Department of Environment
Environmental Protection Service
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ENVIRONMENTAL EFFECTS OF A DEEP MARINE SEWAGE OUTFALL AT FIVE FINGER ISLAND, NANAIMO, BRITISH COLUMBIA, 1977-1980

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by

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ABSTRACT

The Environmental Protection Service monitored the impact of the Five Finger outfall on the receiving environment from 1977 to 1980. Of interest were (1) water quality characteristics of salinity, temperature, dissolved oxygen and nutrients; and (2) benthic characteristics of grain size, organic content, trace metal concentrations and benthic infauna and epifauna. Dives were made in the Pisces IV submersible to examine physical features of the outfall, immediate effects on substrate (deposition or scouring), turbidity changes and any obvious responses of organisms to the outfall.

Results from 1977 to 1980 indicated some minor effects of primary treated sewage effluent and a deep marine outfall on the receiving environment. Oceanographic parameters of salinity, temperature and dissolved oxygen displayed seasonal patterns characteristic of the Strait of Georgia. Dissolved nutrients were elevated around the outfall as were trace metals in prawns and shrimp. An increase in intermediate size sediment particles, sediment organic content and trace metal concentrations were noted. Benthic invertebrate communities surrounding the outfall had a different species composition than those recorded at distance. None of the benthic communities sampled were characteristic of a polluted situation.

RÉSUMÉ

De 1977 à 1980, le Service de la protection de l'environment a étudié les effects de l'exutoire de Five Finger sur le milieu récepteur. L'étude a porté sur les aspects suivants: 1) salinité et nutritifs; 2) granulométrie, teneur en matiéres organiques et en métaux à l'état de traces, endofaune et épifaune bethiques. On a procédé à des plongées à l'aide du Pisces IV pour examiner les caractéristiques physiques de l'xutoire, ses effets directs sur le substrat (sédimenation ou affouillement), les variations dans la turbiditéde l'eau et les réactions les plus caractéerisées des organismes vivants se trouvant dans la zone de l'exutoire.

Les résultats obtenus entre 1977 et 1980 montrent que l'effluent, aprés traitement primaire, l'exutoire étant situéen profoundeur, ont en quelques effects mineurs sure le milieu marin. On a noté les variations saisonniéres caractéristiques du détroit de Géorgie en ce qui concerne les paramétres océanographiques du salinité, de température et du concentration d'oxygéne dissous. Les éléments nutritifs étainent plus élevés tout autour de l'exutoire, de même que la teneur en métaux à l'état de traces trouvée dans les crevettes, grosses et petites. On a relevé également dans les sédiments une plus grande proportion de particules sédimentaires de taille intermédiare, une plus grande concentration de matiéres organiques et de métaux à l'état de traces. Les communautés d'invertébrés bethiques vivant autour de l'exutoire se composaient d'espéces différentes de celles trouvées loin de l'exutoire. Aucune des communautés bethiques étudiées n'était caractéristique d'un millieu pollué.

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CONCLUSIONS

Monitoring conducted around the Five Finger Island sewage outfall to 1980 has indicated that after 6 years of operation its combination of primary treatment and a deep marine discharge has resulted in only minor changes to the receiving environment.

Oceanographic parameters of salinity, temperature and dissolved oxygen were characteristic of prevailing conditions in the Strait of Georgia at the time of sampling. The lack of significantly reduced salinity and dissolved oxygen at depth around the diffuser pointed to the absence of a sewage plume buildup or entrapment. This was supported by visual observations of rapid effluent dispersion made during the Pisces IV dives. However, dissolved nutrients (nitrate and ammonia) in the area of the diffuser were elevated over pre- and early operational levels suggesting some nutrient enrichment, a consequence to be expected. Subsurface maxima of ammonia right at the diffuser in 1978 was a further indication of localized nutrient enrichment.

Considerable spatial-temporal variation was evident for surface sediment particle size and organic content. The general trend was to an increase in intermediate size particles and a gradual increase in organic content with time. Stations closer to the diffuser had similar increases to those farther removed. Surface sediment trace metals varied greatly from station to station. A general increase in concentration was noted from 1978 to 1980, especially for lead, which rose by a factor of about eight. Positive sediment fecal coliform results were obtained at only two stations, both of which had very low levels. Polychaetes dominated the benthic invertebrate community at all sample sites with high species diversity being recorded.

Species composition of communities close to the diffuser differed from those at stations farther removed. A selective effect was suggested, likely based on sediment grain size, organic content and station depth. Delineation of rough provinces appeared possible. None of the benthic communities sampled were characteristic of a polluted area. Further monitoring is required to accurately determine to what extent these changes in substrate parameters reflect an effluent effect and/or one of substrate heterogeneity.

Elevated levels of trace metals were evident in prawns and shrimps between 1977 and 1978. The 1980 survey indicated still higher levels of all but mercury, with copper and iron having the greatest increases.

Pisces dives showed minimal organic buildup and abundant benthic fauna around the diffuser. An increase in the deposition of non-biodegradable material was also evident.

1 INTRODUCTION

The Five Finger Island sewage treatment plant is located on the eastern shore of Vancouver Island at Hammond Bay (49°14'N; 123°57'W) approximately 7 km north of Nanaimo (Figure 1). Operation began in October 1974, with the addition of a diffuser to the system in August 1975. The outfall pipe extends 2030 m from shore into the Strait of Georgia in the vicinity of Five Finger Island. The diffuser, located at a depth of 70 m, is Y-shaped with each arm being ca. 91.5 m long. A total of 104 ports, each 7.6 cm in diameter, are arranged on the seaward side of the arms such that they discharge into the net current thus obtaining maximum dilution. The level of sewage treatment is primary with chlorination. Flows average 6.0 MIGPD with the peak flow rate approaching 17.5 MIGPD. The system is currently servicing a population of 50 000 with a designed capability of 200 000.

The area around the outfall is considered of economic importance. Firstly, proximity to Nanaimo and its large population results in heavy recreational use including fishing and boating. A significant commercial fishery also exists in the region based on salmon, shrimp and crab.

The Marine Programs group of the Environmental Protection Service (EPS) conducts ongoing surveys designed to monitor the effects of effluent discharges on the marine environment. The purpose of this study was to assess the adequacy of primary treatment combined with a deep ocean outfall off Hammond Bay. Objectives included (1) identifying buildup of heavy metals in sediments and biota; (2) measuring responses of benthic invertebrate communities to the discharge; and (3) evaluating changes in water quality.

Measurements of water quality (salinity, temperature, dissolved oxygen and nutrients); sediment characteristics (grain size, organic carbon, fecal coliform and trace metal content); and benthic faunal communities (species composition and trace metal content) have been made at each survey. This report presents data collected in August 1977, April 1978, March and November, 1980. Packman (1977) has described pre-operation and startup data for the above parameters.

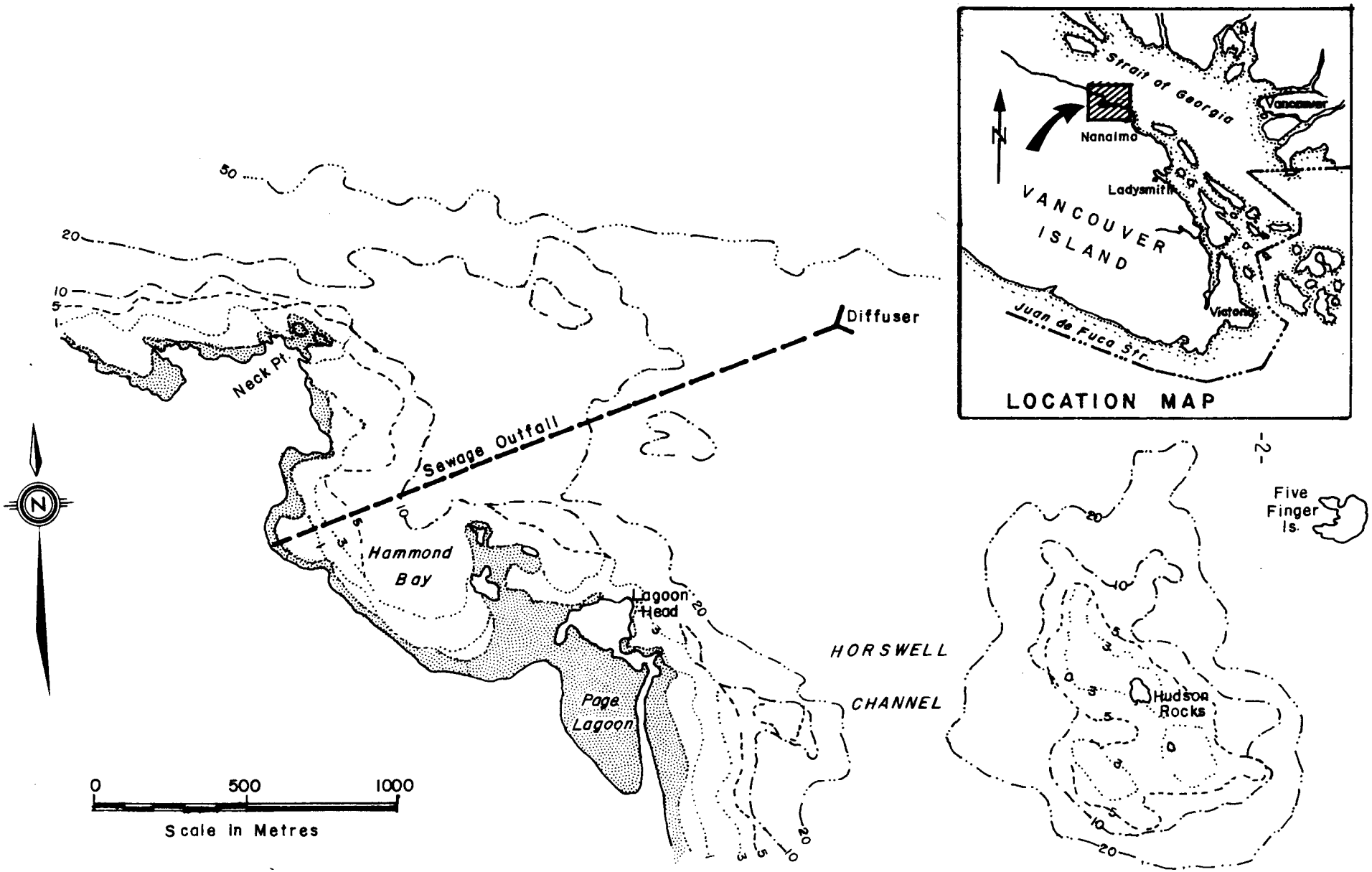

FIGURE 1 STUDY AREA

2 MATERIALS AND METHODS

Oceanographic and benthic sampling were conducted on August 25, 1977, April 28, 1978, and November 11, 1980, from the CSS Vector. Stations assumed to be located correctly in 1977 had to be repositioned by radar in 1978 to radiate out from the true site of the sewage diffuser. Station coordinates are given in Appendix I. Dives were made with the Pisces IV submersible from the Pandora II on April 12, 1978, and March 18, 1980, to conduct a physical examination of the diffuser and the benthic habitat in the immediate vicinity.

2.1 Physical Oceanographic Sampling

Oceanographic parameters were measured at Stations FF-5 to FF-9 (1977) and FF-14 to FF-18 (1978, 1980) (Figure 2). N.I.O. bottles with paired, protected, reversing thermometers were used to collect water samples from selected depths. Temperatures were read and recorded within 5 minutes and re-calculated to the temperature at depth using the equation outlined by Sverdup *et al*. (1946). Salinity was measured using a Guildline salinometer ("Autosal" Model 8400). The azide modification of the Winkler method (Swingle and Davidson, 1979) was used in determining dissolved oxygen concentration. Percent saturation of dissolved oxygen in seawater was calculated according to the equation outlined in Gameson and Robertson (1955).

Water samples collected for nutrient analyses were stored frozen (Strickland and Parsons, 1971). Nitrate, nitrite, ammonia, total phosphate (1978), and ortho-phosphate (1977, 1980) concentrations were determined on an Autoanalyzer at the EPS chemistry laboratory according to methods described by Swingle and Davidson (1979).

2.2 Sediment Sampling

GRABS: Sediment samples were obtained with a 0.17 m^2 Peterson grab sampler from stations FF-1 to 18 (Figure 2). Upon retrieval, the sample was placed in a tub and mixed until homogeneous. Sub-samples were removed for size distribution, organic carbon content and trace metal concentrations. These were stored frozen in "Whirlpak" bags until analyzed.

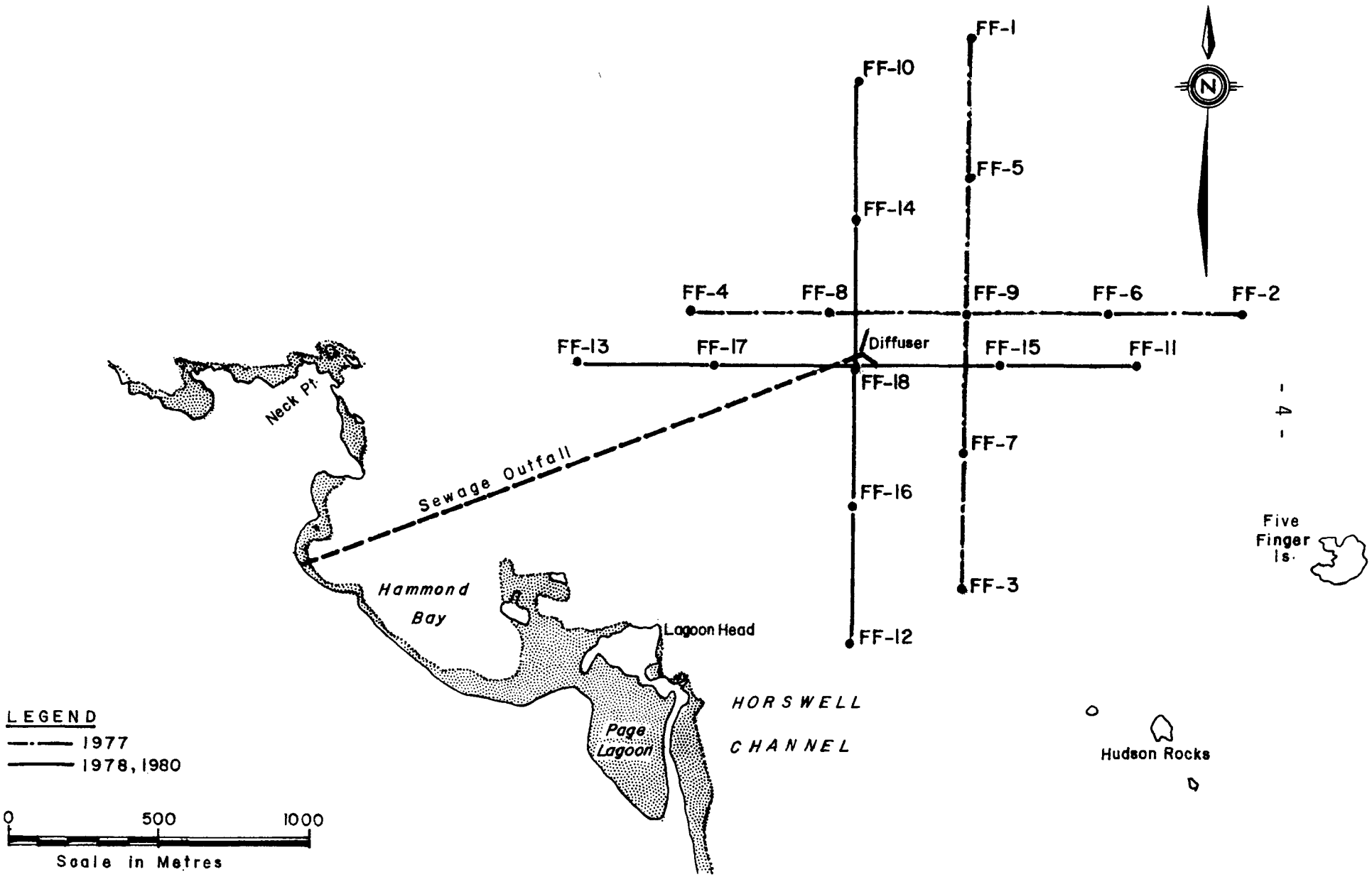

FIGURE 2 LOCATION OF OCEANOGRAPHIC AND BENTHIC STATIONS DURING 1977 and 1978

Sediment size distribution was determined by wet sieving through three sizes of screen (500 um, 250 um and 62.5 um) with the fraction passing through the final screen being obtained by calculation.

Samples for organic carbon content were thawed, dried at 103°C and ground with a mortar and pestle. In 1977 samples were then passed through a 500 um screen before analysis to remove large material. However, in 1978 and 1980, the entire ground sample was used for analysis. Organic carbon was measured by digesting with a chromic acid-sulphuric acid mixture and titrating with ferrous sulphate to obtain a chromic acid oxidation value.

Sediment samples to be analyzed for trace metal concentrations in 1977 were thawed and air dried under cover at room temperature, disaggregated with a ceramic mortar and pestle, and sieved through an 80-mesh nylon sieve (2.5 phi). Portions of the less than 80-mesh fractions were forwarded to the laboratory of Dr. W.K. Fletcher (Department of Geology, University of British Columbia). They were then digested in a 4:1 nitric-perchloric acid mixture, evaporated to dryness over an air bath, taken up in 1.5 ml HCl and analyzed for cobalt (Co), copper (Cu), iron (Fe), manganese (Mn), nickel (Ni), lead (Pb), and zinc (Zn) with a Perkin Elmer 303 Atomic Absorption Spectrophotometer. Background corrections were utilized in the determination of Co, Ni and Pb. Analyses in 1978 and 1980 were done by the EPS chemistry laboratory using similar methods (Swingle and Davidson, 1979).

Benthic invertebrates - infauna and epifauna - were removed from 6 litres of the original April 1978 sediments by sieving through a 500 um screen. The organisms were fixed in 10% buffered formalin and preserved in 70% isopropanol after three days. The invertebrates were later sorted, identified and enumerated.

CORES: In April 1978 sediment core samples were obtained using a "Benthos" gravity corer. Sediment was analyzed for trace metals as described above and for fecal coliform contamination at selected depths in the core. Bacteriological analyses were performed by the EPS Microbiological Laboratory as outlined by Kay (1976).

2.3 Tissue Analysis for Trace Metals

Trace metal accumulation in invertebrate tissue was monitored during the August 1977 and November 1980 surveys. Material was obtained by trawling and by setting prawn traps close to the diffusers (Figure 3). Tail meat from prawns (*Pandalus platyceros*), pink shrimp (*P. borealis*) and squat lobsters (*Munida quadrispina*) was removed for analysis. Rockfish (*Sebastes* sp.) were also analyzed in 1977 using muscle tissue from just below the dorsal fin.

2.4 Pisces IV Submersible Dives

Dives were made around the diffuser to visually assess water turbidity, the physical condition of the substrate and the composition and abundance of benthic communities. Approximate dive tracks are shown in Figure 4. Photographs were taken using a Bolex 16 mm movie camera with Tungsten Ecktachrome EP 7242, ASA 125 film and a Hasselblad 70 mm still camera with Kodak Aerocolor Negative 2445 film. Notes were made on a portable tape recorder for future transcription.

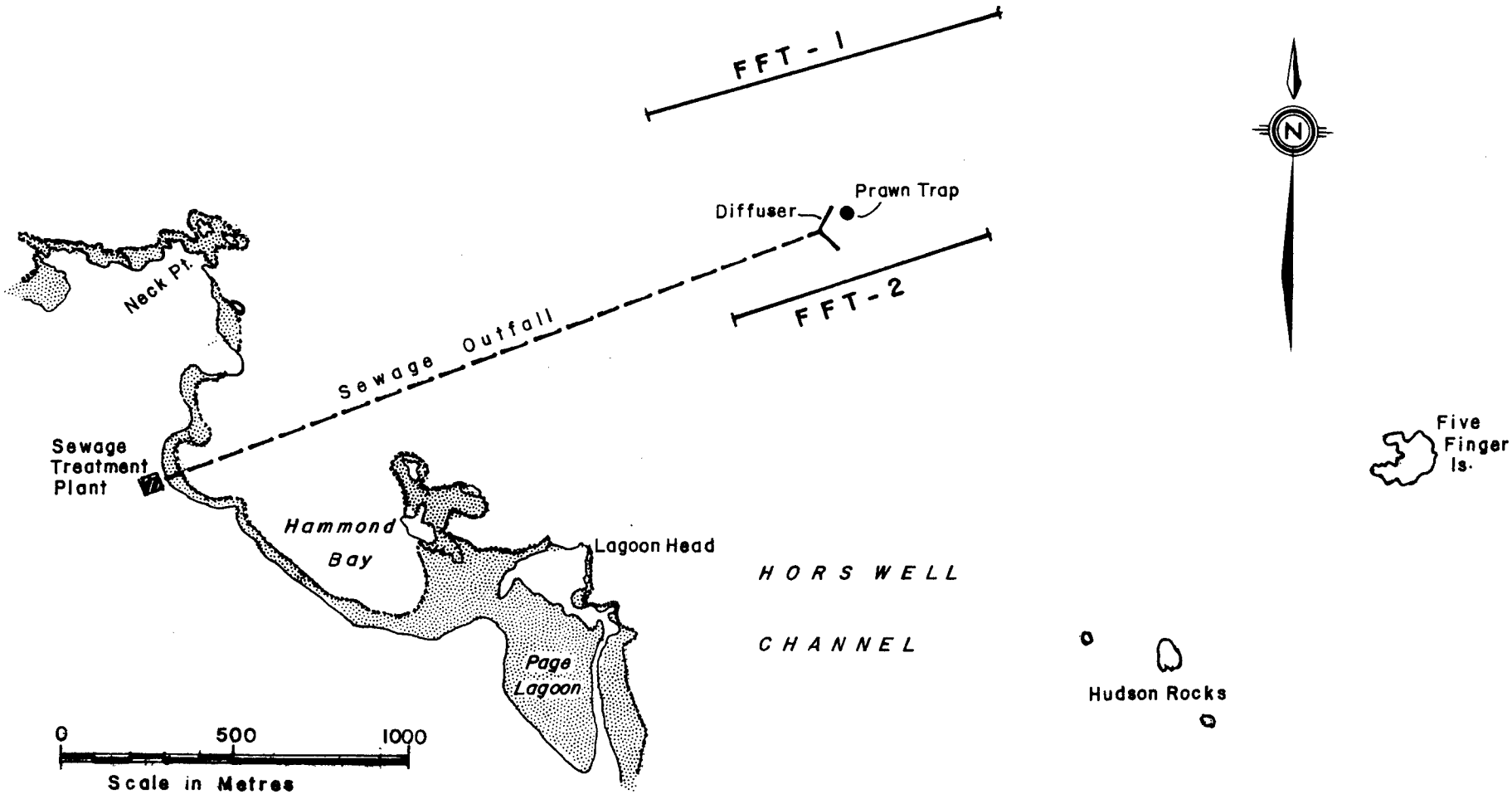

FIGURE 3 LOCATION OF PRAWN TRAPS AND TRAWL STATIONS SAMPLED IN 1978

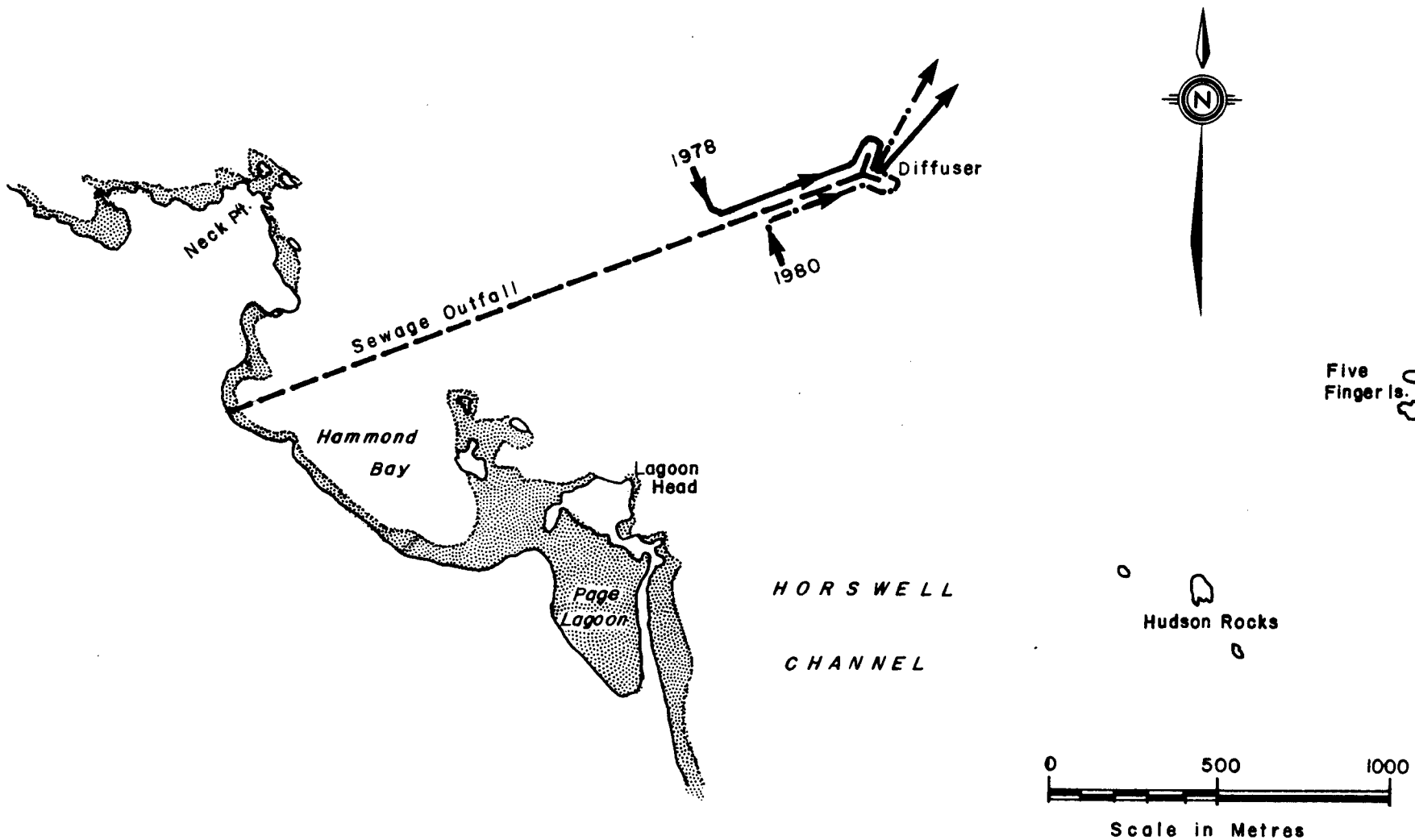

FIGURE 4 PISCES IV DIVE TRACKS - 1978 and 1980 (Approximate only)

3 RESULTS AND DISCUSSION

3.1 Physical Oceanography

Results of physical oceanographic sampling are tabulated in Appendix II and summarized graphically in Figures 5, 6 and 7.

Physical oceanographic parameters monitored around the diffuser gave results typical of those reported for the Strait of Georgia. The water column was somewhat stratified in August 1977, reflecting summer conditions (Figure 5). Mean temperatures ranged from 10.66°C at the surface to 9.13°C at the bottom, indicating warming by insolation. A seasonal thermocline was evident at about the 8-10 m depth. Salinity values extended from a mean of 28.86^{o}/oo at the surface to 29.93^{o}/oo at the bottom. Dissolved oxygen concentrations were reasonably high at all depths, averaging 6.8 mg/l (75.37% saturation) at the surface and 5.58 mg/l (59.83% saturation) at 65 m.

Salinity, temperature and oxygen values reported by EPS for August 1975 (Packman 1977) had similar patterns but much wider depth ranges (e.g., temperature 18.51°C - 8.26°C at bottom; salinity 21.0^{o}/oo - 31.5^{o}/oo at bottom). These yearly variations in summer conditions likely represent differences in freshwater runoff, wind generated currents (mixing) and surface warming due to insolation rather than an effluent effect.

In April 1978 the water column was not as strongly stratified as in August 1977 (Figure 6). This again is typical of spring conditions in the Strait of Georgia where solar heating has not yet warmed the surface waters. The mean temperature recorded in this sampling was 9.14°C at the surface and the minimum temperature was 8.09°C at ca. 60 m depth (bottom). The mean salinity was 28.18^{o}/oo at the surface and 29.34^{o}/oo at ca. 60 m depth. Dissolved oxygen values ranged from a mean of 9.27 mg/l (98.74% saturation) at the surface to 6.86 mg/l (73.22% saturation) at the bottom.

Oxygen was not depressed in the area of the diffuser, suggesting the lack of sewage plume buildup. The higher dissolved oxygen values in April, 1978 compared to August, 1977 represent a normal seasonal variation. Winter mixing conditions result in increased oxygen throughout the water column with the greatest increase near the surface (10 m). Pre-operation

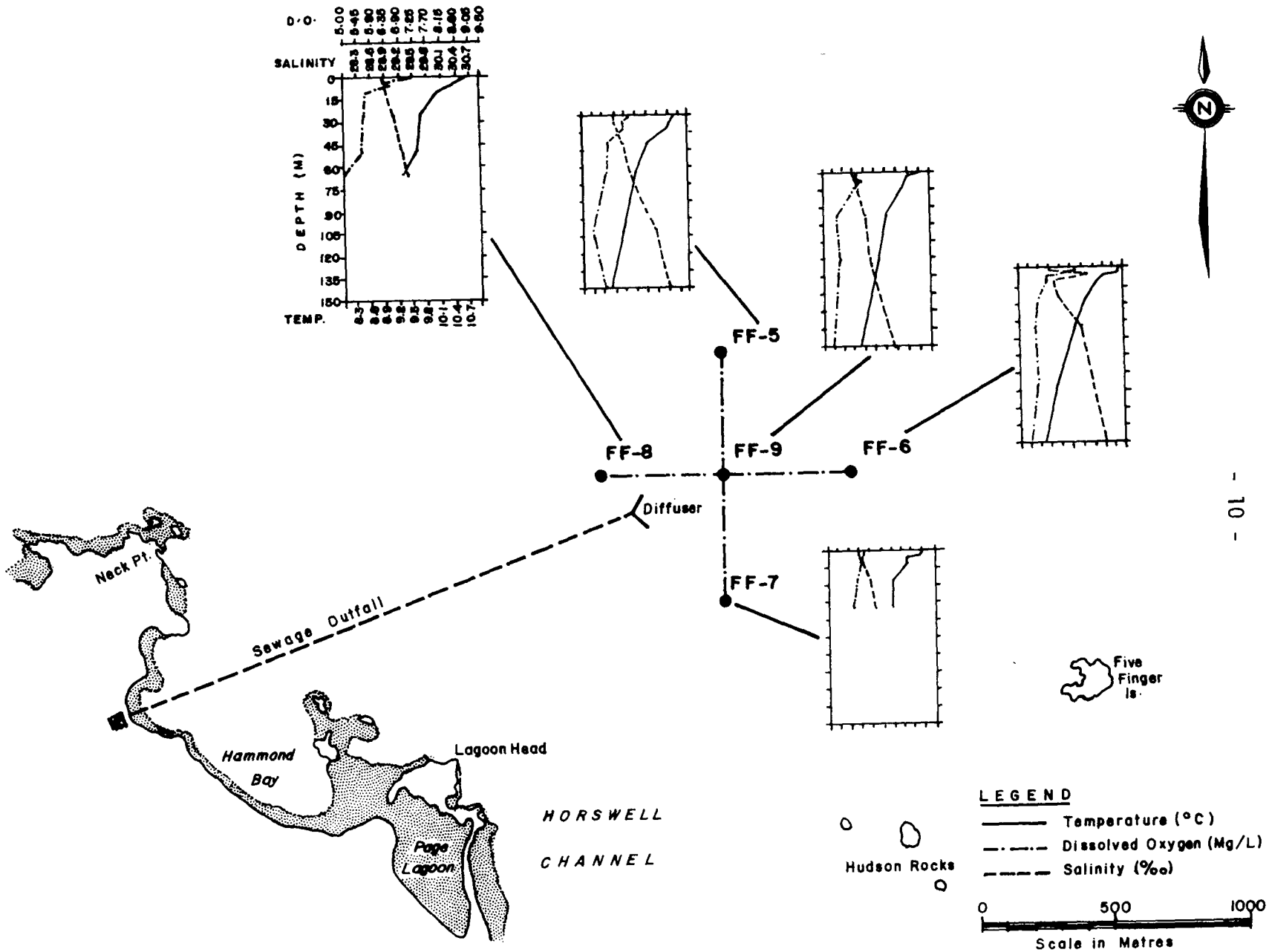

FIGURE 5 WATER QUALITY PROFILES - August 25, 1977

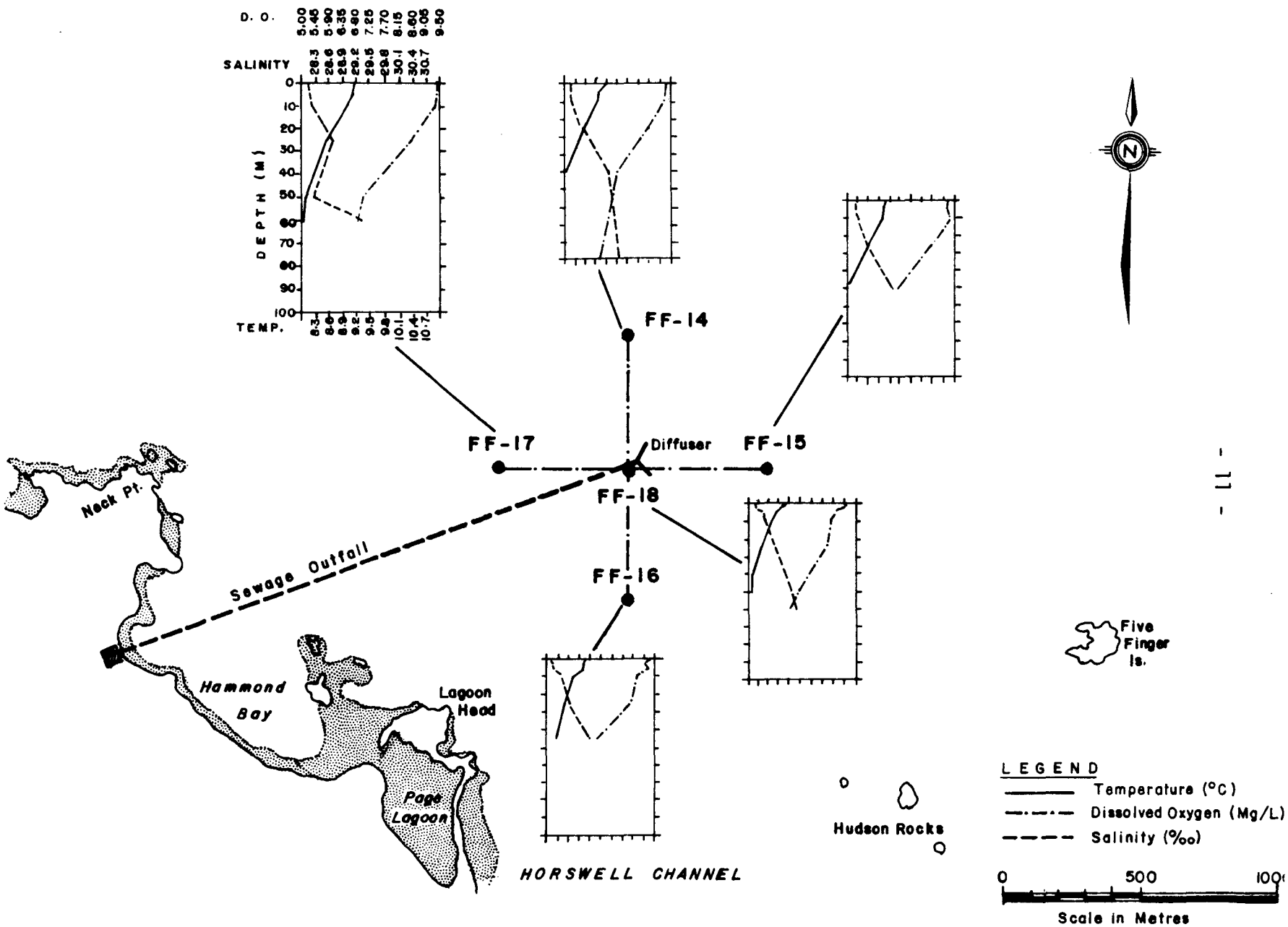

FIGURE 6 WATER QUALITY PROFILES - April 28, 1978

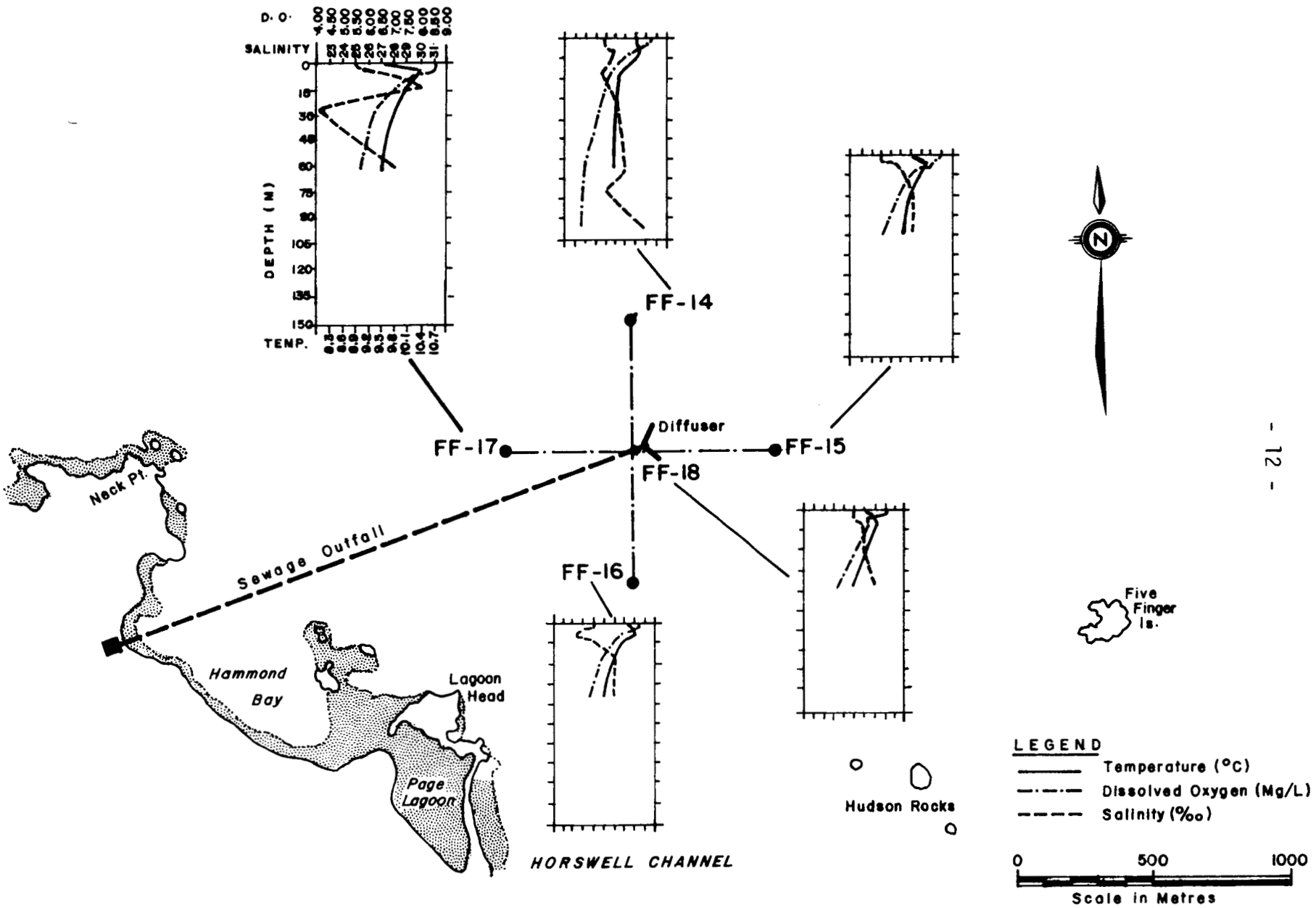

FIGURE 7 WATER QUALITY PROFILES - November 11, 1980

oceanographic data collected by Waters (1975) indicates this condition, with a decrease in winter values to April, a slight increase for May during the spring phytoplankton bloom, a decrease to July, and a second phytoplankton related rise in late August. Stockner and Cliff (1979) reported a similar pattern of dissolved oxygen with maxima corresponding to phytoplankton biomass maxima. In November 1980 salinity, dissolved oxygen and temperature data continued to show no significant effluent effect (Figure 7). Mean surface temperatures of 9.86°C increased to 10.28°C at ca. 5m and then decreased with depth to 9.54°C at ca. 60 m. (bottom). Winter conditions of reduced surface warming and increased freshwater input were evident. Salinities ranged from a mean of 26°/oo at the surface to 28.5^{o}/oo at the bottom. Dissolved oxygen values were intermediate to those recorded in 1977 and 1978 averaging 8.3 mg/l (88.4% saturation) at the surface and 5.65 mg/l (60.42%) at the bottom.

3.1.1 Nutrients. Dissolved nutrient data are presented in Appendix III. Profiles of ammonia around the diffuser in April 1978 are shown in Figure 8. Dissolved nutrient concentrations near the diffuser show an increase over those present in pre- and early operational stages. Nitrate values in August 1975, when the sewage diffuser went into operation, were reported to be less than 0.005 mg/l to 80 m (Packman, 1977). This represents a slight increase over pre-operational values (Brown et al., 1975). EPS monitoring data for August 1977 indicated a significant rise in nitrate concentration at all stations with values ranging from 0.285 mg/l at the surface to 0.405 mg/l at the bottom of station 9 (Appendix III). Nitrite and ammonia was generally doubled over 1974/75 values.

The April 1978 nutrient concentrations were very similar to those from August 1977 (Appendix III). Slightly decreased nitrate in the surface waters may be indicative of the onset of spring phytoplankton bloom conditions. Stockner and Cliff (1979) noted a like pattern for Vancouver Harbour. Elevated nutrient levels were still present in the November, 1980 survey (Appendix III).

A further indication of nutrient addition from the outfall can by seen with respect to depth profiles of ammonia concentration (Figure 8).

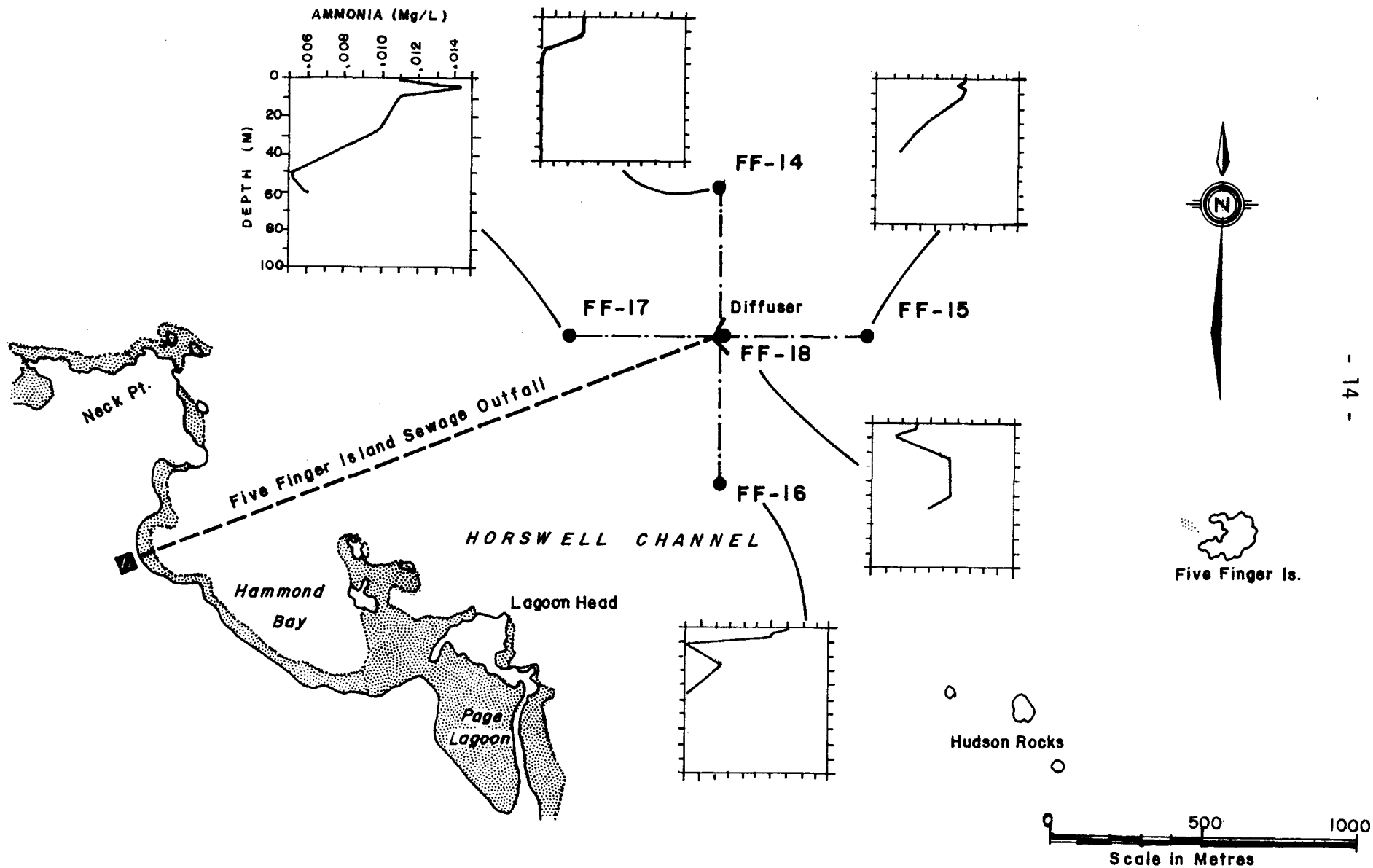

FIGURE 8 PROFILES OF DISSOLVED AMMONIA RECORDED AROUND THE DIFFUSER April 28, 1978.

Station FF-18, right at the diffuser, had increasing concentrations below 10 m during the April, 1978 sampling suggesting it to be within the immediate zone of influence. A rapid upward dispersion of the effluent was noted on the Pisces dive. This upwelling and mixing action may account for the irregular ammonia profiles and increased surface concentration noted at stations FF-15, 16 and 17 further from the diffuser. A similar situation is suggested in the November, 1980 survey with sub-surface ammonia peaks present.

3.2 Sediment Characteristics

3.2.1 Sediment Size Distribution. Examination of grab material at the time of sampling showed the substrate to be a mixture of fine mud, sand, gravel, stones, and sponge fragments (Appendix IV). Composition varied with station depth and location. No overall defined distribution pattern was evident. This lack of substrate homogeneity was verified during Pisces dives made around the outfall.

Percent composition of the various size fractions contained in sediments collected on all surveys displayed considerable spatial variation (Tables 1 and 2). For example, the < 62.5 um fraction ranged from 13.3% to 81.0% with an intermediate value recorded closest to the diffuser in 1977. A somewhat similar range was noted for the 250-62.5 um fraction. The 500-250 um fraction had the least variation and lowest values (0.8% to 7.5%). Station to station sediment heterogeneity was also evident in the 1978 and 1980 surveys.

Some temporal changes were suggested in sediment size distribution (Tables 1 and 2). A general increase in the 250-62.5 um fraction was noted between 1975 startup and 1977, with a concomitant decrease in the larger fractions. The required shift in station locations in 1978 does not permit direct comparison to earlier data. However, the trend through 1980 was to a greater percent composition of the intermediate sedimant size fractions. This may be a true shift in sediment size distribution or it may be a result of change positioning of stations. Further monitoring is required for confirmation.

Pisces dives from 1978 and 1980 did not show any localized accumulation of organic matter around the diffuser ports. However on the opposite

TABLE 1 PERCENT COMPOSITION OF SELECTED SIZE FRACTIONS IN SURFACE SEDIMENTS (AUGUST 1975 AND 1977)

STATION	Sediment Size (% Composition)							
	G500u m		500-250u m		250-62.5u m		L62.5um	
DATE:	1975[a]	1977	1975	1977	1975	1977	1975	1977
FF-1	0.2	0.4	0.1	2.6	0.8	16.0	98.9	81.0
FF-2	52.2	33.6	1.1	3.2	12.7	24.9	34.2	38.3
FF-3	0.7	3.3	0.5	0.8	85.7	82.6	13.1	13.3
FF-4	54.5	37.7	2.2	3.7	12.1	38.2	31.2	20.4
FF-5	0.1	37.8	0.2	3.5	6.2	17.0	93.5	41.7
FF-6	43.0	20.1	1.0	3.0	17.1	40.0	38.9	36.9
FF-7	34.3	42.1	8.4	7.5	36.3	25.7	21.0	24.7
FF-8	67.5	5.2	1.6	1.4	13.8	68.6	18.1	24.8
FF-9	0.7	8.4	0.2	3.3	20.3	41.8	78.8	46.5
Mean	28.1	20.9	1.7	3.2	22.8	39.4	47.5	36.4

[a]from Packman (1977)

G = greater than

L = less than

TABLE 2 PERCENT COMPOSITION OF SELECTED SIZE FRACTIONS IN SURFACE SEDIMENTS (APRIL 1978, NOVEMBER 11, 1980)

STATION	Sediment Size (% Composition)							
	G500u m		500-250u m		250-62.5u m		L62.5um	
	1978	1980	1978	1980	1978	1980	1978	1980
FF-10	2	6.5	2	18.5	50	32.6	46	42.4
FF-11	19	19.0	3	24.5	27	38.8	51	17.7
FF-12	1	56.5	1	13.4	89	19.6	9	10.5
FF-13	2	1.6	2	6.3	38	81.9	58	10.2
FF-14	1	41.8	1	18.6	13	25.1	85	14.5
FF-15	8	6.7	1	17.9	24	50.9	67	24.6
FF-16	2	0.6	1	0.6	35	88.7	62	10.1
FF-17	14	3.2	4	14.4	40	58.3	42	24.1
FF-18	13	31.7	5	9.3	45	50.7	37	8.3
Mean	6.9	18.7	2.2	13.7	40.1	49.5	50.7	18.0

G = greater than

L = less than

side of the pipe slight collections of organics were noted. The effluent itself was observed to be a grey suspension which rose straight up from the ports, diffusing rapidly with no apparent increase in turbidity. Deposition at distance should not be significant.

Thus, based on available information, the presence of the sewage outfall appears to have had minimal effect on sediment distribution patterns. Noted variations were primarily a function of natural substrate heterogeneity.

3.2.2 Organic Carbon Content. Sediment organic content varied considerably from station to station (Table 3), reflecting the patchy nature of the substrate. Mean values for 1975 and 1977 were similar at 1.66% organic and 1.53%, respectively. However, individual stations generally showed great variation, with some decreasing and some increasing in organic content. The shifting of station locations closer to the diffuser in 1978 revealed higher sediment organic content with a mean of 2.07% (Table 3). This level increased in November 1980 to 2.20%. The extent to which this increase represents an outfall effect and not substrate heterogeneity requires further monitoring for clarification.

Elevated organic carbon values may exist directly adjacent to the outfall discharge; however, it is virtually impossible to sample that close to a pipe using surface deployed equipment.

The average sediment organic content in the Strait of Georgia is reported to be approximately 1.08%. The overall average for the present study works out to 1.86%, which is not unreasonable in view of the predominance of low size fraction sediment components.

3.2.3 Trace Metals. Little change in the trace metal concentration of surface sediments has occurred in the area around the Five Finger outfall since discharge began (Table 4-Appendix IV). Mean concentrations for 1975 - 1977 actually show a decrease for all of the metals measured (e.g., Pb 10.63 ppm in 1975 to 5.4 in 1977). A recurrance of low trace metal values was recorded in 1978 even though stations had been repositioned closer to the diffuser. Converse to this trend was an increase in mean concentration of

TABLE 3 PERCENT ORGANIC CARBON CONTENT OF SURFACE SEDIMENTS

	Sediment Organic Carbon Content (%)				
STATION	Aug. 1975 (Packman, 1977)	Aug. 1977	STATION	Aug. 1978	Nov. 1980
FF-1	2.16	2.2	FF-10	2.7	3.7
FF-2	1.43	1.4	FF-11	1.6	2.8
FF-3	0.41	1.2	FF-12	0.8	4.3
FF-4	2.74	1.7	FF-13	2.0	0.7
FF-5	2.11	1.1	FF-14	2.6	1.4
FF-6	1.73	1.1	FF-15	2.6	2.7
FF-7	0.66	2.4	FF-16	2.8	0.9
FF-8	1.54	0.9	FF-17	1.9	2.2
FF-9	2.15	1.8	FF-18	1.6	1.8
Mean	1.66	1.53		2.07	2.20

TABLE 4 MEAN TRACE METAL CONCENTRATIONS IN SURFACE SEDIMENTS

STATIONS	Co (ppm)	Cu (ppm)	Fe (%)	Mn (ppm)	Ni (ppm)	Pb (ppm)	Zn (ppm)	Hg (ppm)
1975								
FF-1 to FF-9	12.09	30.53	2.28	393.46	31.20	10.63	66.29	0.31
1977								
FF-1 to FF-9	11.99	26.07	1.91	216.24	25.78	5.40	54.02	0.06
1978								
FF-10 to FF-18	11.63	25.68	1.52	264.81	22.89	6.64	58.26	0.22
1980								
FF-10 to FF18	-	32.04	2.31	315.94	27.35	48.67	63.45	-

trace metals between 1978 and 1980. Most noteworthy was lead (Pb), which rose from 6.64 ppm to 48.67 ppm (Table 4). Without further sampling, it is difficult to attribute this increase solely to the outfall since pre-operational trace metal levels were higher than those recorded in 1980 for most metals (Table 4).

Considerable variability existed between stations with FF-1 and 10, in the far northeast, being consistently higher for all trace metals (Appendix IV). The station-to-station variation may be due in part to differences in grain size (i.e., patchy nature of the substrate). Turekian (1965) notes an increase in the concentration of absorbing trace metals (Pb, Ni, Mn, Cu) in sediments of smaller particle size which is the case at some of the Five Finger stations.

Trace metals measured in sediment cores at 4 stations indicated some buildup in concentration with time for certain stations (Table 5). Stations FF-11, far from the diffuser, and FF-18, closest to the diffuser, had decreased surface concentrations compared to those at depth for most metals. Conversely, surface increases were evident for the other two stations monitored, both northeast of the diffuser. Highest concentrations were recorded for the most removed station (FF-10).

3.3 Benthic Community

3.3.1 Bacteriology. Benthic stations FF-16 and 12, located south of the outfall in 60 m of water, gave positive sediment fecal coliform results (50/100 g and 80/100 g, respectively) with the highest confirmed coliform counts (Kay, 1978). These results tend to support a general southern movement of subsurface water in April as suggested by the dissolved nutrient data from 1978.

Coliform bacteria had a patchy distribution in sediment surrounding the diffuser with levels at all stations being low. The low sediment counts are not unexpected due to initial low effluent levels (seldom greater than 200/100 ml) and chlorination (Kay, 1978). There does not appear to be a coliform contamination problem as of the 1978 sampling.

TABLE 5 TRACE METAL CONCENTRATIONS IN SEDIMENT CORES COLLECTED APRIL 18, 1978

STATION	Core Depth (cm)	Co (ppm)	Cu (ppm)	Fe (%)	Mn (ppm)	Ni (ppm)	Pb (ppm)	Zn (ppm)	Hg (ppm)
FF-10	0	20.251	39.105	2.462	457.132	38.399	10.883	89.188	0.295
	15	19.040	37.298	2.418	540.847	38.350	8.936	84.166	0.422
	138	17.902	34.636	2.431	420.223	40.196	5.855	81.901	0.391
FF-11	0	11.204	22.778	1.456	302.238	22.338	5.265	51.893	0.346
	12	13.936	51.166	2.300	328.522	26.871	2.039	60.087	0.286
FF-14	0	13.642	28.215	1.841	245.903	28.919	6.839	67.181	0.398
	15	13.978	28.597	1.909	248.913	31.983	4.599	63.978	0.360
	125	10.275	17.056	1.659	180.462	19.796	0.000	36.449	0.304
FF-18	0	8.184	15.781	1.243	153.51	16.667	2.000	36.459	0.266
	15	11.640	37.561	2.161	297.198	25.740	0.000	59.654	0.231
	125	9.207	28.329	1.821	308.052	21.322	1.475	48.470	L0.154

L = less than

TABLE 6 TOTAL SPECIES DIVERSITY AND NUMBER OF ORGANISMS RECORDED IN GRAB SAMPLES (APRIL 28, 1978)

STATION	Species Diversity	Total Number of of Organisms[a]
FF-10	5	5
FF-11	10	52
FF-12	30	111
FF-13	9	12
FF-14	8	15
FF-15	24	61
FF-16	28	76
FF-17	23	68
FF-18	29	220

[a] in 6 liters of sediment

3.3.2 Benthic Fauna. The benthic fauna collected from all grab samples was heavily dominated by polychaetes (Appendix VI). Fewer molluscs and crustaceans were present. Total species diversity ranged from 5 at station FF-10 to 29 at FF-18, nearest the diffuser (Table 6). Likewise, the lowest number of organisms was noted at FF-10 (5) and the highest at FF-18 (18).

The similarity between fauna collected at the various stations was assessed using the following method: the number of individuals in each species is expressed as a percentage of the total number of individuals in the sample. The percentage of the fauna common to a pair of samples is obtained by summing the individual percentages representing those species present in both samples. The resultant value is referred to as an "index of affinity". Indices for all possible pairs of stations are presented in Table 7. Stations FF-15, 16, 17 and 18, surrounding the diffuser, have the highest indices. A similarity in dominant taxa and percent composition was apparent for these stations (Table 8). Thus, the area around the diffuser encompassed by these four stations constitutes a rough province. Depth may be a factor, ranging from 58 m to 73 m (Appendix IV). With the exception of FF-12, all other stations were deeper than 100 m. Further surveys are required to separate the effects of sewage effluent and depth. However, as of the 1978 sampling, the taxa present and the high species diversity around the diffuser do not demonstrate a community structure typical of a highly polluted area.

3.4 Trace Metal Concentrations in Tissues

The influence of the sewage diffuser is evident in tissue trace metal values (Table 9-Appendix VII). Concentrations of all metals measured in prawns (*Pandalus platyceros*) trapped near the diffuser in 1978 were higher in comparison to those captured in 1977 bottom trawls near the outfall (track FF-2). Shrimp (*P. borealis*) caught in 1978 a little further from the outfall (track FF-1) also had high levels. Both prawns and shrimp taken from trawl track FF-2 in 1980 had greatly increased concentrations of all trace metals with the exception of mercury. Copper and iron increased by an order of magnitude (Table 9).

TABLE 7 INDICES OF AFFINITY FOR STATIONS SAMPLED ON APRIL 28, 1978, BASED UPON BENTHIC INVERTEBRATE POPULATIONS

	FF-10	FF-11	FF-12	FF-13	FF-14	FF-15	FF-16	FF-17	FF-18
FF-10									
FF-11	0.0								
FF-12	1.8	12.03							
FF-13	0.0	1.96	27.03						
FF-14	0.0	30.98	30.99	26.67					
FF-15	0.0	23.10	35.18	38.98	47.34				
FF-16	1.35	16.22	26.58	10.81	25.68	34.84			
FF-17	4.48	21.28	32.04	25.37	34.93	50.87	42.46		
FF-18	4.55	12.42	32.61	20.45	28.79	48.19	46.15	55.76	

TABLE 8 DOMINANT TAXA AND PERCENT COMPOSITION OF BENTHIC INVERTEBRATES (APRIL 28, 1978)

Station	Dominant Taxa	Percentage of Total Number of Individuals
FF-10	None	
FF-11	Sipuncula	48
FF-12	Ampharetidae	12
FF-13	None	
FF-14	None	
FF-15	Ampharetidae	16
	Syllidae	13
FF-16	Syllidae	22
	Hesionidae	13
FF-17	Syllidae	15
FF-18	Syllidae	21
	Spionidae	17
	Capitellidae	12
	Ampharetidae	11

TABLE 9 CONCENTRATION OF SELECTED TRACE METALS IN PRAWN AND SHRIMP TISSUE (based on dry weight)

	Cu (ppm)	Fe (ppm)	Zn (ppm)	Pb (ppm)	Cd (ppm)	Hg (ppm)
1) PRAWNS						
Pandalus platyceros						
Trawls - 1977	18.0[a]	12.0	49.0	L1.0	L0.5	0.52
- 1980	115.0	321.0	61.2	L3.86	1.01	0.043
PRAWN TRAP (near diffuser)						
- 1978	33.1	17.69	52.70	L4.26	L0.71	1.38
2) SHRIMP						
Pandalus borealis						
Trawls - 1977	27.0	21.0	54.0	L1.0	L0.5	0.26
- 1980	123.0	231.0	65.2	L3.89	1.02	0.101

[a]mean of small, medium and large size classes.

L = less than

3.5 Pisces IV Observations

Observations made during Pisces dives aided in interpreting water quality and sediment parameters and provided further information on macrofaunal use of habitat near the diffuser.

A detailed dive report from April 1978 is presented in Appendix VIII. On this dive there was no evidence of increased turbidity. Light from the surface extended to the bottom at the diffuser. Zooplankton were noted to increase greatly below 80 m (i.e., amphipods, copepods, euphausids and chaetognaths).

Similar observations relating to the water column were made during the 1980 dive. At this time, as in 1978, the bottom was shown to be very heterogeneous in the immediate area of the diffuser. Substrate varied between sand and gravel with minimal accumulations of organic matter (Plate 1). Farther from the diffuser the bottom was a mixture of detritus covered gravel and rock interspersed with sand and mud. Numerous species of fish and invertebrates were present around the discharge pipe. The numbers of fish, especially rat fish, ling cod, rockfish and pricklebacks, increased as the diffuser was approached. The Five Finger area had the greatest concentration of fish recorded thus far during EPS Pisces IV dives.

There were two major changes noted with regard to the substrate between 1978 and 1980. Firstly, the amount of non-biodegradable debris around the diffuser had increased considerably. An outlet at the centre of the diffuser arms appeared to be the point source. Secondly, scouring was evident around the outfall pipe with undercutting present in some areas (Plate 2). Fish and octopus were noted to occupy these spaces and may have contributed to their formation.

Still (70 mm) and motion (16 mm) films of both dives are on file with EPS.

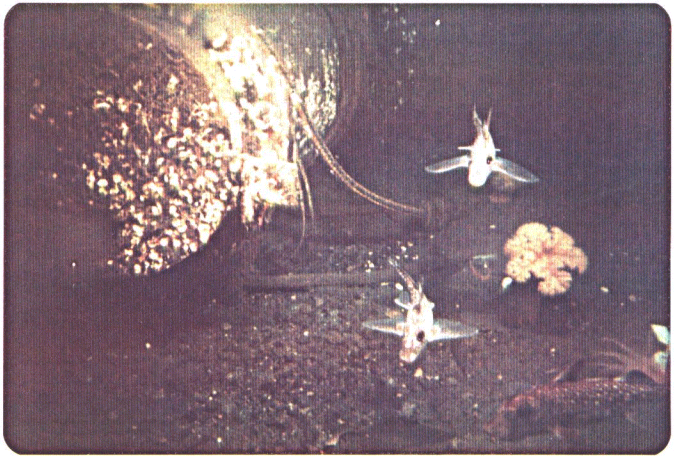

Plate 1 Ratfish (Hydrolagus colliei) and anemone around diffuser port. Rock and sand nature of substrate evident with little build up of organics.

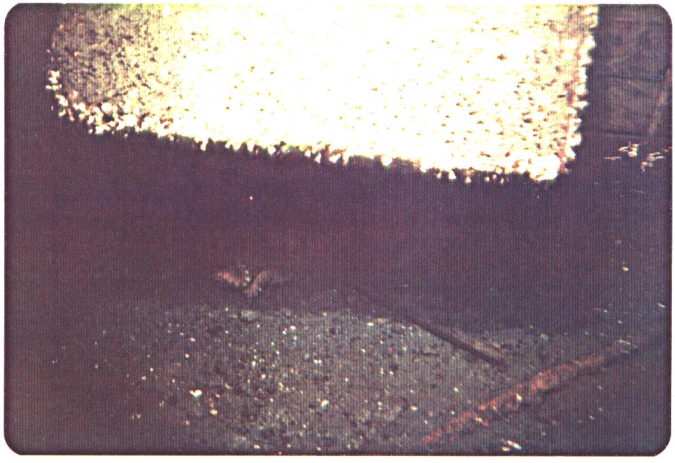

Plate 2 Outfall pipe with cement collar. An example of undercutting with an octopus (left) and a rockfish (Sebastes sp.) (right) occupying the depression.

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APPENDIX I

POSITION OF SAMPLING STATIONS

APPENDIX I POSITION OF SAMPLING STATIONS

Station No.		Latitude	Longitude
1977	1	49° 14.80'N	123° 56'W
	2	49° 14.32'N	123° 55.25'W
	3	49° 13.82'N	123° 56'W
	4	49° 14.32'N	123° 56.75'W
	5	49° 13.45'N	123° 56'W
	6	49° 14.32'N	123° 55.62'W
	7	49° 14.07'N	123° 56'W
	8	49° 14.32'N	123° 56.38'W
	9	49° 14.32'N	123° 56'W
1978	10	49° 14.74'N	123° 56.30'W
	11	49° 14.22'N	123° 55.52'W
	12	49° 13.75'N	123° 56.30'W
	13	49° 14.22'N	123° 57.08'W
	14	49° 14.52'N	123° 56.30'W
	15	49° 14.22'N	123° 55.90'W
	16	49° 13.95'N	123° 56.30'W
	17	49° 14.22'N	123° 56.70'W
	18	49° 14.22'N	123° 56.30'W

TRAWL TRACK No. 1		
Start	49° 14.40'N	123° 56.72'W
Stop	49° 14.58'N	123° 55.88'W
TRAWL TRACK No. 2		
Start	49° 14.10'N	123° 56.50'W
Stop	49° 14.22'N	123° 55.88'W

APPENDIX II

OCEANOGRAPHIC WATER QUALITY DATA

a) August 25, 1977
b) April 28, 1978
c) November 11, 1980

APPENDIX II OCEANOGRAPHIC WATER QUALITY DATA

a) August 25, 1977

Station	Depth (m)	Temperature (°C)	Salinity (°/oo)	Dissolved Oxygen (mg/l)	% Saturation
FF-5	0	10.59	28.87	6.6	73.03
	2	10.58	28.87	6.9	76.32
	5	10.49	28.90	6.7	73.97
	10	10.38	28.95	6.7	73.81
	25	9.80	29.16	6.1	66.41
	50	9.49	29.34	6.0	64.93
	100	9.11	30.08	5.4	58.21
	150	8.76	30.47	5.9	63.24
FF-6	0	10.87	28.83	7.1	79.04
	2	10.79	28.84	7.1	78.89
	5	10.43	29.92	6.2	68.84
	10	10.25	28.99	6.2	68.12
	25	9.90	29.12	5.8	63.27
	50	9.59	29.77	5.7	62.00
	100	9.07	30.09	5.8	62.46
	150	8.73	30.46	5.5	-
FF-7	0	10.58	28.86	6.5	71.89
	2	10.56	28.86	6.5	71.86
	5	10.23	28.95	6.3	69.17
	10	10.20	28.95	6.3	69.12
	25	9.82	29.15	6.2	67.53
	50	9.77	29.32	6.0	65.35
FF-8	0	10.73	28.88	7.3	81.03
	2	10.56	28.91	6.4	70.79
	5	10.39	28.96	6.6	72.74
	10	10.11	29.02	5.8	63.54
	25	9.71	29.13	5.7	61.92
	50	9.56	29.31	5.6	60.68
	65	9.32	29.40	5.1	55.00
FF-9	0	10.55	28.86	6.5	71.85
	2	10.38	28.93	6.4	70.50
	5	10.33	28.94	6.6	72.63
	10	10.22	28.98	6.3	69.17
	25	9.77	29.18	5.6	60.93
	50	9.54	29.32	5.7	61.76
	100	9.06	30.01	5.4	58.12

APPENDIX II OCEANOGRAPHIC WATER QUALITY DATA (continued)

b) April 28, 1978

Station	Depth (m)	Temperature (°C)	Salinity (°/oo)	Dissolved Oxygen (mg/l)	% Saturation
FF-14	0	9.30	28.21	9.30	99.46
	2	9.18	28.20	9.30	99.17
	5	8.98	28.20	9.25	98.17
	10	8.96	28.21	9.20	97.59
	25	8.60	28.50	8.55	90.11
	50	8.00	29.23	7.20	75.16
	100	8.09	29.54	6.50	68.14
FF-15	0	9.07	28.20	9.20	97.85
	2	9.06	28.20	9.20	97.83
	5	9.02	28.22	9.20	97.74
	10	8.97	28.33	9.30	98.77
	25	8.58	28.58	8.55	90.10
	50	8.01	29.30	7.10	74.17
FF-16	0	9.10	28.17	9.30	98.96
	2	9.06	28.20	9.15	97.29
	5	9.04	28.22	9.25	98.32
	10	8.71	28.42	8.80	92.94
	25	8.54	28.66	8.50	89.54
	45	8.26	29.22	7.10	74.58
FF-17	0	9.11	28.10	9.45	100.53
	2	9.11	28.12	9.45	100.55
	5	9.08	28.15	9.45	100.49
	10	8.96	28.19	9.35	99.17
	25	8.55	28.66	8.55	90.99
	50	8.06	28.22	7.00	72.69
	60	8.04	29.32	6.80	71.10
FF-18	0	9.11	28.22	9.10	96.87
	2	8.96	28.23	9.15	97.09
	5	8.80	28.42	8.70	92.09
	10	8.65	28.47	8.50	89.67
	25	8.41	28.79	8.30	87.24
	50	8.04	29.23	7.10	74.19
	60	8.04	29.32	6.80	71.10

APPENDIX II OCEANOGRAPHIC WATER QUALITY DATA (continued)

c) November 11, 1980

Station	Depth (m)	Temperature (°C)	Salinity (°/oo)	Dissolved Oxygen (mg/l)	% Saturation
FF-14	0	10.12	26	8.2	88.09
	2	10.09	26	8.2	88.01
	5	10.20	26	8.2	88.25
	10	10.23	27	7.5	81.29
	25	9.68	26	6.3	66.99
	50	9.58	27	5.8	61.93
	100	9.46	28	4.8	51.44
	140	-	30	4.7	-
	B=157				
FF-15	0	9.83	26	8.6	91.77
	2	10.15	25	8.1	86.50
	5	10.32	26	7.6	82.01
	10	10.09	27	7.0	75.62
	25	9.74	28	6.5	70.12
	60	9.54	28	5.6	60.14
	B=67				
FF-16	0	10.28	26	8.2	88.40
	2	10.34	26	8.2	88.52
	5	10.40	24	7.8	83.24
	10	10.07	26	7.1	76.18
	25	9.88	28	6.5	70.35
	50	9.58	28	5.7	61.27
	B=60				
FF-17	0	9.58	25	8.6	90.63
	2	10.19	25	8.2	87.65
	5	10.41	28	8.0	87.65
	10	10.12	30	7.1	78.30
	25	9.87	22	6.3	65.58
	60	9.53	28	5.7	61.19
	B=68				
FF-18	0	9.93	26	8.2	83.39
	2	9.98	27	8.0	88.87
	5	10.09	27	7.0	89.19
	10	10.17	28	7.1	80.62
	25	NS	28	NS*	-
	60	9.47	29	5.6	57.58
	B=68				

*NS = not sampled

APPENDIX III

DISSOLVED NUTRIENT DATA (mg/l)

a) August 25, 1977
b) April 28, 1978
c) November 11, 1980

APPENDIX III DISSOLVED NUTRIENT DATA (mg/l)

a) August 25, 1977

Station	Depth (m)	Ortho-Phosphate	Nitrate	Nitrite	Ammonia
FF-5	0	0.054	0.300	L0.005	L0.010
	2	0.057	0.320	L0.005	L0.010
	5	0.059	0.310	L0.005	L0.010
	10	0.062	0.340	L0.005	L0.010
	25	0.066	0.385	L0.005	L0.010
	50	0.072	0.405	L0.005	L0.010
	100	0.074	0.335	L0.005	L0.010
	150	0.075	0.370	L0.005	L0.010
FF-6	0	0.058	0.244	0.006	L0.010
	2	0.057	0.267	0.006	L0.010
	5	0.069	0.318	0.005	L0.010
	10	0.060	0.345	L0.005	L0.010
	25	0.065	0.360	L0.005	L0.010
	50	0.065	0.380	L0.005	L0.010
	100	0.067	0.395	L0.005	L0.010
	150	0.068	0.390	L0.005	L0.010
FF-7	0	0.064	0.300	0.005	L0.010
	2	0.065	0.300	0.006	L0.010
	5	0.068	0.325	0.005	L0.010
	10	0.065	0.325	0.006	L0.010
	25	0.065	0.360	L0.005	L0.010
	50	0.068	0.385	L0.005	L0.010
FF-8	0	0.058	0.390	L0.005	L0.010
	2	0.060	0.405	L0.005	L0.010
	5	0.065	0.300	L0.005	L0.010
	10	0.062	0.365	L0.005	L0.010
	25	0.039	0.340	L0.005	L0.010
	50	0.061	0.380	L0.005	L0.010
	65	0.076	0.395	L0.005	L0.010
FF-9	0	0.057	0.285	0.005	L0.010
	2	0.060	0.315	0.005	L0.010
	5	0.061	0.320	0.005	L0.010
	10	0.062	0.335	L0.005	L0.010
	25	0.057	0.370	L0.005	L0.010
	50	0.049	0.390	L0.005	L0.010
	100	0.069	0.405	L0.005	L0.010

L = less than

APPENDIX III DISSOLVED NUTRIENT DATA (mg/l)

b) April 28, 1978

Station	Depth (m)	Nitrate	Nitrite	Ammonia	Total Phosphate
FF-14	0	0.284	L0.005	0.0080	0.0665
	2	0.289	L0.005	0.0080	0.0632
	5	0.280	L0.005	0.0080	0.0642
	10	0.294	L0.005	0.0080	0.0678
	25	0.340	L0.005	L0.0050	0.0709
	50	0.375	L0.005	L0.0050	0.0785
	100	0.385	L0.005	L0.0050	0.0775
FF-15	0	0.282	L0.005	0.0110	0.0650
	2	0.289	L0.005	0.0105	0.0650
	5	0.284	L0.005	0.0110	0.0665
	10	0.288	L0.005	0.0110	0.0655
	25	0.320	L0.005	0.0090	0.0715
	50	0.365	L0.005	L0.0065	0.0770
FF-16	0	0.270	L0.005	0.0120	0.0631
	2	0.280	L0.005	0.0110	0.0630
	5	0.280	L0.005	0.0110	0.0635
	10	0.324	L0.005	0.0050	0.0688
	25	0.315	L0.005	0.0075	0.0735
	45	0.380	L0.005	0.0050	0.0834
FF-17	0	0.261	L0.005	0.0105	0.0655
	2	0.267	L0.005	0.0120	0.0655
	5	0.271	L0.005	0.0145	0.0657
	10	0.271	L0.005	0.0110	0.0661
	25	0.315	L0.005	0.0100	0.0786
	50	0.375	L0.005	0.0050	0.0822
	60	0.390	L0.005	0.0060	0.0865
FF-18	0	0.281	L0.005	0.0080	0.0688
	2	0.284	L0.005	0.0080	0.0717
	5	0.331	L0.005	0.0075	0.0808
	10	0.341	L0.005	0.0065	0.0748
	25	0.335	L0.005	0.0105	0.0783
	50	0.380	L0.005	0.0105	0.0833
	60	0.375	L0.005	0.0090	0.0845

L = less than

APPENDIX III DISSOLVED NUTRIENT DATA (mg/l) (continued)

c) November 11, 1980

Station	Depth (m)	Total Phosphate	Ortho-Phosphate	Nitrate	Nitrite	Ammonia	Silica
FF-14	0	0.0533	0.0540	0.215	0.0070	0.0091	0.64
	2	0.0511	0.0537	0.210	0.0058	0.0278	0.63
	5	0.0557	0.0530	0.190	0.0060	0.0060	0.51
	10	0.0539	0.0571	0.225	0.0062	0.0056	0.64
	25	0.0668	0.0674	0.292	L0.0050	0.0243	0.85
	50	0.0673	0.0692	0.286	L0.0050	0.0263	0.77
	100	NS	NS	NS	NS	NS	NS
	140	0.0689	0.0736	0.312	L0.0050	0.0186	0.82
FF-15	0	0.0523	0.0540	0.236	0.0067	0.0101	0.83
	2	0.0507	0.0509	0.219	0.0052	0.0135	0.68
	5	0.0594	0.0614	0.258	0.0068	0.0104	0.79
	10	0.0684	0.0672	0.299	0.0073	0.0063	0.85
	25	0.0759	0.0777	0.390	L0.0050	L0.0050	1.11
	60	0.0693	0.0706	0.285	L0.0050	0.0066	0.73
FF-16	0	0.0491	0.0487	0.198	0.0061	0.0107	0.52
	2	0.0506	0.0501	0.192	0.0065	0.0089	0.56
	5	0.0555	0.0545	0.219	0.0085	0.0223	0.56
	10	0.0632	0.0645	0.286	0.0078	0.0155	0.85
	25	0.0610	0.0621	0.253	L0.0050	0.0072	0.66
	50	0.0693	0.0697	0.305	L0.0050	0.0184	0.86
FF-17	0	0.0546	0.0537	0.225	0.0074	0.0099	0.62
	2	0.0514	0.0528	0.211	0.0062	0.0143	0.56
	5	0.0539	0.0532	0.213	0.0077	0.0181	0.58
	10	0.0609	0.0627	0.265	0.0068	L0.0050	0.81
	25	0.0597	0.0607	0.268	L0.0050	L0.0050	0.74
	60	0.0714	0.0733	0.315	L0.0050	L0.0050	0.87
FF-18	0	0.0523	0.0541	0.217	0.0067	0.0110	0.73
	2	0.0517	0.0554	0.227	0.0055	0.0159	0.72
	5	0.0553	0.0545	0.234	0.0055	0.0164	0.69
	10	0.0648	0.0667	0.291	0.0074	0.0239	0.85
	25	NS	NS	NS	NS	NS	NS
	60	0.0664	0.0692	0.282	L0.0050	L0.0050	0.87

NS = not sampled
L = less than

APPENDIX IV

VISUAL CHARACTERISTICS OF SEDIMENT GRAB SAMPLES

a) August 25, 1977
b) April 28, 1978
c) November 11, 1980

APPENDIX IV VISUAL CHARACTERISTICS OF SEDIMENT GRAB SAMPLES

a) August 25, 1977

Station	Depth (m)	Sediment Characteristics
FF-1	240	- fine grey clay
FF-2	179	- soft brown mud with stones
FF-3	60	- brown mud, fine sand - many glass sponge fragments
FF-4	57	- brown mud with some stones - glass sponge fragments
FF-5	190	- consolidated sediment with some gravel
FF-6	144	- soft brown mud with some stones
FF-7	60	- brown mud mixed with small stones (up to 1 in.)
FF-8	91	- soft brown mud with some stones
FF-9	100	- brown mud - several glass sponges

APPENDIX IV VISUAL CHARACTERISTICS OF SEDIMENT GRAB SAMPLES

b) April 28, 1978

Station	Depth (m)	Sediment Characteristics
FF-10	235	- soft fine mud, no wood debris
FF-11	150	- soft, fine, grey-brown mud - some sand and rocks (less than 2 in. diameter)
FF-12	55	- soft brown-grey mud - many glass sponge fragments
FF-13	118	- brown-grey mud and a few stones - large glass sponge fragments
FF-14	168	- fine grey mud
FF-15	65	- fine grey-brown mud with glass sponge fragments and a few small stones
FF-16	58	- grey-brown mud - many glass sponge fragments
FF-17	58	- soft brown mud - many glass sponge fragments and stones up to 3 in. diameter
FF-18	73	- brown mud - many glass sponge fragments

APPENDIX IV VISUAL CHARACTERISTICS OF SEDIMENT GRAB SAMPLES

c) November 11, 1980

Station	Depth (m)	Sediment Characteristics
FF-10	240	- soft sediment, no debris
FF-11	155	- soft grey sediment, some sand and small rocks
FF-12	60	- soft grey mud, glass sponges - whole and broken
FF-13	114	- fine grey mud, glass sponge fragments
FF-14	157	- fine grey mud - glass sponges and fragments
FF-15	67	- fine grey mud - glass sponge fragments
FF-16	60	- grey mud - high concentrations of glass sponges (50% of sample)
FF-17	68	- grey mud - glass sponges and fragments
FF-18	68	- brown mud - glass sponges plus small rocks

APPENDIX V

SEDIMENT TRACE METAL DATA

a) August 25, 1977
b) April 28, 1978
c) November 11, 1980
d) Mean concentrations - 1975, 1977, 1978 and 1980

APPENDIX V SEDIMENT TRACE METAL DATA

a) August 25, 1977

Station	Co (ppm)	Cu (ppm)	Fe (%)	Mn (ppm)	Ni (ppm)	Pb (ppm)	Zn (ppm)	Hg (ppm)
FF-1	19.47	41.03	2.88	448.18	40.41	19.48	89.25	0.095
FF-2	14.88	27.21	2.14	243.81	29.85	3.91	60.73	0.083
FF-3	5.37	11.66	1.02	100.39	12.29	0.0	27.60	0.044
FF-4	8.98	28.89	1.51	164.93	19.74	3.11	45.08	0.050
FF-5	14.60	25.48	2.33	218.71	29.18	3.71	57.04	0.059
FF-7	13.05	29.37	2.09	222.30	31.39	3.64	61.65	0.059
FF-8	8.20	15.55	1.47	130.87	17.56	0.0	34.50	0.050
FF-9	11.39	29.37	1.84	200.78	25.80	9.40	57.96	0.059

APPENDIX V SEDIMENT TRACE METAL DATA

b) April 28, 1978

Station	Co (ppm)	Cu (ppm)	Fe (%)	Mn (ppm)	Ni (ppm)	Pb (ppm)	Zn (ppm)	Hg (ppm)
FF-10	19.127	35.632	2.338	376.048	34.395	10.285	89.906	0.085
FF-11	11.702	25.192	1.625	227.151	23.655	6.347	60.919	0.047
FF-12	5.552	7.545	0.756	103.543	7.751	1.825	23.427	0.024
FF-13	10.564	24.352	1.471	197.023	21.931	5.069	55.535	0.047
FF-14	16.833	32.408	2.061	283.092	30.374	6.386	73.767	0.050
FF-15	12.242	29.267	1.537	225.117	26.316	5.835	50.546	0.028
FF-16	11.785	30.018	1.419	403.169	23.838	7.669	63.320	0.053
FF-17	8.736	22.704	1.212	383.595	18.836	9.610	53.443	0.060
FF-18	8.205	23.999	1.260	184.546	18.970	6.741	53.479	0.041

APPENDIX V SEDIMENT TRACE METAL DATA

c) November 11, 1980

Station	Co (ppm)	Cu (ppm)	Fe (%)	Mn (ppm)	Ni (ppm)	Pb (ppm)	Zn (ppm)
FF-10	1.22	53.5	3.73	1050.0	50.5	84.5	112.0
FF-11	L0.56	44.7	2.52	461.0	38.5	59.0	76.0
FF-12	0.67	49.8	2.87	815.0	36.5	65.0	92.5
FF-13	0.91	11.9	1.57	207.0	12.3	26.2	26.9
FF-14	L0.55	37.1	2.75	362.0	33.4	56.5	81.0
FF-15	L0.55	30.0	2.10	270.0	25.9	47.7	60.5
FF-16	0.89	10.9	1.49	184.0	12.6	25.0	26.1
FF-17	L0.55	26.1	1.90	260.0	20.1	39.6	54.0
FF-18	L0.55	24.4	1.90	274.0	16.4	34.6	42.1

APPENDIX V SEDIMENT TRACE METAL DATA

d) Mean concentrations of trace metals in sediments 1975, 1977, 1978 and 1980

Station	Co (ppm)	Cu ppm)	Fe (%)	Mn (ppm)	Ni ((ppm)	Pb (ppm)	Zn (ppm)	Hg (ppm)
1975 (Stns. 1-9) (Packman, 1977)								
Mean	12.1	30.5	2.3	392.2	31.2	10.6	66.3	-
Maximum	18.6	40.3	3.3	1240.2	43.1	18.7	875.0	-
Minimum	5.0	11.5	1.5	122.1	11.8	0.0	40.9	-
1977 (Stns. 1-9)								
Mean	11.993	26.070	1.910	216.246	25.778	5.406	54.226	0.060
Maximum	19.470	41.030	2.880	448.180	40.410	19.480	89.250	0.095
Minimum	5.370	11.660	1.020	100.390	12.290	0.0	27.600	0.044
1978 (Stns. 10-18)								
Mean	11.638	25.680	1.520	264.809	22.896	6.641	58.260	0.222
Maximum	19.127	35.632	2.338	403.169	34.395	10.285	89.906	L0.164
Minimum	5.552	7.545	0.756	103.543	7.751	1.825	23.427	0.292
1980 (Stns. 10-18)								
Mean	-	32.04	2.31	315.94	27.35	48.67	63.45	-
Maximum	-	53.50	3.73	1050.00	50.50	84.50	112.00	-
Minimum	-	10.90	1.49	260.00	12.30	25.00	26.10	-

L = less than

APPENDIX VI

IDENTIFICATION OF BENTHIC INVERTEBRATES FROM GRAB SAMPLES COLLECTED AROUND THE FIVE FINGER OUTFALL APRIL 28, 1978

by

Penny A. O'Rourke

submitted to:
Environmental Protection Service, Pacific Region
in completion of contract number 08SB.KE114-8-1970
October 1978

APPENDIX VI PHYSICAL DESCRIPTION OF SEDIMENT SAMPLES

FF-10, 12, 14	- small samples - no siliceous spicules - some sand, little wood debris
FF-11	- medium sized sample - very little siliceous spicules - many large rocks, no wood debris
FF-13	- large sample - primarily siliceous spicules - little wood debris
FF-15, 16, 17, 18	- all large samples - 90% siliceous spicules - large rocks

These are descriptions of the samples as they appeared before sieving. The polychaetes in the samples composed primarily of siliceous spicules were in poor condition.

The spicules stabbed the polychaetes, often breaking them. This made some identification to species impossible.

APPENDIX VI NUMBER OF INVERTEBRATES IN GRAB SAMPLE STATION BY STATION

Phylum, Class	Family, Genus, Species	10	11	12	13	14	15	16	17	18
NEMERTEA	unidentified	1							3	
NEMATODA	unidentified							2		3
ANNELIDA	Polynoidae (unid.)		1	1			1	1	1	4
Class Polychaeta	Polyodontidae									
	Peisidice aspera				1		1		1	
	Phyllodocidae									
	Phyllodoce sp.						1			
	Eteone longa			3						1
	Hesionidae									
	Gyptis brevipalpa			1				6		
	Hesionidae (unid.)						1	4		4
	Pilargidae									
	Sigambra sp.	1								
	Syllidae									
	Exogone sp.		3				6	1	6	5
	Syllis sp.			2				14	4	13
	Syllidae (unid.)						2	2		29
	Nephtyidae									
	Nephtys sp.			4		2				
	Glyceridae									
	Glycera capitata		1	5				1		
	Glycera tesselata							1	2	3
	Glyceridae (unid.)								1	
	Goniadidae									
	Goniada annulata						1			
	Onuphidae									
	Onuphis iridescens				1					
	Lumbrineridae									
	Lumbrineris sp.		8	8		3	3	2	2	4
	Lumbrineris bicirrata							1		

Phylum, Class	Family, Genus, Species	10	11	12	13	14	15	16	17	18
	Dorvilleidae									
	Dorvillea pseudorubrovittata							1	1	
	Protodorvillea gracilis						1	1	2	8
	Dorvillea annulata									7
	Orbiniidae									
	Scoloplos armiger			4						
	Paraonidae									
	Tauberia gracilis					3	4	1		2
	Aricidea quadrilobata						2			
	Aricidea neosuecica		5							1
	Aricidea ramosa						1			
	Spionidae									
	Polydora caulleryi						1	1	4	16
	Laonice cirrata						1			
	Laonice sp.								2	1
	Prionospio steenstrupi			9						
	Prionospio cirrata						2			21
	Magelonidae									
	Magelona pacifica		5							
	Cirratulidae									
	Tharyx sp.			2	1		2		1	
	Chaetozone sp.			3						
	Cirratulidae (unid.)			4						
	Flabelligeridae									
	Pherusa plumosa							1	1	1
	Scalibregmidae									
	Scalibregma inflatum			3	1		1			
	Asclerocheilus beringianus							2		1
	Capitellidae									
	Decamastus sp.			3				1		3
	Mediomastus sp.			3		1	3	4	7	23
	Notomastus sp.			1						

Phylum, Class	Family, Genus, Species	10	11	12	13	14	15	16	17	18
	Maldanidae (unid.)		1	5	2	2	6	1	4	11
	Oweniidae									
	Myriochele oculata			7			1			2
	Owenia fusiformis			1						
	Ampharetidae (unid.)			13	2	1	10	3	6	24
	Terebellidae (unid.)	1		2				1		6
	Tricobranchidae									
	Terebellides stroemi	1								4
	Sabellidae (unid.)			1				5		4
	Polychaetes (unid.)		2					2	2	2
MOLLUSCA										
Class Amphineura	*Chaetoderma* sp.	1								
Class Bivalvia	*Nucula tennis*			1						
	Axinopsida serricata			4						
	Thyasira gouldii			3					1	
	Psephidia lord.			4						
	Bivalvia (unid.)			4						
Class Gastropoda	Unidentified			2				7		
CRUSTACEA	Isopoda									
	Limnoria sp.								6	
	Amphipoda			7	1	1	3	4	5	10
SIPUNCULA	Unidentified		25			2	5	4	4	7
ECHINODERMATA										
Class Ophuroidea	Unidentified			1					1	
Class Holothuroidea	*Chirodota* sp.				1					
	Total Number of Individuals	5	52	111	12	15	61	76	68	220
	Species Diversity	5	10	30	9	8	24	28	23	29

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APPENDIX VII

TRACE METAL CONCENTRATIONS IN TISSUES

a) Trawl Samples - August 25, 1977
b) Prawns Traps - April 28, 1978
c) Trawl Samples - November 11, 1980

APPENDIX VII TRACE METAL CONCENTRATIONS

a) Trawl Samples - August 25, 1977

STATION	SPECIES	Cu (ppm)	Fe (ppm)	Zn (ppm)	Pb (ppm)	Cd (ppm)	Hg (ppm)	
FF-1	*Pandalus*	6.1	4.8	12.0	L0.2	L0.1	0.06	wet wt.
	borealis	27.0	21.0	54.0	L1.0	L0.5	0.26	dry wt.
	Sebastes	1.6	9.3	5.0	L0.2	L0.1	0.14	wet wt.
	diploproa	7.1	41.0	22.0	L1.0	L0.5	0.61	dry wt.
FF-2	*Pandalus*	4.0	2.6	11.0	L0.2	L0.1	0.11	wet wt.
	platyceros	18.0	12.0	49.0	L1.0	L0.5	0.52	dry wt.
	Sebastes sp.	2.0	22.0	10.0	L0.2	L0.1	L0.02	wet wt.
		8.5	90.0	42.0	L1.0	L0.5	L0.07	dry wt.
	Sebastes sp.	1.3	28.0	5.8	L0.2	L0.1	0.16	wet wt.
		5.6	230.0	26.0	11.0	L0.5	0.74	dry wt.

L = less than

APPENDIX VII TRACE METAL CONCENTRATIONS

b) Prawn Traps - April 28, 1978

SPECIES	Cu (ppm)	Fe (ppm)	Zn (ppm)	Pb (ppm)	Cd (ppm)	Hg (ppm)	Mg (ppm)	Mn (ppm)	As (ppm)	
Pandalus	6.61	7.07	11.30	L0.98	L0.164	0.242	424.0	0.504	5.90	wet wt.
platyceros	29.00	31.00	49.40	L4.32	L0.720	1.070	1860.0	2.210	25.90	dry wt.
(small)										
Pandalus	7.93	1.46	12.10	L0.98	L0.164	0.327	406.0	0.979	15.50	wet wt.
platyceros	34.30	6.32	52.40	L4.25	L0.708	1.420	1760.0	4.240	67.00	dry wt.
(medium)										
Pandalus	7.94	3.46	12.40	L0.92	L0.154	0.365	400.0	1.220	12.70	wet wt.
platyceros	36.10	15.70	56.50	L4.20	L0.700	1.660	1820.0	5.560	57.90	dry wt.
(large)										
Munida	6.29	5.78	9.85	L0.70	0.289	0.151	644.0	2.200	2.74	wet wt.
quadrispina	32.70	30.10	51.30	L3.66	1.510	0.784	3350.0	11.400	14.20	dry wt.

L = less than

APPENDIX VII TRACE METAL CONCENTRATIONS (continued)

c) Trawl Samples - November 11, 1980

STATION	SPECIES	Cu (ppm)	Fe (ppm)	Zn (ppm)	Pb (ppm)	Cd (ppm)	Hg (ppm)	
FF-2	*Pandalus borealis*	27.0	75.3	14.4	L0.906	0.238	0.181	wet wt.
		115.0	321.0	61.2	L3.860	1.010	0.043	dry wt.
	Pandalus platyceros	29.0	54.4	15.4	L0.911	0.239	0.429	wet wt.
		123.0	231.0	65.2	L3.860	1.010	0.101	dry wt.

L = less than

APPENDIX VIII

PISCES IV DIVE REPORT FOR APRIL 13, 1978

DIVE REPORT - FIVE FINGER ISLAND SEWAGE DIFFUSER

Pisces Dive #648
Track 1
Date: April 13, 1978
Film Exposed: 16 mm Rolls 5, 6, 7, 8, 9
70 mm Roll #1 49 - 90
#2 0 - 70

Watercolumn

Both descending and ascending through the watercolumn revealed very little phytoplankton or zooplankton above 80 m. The photic zone was observed to extend at least as far down as 80 m. The number of euphausids increased markedly below the photic zone and continued to increase, being joined by copepods, amphipods, and chaetagnaths as the bottom was approached. In the vicinity of the bottom, dense concentrations of bathypelagic amphipods were apparent. While sitting on the bottom, thousands of amphipods congregated in the light pool from Pisces's main lights.

Throughout the water column there was no evidence of turbidity at all. Light from the surface was observed to extend to the bottom at the diffuser. There was no visually apparent increase in turbidity of plankton concentration during the ascent from the diffuser as compared with the initial descent.

CTD Data

	Temperature	Conductivity	Dissolved Oxygen
Surface	13.00°C	31.18 m mhos/cm	8.86 mg/l
Bottom (on descent)	8.07°C	33.50 m mhos/cm	8.97 mg/l
Bottom (at diffuser)	9.70°C	32.30 m mhos/cm	8.03 mg/l

Bottom Characteristics

At the position of initial descent to the bottom it was observed to be gravelly and rocky with a covering of detritus. The depth at this point was 142 m. These characteristics are felt to be typical of the entire area of discharge pipe and persisted throughout the dive. A cliff was, however, discovered while proceeding from the drop location to the outfall pipe. The cliff was approximately 20' - 30' in height and composed of rock. The depth at the top of the cliff was 112 m with the substrate being very rocky and having no overlying sediment layer.

The substrate in the immediate vicinity of the sewage diffuser varied between sand and gravel. There was no apparent accumulation of organic material opposite the ports.

Biological Observations

Upon initial arrival at the bottom, a dogfish (*Squalus canthisa*), a number of ratfish (*Hydrologus colliei*) and a starfish (*Henricia* sp.), were observed. Also observed along the flat bottom were living and dead sponges (*Aphrocallistes* sp.), sqat lobsters (*Munida quadrispina*), prawns (*Pandulus platyceros*), shrimp (*Pandalus* sp.), hermit crabs (*Pagurus* sp.)., Brachiopoda, and sculpins (Cottidae).

After running along the bottom for a short period of time a rocky cliff was encountered. Fauna inhabiting this rocky area included a large number of siliceous sponges (*Aphrocallistes* sp. and *Chonelasma calyx*), sea anemones (*Metridium senile* and *Stomphia* sp.), an unidentified starfish (Asteroidae), calcareous tubiculous polychaetes and a decorator crab (*Oregonia gracilis*).

After ascending the cliff the bottom composition changed again to what it had been at the commencement of the dive. Shortly thereafter the pipe was located. A variety of fauna was observed in the vicinity of the pipe. These forms included sea anemones (*Stomphia* sp.), starfish (*Ceramaster patagonicus*), skillfish (*Erilepis zonifer*), and lemon sole (*Parophrys vetulus*).

The number of fish increased as the diffuser was approached with lingcod, rockfish and pricklebacks being the dominant types. At any given time, up to ten or more lingcod were visible at the outer edge of the pool of light from the Pisces IV.

The Effluent Diffuser

The effluent diffuser is constructed in a Y shape as indicated in Figure 1. Dams were apparent on each arm and on an extension of the main pipe. These would require a diver to open and close them. A large concrete block was observed directly out from the end of the main diffuser pipe and this was assumed to have been the base from which the pipe was pulled out from shore. It was noted that there was no effluent being discharged from the last eleven ports on each arm.

Diffuser Impact

The most notable observation made in connection with the diffuser was the apparent lack of accumulation of organic material on the bottom adjacent to the ports. There was also very little in the way of non-degradable material around the ports. Some non-degradable material had collected around the end of the centre pipe. This had presumably been deposited before primary treatment had begun.

The effluent was observed to be a grey suspension which rose straight up from ports, diffusing rapidly to the point where it could no longer be seen. In a number of cases sea anemones were observed attached on the upper side of the ports just out of the effluent stream. Fish (lingcod, rockfish and pricklebacks) were also observed in great numbers around the diffuser, staying just out of the effluent stream.

The fauna in the vicinity of the diffuser appeared healthy and was the most abundant that we have ever seen from Pisces IV in terms of fish. It would be advisable, however, to monitor these fish for heavy metal and PCB contamination which may stem from the discharge. This may best be accomplished by means of hand-lining for fish and prawn trapping for invertebrates.