DEPARTMENT OF ENVIRONMENT
ENVIRONMENTAL PROTECTION SERVICE
PACIFIC REGION

B.C. TIMBER PULP MILL, PORPOISE HARBOUR

An Assessment of Mill Impact on the Receiving Environment (1979 to 1982)

Regional Program Report 83-09

by

W.M. Pomeroy

June, 1983

Habitat
Room 228
417 - 2nd Avenue West
Prince Rupert, B.C.
V8J 1G1

ABSTRACT

The Environmental Protection Service conducts regular monitoring of the receiving environment in the vicinity of the B.C. Timber pulp mill, Porpoise Harbour. This report presents data collected from June 1979 to April 1982 relating to water quality, sediment organic and trace metal content and benthic invertebrates.

Environmental affects attributable to the pulp mill and in some cases to nearby fish processing plants were evident in the harbour. Observed spatial and temporal changes in salinity and temperature of the water column were primarily a function of freshwater input from the Skeena River located to the south. However, depression of dissolved oxygen concentrations in the immediate area of the pulp mill diffuser did indicate an effluent effect. The surfacing of effluent also resulted in discoloration of surface waters, decreasing in intensity with distance from the pulp mill. The effects of effluent discharges to Porpoise Harbour were also evident in the sub-tidal sediments. At stations up to 750 m from the diffuser, the percent organic content increased. Organic loading was also evident in the vicinity of the fish processing plants. Invertebrate communities inhabiting the sediments in the vicnity of the mill and fish plants were dominated by Capitella capitata and exhibited reduced species diversity and eveness in comparison to more distant locations in Porpoise Harbour.

RÉSUMÉ

Le Service de la protection de l'environnement fait une étude régulière des effets de la pollution sur le milieu récepteur situé à proximité de l'usine de pâte à papier "B.C. Timber pulp mill" de Porpoise Harbour. Le présent rapport présente les données obtenues de juin 1979 à avril 1982 relativement à la qualité de l'eau, au contenu des sédiments, matières organiques et métaux à l'état de traces, ainsi qu'aux invertébrés benthiques.

Les effets constatés dans la crique de Porpoise Harbour sont dus à la présence de l'usine de pâte à papier et, dans certains cas, des conserveries de poisson voisines. Les variations dans l'espace et dans le temps de la salinité et de la température de la colonne d'eau étaient surtout fonction de l'apport d'eau douce résultant de la présence de la rivière Skeena située plus au sud. Cependant, la baisse relevée dans les degrés de concentration d'oxygène dissous à proximité de l'exutoire de l'usine de pâte à papier révélait la présence d'effluents. Ces derniers avaient également pour effet de décolorer l'eau en surface, phénomène de moins en moins marqué au fur et à mesure que l'on s'éloignait de l'usine de pâte à papier. Par ailleurs, on a noté les effets sur les sédiments subtidaux de Porpoise Harbour du déversement des effluents. A plusieurs stations situées jusqu'à 750 m de l'exutoire on a constaté un accroissement du pourcentage des matières organiques. On a également relevé une proportion importante de matières organiques à proximité des conserveries de poisson. Les colonies d'invertébrés vivant dans les sédiments à proximité de l'usine et des établissements de préparation du poisson étaient en majorité composées de Capitella capaitata. On a constaté que la diversité des espèces et la régularité de leurs proportions respectives étaient moins grandes qu'aux endroits plus éloignés de la crique de Porpoise Harbour.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

LIST OF TABLES

SUMMARY

1) Surveys were conducted between 1979 and 1982 to assess the impact of the B.C. Timber pulp mill on the receiving environment of Porpoise Harbour. Water quality (salinity, temperature, dissolved oxygen), sediment characteristics (organic and trace metal content, particle size), and sediment infauna wera also investigated.

2) Salinity and water temperature in Porpoise Harbour are not affected by mill effluent to any obvious degree but rather display seasonal variations under the influence of the Skeena River flow. Dissolved oxygen concentrations in the immediate area of the diffuser are depressed in comparison to stations farther removed and reflect an effluent effect..

3) Distribution patterns of colour in the surface waters of Porpoise Harbour indicate mill effluent to be a significant contributor. Leaching from the old pulp mill settling lagoons into Wainwright Basin adjacent to the mill has been identified based on localized elevated surface water colour and depressed dissolved oxygen.

4) The percent organic content of subtidal surface sediments up to 750 m from the diffuser increased following startup of effluent discharge in Porpoise Harbour in 1978.

5) Concentrations of trace metals measured in the subtidal surface sediments of Porpoise Harbour varied slightly between 1979 and 1981 but there was no clear indication of a pulp mill effluent effect.

6) Benthic invertebrate communities in the vicinity of the pulp mill and fish processing plants exhibited reduced species diversity and eveness with the polychaete Capitella capitata being extremely abundant. These two factors increased towards the north and south ends of Porpoise Harbour, suggestive of more stable, less impacted communities.

1. INTRODUCTION

1.1 Location

The B.C. Timber Ltd. pulp mill (previously Canadian Cellulose Ltd.) is located at Port Edward, 10.2 km south of Prince Rupert (Figure 1). The mill is situated on Watson Island which is bounded by a series of partially enclosed embayments - Morse Basin, Wainwright Basin and Porpoise Harbour - connected via narrow turbulent passages.

1.2 Mill History

A complete review of the operational history of the Port Edward mill has been presented in a previous EPS publication (Packman, 1979). The following is intended as a summary to aid in the interpretation and discussion of data contained in this report.

Production began in 1951 with a bleached sulphite mill discharging high BOD effluent into onsite settling lagoons followed by release to Wainwright Basin (Figure 2). Mill expansion exceeded the capacity of the lagoons with the result that large amounts of suspended solids (fibers) entered Wainwright Basin. In an effort to correct this, a pipe was laid on the bottom of Porpoise Harbour and across Ridley Island, discharging effluent into Chatham Sound. The system was prone to leaks and failures. Steadily declining dissolved oxygen concentrations and increased habitat degradation were recorded in Wainwright Basin and Porpoise Harbour since establishment of the sulphite mill until its closure in 1976 (Walidichuk 1966, Packman 1977).

Two bleached Kraft mills were built on Watson Island, one in 1966 and one in 1978. The first discharged effluent to the on-site lagoon system. With the start up of the second mill in 1978, all effluent was discharged via a foam tower through a diffuser at a depth of 18 m in Porpoise Harbour (Figure 2). There is no clarifier. Between 1979 and 1981, the average volume of effluent discharged was 146,000 cubic metres per day.

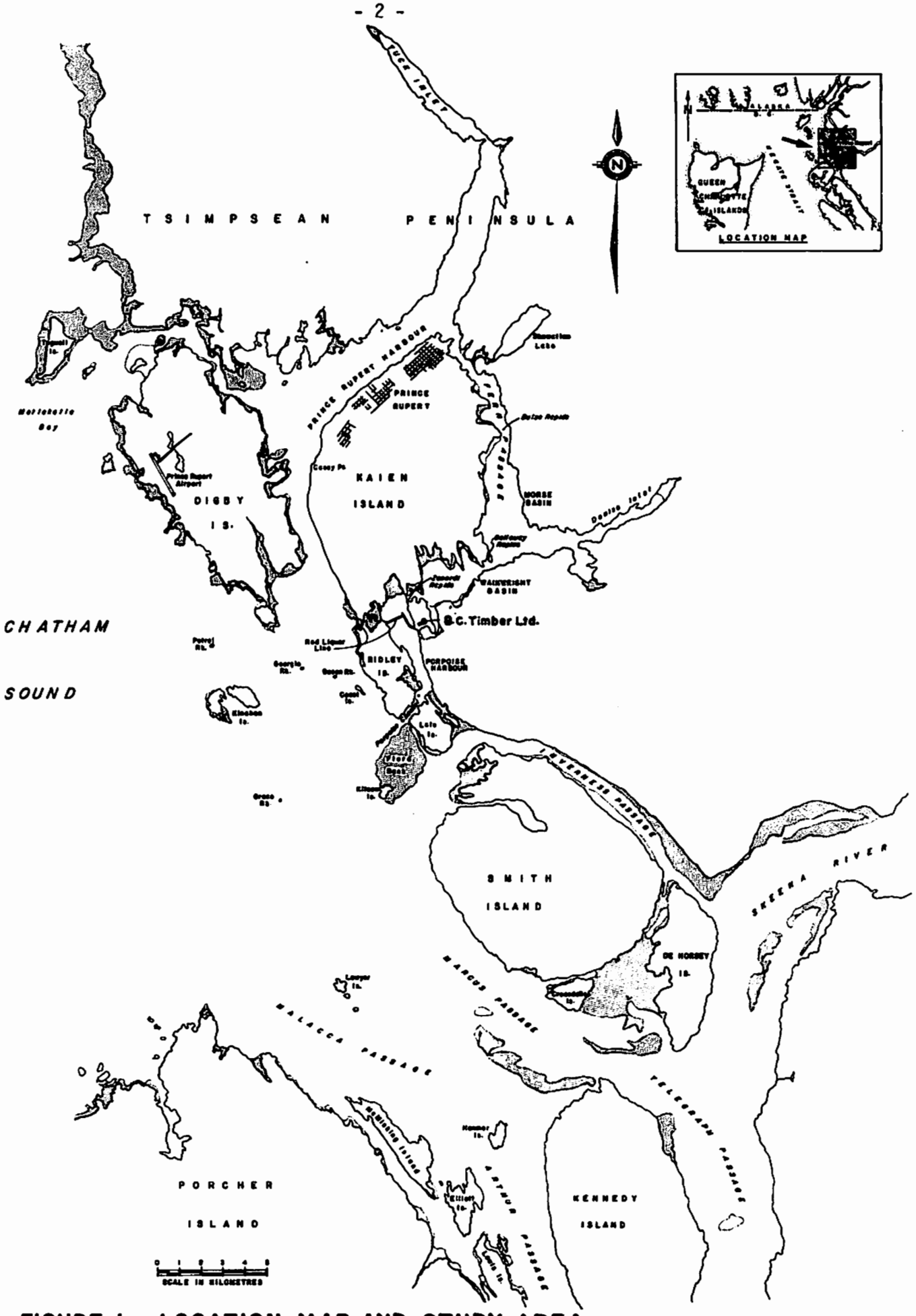


FIGURE 1 LOCATION MAP AND STUDY AREA

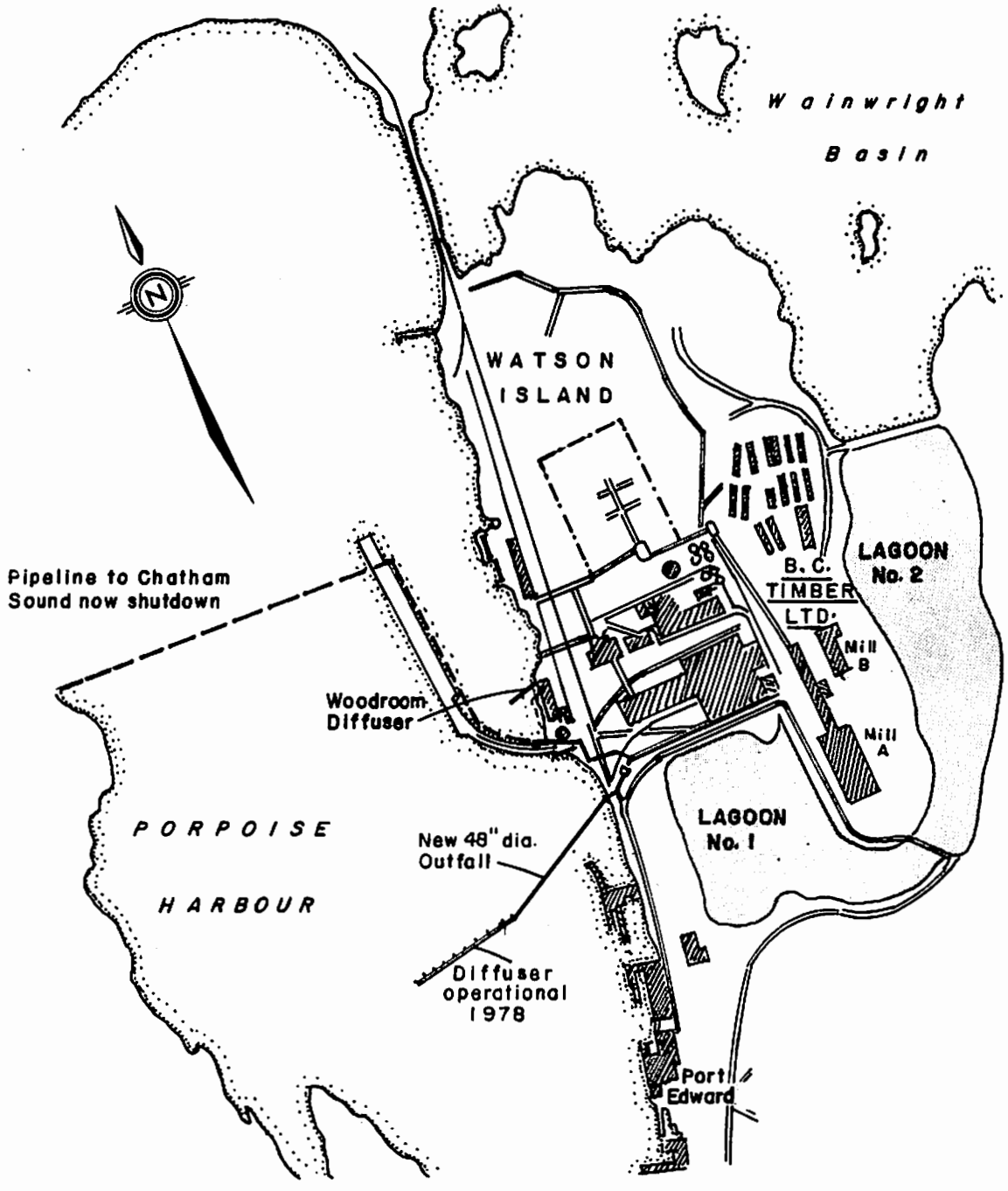


FIGURE 2 MILL LAYOUT AND MAIN EFFLUENT DISCHARGE

The mill utilizes hydraulic debarking, and the resulting wastes are discharged into Porpoise Harbour near the Woodroom (Figure 2).

In an effort to monitor environmental effects of pulp mill discharges on the receiving environment, the Environmental Protection Service (EPS) conducts an ongoing surveillance program in Porpoise Harbour. Assessments of water quality (salinity, temperature and dissolved oxygen), sediment characteristics (particle size, organic carbon and heavy metal content, resin acids), subtidal sediment invertebrates and intertidal communities have been made on an annual basis. This report reviews data collected between 1979 and 1982.

2. MATERIALS AND METHODS

Surveys were conducted by EPS staff in Porpoise Harbour June, 1979, August 1980, October 1981 and April 1982 using research ships of the Department of Fisheries and Oceans.

In addition to mill impact stations located within Porpoise Harbour, control stations were established in Chatham Sound.

Latitude and longitude of all sample stations are given in Appendix I.

2.1 Oceanographic Sampling

Oceanographic sampling was done at stations indicated on Figure 3. A conductivity, temperature, density (C.T.D.) meter was used to obtain profiles of salinity and temperature in 1979, 1980 and 1982. Profiling in 1981 was done using N.I.O. bottles with paired, protected reversing thermometers with salinity being determined on a Guildline salinometer (Autosal Model 8400). Water samples were collected at each survey using N.I.O. bottles.

Dissolved oxygen was determined on board ship using the azide modification of the Winkler method. Water samples collected for nutrient analysis were frozen on board ship and analyzed within 2 weeks for nitrate, nitrite, ammonia and phosphate as described by Swingle and Davidson (1979). Trace metals and colour samples were also collected and analyzed according to Swingle and Davidson (1979).

2.2 Benthic Sampling

Sediment samples were obtained with a Smith-McIntyre grab sampler from stations shown on Figure 4. Following visual examination, sub-samples from the top 2 cm of the grab were removed for particle size distribution and organic carbon and trace metal content. Samples were stored frozen until analyzed at the EPS chemistry laboratory.

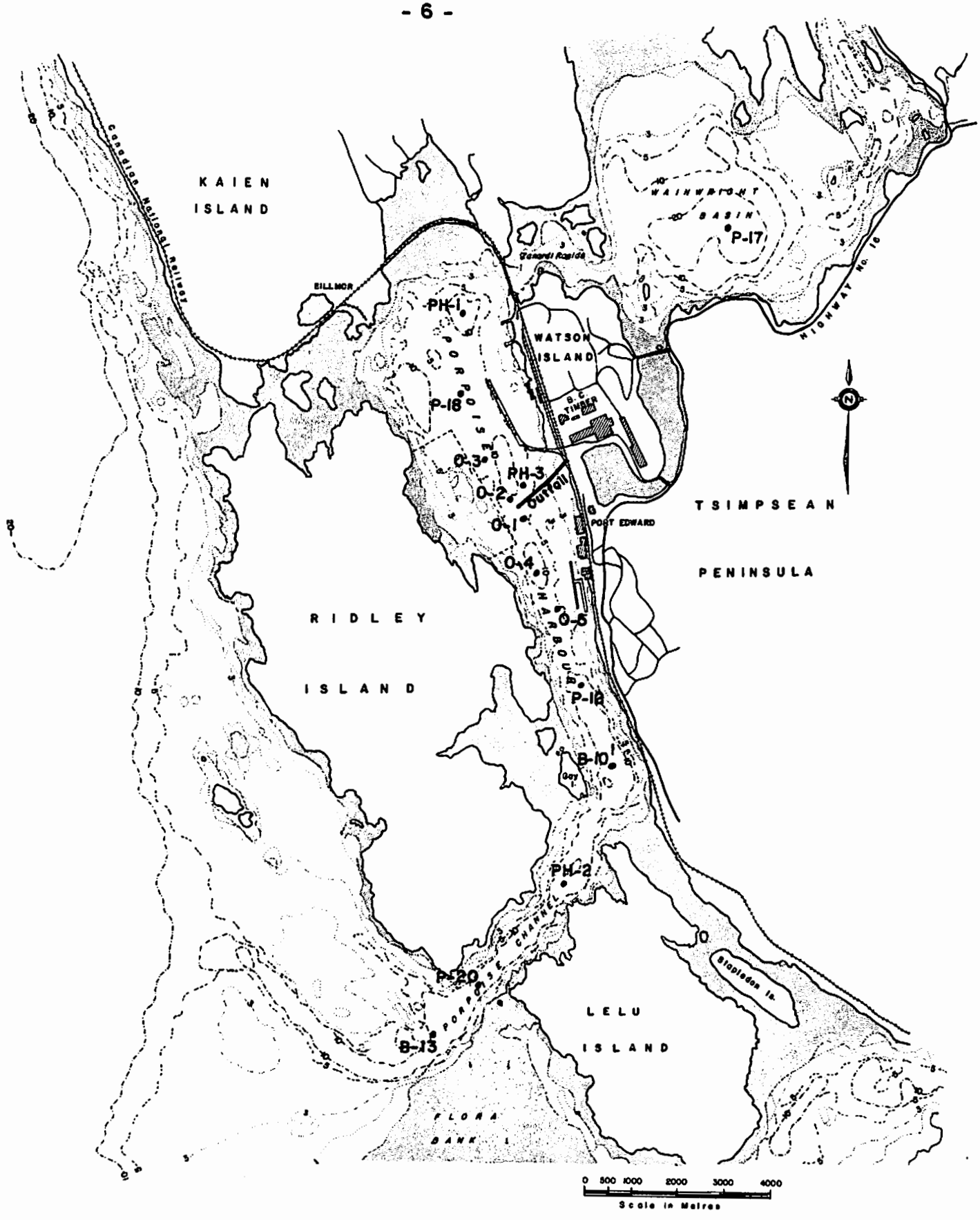


FIGURE 3 OCEANOGRAPHIC SAMPLE STATIONS

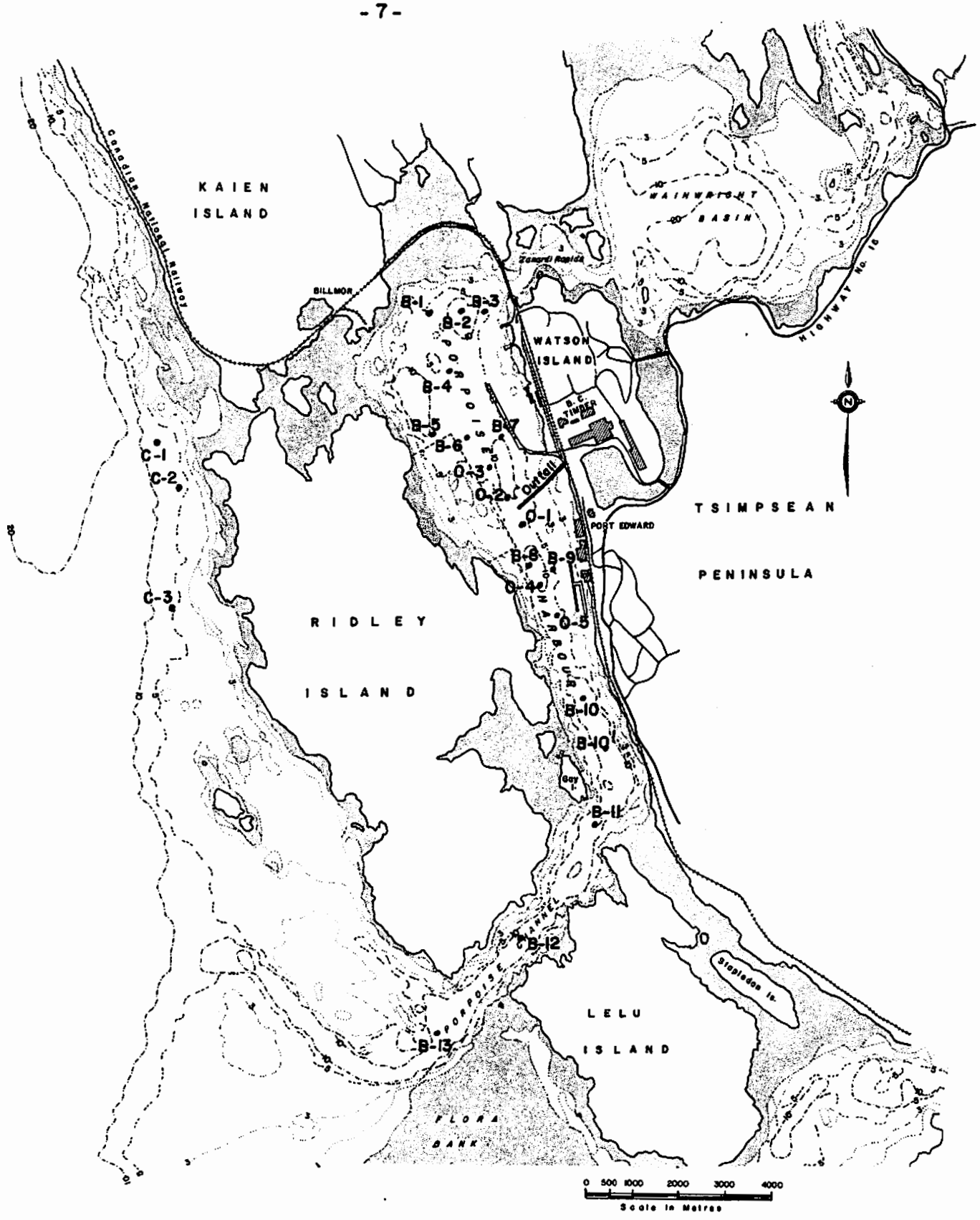


FIGURE 4 BENTHIC SAMPLE STATIONS

Trace metals and organic carbon were determined using the methods described by Swingle and Davidson (1979). Sediment particle size was measured by wet sieving through three sizes of screens (500 um, 250 um and 62.5 um).

Three litres of sediment were collected from grabs at selected stations and passed through a 500 um screen to remove invertebrates. These were fixed in 10% formalin and subsequently preserved in 70% isopropanol for long term storage.

A benthos gravity cover was used to obtain sediment for analysis of historical levels of trace metals, organics and resin acids.

2.3 Intertidal Studies

Photographs were taken at selected stations in Porpoise Harbour and Wainwright Basin during low tide on each survey to document intertidal algal and invertebrate communities. These are available for reference in the West Vancouver office of EPS.

3. RESULTS AND DISCUSSION

3.1 Oceanography

3.1.1 Salinity, Temperature and Dissolved Oxygen (Appendix II).

Limited seasonal water column stratification exists in Porpoise Harbour with respect to salinity, temperature and dissolved oxygen (Packman 1979). Data collected from 1979 through 1982 indicate the intensity or degree of stratification, especially salinity, to reduce from station P-20 at the entrance to Porpoise Channel to Station P-18 near the mill towards the head of Porpoise Harbour (Figure 6). Of the months sampled, the period of greatest stratification occured in June corresponding to a time of increased freshwater flow from the Skeena River. Partial breakdown of stratification was evident in the August 1980 and 1981 surveys. The reduced influence of the Skeena was reflected with surface salinities increased by an average of 10% (Appendix II). Virtually no stratification was recorded in the April 1982 survey.

Available data suggest dissolved oxygen (DO) concentrations in Propoise Harbour to be affected by the discharge of mill effluent (Table 2). In August, 1980 the mill was operating for the full 31 days (Table 1). Measurements done on August 29 at station PH-2 in Porpoise Channel (Figure 3) indicated surface values of 9.90 mg L^{-1} and 8.16 mg L^{-1} at 20 m depth. At station PH-3 near the mill outfall, surface values were 6.21 mg L^{-1}, dropping to 5.68 mg L^{-1} at 20 m depth. Somewhat higher levels were noted at station PH-1 towards the northern end of Porpoise Harbour. Dissolved oxygen concentrations in August 1981 with only two production days varied little between these three stations (Table 2). Results of the April 1981 survey during a month of 29 production days indicated very limited DO reduction in the mill area. It is likely that spring phytoplankton production and resultant oxygen production may be counteracting the oxygen demand imparted by mill effluent.

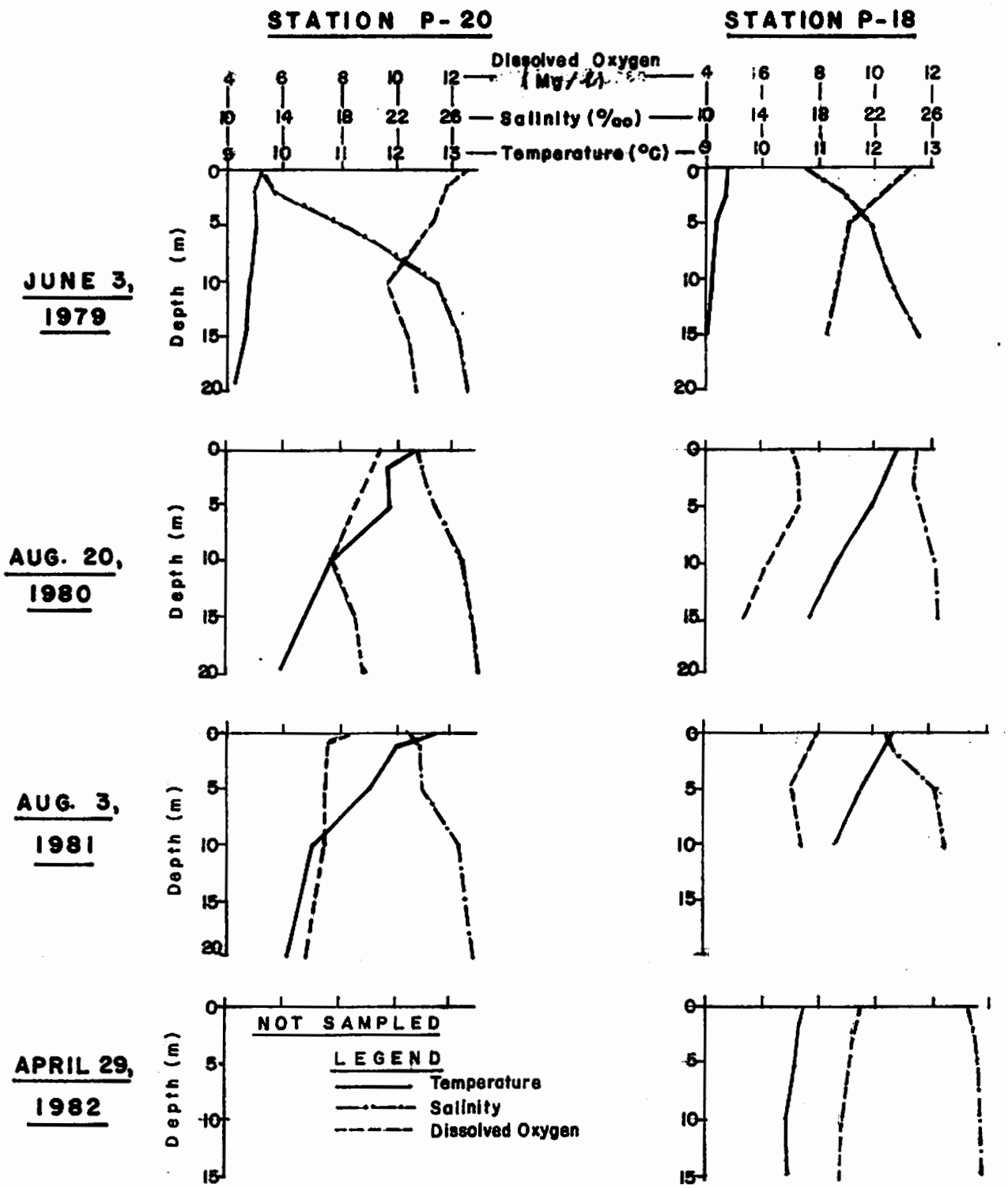


FIGURE 6 WATER COLUMN PROFILES OF SALINITY, TEMPERATURE AND DISSOLVED OXYGEN FOR STATIONS P-20 AND P-18 , 1979 - 1982

TABLE 1 PRODUCTION DAYS FOR B.C. TIMBER PULP MILL 1979-1982

MONTH	1979	1980	1981	1982
January	na[a]	30	30	30
February	na	29	28	28
March	na	31	31	31
April	na	28	27 (3)	29
May	na	31	31	31
June	na[b]	30	30	29
July	10 (21)	29	11 (18)	0 (31)
August	22 (9)	31	2 (29)	0 (31)
September	26 (4)	28	29	1 (29)
October	27 (3)	31	29	31
November	30	30	30	18 (12)
December	29	29	25 (6)	0 (31)

[a]information not available

[b]bracketed number indicates number of days of continuous shutdown > 3 days

TABLE 2 DISSOLVED OXYGEN CONCENTRATIONS IN THE WATER COLUMN AT SELECTED STATIONS 1980 THROUGH 1982

	DEPTH (m)	AUGUST 20, 1980 (31 days)[a]	AUGUST 3, 1981 (2 days)	APRIL 29, 1982 (29 days)
PH-2	0	9.90	8.00	9.75
Porpoise Channel	2	9.60	7.60 (1 m)	9.60
	5	8.32	7.40	9.45
	10	6.80	7.40	9.05
	15	7.80	-	-
	20	8.16	7.35	-
	25	8.52	-	8.80
PH-3	0	6.21	7.70	-
Porpoise Harbour	2	6.58	7.70 (1 m)	-
near diffuser	5	7.63	7.60	-
	10	6.64	7.55	-
	15	5.73	-	-
	20	5.68	-	-
O-2	0	-	-	9.45
Porpoise Harbour	2	-	-	9.14
near diffuser	5	-	-	8.95
and PH-3	10	-	-	8.70
PH-1	0	7.36	7.70	-
Porpoise Harbour	2	8.52	7.60 (1 m)	-
north end	5	7.77	7.50	-
	10	6.44	7.45	-
	15	5.65	-	-
	20	5.75	-	-
	25	5.65	-	-

[a]number of operational days in a month

Salinity and temperature variations in Porpoise Harbour did not appear to be changing in response to mill effluent discharge.

3.1.2 Surface Colour. Mill effluent contributes significantly to the observed surface colour in Porpoise Harbour. The April 29, 1982 survey done on a falling tide showed colour values to increase from 10 (Stn. PH-2) in Porpoise Channel to 93 (Stn. O-1) off the mill and to decrease from this point to 15 (Stn. PH-1) near the north end of Porpoise Harbour (Table 3). Similar spatial distribution patterns for colour were recorded during other studies (IEC Beak, 1983).

A colour determination in Wainwright Basin near the discharge point of the old settling lagoons used by the mill showed a level of 24 colour units (Table 3). Leaching from the lagoons is suggested. Reduced surface dissolved oxygen levels have also been recorded. This region should be watched for possible effects of leaching and monitored more frequently than has been done since 1979.

3.2 Sediment Characteristics

3.2.1 Organic Carbon Content. Visual examination of grab samples in the field indicated the existence of black reducing sediments containing fibre material extending from station B-10 near the entrance to Porpoise Harbour (Figure 4) up to the northern end (Appendix III). The bottom south of B-10, towards and into Porpoise Channel, consisted of shale, rocks and some fine mud.

In 1981 additional sediment stations (series O-, Figure 4) were established adjacent to the outfall to monitor effects in the immediate area. Sediments were reducing as at other stations in the harbour but were visually higher in fibre content.

The percent organic content of surface sediments in parts of Porpoise Harbour increased following startup of effluent discharge through the diffuser in January, 1978 (Table 4). Stations within 500 m south of

TABLE 3 SURFACE COLOUR LEVELS FROM PORPOISE HARBOUR APRIL 29, 1982

STATION	SURFACE (APCU units)
PH-2 Porpoise Channel	10
B-10 Porpoise Harbour, south end	16
P-12	12
O-5	17
O-4	40
O-1 Outfall	93
O-2	41
P-18	35
PH-1 Porpoise Harbour, north end	15
P-29 Wainwright Basin, near old lagoon culvert	24

TABLE 4 PERCENT ORGANIC CONTENT OF SURFACE SEDIMENTS IN PORPOISE HARBOUR

STATION	DISTANCE FROM OUTFALL (m)	DEPTH (m)	1977	1978	1979	1980	1981	1982
B-1	[a]N 1400	16	3.7	-	-	1.5	3.0	-
B-2	N 1340	16	2.7	-	-	-	12.0	-
B-4	N 1060	24	3.1	3.5	3.0	2.5	19.0	-
B-5	N 750	22	1.9	3.9	5.1	5.5	21.0	-
B-6	N 600	20	3.7	2.8	3.8	5.0	-	-
B-7	N 500	24	3.6	3.1	4.4	5.3	-	-
0-3	N 320	22	-[c]	-	-	-	11.0	-
0-2	N 120	22	-	-	-	-	5.0	-
OUTFALL								
0-1	[b]S 100	44	-	-	-	-	6.0	-
B-8	S 340	25	2.1	2.7	2.8	4.2	-	-
0-4	S 360	24	-	-	-	-	6.0	-
B-9	S 420	17	2.2	3.3	4.1	4.8	-	-
0-5	S 750	22	-	-	-	-	6.0	-
B-10	S 760	24	2.2	3.7	2.0	3.0	-	-
B-12	S 3190	30	1.3	-	-	1.6	-	-
B-13	S 4100	35	2.4	3.3	-	3.4	-	-

[a]N indicates north of outfall

[b]S indicates south of outfall

[c]not sampled

the outfall had an approximate doubling in organic content from 1977 to 1980 (e.g. Stn. B-8: 2.1% to 4.2%). Available data indicate only minor increases in organic content beyond about 500 m (e.g. Stn. B-10: 2.2% to 3.0%). Stations north of the outfall had higher organic readings in 1977 by about 1.0% compared to stations to the south (Table 4). Increases in organic content were noted for stations within about 750 m of the outfall (e.g. Stn. B-6: 3.7% to 5.0%). Stations B-2, B-4 and B-5 north of the outfall showed dramatic increases in organic content between 1980 and 1981 (e.g. Stn. B-4: 2.5% to 19.0%). This unreasonably large increase in the northern end of Porpoise Harbour may be related to Ridley Island development activities and requires further investigation.

3.2.2 Particle Size Distribution. Considerable spatial variation exists over the study area with regard to surface sediment particle size distribution (Appendix IV). The discharge of mill effluent does not have any obvious effect on observed distribution patterns. Variations noted at a particular station between 1979 and 1981 reflect natural variations in sediment composition (i.e. heterogeneous substrate). One recurrent feature of the reducing sediments in Porpoise Harbour is that in most areas, over 50% of a sample consisted of particles less than 250 um.

3.2.3 Trace Metal Concentrations. Concentrations of trace metals measured in the subtidal sediments of Porpoise Harbour varied somewhat between 1979 and 1981 with no clear indication of a pulp mill effluent effect. Station B-4 at the north end of Porpoise Harbour was quite similiar in metal content to Station B-7 off the mill outfall and Station B-10 at the south end of the harbour (Table 5).

Sediments in Porpoise Harbour had higher levels of Cd and Cu and generally lower levels of Fe and Mn than were recorded in Chatham Sound on the west side of Ridley Island (Table 6). Concentrations were similiar to or greater than those recorded north of Porpoise Harbour at Port Simpson, the site of a small town and fish cannery (Pomeroy, 1982). Trace

TABLE 5 SURFACE SEDIMENT TRACE METAL CONCENTRATIONS AT SELECTED STATIONS IN PORPOISE HARBOUR, 1979 AND 1981

STATION	Cd (ppm)	Cu (ppm)	Fe (%)	Mn (ppm)	Ni (ppm)	Pb (ppm)	Zn (ppm)	Hg (ppm)
B-4 (Porpoise Harbour, north end)								
June 3, 1979	< 1.24	43.95	3.10	444.5	29.6	< 9.95	99.35	0.503
August 4, 1981	1.60	41.4	3.08	458.0	20.9	12.1	103.0	0.240
B-7 (off mill)								
June 3, 1979	< 1.16	43.0	3.33	471.0	27.5	< 9.30	103.0	0.425
August 4, 1981	1.10	40.5	3.30	488.0	22.0	8.70	95.9	-
B-10 (Porpoise Harbour, south end)								
June 3, 1979	< 1.15	35.0	3.36	465.5	28.9	< 9.24	93.60	0.287
August 4, 1981	1.30	39.0	3.58	495.0	22.3	8.70	89.8	0.220

metal levels from the Comox/Cape Lazo area of north east Vancouver Island, a region of little industrial activity, were 2 to 5 times lower than those recorded in Porpoise Harbour sediments (Holman et al, 1981).

3.3 Benthic Faunal Communities

The benthic invertebrate community at most stations sampled in 1981 was dominated by the polychaete Capitella capitata (Appendix VI). Stations O-1 and O-2 adjacent to the pulp mill diffuser and station B-9 in the vicinity of fish processing plants and pulp mill influence had the highest numbers of individuals at 2744, 1247 and 3376, respectively per three litres of sediment. Numbers decreased substantially (one to two orders of magnitude) towards the north and south ends of Porpoise Harbour where direct organic input is reduced. The relationship of C. capitata and organic loading is well known (Bellan, 1967) and in the case of Porpoise Harbour, reflects a combined pulp mill and fishing industry impact.

Basic statistical analysis of benthic invertebrate data indicated differences in community structure throughout the harbour (Table 7). Eveness values were lowest in the central portion of Porpoise Harbour associated with industrial activity and generally increased to the north and south. Higher eveness values reflect more equal distribution of individuals among species. Species diversity indices (Shannon-Weaver) like eveness generally increase with distance from the mill outfall (Table 7). The greater diversity and more even distribution of individuals among species suggests communities to be more stable and under less stress and impact with increasing distance from the pulp mill and fish processing areas of Porpoise Harbour.

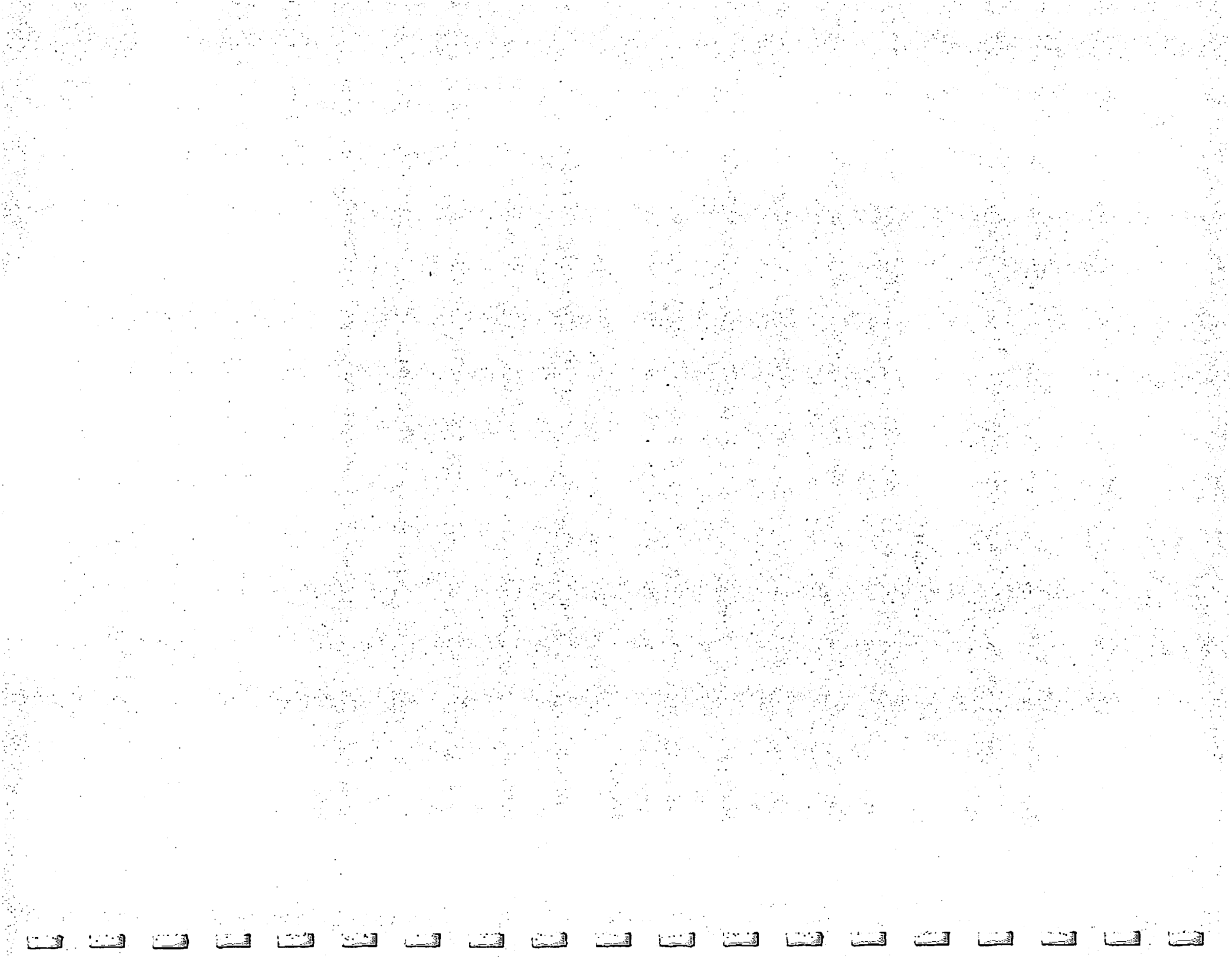


TABLE 6 MEAN SURFACE SEDIMENT TRACE METAL CONCENTRATIONS IN CHATHAM SOUND, 1981

STATION	Cd (ppm)	Cu (ppm)	Fe (%)	Mn (ppm)	Ni (ppm)	Pb (ppm)	Zn (ppm)	Ag (ppm)
C-1	0.4	34.8	21	645.0	26.0	12.0	108.0	0.28
C-2	< 0.3	32.8	4.14	746.0	25.0	9.0	104.0	0.29
C-3	0.5	34.0	4.32	735.0	25.0	12.0	108.0	0.29

TABLE 7 SPECIES DIVERSITY INDICES AND EVENESS VALUES FOR INVERTEBRATE COMMUNITIES AT SELECTED STATIONS IN PORPOISE HARBOUR, AUG. 3, 1981

STATION	DEPTH (m)	DIVERSITY INDEX ($\log^2$)	EVENESS
B-1	15	2.507	0.659
B-4	18	2.090	0.629
B-5	20	1.038	0.370
B-6	16	0.742	0.207
B-7	22	0.438	0.124
0-3	20	1.462	0.384
0-2 (OUTFALL)	20	0.372	0.117
0-1	13	0.024	0.015
B-9	14	0.110	0.039
B-10	26	3.050	0.595

4 EXPECTED ENVIRONMENTAL IMPACTS WITH PRESENT ABATEMENT EQUIPMENT

Based upon the present level of pollution abatement and the results of EPS studies and those conducted by B.C. Timber, the following 'predictions' can be made regarding the receiving environment in Porpoise Harbour.

Recovery:

a) Further recovery of Wainwright Basin in terms of water quality and intertidal communities except for the area adjacent to the mill where the outflow from the old lagoons enters the basin.

b) Some improvement in diversity and 'apparent health' of intertidal communtities in Porpoise Harbour.

Impact:

a) Continued dissolved oxygen depression in surface waters at certain times of the year in the vicinity of the effluent diffuser.

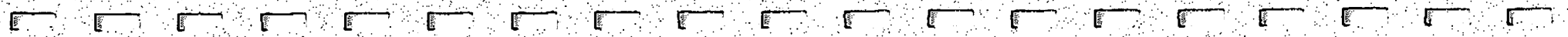
b) Continued effluent-induced surface colour which reduces light penetration and, potentially, phytoplankton production.

c) Continued buildup of organic matter (fibre, etc.) from mill activities in subtidal sediments of Porpoise Harbour. High organic loading creates anaerobic/reducing sediments which support much less diverse invertebrate communities in terms of macro- and micro-fauna. The effect of this on fisheries resource species present in the harbour is yet to be determined.

Unknown Impacts:

a) Effluent toxicity (acute and sublethal) will continue to be an area of uncertainty until such time as further bioassay, bioaccumulation and necessary support studies are conducted. Data from other mills indicate *in situ* toxicity associated with mill effluent and an impact on fisheries resources.

b) Effluent may be interfering with the movement of some fish species through Porpoise Harbour (avoidance behaviour) and may be affecting juvenile fish growth.



REFERENCES

Bellan, G. Pollution et peuplements benthiques sur substrat meuble dans la region de Marseille deuxime partie, l'ensemble portuaire marseillais. Rev. Intern. Oceanogr. Med. 8:51-95. 1967.

Holman, N., M. Pomeroy and G. Packman. Baseline Environmental Data Collected at Cape Lazo, Vancouver Island Prior to Installation of Domestic Sewage Outfall. EPS Regional Program Report: 81-1 (1981).

IEC Beak Consultants Ltd. Water Quality and Biological Studies in the Marine Environment Near the B.C. Timber Pulp Mill - 1982. March, 1983.

Packman, G.A. Environmental Surveillance in the Vicinity of the Canadian Cellulose Co. Ltd. Pulp Mill and Prince Rupert, British Columbia. EPS Surveillance Report, Number EPS 5 PR-77-8, 1977.

Packman, G.A. Pulp Mill Environmental Assessment Canadian Cellulose Ltd. Northern Operations Port Edward, British Columbia. EPS Regional Program Report: 79-7. 1979.

Pomeroy, W.M. Baseline Marine Environmental Conditions at Port Simpson, B.C. The Site of a Proposed Liquid Natural Gas Plant. EPS Regional Program Report: 82-11.

Swingle, R.B. and J.W. Davidson. Environmental Laboratory Manual. Department of Environment, EPS, 1979.

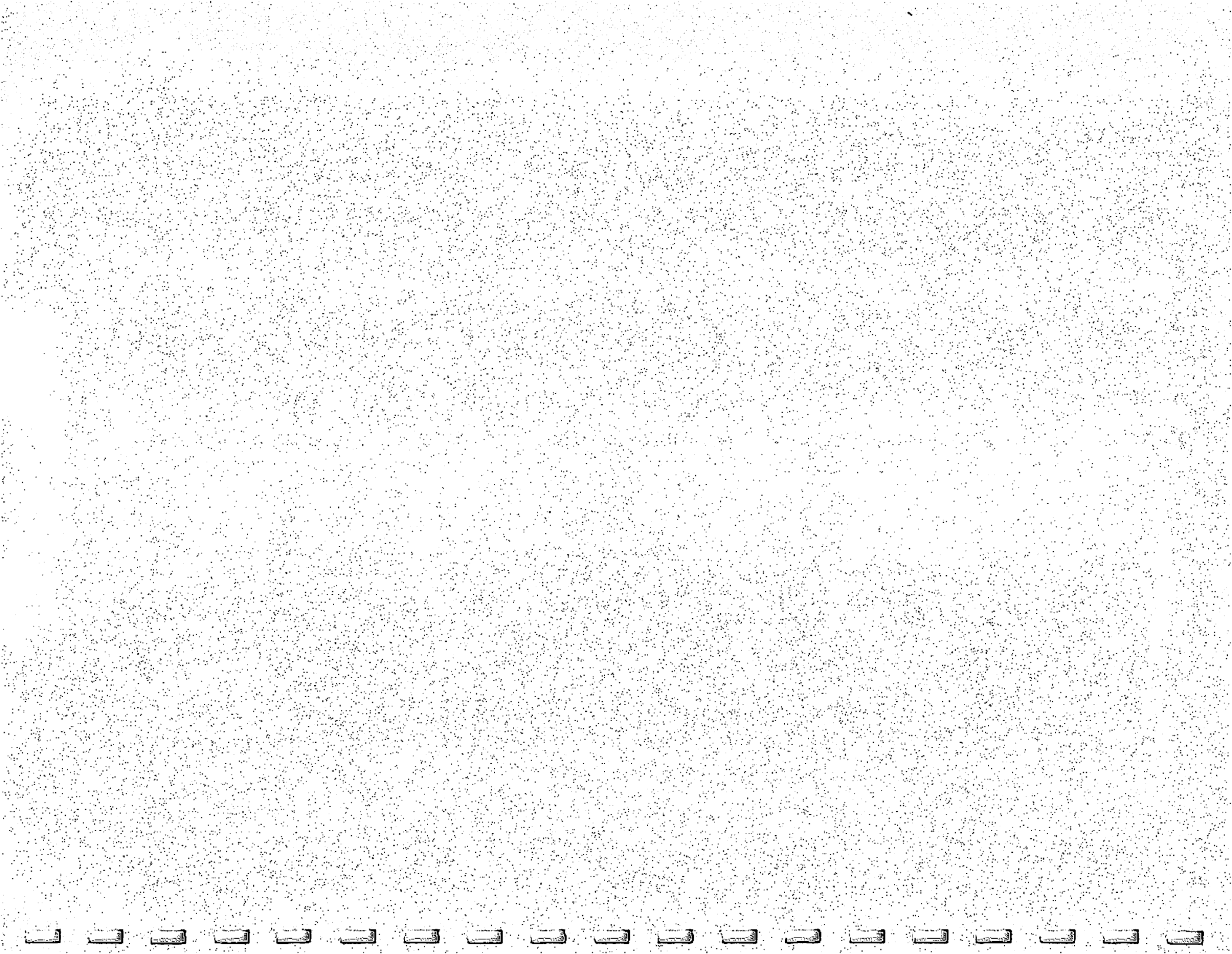
Waldichuk, M. Effects of Sulphite Mill Wastes in a Partially Enclosed Marine System in B.C. J. Water Pollut. Control. 28(9), 1484-1505. 1966.

ACKNOWLEDGEMENTS

The author would like to thank N. Holman, B. Kooi and L. Harding for their assistance in field studies.

The assistance of the officers and crews of the Department of Fisheries and Oceans research ships were invaluable in the successful completion of annual field surveys.

APPENDICES



APPENDIX I

LATITUDE AND LONGITUDE OF SAMPLE STATIONS

APPENDIX I PRINCE RUPERT SAMPLING STATIONS

STATION	LATITUDE	LONGTITUDE
OCEANOGRAPHIC/BENTHIC		
0-1	54° 13.80' N	130° 18.04' W
0-2	54° 13.91' N	130° 18.07' W
0-3	54° 14.04' N	130° 18.10' W
0-4	54° 13.68' N	130° 17.91' W
0-5	54° 13.47' N	130° 17.80' W
PH-1	54° 14.55' N	130° 18.34' W
PH-2	54° 12.51' N	130° 17.72' W
PH-3	54° 13.90' N	130° 18.05' W
P-12	54° 13.22' N	130° 17.63' W
P-17	54° 15.03' N	130° 16.95' W
P-18	54° 14.25' N	130° 18.40' W
P-20	54° 12.10' N	130° 18.30' W
P-29	54° 14.53' N	130° 17.23' W
B-1	54° 14.57' N	130° 18.58' W
B-2	54° 14.53' N	130° 18.73' W
B-3	54° 14.44' N	130° 18.73' W
B-3[1]	54° 14.33' N	130° 18.69' W
B-4	54° 14.39' N	130° 18.40' W
B-5	54° 14.14' N	130° 18.58' W
B-6	54° 14.17' N	130° 18.30' W
B-7	54° 14.13' N	130° 18.10' W
B-9	54° 13.66' N	130° 17.80' W
B-10	54° 13.19' N	130° 17.60' W
B-10[1]	54° 12.96' N	130° 17.48' W
B-13	54° 11.90' N	130° 18.58' W
INTERTIDAL		
I-9	54° 14.57' N	130° 17.03' W
I-10	54° 14.60' N	130° 17.24' W
I-15A	54° 14.45' N	130° 19.04' W
I-16	54° 14.15' N	130° 18.80' W
I-17	54° 13.73' N	130° 18.30' W
I-18	54° 13.39' N	130° 17.89' W
I-19	54° 12.81' N	130° 17.60' W
I-20	54° 12.26' N	130° 17.83' W

APPENDIX II

OCEANOGRAPHIC DATA (1979-1982)

APPENDIX II OCEANOGRAPHIC DATA - June 3, 1979

STATION (Sample time-PST)[a]	DEPTH (m)	TEMPERATURE (°C)	SALINITY (o/oo)	DISSOLVED OXYGEN (mg/l)	% SATURATION
B-13	0	9.35	12.09	12.60	121.89
(1512-	2	9.26	12.84	11.98	116.17
1530)	5	9.17	17.02	11.24	111.56
	10	8.42	25.24	9.84	101.07
	15	8.09	26.08	10.28	105.34
	20	8.01	26.31	10.80	110.62
	25	7.93	26.38	10.91	111.58
P-20	0	9.47	12.16	11.75	114.03
(1540-	2	9.19	12.47	11.86	114.56
1600)	5	9.17	18.26	10.16	101.62
	10	8.92	24.84	9.39	97.35
	15	8.76	26.07	9.92	103.28
	20	8.12	26.27	10.53	108.11
	25	8.01	26.33	10.69	109.51
PH-2	0	9.46	12.40	12.00	116.60
(1607-	2	9.32	13.66	11.85	115.64
1620)	5	9.16	21.44	9.14	93.24
	10	8.84	23.77	8.84	90.84
	15	8.19	25.97	9.85	101.10
	20	8.07	26.15	10.23	104.82
	25	8.00	26.32	10.80	110.60
B-10'	0	9.39	14.71	11.41	112.24
(1435-	2	9.32	16.09	11.59	114.78
1447)	5	9.18	21.45	9.09	92.78
	10	8.92	23.81	8.16	84.04
	15	8.21	25.94	9.59	98.46
	20	8.07	26.18	10.23	104.84
	25	8.07	26.18	10.48	107.40

Continued...

APPENDIX II OCEANOGRAPHIC DATA - June 3, 1979

(Continued)

STATION (Sample time-PST)[a]	DEPTH (m)	TEMPERATURE (°C)	SALINITY (o/oo)	DISSOLVED OXYGEN (mg/l)	% SATURATION
P-12	0	9.41	14.48	11.72	115.18
(1655-	2	9.30	17.98	10.74	107.56
1703)	5	9.09	21.69	8.70	88.75
	10	8.81	24.47	8.89	91.71
	15	8.20	25.93	9.79	100.48
PH-3	0	9.42	15.18	11.89	117.38
(1725-	2	9.31	20.03	9.79	99.33
1736)	5	9.26	21.67	9.18	94.00
	10	9.05	22.77	8.82	90.51
	15	8.58	25.40	9.02	93.10
	20	8.30	25.78	9.20	94.56
P-18	0	9.41	17.03	11.43	114.10
(1753-	2	9.35	19.91	10.11	102.60
1800)	5	9.16	21.77	9.26	94.66
	10	9.03	23.18	8.90	91.52
	15	8.47	25.72	8.35	86.14
PH-1	0	9.47	16.87	11.36	113.44
(1814-	2	9.44	19.15	10.01	101.31
1825)	5	9.20	21.63	8.90	90.99
	10	9.18	23.94	8.35	86.59
	15	8.70	25.23	8.34	86.23
	20	8.22	26.03	8.18	84.05
	25	8.18	26.06	8.53	87.58

[a]low slack - 1335 h 2.3 m
high slack - 2020 h 5.2 m

APPENDIX II OCEANOGRAPHIC DATA - June 4, 1979

STATION (Sample time-PST)[a]	DEPTH (m)	TEMPERATURE (°C)	SALINITY (o/oo)	DISSOLVED OXYGEN (mg/l)	% SATURATION
B-13	0	8.84	13.37	12.35	118.96
(1015-	2	8.83	13.40	12.03	115.89
1030)	5	8.86	18.34	11.32	112.46
	10	8.07	25.75	11.24	114.87
	15	7.96	26.17	11.07	113.14
	20	7.89	26.27	11.30	115.39
	25	7.87	26.33	11.32	115.57
P-20	0	8.96	13.49	12.08	116.99
(1040-	2	9.02	13.81	12.18	118.13
1054)	5	8.90	20.27	11.26	113.33
	10	8.02	25.97	11.25	115.00
	15	7.93	26.20	11.05	112.88
	20	7.91	26.23	11.02	112.54
	25	7.90	26.24	11.38	116.20
PH-2	0	9.12	14.73	11.35	110.96
(1112-	2	9.06	15.74	11.32	111.19
1124)	5	9.00	20.01	10.35	104.24
	10	8.30	25.29	9.32	95.49
	15	8.10	25.93	9.96	101.98
	20	8.00	26.07	10.04	102.65
	25	7.99	26.13	9.97	101.95
B-10'	0	8.98	12.00	11.41	109.36
(1140-	2	9.07	18.26	10.88	108.59
1153)	5	9.24	20.36	9.54	96.84
	10	8.93	23.22	8.43	86.51
	15	8.24	25.53	8.90	91.20
	20	8.04	26.06	9.94	101.72
	25	8.03	26.13	9.60	98.26

Continued...

APPENDIX II OCEANOGRAPHIC DATA - June 4, 1979
(Continued)

STATION (Sample time-PST)[a]	DEPTH (m)	TEMPERATURE (°C)	SALINITY (o/oo)	DISSOLVED OXYGEN (mg/l)	% SATURATION
P-12	0	9.01	11.81	11.56	110.75
(1205-	2	9.12	15.61	10.28	101.04
1218)	5	9.22	19.84	9.97	100.83
	10	8.87	23.67	9.00	92.49
	15	8.39	25.63	9.36	96.32
	20	8.11	25.98	9.33	95.58
PH-3	0	9.20	14.64	11.20	109.64
(1233-	2	9.19	17.64	10.07	100.38
1242)	5	9.21	19.53	9.84	99.30
	10	8.90	23.78	8.42	86.66
	15	8.34	25.78	8.39	86.32
	20	8.13	26.02	9.44	96.78
P-18	0	9.28	16.67	10.83	107.54
(1255-	2	9.28	18.56	10.01	100.57
1302)	5	9.27	19.61	9.80	99.08
	10	8.76	24.41	8.29	85.38
	15	8.36	25.79	8.68	89.35
PH-1	0	9.30	16.96	11.03	109.77
(1314-	2	9.29	18.75	10.12	101.82
1325)	5	9.28	20.58	10.15	103.27
	10	8.89	23.38	9.23	94.73
	15	8.33	25.85	9.23	94.98
	20	8.23	25.96	8.72	89.58
P-17	0	9.33	20.93	10.08	102.91
(1355-	2	9.31	20.94	9.58	97.76
1408)	5	9.25	21.13	9.80	99.99
(Wainwright	10	9.26	21.27	9.08	92.74
Basin Station)	15	9.32	21.65	9.09	93.20
	20	9.30	21.83	9.99	102.50

[a]low slack - 0835 h 4.8 m
high slack - 1435 h 2.4 m

APPENDIX II OCEANOGRAPHIC DATA - August 20, 1980

STATION (Sample time-PST)[a]	DEPTH (m)	TEMPERATURE (°C)	SALINITY (o/oo)	DISSOLVED OXYGEN (mg/l)	% SATURATION
P-20	0	12.21	22.52	9.60	105.66
(1430-	2	11.86	23.60	9.30	102.28
1440)	5	11.87	24.56	8.54	94.52
	10	10.91	26.38	7.82	85.73
	15	10.39	27.07	8.32	90.55
	20	9.95	27.38	8.62	93.07
	25	9.86	27.42	8.38	90.31
PH-2	0	12.40	23.40	9.90	110.03
(1450-	2	12.27	23.99	9.60	106.80
1505)	5	11.97	24.77	8.32	92.42
	10	11.54	25.90	6.80	75.37
	15	10.46	26.83	7.80	84.89
	20	10.02	27.28	8.16	88.18
	25	10.02	27.29	8.52	92.08
P-12	0	12.75	23.36	8.86	99.20
(1530-	2	12.42	24.34	8.08	90.39
1545)	5	12.01	24.72	8.06	89.58
	10	11.82	25.56	6.27	69.77
	15	10.90	26.52	6.04	66.26
	20	10.13	27.19	7.31	79.15
PH-3	0	12.29	25.24	6.21	69.68
(1550-	2	12.23	25.22	6.58	73.72
1605)	5	12.21	25.22	7.63	85.45
	10	12.04	25.40	6.64	74.17
	15	11.21	26.26	5.73	63.19
	20	10.22	27.14	5.68	61.61

Continued...

APPENDIX II OCEANOGRAPHIC DATA - August 20, 1980

(Continued)

STATION (Sample time-PST)[a]	DEPTH (m)	TEMPERATURE (°C)	SALINITY (o/oo)	DISSOLVED OXYGEN (mg/l)	% SATURATION
P-18	0	12.46	25.18	7.02	79.03
(1610-	2	12.42	25.17	7.16	80.53
1620)	5	11.99	25.23	7.16	79.80
	10	11.46	26.02	6.04	66.88
	15	10.82	26.58	5.65	61.90
PH-1	0	12.23	24.73	7.36	82.20
(1630-	2	12.21	25.05	8.52	95.31
1640)	5	12.28	25.14	7.77	87.10
	10	11.80	25.59	6.44	71.65
	15	10.97	26.50	5.65	62.07
	20	10.43	27.00	5.75	62.61
	25	10.30	27.03	5.65	61.35
P-17	0	12.84	25.06	7.30	82.79
(1650-	2	12.51	25.08	7.58	85.37
1700)	5	12.25	25.21	6.25	70.05
	10	12.05	25.30	6.56	73.25
	15	12.06	25.32	6.66	74.39
	20	12.03	25.39	6.25	69.79

APPENDIX II OCEANOGRAPHIC DATA - August 3, 1981

STATION (Sample time-PST)[a]	DEPTH (m)	TEMPERATURE (°C)	SALINITY (o/oo)	DISSOLVED OXYGEN (mg/l)	% SATURATION
B-13	0	12.14	22.31	7.80	85.60
(1005-	1	11.72	23.72	7.55	82.84
1025)	5	11.70	23.91	7.35	80.71
	10	10.81	26.41	7.05	77.13
	20	10.02	27.22	6.85	74.00
P-20	0	12.72	22.49	8.25	91.79
(1030-	1	11.96	23.17	7.60	83.53
1050)	5	11.52	23.88	7.45	81.46
	10	10.49	26.12	7.40	80.22
	20	10.09	27.44	6.80	73.68
PH-2	0	12.39	23.19	8.00	88.77
(1825-	1	12.30	23.89	7.60	84.55
1840)	5	11.73	24.62	7.40	81.68
	10	11.51	25.99	7.40	82.01
	20	10.07	26.77	7.35	79.26
PH-3	0	12.40	24.92	7.70	86.42
(2195-	1	12.13	25.11	7.70	86.02
2201)	5	12.04	25.28	7.60	84.83
	10	11.91	26.07	7.55	84.46
B-10'	0	12.41	22.76	8.00	88.57
(1800-	1	12.03	23.61	7.90	87.21
1810)	5	11.67	26.79	7.70	86.09
	10	11.40	27.01	7.55	84.03
P-12	0	12.83	22.91	7.50	83.87
(1500-	1	12.59	23.54	7.70	86.01
1515)	5	11.90	26.81	7.50	84.29
	10	11.43	27.21	7.35	81.97

Continued...

APPENDIX II OCEANOGRAPHIC DATA - August 3, 1981

(Continued)

STATION (Sample time-PST)[a]	DEPTH (m)	TEMPERATURE (°C)	SALINITY (o/oo)	DISSOLVED OXYGEN (mg/l)	% SATURATION
P-18	0	12.40	22.83	8.00	88.59
(2210-	1	12.02	23.71	7.55	83.38
2220)	5	11.79	26.84	7.10	79.62
	10	11.31	27.49	7.20	80.23
PH-1	0	12.24	22.71	7.70	84.90
(1428-	1	12.32	23.60	7.60	84.43
1435)	5	12.01	26.99	7.50	84.60
	10	11.69	27.09	7.45	83.50
P-17	0	12.71	22.92	8.00	89.24
(1450-	1	12.63	23.94	7.75	86.87
1500)	5	12.04	26.47	7.65	86.05
	10	11.92	27.13	7.68	86.53

[a]low slack - 0940 h 0.7 m
high slack - 1545 h 6.2 m

APPENDIX II OCEANOGRAPHIC DATA - April 29, 1982

STATION (Sample time-PST)[a]	DEPTH (m)	TEMPERATURE (°C)	SALINITY (o/oo)	DISSOLVED OXYGEN (mg/l)	% SATURATION
PH-2	0	6.94	29.216	9.75	99.17
(1330-	2	6.94	29.219	9.60	97.65
1340)	5	6.94	29.228	9.45	96.13
	10	6.95	29.225	9.05	92.08
	25	6.94	29.325	8.80	89.58
B-10'	0	6.95	28.958	9.65	98.01
(1415-	2	6.94	28.985	9.50	96.42
1425)	5	6.94	29.049	9.25	93.98
	10	6.94	29.138	8.90	90.48
	20	6.92	29.242	8.50	86.43
P-12	0	6.93	29.008	9.70	98.50
(1430-	2	6.93	29.014	9.65	98.00
1440)	5	6.92	29.025	9.40	95.44
	10	6.92	29.131	9.05	91.96
	20	6.92	29.367	8.80	89.56
P-18	0	7.26	28.731	9.35	95.55
(1550-	2	7.16	28.805	9.05	92.30
1600)	5	7.01	28.876	9.00	91.50
	10	6.93	28.928	8.90	90.33
	15	6.92	28.999	8.70	88.32
0-1	0	7.30	28.605	9.90	101.18
(1530-	2	7.12	28.838	9.75	99.36
1540)	5	7.02	28.923	8.90	90.53
	10	6.93	29.015	8.60	87.34
	20	6.93	29.131	9.00	91.47
0-2	0	7.34	28.631	9.45	96.70
(1540-	2	7.04	28.937	9.14	93.03
1545)	5	7.00	28.962	8.95	91.02
	10	6.95	29.018	8.70	88.40

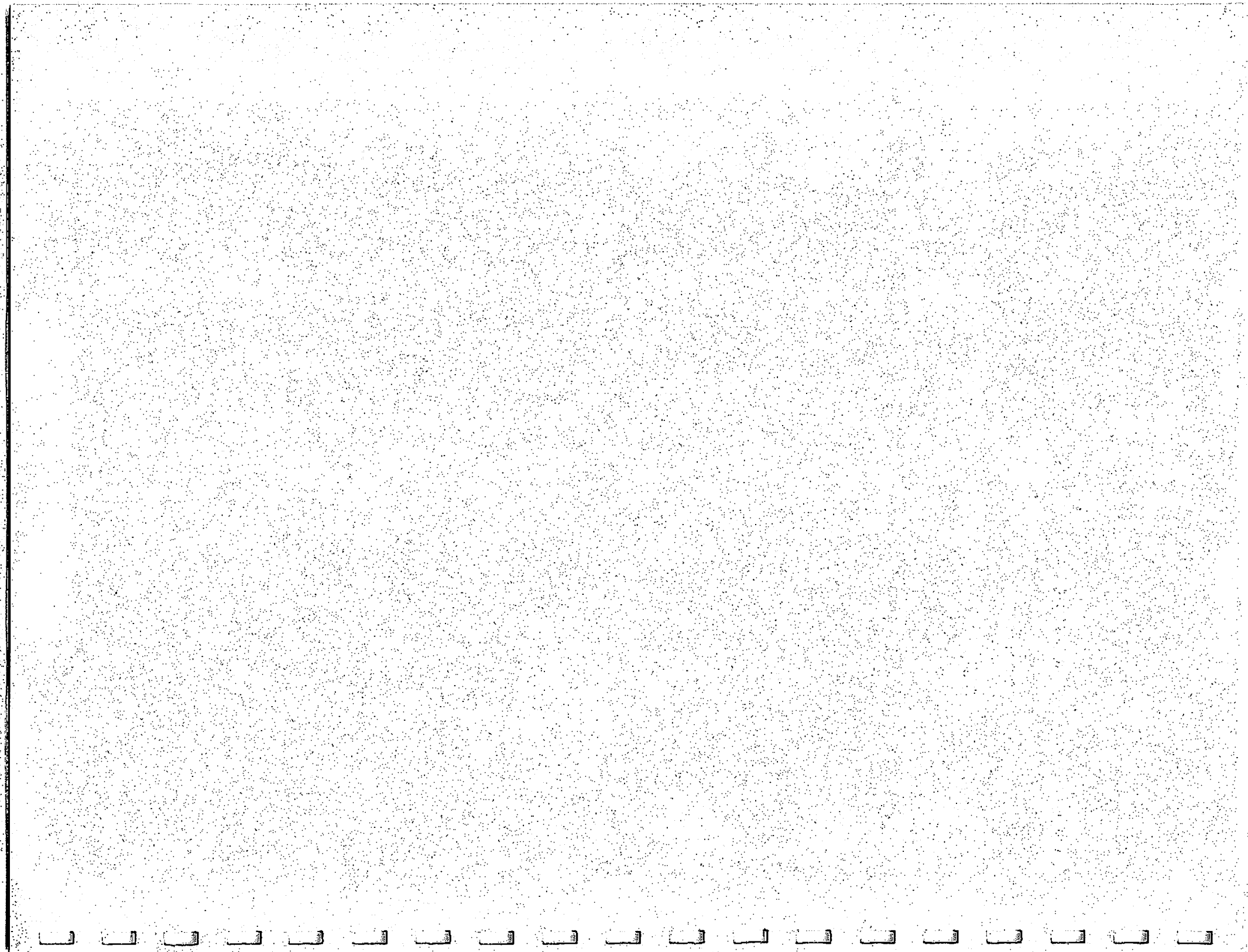
Continued...

APPENDIX II OCEANOGRAPHIC DATA - April 29, 1982

(Continued)

STATION (Sample time-PST)[a]	DEPTH (m)	TEMPERATURE (°C)	SALINITY (o/oo)	DISSOLVED OXYGEN (mg/l)	% SATURATION
0-4	0	7.10	28.877	9.30	94.76
(1450-	2	7.02	28.922	9.25	94.09
1500)	5	6.98	28.942	8.95	90.96
	10	6.92	29.050	8.75	88.86
	20	6.91	29.165	8.80	89.41
0-5	0	6.96	28.962	9.70	98.55
(1440-	2	6.96	28.963	9.40	95.50
1450)	5	6.94	28.976	8.95	90.90
	10	6.92	29.032	8.90	90.37
	15	6.92	29.122	8.90	90.43

[a]low slack - 1035 h 4.8 m
high slack - 1605 h 3.0 m

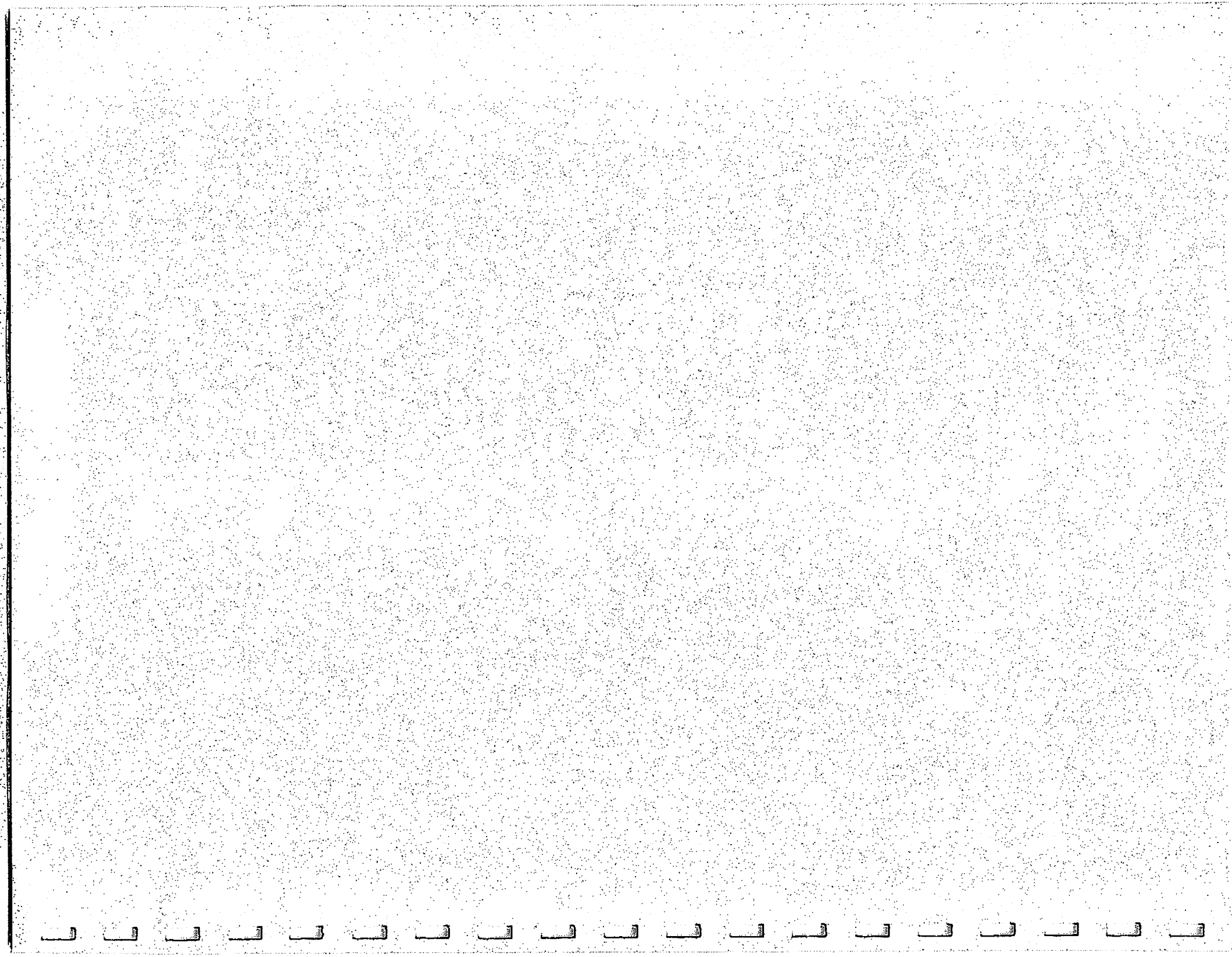


APPENDIX III

VISUAL CHARACTERISTICS OF SEDIMENT GRAB SAMPLES

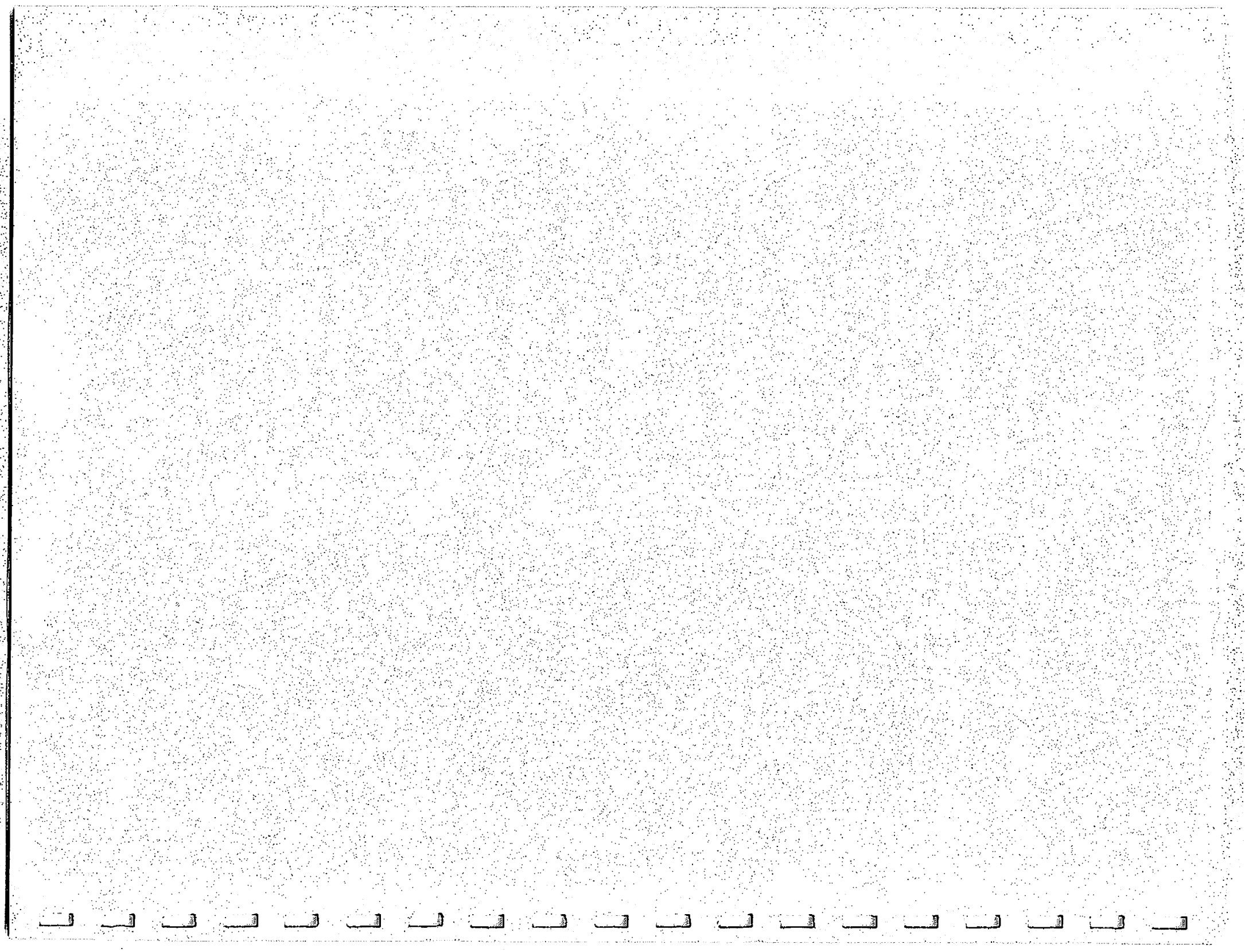
APPENDIX III VISUAL CHARACTERISTICS OF SEDIMENTS - June 3, 1979

STATION	DEPTH (m)	VISUAL DESCRIPTION
B-1	10	Black mud with reducing fibre.
B-2	25	Rocky - no sample.
B-3	19	Rocky - no sample.
B-4	18	Black reducing mud and fibre plus coarse wood debris.
B-5	16	Black reducing mud, fibre and bark.
B-6	18	Strongly reducing mud and fibre - some capitellids present.
B-7	20	Strongly reducing mud and fibre - some capitellids present.
B-8	26	Black reducing mud with a few polychaetes present.
B-9	17	Black reducing mud and fibre, H_2S odour.
B-10	24	Black reducing mud with some stones (= 8 cm); 1 amphipod noted; strong H_2S odour.
B-10[1]	31	Shale and rocks.
B-11	28	Shale - little or no mud.
B-12	30	Shale - little or no mud - scallops and empty shells also in sample.
B-13	33	Sandy silt, small wood fibres.



APPENDIX III VISUAL CHARACTERISTICS OF SEDIMENTS - August 20, 1980

STATION	DEPTH (m)	VISUAL DESCRIPTION
B-1	12	Black reducing sediments, fibre present.
B-2	22	Rocky substrate - no mud.
B-4	17	Black reducing sediment - fibre and wood debris.
B-5	16	Black reducing sediment, fibre and wood debris.
B-6	17	Strongly reducing sediments - fibre present.
B-7	20	Strongly reducing fine sediments - fibre present.
B-8	20	Strongly reducing sediment - fibre present.
B-9	15	Black reducing sediment - fibre present.
B-10	24	Black reducing sediment - some stones present.
B-10[1]	28	Brown sediments, shale and rocks.
B-11	26	Rocky, little sediment in sample.
B-12	28	Rocky, little sediment in sample.
B-13	20	Fine reducing layer over sand substrate, fibres present.
B-38	75	Fine sedimens, no H_2S evident.
WRB-1	75	Fine reducing sediments.



APPENDIX III VISUAL CHARACTERISTICS OF SEDIMENTS - August 3, 1981

STATION	DEPTH (m)	VISUAL DESCRIPTION
B-1	15	Black mud, H_2S smell. Very little wood debris.
B-4	18	Fine black mud, H_2S smell. Light brown surface layer, little wood debris.
B-5	20	Fine black mud with pieces of bark and wood.
B-6	16	Fibrous black mud, H_2 smell. Lighter brown surface layer. Little wood debris.
B-7	22	Fibrous, oozy, black mud with H_2S smell.
0-3	20	As per B-7 with more fibre.
0-2	20	As per B-7.
0-1	13	As per B-7.
B-9	14	Black, fibrous mud with H_2S smell.
B-10	26	Surface layer of light brown overlying black mud. The latter contains shell fragments, pieces of wood, bark and shale. H_2S smell.

APPENDIX IV

SURFACE SEDIMENT PARTICLE SIZE DISTRIBUTION

APPENDIX IV SEDIMENT PARTICLE SIZE DISTRIBUTION, June 3,1979

STATION	PARTICLE SIZE DISTRIBUTION			
	> 500 um	500-250 um	250-62.5 um	< 62.5 um
B-4	11.4	21.4	27.4	39.8
B-5	5.9	27.9	32.0	34.2
B-6	3.3	16.1	38.4	43.2
B-7	3.2	18.2	37.5	41.1
B-8	9.7	14.2	40.3	35.8
B-9	1.8	18.0	38.7	41.4
B-10	64.5	8.1	16.2	11.2
B-13	2.5	23.2	50.5	23.7

APPENDIX IV SEDIMENT PARTICLE SIZE DISTRIBUTION, August 21,1980

STATION	PARTICLE SIZE DISTRIBUTION			
	> 500 um	500-250 um	250-62.5 um	< 62.5 um
B-4	26.0	20.1	37.5	16.4
B-5	20.0	18.9	38.1	23.0
B-6	12.5	10.9	53.1	23.5
B-7	20.9	19.7	41.0	18.4
B-8	16.0	19.3	31.0	33.7
B-9	7.6	17.1	35.4	39.9
B-10	41.8	19.0	32.2	7.0
B-13	14.9	18.8	45.2	21.1

APPENDIX IV SEDIMENT PARTICLE SIZE DISTRIBUTION, August 4, 1981

STATION	PARTICLE SIZE DISTRIBUTION			
	> 500 um	500-250 um	250-62.5 um	< 62.5 um
B-2	1.8	9.7	41.3	47.2
B-4	37.3	22.7	22.1	17.8
B-5	29.1	23.1	26.5	16.3
0-2	1.8	7.9	39.7	38.9
0-3	7.2	16.0	46.2	30.5
0-4	7.1	8.3	46.5	38.1
0-5	8.0	8.9	41.6	41.5

APPENDIX V

SURFACE SEDIMENT TRACE METAL DATA

APPENDIX V SEDIMENT TRACE METAL DATA, June 3, 1979

STATION	Cd (ppm)	Cu (ppm)	Fe (%)	Mn (ppm)	Ni (ppm)	Pb (ppm)	Zn (ppm)	Cr (ppm)	Hg (ppm)
B-1	< 1.24	43.95	3.10	444.5	29.6	< 9.95	99.35	41.85	0.503
B-4	< 1.18	50.0	3.37	487.5	33.95	< 9.46	110.0	37.20	0.366
B-5	1.49	48.45	3.26	480.5	29.6	< 9.63	104.0	39.2	1.460
B-6	1.2	39.0	3.15	460.5	27.85	< 9.62	99.75	38.30	0.293
B-7	< 1.16	43.0	3.33	471.0	27.5	< 9.30	103.00	39.65	0.425
B-8	< 1.23	37.0	3.26	465.0	28.45	< 9.80	95.05	34.7	0.413
B-9	< 1.15	44.8	3.30	461.0	30.75	< 9.24	102.50	38.25	0.459
B-10	< 1.15	35.0	3.36	465.5	28.9	< 9.24	93.60	35.70	0.287
B-11[1]	1.18	37.3	3.48	483.0	27.8	< 9.43	98.00	36.70	0.813
B-13	< 1.19	30.6	3.60	516.5	24.45	< 9.52	83.35	31.05	0.234

APPENDIX V SEDIMENT TRACE METAL DATA, August 21, 1980

STATION	Cd (ppm)	Cu (ppm)	Fe (%)	Mn (ppm)	Ni (ppm)	Zn (ppm)
B-1	1.60	66.0	3.42	460.0	29.3	146.0
B-2	< 1.21	45.0	3.07	441.0	27.4	91.5
B-4	< 1.24	41.5	3.84	510.0	32.2	110.0
B-5	1.48	65.0	3.60	520.0	37.2	117.0
B-6	1.31	46.1	3.27	474.0	31.0	98.5
B-7	< 1.30	69.0	4.22	489.0	36.6	193.0
B-8	1.62	51.5	3.70	499.0	32.6	114.0
B-9	< 1.25	49.7	3.37	480.0	32.8	93.5
B-10	< 1.24	43.6	3.59	500.0	30.6	104.0
B-10[1]	< 1.24	40.6	3.52	480.0	32.0	93.0
B-11[1]	< 1.22	47.6	3.69	498.0	32.6	105.0
B-12	< 1.24	41.0	3.69	525.0	31.8	96.5
B-13	< 1.21	26.5	3.46	460.0	26.7	81.0
WRB-1	5.15	59.5	3.31	483.0	33.4	119.0

APPENDIX V SEDIMENT TRACE METAL DATA, August 4, 1981

STATION	Cd (ppm)	Cu (ppm)	Fe (%)	Mn (ppm)	Ni (ppm)	Pb (ppm)	Zn (ppm)	Hg (ppm)
B-1	1.6	41.4	3.08	458.0	20.9	12.1	103.0	0.24
B-4	1.9	47.6	3.50	512.0	25.5	9.4	107.0	0.27
B-5	2.0	49.4	3.50	529.0	33.9	12.5	111.0	0.24
B-6	2.2	39.8	3.34	489.0	25.4	9.4	94.9	0.21
B-7	1.1	40.5	3.30	488.0	22.2	8.7	95.9	-
B-9	1.1	40.1	3.36	472.0	19.9	9.6	91.0	0.21
B-10	1.3	39.0	3.58	495.0	22.3	8.7	89.8	0.22
0-1	1.7	42.0	3.45	508.0	21.4	9.9	91.9	0.24
0-2	1.2	54.4	3.56	520.0	26.3	9.7	92.9	0.25
0-3	1.8	47.8	3.37	514.0	34.4	11.2	103.0	0.24
0-4	1.1	42.2	3.40	523.0	29.7	9.4	94.5	0.25
0-5	1.2	41.8	3.21	504.0	24.6	9.1	86.2	0.23

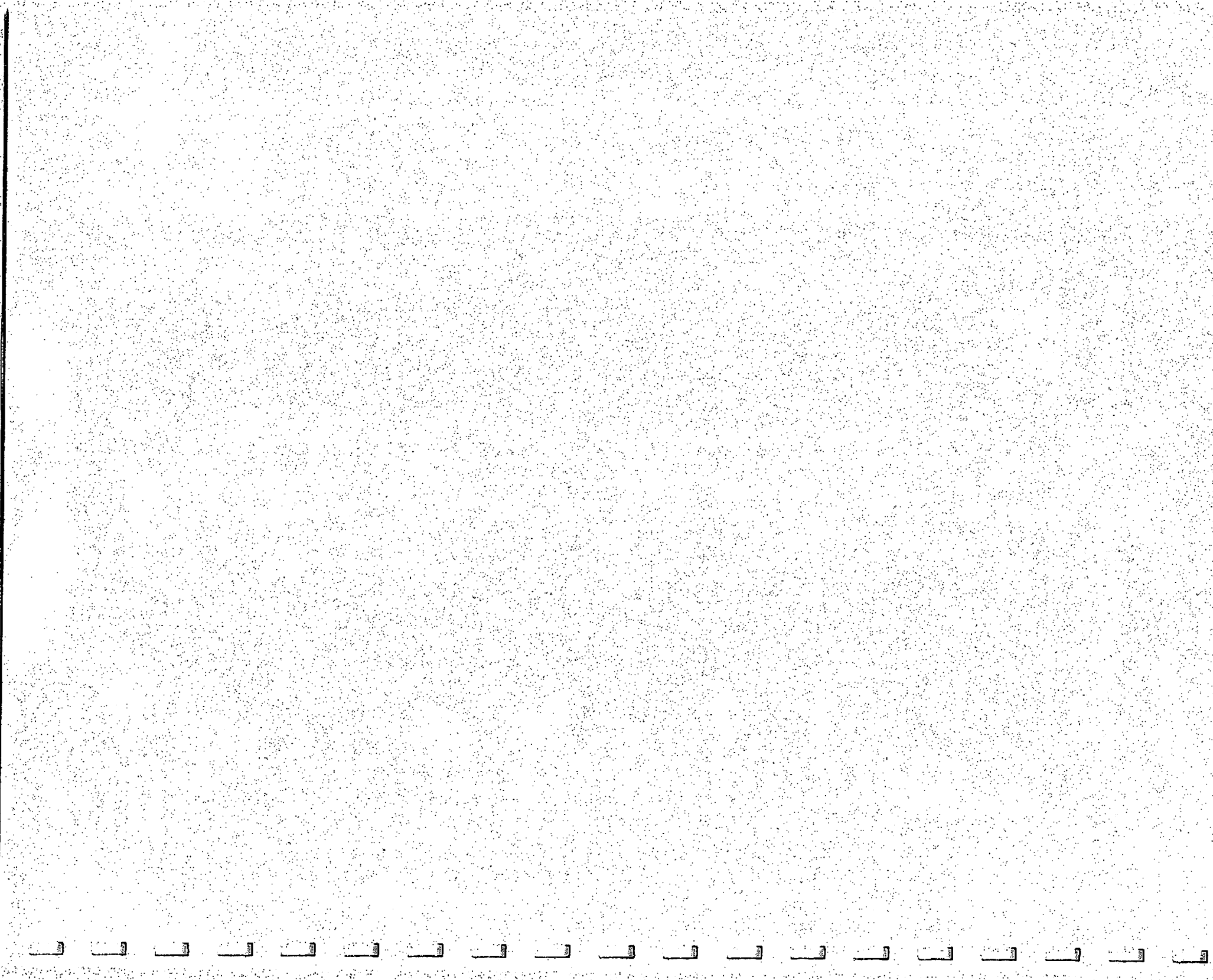
APPENDIX VI

BENTHIC INFAUNA REMOVED FROM GRABS TAKEN AUGUST 3, 1981

APPENDIX VI BENTHIC INFAUNA REMOVED FROM SEDIMENT GRABS TAKEN AUGUST 3, 1981
Number in 3 litres of sediment

TAXA	STATIONS									
	01	02	03	B1	B4	B5	B6	B7	B9	B10
Nematoda	V.A.[a]	V.A.[a]	V.A.[a]	pa	A[a]	pa	pa	pa	A[a]	pa
Nemertea		4								2
Annelida										
Harmothoe imbricata										8
Peisidice aspera										4
Eteone longa		2	18		11		6	3	4	2
Phyllodoce groenlandica										8
Microphtalmus sp.				4			12		4	2
Autolytus sp (juv.)[b]				4						
Exogone verugera										6
Syllis adamantea adamantea							4			
Nereis sp (juv.)				4						4
Nereidae sp. (dam.)[c]					1					
Nephtys sp.										4
Glycera siphonostoma										2
Glycera sp. (juv.)		1								18
Lumbrinereis luti										26
Schistomeringos rudolphi					1					
Ophryotrocha puerilis										24
Dorvilleidae sp. (dam.)				4						
Orbiniidae sp. (juv.)										4
Prionospio cirrifera			2	4	1			2	4	362
Prionospio steenstrupi										2
Chaetozone sp. (dam.)				8				2		
Cirratulidae sp. I								1	4	
Cirratulidae spp. (dam.)										8
Capitella capitata	2744	1247	780	28	46	730	896	743	3376	274
Mediomastus sp.										44
Maldanidae spp. (dam.)										2
Armandia brevis					3					10
Abarenicola pacifica		1					1			
Asabellides sibirica										2
Ampharete finmarchica										2
Polycirrus sp. (dam.)										8
Laonome kroyeri										2
Oriopsis minuta				4						4
Oligochaeta			4				4		8	18

Continued...



APPENDIX VI BENTHIC INFAUNA REMOVED FROM SEDIMENT GRABS TAKEN AUGUST 3, 1981
Number in 3 litres of sediment
(Continued)

TAXA	STATIONS									
	01	02	03	B1	B4	B5	B6	B7	B9	B10
Mollusca										
Lucinoma tenuisculpta										4
Tellinidae sp. (dam.)		4	16	20						
Macoma sp. (dam.)	5				12	1	11	11	12	40
Cardiidae sp. (juv.)			2				12			2
Bivalve sp. I (dam.)	1									
Arthropoda										
Ostracoda spp.										2
Leptostraca										
Nebalia pugettensis		28	80	112	2	164				
Cumacea										
Diastylis sp.								2		
Leptostylis sp.			4							
Oxyurostylis pacifica				4			4			
Tanaidacea										
Anatanais normani		4								
Leptochelia dubia			2							
Isopoda										
Limnoria liguorum			4	4	1	4				
Valvifera sp. I								1		
Isopoda sp. I								1		
Amphipoda										
Atylus collingi		8	6				28	7		
Aoroides spinosus			66	24			4	1		6
Melita dentata										50
Anisogammarus pugettensis						20				2
Amphipoda sp. I		12	10		4	4	8	8		4
Amphipoda sp. (dam.)			36	144		20		2		16

Continued...

APPENDIX VI BENTHIC INFAUNA REMOVED FROM SEDIMENT GRABS TAKEN AUGUST 3, 1981
Number in 3 litres of sediment
(Continued)

TAXA	STATIONS									
	01	02	03	B1	B4	B5	B6	B7	B9	B10
Decapoda										
Natantia sp. (dam.)								1		
Pinnixa sp. (dam.)								1		
Total # of Taxa	4	11	15	15	11	8	13	16	8	37
Total # of individuals	2750	1311	1030	368	82	943	990	786	3412	978

[a] - V.A. = very abundant > 1000
- A = abundant < 1000
- P = present > 100

[b] = juvenile

[c] = damaged specimens