FRASER RIVER ESTUARY MONITORING

A RECOMMENDED APPROACH

prepared by

The Working Committee on Fraser River
Estuary Monitoring

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PREFACE

A Federal-Provincial study was initiated in 1977 to develop a management plan for the Fraser River Estuary. The area under consideration was the Fraser River downstream from Kanaka Creek to Roberts and Sturgeon Banks including Boundary Bay. The purpose of the first phase of the study was to assemble and analyse existing information on a variety of subjects, including water quality. This was followed by a second phase, which ended in March 1982, with the completion of a proposed management plan.

Phase 1 resulted in the publication of eleven detailed technical reports and a summary report on water quality, which analysed information collected up to about 1978. The reports covered a variety of topics, including effluent discharges, water chemistry, microbiology, sediments and aquatic biology. The reports made recommendations for monitoring programs with which to assess environmental change and determine the need for future controls.

The second phase resulted in a proposed management plan that outlined certain water quality goals and objectives. Generally the plan stipulated that the ambient water quality of the Fraser River and estuary should be suitable to support fisheries and wildlife, and suitable for water contact recreation (where such takes place) or the irrigation of crops. As well, the special requirements of the main channels, side channels, Roberts Bank and Boundary Bay should be recognized. The proposed management plan also identified a need to establish an ongoing integrated water quality monitoring program. A monitoring committee was formed in March, 1982 to develop such a program.

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SUMMARY

In March 1982 a committee was formed to develop a long term monitoring program for the Fraser River Estuary.

The committee agreed to consider conditions that would broadly affect the principal user groups of the estuary; namely humans, fish, invertebrates and wetland birds and also agreed to include principal tributaries in the program.

Although it would be desirable to recommend a comprehensive monitoring program which could be carried out in one year over the entire study area, the costs for such an undertaking were considered prohibitive. Consequently, a basic monitoring program referred to as Package 1, was prepared which spans a period of 5 years. Package 1 deals with monitoring in the Fraser River and outer estuary but excludes the tributaries. This monitoring covers birds and effluents in the first year, sediments and invertebrates in the main river in the second year, fish in the main river in the third year, sediments and invertebrates in the outer estuary in the fourth year and fish in the outer estuary in the final year. Supplementary packages 2, 3 and 4 were provided to allow the program to be enhanced as additional funds become available. These packages add parameters to those analysed in package 1, allow work to be conducted on the tributaries and increase the frequency of data collection. It was recognized that a five year frequency would allow trend determinations to be made only once every five years once a data base has been established. It was further recognized that the program could not address all present nor certainly all future issues, and that it was essential that the program be flexible and upgraded as priorities, resources and scientific/technical developments allow.

The proposed program builds upon a base of existing monitoring programs at the Mission water quality station, at numerous bathing beach sites and several sites where environmental degradation is evident. Specific problems that do not require ongoing monitoring have been listed

as special studies and have not been costed into the proposed estuary monitoring program described in this report.

The annual (1983/84 dollars) costs for the rotating program range from $38,000 to $72,000 at the Package 1 level depending on the sub-area and require from 27 to 256 staff days to implement. These figures rise to $123,000 to $720,000 and 94 to 352 days, respectively, for the full field program (Packages 1 to 4).

The final section of the report makes recommendations regarding continuing implementation of the program including the review and coordination of program activities. Manpower requirements for these actitivies were not developed at this time.

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1. INTRODUCTION

The study area examined, includes the Fraser River downstream from Kanaka Creek and the outer estuary from Point Grey to Boundary Bay (Figure 1). Selected side channels and tributaries of environmental concern are also included. This entire area has been divided into four sub-areas to facilitate program development. These sub-areas are: the Fraser River, the outer-Estuary (including Boundary Bay and the Banks), tributaries to the Fraser River and tributaries to Boundary Bay. Boundaries shown on Figure 1 were determined on the basis of such factors as watershed areas, arms of the river, or distinct geographical zones.

The terms of reference (Appendix 1) required that the committee recommend a long-term monitoring program which would "enable management authorities to determine when and where the requirements for fish and biological productivity are not being satisfied in the Fraser estuary." The committee decided that unique requirements for humans and wetland birds also required attention, and that tributaries could not be overlooked. These were also included in the program.

The monitoring program also should provide information on both the status of the study area's water quality at any given time and, over the long term, it should signal any improvement or deterioration in the "health of the estuary." To do this the program should:

- Establish and priorize sampling locations.
- Determine and priorize variables to be measured at each location: measurements may be performed on the water column, sediments, aquatic life, wetland birds and on discharges where required.
- Recommend the intensity of sampling in both time and space.
- Recommend procedures for collecting samples.
- Estimate the cost and manpower requirements of each sampling scheme proposed.

The committee felt that prior to implementing a monitoring program, certain topics should first be addressed. These would include

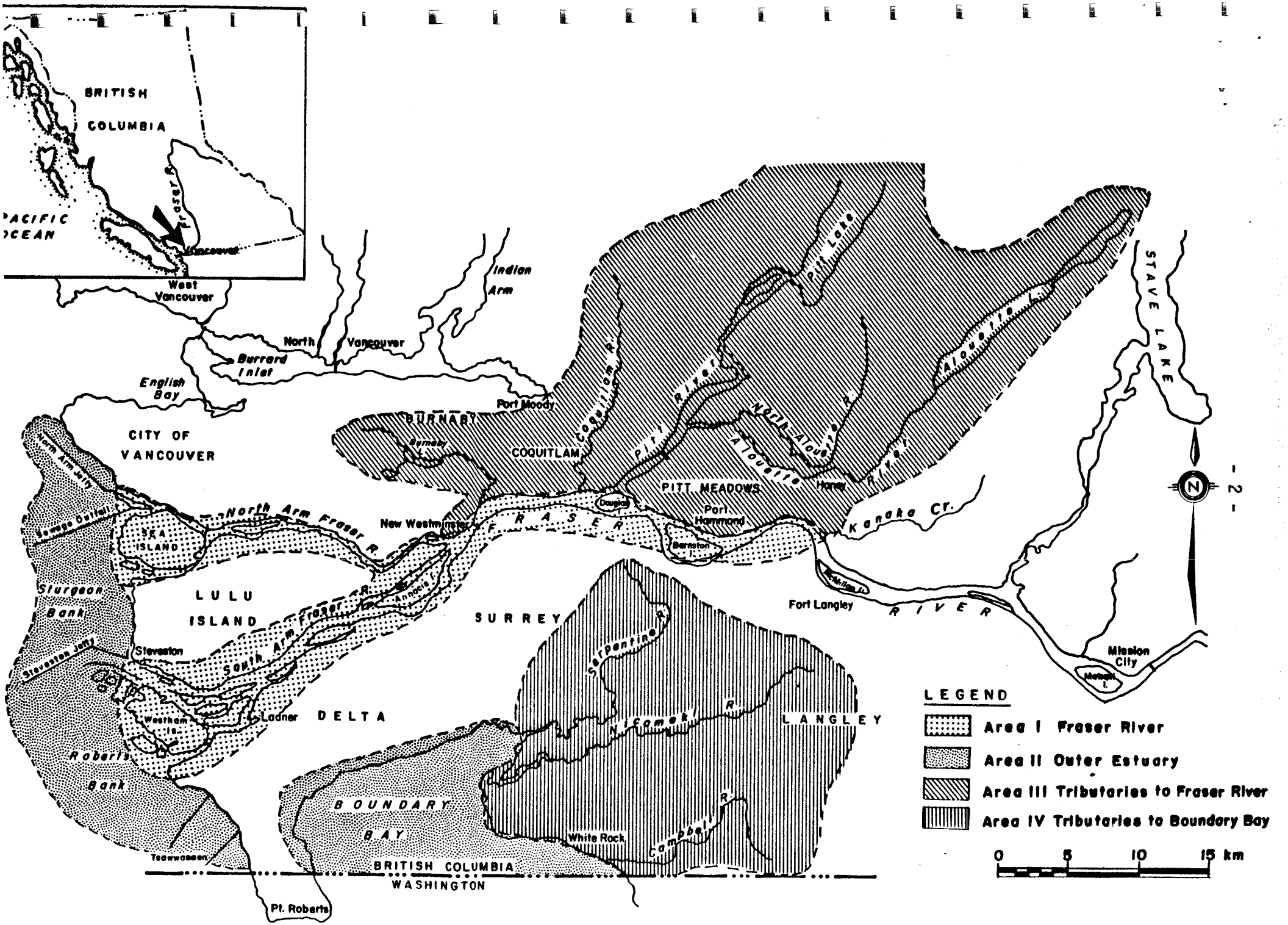

FIGURE 1 MONITORING PROGRAM SUB-AREAS IN THE LOWER FRASER RIVER

sampling materials, the number of replicate samples to be collected, the exact locations of sampling sites, the optimum sampling frequency and the time period during the year that samples should be collected.

This preliminary work will, in certain cases, be accomplished by a review of existing data or literature. Where information or data are absent or significantly dated, a "pilot project" will be implemented. The program proposed in this report is intended to provide a flexible framework on which to base estimates of monitoring costs. Initial pilot projects, literature research and data review will enable refinements to be made to the program in the early stages, as will water quality objective, new funding circumstances and other future considerations.

The terms of reference also stated that the "working committee should assume that the program would be implemented through existing agency programs, augmented where possible by private sector funding obtained to satisfy regulatory requirements". This has resulted in the minimum number of sampling sites and the lowest sampling frequency being put forth for each of several levels of monitoring priority. Specific problems may be addressed through separate regulatory or research efforts for which a list of special studies has been prepared.

It is beyond the scope of the program to address all future monitoring concerns and for this reason the program must be kept flexible. It is expected that as the program progresses, new approaches may be required to replace ones listed herein. For example, as water quality objectives are set, monitoring parameters and frequencies may have to be adjusted accordingly.

Emphasis in the proposed monitoring program is on the input of contaminants to the Fraser River estuary and their presence in the environment. This report details the monitoring program as well as the justifications and rationale related thereto. The program presented will allow values to be compared between some environmental compartments and locations within each monitoring sub-area. It is recognized that data will have to be collected over a lengthy period of time before sufficient results become available to allow trend analyses to be performed.

2. ASSESSMENT OF MONITORING PROGRAM PRIORITIES

Two basic subjects were assessed prior to developing the monitoring program. First, the principal user groups on the estuary were examined to identify primary areas of concern and important components for monitoring. Secondly, criteria were prepared to assist in the development of monitoring priorities. These topics are covered in Sections 2.1 and 2.2, respectively.

2.1 Principal User Groups

Principal user groups which may be affected by poor water quality include humans, fish, invertebrates and wetland birds. A brief discussion of each group's use of the monitoring area and existing and potential matters of concern follow. Further discussion of some of these topics is also provided in reports generated in Phases I and II of the Fraser River Estuary Study.

2.1.1 Humans. Human use of the estuary is diverse and includes transportation, recreation, irrigation of crops, harvesting fish and crustaceans for food and waste assimilation. Inherent in some of these uses is the possibility that humans may come into contact with microbiological or chemical contaminants.

Pathogenic bacteria, viruses and parasites are associated with sewage contaminated waters. Since most pathogens are technically difficult and costly to monitor, the measurement of fecal coliforms is incorporated into the basic monitoring program.

Viruses can pass unaffected through primary wastewater treatment processes and may be of concern in parts of the estuary where bathing beaches are downcurrent from sewage treatment plants. Examination of the presence of viruses at bathing beaches should be a special study.

All of the monitoring area is closed to molluscan shellfish harvesting because of unacceptable ($\geq$ 14 MPN/100 mL) fecal coliform concentrations (Fisheries and Oceans, 1983). Shellfish concentrate bacteria and associated pathogens in their bodies, making them unsafe for consumption. With the closure of the area to molluscan shellfish harvesting, there is little risk to humans unless illegal harvesting takes place.

Ditch waters containing chemical contaminants may be used for irrigating crops (no documented cases). Current standards for the quality of irrigation waters are not as stringent as for other water uses. Examination of the quality of ditch waters should also be a special study.

The greatest potential risk of chemical contamination to humans comes through the possible consumption of non-migratory fish and crustacean (crab, shrimp) species. Singleton (1983) reported that fish sampled and tested in 1980 were all at levels safe for consumption except some northern squawfish with elevated mercury levels. While these results indicate effects on aquatic life, there is little threat to humans since squawfish and similar species are not usually consumed. Stancil (1980) reported elevated levels of mercury and possibly copper in Dungeness crabs from certain parts of the estuary and Garrett (1980) reported elevated levels of PCB's and phthalate esters in the same species and locations. Nearby Howe Sound was closed to fishing from 1970 to 1979 due to high mercury levels (Squamish Estuary Management Plan, 1980), illustrating the possibility of contamination occurring locally and the importance of an effective surveillance program.

2.1.2 Fish and Invertebrates. Deteriorated environmental conditions such as low dissolved oxygen or the presence of toxic substances pose an immediate threat to fish and invertebrates. Toxic substances discharged to the monitoring area include un-ionized ammonia, anionic surfactants, cyanide, wood extractives (leachates), sulphides, oxygen demanding wastes, trace metals, residual chlorine (Singleton 1980) and several chlorinated organics. A review of effluents discharged to the Fraser River reveal that

many are, to varying degrees, acutely toxic to test fish species (rainbow trout) (Singleton, 1980; Swain, 1980a; Cain and Swain, 1980) and thus may threaten fish and invertebrates in the dilution zone of effluents.

Fish kills have been recorded in the monitoring area. Swain and Alexander (1981) summarized 20 fish kills that occurred between 1958 and 1979 in the rivers entering Boundary Bay. Stancil (1980) summarized another 10 kills in the tributaries to the lower Fraser River that occurred between 1959 and 1977. Although few causes of the earlier kills were determined, recent information on tributaries to Boundary Bay suggests that a direct cause was low oxygen levels (Gough and Moore 1983).

Fish and invertebrates may also be exposed to contaminants in sediments and/or food sources. Sediments tend to accumulate contaminants from the overlying waters and thus, act as reservoirs for the future entry of contaminants into the food web through benthic and epibenthic invertebrates and bottom feeding fish.

Various trace metals (Singleton, 1980; Drinnan and Clark, 1980; Stancil, 1980), and/or organic contaminants (Singleton, 1980; Garrett, 1980; Gough and Moore, 1983) have been identified in effluent discharges, the water column and sediments in the monitoring area.

There are few data on organic contaminants in invertebrates other than in crab or bivalve tissues. As noted earlier, Garrett (1980) reported elevated levels of PCB's in Dungeness crabs near Iona Island, Steveston and Roberts Bank. Crabs on both Sturgeon and Roberts Banks contained detectable levels of phthalate esters, heptachlor epoxide, DDE, and dieldrin. Contamination of clams by PCB's, phthalate esters and PAH's has been recorded on the two Banks (Garrett, 1980).

Other deteriorated environmental conditions that can affect the well being of fish and invertebrates, include low dissolved oxygen levels and silt. Low dissolved oxygen levels in some tributaries and backwaters in the monitoring area are known to occur at certain times of the year.

Davis (1975) recommends dissolved oxygen cirteria which vary depending on the degree of protection to be afforded various fish groups.

For example, he specifies a dissolved oxygen level of 9.75 mg O_2/l ($\geq$ 98% air saturation) as a criterion which would provide a high degree of safety for salmonid larvae and mature eggs of salmonids. Dissolved oxygen criteria of 9.0 mg O_2/l (100% air saturation) and 7.75 mg O_2/l ($\geq$ 76% air saturation) would provide a similar degree of safety for anadromous marine species (including salmonids) and freshwater salmonids, respectively. Levels below these oxygen criteria could seriously affect salmon stocks which utilize the lower Fraser River and estuary.

Dissolved oxygen levels below 7.75 mg/L are regularly found in side channels, including the Iona portion of Sturgeon Bank (Birtwell et al, 1983), Cannery Channel (Anderson, 1981), Deas and MacDonald Sloughs (Birtwell, personal communication), and the Serpentine and Nicomekl Rivers (Gough and Moore, 1983). Decreases in dissolved oxygen levels originate from several causes including the decomposition of algae, elevated water temperatures, flow restrictions which inhibit oxygen exchange, and the input of foreign substances with a high oxygen demand.

Suspended silt, under some conditions and at sufficient concentrations, can adversely affect sensitive fish species by clogging gills and abrading gill or body surfaces. Respiratory capability can be impaired, and the organism can become susceptible to fungal or bacterial diseases. Suspended silt may also affect feeding efficiencies, and migratory behaviour. Deposited silt can smother fish spawning beds, or may adversely affect the distribution or growth of fish food items. Silt has deteriorated spawning habitat in the Coquitlam River (Ministry of the Environment, 1978) and siltation has been noted in the Serpentine and Nicomekl Rivers (Schubert, 1982).

2.1.3 Wetland Birds. Due to their position at the top of food webs, some wetland birds can accumulate measurable levels of contaminants before they are detectable in water, sediment or other biota. The greatest potential environmental threat to wetland birds in the estuary is through the ingestion of contaminated food or external exposure to chemical or oil spills. Collections of birds or their eggs have been made in the past in

the Fraser River estuary. While concentrations of most organic chemicals were low, significant levels of dioxin (Norstrom and Simon, 1982), PCB's and DDE have been found in heron eggs, and in tissues of dunlin, and in several raptors (Garrett, 1980). Available information is limited, but indicates that birds in the Fraser estuary are not being significantly affected by heavy metals or toxic organic contaminants originating from the estuary itself.

Most species of wetland birds found in the estuary are migratory and therefore not appropriate for examination since they may reflect influences from other geographical areas. Although the Great Blue Heron (and its eggs) is well suited for monitoring since it is resident year round, forages for fish in potentially contaminated areas, and occurs in reasonably large numbers, it is desirable for conservation purposes to analyse limited samples of eggs and only adult specimens that have been killed by mishaps (eg. road kills) which do not affect sample quality.

Heron colonies are located at the University of British Columbia (UBC), Coquitlam, Crescent Beach and Point Roberts in the United States. The colony at UBC forages the estuary north from the Steveston Jetty to Sturgeon Bank; the Coquitlam colony forages the Fraser River Main Stem, Burnaby Lake and Brunette River; the Crescent Beach colony forages Boundary Bay, while the Point Roberts colony forages Boundary Bay and Roberts Bank as far north as the Steveston jetty (Whitehead, personal communication).

2.2 Criteria for Development of Routine Monitoring Programs

The terms of reference requested a comprehensive monitoring program which would determine "the overall condition of the aquatic environment on an ongoing basis and enable management and regulatory authorities to determine when and where the requirements for fish and biological productivity are not being satisfied". As well, the program should "...be implemented through existing agency programs augmented where possible by private sector funding obtained to satisfy regulatory requirements". Although it would be desirable to recommend a comprehensive monitoring

program which could be carried out in one year for the entire study area, the cost of such an undertaking would be prohibitive. For this reason a priorized flexible program was developed which would permit at least some monitoring to be undertaken yearly, the extent depending on agency budgets. Criteria were developed to accomplish this.

Programs proposed under the first priority category (Package 1) provide the minimum information required for the monitoring area. The following factors have been minimized for the first package: the frequency of sampling, the number of sites sampled and the number of parameters analysed. In each subsequent package there is an increase in at least one of these factors, thus increasing the information produced by the monitoring program. That is, in Package 2, the number of parameters analysed is increased; in Package 3 the number of sampling sites is increased; while in Package 4 the frequency of data collection is doubled. Package 4 is not meant to imply the "ultimate program": it simply represents the most complete package prepared by the committee.

More detail on the criteria used to develop the minimum acceptable baseline program (Package 1) follow:

A. Parameters and Species: Analyses will be carried out for those contaminants known to be widespread in the estuary. These include substances that are toxic, persistent, bioaccumulative or contributors to deteriorated environmental conditions such as low oxygen levels. In the case of sewage treatment plants, the variety of contaminants and their loadings dictate a more extensive program.

Biota to be monitored include species in the salmon food web (invertebrates) and those consumed by humans that are easily obtained and prepared for analyses. One wetland bird species will be selected to represent the highest level of the estuarine food web.

B. Monitoring Sites: Monitoring will occur at a control site, and sites at the lower and upper ends of the major reaches (Section 2.3) of the

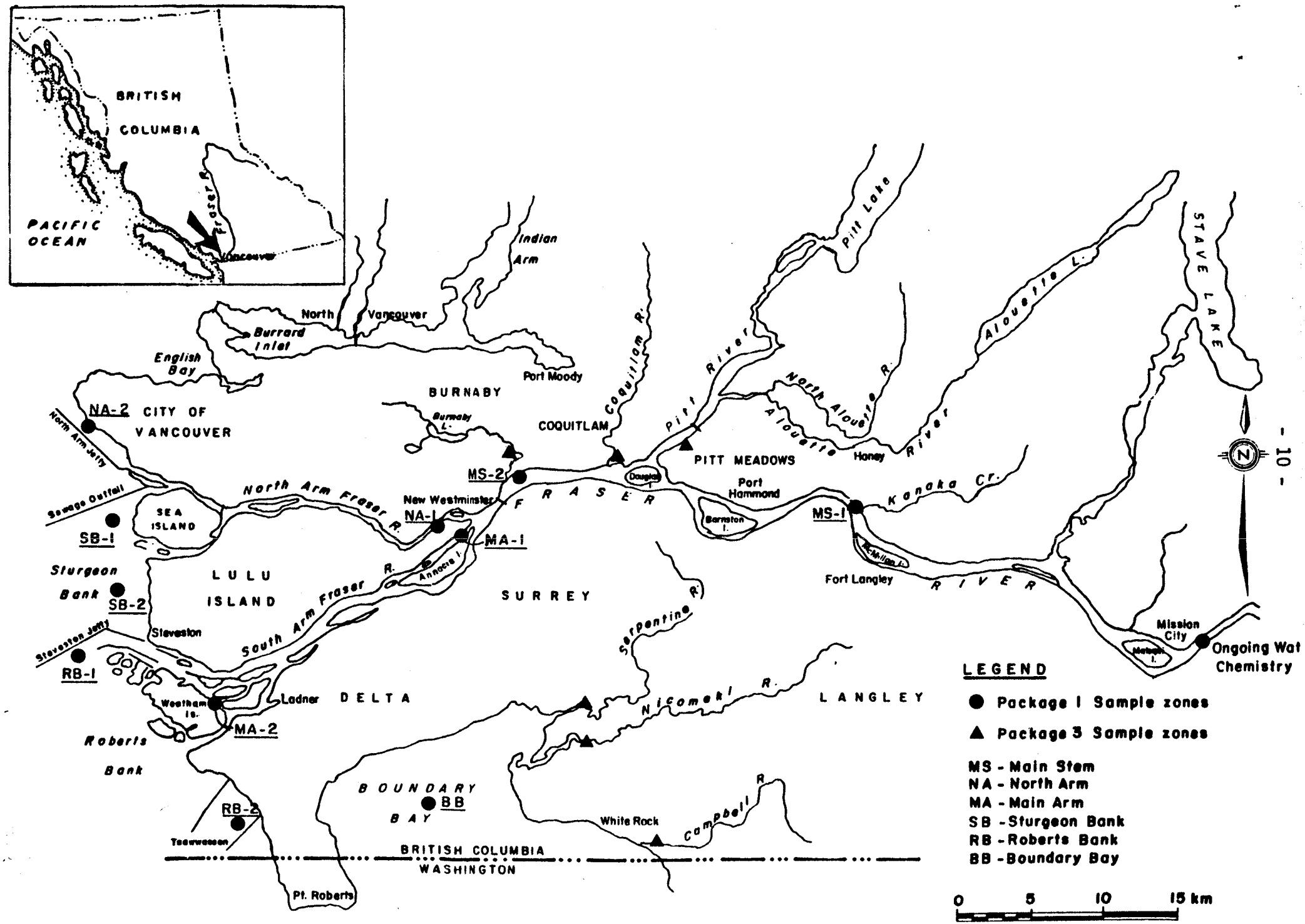

FIGURE 2 RECEIVING ENVIRONMENT MONITORING SITES

Fraser River. Monitoring will also be carried out at significant salmon rearing locations in the outer estuary. The general location of these sites is indicated in Figure 2 although specific locations will be determined on the basis of pilot sampling.

Recreational use is made of several outer estuary bathing beaches which are presently sampled by the Ministry of Health and the Greater Vancouver Sewerage and Drainage District (GVS & DD). It is assumed that this important work will continue to be funded. The locations of the bathing beaches are indicated on Figure 3. It is assumed that other monitoring such as water column sampling at Mission and the monitoring of deteriorated environmental conditions will also continue.

The selection of discharge monitoring sites ultimately will depend on a process reveiw of individual operations. Some preliminary choices, based upon present knowledge of contaminants from these sources, are indicated on Figure 4.

C. Timing and Frequency of Monitoring: A noteworthy aspect of the study area is the complex movement of water as a result of the interaction between tides and river flow. During periods of low to moderate flow, daily reversals occur throughout the area for several hours. To minimize, but not necessarily eliminate the effect of flow reversals upon the accuracy and consistency of the samples, water column monitoring in the main arms of the Fraser River should be carried out at maximum ebb flow. However, where deteriorated environmental conditions are being monitored "worst conditions" may dictate other sampling times.

Environmental monitoring at the minimum frequency will be restricted to the time of year at which worst conditions can be assessed. Sediments and biota will both be sampled at a consistent time of the year. For example, sediments will be sampled at low river flow (Feburary or March) when downstream movements of sediments is minimal. Although it is preferable to sample invertebrates at that stage in their life cycle when they could have the highest contaminant levels, it will be more convenient

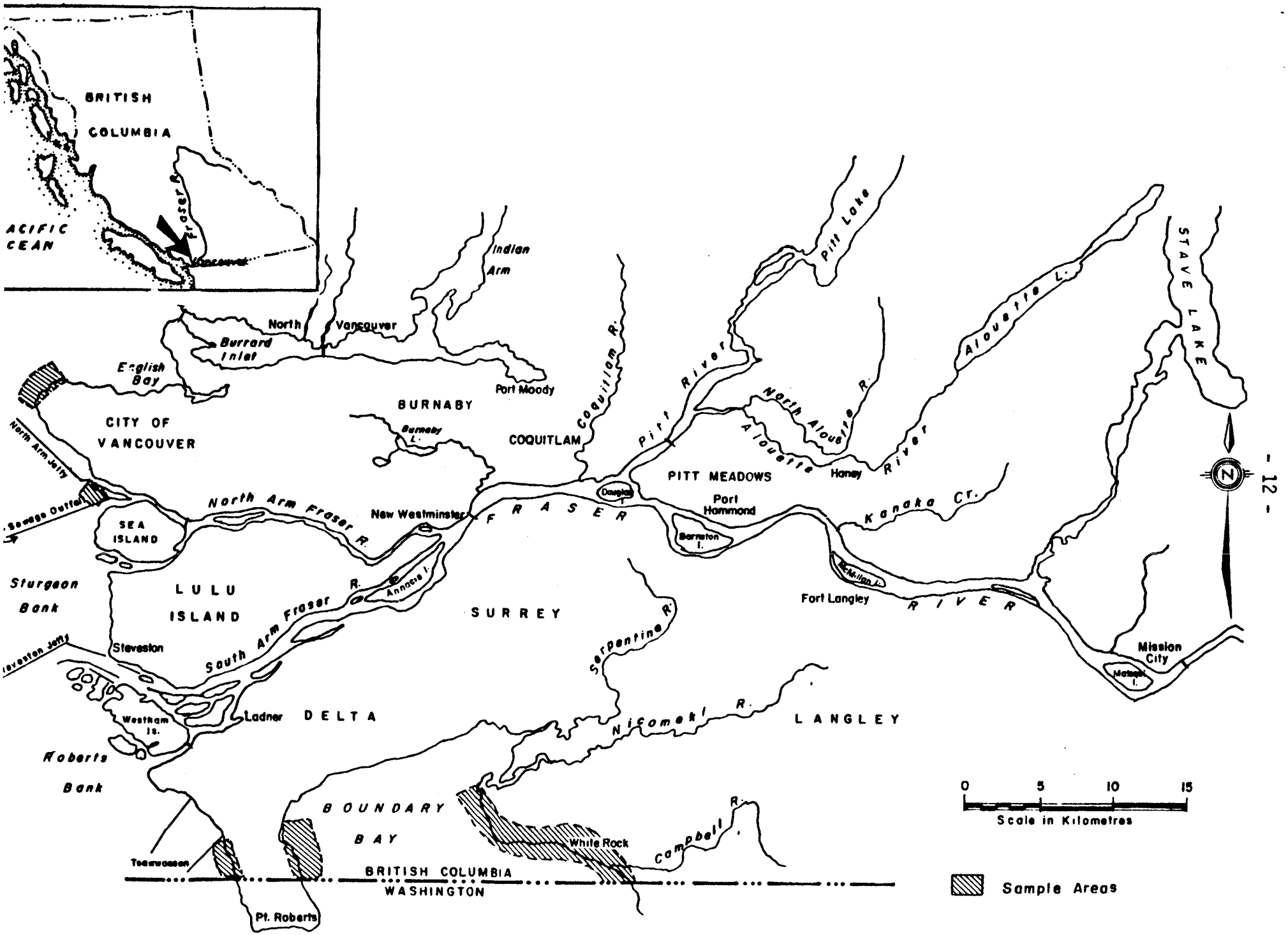

FIGURE 3 LOCATION OF BATHING BEACHES MONITORED BY MINISTRY OF HEALTH AND GVS AND DD

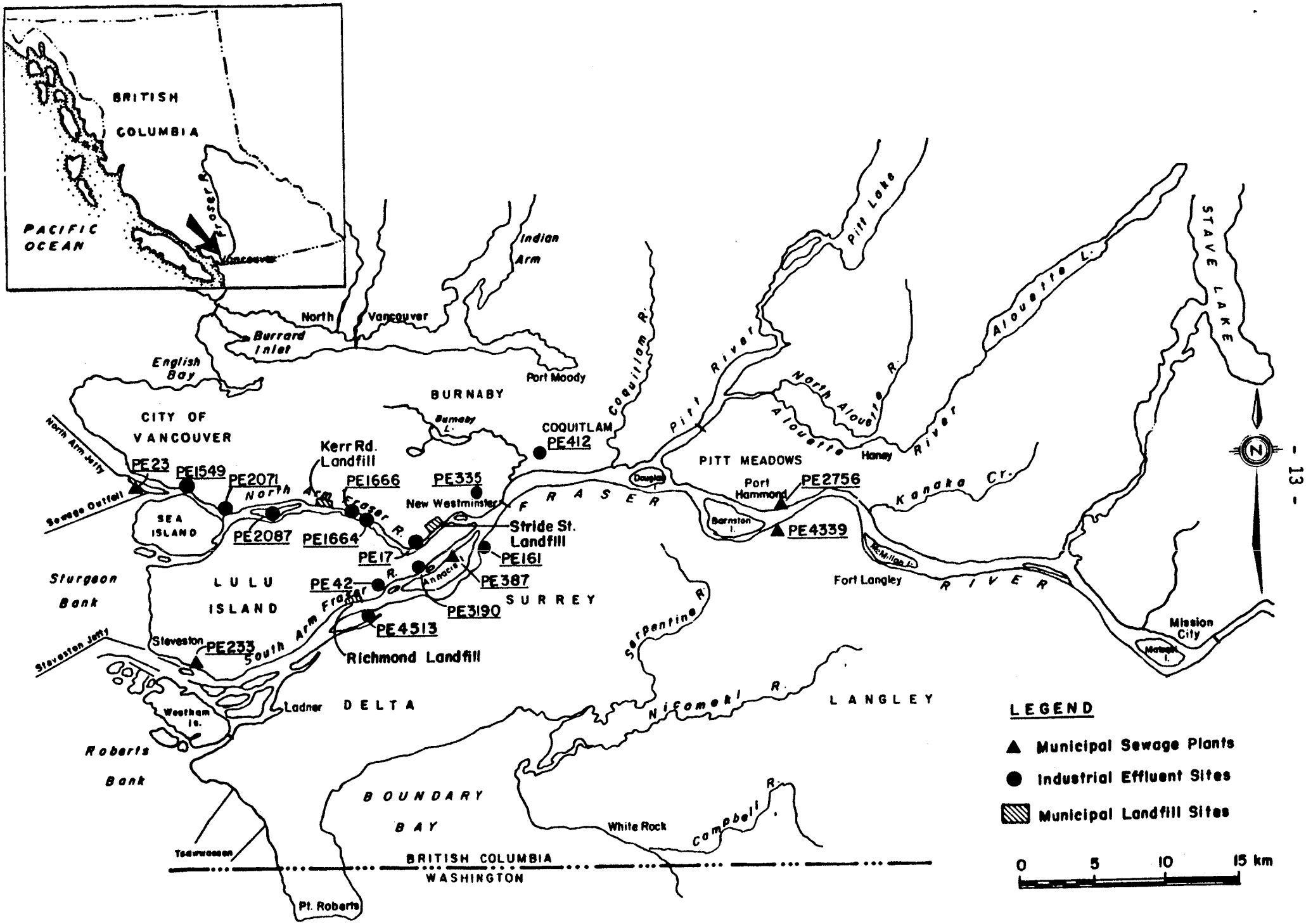

FIGURE 4 DISCHARGE MONITORING SITES (Numbers refer to WMB Permits listed in Table 3)

to sample them when sediments are collected. In the event that a twice yearly frequency (Package 4) is possible, sampling will also be undertaken when contaminants in the invertebrate tissues are believed to be at peak levels.

Effluent monitoring will take place at suspected peak contamination periods and during normal operating times. Monitoring will take place at a frequency which would confirm the presence of substantial loadings of specific contaminants and is meant to be in addition to and not replace that monitoring required of the operation under the terms of its Waste Management permit.

D. Monitoring Compartments: Water chemistry monitoring will be undertaken at Mission to establish loadings coming into the study area. Water column monitoring is presently carried out at Mission and will be undertaken at other sites for parameters such as dissolved oxygen and fecal coliforms to determine deteriorated environmental conditions. This monitoring should continue.

Past data indicate that sediments and biota should be monitored for selected persistent and cumulative contaminants. Discharges will be monitored for process-specific contaminants. In this regard composite samples will be collected for persistent contaminants, while discrete samples will be collected for acutely toxic contaminants.

2.3 Minimum Monitoring Program

Ideally, water, sediment, biota and effluents should be monitored in all sub-areas of the estuary each year. However, funding considerations dictate that the program be spaced over a five (5) year period. The program area is thus sub-divided as follows:

Year 1 - River and Outer-Estuary* (sub-areas 1+2) - Birds and effluents
Year 2 - Fraser River (sub-area 1) - Sediments and invertebrates
Year 3 - Fraser River (sub-area 1) - Fish
Year 4 - Outer Estuary* (sub-area 2) - Sediments and invertebrates
Year 5 - Outer Estuary* (sub-area 2) - Fish

*Roberts and Sturgeon Banks and Boundary Bay

These sub-units were chosen on the basis of natural geographic boundaries (river vs. outer areas), compatible environmental monitoring (sediment and invertebrates), and the desire to maintain a balanced work load and analytical expenditure from year to year. These divisions will introduce difficulties in relating changes in fish to changes in sediments, the food web and effluents because the measurements are in different years. Nevertheless, this design provides a suitable compromise as dictated by cost limitations. Tributaries (sub-areas 3 and 4) are excluded from the minimum program.

2.4 Criteria for Development of Special Studies

Special studies which are beyond the terms of reference for the monitoring program but which are required to address specific environmental problems in the estuary are not included or costed into the routine monitoring program. These studies should be conducted by groups with the appropriate research expertise. Most of the studies were recommended in Phase I (Summary Report, 1979) of the Fraser River Estuary Study. The criteria for categorizing special studies are one or more of the following:

- studies that are appropriately executed by a more intensive sampling approach over a finite time period as opposed to the infrequent sampling and long-term approach of the routine monitoring program.

- studies that address specific environmental problems that are not thought to be as immediate an environmental hazard as the concerns addressed by the routine monitoring program.

- studies that address problems covered by the routine monitoring program, but in a more detailed manner.

Studies which meet these criteria are listed in Section 3.4.

3. EXISTING AND PROPOSED MONITORING PROGRAM

The monitoring program will consist of discrete packages implemented in a given year. In the following years the number of packages undertaken may vary according to funding. Package 1 is the minimum monitoring program and packages 2, 3, and 4 are supplemental and can be carried out as funding permits (See Table 4).

The supplemental packages are considered important in raising scientific and statistical confidence in the monitoring data. The baseline program will consist of monitoring in environmental compartments such as water, sediments and biota and monitoring of effluent discharges. Considerations on these matters are discussed in the following sections.

3.1 Receiving Environment Compartments

Table 1 summarizes current collection procedures presently used by the Ministry of Environment (details in collection may vary with other agencies). These are presented only as a guideline and may be modified as the monitoring agencies require.

3.1.1 Water Quality. There is a need for up-to-date water quality information on which to base loading calculations and management decisions. At present, levels of copper, zinc, mercury (Drinnan and Clark, 1980) and fecal coliforms (Churchland, 1980) may influence decisions on the permitted quality of effluents in the study area. Thus, monitoring at a control site on the Main Stem of the Fraser is warranted. Existing, well-established sites at Pattullo and Mission Bridges were considered and although the site at Mission is outside the study area it was chosen due to its location beyond significant tidal influence. This site also has a flow gauging station. Presently, surface samples are collected six times per year at this station. A study being conducted by the Ministry of Environment will provide information to determine on the number of sample replicates that should be collected.

Parameters chosen for analysis include field measurements of pH, dissolved oxygen, temperature and specific conductance and laboratory measurements for nitrate/nitrite, Kjeldahl and ammonia nitrogen, ortho and total phosphorus, suspended solids, mercury, lead, zinc, and copper. The metals will be measured as dissolved and total. In addition to these contaminants, fecal coliform values should be determined.

Surface water monitoring involving expensive laboratory analyses at lower estuary sites was excluded due to strong reservations over the reliability of the measurements in an estuarine setting or alternately the costs of extensive replicate analyses. It was concluded that they only reliable season for broader estuarine sampling was during freshet but that at that time dilution would reduce many values to near ambient levels.

Current water quality monitoring in tributaries, backwaters and sloughs, is intermittent at present and examines only those conditions and areas associated with specific cases of environmental deterioration. Generally, these deteriorated conditions occur during the low flow period(s) of the year. This monitoring is meant only to provide an estimate of critical conditions, and includes field measurements for pH, temperature, dissolved oxygen, and specific conductance (no laboratory costs). "For the package 1 program sites at Sturgeon Bank, Cannery Channel, Deas and MacDonald Soughs and Serpentine and Nicomekl Rivers will be monitored twice in the late summer at low flow/high temperature periods during slack tide. These sites will be monitored for the field measurements listed above. If low oxygen levels are detected, the duration (Davis criteria) of these low levels should be ascertained. In package 3, six additional sites, (See Table 4) are included."

Bathing beaches should continue to be monitored for fecal coliform levels. This program is routinely carried out by Ministry of Health and GVS & DD staff at beaches shown in Figure 3. As a special study, monitoring for viruses and pathogens should be conducted at beaches potentially affected by sewage treatment plants, or where the log mean average fecal coliform value of five samples over a 30-day period exceeds 200 MPN/100 mL (Federal-Provincial Working Group on Recreational Water Quality, 1983).

TABLE 1 CURRENT MINISTRY OF ENVIRONMENT COLLECTION PROCEDURES

1. CHEMICAL ANALYSES	SEDIMENT	WATER	TISSUE
1.1 GENERAL METHOD			
Sampler	Ponar dredge/corer	Van Dorn/scoop/peristaltic pump	Stainless Steel Knife
Replicates	≥ 3	≥ 3	≥ 3
Sample Location	Equally Spaced	Equally Spaced	-
Sample Notes	Sediment Surface	Without Disturbing Sediment	Whole (Specific Organs)
1.2 GENERAL IONS			
Volume	-	4500 mL[7]	-
Container	-	4500 mL poly bottle	-
Preservation	-	Cool	-
Transit Time	-	48 hours	-
1.3 METALS			
Volume	250 mL	500 mL[9]	10 g (wet wt.)[2]
Container	250 mL polycup[1]	500 mL poly bottle[1]	bag/cup[8]
Preservation	Cool	2 mL HNO_3	Freeze immediately
Transit Time	-	-	
1.4 MERCURY			
Volume	250 mL	1250 mL	20 g (wet wt.)
Container	250 mL polycup[1]	1250 mL poly bottle[1]	bag/cup[8]
Preservation	Cool	6 mL 10% $K_2Cr_2O_7$+ 6 mL H_2SO_4	Freeze immediately
Transit Time	-	-	
1.5 ORGANICS			
Volume	400 g (dry wt.)[4]	4500 or 500 mL[7]	10 g. (wet wt.)[5]
Container	500 mL glass bottle[3] or alum. foil[10]	glass bottle	alum. foil wrapper[10]
Preservation	Freeze immediately		Freeze immediately
Transit Time	14 days (frozen to Lab)	14 days	14 days (frozen to lab)

TABLE 1 CONTINUED

1. CHEMICAL ANALYSES	WATER
1.6 CYANIDE	
Volume	500 mL
Container	500 mL poly bottle
Preservation	pH 12 with NaOH
Transit Time	NA
1.7 PHENOL	
Volume	500 mL
Container	500 mL poly bottle
Preservation	pH 4 with H_3PO_4
Transit Time	NA
1.8 SULPHIDE	
Volume	500 mL
Container	500 mL polybottle
Preservation	20 drops 2N. $ZnC_2H_3O_2$
	fill bottle completely

Footnotes:

[1]Acid washed
[2]20 grams for metals and mercury
[3]Foil under caps/pre-cleaned by lab
[4]Composite sample
[5]Muscle or specific organs only
[6]Narrow mouth bottle with foil under cap
[7]Depending on the number of tests, sample volume may be reduced
[8]Cup is preferred as the bag is unsuitable for moisture measurements
[9]Dissolved - Filter in Field before Acidification
Total - Acidify directly
[10]Solvent cleaned

TABLE 1 CONTINUED

2. PHYSICAL ANALYSES	SEDIMENT	WATER	TISSUE
2.1 PARTICLE SIZE			
Volume	250 mL	-	-
Container	250 mL poly cup	-	-
Preservation	None	-	-
Transit Time	-	-	-
2.2 PERCENT MOISTURE			
Volume	-	-	-
Container	-	-	At least 20 g (wet wt.) in a cup with lid
Preservation	-	-	Aquatic veg.-air dry and freeze. Animal tissue freeze
Transit Time	-	-	48 hours
2.3 FLOW/VOLUME			
Apparatus	-	Flow meter or equiv.	-
Methods	-	Insert probe in water depth cross-section and width measurements required for volume est.	
2.4 TEMPERATURE			
Apparatus	-	Thermometer/thermistor	-

TABLE 1 CONTINUED

3. BIOLOGICAL ANALYSES

	BENTHIC ORGANISMS	FISH
3.1 GENERAL		
Sampler	Grabs: Eckman, Ponar Peterson etc. Sieve Devices: Surber, Drift nets, artificial substrate etc.	net/angling/traps
Replicates	≥ 3	≥ 3
Sample Location	Accretion areas	Accretion areas
Sample depth	Sediment surface	Optional
3.2 TAXONOMY/BIOMETRIC DATA		
Volume	0.27 m^2 quadrat	
Container	500 mL wide mouth glass jar with cap	
Preservation	50-70% Ethanol	
Transit Time	-	-
Field Apparatus	-	Scale ruler, identification key
Field Method	-	Measure length, wt., #, identify to species
3.3 BIOASSAY		
		FISH BIOASSAY
Volume		LC50-100 L (filled to top) DT50-40 L (filled to top)
Container		20 L Non-toxic poly cubic container
Preservation		-
Transit Time		Max. 5d from collection to start of analyses

3.1.2 Sediments. The Water Survey of Canada has monitored suspended and bed-load sediment movement at a number of sites upstream from New Westminster, including Mission, since 1965. During freshet, samples have been collected for particle size analysis.

A uniform method of core and grab sampling for sediments should be adopted. A coring technique would identify the volume and depth of a sample whereas a dredge would collect more recent sediment depositions, and would be generally more reliable in collecting samples in areas littered with larger debris.

It is recommended that ten replicate samples be collected from areas of fine sediment deposition, usually along the shores. Variables to be analysed include cadmium, chromium, copper, lead, mercury, nickel, silver, zinc, chlorophenol and PCB's. In addition, particle size and percent organic carbon analyses should be performed to determine the silt and organic content of the sediments. Additional analyses (including PAH's and phthalate esters) would be carried out at increased funding levels (Package 2).

3.1.3 Biota. Biological monitoring provides information on the availability and bio-accumulation of contaminants. Representative species (Table 2) of fish, invertebrates, and wetland birds were restricted to applicable primary food sources for man, salmon, and heron. In addition, species were selected based upon their availability through standard sampling techniques, ease of sampling, distribution in the area, and the effort required to prepare the sample for analysis. An attempt should be made to collect at least one species in as many areas as possible for comparative purposes.

Invertebrates recommended for sampling include tubificids or other oligochaetes and mysids or amphipods depending on their availability in a specific sample area. Some of these species have been analysed successfully in the past (C. Levings, personal communication, Northcote et al. 1976), whereas invertebrates such as chironomids have been difficult to

TABLE 2 BIOTA SELECTED FOR SAMPLING IN VARIOUS LOCALES WITHIN THE MONITORING AREA

	ROBERTS BANK STURGEON BANK BOUNDARY BAY	FRASER RIVER	TRIBUTARIES
Fish	3 Spine Stickleback** Sculpin* Starry Flounder** Peamouth Chub** Salmonid***	3 Spine Stickleback** Largescale Sucker* Peamouth Chub** Squawfish* Salmonid*** Starry Flounder** Prickly Sculpin*	3 Spine Stickleback** Largescale Sucker* Peamouth Chub** Salmonid*** Starry Flounder Prickly Sculpin
Invertebrates	Crabs Bivalves Mysids, Amphipods	Tubificids Other Oligochaetes Mysids, Amphipods	Tubificids Other Oligochaetes Mysids, Amphipods
Birds	Heron (adult & eggs)	Heron (adult & eggs)	

*normally gill netted
**normally beach seined
***Chinook smolts recommended, if available.

collect (however, chironomids are an important food source for salmon). On Sturgeon and Roberts Banks and in Boundary Bay, bivalves and crabs should be monitored.

Fish species which have been found in at least some portions of the chosen sub-areas are listed in Table 2. Since there are many unknowns regarding the temporal and spatial variations of estuarine fish, the final selection of monitoring species may have to be determined from a pilot project. Species will be weighed, measured and the sex will be determined prior to being analysed for tissue contaminants. (Liver tissue will be analysed if of sufficient quality.)

It is assumed that ten replicate samples of two species of fish and invertebrates will be analysed. Specimens of other species collected should be frozen for future analysis. In addition, six replicates of herons from road kills should be analysed if available. Analyses will be conducted for arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, zinc, PCB's and chlorophenols. Eggs from Blue Heron will be weighed, sized and analysed for mercury and several persistent organochlorine compounds. The shell thickness will also be determined.

3.2 Effluent Discharges

A description of municipal effluent discharges to the study area is found in Cain and Swain (1980). Due to their volume and wide range of contaminants present from numerous sources discharging to the sewerage system, sewage effluents pose the single greatest potential threat to the receiving environment. Sampling at the plants will occur monthly during year 1 of the monitoring cycle.

The three major sewage treatment plants (Figure 4) in the study area are Annacis (PE 387), Iona (PE 23) and Lulu (PE 233), all administered by the GVS & DD. The GVS & DD monitor these effluents monthly for nutrients, phenol, toxicity, metals, and more frequently for flow, fecal coliforms, BOD_5, suspended solids, dissolved oxygen, temperature, chlorides, pH, COD, and residual chlorine. This provides a basic continuous program

which will be enhanced once every five years when monitoring occurs in the area in which these sewage treatment plants are located. Sampling should be carried out monthly at the outfall from the chlorine contact chamber or dechlorination chamber where applicable. The proposed analyses are included in Table 3 and are based on the information from phase 1 and subsequent reports. In general, persistent contaminants should be measured in composite samples and acutely toxic contaminants in discrete samples. In addition to sampling at Annacis, Iona, and Lulu, sampling should also be carried out at the Langley STP.

A number of industrial effluent discharges enter the Fraser River Estuary within the study area. Information is lacking on individual or collective impacts from a number of more important discharges. Implicit in an analysis of effluent discharges is a thorough examination of industrial processes involved, from which a list of parameters to be monitored can be formulated.

A preliminary list of operations known or suspected of discharging specific contaminants is given in Table 3. This list should be revised upon completion of a detailed review of the industrial processes at these or other sites in each area. Non-point discharges such as drainage from wood preservation dip tank areas also should be considered in this review.

3.3 Program Integration

A baseline program (Package 1) with additional packages (2, 3, 4), as funding permits, will be carried out in a given area in a given year. In addition, existing monitoring programs at Mission and bathing beaches will be carried out. Sites with deteriorated water quality and permitted (Waste Management) discharge sites will also be sampled. Elements for each of the packages are presented in Table 4 based upon considerations discussed in sections 3.1 and 3.2. Generally, Package 2 increases the number of organic parameters, Package 3 increases the number of tributary monitoring sites and Package 4 doubles the frequency of

TABLE 3 PROPOSED DISCHARGE MONITORING

DISCHARGE	METALS (Dissolved and Total)	TOTAL PHENOL	CHLORINATED PHENOLS	PCB'S	TOXICITY (96 h LC_{50})	SULPHIDE	FECAL COLIFORM	NUTRIENTS OP, TP NH_3, TKN, NO_2/NO_3	pH*, T*, COD ALKALINITY	FLOW*, CHLORINE RESIDUAL*	OTHERS
SAMPLE TYPE	C	C	C	C	D	D	D	C	C	D	C or D
1. SEWAGE TREATMENT PLANTS PE 23, PE 233, PE 387, PE 4339	Metals Scan	X	X	X	X	X	X	X	X	X	Phthalate esters PAH's
2. FOREST											
PE 17	-	-	X	X	X	-	-	X	X	Flow	-
PE 335, PE 412,	-	-	X	-	X	-	-	X	X	Flow	-
PE 1664, PE 1666	-	-	X	-	X	-	-	X	X	Flow	-
PE 2756	-	-	X	-	X	-	-	X	X	Flow	-
3. METAL FINISHING AND FABRICATING											
PE 161, PE 2087	Cr, Cu, Fe,	X	-	-	X	-	-	-	X	Flow	CN
PE 3190	Pb, Zn	X	-	-	X	-	-	-	X	Flow	CN
4. CONCRETE											
PE 42, PE 4513	Cr, Cu, Pb, Zn	-	-	-	X	X	-	OP, TP	X	Flow	-
5. MISCELLANEOUS											
PE 1549	Fe, Pb, Zn,	X	X	-	-	-	-		-	-	CN
PE 2071	Cr, Cu, Pb, Zn	-	-	-	X	X	-	OP, TP	X	Flow	-
6. LANDFILLS	Metals Scan	-	-	X	X	X	-	NH_3	X	Flow	

*: In Situ testing
X: Tests to be performed. Where no X appears, no tests or only those individual tests indicated of the group are to be performed
C: Composite (6 hour minimum, 24 hour maximum): flow proportional or with 15 minute additions, if possible
D: Discrete sample
OP: Ortho Phosphorus
TP: Total Phosphorus
PE 17: Delkin Packaging
PE 23: Iona STP
PE 42: La Farge Cement
PE 161: Titan Wire and Steel
PE 233: Lulu STP
PE 335: Scott Paper
PE 387: Annacis STP
PE 412: Crown, Zellerbach, Fraser Mills
PE 1549: Borden Company, Ltd.
PE 1664: McMillan Bloedel, New Westminster
PE 1666: McMillan Bloedel, Canadian White Pine
PE 2071: Globe West Products
PE 2087: Western Canada Steel Ltd.
PE 2756: B.C. Forest Products, Hammond
PE 3190: Tree Island Steel
PE 4339: Langley STP
PE 4513: Genstar

TABLE 4 SUMMARY OF PACKAGES BY ENVIRONMENTAL COMPARTMENT

PACKAGE	DESCRIPTION	
1	Effluent, Sediments	At effluent sites and for analyses listed in Table 3. Ten replicate samples from each site for sediments. Analyses for particle size, % organic C, As, Ag, Cd, Cu, Cr, Pb, Ni, Hg, Zn, chlorophenols, and PCB's.
	Invertebrates, Fish, Wading Birds*	Ten replicate samples of each species (Table 2). Analyses for As, Ag, Cd, Cu, Cr, Pb, Hg, Ni, Zn, PCB's, and chlorophenols.
	Water Quality (low no sites)	Field analyses for DO., pH, temperature, specific conductance.
2	Add Parameters	Using the same 10 replicates as were used for package 1 analyses, further tests will be conducted for PAH's and phthalate esters.
3	Add Tributary Sites	Establish one sampling site on each tributary to the Main Stem and to Boundary Bay (Brunette, Coquitlam, Pitt, Serpentine, Nicomekl, Campbell). Obtain 10 replicate samples (of each species, if appropriate).
	Add Low DO Sites	Add sites at Richmond Island, Gunderson Slough, Annacis Slough, Deering Island Slough, Little Campbell R., Fraser Surrey Dock sidechannel.
4	Increase Monitoring as Follows: Sediments, Fish Invertebrates	Collect 10 replicate samples (of each species, if appropriate) during another time of the year. Analyse as per packages 1 and 2.
	Water Quality	Monitor water chemistry every 10 days at Mission during freshet. Analyse for pH, DO, sp. cond., NO_2/NO_3, TKN, TN, OP, TP, SS, Hg, Cu, Pb, Zn (metals: total and diss.), fecal coliform.
	Effluents	Double frequency of collection in package 1.

*Road kill samples - as available

sampling. Each package builds upon the previous one. Additional supplementary packages would definitely be useful in examining more salmonid tributaries or increasing monitoring frequencies to levels more suitable for trend analyses.

3.4 Special Studies

Based on the criteria presented in Section 2.4 a list of special studies has been prepared. They are relevant to management decisions, but considered to be limited rather than long-term investigations. Such studies have neither been priorized nor costed. The committee feels that these investigations should proceed when time and funding permit. Such studies include:

- a study of the input of nutrients to tributary watersheds, their influence on algal growths and the effect of subsequent algal decay on dissolved oxygen levels. Components which should be examined include runoff quality, the contribution of sediments to oxygen demand, recycling of nutrients, and general water chemistry.

- an investigation of the quality of irrigation waters.

- a study on the sources of mercury to the lower Fraser River to explain mercury accumulation in sediments and biota.

- speciation and biological availability of copper and zinc in the Fraser River water.

- a study of the dilution and survival of fecal coliforms in the Fraser River plume as it extends into the Strait of Georgia at different seasons and river flow conditions.

- a study to determine the levels of fecal coliforms in the Main and North Arms in winter when the sewage treatment plants are not disinfecting effluents. This study may have some relevance to the above study.

- a study on the effects of landfill leachates on the river water quality and, when diverted to sewage treatment plants, on the plant effluent quality and toxicity.

- a study on the nutrient inputs from the Fraser River into the Strait of Georgia.

- further studies on the quality of stormwater inputs from residential, industrial and agricultural catchment areas. These studies should include investigations on the quality of combined sewer outflows.

- a study on pesticide accumulation in irrigation ditches and other areas in the lower Fraser River.

- studies on the chronic toxicity of sewage treatment plant and other effluents to better understand the continued input of toxicants into the river.

- an investigation of the presence and accumulation in sediments, water, and biota of toxic organic compounds that are not analysed in the routine monitoring program.

- a study on the effects of woodwaste leachate on water quality.

- a study on organic contaminant accumulation in periphyton sampled from artificial substrates and the feasibility of using this technique for organic contaminant monitoring.

- studies on the water quality in the Annacis effluent zone of influence. These studies should be conducted at various river flow conditions, and especially at times of salmonid migrations to determine the effects on the migrating stocks.

- an investigation of the presence or absence of viruses at bathing beaches.

- a determination of environmental conditions in sloughs and backwaters. This should include an examination organics and other toxic substances in fish, invertebrates and sediments.

4. OTHER PROGRAM CONSIDERATIONS

Certain organizational and funding matters require attention both before and after the monitoring program is implemented.

Agencies involved in the program should be chosen from those hving demonstrated expertise in a given area of monitoring. Table 5 outlines agencies which presently have such expertise, however, the inclusion of any agency on the list does not imply a committment on behalf of that agency. It merely indicates to management where existing expertise lies, and to which agencies funding could be provided for monitoring.

Opportunities for additional sample collection or further analyses which may become available through special funding or research - university interests should also be pursued. However, where non-government laboratories are to perform analyses, a quality assurance program should be established both prior to and during the period when analyses are being performed.

4.1 Program Co-ordination

Wherever possible, sampling of sediments and invertebrates should be carried out concurrently. This will allow agencies to work together in collecting samples, and will permit equipment, personnel and maintenance costs to be spread among those agencies with a particular interest or with available funding.

In order to coordinate working arrangements and to prevent duplication of effort on a yearly basis, provision should be made for all agencies to be advised of monitoring programs undertaken.

4.2 Analytical Costs

The analytical costs of projects outlined in Table 4 are presented in Table 6. These costs are based on a price list prepared by the Ministry of Environment, Environmental Laboratory for 1983/84 and are meant only as a general guide.

TABLE 5 SUMMARY OF MONITORING EXPERTISE

AGENCY	ENVIRONMENTAL COMPARTMENT					
	WATER COLUMN	INVERTEBRATES	FISH	SEDIMENTS	EFFLUENTS	WADING BIRDS
Canadian Wildlife Service	-	-	-	-	-	LT
Environmental Protection Service	P	P	P	P	P	-
Fisheries and Oceans	P	P	P	-	-	-
Greater Vancouver Sewerage and Drainage District	LT	-	-	-	LT	-
Ministry of Health	LT*	-	-	-	-	-
Inland Waters Directorate	LT	P	P	P	-	-
Waste Management	LT	P	-	P	LT	-
Water Management	LT	P	P	P	P	-
Fish and Wildlife	P	P	P	P	P	-

*Microbiological Sampling

P: Sampling is predominantly project-oriented.

LT: Sampling is predominantly long-term in nature.

Beside each item and under each year listed in Table 6, two prices are presented. The first is the cost of that item, while the second cost (in brackets) is the total cost of all items to that point. The latter figure has been provided so that the approximate amount of work which might be accomplished for a certain level of funding can be determined. Further reduction in yearly costs may be possible if samples are frozen (freeze-drying available) for testing in later years. Details related to the breakdown of costs associated with the baseline program (package 1) are presented in Table 7.

4.3 Personnel Requirements

Field Personnel estimated to be required for studying processes associated with each effluent discharge and for collecting effluent, water, sediment, and biologial samples are presented in Table 8. Personnel requirements have been prepared according to each of the funding packages proposed in Table 4, with these requirements further sub-divided according to the activity of the personnel. At the first package level, it has been estimated that: an engineer will be required for 10 days at each operation to study its process; a technician will be required 0.5 days for sample collection per operation; and 3 biologists/technicians will be required for 2 days each per site for sediment and biota collection and one day each per site for fish collection. Further staff time for sample collection is required for the two lowest ranked (3, 4) priority packages. Allowance for field monitoring at sites suspected to have low oxygen is two half-day sessions per site (2 technicians/biologists per session of boat work).

Beside each item and under each year listed in Table 8, two minimum personnel requirements are presented. The first is the required number of personnel for that item, while the second number (in brackets) is the total number of personnel required to that point. The latter number has been provided in order that appropriate minimum staff funding can be provided in the future to undertake the monitoring program.

TABLE 6 SUMMARY OF MONITORING PRIORITIES AND ANALYTICAL COSTS
(Based upon price list prepared by the Ministry of Environment, Environmental Laboratory for 1983/84)

PACKAGE	PACKAGE DESCRIPTION (See Table 4)	ANALYTICAL COSTS					
		EVERY YEAR	YEAR 1 All Areas (Birds, Effluents)	YEAR 2 Fraser River (Sediments, Invertebrates)	YEAR 3 Fraser River (Fish)	YEAR 4 Outer Estuary (Sediments, Invertebrates)	YEAR 5 Outer Estuary (Fish)
Existing	Water Quality @ Mission (6/yr)	$2500	-	-	-	-	-
	Fecal Coliforms @ Bathing Beaches Field Measurements Environmental Conditions	$2500	-	-	-	-	-
1	Basic Program	-	61 400	72 200	45 100	60 200	37 600
		-	(61 400)	(72 200)	(45 100)	(60 200)	(37 600)
2	Add Parameters	-	0	108 000	72 000	90 000	60 000
			(61 400)	(180 200)	(117 100)	(150 200)	(97 600)
3	Add Tributary Sites	-	0	180 200	117 100	180 200	117 100
			(61 400)	(360 400)	(234 200)	(330 400)	(214 700)
4	Increase Frequency	-	61 400	360 400	234 200	330 400	214 700
			(122 800)	(720 800)	(468 400)	(660 800)	(429 400)

Numbers in brackets are cumulative totals of all costs to that level of priority.

TABLE 7 A DETAILED BREAKDOWN OF SAMPLING SITES AND ANALYTICAL COSTS ASSOCIATED WITH THE BASELINE PROGRAM (PACKAGE 1)

ENVIRONMENTAL COMPARTMENT	SAMPLING SITES AND TOTAL SAMPLES COLLECTED OVER 5 YEARS											
	MAIN STEM		NORTH ARM		MAIN ARM		STURGEON-ROBERTS		BOUNDARY BAY		TOTAL	
	N	NS	N	NS	N	NS	N	NS	N	NS	N	NS
Effluents	4	30	8	40	7	48	1	12			20	130
Waterfowl	1	12					2	24	1	12	4	48
Sediments	2	20	2	20	2	20	4	40	1	10	11	110
Invertebrates	2	40	2	40	2	40	4	80	1	20	11	220
Fish	2	40	2	40	2	40	4	80	1	20	11	220

N = no. of sample areas or sites
NS = total number of samples collected in five years

	ANALYTICAL COSTS (1983 $) OVER 5 YRS.					
	MAIN STEM	NORTH ARM	MAIN ARM	STURGEON-ROBERTS	BOUNDARY BAY	TOTAL
Existing Mission Water Quality	10 000	-	-	-	-	10 000
Existing Bathing Beach Monitoring	-	4 250	-	2 000	6 250	12 500
Effluents	3 888	15 880	21 264	8 400	-	49 432
Waterfowl	3 000	-	-	6 000	3 000	12 000
Sediments	9 040	9 040	9 040	18 080	4 520	49 720
Invertebrates	15 040	15 040	15 040	30 080	7 520	82 720
Fish	15 040	15 040	15 040	30 080	7 520	82 720
TOTAL	56 008	59 250	60 384	94 640	28 810	299 092

SAMPLE CYCLE PROGRESSION		($/YR)
Annual	Mission water quality and Ministry of Health bathing beach monitoring	4 500
Year 1	Effluents and Waterfowl throughout the study area	61 400
Year 2	Sediments and Invertebrates, Fraser River stations	72 240
Year 3	Fish, Fraser River stations	45 120
Year 4	Sediments and invertebrates, Outer Estuary stations	60 200
Year 5	Fish, Outer Estuary stations	37 600

TABLE 8 MINIMUM PERSONNEL REQUIREMENTS (Staff Days)

PACKAGE NUMBER AND DESCRIPTION	ACTIVITY	MINIMUM ESTIMATED STAFF DAYS REQUIRED					
		YEAR 1 ALL AREAS (Effluents)		YEAR 2 FRASER RIVER (Sediments & Invertebrates)	YEAR 3 FRASER RIVER (Water & Fish)	YEAR 4 OUTER ESTUARY (Sediments & Invertebrates)	YEAR 5 OUTER ESTUARY (Water & Fish)
		Engineers	Technicians	Biologists/Technicians	Biologists/Technicians	Biologists/Technicians	Biologists/Technicians
Existing*	Sample Collection			10**		60**	
1. Baseline Program	Study of process	160	0	0	0	0	0
		(160)	(0)	(0)	(0)	(0)	(0)
	Sample collection	0	96	36	30	30	27
		(160)	(96)	(36)	(30)	(30)	(27)
2. Increase No. of Analyses	No field work	0	0	0	0	0	0
		(160)	(96)	(36)	(30)	(30)	(27)
3. Additional Tributaries & low DO sites	Sample collection	0	0	36	28	36	20
		(160)	(96)	(72)	(58)	(66)	(47)
4. Double the Frequency of Sampling	Sample collection	0	96	72	58	66	47
		(160)	(192)	(144)	(116)	(132)	(94)

Note: Numbers in brackets are cumulative totals of all personnel requirements to that level.

*This item includes the present Waste Management Branch water quality program (6 times per year frequency) transferred to Mission and bathing beach monitoring.

**Not included in cumulative totals.

4.4 Monitoring Program Review

Periodic review of the monitoring results and program design should be conducted by agencies involved in the program. An appropriate time for this review would be at the end of each five year cycle. Included in this review should be a consideration of sampling locations, frequencies, parameters, sample sizes, numbers of replicates, and sampling and analytical methods. The monitoring design should be evaluated with respect to its effectiveness in addressing the original terms of reference, water quality objectives developed for the estuary, or new environmental problems.

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APPENDIX I

INTRODUCTION

In late 1981, the Regional Director General for the Pacific and Yukon Region and the Assistant Deputy Minister for the Assessment and Planning Division of the B.C. Ministry of Environment agreed to improve coordination, eliminate overlap, and make better use of resources in the Fraser River Estuary. Terms of reference were subsequently developed for a committee to develop a Fraser River Estuary Monitoring Program.

TERMS OF REFERENCE

WORKING COMMITTEE ON FRASER RIVER ESTUARY MONITORING

Preamble

It is assumed that fish and biological productivity will be recognized in the Fraser River Estuary Management Plan as an ongoing principal use of the Fraser River Estuary, and that aquatic environmental quality requirements for fish and biological productivity are the most stringent of all principal users of the Fraser River Estuary. Consequently, it is proposed that the ongoing program to monitor the quality of the aquatic environment in the Fraser River Estuary should enable management and regulatory authorities to determine when and where the requirements for fish and biological productivity are not being satisfied. To improve the effectiveness of the limited resources available for this purpose, it is proposed to develop a design of the long term monitoring program including a standardized protocol for sampling, for the variables to be measured, for the handling of samples and for laboratory and data management procedures. The proposed first step in this process is to establish an ad hoc committee to advise on the design of the sampling program and those activities leading to the delivery of samples to the laboratories. Subsequent activities, such as laboratory procedures,

quality control, data management and interpretation, and implementation of the monitoring program will be considered separately.

It is emphasized that the monitoring program to be the subject of consideration is not for the purpose of research, for apprehending violators, for habitat inventory, for restoration or dealing with applications for pollution control permits, but for determining the overall condition of the aquatic environment on an ongoing basis. Special purpose monitoring or sampling would be undertaken at the discretion of agencies which require them outside the scope of this monitoring program.

Working Committee

Membership of the Working Committee should include representatives of the following agencies:

Federal - Environmental Protection Service, Environment Canada

- Inland Waters Directorate, Environment Canada

- Fisheries Management Service, Fisheries and Oceans Canada

- Institute of Ocean Sciences, Fisheries and Oceans Canada

Provincial - Lower Mainland Region, Ministry of Environment

- Waste Management Branch, Ministry of Environment

- Aquatic Studies Branch, Ministry of Environment

- Environmental Laboratory, Ministry of Environment

The committee shall appoint one British Columbia representative to act as chairman.

The Working Committee would dissolve on completion of the tasks specified herein. It is understood that participation by agency representatives in this Working Committee does not imply an ongoing commitment for any subsequent program.

Members of the Working Committee may secure advice from agencies not represented on the Working Committee as they may require, at their discretion.

Specific Terms of Reference

The monitoring program shall recognize the main channels, the backwaters and the intertidal flats on Sturgeon and Roberts Banks and Boundary Bay as distinct sub-regions of the estuary, and shall make provisions for the special requirements of each.

Sampling locations shall be priorized without regard to the sub-region they are located in so that the priority of each can be determined with respect to all others.

Sampling may include, where appropriate, effluent conditions as well as ambient conditions.

The specific variables proposed for measurement shall be priorized for each location.

The specific variables (e.g., substances, or physical, chemical or biological attributes) proposed for measurement may include appropriate parts of the food chain from the abiotic environment (water and sediments) through lower organisms and fish to man.

The recommendations of the Working Committee shall include recommendations on intensity of sampling, in both time and space.

The monitoring program design shall provide for establishing the baseline conditions and for perpetual or ongoing monitoring to update the baseline. Appropriate scheduling of sampling intensity and variables measured to accomplish these objectives shall be recommended. Provision should also be made for periodic review and revision.

The procedures up to and including delivery of samples to analytical laboratories shall be within the scope of the Working Committee.

Recommendations for the Working Committee shall include explanation of the reasons for collecting any information recommended for collection.

The recommended program design(s) should include approximate costs for the component activities. The Working Committee should assume that the program would be implemented through existing agency programs augmented where possible by private sector funding obtained to satisfy regulatory requirements.

The Working Committee should report back at an early date to describe how it proposes to function, its schedule for submitting a preliminary design, and its target for completion of the overall task.