422+13449 (6920-50200)

Other Contaminants:

Alpha-Chlordane	Gamma-Chlordane	Mirex	Photomirex	B-BHC
23+15 (L10-60)	12+4 (L10-20)	36+40 (ND-140)	38+28 (ND-70)	29+73 (ND-260)

TR = trace
ND = not detectable

APPENDIX 6

APPENDIX 6.1 A. ORGANIC CONTAMINANTS IN MUNICIPAL SEWAGE TREATMENT PLANT EFFLUENTS, 1978 (ppb) (88)

	Annacis Island Effluent	Iona Island Effluent	Lulu Island Effluent
CHLORINATED HYDROCARBONS			
Hexachlorobenzene	0.006	0.004	0.005
Polychlorinated Biphenyls	0.24	0.3	0.13
HYDROCARBONS			
C Benzenes			*
C Benzenes			?
Long chain Alkyl Benzene	-		
PHENOLICS			
p-Cresol			*
Pentachlorophenol	9	6	8
Tetrachlorophenol	9	30	1
PHTHALATE ESTERS			
Dibutylphthalate	2	20	
Diethylphthalate	4	2	40
Dimethylisophthalate		50	
Dimethylphthalate		10	
Dioctylphthalate	?	?	?
TERPENES			
Alpha-Terpineol	*		*
Terpineol Isomer			*
3,7,Dimethyl-1,6-Octadien-3-01		?	?
3,7,11-Trimethyl-2,6,10-Dodecatrien-1-01	?	?	?
FATTY ACIDS			
Dodecanoic Acid (Lauric)			?
Eicosanoic Acid (Arachidic)			40
Hexadecanoic Acid (Palmitic)	270	100	3000
Octadecanoic Acid (Stearic)		200	5000
Tetradecanoic Acid (Myristic)			110

APPENDIX 6.1 (CONT'D) A. ORGANIC CONTAMINANTS IN MUNICIPAL SEWAGE TREATMENT PLANT EFFLUENTS, 1978 (ppb) (88)

	Annacis Island Effluent	Iona Island Effluent	Lulu Island Effluent
FATTY ACID METHYL ESTERS			
Hexanedioic Acid Ester	*		
Methyl Hexadecanoate	?		?
Methyl Octadecanoate	?		?
STEROIDS			
Cholesterol	110	70	400
Coprostanol	90	70	450
DRUGS			
Caffeine	20	10	60
Nicotine			*
OTHERS			
6,10,14-Trimethyl-2-Pentanone	?		

NOTE: ? = Tentatively identified.
* = Identified but not quantitated.
- = Only identified to class

APPENDIX 6.1 B. ORGANIC COMPOUNDS IDENTIFIED IN ANNACIS SEWAGE SAMPLES 1977-1979 (68)

Compound Type	Name of Compound	Untreated	Treated	Hi-Chlor
Volatiles	Methylene chloride			
	Trichloroethylene			
	Tetrachloroethylene		x	
	Toluene			
	Chloroform			
	1,1,1-Trichloroethene			
Fatty acids	Lauric acid	x	x	
	Myristic acid	x	x	x
	Pentadecanoi acid	x	x	x
	Palmitic acid	x	x	x
	Margaric acid	x	x	
	Margaric (isomer) acid	x		
	Stearic "	x	x	x
	Palmitoleic "	x	x	x
	Linoleic "	x		
	Oleic "	x	x	x
Resin acids	Pimaric acid	x		
	Isopimaric "	x	x	
	Dehydroabietic acid	x	x	x
	Abietic "	x	x	
	Neoabietic "	x		
Douglas-fir Acids	Todomatuic acid	x		x
	Cis-dihydrotodomatuic acid	x	x	x
	Aromatic todomatuic "			x
	4-p-carboxyphenylvaleric "			x
	4-p-tolylvaleric acid	x	x	x
	Dehydro-4-p-Tolylvaleric		x	
Diter-penes	Manool	x	x	
	Manoyl oxide		x	
	Dehydroabietane	x		
	Isopimaral	x	x	
	Abietal	x		
	Dehydroabietal	x	x	
	18-Nordehydroabietol	x		
Organo-chlorines	2,4,6-Trichlorophenol			x
	Monochloro-4-p-tolylvaleric acid			x
	Dichlorobenzoic acid		x	
Phthalate esters	Dimethyl phthalate			x
	Diethyl phthalate			x
	Dibutyl phthalate	x	x	
	Dioctyl phthalate	x		
Miscel-laneous	Benzoic Acid			x
	Phenylacetic acid			x
	Phenylpropionic acid			x
	Cholestrol	x	x	
	Coprostanol	x	x	
	4-p-Tolyl-1-pentanol	x	x	x
	-Terpineol	x		
	Caffeine	x		
	Anthracene	x		
	Phenanthrene			

APPENDIX 6.2 LEVELS OF PCBs IN INDUSTRIAL AND MUNICIPAL DISCHARGES AND URBAN RUNOFF (refer to Figure 1)

Location	Date	No. of Samples	Type of Effluent	PCB Concentration (ppb)	Data Source Reference
Dow Chemical, Delta	Jan/77	2	combined process and cooling water	ND (ND-ND)	62
Domtar Chemicals, New Westminster	Feb/77	1	cooling water	ND	62
Roberts Bank Coal Superport, Westshore Terminals, Tsawwassen	Jan/77	1	settling pond	2.98	62
	Jul/78	1	runoff pond	L0.05	62
Belkin Paperboard Ltd., Burnaby	Apr/76	1	final effluent	0.45	87
	Nov/78	composite	clarifier overflow	0.25	62
	Apr/79-May/79	4 composites	final effluent	2.4±2.1 (0.07-4.6)	62
	Apr/79-May/79	4	clarifier sludge	26650±30469 (3400-68500)	62
Scott Paper Ltd., Burnaby	Apr/76	1	final effluent	ND	87
Island Paper Mills, Annacis Island	Apr/76	1	final effluent	ND	87
Iona Island STP	Aug/76	4	influent	0.14±0.04 (0.11-0.19)	62
		4	effluent (prechlorination)	0.09±0.02 (0.07-0.11)	62
		4	chlorinated effluent	0.08±0.02 (0.06-0.10)	62

APPENDIX 6.2 (CONT'D) LEVELS OF PCBs IN INDUSTRIAL AND MUNICIPAL DISCHARGES AND URBAN RUNOFF (refer to Figure 1)

Location	Date	No. of Samples	Type of Effluent	PCB Concentration (ppb)	Data Source Reference
Annacis Island STP	Oct/76	4	influent	0.06±0.02 (0.03-0.08)	62
		4	dechlorinated effluent	0.03±0.03 (0.02-0.07)	62
Richmond Landfill	1976	1	leachate	20.0	83
Site A	1977	1	leachate	ND	62
Site B	1977	1	leachate	1.4	62
Byrne Road, Burnaby	Jul/76	1	storm sewer	0.06	62
Kaymar Ravine, Burnaby	Jul/76	1	storm sewer	0.69	62
Grandview Hwy. and Nootka, Vancouver	Jul/76	1	storm sewer	0.10	62
Boundary Rd. and 2nd Ave., Vancouver	Jul/76	1	storm sewer	0.17	62
Deer Lake at Buckingham, Burnaby	Jul/76	1	storm sewer	0.56	62
Springer Rd. at Lumberland, Burnaby	Jul/76	1	storm sewer	0.33	62
Collingwood St., Vancouver	Jul/76	1	storm sewer	0.35	62

ND = not detectable
L = less than

APPENDIX 6.3 STREET SURFACE CONTAMINANTS (ppb dry weight)
(From Hall et al, [61])

Land Use	Location	p,p'-DDT	p,p'-DDE	p,p'-DDD	Chlordane		PCBs
					Alpha	Gamma	
Industrial							
	Rupert St. (between Grandview & Broadway)	5	-	2	2	1	57
	Boundary Rd. and Myrtle Avenue	5	-	2	1	2	126
	Gilmore Ave. North of Still Creek	21	-	8	7	5	140
	Willingdon North of 401 Interchange	5	-	4	2	4	208
	Douglas Road at Still Creek	1	-	-	0.3	0.5	96
	Industrial Park (Lake City)	1	-	L1	L0.5	0.6	34
	Spruce Ave. opposite Labatts	1	-	L1	0.8	0.5	56
	Spruce Ave. opposite Capilano Lumber	3	-	1	0.5	0.8	48

APPENDIX 6.3 STREET SURFACE CONTAMINANTS (ppb dry weight) (Continued)
(From Hall et al, [61])

Land Use	Location	p,p'-DDT	p,p'-DDE	p,p'-DDD	Chlordane		PCBs
					Alpha	Gamma	
Commercial	Canada Way at Boundary Road	12	-	4	4	2	57
	Willingdon at Lougheed (Brentwood Shopping Centre)	24	-	11	11	8	240
	Austin at Lougheed (Lougheed Shopping Centre)	3	-	4	4	7	184
	North Road at Lougheed	-	7	-	0.8	0.5	71
	Sperling at Canada Way	4	-	3	4	5	136
	Braid at Columbia	6	-	6	2	4	156
Residential	East 14th Ave. (blk. East of Renfrew)	7	-	4	3	5	255
	East 16th Ave. (between Renfrew and Rupert	10	4	3	2	1	40
	Smith Ave. at Spruce Ave.	14	-	3	2	2	67
	Whitsell Ave. at Williams Ave.	18	-	5	2	3	127

APPENDIX 6.3 STREET SURFACE CONTAMINANTS (ppb dry weight) (Continued)
(From Hall et al, [61])

Land Use	Location	p,p'-DDT	p,p'-DDE	p,p'-DDD	Chlordane		PCBs
					Alpha	Gamma	
	2400 Duthie Street	20	-	5	2	2	31
	Mahon at Eglington	9	-	3	2	2	70
	Mayfield and Canada Way	31	-	7	2	2	35
	Lee and 10th Ave.	33	-	7	3	3	102
Green Space	Forest Lawn Cemetery	22	7	11	11	7	30
	Robert Burnaby Park	21	-	4	1	1	87
	Gaglardi Way at Esterbrook	1	-	-	0.7	0.5	32
	Phillips and Halifax (near golf course)	6	-	1	2	1	63

L = denotes "less than".
- = not detected

APPENDIX 6.4 OTHER ORGANIC CONTAMINANTS IN WASTEWATER SYSTEMS (90)

Location	Date	No. of Samples	Type of Discharge	Hydrocarbon as Isooctane (ppm)	Hydrocarbon as Benzene (ppm)	Phenolic Compounds as Phenol (ppb)	Detergents as MBAS (ppm)
Renfrew Sanitary	Jul/74	6	residential waste	16.4+7.5 (8.9-26.5)	60.0+31.1 (37.0-114.8)	6.6+3.9 (L0.5-12.0)	0.8+0.2 (0.6-1.2)
Balaclava Trunk	Aug/74	5	residential waste	13.8+10.4 (2.6-28.2)	59.6+45.0 (10.8-121.7)	7.3+6.1 (L0.5-16.5)	0.7+0.3 (0.2-1.1)
University Residential	Jun/74	6	residential waste	22.9+17.3 (9.2-49.2)	81.4+53.7 (35.2-G150.0)	3.3+4.4 (L0.5-10.0)	
Burnaby Central	Jul/74	6	mixed wastes	27.6+15.5 (11.8-50.1)	102.5+55.1 (51.0-G200.0)	21.6+8.2 (10.5-35.5)	0.6+0.3 (0.3-1.0)
Burnaby South Slope	Jul/74	6	mixed wastes	27.2+15.4 (15.3-57.1)	101.1+52.4 (52.1-G200.0)	0.5+0.3 (0.29-1.1)	0.5+0.2 (0.3-0.8)
North Sewer - UBC	Jun/74	6	mixed wastes	5.9+5.0 (1.5-14.4)	22.8+20.3 (3.9-57.8)	43.2+68.1 (0.5-180.0)	
South Sewer - UBC	Jun/74	6	mixed wastes	14.6+12.2 (3.0-35.7)	53.2+48.3 (12.6-G140.0)	18.0+21.1 (L0.5-54.5)	
Renfrew Storm Sewer	Jul/74	HC-4 PH-6 DET-6	storm water	0.1+0.1 (1.5-14.4)	0.4+0.7 (3.9-57.8)	8.3+7.2 (0.5-180.0)	0.04+0.02 (0.02-0.06)
Iona Island STP	Aug/74	3	influent	10.3+5.0 (6.1-15.8)	26.8+23.2 (25.4-68.4)	12.5	0.5 (0.5-0.5)

APPENDIX 6.5 LEVELS OF PHENOLIC COMPOUNDS IN INDUSTRIAL AND MUNICIPAL DISCHARGES IN GREATER VANCOUVER AREA, 1978 (ppb) (88)

Compound	Scott Paper	MacMillan Bloedel			B.C. Forest Products	Crown Zellerbach		Coast Laminated Timber
		before composite sampler	cooling water discharge to drainage ditch	after retention tank		Coast Prod.	Wood Div. Richmond Lumber Mill	
Phenol	-	-	-	-	-	-	-	-
p-cresol	-	-	-	-	-	-	-	-
2,4-dimethylphenol	-	-	-	-	-	-	-	-
2,5-dimethylphenol	-	-	-	-	-	-	-	-
p-chlorophenol	-	-	-	-	-	-	-	-
2,3,6-trimethylphenol	-	-	-	-	-	-	-	-
4-chloro-2-methylphenol	-	-	-	-	-	-	-	-
2,4-dichlorophenol	-	-	-	-	-	-	-	TR
2,6-dichlorophenol	-	-	-	-	-	-	-	2.4
2,3,4-trichlorophenol	-	-	-	-	-	-	-	0.2
2,4,5-trichlorophenol	-	-	-	-	-	-	TR	2.3
2,4,6-trichlorophenol	5.4	-	TR	-	-	-	TR	1.0
3,4,5-trichlorophenol	-	-	-	-	-	-	-	0.7
pentachlorophenol	0.2	0.2	1.2	-	0.2	1.3	1.6	6000.0
2,3,4,6-tetrachlorophenol	0.2	0.2	6.0	-	0.7	3.0	0.8	2100.0
2,3,4,5-tetrachlorophenol	-	-	-	-	-	-	-	TR
2,3,5,6-tetrachlorophenol	-	-	-	-	-	-	-	TR

APPENDIX 6.5 (CONT'D) LEVELS OF PHENOLIC COMPOUNDS IN INDUSTRIAL AND MUNICIPAL DISCHARGES IN GREATER VANCOUVER AREA AREA, 1978 (ppb) (88)

Compound	Belkin Packaging	Ioco Oil Refinery[1]		Dow Chemical	Reichold Chemicals[1]	Later Chemicals		Richmond Landfill Leachate	
		Main discharge pipe	after separator #4			S.W. Ditch	N.W. Ditch	Drainage Ditch	Ditch just above discharge to Fraser
Phenol	-	-	-	-	-	TR	-	-	-
p-cresol	-	-	-	-	-	TR	-	-	-
2,4-dimethylphenol	-	-	-	-	-	600.0	TR	-	-
2,5-dimethylphenol	-	-	-	-	-	600.0	TR	-	-
p-chlorophenol	-	-	-	-	-	150.0	-	-	-
2,3,6-trimethylphenol	-	-	-	-	-	1000.0	TR	-	-
4-chloro-2-methylphenol	-	-	-	-	-	300.0	-	-	-
2,4-dichlorophenol	-	-	-	-	-	330.0	51.0	-	-
2,6-dichlorophenol	-	-	-	-	-	220.0	-	-	2.0
2,3,4-trichlorophenol	-	-	-	-	-	-	3.6	-	-
2,4,5-trichlorophenol	TR	-	-	-	-	2400.0	135.0	TR	0.8
2,4,6-trichlorophenol	TR	0.3	-	TR	-	3120.0	81.0	TR	-
3,4,5-trichlorophenol	-	-	-	-	-	-	-	-	-
pentachlorophenol	5.4	4.9	3.6	1.4	0.3	2520.0	1125.0	1.2	1.4
2,3,4,6-tetrachlorophenol	7.2	0.4	-	0.2	0.3	96.0	166.0	0.3	-
2,3,4,5-tetrachlorophenol	-	-	-	-	-	-	12.0	-	0.09
2,3,5,6-tetrachlorophenol	-	-	-	-	-	-	-	-	1.2

1 Ioco Oil Refinery and Reichold Chemicals are not located on the Fraser River but effluents are routed to Annacis Island sewage treatment plant.

APPENDIX 6.5 (CONT'D) LEVELS OF PHENOLIC COMPOUNDS IN INDUSTRIAL DISCHARGES AND MUNICIPAL DISCHARGES IN GREATER VANCOUVER AREA, 1978 (ppb) (88)

	Burns Bog Landfill		N. of Richmond Landfill Illegal Hogfuel Dump (8931 River Rd.) standing water	Vito Steel Boat & Barge Co. Ltd. bog water	Lougheed Mills, Surrey Ditch (133 St. & 116 A St.)
	N.W. Ditch	N.W. & S.W. ditches combined			
Phenol	-	-	-	-	-
p-cresol	-	-	-	-	-
2,4-dimethylphenol	-	-	-	-	-
2,5-dimethylphenol	-	-	-	-	-
p-chlorophenol	-	-	-	-	-
2,3,6-trimethylphenol	-	-	-	-	-
4-chloro-2-methylphenol	-	-	-	-	-
2,4-dichlorophenol	-	-	-	-	-
2,6-dichlorophenol	-	-	-	-	-
2,3,4-trichlorophenol	-	TR	-	-	-
2,4,5-trichlorophenol	TR	TR	-	-	0.7
2,4,6-trichlorophenol	TR	TR	-	-	-
3,4,5-trichlorophenol	-	-	-	-	0.3
pentachlorophenol	0.6	1.6	6.0	-	2.4
2,3,4,6-tetrachlorophenol	0.2	-	0.4	0.5	1.2
2,3,4,5-tetrachlorophenol	-	-	-	-	-
2,3,5,6-tetrachlorophenol	-	-	-	-	-

APPENDIX 6.5 (CONT'D) LEVELS OF PHENOLIC COMPOUNDS IN INDUSTRIAL AND MUNICIPAL DISCHARGES IN GREATER VANCOUVER AREA, 1978 (ppb) (88)

	Domtar N.W. Preservers		Vendev Landfill	Braid Street Landfill, Coquitlam		
	Ditch at Railroad	Refuse Site	- leachate	- leachate from swamp	- combined leachate at pumphouse	-ditch on west side
Phenol	-	-	-	-	-	-
p-cresol	-	-	-	-	-	-
2,4-dimethylphenol	-	-	-	-	-	-
2,5-dimethylphenol	-	-	-	-	-	-
p-chlorophenol	-	-	-	-	-	-
2,3,6-trimethylphenol	-	-	-	-	-	-
4-chloro-2-methylphenol	-	-	-	-	-	-
2,4-dichlorophenol	-	-	-	-	-	-
2,6-dichlorophenol	-	-	-	-	1.2	5.6
2,3,4-trichlorophenol	-	-	-	-	-	0.3
2,4,5-trichlorophenol	-	4.2	-	1.7	0.4	1.5
2,4,6-trichlorophenol	-	-	-	1.0	-	0.4
3,4,5-trichlorophenol	-	-	-	0.5	-	0.8
pentachlorophenol	-	120.0	0.9	7.2	15.0	42.5
2,3,4,6-tetrachlorophenol	-	38.6	0.8	3.2	1.8	7.4
2,3,4,5-tetrachlorophenol	-	-	-	0.6	0.3	1.4
2,3,5,6-tetrachlorophenol	-	35.0	-	-	1.5	-

APPENDIX 6.5 (CONT'D) LEVELS OF PHENOLIC COMPOUNDS IN INDUSTRIAL AND MUNICIPAL DISCHARGES IN THE GREATER VANCOUVER AREA, 1978 (ppb) (88)

	Annacis Island S.T.P.				Iona Island S.T.P.				Lulu Island S.T.P.				Ladner Sewage Lagoon
	Effluent		Influent		Effluent		Influent		Effluent		Influent		Effluent
	#1*	#2	#1	#2	#1*	#2	#1	#2	#1*	#2	#1	#2	
Phenol	-	-	TR	-	-	-	-	-	-	-	-	-	-
p-cresol	-	-	TR	-	-	-	-	-	-	-	-	-	-
2,4-dimethylphenol	-	-	-	-	-	-	-	-	-	-	-	-	-
2,5-dimethylphenol	-	-	-	-	-	-	-	-	-	-	-	-	-
p-chlorophenol	-	-	-	-	-	-	-	-	-	-	-	-	-
2,3,6-trimethylphenol	TR	-	-	-	-	-	-	-	-	-	-	-	-
4-chloro-2-methylphenol	TR	-	-	-	-	-	-	-	-	-	-	-	-
2,4-dichlorophenol	-	-	-	-	-	-	-	-	-	-	-	-	-
2,6-dichlorophenol	-	-	-	-	-	-	-	-	-	-	-	-	-
2,3,4-trichlorophenol	-	-	-	-	-	-	-	-	TR	-	-	-	-
2,3,5-trichlorophenol	-	-	-	-	-	-	-	-	TR	TR	TR	-	-
2,3,6-trichlorophenol	0.7	1.2	0.7	-	TR	-	-	-	TR	0.1	0.09	0.9	-
3,4,5-trichlorophenol	-	-	-	-	-	-	-	-	TR	-	TR	-	-
pentachlorophenol	4.7	1.2	7.8	12.0	1.4	1.2	1.3	1.2	1.1	3.0	4.5	2.8	0.5
2,3,4,6-tetrachlorophenol	28.3	13.2	8.7	10.8	1.0	0.7	1.4	0.7	0.6	1.7	0.6	10.0	-
2,3,4,5-tetrachlorophenol	-	-	-	-	-	-	-	-	-	-	-	-	-
2,3,5,6-tetrachlorophenol	-	-	-	-	-	-	-	-	-	-	-	-	-

* = results for effluent sample #1 from each plant based on 2 replicates.
\- = not detected
TR = trace
L = less than
G = greater than