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ENVIRONMENTAL PROTECTION SERVICE
PACIFIC REGION

SHELLFISH GROWING WATER SANITARY
SURVEY OF SEMIAHMOO BAY AND SELECTED
AREAS OF BOUNDARY BAY

Regional Program Report: 78-11

by

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ABSTRACT

A sanitary and bacteriological survey of the intertidal waters of Semiahmoo Bay and the eastern portion of Boundary Bay from Crescent Beach to Kwomais Point was conducted by personnel of the Environmental Protection Service, Pacific Region, between November 14 and December 20, 1977.

The bacteriological study was undertaken to evaluate bivalve molluscan shellfish growing water quality and permit a review of relevant portions of the existing British Columbia Fisheries Regulations Schedule 1 Contaminated Shellfish Closure 29-1. The sanitary survey was conducted concurrently to identify and evaluate major sources of bacterial contamination to the study area.

A total of 81 marine stations were established to monitor the bacteriological water quality of the survey area and all but two stations exceeded the approved shellfish growing water quality standard.

The Serpentine and Nicomekl rivers were identified as the major sources of bacterial contamination to the eastern portion of Boundary Bay and the Campbell River was identified as the major source to Semiahmoo Bay.

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RÉSUMÉ

Du 14 novembre au 20 décembre 1977, le Service de la protection de l'Environnement de la région du Pacifique a réalisé une étude bactériologique et sanitaire des eaux intertidales de la baie Semiahmoo et de la zone orientale de la baie Boundary, de Crescent Beach à Kwomais Point.

L'étude bactériologique a servi à évaluer la qualité des eaux maricoles où croissent les lamellibranches et a permis de réviser les articles pertinents de l'annexe I du Règlement sur les pêches de la Colombie-Britannique, qui concerne l'interdiction numéro 29-1 de pêcher les mollusques contaminés. L'étude sanitaire s'est déroulée en même temps pour identifier et évaluer les sources principales de contamination bactérienne dans la zone considérée.

Quatre-vingt-une stations marines au total ont permis de contrôler la qualité bactériologique de l'eau et , dans toutes ces stations, à l'exception de deux, la qualité du milieu aquatique était supérieure aux normes fixées pour la mariculture.

On a pu déterminer que les rivières Serpentine et Nicomekl sont les principales sources de contamination bactérienne dans la zone orientale de la baie Boundary et que la rivière Campbell est la source majeure de contamination de la baie Semiahmoo.

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CONCLUSIONS

CONCLUSIONS

1. The tidal foreshore waters of Semiahmoo Bay from Kwomais Point to the International Boundary are exposed to fecal contamination to the extent that consumption of molluscan shellfish from this area can constitute a health hazard. Significant bacteriological contamination to Semiahmoo Bay as indicated by high fecal coliform counts was noted from the following sources.

- a) Campbell River - Fecal pollution that enters the Campbell River largely in runoff from agricultural land was the major identified source of contamination to Semiahmoo Bay.
- b) two stormwater drainage systems in the City of White Rock.
- c) the Douglas Border Crossing stormwater collection system.
- d) a small stream in the Municipality of Surrey, between 133A and 132B streets.

Five incidents of sewage overflows from the City of White Rock sanitary collection system were noted during the survey. In four cases, sewage overflowed in the manhole at Kent and Columbia streets, and of these, three resulted in direct discharge of sewage through the City of White Rock Sewage Treatment Plant outfall to the Campbell River, and thence to Semiahmoo Bay. Due to the large amount of fecal contamination entering the Campbell River in runoff from agricultural land, it is difficult to assess the incremental impact of these overflows.

2. The bacteriological quality of the waters of Semiahmoo Bay did not appear to significantly improve as a consequence of the cessation of the sewage discharge to the Campbell River. However, this is due in part, to the high level of precipitation encountered during the survey. An improvement in bacteriological water quality is predicted

during summer months since the former discharge from the White Rock STP constituted a significant portion of the Campbell River summer flows. However, it is unlikely that the bacteriological water quality will meet acceptable shellfish harvesting standards.

3. The tidal foreshore waters of Boundary Bay from Crescent Beach to Kwomais Point are exposed to fecal contamination to the extent that consumption of molluscan shellfish from this area can constitute a health hazard. The Serpentine and Nicomekl rivers were the significant identified sources of contamination to this area.

SCHEDULE 1 CLOSURES

Contaminated Area 29-1 of the British Columbia Fisheries Regulations
Schedule 1 closure which reads:

The waters and tidal foreshore of Boundary Bay, Mud Bay, and Semiahmoo Bay, Area 29, lying inside, that is, northerly of the International Boundary Line,
and as illustrated in Figure 1, should remain in effect.

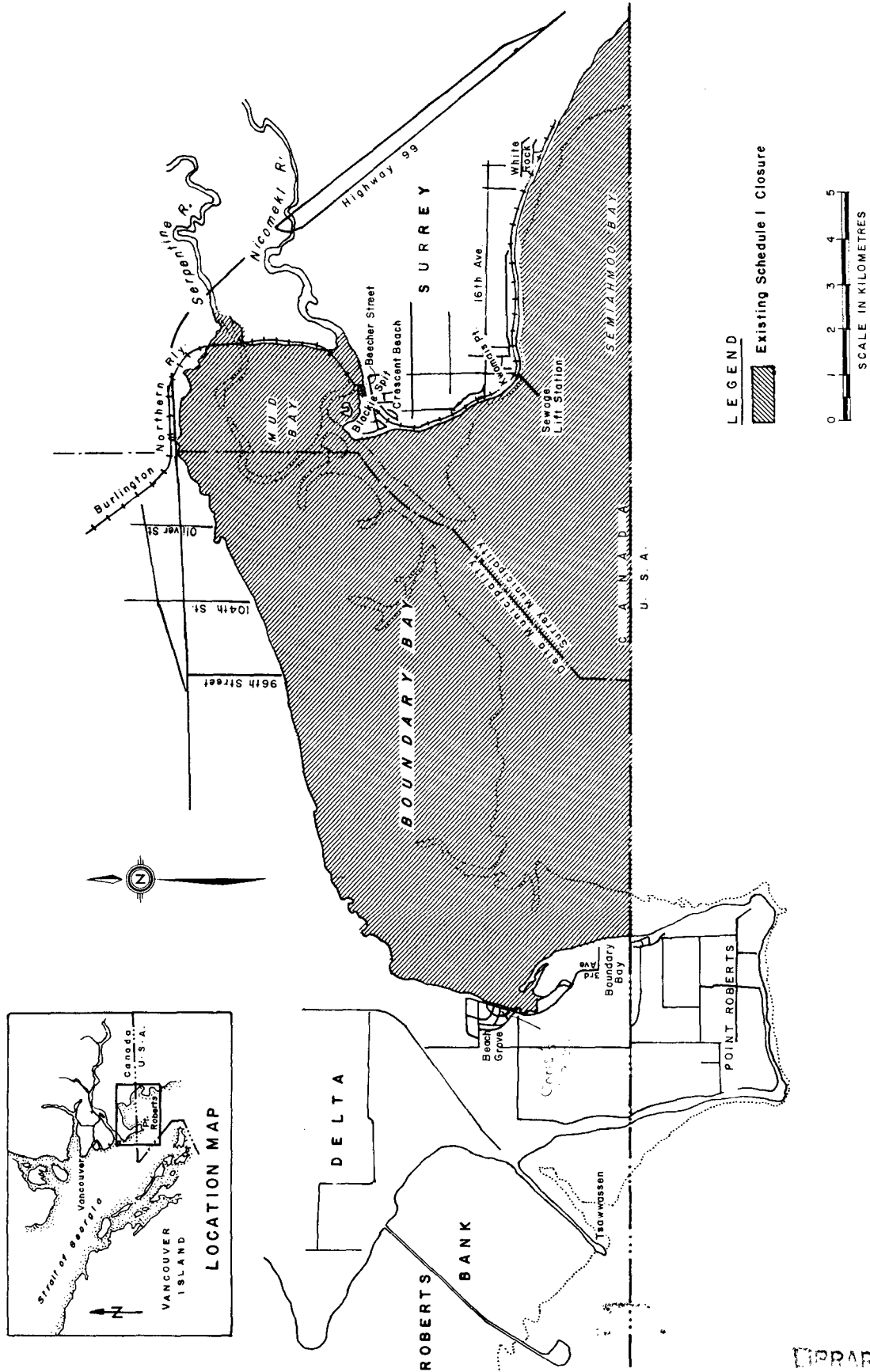


FIGURE 1 EXISTING AREA 29-1 SCHEDULE "1" CLOSURE

1 INTRODUCTION

As the result of a bacteriological survey carried out in 1962, the commercial oyster beds in Mud Bay were closed to harvesting by order of the B.C. Minister of Health. In 1972, the Shellfish Sanitary Control Program in B.C. was transferred from Provincial to Federal jurisdiction. The enabling Federal regulations enacted to accommodate the Provincial request recognized a health responsibility to the recreational consumer of shellfish as well as to the consumer of exported shellfish. Consequently, in consideration of known high fecal coliform levels in the Serpentine, Nicomekl and Campbell rivers, a shellfish closure under the British Columbia Fisheries Regulations was invoked for the waters of Boundary Bay, Mud Bay and Semiahmoo Bay.

In early summer 1973, a preliminary bacteriological assessment of the water quality of Semiahmoo Bay and Mud Bay was conducted by personnel of the Shellfish Water Quality Program, Environmental Protection Service (1). The sampling program was not extensive due to manpower and resource limitations, but the results did indicate that sewage discharged from the City of White Rock municipal sewage treatment plant and fecal contamination from agricultural drainage into the Campbell River, impaired the water quality of Semiahmoo Bay. Due to the findings of this survey, Semiahmoo Bay remained closed to bivalve molluscan shellfish harvesting.

Discussions between the City of White Rock, Greater Vancouver Sewerage and Drainage District (GVSD), and Provincial and Federal Government officials culminated in a decision to connect the City of White Rock sewage collection system to the GVSD system. In July 1977, this connection was completed, resulting in the cessation of the White Rock sewage treatment plant discharge to the Campbell River.

As a result of interest by City of White Rock officials, and a request by the Fisheries and Marine Service, Department of Fisheries and

Environment Canada, a bacteriological and sanitary survey of Semiahmoo Bay was conducted by personnel of the Environmental Protection Service from November 14 to December 20, 1977. The purpose of the survey was:

- 1) to determine whether improvement had occurred in the water quality of Semiahmoo Bay as a result of the cessation of sewage discharge from the City of White Rock sewage treatment plant, and,
- 2) to identify areas of acceptable shellfish growing water quality, if any, that could be used for relaying or depuration of a commercial oyster resource in Mud Bay, should one be re-established.
- 3) to identify and evaluate any other sources of fecal contamination to the study area.

During this survey of Semiahmoo Bay, a portion of Boundary Bay, from Crescent Beach to Kwomais Point, was also re-examined. The shellfish growing waters in this area had demonstrated acceptable shellfish growing water quality during a survey in Spring, 1976 (2) and a re-evaluation of water quality was considered necessary during the higher rainfall months of November and December in order to determine the pollution impact of land drainage.

2 SAMPLE STATION LOCATIONS

A total of 15 marine sample stations were established for bacteriological analysis in the eastern portion of Boundary Bay from Crescent Beach to Kwomais Point (Stations 1-15) to assess foreshore water quality (Figure 2). Freshwater sample stations around Boundary Bay were established at the five Municipality of Delta land drainage pump stations (P1 to P5), the Serpentine (S1) and Nicomekl (S2) rivers, and a small stream at Kwomais Point (S3) as shown in Figure 3.

Sixty-six marine sample stations were selected for bacteriological analysis in Semiahmoo Bay from Kwomais Point to the International Boundary (Figure 4). Freshwater stations around Semiahmoo Bay were established at four streams and 15 storm drains from Kwomais Point to the Douglas Border Crossing.

Detailed marine and freshwater sample station location descriptions are given in Appendices I and II.

Grab samples for nutrient and selected total metal analyses were collected from the Oliver Street, Delta, land drainage pump station, the stormwater manhole at the corner of Buena Vista and Oxford streets in White Rock, and the Campbell River at 172nd Street. Samples were collected for only nutrient analyses from the 3rd Avenue, Delta, land drainage pump station.

Grab samples for 96 hour LC_{50} bioassays were initially collected from all five Municipality of Delta land drainage pump stations and the White Rock stormwater manhole at Buena Vista and Oxford streets.

Sediment samples were obtained adjacent to the five Municipality of Delta land drainage pump stations, and were analyzed for polychlorinated biphenyls (PCB).

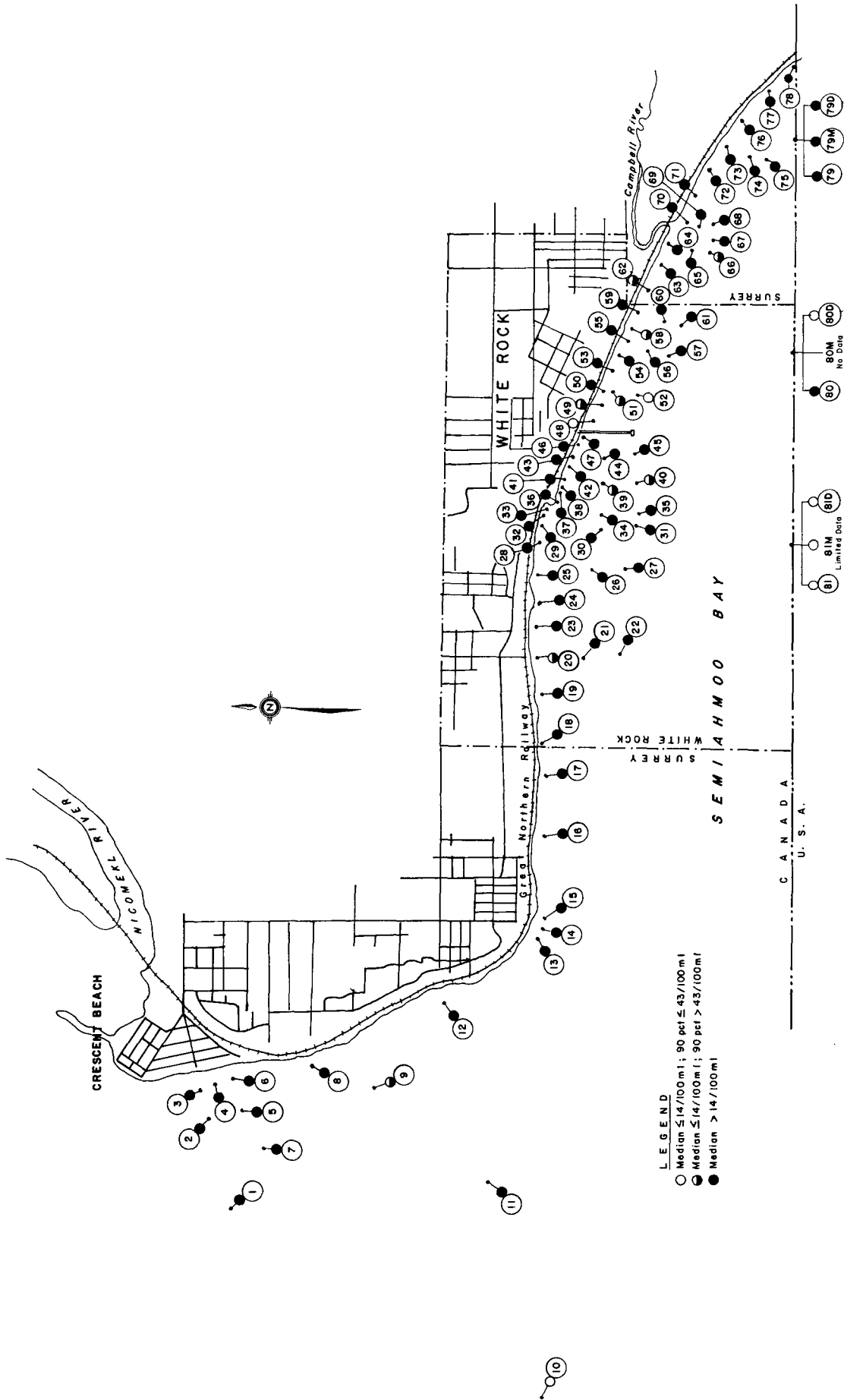


FIGURE 2 MARINE SAMPLE STATION LOCATIONS

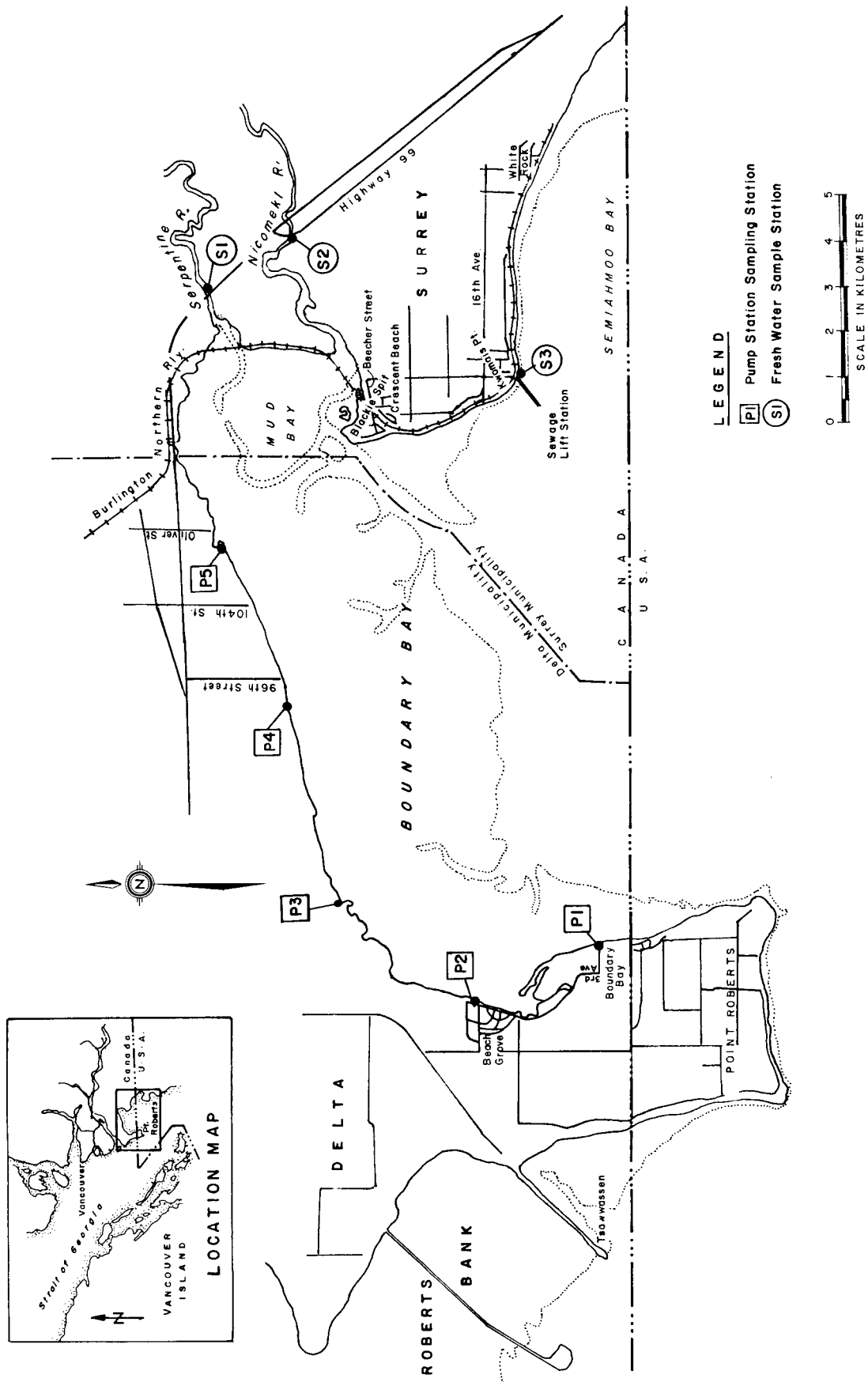


FIGURE 3 BOUNDARY BAY FRESHWATER SAMPLE STATION LOCATIONS

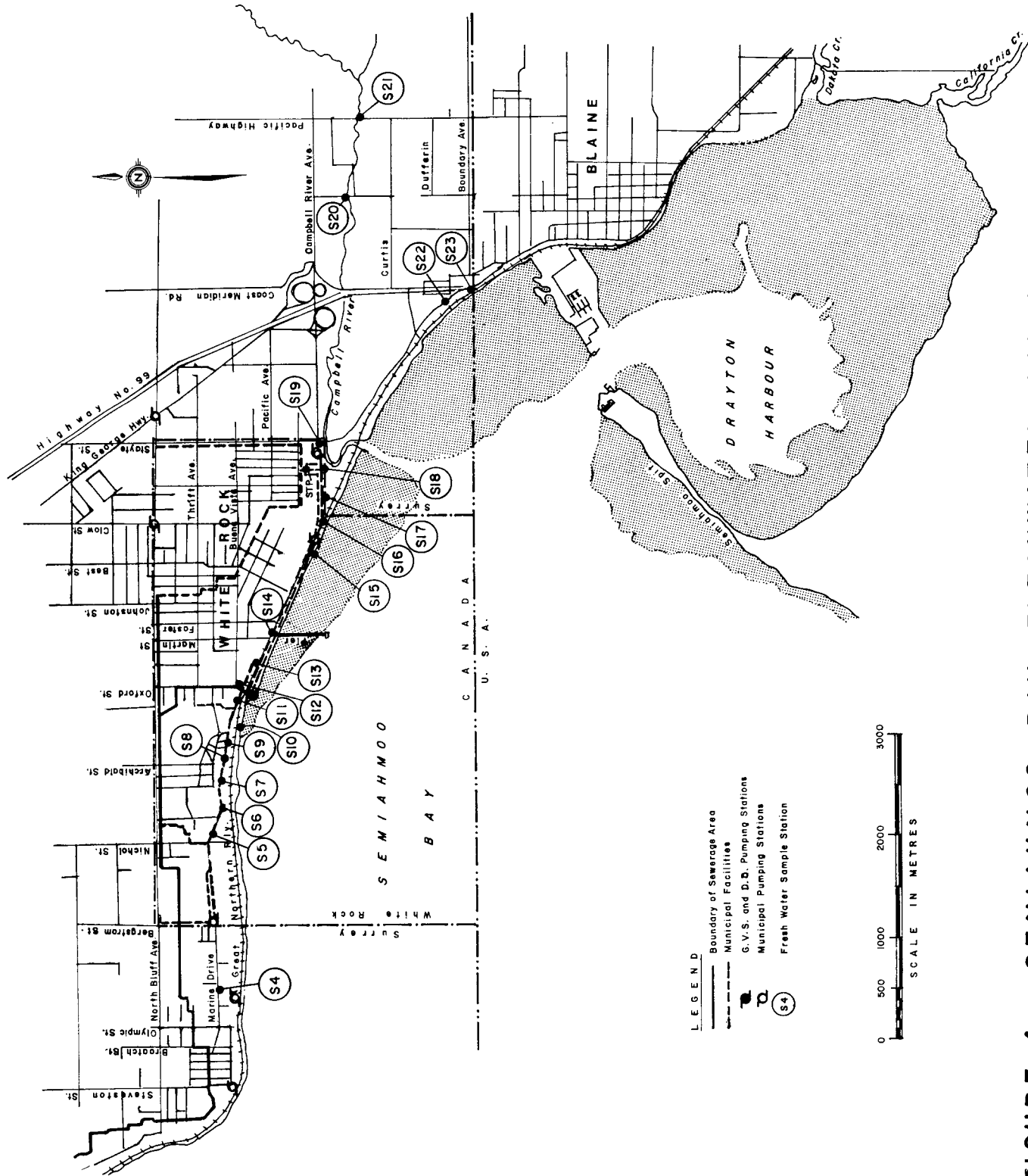


FIGURE 4 SEMIAHMOO BAY FRESHWATER SAMPLE STATION LOCATIONS

3 FIELD PROCEDURES AND METHODS

Sampling stations were selected, and a bacteriological, chemical, and physical water-testing program was developed to assess shellfish growing water quality and the source of pollutants.

3.1 Bacteriological Sampling and Analyses

3.1.1 Marine Samples. All water samples for bacteriological analyses were collected in sterile 170 cc wide-mouth glass bottles, approximately 15 to 30 cm below the water surface. The water depth at collection points over shellfish beds did not exceed 2 meters. Samples were collected by boat or by wading. The samples were stored in coolers at temperatures not exceeding 10°C until processed. Analyses were carried out within three hours of collection at the EPS Regional Microbiology Laboratory.

The fecal coliform most probable number (MPN) per 100 ml was determined using the multiple tube fermentation technique (at least 3 decimal dilutions of 5 tubes each) as described in Part 407C of the 14th edition of Standard Methods for the Examination of Water and Wastewater (3). The culture medium used was the A-1 medium, as described by Andrews and Presnell (4). This medium and the method described below were accepted by the Canadian government in April 1977, as the method of choice for the enumeration of fecal coliforms in shellfish growing waters.

The "modified A-1" method involves the inoculation of a series of dilutions in accordance with the multiple tube fermentation technique. Ten milliliter volumes of sample water were inoculated into five double strength tubes of A-1 medium, and 1.0 ml and 0.1 ml volumes were inoculated into five tubes each of single strength medium. The tubes were incubated at $35 \pm 0.5^\circ\text{C}$ in air incubators for three hours prior to being transferred to a water bath at $44.5 \pm 0.2^\circ\text{C}$ and incubated for a

further 21 hours for a total of 24 ± 2 hours. All gassing tubes with growth were considered to be fecal coliform positive. The most probable number of each sample was then determined according to the manner described in Standard Methods.

3.1.2 Freshwater Samples. All freshwater samples were collected in 450 cc sterile wide-mouth glass bottles. Samples were tested for total coliform, fecal coliform, and fecal streptococci, using the membrane filtration (MF) method described in Part 909 of the 14th edition of Standard Methods. Media used were m-endo LES, m-FC, and KF streptococcus agars¹ for the total coliform, fecal coliform, and fecal streptococcus tests respectively. The membrane filters used were Millipore HC, obtained from Millipore Limited, Mississauga, Ontario.

3.1.3 Biochemical Identification of Bacterial Isolates. A series of seven biochemical tests were performed on selected gas-positive tubes. The tests included: gas production at 44.5°C (EC medium), motility, indole production, glucose metabolism (methyl red), citrate metabolism, acetyl methicarbino! production (Voges-Proskauer) and ornithine decarboxylase. Procedures followed for all seven tests are those described by Douglas and Washington (5).

3.2 Physical and Chemical Testing Equipment and Analyses

3.2.1 Marine Stations. Temperature measurements were made at a depth of 15-30 cm below the water surface, using an immersible Celsius thermometer. An American Optical refractometer, Catalogue No. 10413 which has a resolution to the nearest 0.5 parts per thousand was employed for the salinity determinations.

Tidal data used was for Point Atkinson.

¹Obtained from Difco Laboratories, Detroit, Michigan, U.S.A.

3.2.2 Freshwater Stations. Freshwater grab samples for chemical analyses were collected and preserved as outlined in the Environment Canada Pollution Sampling Handbook (6). All samples were delivered within two hours of the completion of each sampling run to the Fisheries and Environment Canada laboratory in West Vancouver. Analyses were performed according to the latest edition of the Environment Canada Laboratory Manual (7).

Samples collected for bioassays were transferred in three 5 gallon capacity plastic jerry cans to the Environmental Protection Service Aquatic Toxicity Laboratory in North Vancouver. These samples were also delivered within two hours of the completion of the sampling run and analyzed according to the latest edition of the Environment Canada Laboratory Manual (7).

4 RESULTS

Shellfish growing waters are classified according to the following criteria: In order that an area can be considered bacteriologically safe for the harvesting of shellfish, the fecal coliform median MPN of the water must not exceed 14/100 ml, and not more than 10% of the samples ordinarily exceed an MPN of 43/100 ml for a 5 tube decimal dilution test in those portions of the area most probably exposed to fecal contamination during the most unfavourable hydrographic and pollution conditions.

A total of 81 marine stations were established to monitor the bacteriological water quality of Semiahmoo Bay and the eastern portion of Boundary Bay, and all but two stations exceeded the approved shellfish growing water bacteriological standards as shown in Figure 2 and Table 1.

4.1 Bacteriological Analyses Results - Boundary Bay

4.1.1 Marine Stations. All stations in this area exceeded the standard with the exception of Station 10, (a control station) with Stations 1 to 8, and 11 to 15, exceeding the standard at the median level, indicating continuous bacterial pollution at the time of sampling. Station 9 exceeded the 90 percentile limit, an indication of intermittent fecal contamination. A number of these stations were also sampled during the 1973 and 1976 surveys conducted by the Environmental Protection Service, and the fecal coliform analyses results for these stations are presented in Table 2.

The 1976 EPS water quality results are lower than those obtained during this survey. The higher levels obtained in 1977 are probably due to the increased rainfall during the survey as shown in Figure 5, with consequent increased fecal pollution in the Serpentine and Nicomekl rivers, contributing to deterioration of receiving water quality.

This report expresses the 10 percent limit in terms of a 90 percentile MPN value which must not exceed 43/100 ml.

TABLE 1 SUMMARY OF FECAL COLIFORM DATA FOR MARINE
SAMPLE STATIONS

Sample Station	No. of Samples	MPN Range	MPN per 100 ml	
			Median	90 Percentile
1	6	5-240	28	143.4
2	6	22-920	120	692
3	6	49-350	170	284
4	6	49-240	124.5	228
5	6	33-540	79	294
6	6	33-110	49	91.4
7	6	9-540	132	540
8	6	26-230	130	170
9	6	5-79	18	11
10	6	5-11	9.5	11
11	6	2-430	58	274
12	6	23-230	89.5	170
13	6	22-350	49	169.4
14	6	13-79	47.5	61
15	6	11-170	23	87.8
16	6	11-110	55	110
17	6	8-130	35.5	94
18	6	2-170	59.5	115.4
19	6	5-350	24.5	159.8
20	9	<2-350	13	161
21	9	<2-540	22	125.1
22	9	<2-170	22	88.1
23	6	2-920	15	395.6
24	6	5-1600	15	669.4
25	6	5-1600	27	669.4
26	5	8-920	33	499.5
27	5	23-920	49	515

TABLE 1
SUMMARY OF FECAL COLIFORM DATA FOR MARINE
SAMPLE STATIONS (continued)

Sample Station	No. of Samples	MPN Range	MPN per 100 ml	
			Median	90 Percentile
28	7	8-130	33	94.3
29	7	13-220	49	143
30	5	21-350	79	214.5
31	5	13-540	33	309.5
32	6	8-130	56	130
33	7	8-110	49	88.3
34	5	11-170	49	155
35	5	11-350	49	260
36	6	8-170	36	97.4
37	6	11-170	31.5	115.4
38	7	5-240	110	240
39	7	<2-350	7	273
40	8	<2-350	10.5	109.2
41	6	8-170	25	146
42	7	2-540	49	407
43	6	7-350	109.5	284
44	5	11-170	70	170
45	5	11-170	33	140
46	7	5-350	170	273
47	6	5-350	20	187.4
48	6	<2-240	28	143.4
49	6	2-540	12	263.4
50	6	<2-350	24.5	206
51	6	2-540	13.5	229.8
52	6	<2-240	7.5	100.8
53	6	<2-920	41	446
54	7	2-540	17	211

TABLE 1 SUMMARY OF FECAL COLIFORM DATA FOR MARINE
SAMPLE STATIONS (continued)

Sample Station	No. of Samples	MPN Range	MPN per 100 ml	
			Median	90 Percentile
55	8	2-920	22.5	220.8
56	5	2-240	22	175
57	5	8-130	46	89.5
58	7	4-540	14	194.2
59	6	2-350	15	252
60	5	13-220	33	149.5
61	5	46->1600	79	885
62	7	8-1600	13	535.3
63	7	8-220	17	100.3
64	6	17-920	79.5	512
65	8	2-220	17.5	107.2
66	6	2-110	11	91.4
67	6	2-240	19	123.6
68	5	2-130	19	118
69	6	< 2-540	70.5	360
70	6	5-920	56	415.4
71	8	7-1600	28	1600
72	6	8-920	28	692
73	6	17-350	124.5	350
74	5	49-540	170	410
75	5	33-170	70	140
76	6	79-920	205	920
77	6	79-1700	162	850
78	6	27->1600	245	1192
79	6	23-240	59.5	174
79-M	3	46-170	79	142.7
79-D	5	11-79	49	64

TABLE 1 SUMMARY OF FECAL COLIFORM DATA FOR MARINE
SAMPLE STATIONS (continued)

Sample Station	No. of Samples	MPN Range	MPN per 100 ml	
			Median	90 Percentile
80	6	<2-130	19	81.4
80-M	1	5	-	-
80-D	4	<2-33	5	23
81	5	2-33	11	23.4
81-M	2	<2-8	-	-
81-D	4	<2-33	12	28.6

TABLE 2 FECAL COLIFORM MPN DATA FOR MARINE STATIONS SAMPLED
IN 1973, 1976, AND 1977 ENVIRONMENTAL PROTECTION
SERVICE SURVEYS (8)

Station Number	Fecal Coliform MPN/100 ml					
	1977 Survey		1976 Survey		1973 Survey	
	Median	90%	Median	90%	Median	90%
1	28	143.4	2	22.0	not sampled	
2	120	692	2	3.2	not sampled	
3	170	284	5	28.2	17	30
4	124.5	228	not sampled		not sampled	
5	79	294	not sampled		not sampled	
6	49	91.4	2	7.9	not sampled	
7	132	540	2	14.4	not sampled	
8	130	170	2	3.2	not sampled	
9	18	61	2	3.8	not sampled	
10	9.5	11	2	8	not sampled	
11	58	274	2	7.4	not sampled	
12	89.5	170	3	12.5	not sampled	
13	49	169.4	2	3.8	2	46.2

The prevailing wind during the 1976 survey was from the S-SW while easterly winds (Figure 6) were encountered in this survey. It is not known what effect, if any, the wind direction had on the respective survey results.

Beach sampling by the Greater Vancouver Regional District (GVRD)(11) at their stations 8 (2A) and 9 (Appendix VII) indicates that the water quality remains unacceptable for shellfish harvesting during both summer and "non-summer" months (1975-1976) with the exception of 1977, at station 9 when the 90 percentile fecal coliform MPN was 40/100 ml. The median MPN for GVRD summer 1977 data was indeterminant (< 30/100 ml) and therefore, the shellfish growing water quality is still questionable.

Sample stations around Kwomais Point exhibited similar fecal coliform counts to those near Crescent Beach.

4.1.2 Freshwater Stations. Results from bacteriological sampling at the five Municipality of Delta land drainage pump stations reveal relatively low levels of bacterial contamination as shown in Table 3. Of the five, the airport pump station exhibited the highest mean fecal coliform count (700/100 ml for 3 samples).

Membrane filtration fecal streptococci analyses were performed on all freshwater samples in an attempt to determine the origin of fecal contamination observed in the freshwater inputs. Geldreich and Kenner (12) have reported higher fecal streptococci (FS), than fecal coliform (FC) densities in all warm-blooded animal feces except for humans. The FC:FS ratio in humans was 4.4, whereas in other warm-blooded animals the ratio was less than 0.7.

The mean FC:FS ratio was less than 0.7 for all the land drainage pump stations and therefore, the bacteria are believed to be primarily of animal origin. Much of the land in the Municipalities of

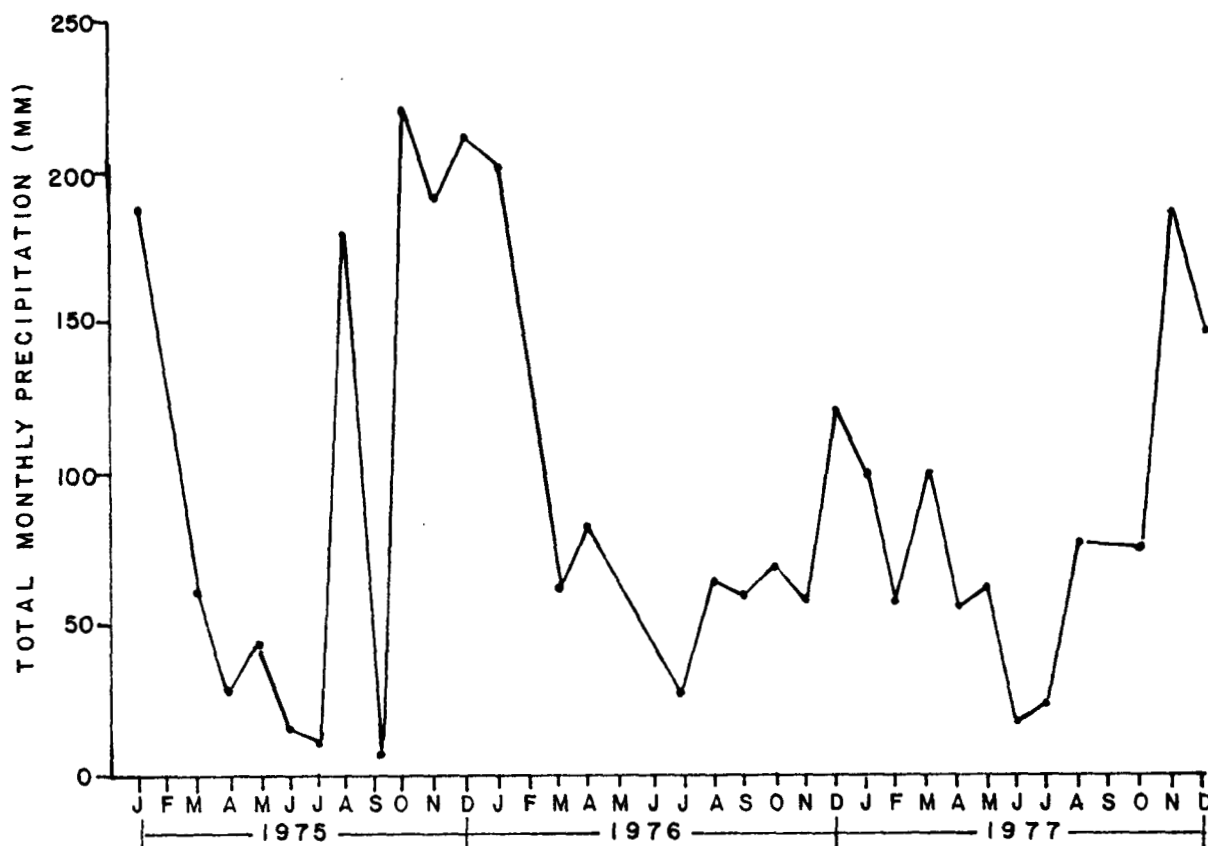


FIGURE 5 TOTAL MONTHLY PRECIPITATION AT WHITE ROCK 1975 to 1977 (9)

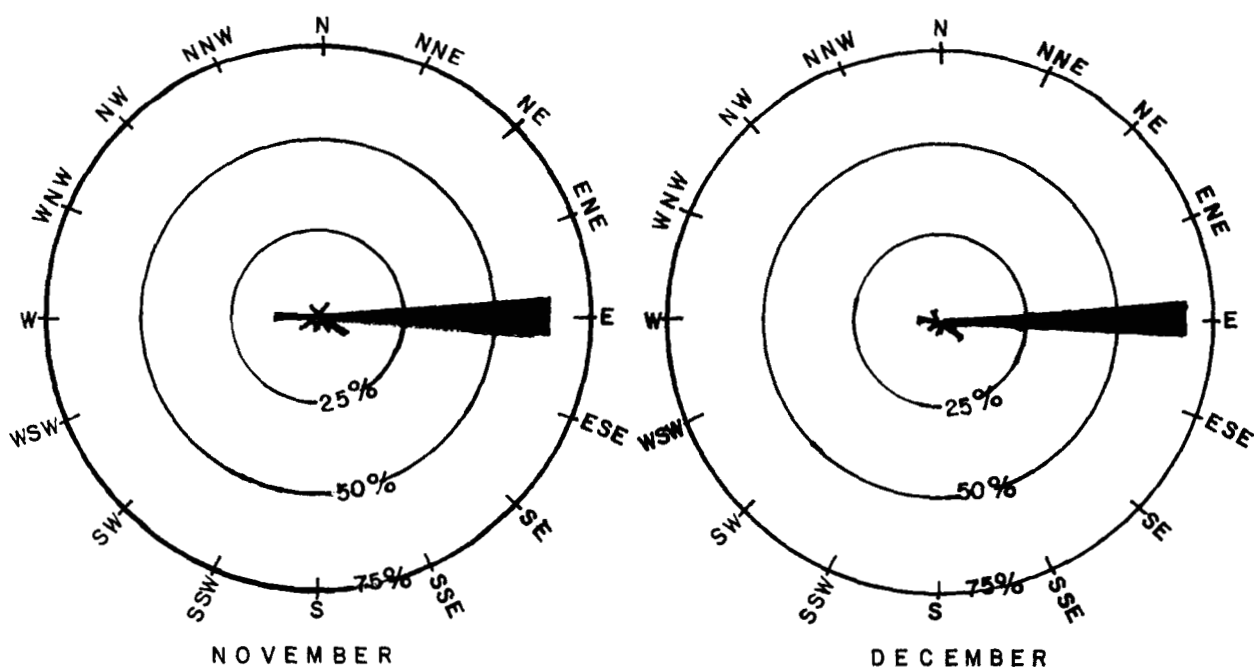


FIGURE 6 WIND DIRECTION FREQUENCY - November-December, 1977 (10)

TABLE 3 SUMMARY OF BOUNDARY BAY FRESHWATER MEMBRANE
FILTRATION DATA

Sample Station	No. of Samples	Fecal Coliforms counts/100 ml		Fecal Streptococci counts/100 ml	FC:FS
		Range	Mean	Mean	
P1	4	58-180	100	430	0.23
P2	4	10-180	64	460	0.14
P3	3	40-1920	700	4400	0.16
P4	3	20-680	440	1600	0.28
P5	3	10-230	110	280	0.39
S1	2	540-790	665	*	
S2	2	350-1300	825	*	
S3	5	10-1320	420	670	0.6

*MPN results - no FS analysis done.

Surrey and Delta is used for agricultural purposes and bacterial contamination noted at the pump stations probably arises from runoff from these lands.

Fecal coliform MPN analyses results for the Serpentine (S1) and Nicomekl (S2) rivers are higher than those obtained during the 1973 and 1976 surveys (Appendix VIII). Although no flow data is available, the flow from the Nicomekl and Serpentine rivers was likely greater during the 1977 survey than the 1976 survey due to increased rainfall. Assuming increased flows and higher bacteria counts, the two rivers would have contributed substantially greater bacteriological contamination during the 1977 survey. This resulted in the reduced water quality during this survey at marine stations from Crescent Beach to Kwomais Point compared to 1976.

The concept of "population equivalents" may be used to compare the theoretical relative receiving water impact of the Serpentine and Nicomekl rivers to other freshwater inputs. The population equivalent of a source of fecal contamination was calculated using an average per capita value for the fecal coliform contribution to a sewer system. An average person discharges 1.6×10^{11} total coliforms/day and the fecal coliform concentration in domestic sewage has been estimated at 20% of the total concentration (13). This yields a value of 3.2×10^{10} fecal coliforms/person/day. The equation used for calculating population equivalents was:

$$\text{Population Equivalents} = \frac{\text{Fecal coliforms discharged per day}}{\text{Fecal coliforms/person/day}}$$

$$\frac{\text{Flow} \times \text{Fecal coliform concentration}}{3.2 \times 10^{10}} \quad (\text{equation 1})$$

Population equivalents for inputs to Boundary Bay are shown in Table 4. No flow data is available for pump stations P1 to P4 and therefore, population equivalents cannot be calculated for them. Available flow data for the Serpentine River at Port Kells is too far

TABLE 4 MEAN POPULATION EQUIVALENTS FOR SELECTED BOUNDARY BAY
FRESHWATER STATIONS

Sample Station	Mean Fecal Coliforms counts/100 ml	Average flow during survey (m ³ /sec)	Mean Population Equivalents
P5	110	2.40	7.1
S2	825	6.67	148
S3	430	0.052	0.6

from the mouth to be useful for this analysis. The average flow noted for the Nicomekl River (S2) is the mean flow for November - December, 1952-1963 as measured at 192nd Street (14). Flows at the mouth of the river would be higher because of additional water inputs between it and the stream gauging location. The Serpentine River is larger than the Nicomekl and its population equivalent would be greater. As Table 4 indicates, the Nicomekl River is a significant source of fecal contamination and when combined with the discharge from the Serpentine River, accounts for the unacceptable shellfish growing water quality observed during this survey. By comparison the stream which discharges freshwater to Boundary Bay at station S3 contributes very little fecal pollution.

4.2 Bacteriological Analyses Results - Semiahmoo Bay

4.2.1 Marine Stations. Sample stations 16 to 81 were established in Semiahmoo Bay and all exceeded the approved shellfish growing water quality standard with the exception of stations 80M to 81D. Stations 20, 39, 40, 49, 51, 52, 62, and 66 met the standard at the median level, but exceeded the standard at the 90 percentile level.

The water quality at marine stations immediately east of Kwomais Point in Semiahmoo Bay was slightly better compared to stations west of the point, however, the median still exceeded 14/100 ml. The

poorest water quality was observed at stations 30, 32, 38, 43, 44, 46, 61, 64, 69, 70, 73, and 74 to 79. The water quality at stations southeast of the Campbell River was generally the poorest due to both the influence of the Campbell River and the contaminated stormwater discharged from the Douglas Border Crossing. Freshwater from the Campbell River was observed to move into the eastern portion of Semiahmoo Bay on flooding tides.

Float studies done by Schwartz (15) and observations by EPS personnel and White Rock residents, indicate that the movement of water along the foreshore in Semiahmoo Bay is towards the east on flooding tides and to the west on outgoing tides. This "back and forth" motion probably results in contaminated water from the Campbell River reaching most of the Semiahmoo Bay.

Sample stations located 200 and 400 metres offshore still showed high fecal coliform counts and in most cases, the medians were comparable to corresponding shoreline stations.

Perimeter control stations were not extensively sampled at mid and bottom depths due to difficulties with the depth sampler. Surface samples taken at stations 79, 80, and 81 showed improving water quality to the west. This was due in part to the increased volume of water available for dilution, as well as the greater distance from observed pollution sources. Mid (1.5 metres) and bottom (3 metres), depth samples at station 79 indicated the entire water column was contaminated. Bottom depth samples (13 metres) at station 80 were minimally contaminated indicating that the contaminated water remained in the surface layer.

A comparison of results from this survey with the GVRD sample station results for the years 1975 to 1977 can be found in Appendix VII. On the basis of the GVRD data, all of their sample stations have not met the shellfish growing water standards over the past three years and, with two exceptions, the medians obtained using GVRD data exceed those

obtained during this survey. However, this may be due in part to differences in the testing procedure employed.

GVRD stations 10A and 11A, which correspond to EPS stations 77 and 78 are located in the south-east corner of Semiahmoo Bay. A comparison of data gathered before and after the connection of the White Rock sewage collection system to the GVRD trunk line, indicates that the cessation of the White Rock sewage discharge to the Campbell River did not result in improved water quality in this sector.

GVRD sample stations west of the Campbell River showed unchanged or slightly worsened water quality on post-hook up sampling. (This worsened water quality may be due to the onset of heavier rains during September after an extremely dry summer).

The water quality was generally better during the 1973 EPS survey (Table 5) although, all stations, except 45, still exceeded the growing water standard. The 1973 results are lower due to the lower rainfall encountered during that survey. A total of 57 mm of rain fell during the 11 sampling days of the 1973 survey (average of 5 mm/day), while 126 mm of rain fell during the 14 Semiahmoo Bay sampling days of this survey (average of 9 mm/day)(10).

TABLE 5 ENVIRONMENTAL PROTECTION SERVICE SEMIAHMOO BAY
MARINE MPN DATA, 1973 AND 1977

Sample Station	MPN Fecal Coliforms/100 ml			
	1977		1973	
	Median	90 Percentile	Median	90 Percentile
77	162	850	4	69
71	28	1600	23	1375
64-70 composite	26	240	33	323
59	15	252	6	49
45	33	140	2	32
28	33	94.3	2	49

4.2.2 Freshwater Stations. Sample stations were established on the major freshwater inputs to Semiahmoo Bay. A summary of the results is presented in Table 6, while a detailed account is in Appendix VI.

The most significant freshwater contributor of fecal contamination to Semiahmoo Bay was the Campbell River. This source demonstrated a population equivalent of 122, which accounted for 77% of the total contamination entering the Bay from identified sources (Table 7). Generally, the highest fecal coliform concentrations were noted during periods of greatest rainfall. Fecal coliform counts of 9400/100 ml for S20 and 8400/100 ml for S21 were noted on November 25, when a total of 46 mm of rain fell. These results indicate that the bacteria enter the river in runoff from agricultural land.

Bacteriological data compiled by EPS (1973) and the Pollution Control Branch (16) (1972 to 1977) from sampling points on the Campbell River, generally compare favourably with data gathered during this survey (Appendix VIII). The average fecal coliform concentration for all results obtained during the 1973 survey was 1500/100 ml, while for this survey, the average concentration for S20 and S21 was 2300/100 ml. The average precipitation encountered in the 1973 survey was 2.5 mm/day while an average of 9 mm/day was noted for this survey, and it is therefore likely more bacteria were contributed to the river by agricultural runoff during the latter sampling.

Other stations which exhibited high mean population equivalents include S4, S10, S14, and S22. Station S14 is one of 13 sub-surface stormwater collection system outfalls in the City of White Rock. Bacteriological results of samples collected from this system indicate that there is a cross connection from the sanitary sewage collection system to the stormwater system. Samples taken during periods of low rainfall showed high fecal coliform counts, whereas those taken during high rainfall generally exhibited lower counts. The average FC:FS ratio was 27 which suggest that the contamination is primarily of human origin.

TABLE 6 SUMMARY OF SEMIAHMOO BAY FRESHWATER MEMBRANE
FILTRATION DATA

Sample Station	No. of Samples*	Fecal Coliforms counts/100 ml		Fecal Streptococci counts/100 ml	FC:FS
		Range	Mean	Mean	
S3	5	10-1320	430	670	0.6
S4	6	200-1.44x10 ⁴	3400	610	5.6
S5	4	61-1100	380	240	1.6
S6	2	10-890	450	370	1.2
S7	3	10-540	200	720	0.3
S8	4	94-1630	490	2200	0.2
S9	3	500-7600	3600	1.4x10 ⁴	0.3
S10	4	90-1600	500	690	0.7
S11	2	130-430	280	8300	0.03
S12	6	10-5300	1900	2100	0.9
S13	2	1900-4100	3000	5900	0.5
S14	6	1000-1.4x10 ⁵	3.2x10 ⁵	1.2x10 ⁴	27
S15	3	200-1250	900	3350	0.3
S16	3	100-1700	660	5400	0.1
S17	3	100-5600	3300	830	4.0
S18	3	100-3200	1300	6000	0.2
S19	3	580-4700	2400	5100	0.5
S20	7	220-9400	1700	740	2.3
S21	6	130-9000	3000	1200	2.5
S22	4	100-> 80 000	4700	1.2x10 ⁴	0.4
S23	2	<10-170	90	3200	0.03

* Indeterminate results were not used in the calculation of means.

TABLE 7
MEAN POPULATION EQUIVALENTS FOR SEMIAHMOO BAY
FRESHWATER STATIONS

Sample Station	No of Samples	Mean Fecal Coliform counts/100 ml	Average Estimated Flow (m ³ /sec)	Mean Population Equivalent	% of Total
S3	2	430	0.051	0.60	-
S4	6	3400	0.083	7.6	5
S5	4	380	0.083	0.85	-
S6	3	450	0.064	0.77	-
S7	3	200	0.0045	0.025	-
S8	4	4900	0.0017	0.23	-
S9	3	3600	0.00004	0.0037	-
S10	4	500	0.091	1.2	1
S11	2	280	-	-	-
S12	6	1900	0.015	0.78	-
S13	2	3000	0.00030	0.024	-
S14	6	320000	0.0026	22	14
S15	3	900	0.00038	0.0092	-
S16	3	660	-	-	-
S17	3	3300	-	-	-
S18	3	1300	0.00011	0.0040	-
S19	3	2400	0.00049	0.032	-
S20	7	1700	1.9	88 (122)	77
S21	6	3000	1.9	155	
S22	5	4700	0.014	1.8	1
S23	4	90	0.0036	0.0088	-

Contaminated stormwater discharged through this collection system's outfall impaired the marine water quality in the immediate area, although samples taken outside the zone of influence also did not meet the shellfish growing water quality standards.

Station 10 is also located at a City of White Rock stormwater collection system discharge. Higher fecal coliform counts for samples from this station were noted during periods of high rainfall. The average FC:FS ratio was 0.7 and the contamination probably arises from animal fecal matter in street runoff.

Most of the runoff west of the City of White Rock boundary that discharges to Semiahmoo Bay flows to the stream at station S4. Fecal coliform concentrations from this station were variable showing no particular relationship to precipitation. The FC:FS ratio was also variable. There are septic tanks in this area and although no visible signs of seepage were found, the potential for contamination exists.

Stormwater collected at the Douglas Border Crossing discharges through an outfall located adjacent to the fence line in Peace Arch Park at S22. Prior to 1975 this outfall discharged both stormwater and sanitary sewage. Aspects of the present sewage collection system and the source of contamination to the stormwater system are discussed in section 4.3.3 of this report.

4.2.3 Biochemical Analyses Results. A total of 670 bacterial isolates were subjected to the seven biochemical tests described in Section 3.1.3. The purpose of the testing was to determine the selectivity of the A-1 culture medium for Escherichia coli. The test results indicate the medium is highly selective, with 97.6% (654) of all gas-positive tubes shown to contain E. coli. The data demonstrate that virtually all of the bacterial pollution measured resulted from fecal sources, rather than non-fecal sources which, on occasion, will cause false positive reactions in the MPN procedure.

The efficacy of the modified A-1 method in recovering fecal coliforms was compared with the APHA Standard Method during each sampling run. The MPN's obtained were highly comparable indicating a good correlation between the two methods. Additional information on the evaluation of the A-1 medium is provided by Kay (8).

4.3 Sewage Collection and Disposal Systems

4.3.1 City of White Rock. With the exception of a few homes along Terry Road, all of White Rock is serviced by a sewage collection system. Sewage flows by gravity, or is pumped by one of three pump stations along Marine Drive to the GVSDD pump station located at the intersection of Marine Drive and Oxford streets. The characteristics of these pump stations are summarized in Table 8.

In the event of a power failure at the GVSDD pump station, a diesel generator is automatically activated. Should this auxilliary system fail, sewage would back up in the sewer-system and discharge into a stormwater manhole located about 400 metres east of the pump station.

During the survey, five incidents of sewage overflows were noted, as shown in Table 9. On November 25, the pumping capacities of pump station No. 2 and No.3 were exceeded due to excessive flows in the collection system and overflows occurred. Pump station No. 3 overflowed on November 28 because the force main between stations No. 2 and No. 3 broke. It is not known what quantity of sewage was discharged.

Overflows occurred on November 25 to 26, December 1 to 2, and December 10 through a sewage collection system by-pass line. This line was designed to divert excessive flows in the collection system from the manhole at the intersection of Kent and Columbia streets through the old White Rock Sewage Treatment Plant (STP) distribution box, by a 20 cm diameter pipe down Keil Street, and finally, to the Campbell River through the STP outfall (Figure 7). The system did not work as designed

TABLE 8 CHARACTERISTICS OF THE CITY OF WHITE ROCK SEWAGE PUMP STATIONS

Pump Station No.	Location	No. of Pumps	H.P. (each)	Rated Flow Capacity (USGPM)	% of Collected Sewage Pumped by Station	Time to Overflow (avg. flows)	Overflow to
1*	Oxford and Marine	6	125	1975	100		storm drain - Semiahmoo Bay (auxilliary power)
2	Ash and Marine	2	10	500	6.7	3.5 hours	storm drain - Semiahmoo Bay
3	Habgood and Marine	2	7-1/2	500	4.1	10 hours	storm drain - Campbell River ditch - Semiahmoo Bay
4	Bergstrom and Marine	4	3 and 5	50	3.1	2 hours	storm drain - Semiahmoo Bay
Gravity					86.1		bypass - Semiahmoo Bay

*The City designates the GVSDD pump station as No. 1

TABLE 9 SEWAGE OVERFLOWS IN THE CITY OF WHITE ROCK

Overflow No.	Type of Overflow	Date	Start Time	Finish Time	Time Valve Opened	% Valve Opened	Discharged		Held	
							Volume m ³ (gal)	Population Equivalent per day	Volume m ³ (gal)	Population Equivalent per day
1	by-pass	Nov. 1 Nov. 2	830	815	830	100	6800 (1 500 000)	106	90 (20 000)	1.4
2	by-pass	Nov. 25 Nov. 26	1245	800	1300	100	5000 (1 100 000)	78	0	0
3	P.S. #2 and #3	Nov. 25	1430	1830						
3	P.S. #3	Nov. 28	905	1000						
4	by-pass	Dec. 1 Dec. 2	900	1245	900	50-30-20	2400 (530 000)	37	45 (10 000)	0.7
5	by-pass	Dec. 10	during the night		0	0	0	0	90 (20 000)	1.4

P.S. - denotes pump station

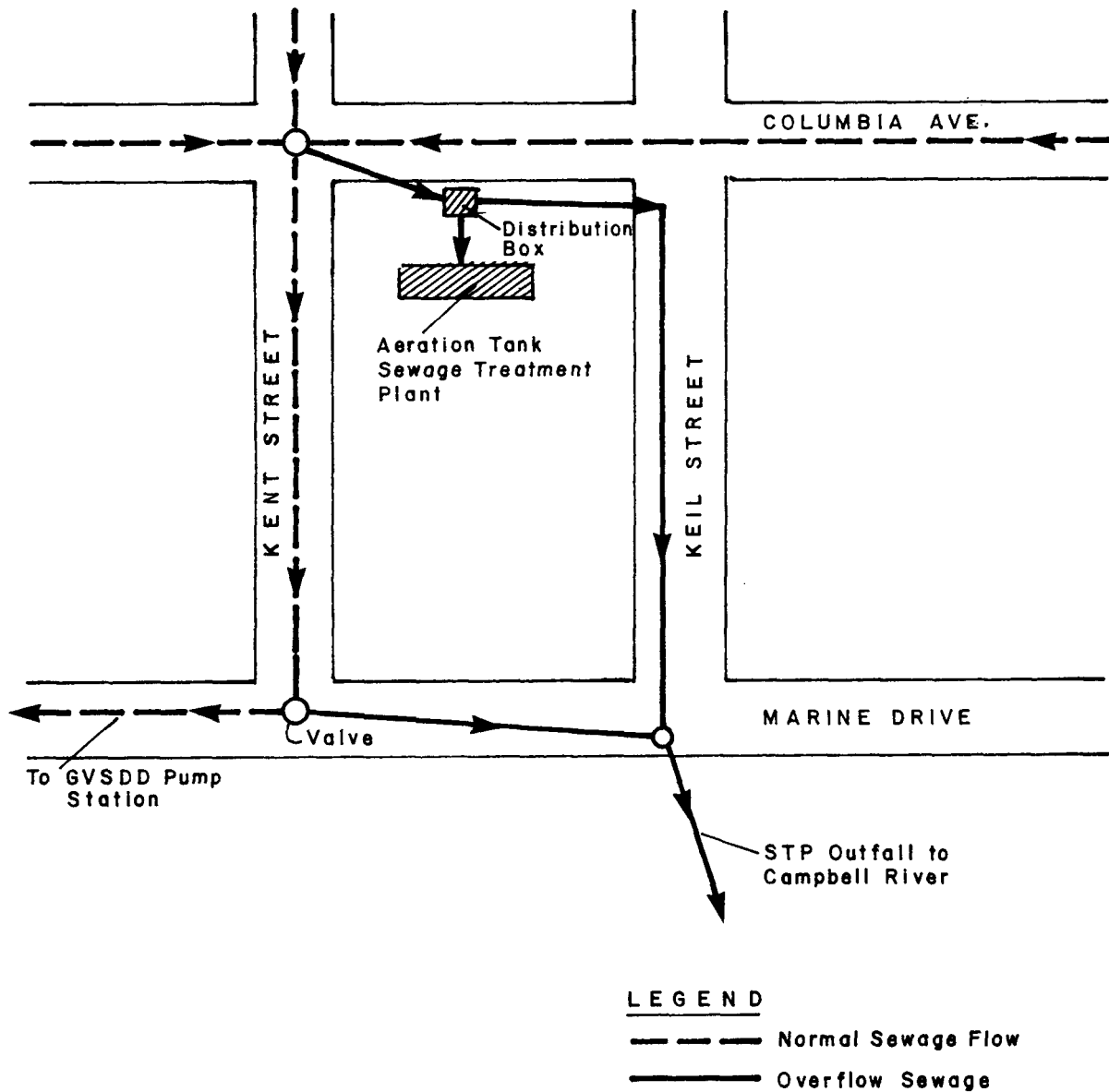


FIGURE 7 CITY OF WHITE ROCK SEWAGE OVERFLOW SYSTEM - COLUMBIA AVENUE AND KENT STREET

because the pipe from the distribution box to Keil Street was uphill. Initially during overflows, the sewage topped the distribution box and flowed into the aeration tanks of the old STP. When this occurred, a White Rock city employee usually opened a valve at the intersection of Kent and Marine Drive which allowed the sewage to flow through a 25 cm diameter pipe to the STP outfall.

Overflows through this by-pass system occurred three times during the survey and once before the survey began (November 1 to 2). In three out of four cases, sewage was discharged to the Campbell River and in the other case the sewage was retained in the STP aeration tanks.

Population equivalents per day were calculated for all overflows where possible (Table 9). The approximate average velocity of the sewage discharged through the 25 cm diameter line to the Campbell River outfall was calculated using the Manning Equation:

$$V = \frac{1.486 R^{2/3} S^{1/2}}{n} \quad (\text{equation 2})$$

where: V = velocity

R = hydraulic radius (0.21)

S = slope (0.020)

n = coefficient of roughness (0.015)

The approximate quantity of sewage discharged was calculated using:

$$Q = \frac{VAX}{100} \quad (\text{equation 3})$$

where: Q = discharge

A = cross-sectional area of pipe

X = percent opening of valve

A fecal coliform concentration for the diluted sewage of 5×10^4 MPN/100 ml, (based on samples taken from pump station No. 2 and No. 3 wet wells during a by-pass overflow), the approximate quantity of sewage discharged, and equation 1, were used to calculate the population equivalent.

It is difficult to assess the incremental impact of these overflows on the water quality of the Campbell River and Semiahmoo Bay since almost all occurred during periods of heavy rainfall when fecal contamination from agricultural runoff to the River was at a maximum. The maximum overflow population equivalent (106) is close to the average population equivalent for stations S20 and S21 (122) on the Campbell River.

Flows through the GVSDD pump station (11) vary markedly in response to precipitation as shown in Figure 8. It is apparent that the White Rock sewage collection system is affected by excessive groundwater infiltration and stormwater inflow. The City is continuing its efforts to eliminate this problem.

An average of $2700 \text{ m}^3/\text{day}$ (0.6 MIGPD) of sewage was discharged through the City of White Rock treatment plant to the Campbell River before the collection system was connected to the GVSDD trunk line. However, the design peak flow of $6800 \text{ m}^3/\text{day}$ (1.5 MIGPD) was exceeded up to 30% of the time, resulting in the by-pass of the sewage treatment plant and discharged of untreated dilute sewage to the Campbell River. Data gathered by the Boundary Health Unit (15) and the Pollution Control Branch (16) from 1969 to 1976 indicates that the mean final effluent fecal coliform concentration was 111 200 MPN/100 ml (54 samples). Using this data, the mean population equivalent for the treatment plant discharge is 95.

If the treatment plant had been in operation during this survey, the total mean population equivalent contribution from all sources of Semiahmoo Bay would have been 158 (Table 7), plus 95, or 253. The cessation of the discharge, therefore, resulted in a 38% reduction in the total fecal coliform load to Semiahmoo Bay. The effect of this reduction on water quality would be greater during lower precipitation periods than those which occurred during this survey, because the bacteria load from agricultural runoff into the Campbell River would be

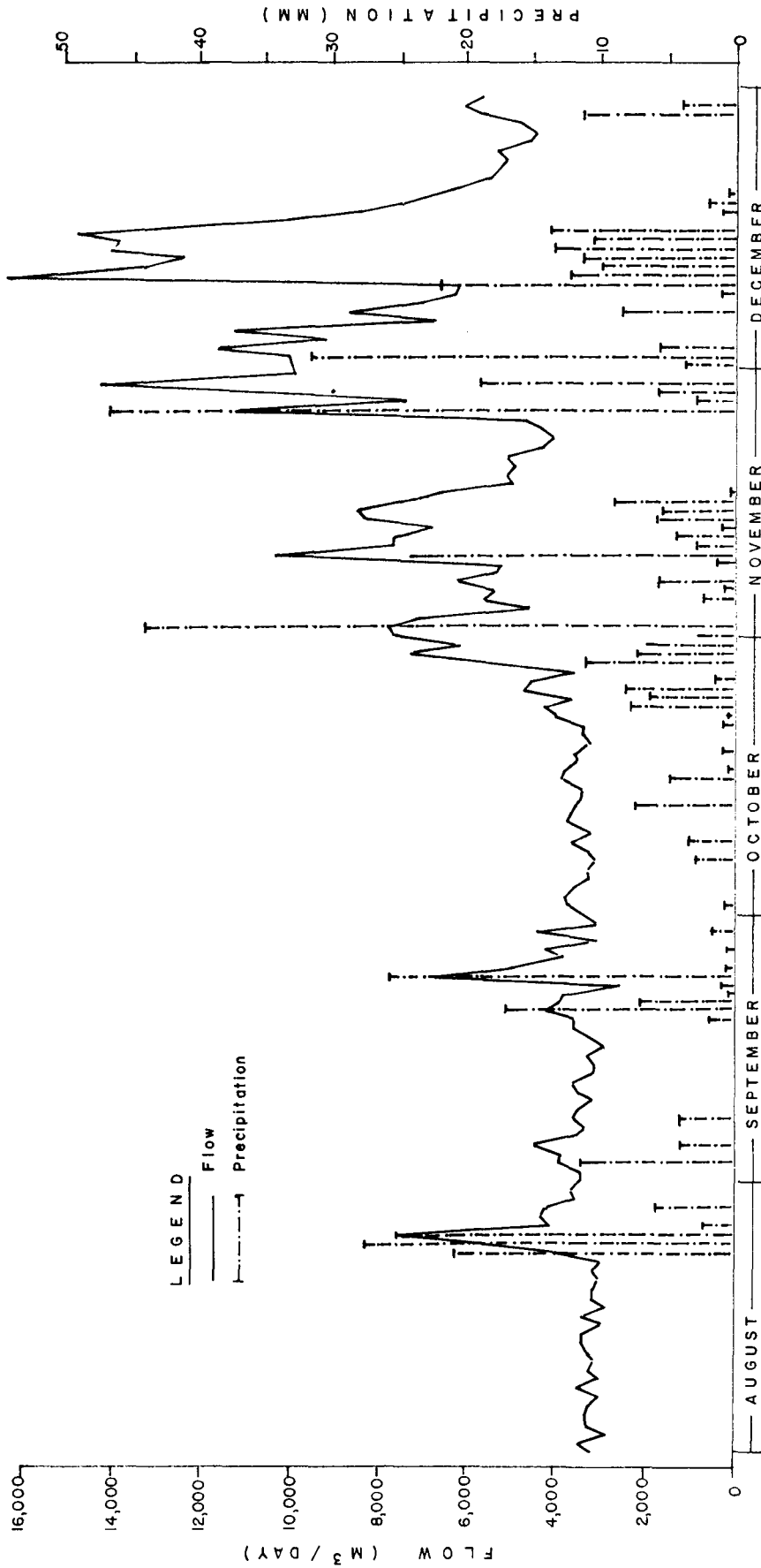


FIGURE 8 SEWAGE FLOW THROUGH GVSDD PUMP STATION AND DAILY PRECIPITATION
AUGUST - DECEMBER, 1977

lower. It is, therefore, probable that significant improvement in water quality will be observed during the low precipitation summer months.

4.3.2 Municipality of Surrey. Two pump stations in the Kwomais Point area pump sewage to the GVSDD trunk line. Two 3.7 kw (5 H.P.) pumps rated at $0.38 \text{ m}^3/\text{min}$ (100 USGPM) each are in a station located at the corner of 128 Street and 13 Avenue, and two 37 kw (50 H.P.) pumps rated at $1.7 \text{ m}^3/\text{min}$ (460 USGPM) each are in a station located at 132 B Street and 13 Avenue.

A telemetry system which will warn personnel in a 24 hour manned fire hall of pump malfunction at the sewage pump stations is being installed. After the warning signal is received, mobile generators and pumps would be used to maintain sewage flow from the pump stations to the GVSDD trunk lines.

Should an overflow occur, sewage from the 128 Street pump station would flow through a pipe to the drainage ditch adjacent to the Burlington Northern Railroad tracks and thence to Semiahmoo Bay. There is no overflow pipe in the 132 B Street pump station wet well and overflow sewage would top the manhole and seep into the adjacent soil. No indications of a sewage overflow at either pump station were noted during the time of this survey.

With the exceptions of a few homes at the foot of 132 B Street, virtually all the residences on the shore of Semiahmoo Bay from Kwomais Point to the White Rock-Surrey boundary are not connected to the sewage collection system and are serviced by septic tanks. No obvious signs of septic tank seepage were noted during the survey, however, the high fecal coliform concentrations found in samples from station S4 could result from seepage.

The Semiahmoo Indian Band Reserve is unsewered. Possible septic tank seepage was noted near three residences, however, it is doubtful if the seepage could exert a significant impact on the water quality.

4.3.3 Douglas Border Crossing. Prior to 1975, sewage collected from the Douglas Border Crossing facilities were treated in septic tanks and discharged along with stormwater to Semiahmoo Bay. In 1975, the system was modified and the septic tanks were used for holding purposes only. Sewage continues to be pumped out by tanker truck and discharged at the Iona Island Sewage Treatment Plant.

Bacteriological results of samples from the stormwater manhole in Peace Arch Park (S22) and observation of the holding tanks confirm that from time to time, sewage enters the stormwater collection system and discharges to Semiahmoo Bay. A plug in the bottom of the south holding tank is used to prevent sewage from entering the stormwater collection system. However, on some days, this plug was displaced and stormwater samples obtained from the manhole revealed high fecal coliform counts (80 000 FC/100 ml on November 17).

Contracts have been awarded for construction of a trunk sewer line that will enable hook-up of the Douglas and Pacific Border Crossing, Peace Arch Park and the B.C. Tourist Bureau facilities to the GVSDD system. The expected construction completion date is Fall, 1978.

4.3.4 City of Blaine. At present, sewage collected in the City of Blaine is comminuted, treated in a Dorr-Oliver type clarifier-digester, and chlorinated prior to discharge through a 490 metre (1600 ft) outfall to the mouth of Drayton Harbour. The collection system is subject to excessive infiltration and inflow, such that the sewage treatment plant is sometimes by-passed and chlorinated raw sewage is discharged. At these times, shellfish harvesting is stopped in Drayton Harbour (18).

A new $3000 \text{ m}^3/\text{day}$ (800 000 USGPD) Rotating Biological Contactor (RBC) secondary sewage treatment system is scheduled to be built for the City. The treatment plant will be located at the "neck" of Semiahmoo Spit (corner of Drayton Harbour Road and Semiahmoo Drive) and will discharge treated sewage through a 790 m (2600 ft) outfall to Semiahmoo Bay (19).

Little data is available to assess the impact of the present City of Blaine STP on Semiahmoo Bay since sampling of the final effluent is not possible as the outfall pipe is also used as a chlorine contact chamber. Marine sample stations 80-D, 81, and 81-D established along the International Boundary met shellfish water quality standards, whereas stations 79, 79-M, and 79-D did not. The Campbell River and Douglas Border Crossing stormwater outfall contribute significant contamination to these latter stations, and therefore, the influence of Blaine's STP cannot be evaluated.

4.4 Chemical Analyses Results

Grab samples were collected at the 3rd Avenue and Oliver Street Delta land drainage pump stations, the City of White Rock stormwater manhole at the corner of Oxford and Buena Vista streets, and the Campbell River; and were analyzed for pH, orthophosphate, total phosphate, ammonia nitrogen, nitrite nitrogen, and nitrate nitrogen. Samples were collected at each site on November 22, 23, and 29, and December 7 and 12.

With the exception of the 3rd Avenue pump station, samples were collected at all the nutrient sampling locations and analyzed for total copper, lead, cadmium, arsenic and mercury.

Table 10 summarizes the results of the nutrient sampling program while a detailed account, and the results of metal analyses, may be found in Appendix IX. Nutrient analyses results are generally low with the White Rock stormwater collection system exhibiting the higher levels.

Data gathered by the Pollution Control Branch (16) from two sampling points on the Campbell River exhibit slightly lower mean nutrient concentrations than were found in this survey (Appendix IX). This is not surprising since their samples were taken throughout the year while this survey obtained samples only during November and December when

TABLE 10 SUMMARY OF NUTRIENT ANALYSES RESULTS

Parameter	No. of Samples	Station			
		3rd Ave.	Oliver St.	White Rock	Campbell
		Pump Station	Pump Station	Storm Drain	River
mg/l					
pH	2	7.0	5.8	7.6	7.2
ortho PO ₄ -P	2	0.098	0.10	0.12	0.047
total PO ₄ -P	3	0.26	0.22	0.49	0.093
NO ₂ -N	3	0.013	0.013	0.048	0.012
NO ₃ -N	3	0.93	2.7	2.7	2.1
NH ₃ -N	3	0.33	0.59	0.78	0.11

runoff was greater. The data shows that the average nutrient concentration was higher at the downstream sampling points compared to the upstream. As such, nutrients are added to the river between these points.

Results of the selected total metals sampling program are low with many below the analytical detection limit. Neither the selected metals nor nutrient concentrations noted during this chemical sampling program would be expected to exert a significant impact on the water quality of Semiahmoo Bay.

4.5 Bioassay Results

Samples were initially collected from all five Municipality of Delta land drainage pump stations, and the White Rock stormwater manhole at Oxford and Buena Vista streets, and were analyzed to determine the 96 hour lethal concentration at 50% test fish mortality (LC_{50}). Since the first series of samples collected on November 14 were non-toxic (Table 11), the program was modified and samples from the 3rd Avenue pump station, the Oliver Street pump station, and the White Rock stormwater manhole only were collected on November 24. These samples were also found to be non-toxic.

4.6 Polychlorinated Biphenyl Sediment Analyses Results

Elevated concentrations of polychlorinated biphenyls (PCB) were found in some sediment samples collected adjacent to the five Municipality of Delta land drainage pump stations as shown in Table 12. Compared to results of PCB analyses on sediments collected at two background stations at 88 Street and 17 A Avenue, high levels of PCB's were found in sediment immediately adjacent to the airport and 96th Street pump stations. This area of contamination appears to be localized. The origin of this contamination is not known.

It should be noted that sampling conducted subsequent to this survey did not reveal high levels of PCB's in the sediments adjacent to the Airport pump station discharge.

TABLE 11 BIOASSAY RESULTS

Location	<u>Sampling</u>		Bioassay Test Start	96 hour LC ₅₀ Results
	Date	Time		
3rd Avenue pump station	Nov. 14 24	1100 905	Nov. 15 25	NT* NT
12th Avenue pump station	14	1130	15	NT
Airport pump station	14	1200	15	NT
96th Street pump station	14	1230	15	NT
Oliver Street pump station	14 24	1300 1010	15 25	NT NT
White rock stormwater manhole (at Oxford and Buena Vista)	14 24	1345 1100	15 25	NT NT

*NT - non-toxic

TABLE 12 PCB ANALYSIS OF BOUNDARY BAY SEDIMENTS RESULTS

Sample Station Locations	Distance from station outfall (metres)	Concentration	
		Arochlor 1260 (ppb)	Hexachloro- benzene (ppb)
<u>Delta land drainage pump stations</u>			
3rd Avenue	0.30 (S)*	36	
	4.6 (N)	34	
	6.1 (S)	55	
12th Avenue (gravity discharge)	9.1 (N)	23	
	12.2 (S)	18	
	10.7 (N)	78	
Airport	4.6 (W)	1200	L1**
	15.2 (W)	93	
	15.2 (E)	110	
96th Street	4.6 (W)	3800	L1
	7.6 (E)	72	
	9.1 (W)	370	
Oliver Street	4.6 (W)	59	L1
	4.6 (E)	50	
	15.2 (W)	66	
Background Stations		31	
88th Street		480	
17A Avenue			

* denotes side of outfall

** L1 - less than 1 ppb

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APPENDICES

APPENDIX I

MARINE SAMPLE STATION LOCATION DESCRIPTIONS

APPENDIX I

MARINE SAMPLE STATION LOCATION DESCRIPTIONS

Sample			
Station	Latitude	Longitude	Description
1	49° 02.78'	122° 54.10'	At seventh Boundary Bay Channel marker from the southern end.
2	49° 03.14'	122° 53.34'	Approximately 400 m offshore from the foot of Beecher Street (Crescent Beach).
3	49° 03.11'	122° 53.05'	At foot of Beecher Street (Crescent Beach)
4	49° 03.05'	122° 53.04'	Approximately 300 m south of station 3, off brown house with yellow trim.
5	49° 02.95'	122° 53.21'	Approximately 400 m offshore from station 6.
6	49° 02.95'	122° 53.00'	Approximately 600 m south of station 3, off large brown house.
7	49° 02.74'	122° 53.49'	Midway between station B and station 1.
8	49° 02.51'	122° 52.85'	Approximately 2 km south of station 6 off eroded bluffs.
9	49° 02.18'	122° 53.21'	Midway between station 1 and Kwomais Point approximately 400 m offshore.
10	49° 02.29'	122° 54.61'	At third Boundary Bay channel marker in line with Kwomais Point.
11	49° 01.94'	122° 53.46'	Midway between stations 10 and 12 approximately 2 km offshore.
12	49° 01.90'	122° 52.50'	Off small train bridge north of Kwomais Point.
13	49° 01.49'	122° 52.04'	Kwomais Point - off storm Culvert.

APPENDIX I MARINE SAMPLE STATION LOCATION DESCRIPTIONS (Cont'd)

Sample			
Station	Latitude	Longitude	Description
14	49° 01.47'	122° 51.95'	Kwomais Point at foot of 128th Street.
15	49° 01.47'	122° 51.80'	Off small train bridge approximately 100 m east of station 14.
16	49° 01.45'	122° 51.19'	Off storm culvert east of 15.
17	49° 01.45'	122° 50.60'	Off train signals east of 16.
18	49° 01.48'	122° 50.12'	Off second telephone pole east culvert east of station 16.
19	49° 01.49'	122° 49.83'	Off old train signal foundation east of 18.
20	49° 01.49'	122° 49.60'	Off small railway trestle near Surrey-White Rock border.
21	49° 01.39'	122° 49.60'	250 m offshore from station 20.
22	49° 01.24'	122° 49.60'	500 m offshore from station 20.
23	49° 01.49'	122° 49.40'	Shore station east of station 20 between two storm drains
24	49° 01.46'	122° 49.24'	East of station 23 off train signals.
25	49° 01.44'	122° 49.08'	East of station 24 off white house with cement retaining wall.
26	49° 01.30'	122° 49.10'	250 m offshore from station 25.
27	49° 01.19'	122° 49.15'	500 m offshore from station 25.
28	not done	not done	White Rock - at foot of Bay Street, 14586 Marine Drive.
29	not done	not done	White Rock - off storm drain midway between station 28 and 30 at 14655 Marine Drive.

APPENDIX I MARINE SAMPLE STATION LOCATION DESCRIPTIONS (Cont'd)

Sample Station	Latitude	Longitude	Description
30	not done	not done	White Rock - 250 m offshore of station 29.
31	not done	not done	White Rock - 500 m offshore of station 29.
32	not done	not done	White Rock - at foot of Anderson Street.
33	not done	not done	White Rock - off storm drain midway between stations 32 and 34.
34	not done	not done	White Rock - 250 m offshore of station 33.
35	not done	not done	White Rock - 500 m offshore of station 33.
36	not done	not done	White Rock - off GVS and DD pump station.
37	not done	not done	White Rock - off Oxford Street storm drain.
38	not done	not done	White Rock - off 14821 Marine Dr.
39	not done	not done	White Rock - off 250 m offshore of station 38.
40	not done	not done	White Rock - 500 m offshore of station 38.
41	not done	not done	White Rock - at foot of Elm Street.
42	not done	not done	White Rock - at foot of Vidal Street.
43	not done	not done	White Rock - off old train station.
44	not done	not done	White Rock - 250 m offshore of station 43.

APPENDIX I MARINE SAMPLE STATION LOCATION DESCRIPTIONS (Cont'd)

Sample Station	Latitude	Longitude	Description
45	not done	not done	White Rock - 500 m offshore of station 43.
46	not done	not done	White Rock - off small covered checkerboard playing area east of train station.
47	not done	not done	White Rock - shoreline station at pier.
48	not done	not done	White Rock - off 15097 Marine Dr.
49	not done	not done	White Rock - off White Rock landmark.
50	not done	not done	White Rock - off 15241 Marine Dr.
51	not done	not done	White Rock - 250 m offshore of station 50.
52	not done	not done	White Rock - 500 m offshore of station 50.
53	not done	not done	White Rock - off 15301 Marine Dr.
54	not done	not done	White Rock - off brick apartments at Cypress and Marine.
55	not done	not done	White Rock - off public washrooms at foot of Balsam.
56	not done	not done	White Rock - 250 m offshore of station 55.
57	not done	not done	White Rock - 500 m offshore of station 55.
58	not done	not done	White Rock - at foot of Ash Street off Chit Chat Cafe.
59	not done	not done	White Rock - off Bay Hotel.
60	not done	not done	White Rock - 250 m offshore of station 59.

APPENDIX I MARINE SAMPLE STATION LOCATION DESCRIPTIONS (Cont'd)

Sample Station	Latitude	Longitude	Description
61	not done	not done	White Rock - 500 m offshore of station 59.
62	49° 00.86'	122° 47.08'	White Rock - off stage in Semiahmoo Park.
63	49° 00.82'	122° 46.92'	White Rock - off train signals at foot of Hill Street.
64	49° 00.81'	122° 46.81'	Approximately 100 m west of Campbell River mouth off white house.
65	49° 00.70'	122° 46.85'	250 m offshore of station 64.
66	49° 00.57'	122° 46.90'	500 m offshore of station 64.
67	49° 00.52'	122° 46.71'	500 m offshore of Campbell River mouth.
68	49° 00.50'	122° 46.58'	500 m offshore of station 70.
69	49° 00.61'	122° 46.54'	250 m offshore of station 70.
70	49° 00.74'	122° 46.51'	Approximately 100 m east of Campbell River mouth.
71	49° 00.70'	122° 46.40'	Off Oddfellows Lodge.
72	49° 00.63'	122° 46.26'	Off Royal Canadian Legion.
73	49° 00.58'	122° 46.11'	Off brown house with white trim.
74	49° 00.50'	122° 46.22'	250 m offshore of station 73.
75	49° 00.40'	122° 46.35'	500 m offshore of station 73.
76	49° 00.36'	122° 45.76'	Off yellow and white Fabco trailer.
77	49° 00.22'	122° 45.59'	Off Douglas border crossing outfall pipe.
78	49° 00.00'	122° 45.31'	Off Peace Arch at international boundary.

APPENDIX I

MARINE SAMPLE STATION LOCATION DESCRIPTIONS (Cont'd)

Sample			
Station	Latitude	Longitude	Description
79 (S, M, D)	49° 00.00'	122° 46.15'	On International Boundary line midway between Peace Arch and first marine boundary marker (S = surface; M = approximately 1.5 m; D = approximtely 3 m).
80 (S, M, D)	49 00.00	122 47.63	West of station 79 on boundary line approximately midway between first marine boundary marker and end of White Rock pier (S = surface; M = approximately 6.5 m; D = approximately 13 m).
81 (S, M, D)	49 00.00	122 49.04	On boundary line in line with the foot of Bay Street (S = surface; M = approximately 11.5 m; D = approximately 23 m).

Note: Latitude and longitudes were not done for stations 28-61 due to their close proximity to each other.

APPENDIX II

FRESHWATER SAMPLE STATION LOCATION DESCRIPTIONS

APPENDIX II

FRESHWATER SAMPLE STATION LOCATION DESCRIPTIONS

Sample Station	Description
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<u>Municipality of Delta land drainage pump stations</u>	
P1	3rd Avenue (Beach Grove)
P2	12th Avenue (Beach Grove)
P3	Airport
P4	96th Street - Beharrel
P5	Oliver Street
 <u>Streams and Stormdrains</u>	
S1	Serpentine River at Highway 99 bridge
S2	Nicomekl River at Highway 99 bridge
S3	Stream at 128th Street and 13th Avenue
S4	Stream between 133 A Street and 132 B Street on Marine Drive
S5	Stream between Bishop and Nicol on Marine Drive
S6	Stream between Kerfoot and Bishop on Marine
S7	Catchbasin at Kerfoot and Marine
S8	Catchbasin at Magdalen Crescent and Marine
S9	Catchbasin at High and Marine
S10	Stormwater outfall between Anderson and Bay
S11	Manhole between Oxford and Anderson on Marine
S12	Manhole at Oxford and Buena Vista
S13	Catchbasin at Vidal and Marine
S14	Manhole at Martin and Marine
S15	Catchbasin at Balsam and Marine
S16	Catchbasin between Balsam and Ash on Marine
S17	Manhole at Maple and Marine
S18	Catchbasin at Keil and Marine
S19	Manhole at Stevens and Marine
S20	Campbell River at 172nd Street culvert
S21	Campbell River at No. 15 Road bridge
S22	Manhole at end of fence line in Peace Arch Park (Douglas Border Crossing)
S23	Wood chamber opposite Peace Arch (Douglas Border Crossing)

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE STATIONS

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE STATIONS

Sample Station	Date of Collection	Time of Collection	Fecal Coliform MPN/100 ml
1	Dec. 1/77	1035	33
	5	1315	17
	7	1235	5
	8	1025	240
	12	0910	79
	13	1010	23
2	Dec. 1/77	1010	540
	5	1340	130
	7	1250	22
	8	1225	920
	12	1105	79
	13	0940	110
3	Dec. 1/77	1110	240
	5	1340	170
	7	1250	49
	8	1225	170
	12	1105	130
	13	0940	350
4	Dec. 1/77	1015	240
	5	1335	49
	7	1245	79
	8	1220	220
	12	1100	170
	13	0945	79

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE STATIONS

Sample Station	Date of Collection	Time of Collection	Fecal Coliform MPN/100 ml
5	Dec. 1/77	1015	79
	5	1330	33
	7	1245	49
	8	1220	540
	Dec. 12/77	1100	130
	13	0945	79
6	Dec. 1/77	1015	110
	5	1335	33
	7	1245	49
	8	1220	79
	12	1100	49
	13	0945	49
7	Dec. 1/77	1030	170
	5	1325	94
	7	1235	9
	8	1035	540
	12	0925	79
	13	1010	540
8	Dec. 1/77	1020	130
	5	1330	130
	7	1240	130
	8	1035	49
	12	0930	230
	13	0950	26

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE STATIONS

Sample Station	Date of Collection	Time of Collection	Fecal Coliform MPN/100 ml
9	Dec. 1/77	1045	23
	5	1310	12
	7	1215	5
	8	1030	79
	12	0920	49
	13	1000	13
<hr/>			
10	Dec. 1/77	1040	5
	5	1315	5
	7	1230	8
	8	1025	11
	12	0915	11
	13	1015	11
<hr/>			
11	Dec. 1/77	1050	33
	5	1305	46
	7	1210	2
	8	1035	430
	12	0935	70
	13	1005	170
<hr/>			
12	Dec. 1/77	1055	49
	5	1300	23
	7	1040	130
	8	0940	49
	12	0955	230
	13	1210	130

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE STATIONS

Sample Station	Date of Collection	Time of Collection	Fecal Coliform MPN/100 ml
13	Dec. 1/77	1055	22
	5	1050	49
	7	1205	350
	8	1045	49
	12	0945	46
	13	1025	49
14	Dec. 1/77	1100	13
	5	1050	46
	7	1205	79
	8	1045	49
	12	0945	49
	13	1030	17
15	Dec. 1/77	1105	23
	5	1055	23
	7	1200	33
	8	1050	23
	12	0945	170
	13	1030	11
16	Dec. 1/77	1110	22
	5	1055	79
	7	1200	17
	8	1050	31
	12	0950	110
	13	1035	110

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE STATIONS

Sample Station	Date of Collection	Time of Collection	Fecal Coliform MPN/100 ml
17	Dec. 1/77	1110	22
	5	1055	130
	7	1155	8
	8	1050	17
	12	0955	49
	13	1035	70

18	Dec. 1/77	1110	2
	7	1105	79
	8	1055	49
	12	0955	170
	13	1040	33

19	Dec. 1/77	1115	5
	5	1110	350
	7	1145	13
	8	1100	27
	12	1000	22
	13	1040	33

20	Nov. 17/77	0930	2
	18	0935	13
	21	0935	8
	22	1040	2
	24	1025	2
	28	0940	350
	Dec. 5	1110	140
	7	1140	70
	8	1100	33

APPENDIX III DAILY BACTERIOLOGICAL RESULTS FOR MARINE STATIONS

Sample Station	Date of Collection	Time of Collection	Fecal Coliform MPN/100 ml
21	Nov. 17/1977	0930	22
	18	0935	4
	21	0935	2
	22	1040	23
	24	1025	14
	28	0940	540
	Dec. 5	1120	21
	7	1140	26
	8	1100	79
22	Nov. 17/77	0930	8
	18	0930	8
	21	0935	2
	22	1035	22
	24	1020	2
	28	0935	170
	Dec. 5	1115	49
	7	1140	22
	8	1100	79
23	Nov. 17/77	0935	46
	18	0940	8
	21	0940	22
	22	1045	2
	24	1030	4
	28	0945	920

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE STATIONS

Sample Station	Date of Collection	Time of Collection	Fecal Coliform MPN/100 ml
24	Nov. 17/77	0940	7
	18	0940	5
	21	0940	23
	22	1045	49
	24	1030	7
	28	0950	1600
25	Nov. 17/77	0945	49
	18	0940	5
	21	0940	21
	22	1050	33
	24	1035	13
	28	0950	1600
26	Nov. 28/77	0950	920
	Dec. 1	1120	8
	5	1120	33
	7	1135	33
	8	1105	79
27	Nov. 28/77	0950	920
	Dec. 1	1120	23
	5	1125	110
	7	1135	33
	8	1105	49

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE STATIONS

Sample Station	Date of Collection	Time of Collection	Fecal Coliform MPN/100 ml
28	Nov. 14/77	1320	33
	17	0950	130
	18	0940	8
	21	0945	33
	22	1050	79
	24	1035	14
	25	1235	49

29	Nov. 14/77	1340	49
	17	0950	220
	18	0945	14
	21	0945	13
	22	1055	33
	24	1035	110
	25	1135	79

30	Nov. 28/77	1000	350
	Dec. 1	1125	21
	5	1130	49
	7	1130	79
	8	1110	79

31	Nov. 28/77	1000	540
	Dec. 1	1125	33
	5	1125	13
	7	1130	17
	8	1110	49

APPENDIX III DAILY BACTERIOLOGICAL RESULTS FOR MARINE STATIONS

Sample Station	Date of Collection	Time of Collection	Fecal Coliform MPN/100 ml
32	Nov. 14/77	1335	63
	17	1000	130
	18	0945	8
	21	0945	49
	22	1055	130
	24	1040	31

33	Nov. 14/77	1345	49
	17	1000	79
	18	0945	8
	21	0955	49
	22	1055	33
	24	1040	33
	25	1125	110

34	Nov. 28/77	1000	170
	Dec. 1	1125	13
	5	1130	49
	7	1130	11
	8	1110	140

35	Nov. 28/77	1005	350
	Dec. 1	1125	11
	5	1130	49
	7	1130	23
	8	1110	170

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE STATIONS

Sample Station	Date of Collection	Time of Collection	Fecal Coliform MPN/100 ml
36	Nov. 14/77	1350	23
	17	1000	49
	18	0945	17
	21	0955	8
	22	1055	170
	24	1040	49
37	Nov. 14/77	1355	49
	17	1000	11
	18	0950	11
	21	0955	14
	22	1055	79
	24	1045	170
38	Nov. 14/77	1400	46
	17	1005	130
	18	0950	23
	21	1000	5
	22	1055	240
	24	1045	110
	25	1110	240
39	Nov. 17/77	1005	2
	18	0950	2
	21	1000	2
	22	1100	7
	24	1095	14
	28	1010	240

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE STATIONS

Sample Station	Date of Collection	Time of Collection	Fecal Coliform MPN/100 ml
40	Nov. 17/77	1010	2
	18	0950	8
	21	1000	2
	22	1100	2
	24	1050	13
	28	1015	350
	Dec. 7	1125	49
	8	1115	49

41	Nov. 14/77	1405	33
	17	1015	17
	18	1000	13
	21	1005	8
	22	1105	130
	24	1050	170

42	Nov. 14/77	1405	49
	17	1015	49
	18	1000	2
	21	1005	7
	22	1105	540
	24	1050	350
	25	1105	33

43	Nov. 14/77	1410	240
	17	1020	49
	18	1000	7
	21	1005	33
	22	1105	170
	24	1055	350

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE STATIONS

Sample Station	Date of Collection	Time of Collection	Fecal Coliform MPN/100 ml
44	Nov. 28/77	1010	170
	Dec. 1	1130	13
	5	1145	70
	7	1120	11
	8	1115	170

45	Nov. 28/77	1015	170
	Dec. 1	1130	11
	5	1145	110
	7	1120	13
	8	1115	33

46	Nov. 14/77	1415	350
	17	1020	22
	18	1000	240
	21	1005	5
	22	1105	79
	24	1055	170
	25	1045	240

47	Nov. 14/77	1420	350
	17	1020	11
	18	1000	5
	21	1005	23
	22	1110	79
	24	1055	17

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE STATIONS

Sample Station	Date of Collection	Time of Collection	Fecal Coliform MPN/100 ml
48	Nov. 17/77	1025	79
	18	1055	33
	21	1010	7
	22	1115	2
	24	1110	23
	28	1020	240

49	Nov. 17/77	1025	79
	18	1005	13
	21	1015	2
	22	1115	11
	24	1110	11
	28	1020	540

50	Nov. 17/77	1030	110
	18	1005	26
	21	1020	23
	22	1115	2
	24	1110	8
	28	1020	350

51	Nov. 17/77	1030	2
	18	1010	23
	21	1020	2
	22	1125	5
	24	1115	22
	28	1025	540

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE STATIONS

Sample Station	Date of Collection	Time of Collection	Fecal Coliform MPN/100 ml
52	Nov. 17/77	1035	2
	18	1010	8
	21	1015	2
	22	1125	7
	24	1115	8
	28	1025	240

53	Nov. 17/77	1035	130
	18	1015	6
	21	1020	49
	22	1125	2
	24	1115	33
	28	1030	920

54	Nov. 17/77	1040	17
	18	1015	8
	21	1025	2
	22	1030	8
	24	1120	33
	28	1030	540
	Dec. 5	1200	70

55	Nov. 17/77	1045	33
	18	1015	2
	21	1025	8
	22	1130	2
	24	1120	22
	25	1035	23
	28	1030	920
	Dec. 5	1200	46

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE STATIONS

Sample Station	Date of Collection	Time of Collection	Fecal Coliform MPN/100 ml
56	Nov. 28/77	1035	240
	Dec. 1	1140	2
	5	1200	22
	7	1110	17
	8	1120	110

57	Nov. 28/77	1035	130
	Dec. 1	1140	8
	5	1200	46
	7	1110	11
	8	1120	49

58	Nov. 17/77	1050	46
	18	1020	14
	21	1030	4
	22	1130	11
	24	1120	8
	25	1030	17
	28	1040	540

59	Nov. 17/77	1050	17
	18	1020	170
	21	1030	2
	22	1130	13
	24	1125	8
	28	1040	350

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE STATIONS

Sample Station	Date of Collection	Time of Collection	Fecal Coliform MPN/100 ml
60	Nov. 28/77	1040	220
	Dec. 1	1140	13
	5	1205	13
	7	1110	33
	8	1125	79

61	Nov. 28/77	1040	170
	Dec. 1	1140	1600
	5	1205	79
	7	1110	46
	8	1120	49

62	Nov. 17/77	1055	8
	18	1020	13
	21	1030	13
	22	1135	11
	24	1125	23
	25	1015	79
	28	1050	1600

63	Nov. 17/77	1100	49
	18	1025	13
	21	1035	17
	22	1135	33
	24	1125	8
	25	1010	17

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE STATIONS

Sample Station	Date of Collection	Time of Collection	Fecal Coliform MPN/100 ml
64	Nov. 17/77	1100	240
	18	1025	110
	21	1040	17
	22	1135	22
	24	1135	49
	28	1055	920
65	Nov. 17/77	1105	2
	18	1030	2
	21	1040	2
	22	1140	13
	24	1135	22
	28	1055	220
	Dec. 7	1105	79
	8	1125	79
66	Nov. 17/77	1105	5
	18	1030	4
	21	1045	2
	22	1140	17
	24	1135	79
	28	1100	110
67	Nov. 17/77	1110	2
	18	1030	5
	21	1045	5
	22	1145	33
	24	1145	46
	28	1100	240

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE STATIONS

Sample Station	Date of Collection	Time of Collection	Fecal Coliform MPN/100 ml
68	Nov. 17/77	1110	2
	18	1035	7
	21	1045	5
	22	1145	110
	24	1145	31
	28	1100	130

69	Nov. 17/77	1110	11
	18	1035	5
	21	1050	2
	22	1145	130
	24	1145	240
	28	1100	540

70	Nov. 17/77	1115	79
	18	1040	33
	21	1050	5
	22	1150	13
	24	1150	79
	28	1105	920

71	Nov. 17/77	1115	33
	18	1040	17
	21	1055	7
	22	1150	7
	24	1150	23
	28	1105	1600
	Dec. 1	1100	110
	8	1130	1600

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE STATIONS

Sample Station	Date of Collection	Time of Collection	Fecal Coliform MPN/100 ml
72	Nov. 17/77	1120	23
	18	1045	17
	21	1055	8
	22	1150	33
	24	1150	920
	28	1105	540

73	Nov. 17/77	1125	49
	18	1045	79
	21	1100	17
	22	1205	170
	24	1155	350
	28	1110	350

74	Nov. 28/77	1115	540
	Dec. 1	1155	49
	5	1210	130
	7	1050	280
	8	1130	170

75	Nov. 28/77	1115	110
	Dec. 1	1155	70
	5	1210	170
	7	1050	33
	8	1135	70

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE STATIONS

Sample Station	Date of Collection	Time of Collection	Fecal Coliform MPN/100 ml
76	Nov. 17/77	1125	79
	18	1050	920
	21	1105	170
	22	1205	170
	24	1155	920
	28	1120	240

77	Nov. 17/77	1130	84
	18	1055	1600
	21	1110	79
	22	1210	79
	24	1155	240
	28	1120	350

78	Nov. 17/77	1135	140
	18	1105	920
	21	1110	110
	22	1210	27
	24	1200	350
	28	1125	1600

79	Dec. 1/77	1200	240
	5	1210	49
	7	1040	33
	8	1140	130
	12	1030	23
	13	1100	70

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE STATIONS

Sample Station	Date of Collection	Time of Collection	Fecal Coliform MPN/100 ml
79-M	Dec. 5/77	1225	46
	7	1040	79
	8	1145	170

79-D	Dec. 1/77	1200	11
	5	1215	49
	7	1040	49
	8	1140	130
	13		17

80	Dec. 1/77	1205	130
	5	1230	27
	7	1030	2
	8	1150	2
	12	1025	11
	13	1055	49

80-M	Dec. 5/77	1230	5

80-D	Dec. 5/77	1230	2
	7	1030	8
	8	1155	2
	13		33

81	Dec. 1/77	1210	5
	5	1235	17
	7	1025	2
	8	1200	2
	12	1010	17
	13	1050	33

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE STATIONS

Sample Station	Date of Collection	Time of Collection	Fecal Coliform MPN/100 ml
81-M	Dec. 5/77	1235	2
	7	1025	8
<hr/>			
81-D	Dec. 5/77	1235	33
	7	1025	2
	12	1010	2
	13	1050	22

APPENDIX IV

SUMMARY OF SALINITY DATA FOR MARINE SAMPLE STATIONS

APPENDIX IV SUMMARY OF SALINITY DATA FOR MARINE STATIONS

Sample Station	No. of Samples	Salinity Range (ppt)	Mean Salinity (ppt)	Sample Station	No. of Samples	Salinity Range (ppt)	Mean Salinity (ppt)
1	6	26.5-28.5	27.8	28	7	26.5-28.5	27.8
2	5	24.5-28.5	27.8	29	7	26.5-29.5	28.0
3	6	25.5-28.5	27.0	30	5	25.5-28.5	27.3
4	6	26.5-28.5	27.1	31	5	26.0-28.5	27.4
5	6	26.5-28.5	27.6	32	6	27.5-29.5	28.3
6	6	25.5-28.5	26.7	33	7	24.5-28.5	27.6
7	6	27.5-28.5	28.2	34	5	26.5-29.5	28.1
8	6	26.5-28.5	27.6	35	5	26.5-29.5	27.9
9	6	27.5-28.5	28.2	36	6	27.5-29.5	28.5
10	6	26.5-29.5	28.3	37	6	27.5-29.5	28.7
11	6	27.5-28.5	28.2	38	7	27.5-29.5	28.4
12	6	26.5-28.5	27.7	39	7	24.5-29.5	27.9
13	6	26.5-27.5	27.3	40	8	26.5-29.5	28.4
14	6	27.0-28.0	27.5	41	6	27.5-29.5	28.2
15	6	27.0-28.0	27.6	42	7	26.5-29.5	28.1
16	6	27.0-28.5	27.7	43	6	27.5-29.5	28.3
17	6	27.0-28.5	27.8	44	5	24.45-28.5	27.1
18	6	27.0-28.5	27.7	45	5	26.5-28.5	27.5
19	6	26.5-28.5	27.3	46	7	27.5-29.5	28.1
20	9	23.5-28.5	27.2	47	6	27.5-29.5	28.4
21	9	24.5-29.5	27.8	48	6	24.5-28.5	27.6
22	9	26.5-29.5	27.9	49	6	22.5-29.5	27.7
23	6	22.5-28.5	27.1	50	6	23.5-29.5	27.7
24	6	20.5-28.5	27.1	51	6	25.5-29.5	28.4
25	6	20.5-29.5	26.9	52	6	26.5-29.5	28.1
26	5	23.5-28.5	27.1	53	6	23.5-29.5	27.8
27	5	25.5-28.5	27.5	54	7	24.5-29.5	27.7

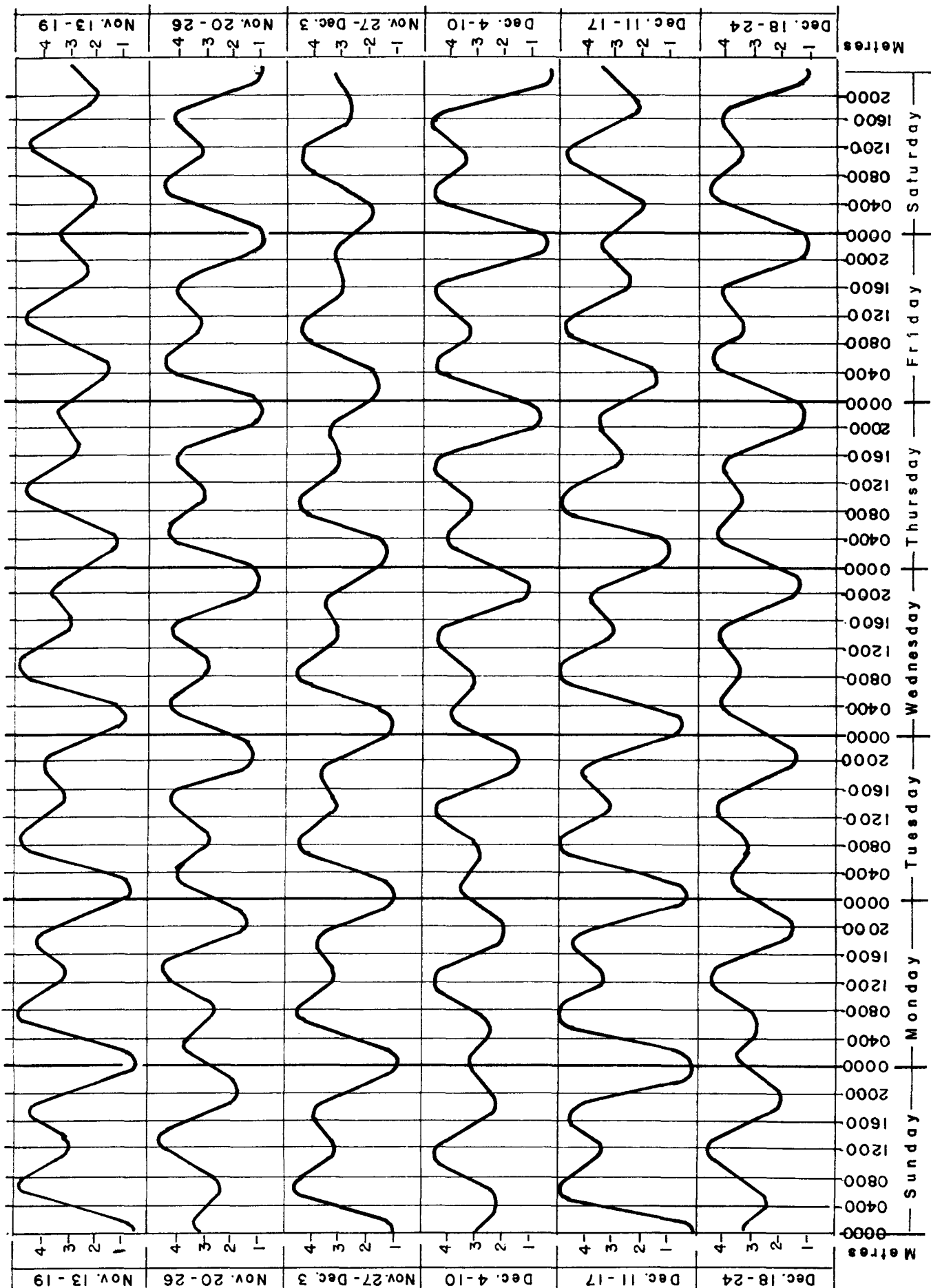
APPENDIX IV SUMMARY OF SALINITY DATA FOR MARINE STATIONS (continued)

Sample Station	No. of Samples	Salinity Range (ppt)	Mean Salinity (ppt)	Sample Station	No. of Samples	Salinity Range (ppt)	Mean Salinity (ppt)
55	8	23.5-29.5	27.4	72	6	27.5-29.5	28.2
56	5	26.5-28.5	27.5	73	7	25.0-28.5	27.0
57	5	27.0-28.5	27.6	74	5	26.0-27.5	27.2
58	7	20.5-28.5	27.0	75	5	27.0-28.5	27.8
59	6	23.0-28.5	26.9	76	6	24.5-28.5	27.3
60	5	24.5-28.5	26.9	77	6	26.5-29.5	28.0
61	5	27.0-28.5	27.6	78	6	24.5-28.5	27.1
62	7	21.5-28.5	26.6	79	7	25.5-29.5	27.9
63	7	22.5-29.5	26.9	79-M	3	27.5	27.5
64	6	25.5-28.5	27.4	79-D	4	27.5-28.5	27.9
65	8	26.5-29.5	28.0	80	7	27.0-29.5	28.5
66	6	27.5-29.5	28.3	80-M	2	29.0	29.0
67	6	27.5-29.5	28.7	80-D	3	28.5-29.0	28.7
68	6	26.5-29.5	28.3	81	6	27.5-29.5	28.7
69	6	25.5-29.5	28.2	81-M	2	28.5	28.5
70	6	23.5-28.5	27.3	81-D	3	27.5-29.5	28.5
71	8	24.5-29.5	27.5				

APPENDIX V

TIDAL DATA

APPENDIX V - TIDAL FLUCTUATIONS - Nov. 13 to Dec. 24, 1977 -- Reference - POINT ATKINSON



APPENDIX VI

DAILY BACTERIOLOGICAL ANALYSES RESULTS
AND SAMPLING CONDITIONS FOR FRESHWATER SAMPLES

APPENDIX VI DAILY BACTERIOLOGICAL ANALYSES RESULTS AND SAMPLING CONDITIONS
FOR FRESHWATER SAMPLES

Station	Sample		Results				Precipitation	
	Date	Time	Total	Fecal	Fecal	FC:FS	Sample Hour	Daily
			Coliform	Coliform	Streptococci		(mm)	(mm)
			<u>(MF counts/100 ml)</u>					
P1	Nov. 15	1020	1100	180	240	0.75	4.3	8.8
	25	930	2100	110	770	0.14		47
	Dec. 14	910	2900	72	500	0.14		10.4
	16	855	2700	58	230	0.25		T
P2	Nov. 15	1015	220	10	360	0.03	4.3	8.8
	15	1015	320	20	450	0.04		8.8
	25	940	200	46	87	0.53		47
	Dec. 14	920	750	180	960	0.19		10.4
P3	Nov. 15	1000	2300	1920	3700	0.52	3.3	8.8
	25	1005	9100	40	530	0.07		47
	Dec. 14	940	5400	140	9000	0.15		10.4
P4	Nov. 15	950	2300	680	890	0.76	3.3	8.8
	25	1020	8000	20	1000	0.02		47
	Dec. 14	950	3100	610	3000	0.20		10.4
P5	Nov. 15	940	1200	> 800	470		3.3	8.8
	24	1010	200	10	70	0.14		
	25	1035	320	80	210	0.38		47
	Dec. 14	1000	1240	230	380	0.60		0.8
S1	Dec. 14	1020		790*			0.8	10.4
	16	1005		540*				T

*MPN/100 ml

T - trace

APPENDIX VI DAILY BACTERIOLOGICAL ANALYSES RESULTS AND SAMPLING CONDITIONS
FOR FRESHWATER SAMPLES (continued)

Station	Sample		Results				Precipitation	
	Date	Time	Total	Fecal	Fecal	FC:FS	Sample Hour	Daily
			Coliform	Coliform	Streptococci			
			(MF counts/100 ml)				(mm)	(mm)
S2	Dec. 14	1040		1300*			0.8	10.4
	16	1015		350*				
S3	Nov. 17	845	630	10	30	0.33		T
	25	1105	4000	630	2710	0.23	3.8	47
	Dec. 14	1040	3100	160	180	0.89	0.8	10.4
	16	1250	2800	1320	390	3.4		T
	20	1010	240	20	20	1.0		
S4	Nov. 17	905	28 000	1600	480	3.3		T
	25	1110	36 000	14 400	1500	9.6	3.8	47
	Dec. 1	1040	5700	1300	300	4.3	1.3	31.4
	14	925	3100	200	1300	0.15		10.4
	16	1220	600	380	40	9.5		T
	20	945	3000	2400	48	50		
S5	Nov. 15	1400	430	<100	50			8.8
	25	1255	7400	1100	1000	1.1	3.6	47
	Dec. 2	1025	880	100	50	2.0		5.6
	14	1005	410	61	60	1.0	0.8	10.4
	16	1210	230	280	35	8.0		T
S6	Nov. 15	1350	50	<100	170			8.8
	25	1250	6600	890	1200	0.75	3.6	47
	Dec. 14	955	170	<10	70			10.4
	16	1205	37	10	28	0.35		T

APPENDIX VI DAILY BACTERIOLOGICAL ANALYSES RESULTS AND SAMPLING CONDITIONS
FOR FRESHWATER SAMPLES (continued)

Station	Sample		Results				Precipitation	
	Date	Time	Total	Fecal	Fecal	FC:FS	Sample Hour	Daily
			Coliform	Coliform	Streptococci			
			(MF counts/100 ml)				(mm)	(mm)
S7	Nov. 15	1345	180	40	150	0.27		8.8
	25	1245	1870	540	1660	0.32	3.6	47
	Dec. 14	950	860	10	350	0.28		10.4
S8	Nov. 15	1335	6100	100	400	0.25		8.8
	25	1240	5900	1630	7900	0.21	3.6	47
	Dec. 2	1015	540	140	330	0.42		5.6
	14	945	1300	94	250	0.38		10.4
S9	Nov. 15	1330	6400	500	16 500	0.03		8.8
	25	1230	162 000	7600	24 000	0.32	3.6	47
	Dec. 2	1010	57 000	2700	2100	1.3		5.6
S10	Nov. 15	1325	720	> 800	230			8.8
	25	1135	4600	1600	2400	0.67	3.8	47
	Dec. 2	1005	2000	200	< 100			5.6
	14	935	830	90	100	0.90		10.4
	16	1200	190	100	38	2.6		T
S11	Nov. 15	1315	600	130	800	0.16		8.8
	25	1125	3500	430	15 800	0.03	3.6	47

APPENDIX VI DAILY BACTERIOLOGICAL ANALYSES RESULTS AND SAMPLING CONDITIONS
FOR FRESHWATER SAMPLES (continued)

Station	Sample		Results				Precipitation	
	Date	Time	Total	Fecal	Fecal	FC:FS	Sample Hour	Daily
			Coliform	Coliform	Streptococci			
			(MF counts/100 ml)				(mm)	(mm)
S12	Nov. 14	1255	690	10	110	0.09		8.8
	24	1100	5100	3400	> 800			
	25	1115	41 000	1400	3100	0.45	3.6	47
	Dec. 1	1050	5900	800	1400	0.57	1.3	31.4
	14	930	24 000	5300	330	16		10.4
	16	1155	1300	330	5600	0.06		T
S13	Nov. 14	1305	45 000	1900	6300	0.30		8.8
	25	1105	26 000	4100	6400	0.64	3.6	47
	Dec. 2	1000	>80 000	>80 000	5000			5.6
S14	Nov. 15	1200	>80 000	380 000	29 000	13		8.8
	25	1045	20 000	1000	6400	0.15	3.3	47
	Dec. 2	955	63 000	9400	<100			5.6
	14		69 000	2160	1100	2.0		10.4
	16	1120	49 000	114 000	3800	30		T
	20	1110	920 000	1 140 000	20 000	70		
S15	Nov. 15	1150	10 400	1250	350	3.6		8.8
	25	1035	17 000	1250	9300	1.3	3.3	47
	Dec. 2	950	2300	200	400	5.0		5.6
S16	Nov. 15	1145	18 000	180	2400	0.08		8.8
	25	1030	73 000	1700	13 200	0.13	3.3	47
	Dec. 2	950	1700	100	600	0.16		5.6

APPENDIX VI DAILY BACTERIOLOGICAL ANALYSES RESULTS AND SAMPLING CONDITIONS
FOR FRESHWATER SAMPLES (continued)

Station	Sample		Results				Precipitation	
	Date	Time	Total	Fecal	Fecal	FC:FS	Sample Hour	Daily
			Coliform	Coliform	Streptococci			
			(MF counts/100 ml)				(mm)	(mm)
S17	Nov. 15	1140	2520	5600	1000	5.6		8.8
	25	1020	9200	4200	1400	3.0	3.3	47
	Dec. 2	945	2000	100	100	1.0		5.6
S18	Nov. 15	1120	2600	710	1200	0.59		8.8
	25	1005	13 600	3200	15 000	0.21	3.3	47
	Dec. 2	940	1200	100	1800	0.06		5.6
S19	Nov. 15	1130	880	580	1800	0.32		8.8
	25	1000	22 000	4700	13 500	0.35	3.3	47
	Dec. 2	935	4300	2000	100	20		5.6
S20	Nov. 17	920	610	370	370	1.0		T
	24	1120	850	460	430	1.1		
	25	1125	21 200	9400	1390	6.8	3.8	47
	Dec. 2	855	2500	1000	200	5.0		5.6
	14	1005	300	390	1800	0.22	0.8	10.4
	16	1055	450	300	840	0.36		T
	20	940	490	220	150	1.5		
S21	Nov. 17	945	670	210	160	1.3		T
	25	1230	17 100	8400	1230	6.9	3.6	47
	Dec. 2	905	62 000	9000	2100	4.3		5.6
	14	1040	1500	290	2900	0.10	0.8	10.4
	16	1105	620	300	610	0.49		T
	20	930	400	130	70	1.9		

APPENDIX VI DAILY BACTERIOLOGICAL ANALYSES RESULTS AND SAMPLING CONDITIONS
FOR FRESHWATER SAMPLES (continued)

Station	Sample		Results				Precipitation	
	Date	Time	Total	Fecal	Fecal	FC:FS	Sample Hour	Daily
			Coliform	Coliform	Streptococci		(mm)	(mm)
			(MF counts/100 ml)					
S22	Nov. 17	1030	> 80 000	> 80 000	> 80 000			T
	25	1310	800 000	4000	< 10 000		4.6	47
	Dec. 2	915	100	100	< 100			5.6
	14	1030	82 000	14 000	2200	6.4	0.8	10.4
	16	1035	17 000	760	23 000	0.03		T
S23	Nov. 24	1250	21 000	170	4500	0.04	3.6	47
	Dec. 2	925	970	< 10	< 10			5.6
	14	1040	420	10	5200	0.002	0.8	10.4
	16	1050	20	< 10	20			T

APPENDIX VII

SUMMARY OF GREATER VANCOUVER REGIONAL DISTRICT
BACTERIOLOGICAL ANALYSES RESULTS, 1975-1977

APPENDIX VII

SUMMARY OF GREATER VANCOUVER REGIONAL DISTRICT
BACTERIOLOGICAL ANALYSES RESULTS, 1975-1977

	No. of Samples	Median	90 percentile
<hr/>			
Composite Results: GVRD Stations 22-25 Approximates EPS Station 63 (<u>Median</u> : 17; <u>90 pct</u> : 100.3)			
Feb. - Sept., 1975	94	55	430
Feb. - May, Sept., 1975 (non-summer)	52	40	430
June-Aug., 1975 (summer)	42	90	430
Apr. - Aug., 1976	47	40	2970
May - July, 1977 (pre-hookup)	47	40	233
Aug. - Sept., 1977 (post-hookup)	38	40	494
May - Sept., 1977	84	40	350

GVRD Station 26 Approximates EPS Station 62
(Median: 13; 90 pct: 535.3)

Feb. - Sept., 1975	24	90	230
Feb. - May, Sept., 1975 (non-summer)	13	90	224
June - Aug., 1975 (summer)	11	70	230
Apr. - June, 1976	9	70	3237
May - July, 1977 (pre-hookup)	11	40	216
Aug. - Sept., 1977 (post-hookup)	10	90	230
May - Sept., 1977	21	40	230

APPENDIX VII SUMMARY OF GREATER VANCOUVER REGIONAL DISTRICT
BACTERIOLOGICAL ANALYSES RESULTS, 1975-1977 (Cont'd)

	No. of Samples	Median	90 percentile
GVRD Station 27 Approximates EPS Station 54 (<u>Median</u> : 17; <u>90 pct</u> : 211)			
Feb. - Sept., 1975	23	140	930
Feb. - May, Sept., 1975 (non-summer)	13	90	930
June - Aug., 1975 (summer)	10	220	930
Apr. - June, 1976	9	40	1767
Sept., 1977	2	485	752
GVRD Station 3A Approximates EPS Station 18 (<u>Median</u> : 59.5; <u>90 pct</u> : 115.4)			
June - Aug., 1976	11	43	438
Aug., 1977	11	43	460
GVRD Station 28 Approximates EPS Station 45 and 52 (Composite <u>Median</u> : 11; <u>90 pct</u> : 164)			
Feb. - Sept., 1975	24	55	430
Feb. - May, Sept., 1975 (non-summer)	13	70	430
June - Aug., 1975 (summer)	11	40	396
Apr. - June, 1976	9	40	174
Sept., 1977 - Limited statistical reliability	2	765	1206

APPENDIX VII SUMMARY OF GREATER VANCOUVER REGIONAL DISTRICT
BACTERIOLOGICAL ANALYSES RESULTS, 1975-1977 (Cont'd)

	No. of		
	Samples	Median	90 percentile

GVRD Station 29 Approximates EPS Station 37
(Median: 31.5; 90 pct: 115.4)

Feb. - Sept., 1975	23	90	370
Feb. - May, Sept., 1975 (non-summer)	13	90	230
June - Aug., 1975 (summer)	10	120	430
Apr. - June, 1976	10	40	817
Sept., 1977 - Limited statistical reliability	2	485	752

GVRD Station 30 Approximates EPS Station 28
(Median: 33; 90 pct: 94.3)

Feb. - Sept., 1975	24	55	326
Feb. - May, Sept., 1975	13	90	370
June - Aug., 1975	11	40	216
Apr. - June, 1976	9	40	817
Sept., 1977 - Limited statistical reliability	2	90	126

APPENDIX VII

SUMMARY OF GREATER VANCOUVER REGIONAL DISTRICT
BACTERIOLOGICAL ANALYSES RESULTS, 1975-1977 (Cont'd)

	No. of Samples	Median	90 percentile
GVRD Station 10A and 11A Approximates EPS Stations 77 and 78 (<u>Median</u> : 190; <u>90 pct</u> : 1464)			
June - Aug., 1976	16	58	328
June - Aug., 1977	24	68	1100
June, July, 1977 (pre-hookup)	16	43	716
Aug., 1977 (post-hookup)	8	166.5	1100

GVRD Station 8 (2A) Approximates EPS Station 3 (<u>Median</u> : 170; <u>90 pct</u> : 284)			
Feb. - Sept., 1975	24	40	198
Feb. - May, Sept., 1975 (non-summer)	13	40	230
June - Aug., 1975 (summer)	11	40	90
Apr. - Aug., 1976	20	30	240
Apr. - May, 1976 (non-summer)	5	90	160
June - Aug, 1976 (summer)	15	15	350
May - Sept., 1977	24	<30	80
June - Aug., 1977 (summer)	15	<30	120
May - Sept., 1977 (non-summer)	9	<30	45

APPENDIX VII

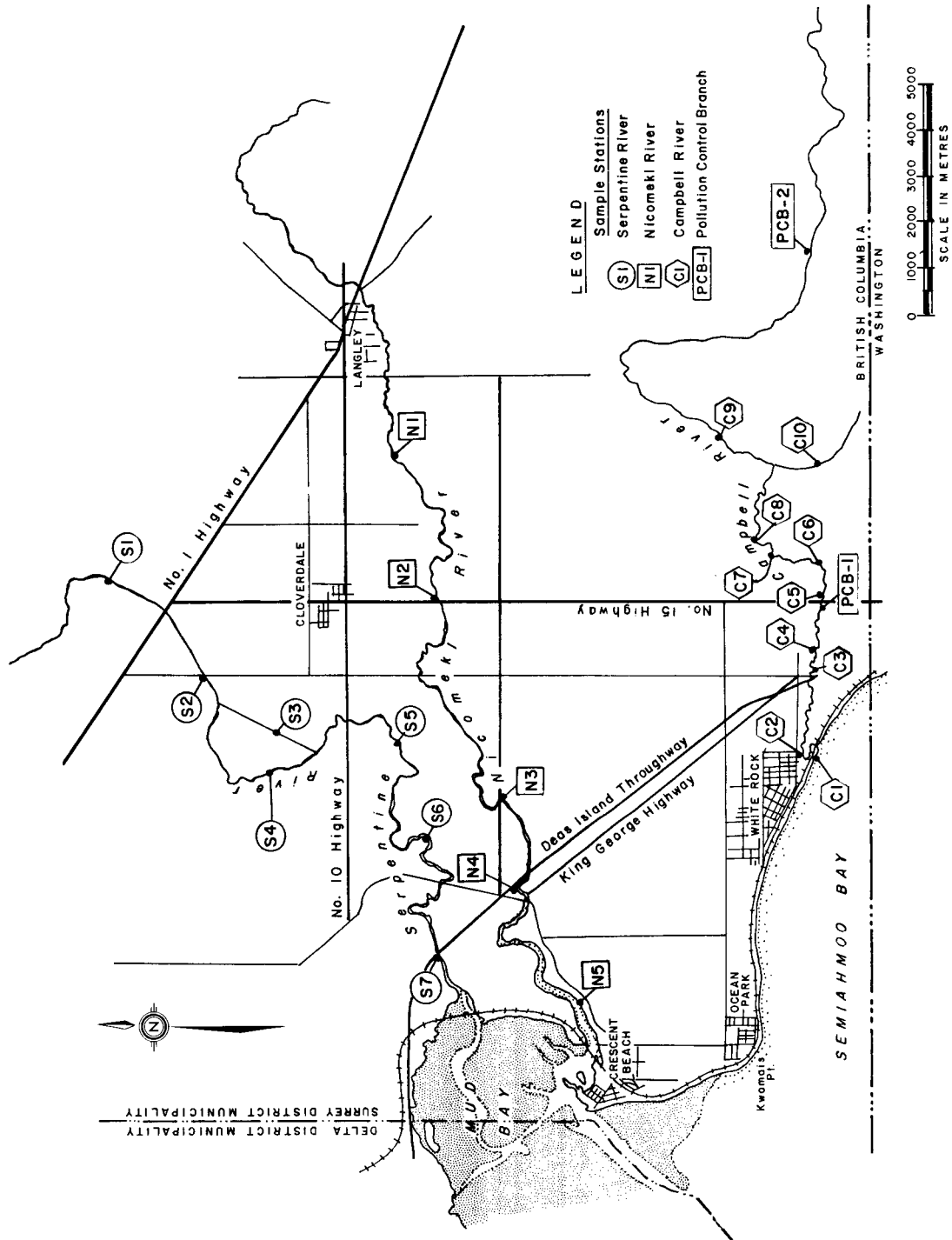
SUMMARY OF GREATER VANCOUVER REGIONAL DISTRICT
BACTERIOLOGICAL ANALYSES RESULTS, 1975-1977 (Cont'd)

	No. of Samples	Median	90 percentile
GVRD Station 9 Approximates EPS Station 4 (<u>Median</u> : 124.5; <u>90 pct</u> : 228)			
Feb. - Sept., 1975	23	30	206
Feb. - May, Sept., 1975 (non-summer)	13	30	132
June - Aug., 1975 (summer)	10	30	230
Apr. - June, 1976	9	90	212
May - Sept., 1977	22	30	80
June - Aug., 1977 (summer)	13	30	40
May, Sept., 1977 (non-summer)	9	30	158

APPENDIX VIII

SUMMARY OF FECAL COLIFORM MPN DATA
FOR SERPENTINE, NICOMEKL, AND CAMPBELL RIVERS, 1973-1977

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APPENDIX VIII BACTERIOLOGICAL SAMPLE STATIONS ON THE SERPENTINE, NICOMEKL AND CAMPBELL RIVERS - 1973-1977

APPENDIX VIII SUMMARY OF FECAL COLIFORM MPN DATA FOR SERPENTINE, NICOMEKL, AND CAMPBELL RIVERS, 1973-1977

Sampling Dates	Serpentine River		Nicomkel River		Campbell River	
	Station	Fecal MPN/100 ml	Station	Fecal MPN/100 ml	Station	Fecal MPN/100 ml
May-June, 1973	S7 (7)	66.7 (2)	N5 (11)	15.3	C1 (3)	600
June 7, 1973	S6 (1)	1600	N2 (1)	> 1600	C2 (2)	8000
Sept. 17-19, 1973					C3 (3)	410
Sept. 17-19, 1973					C4 (3)	250
Sept. 17-19, 1973					C5 (2)	160
Sept. 17-19, 1973					C6 (3)	3980
Sept. 17-19, 1973					C7 (3)	1900
Sept. 17-19, 1973					C8 (2)	1490
Sept. 17-19, 1973					C9 (3)	1000
Sept. 17-19, 1973					C10 (3)	350
Oct.-Nov., 1973					PCB1 (2)	140*
Oct.-Nov., 1973					PCB2 (2)	260*
Feb.-Nov., 1974					PCB1 (4)	2700*
Feb.-Nov., 1974					PCB2 (4)	280*
Feb.-Dec., 1975					PCB1 (4)	900*
Feb.-Dec., 1975					PCB2 (4)	140*
March 11, 1975	S1 (1)	540	N1 (1)	920		
March 11, 1975	S2 (1)	79	N2 (1)	1600		
March 11, 1975	S3 (1)	540	N3 (1)	240		
March 11, 1975	S4 (1)	350	N4 (1)	540		
March 11, 1975	S5 (1)	170				
March 11, 1975	S6 (1)	350				
Feb.-May, 1976					PCB1 (2)	790*
Feb.-May, 1976					PCB2 (2)	80*
March 22-31, 1976	S7 (5)	422	N5 (6)	305		
Feb.-Sept., 1977					PCB1 (3)	590*
Feb.-Sept., 1977					PCB2 (3)	140*

Numbers in brackets denote number of samples used to arrive at average.

*Reference (13)

APPENDIX IX

CHEMICAL ANALYSES RESULTS FOR FRESHWATER STATIONS

APPENDIX IX CHEMICAL ANALYSES RESULTS FOR FRESHWATER STATIONS
(Environmental Protection Service)

(Environmental Protection Service)																																					99										
3rd Avenue Pump Station											Oliver Street Pump Station											White Rock Storm Drain (Oxford and Buena Vista Street)											Campbell River at 172nd Street														
Parameter		November					December					November					December					November					December					November					December										
		Date	22	23	29	7	12	22	23	29	7	12	22	23	29	7	12	22	23	29	7	12	22	23	29	7	12	22	23	29	7	12															
Nutrients mg/l (except Hg µg/l)																																															
pH		7.0					6.9					4.7				7.6					0.23				7.6					7.4					6.9												
ortho P _{O4}					0.17		0.026					0.17				0.036					0.82				0.019					0.085				0.01													
total P _{O4}		0.34			0.25		0.18				0.15		0.27			0.48					0.82				0.16					0.14				0.07													
NO ₂ -N		0.11			0.018		0.012				0.016		0.020			0.084					0.042				0.017					0.017				0.00													
NO ₃ -N		0.54			1.4		0.84				1.4		3.5			3.3					2.1				2.6					1.7				2.4													
NH ₄ -N		0.44			0.25		0.29				0.83		0.47			1.83					0.31				0.22					0.093				0.10													
Metals																																															
Cu												0.02	<0.01		0.027					0.01	<0.01		<0.020					<0.01	<0.01		0.025																
Pb												<0.02	<0.02		0.15					<0.02	0.02		<0.10					<0.02	<0.02		<0.10																
Cd												<0.01	<0.01		<0.01					<0.01	<0.01		<0.01					<0.01	<0.01		<0.01																
As*												0.001	0.002		<0.020					0.002	0.010		<0.20					<0.001	<0.001		<0.20																
Hg												<0.2	<0.2		<0.2					<0.2	<0.2		<0.2					<0.2	<0.2		<0.2																

* detection limit variable due to different analytical methods

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APPENDIX IX

SUMMARY OF MINISTRY OF ENVIRONMENT, POLLUTION
CONTROL BRANCH (13) NUTRIENT ANALYSIS DATA,
1972-1977

Parameter*	Location		
	Campbell River at 176th Street	Campbell River at 216th Street	Semiahmoo Bay (1 mile S.W. of White Rock pier)
pH	7.4 (31)	6.8 (33)	8.0 (54)
ortho PO ₄ -P	0.038 (19)	0.018 (19)	0.041 (37)
total PO ₄ -P	0.074 (27)	0.061 (28)	0.065 (45)
NO ₂ -N	0.013 (22)	0.0066 (23)	0.0068 (40)
NO ₃ -N	1.02 (22)	0.46 (23)	0.19 (40)
NH ₃ -N	0.063 (19)	0.051 (19)	0.016 (41)

*All parameters in mg/l units except pH (pH units)

Numbers in brackets denote number of samples used to arrive at average