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Environmental Surveillance in the Vicinity of the Canadian Cellulose Co. Ltd. Pulpmill at Prince Rupert, British Columbia.

Surveillance Report
EPS 5-PR-77-8

Pacific Region
May, 1977

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ENVIRONMENTAL SURVEILLANCE IN THE VICINITY OF THE CANADIAN CELLULOSE CO. LTD. PULPMILL AT PRINCE RUPERT, BRITISH COLUMBIA

by

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ABSTRACT

Two surveys were undertaken in the Prince Rupert area in 1974 in order to determine the impact of spent sulphite liquor disposal into Chatham Sound. A re-examination of oceanographic conditions in Wainwright Basin and Porpoise Harbour relative to kraft and other mill discharges in these areas was also undertaken. Watercolumn temperature, salinity, and dissolved oxygen were examined at all stations in Chatham Sound, Porpoise Harbour, and Wainwright Basin. In addition, an examination of benthic invertebrate populations was conducted at some of the stations in Chatham Sound as well as a brief assessment of intertidal communities in the area of the spent sulphite discharge.

Chatham Sound water quality appeared unaffected by the spent sulphite liquor discharge as reflected by the high dissolved oxygen values and temperature/salinity values which were typical of the area. Spent sulphite liquor was however very apparent in the surface water of Chatham Sound extending as far north as Prince Rupert Harbour and as far south as Coast Island turning the water a coffee brown colour. Benthic species diversity in Chatham Sound was unchanged except in the immediate vicinity of the spent sulphite liquor discharge where it was depressed. Visible damage to the intertidal zone attributable to the discharge of spent sulphite liquor was found to extend up to 0.25 nautical miles on either side of the discharge outlet. The dissolved oxygen concentrations in Porpoise Harbour were determined to be low (down to 3.3 mg/l) but not as low as previously recorded (0.5 mg/l; Waldichuk, 1962).

RESUMÉ

En 1974, on a entrepris deux études dans la région de Prince Rupert pour déterminer l'effet des liqueurs usées de bisulfite déversées dans le passage Chatham. On a également procédé à un nouvel examen des donditions océanographiques de la baie Wainwright et du havre Porpoise où se déversent les effluents d'usines de papier Kraft ou autres. On a mesuré la température de la masse d'eau verticale, la salinité et l'oxygène dissous à toutes les stations du passage Chatham, du havre Porpoise et de la baie Wainwright. On a, en outre, étudié les populations d'invertébrés benthiques à certaines stations du passage Chatham et évalué sommairement les communautés intercotidales dans la zone de déversement du bisulfite usé. Cet effluent n'a pas semblé avoir modifié la qualité de l'eau du passage Chatham, comme l'indiquaient le fort taux d'oxygène dissous et les indices de température et de salinité, qui étaient typiques de la région. Cependant, la liqueur usée de bisulfite était très visible à la surface du passage Chatham; elle s'étendait jusqu'au port de Prince Rupert au nord et jusqu'à l'île Coast au sud, donnant à l'eau une couleur brun café. Le nombre des espèces benthiques dans le passage Chatham était inchangé, sauf dans le voisinage de la décharge d'où s'écoule la liqueur de bisulfite usé, où il avait diminué. On a observé, dans la zone intercotidale, des dégâts dus au bisulfite usé; ils s'étendaient jusqu'à 0.25 mille marin de chaque côté de la décharge. Au havre Porpoise, on a noté que les concentrations d'oxygène dissous étaient faibles (3.3 mg/l), mais pas autant que celles enregistrées auparavant (0.5 mg/l: Waldichuk 1962).

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CONCLUSIONS

1. Watercolumn dissolved oxygen concentrations in Porpoise Harbour ranged from 9.7 mg/l in the surface water near Flora Bank to 3.3 mg/l at the 5 metre depth at the upper end of Porpoise Harbour (PH-1).

2. There appeared to be an intrusion of water with a low dissolved oxygen content into the upper end of Porpoise Harbour from Wainwright Basin via Zanardi Rapids.

3. From the parameters examined (i.e., temperature, salinity, and dissolved oxygen), the water quality in Chatham Sound appeared unaffected by the spent sulphite liquor discharge.

4. The spent sulphite liquor was observed to spread as far south as the vicinity of Coast Island and as far north as Casey Point, while the effluent was being discharged via an open submarine pipe in the center of "Discharge Cove".

5. Benthic species diversity was high (up to 3.302) in Chatham Sound with the exception of Discharge Cove, where a diversity value of 1.429 was recorded. A definite reduction in community composition was observed in the vicinity of the outfall.

6. Considerable damage to the intertidal biota was evident in "Discharge Cove". The area directly adjacent to the outfall was observed to be completely sterile with the substrate composed of bare rocks and reduced sediments. Considerable fibrous material was evident on the exposed shore at low tide at the time of inspection. Damage to the intertidal zone resulting from the red liquor discharge was observed to extend approximately 0.25 nautical miles (456 m) on either side of the discharge.

1 INTRODUCTION

1.1 Intent of Survey

A survey of the marine receiving environment adjacent to the Cancel pulp mill owned by Canadian Cellulose Company Ltd. in Prince Rupert, B.C., was undertaken by the Marine Studies group of the Environmental Protection Service in the summer of 1974. Two field trips were made to the area, one in the period July 8 to 12 and a second from August 5 to 9.

The purpose of these surveys was to examine the effects of discharges from the Cancel pulp mill on the adjacent marine environment. Of special interest was the fact that a new extension and diffuser were being installed by Cancel on the end of their Ridley Island spent sulphite liquor pipeline. It was felt that it would be of value to assess the impact of the installation and operation of the diffuser on the environmental quality of Chatham Sound.

Physical oceanographic parameters investigated at all stations included temperature, salinity, and dissolved oxygen. A cursory examination of the subtidal and intertidal invertebrates in the Chatham Sound area was also made.

1.2 Study Area

Prince Rupert is located on the north coast of British Columbia near the mouth of the Skeena River (Figure 1). It is at the eastern extremity of the Dixon Entrance - Chatham Sound system on Kaien Island.

The Cancel pulp mill is 5.5 miles south of the City of Prince Rupert on Watson Island, being separated from the city by a mountain approximately 2,000 ft (610 m) in height (Hays Mountain). The pulp mill is located on a series of partially enclosed embayments; Morse Basin, Wainwright Basin, and Porpoise Harbour, which are connected with one another by constricted turbulent passages (Figure 1). Although there is considerable tidal flow through this system, flushing is drastically reduced by a series of shallow sills connecting the embayments.

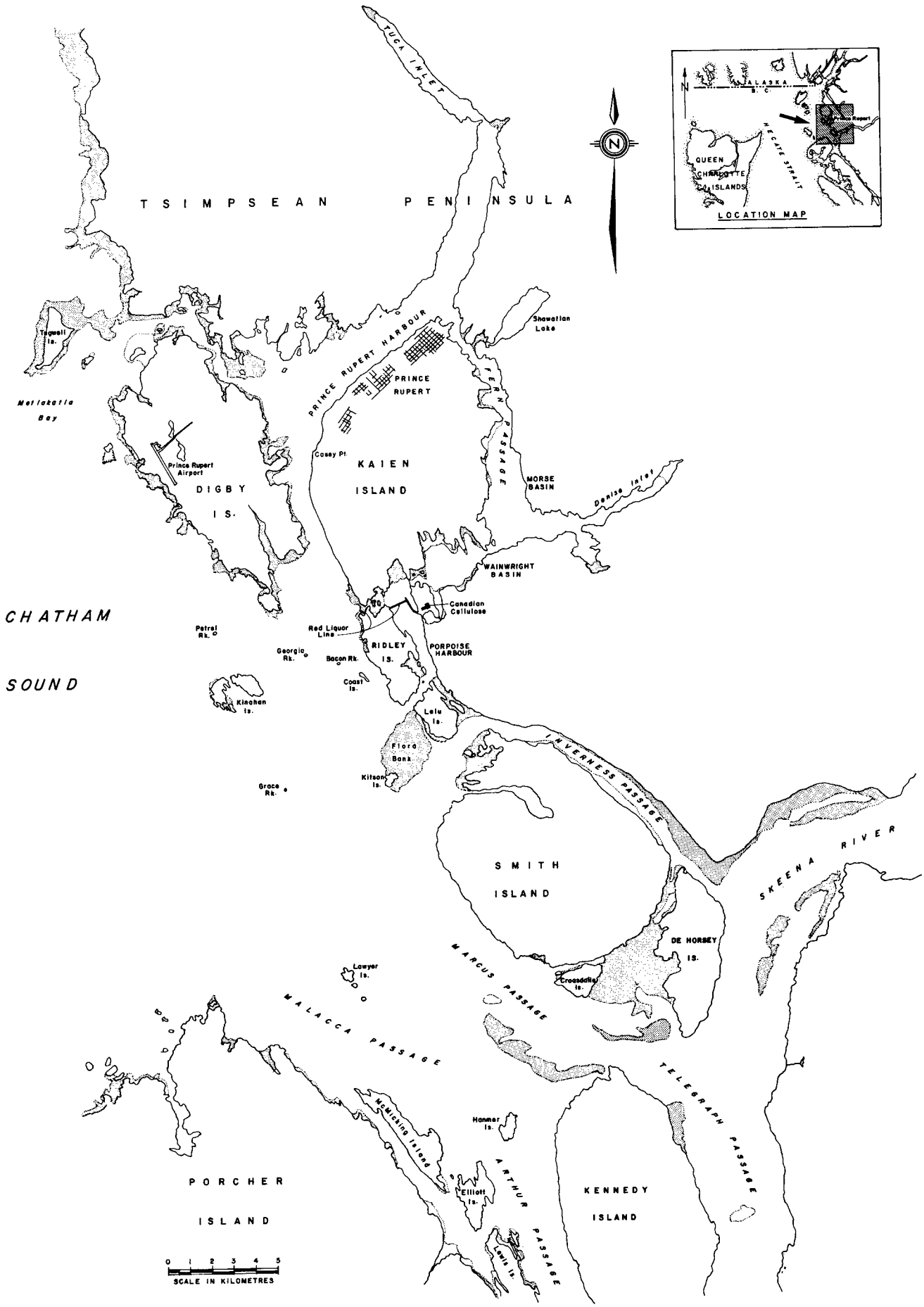

FIGURE 1 STUDY AREA

The pulp mill is separated from Chatham Sound by Ridley Island. Chatham Sound has been described as a semi-enclosed basin of water with an area of 600 square miles (Trites, 1956). Flushing is good in the vicinity of Ridley Island with current velocities up to 1.2 knots present at certain tidal stages.

1.3 Climate

The climate of the Prince Rupert area is a modified maritime climate. Monthly mean temperatures range from 1.8°C in January to 13.5°C in July. The mean annual precipitation is 95.06 inches (241.45 cm). The prevailing winds are from the southeast with an annual mean velocity of 7.1 mph (Hoos, 1975).

1.4 Cancel

The Cancel pulp mill was established in 1950 as a 500 tons/day (TPD) sulphite mill with the original discharge being into Wainwright Basin and Porpoise Harbour via settling ponds (Figure 2). In 1967, a 750 TPD full bleached kraft mill was established. Concurrent with this installation, a study of discharge methods was conducted by the British Columbia Research Council in which it was recommended that the spent sulphite liquor discharged from the old sulphite mill should be piped across Porpoise Harbour and Ridley Island to effect a discharge into Chatham Sound. This pipeline was constructed in 1968. The discharge locations at the time our present surveys were conducted were as shown in Figure 2 (Ker, Priestman, Keenan, and Associates, 1970).

The sulphite mill at the time of sampling was producing 188,000 tons of pulp per year while the kraft mill was producing 290,000 tons per year.

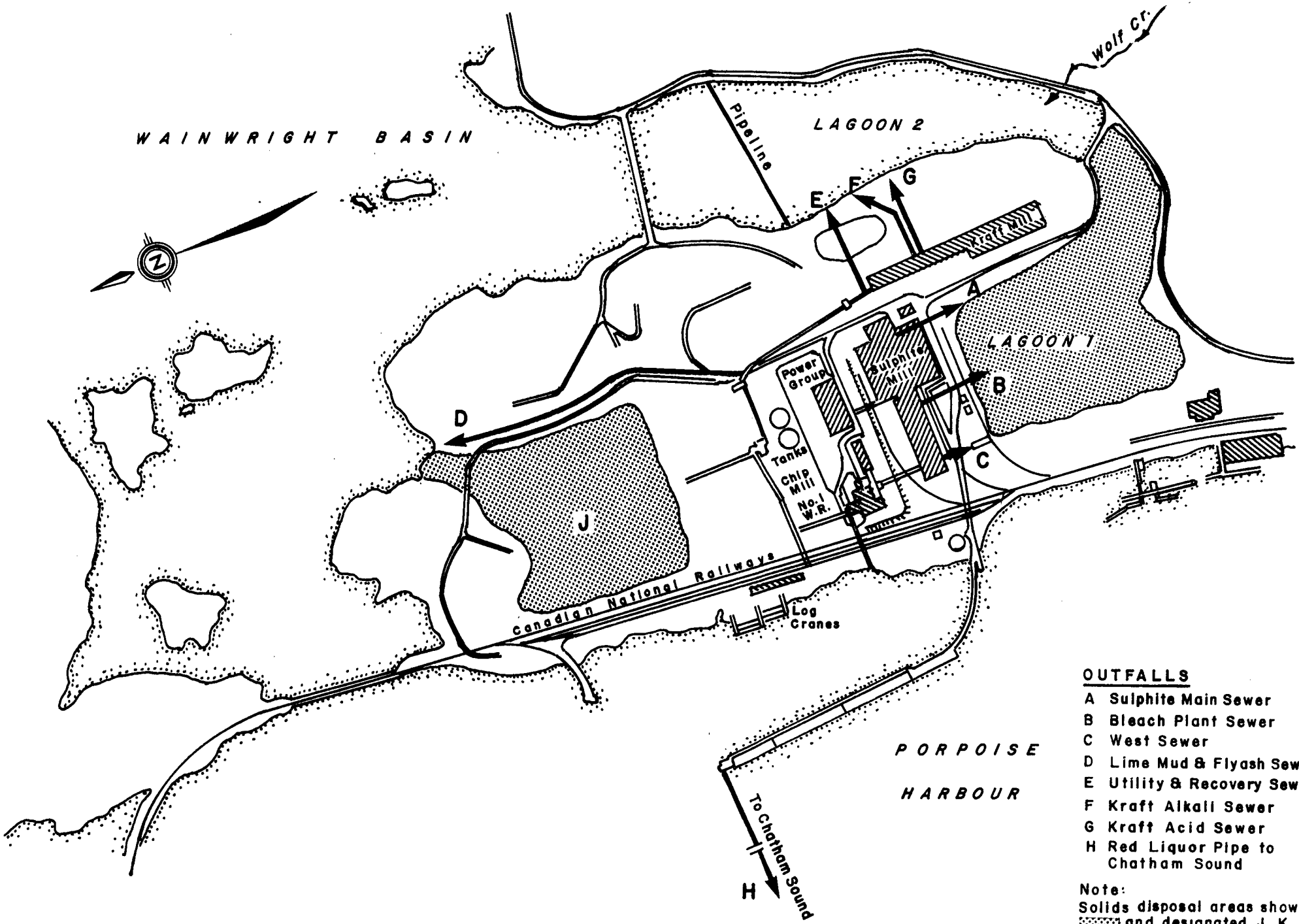

FIGURE 2 CANCEL PULPMILL OUTFALLS

Effluent volumes discharged at the time of sampling were as follows:

Source	Discharge Location	Volume (IGD)
Woodroom	Porpoise Harbour	2,300,000
Sulphite Mill	Wainwright Basin	32,000,000
Kraft Mill	Wainwright Basin	29,000,000
Sulphite Mill	Chatham Sound	3,600,000

(Hoos, 1975)

Cancel has historically had a number of pollution problems stemming primarily from the poor flushing characteristics of Morse Basin, Wainwright Basin and Porpoise Harbour. Low dissolved oxygen values were first noted by Stokes (1953). Values as low as 3.8 mg/l in the deep water of the central portion of Porpoise Harbour and 4.4 mg/l in Wainwright Basin were obtained. Waldichuk (1962) found dissolved oxygen values as low as 0.5 mg/l just off the pulp mill in Porpoise Harbour in the intermediate depths. A short history of Cancel's pollution problems is provided in an E.P.S. memo by Holman (1973).

2 METHODS AND MATERIALS

Two surveys of the study area were undertaken, during the periods July 8 to 12, 1974, and August 5 to 9, 1974. The initial survey included oceanographic sampling at stations in Porpoise Harbour and Wainwright Basin (Figure 3), benthic sampling at selected Chatham Sound stations, and a brief intertidal survey in the vicinity of "Discharge Cove" on Ridley Island (Figure 4). The second survey involved oceanographic sampling at the Porpoise Harbour and Chatham Sound stations. All stations were established by means of horizontal sextant angles subsequently plotted with a Douglas protractor.

2.1 Oceanographic Sampling

In the first survey, oceanographic sampling was conducted at the stations off Flora Bank in Porpoise Harbour and in Wainwright Basin (Figure 3). Four of these stations, P-20, P-12, P-18, and P-17 were established by Waldichuk in 1961 (Waldichuk, 1962) while the remaining two were new stations established by the Marine Studies Group. Sampling was conducted on a rising tide in order to maximize the effects of the pulp mill discharge.

In the second survey, oceanographic sampling was conducted at all Porpoise Harbour stations with the exception of P-17. This sampling was again completed on a rising tide. All of the stations in Chatham Sound were sampled on both flood and ebb tides to determine the effects of the red liquor discharge on the water quality in Chatham Sound at varying stages in the tidal cycle.

The water samples were obtained with Nansen bottles at standard oceanographic depths to the bottom at all stations. Temperatures were determined using standard centigrade thermometers placed in the samples immediately upon their arrival at the surface. Salinity was measured using

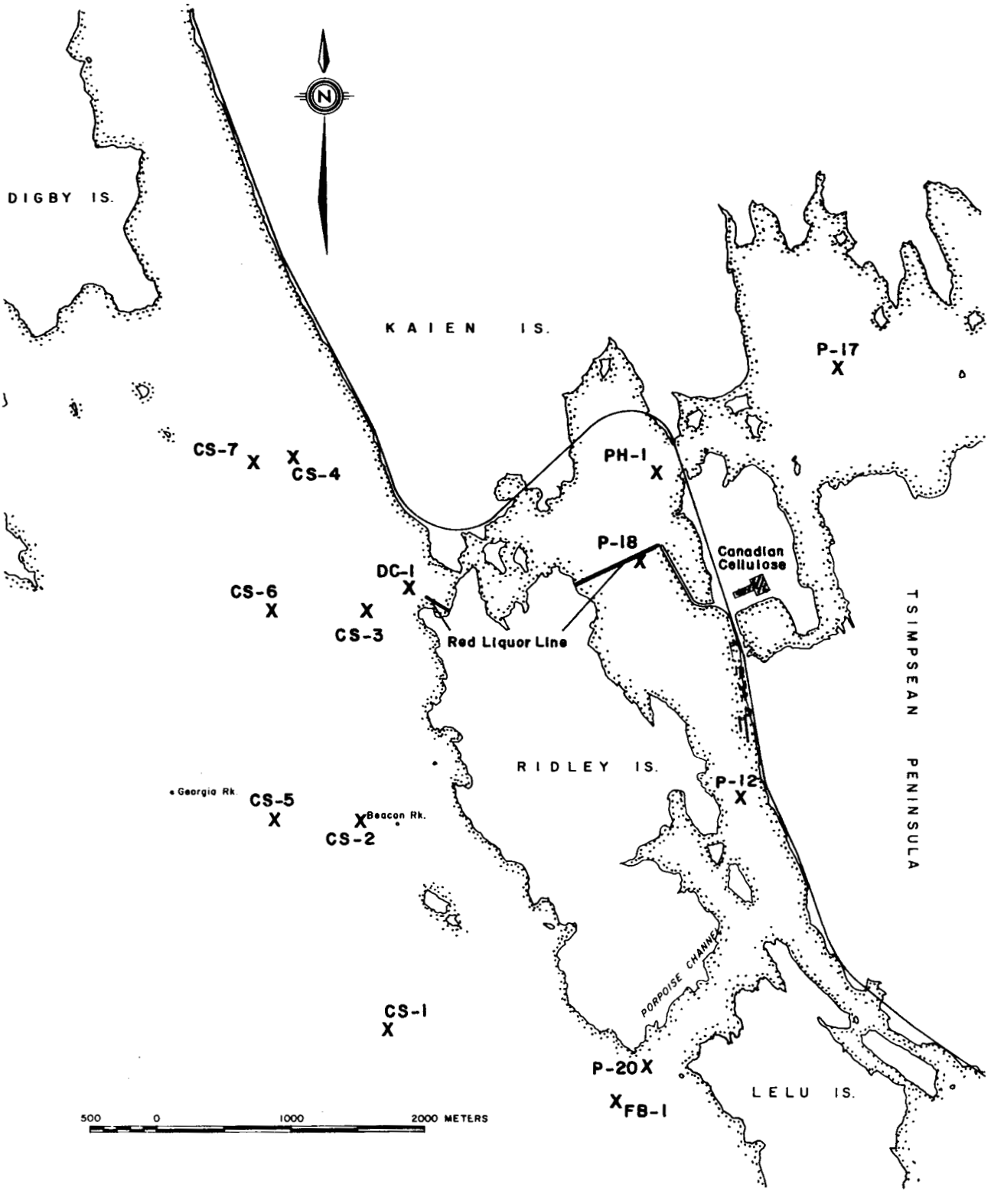

FIGURE 3 OCEANOGRAPHIC SAMPLE STATIONS

a refractometer previously calibrated by hydrometric and electroconductivity techniques. Dissolved oxygen content was measured using the azide modification of the Winkler technique (Davidson et al, 1974). The percent saturation of oxygen was calculated according to the equation of Gameson and Robertson (1955).

2.2 Benthic Sampling

Benthic samples were obtained at Stations DC-1, CS-2, CS-3, CS-4, CS-6, and CS-7 in Chatham Sound (Figure 4). The samples were collected using a 0.092 square metre Ponar grab. Upon collection, the samples were washed through a 0.5 mm stainless steel screen in order to extract the infaunal organisms. The organisms thus collected were fixed in buffered 10% formalin which was later changed to 90% isopropyl alcohol for preservation until such time as they could be sorted and identified in Vancouver. All of the polychaete identifications were made at the British Colulmbia Provincial Museum by K.D. Hobson.

Lists of the identified species from each station were compiled and species diversity was calculated according to the equation of Pielou (1966).

2.3 Intertidal Survey

A qualitative intertidal survey was conducted in the vicinity of the Ridley Island outfall and also at a point near Watson Island on Wainwright Basin.

Six locations were examined along the Ridley Island/Kaien Island shore (Figure 5). At each station the community composition was noted and representative photographs obtained. Along the shore of Wainwright Basin, the quality and composition of the intertidal biota was evaluated.

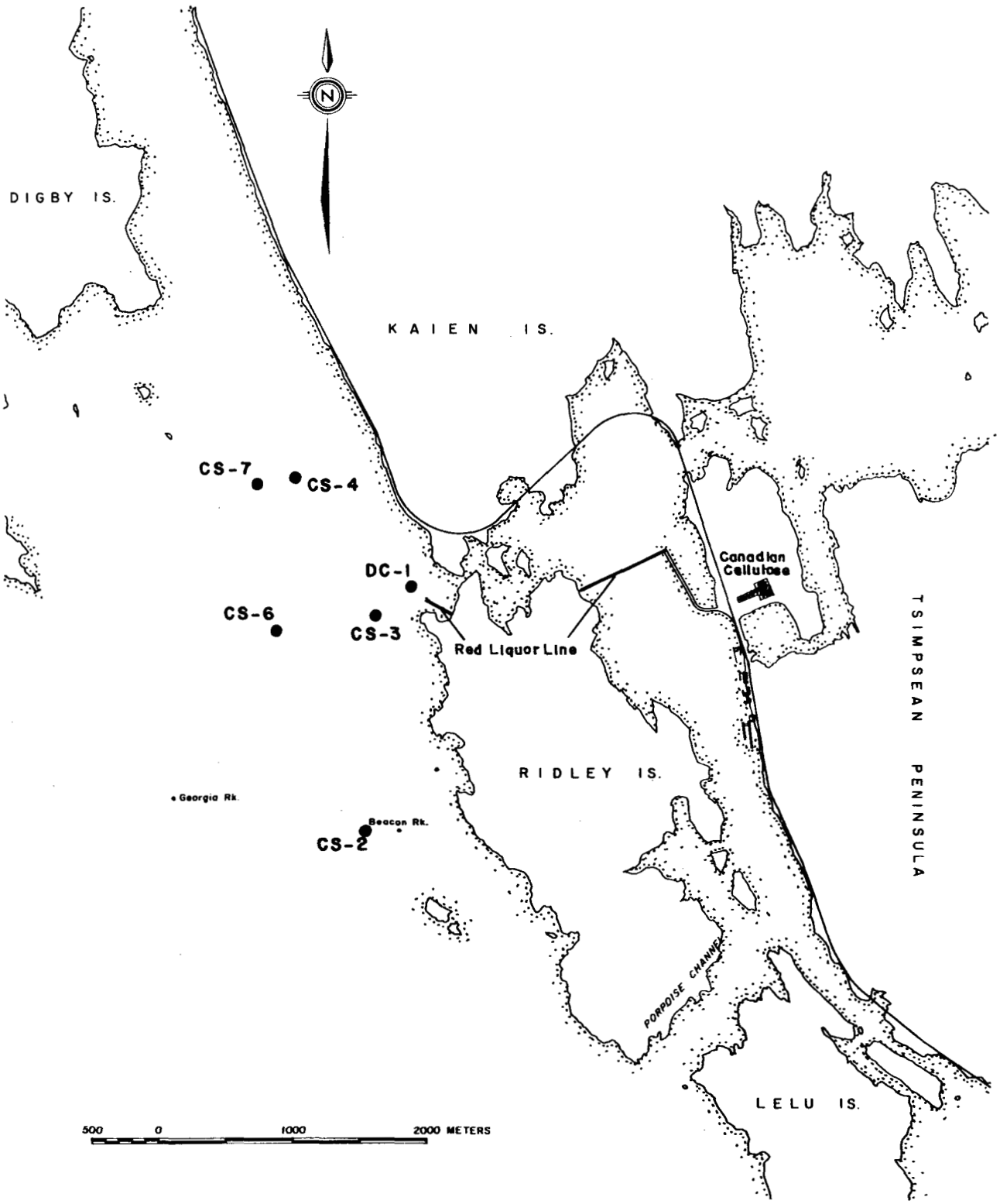

FIGURE 4 BENTHIC SAMPLE STATIONS

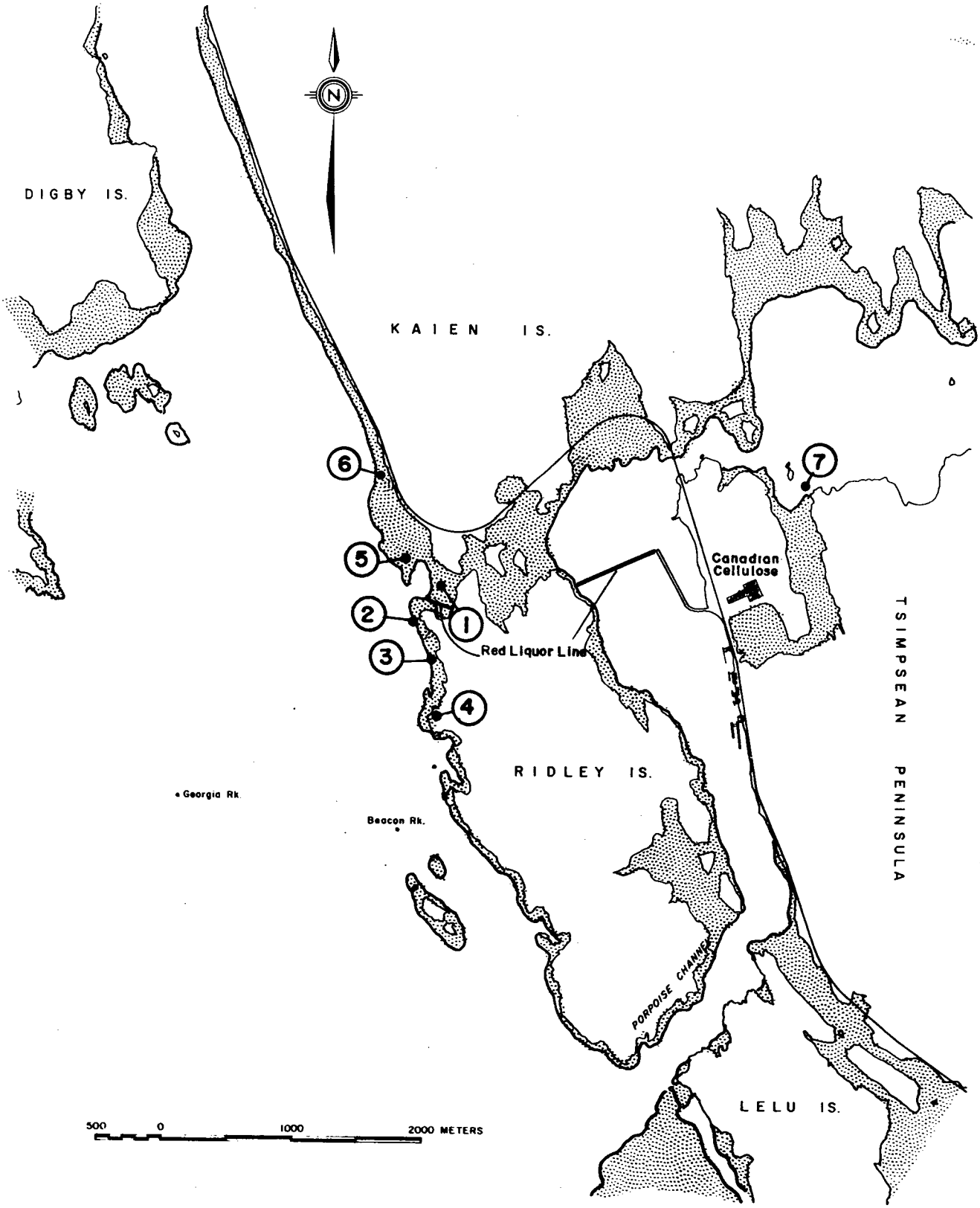

FIGURE 5 INTERTIDAL STATIONS

3 RESULTS AND DISCUSSION

3.1 Oceanography

3.1.1 Porpoise Harbour. The stations in Porpoise Harbour were sampled on two occasions, July 9 and August 7, 1974, both on a rising tide. The data obtained in the course of this work is contained in Appendix I and displayed in the form of water column profiles in Figures 6 to 11.

The area in question involves essentially three distinct, yet connected, water bodies. The portion in the vicinity of Flora Bank and the mouth of Porpoise Harbour is affected to a high degree with respect to oceanographic properties, by the flow of the Skeena River. This is verified by the data, which shows a surface salinity of 19.0‰ in the July sampling period at a time of high runoff, compared to a salinity of 26.0‰ in August when the Skeena flows were somewhat reduced. Dissolved oxygen concentrations were high in this portion (9.7 mg/l (102.3% sat.) on July 9 and 8.8 mg/l (94.4% sat.) on August 7 in the surface water. Dissolved oxygen in the bottom water in this area was found to be 7.4 mg/l (82.5% sat.) on July 9 and 6.9 mg/l (76.95% sat.) on August 7. These values suggested that the pulpmill was exerting little effect on the dissolved oxygen concentration in the water in the vicinity of Flora Bank. There appeared to be no significant change in temperature values between the two data sets. Surface temperatures were found to be 11.5°C and 11.2°C on July 9 and August 7 respectively while bottom temperatures ranged from 10.4°C on July 9 to 10.7°C on August 7.

The area in the central portion of Porpoise Harbour appeared less affected by the changing flows of the Skeena River. Surface salinities at Stations P-12, P-18, and PH-1 remained reasonably unchanged, with a total range of 1.9‰ (24.6‰ to 26.5‰) between stations and sampling periods. However, there did appear to be a difference in the dissolved oxygen profiles between these stations. Comparing the two profiles (Figures 8 and 11), a slightly more pronounced intrusion of water containing a lower dissolved oxygen content was observed in the August sampling. This intrusion was not as prominent in July when the mill was on strike and,

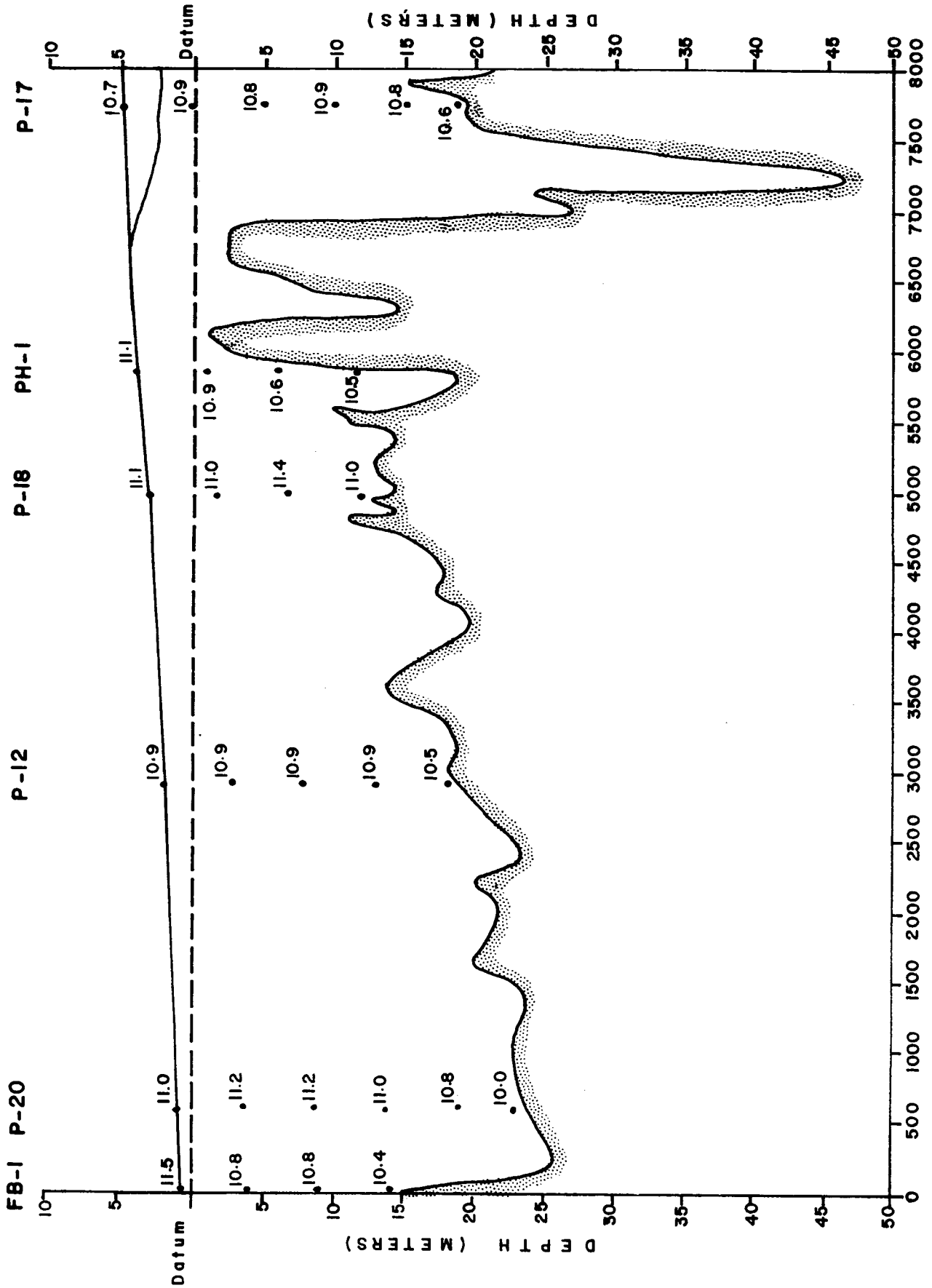

FIGURE 6 TEMPERATURE (°C) - July 9, 1974

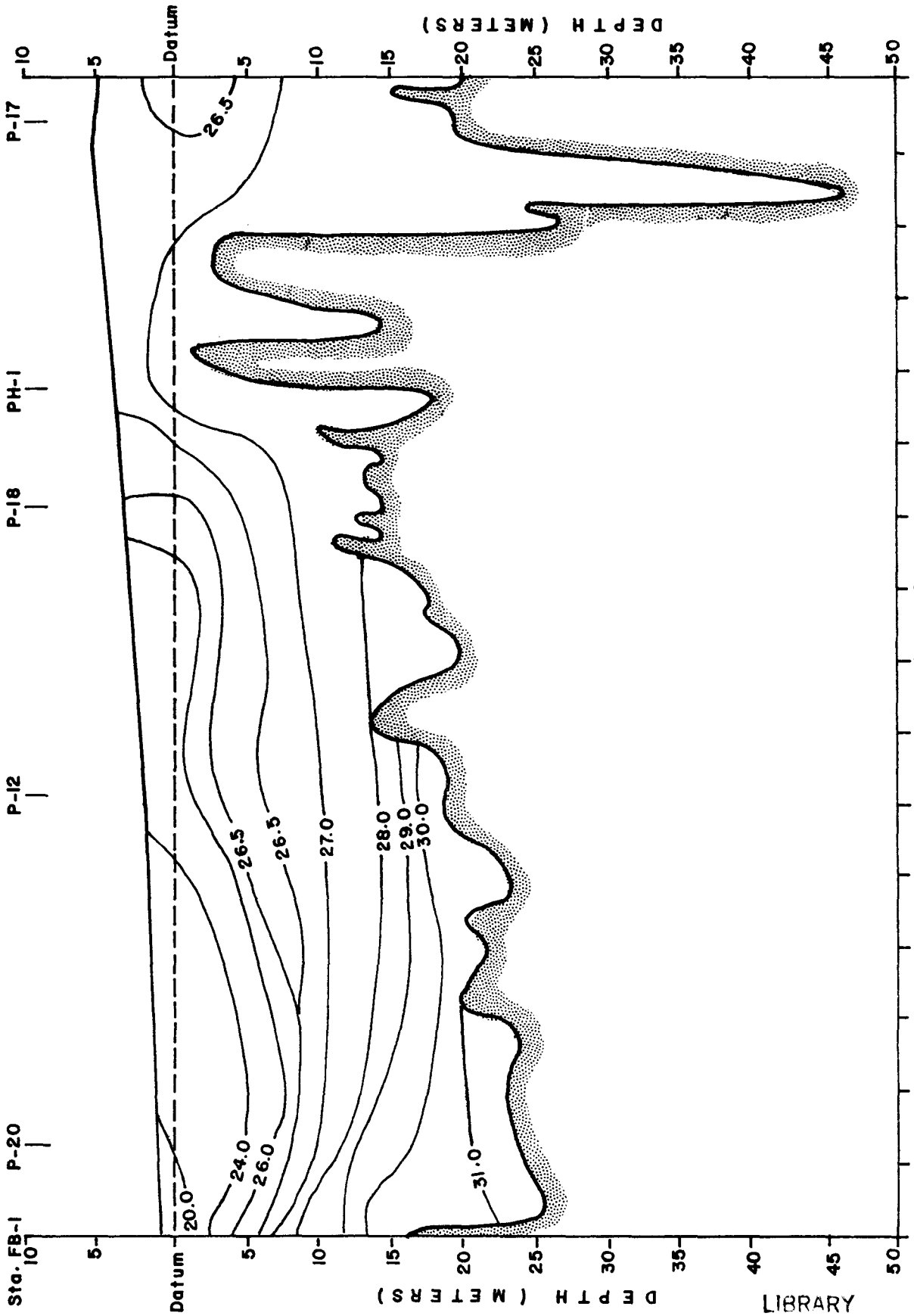

FIGURE 7 SALINITY (‰) - July 9, 1974

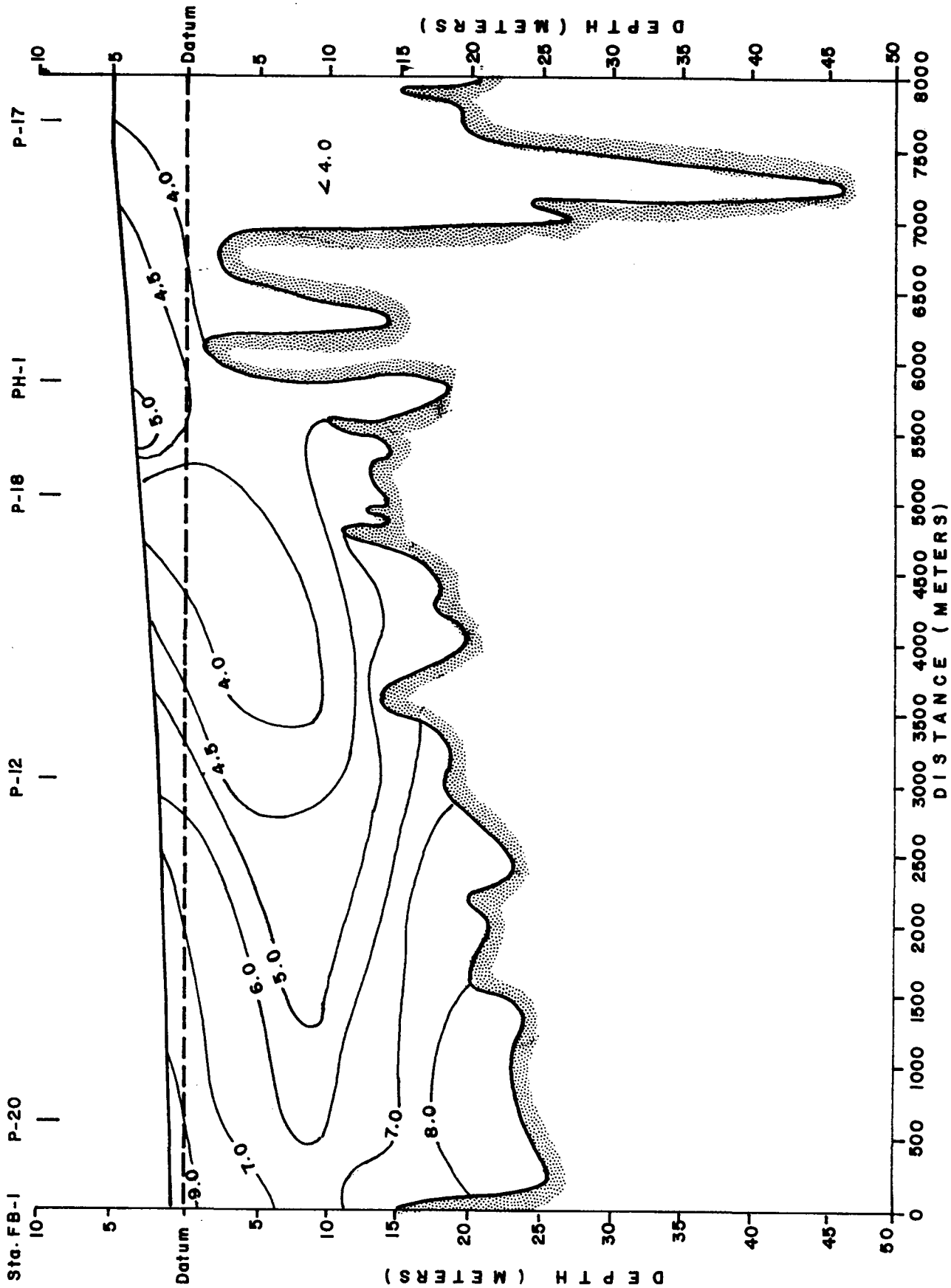

FIGURE 8 DISSOLVED OXYGEN (Mg/L) - July 9, 1974

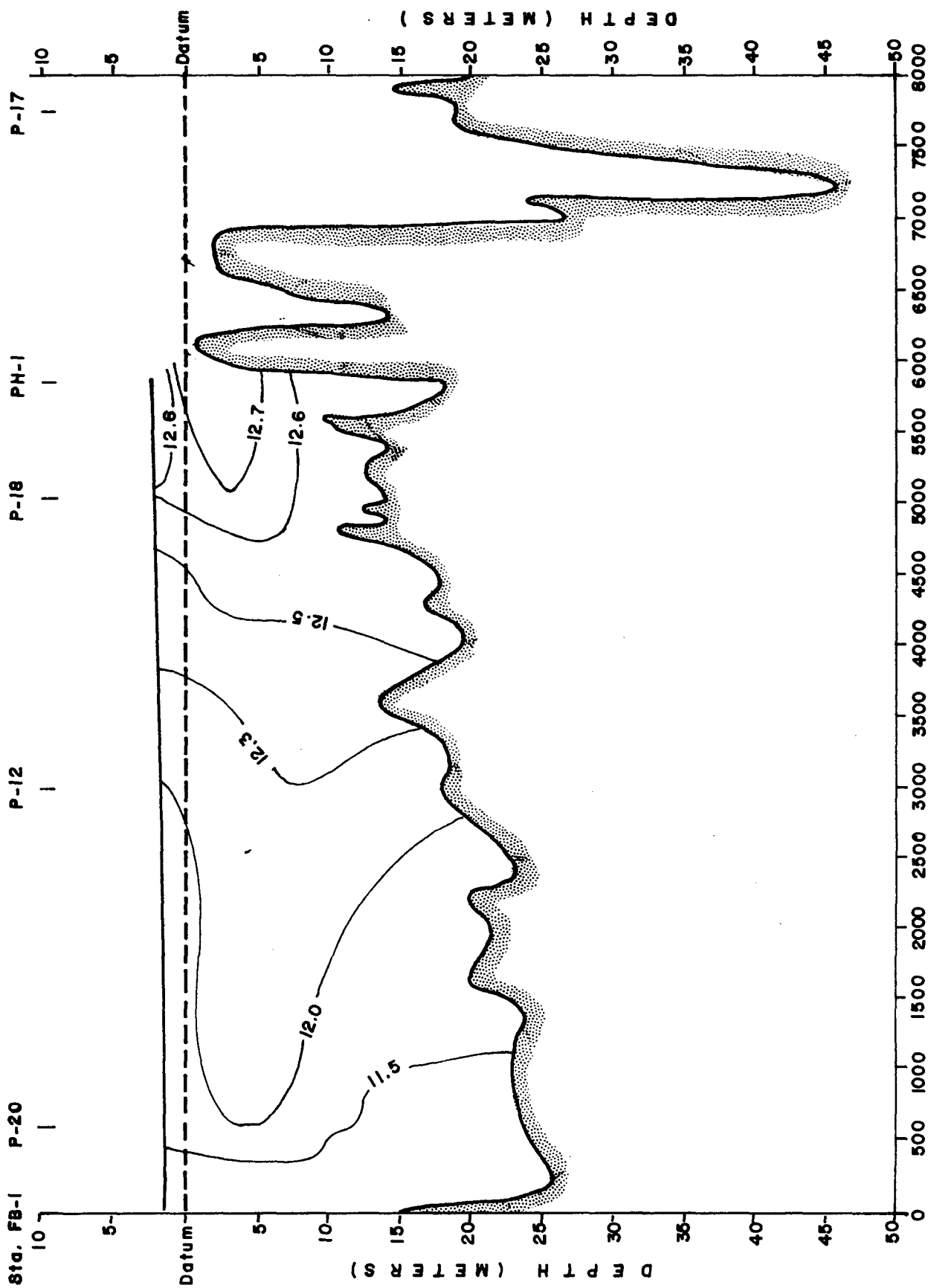

FIGURE 9 TEMPERATURE (°C) - August 9, 1974

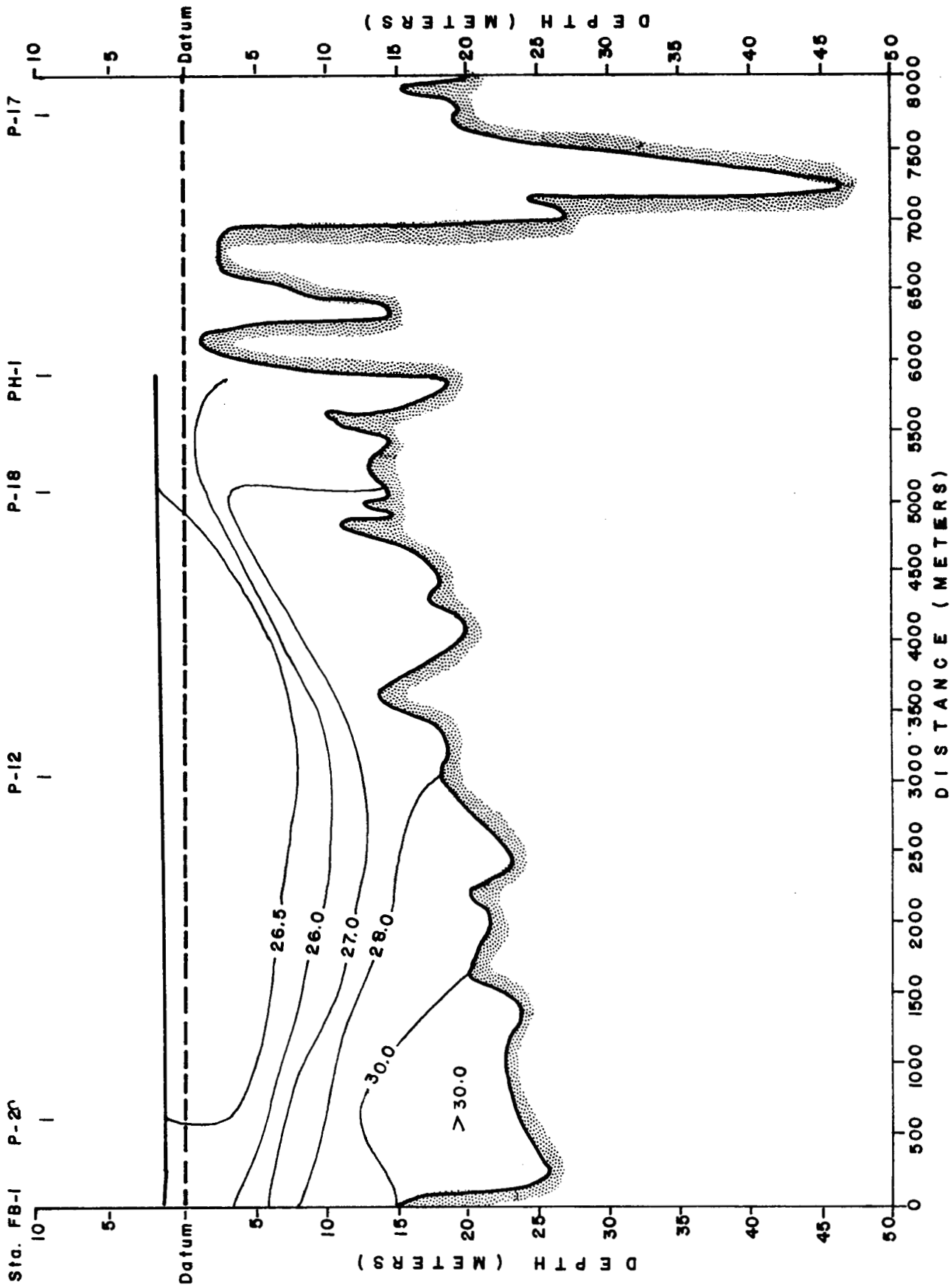

FIGURE 10 SALINITY (‰) - August 9, 1974

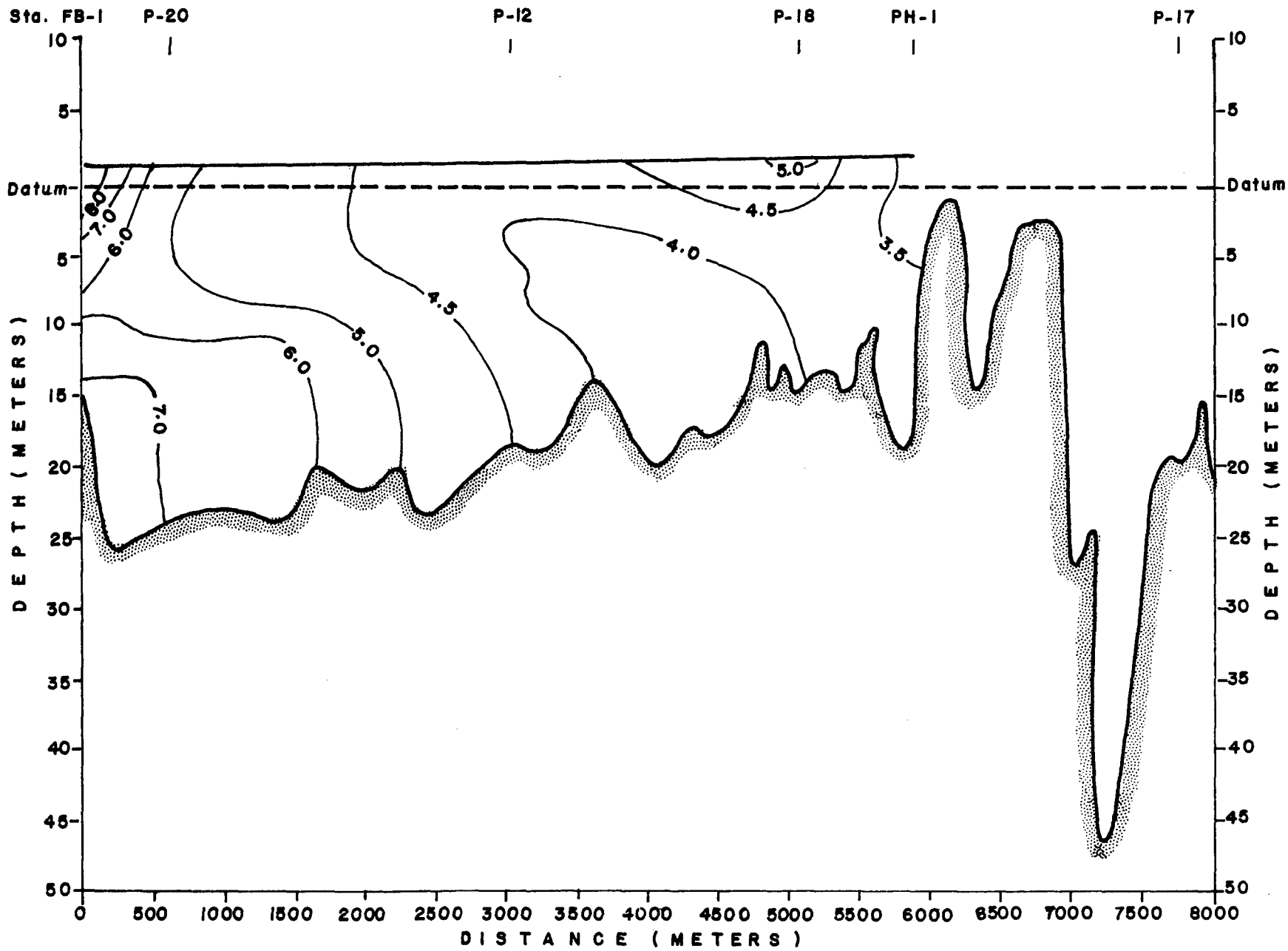

FIGURE 11 DISSOLVED OXYGEN (Mg/ℓ) - August 9, 1974

therefore, not discharging effluent which would place an oxygen demand on the water of Wainwright Basin. It should be mentioned here, that Waldichuk (1962) found dissolved oxygen levels in the vicinity of Station P-18 to be less than 0.5 mg/l in the middle depths. This situation appears to have improved substantially as the lowest value found at this station in our work was 3.9 mg/l.

The third discreet portion of the Porpoise Harbour sampling area was Wainwright Basin. This was sampled at one station (P-17) on July 9 only. The dissolved oxygen concentrations were low at the time (4.0 mg/l at the surface; and 3.6 mg/l in the bottom water), however, not as low as had been reported in the past (0 - 3.5 mg/l; Waldichuk, 1962).

3.1.2 Chatham Sound. In Chatham Sound, a total of 8 stations were sampled on two consecutive days. On August 6 the sampling was conducted on a flood tide, while on August 7 the stations were sampled on an ebb tide. The data obtained from this sampling are contained in Appendix I and depicted graphically in Figures 12 and 13.

The water column was slightly stratified at all stations and uniform with respect to the parameters investigated throughout the area sampled. Temperatures ranged from a high of 13.5°C at the 5 meter depth at Stations CS-4 and CS-5 to 11.5°C in the bottom water at CS-6 on August 6; and 12.5°C at the surface at Station CS-5 to 9.8°C at the bottom at CS-5 on August 7. Salinity ranged from 23.0 at the surface at CS-2 and DC-1 to 34.0 at the bottom at CS-6 on August 6. On August 7 the salinity values ranged from a low of 21.5 at the surface at all stations except CS-1 and CS-5 to 32.0 at the bottom at CS-5, CS-6 and CS-7. Dissolved oxygen values ranged from 11.9 mg/l (134.1% sat.) at the surface at CS-6 to 6.5 mg/l (75% sat.) in the bottom water at the same station on August 6, and from a high of 10.6 mg/l (116.0% sat.) at the surface at CS-1 to 6.0 mg/l (66.9% sat.) at the bottom at CS-6 on August 27.

These results imply that there was no significant depletion of dissolved oxygen attributable to the spent sulphite liquor discharge. The slight changes in values between the two days were probably the result of differing stages in the tidal cycle at the time of sampling.

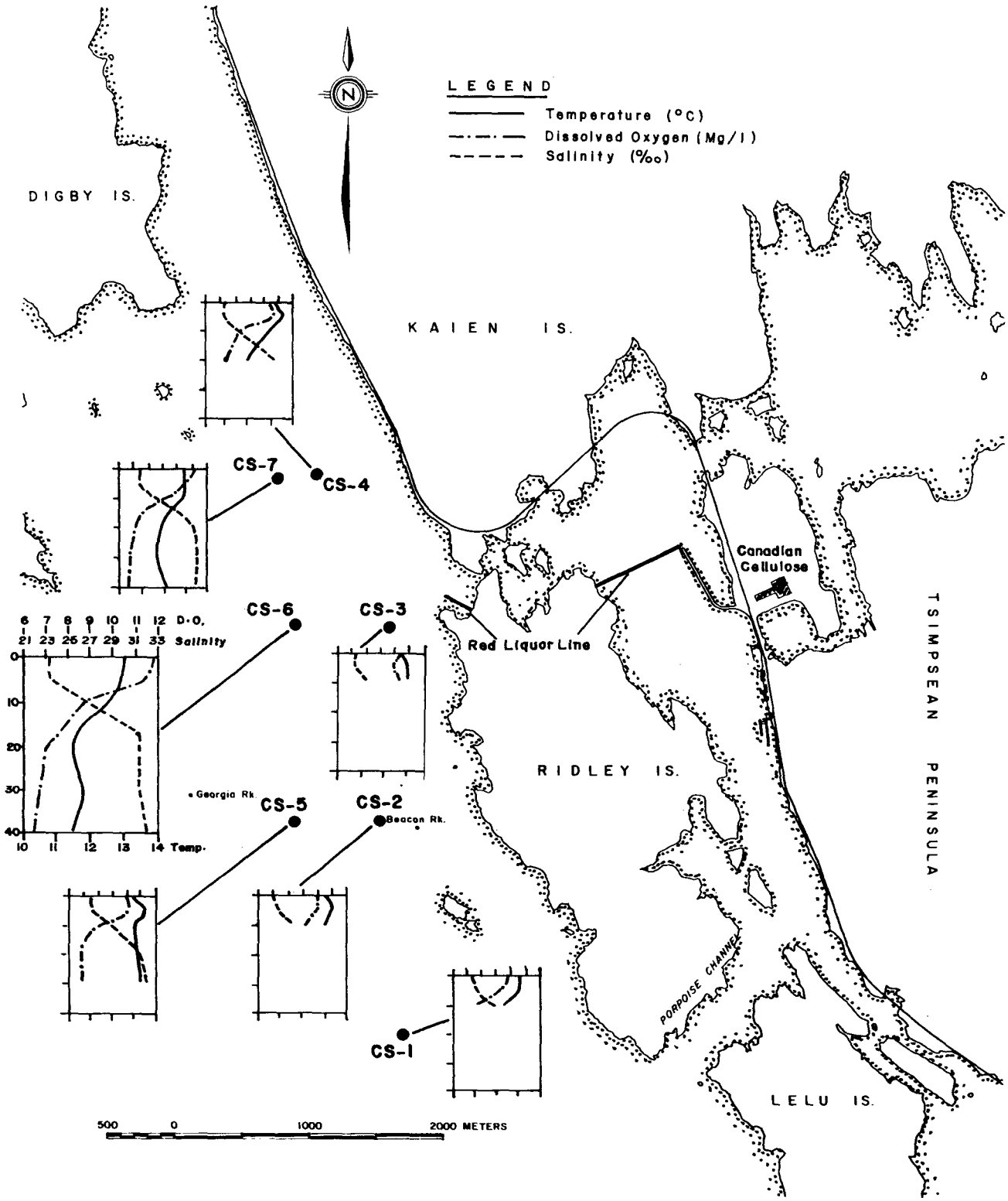

FIGURE 12 WATERCOLUMN PROFILES FLOOD TIDE

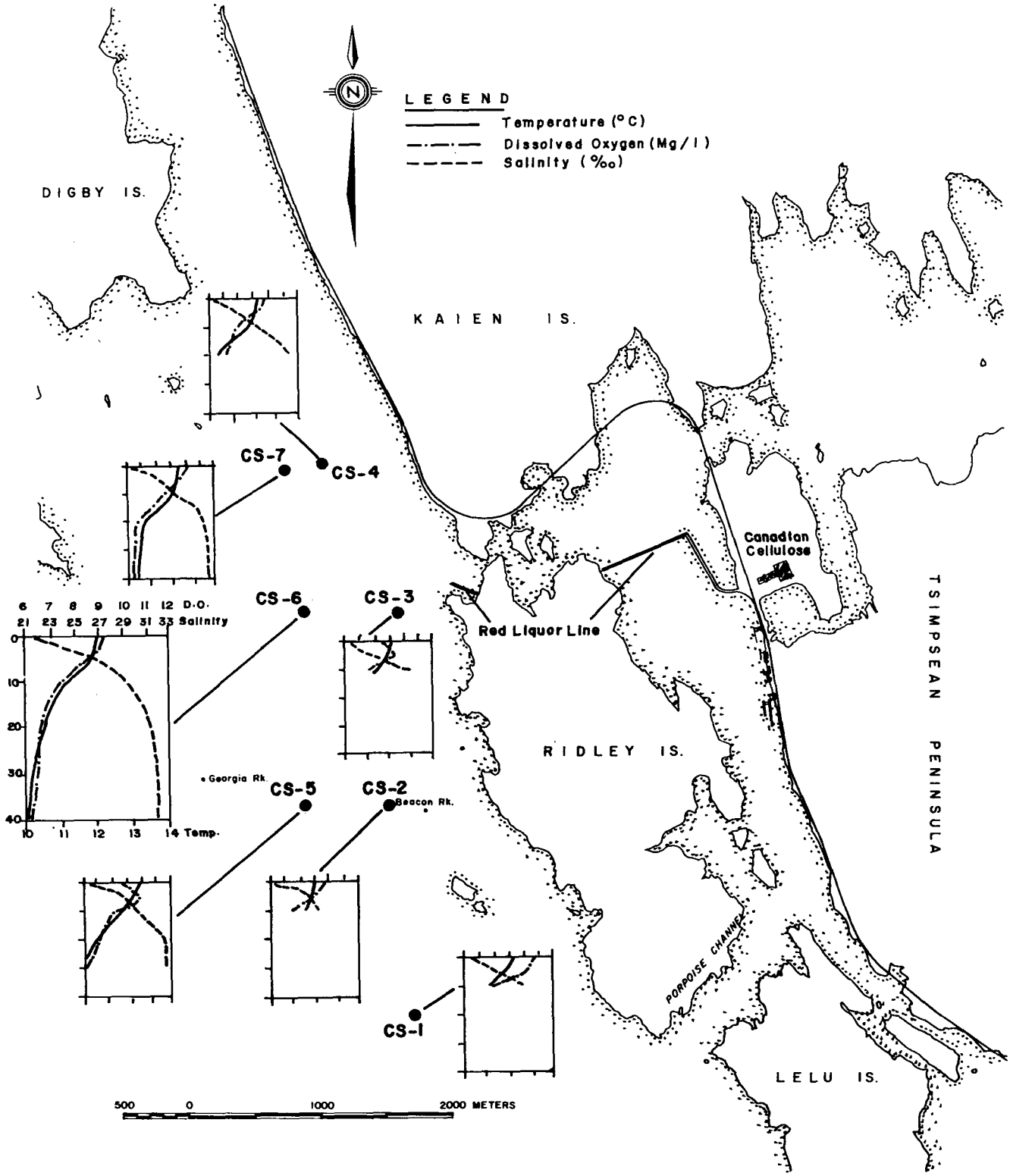

FIGURE 13 WATERCOLUMN PROFILES EBB TIDE

The one observation which was made at the time of sampling, and felt to be cause for concern, was the extent of the visible surface distribution of the red liquor effluent in the direction of Flora Bank on an ebb tide. The extent of this flow is indicated in Figure 14. The effluent was also observed in the surface water as far north as Casey Point on a flood tide.

It should be noted that the planned diffuser was not in operation and discharge was from an open-ended pipe extended into the center of "Discharge Cove" and on the bottom. It was assumed, however, that a similar problem of surface spreading of effluent would prevail when the diffuser was put into operation. The effluent, aside from being aesthetically unattractive, could have a toxic effect on the intertidal biota. It was felt that this effect, with the changed disposal method, could be much more far reaching than it had previously been.

3.2 Benthic Survey

The benthic grab samples obtained revealed no extensive spreading of pulpwood fibre into Chatham Sound. Fibre was observed to cover some portions of the intertidal zone in "Discharge Cove" and some fibre was obtained in the sample from Station DC-1; however, there was no evidence of fibre or reduced sediments in Chatham Sound itself.

The benthic faunal populations at most stations were found to have high numbers of individuals as well as a diverse specific representation. This may be seen by examining Appendix II. The station located in "Discharge Cove" was the sole exception. At this station, only a limited number of polychaete species (*Glycinde picta*, *Cirratulis cirratus spectabilis*, and *Capitella capitata*), oligochaetes, and amphipods were found.

The diversity indices calculated from the results of the benthic grabs are presented in Table 1. It may be seen from examination of this table that DC-1 was the only station at which the diversity was significantly lowered.

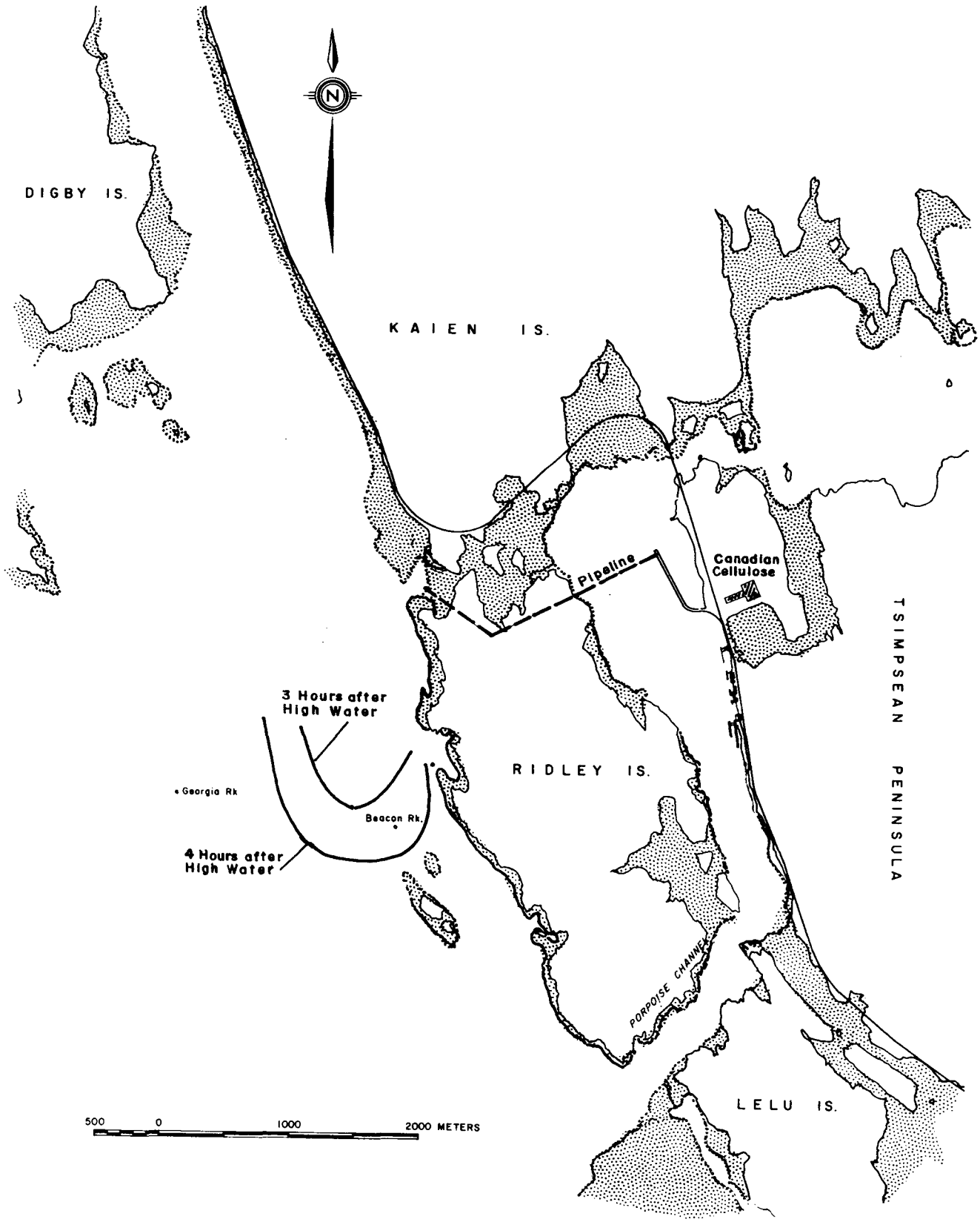

FIGURE 14 EXTENT OF SURFACE SPREADING OF SPENT SULPHITE LIQUOR ON AN EBB TIDE

TABLE 1

BENTHIC DIVERSITY INDICES

STATION	LOG E	EVENESS
D.C.1	1.429	0.797
CS-2	3.302	0.867
CS-3	3.102	0.853
CS-4	2.917	0.731
CS-6	2.976	0.844
CS-7	3.015	0.823

3.3 Intertidal Survey

A brief qualitative intertidal survey was undertaken on July 11 in an attempt to determine the zone of influence of the effluent discharge with respect to the intertidal biota. The stations examined are depicted in Figure 5.

"Discharge Cove", the first area examined was characterized by an appearance of almost complete sterility. The infaunal organisms had been killed but had not decayed in the least, suggesting that microbial populations had been eliminated as well (Plate 1). While the rocks were completely bare, some of the mud flats were covered with a thin layer of fibre (Plates 2 and 3). Below the surface of the flats, the sediments were composed of black hydrogen sulphide ooze indicative of strongly reduced conditions. Approximately 100 metres away from the outfall along the southerly shore, the rocks became coated with an orange ooze probably containing bacterial and/or algal slimes and the calcareous remains of barnacles were observed (Plate 4).

At Station 2 (Landing Point) the coating of orange slime came to an abrupt end, being replaced by patches of chlorophytic algal growth (Plate 5). A short distance south of this point, stunted growths of Fucus sp. were noted. Also noted were growths of Enteromorpha sp. and small populations of Littorina sp., Balanus sp., Acmaea sp., and Gammarid amphipods. However, at the time only 50% of the barnacles (Balanus sp) were found to be alive. It was noted that the live barnacles and limpets possessed extremely soft shells, presumably the result of the effects of the spent sulphite liquor discharge. Large populations of polychaetes (Capitella sp.) were also observed, underneath loose rocks.

Numbers and apparent health of organims increased with increasing distance from the discharge in a southerly direction. At a position approximately 150 to 200 m south of the cove, Hemigrapsus sp. and Mytilus sp. were observed, as well as large numbers of Gammarid amphipods.

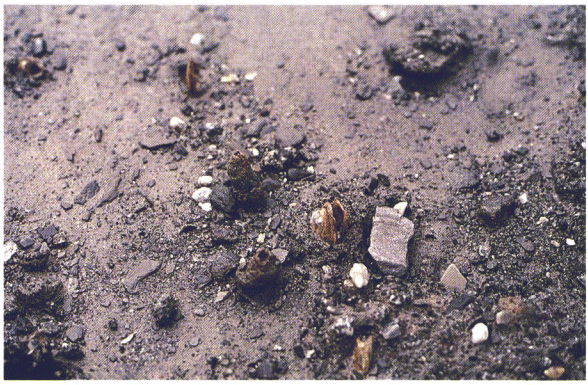

Plate 1. Discharge Cove. Close-up of dead bivalves on mudflat.

Plate 2. Tidal Flats in Discharge Cove showing fibre deposits.

Plate 3. Close-up of fibre deposits on Discharge Cove tidal flats.

Plate 4. Discharge Cove Entrance. Close-up of slime showing dead barnacle shells.

Plate 5. Discharge Cove Entrance. Transition from orange slime to unicellular Chlorophyta.

Plate 6. 0.8 km south of Discharge Cove showing the naturally diverse faunal composition.

At Station 3, 0.25 nautical miles (456 m) south of the discharge area, the intertidal populations appeared healthy (Plate 5) and the diverse fauna represented is outlined in Appendix III.

At Station 4, 0.5 nautical miles (912 m) south of "Discharge Cove", the biotic communities appeared typical of a natural environment, (Plate 6). Appendix III summarizes all species found.

At Station 5, 0.25 nautical miles (456 m) north of the discharge, a partial improvement in conditions over those of the discharge area was noted. The presence of such flora and fauna as Fucus sp., Balanus sp., and Acmaea sp. was indicative of that improvement; however, the diversity of the community was extremely low. It was also noted that the Fucus sp. was stunted and the limpets and barnacles possessed extremely soft shells.

Station 6 was located 0.5 nautical miles (912 m) north of the discharge on Kaien Island. This station was a wave-washed beach composed of small boulders and characterized by a very limited number of organisms, the representatives of which are summarized in Table 4. Although the biota in this location was limited, it was felt that it was characteristic for that type of beach and had not suffered significantly from the presence of the red liquor discharge.

Station 7 was located in Wainwright Basin on the shore of Watson Island near the outlet of Settling Lagoon #2. This station exhibited considerable degradation. Species diversity was very low and contained macrobiota such as Enteromorpha sp., a few stunted Fucus sp., Capitella sp., Littorina sp., some first-year barnacles (Balanus sp.), as well as a few amphipods and isopods. The beach also had a fine layer of brown fibre covering a mass of black hydrogen sulphide ooze. This situation was very similar to the conditions noted in previous reports (Goyette et al, 1970).

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APPENDIX I

OCEANOGRAPHIC DATA

Results of Porpoise Harbour Area Water Quality Survey - July 9, 1974

Station	Time	Sample Depth (m)	Temperature °C	Salinity °/oo	Dissolved Oxygen mg/1	% Saturation Oxygen
FB-1	1110	0	11.5	19.0	9.7	102.3
		5	10.8	26.0	7.7	84.0
		10	10.8	28.0	6.7	74.4
	1145	15	10.4	30.6	7.4	82.5
P-20	1150	0	11.0	18.8	9.6	100.0
		5	11.2	24.2	6.6	71.8
		10	11.2	26.7	5.8	64.1
		15	11.0	29.1	6.7	74.4
		20	10.8	30.4	8.1	91.9
		24	10.0	31.8	8.2	91.3
P-12	1240	0	10.9	24.6	6.3	68.3
		5	10.9	26.5	4.3	46.6
		10	10.9	26.7	4.3	46.7
		15	10.9	27.2	4.9	53.4
		20	10.5	30.4	7.2	80.3
P-18	1410	0	11.1	26.5	3.9	43.0
		5	11.0	26.5	3.9	42.3
		10	11.4	26.7	4.1	45.5
		15	11.0	27.3	5.5	60.2
PH-1	1505	0	11.1	26.6	6.0	66.2
		5	10.9	27.2	4.4	48.5
		10	10.6	27.2	4.3	47.1
		15	10.5	27.2	4.4	47.5
P-17	1800	0	10.7	26.7	4.0	43.7
		5	10.9	26.5	3.9	42.8
		10	10.8	26.4	3.9	42.1
		15	10.9	27.1	4.0	43.5
		20	10.8	27.1	3.8	41.6
		25	10.6	27.1	3.6	38.4

Results of Porpoise Harbour Area Water Quality Survey - August 7, 1974

Station	Time	Sample Depth (m)	Temperature °C	Salinity °/oo	Dissolved Oxygen mg/l	% Saturation Oxygen
FB-1	1000	0	11.2	22.0	8.8	94.4
		5	11.4	26.0	7.0	77.4
		10	11.3	28.0	5.9	66.0
		15	10.7	29.5	6.9	76.9
P-20	1100	0	11.8	26.5	5.1	57.1
		5	12.0	26.5	5.0	56.2
		10	11.8	27.5	5.4	60.8
		15	11.4	30.5	6.9	78.6
		20	11.3	31.5	6.9	79.0
P-12	1120	0	12.0	26.5	4.2	47.2
		5	12.2	26.5	4.0	45.2
		10	12.3	26.5	4.1	46.4
		15	12.2	27.0	4.4	49.8
P-18	1200	0	12.6	26.5	5.1	58.1
		5	12.6	27.0	4.4	50.4
		10	12.6	27.0	4.1	46.9
		15	13.0	27.0	4.0	46.1
PH-1	12	0	12.5	26.0	3.4	38.5
		5	13.0	26.0	3.3	37.8
		10	12.6	26.5	3.8	43.3

Results of Chatham Sound Water Quality Survey - August 6, 1974

Station	Time	Sample Depth (m)	Temperature °C	Salinity °/oo	Dissolved Oxygen mg/l	% Saturation Oxygen
CS-1	1130	0	13.1	24.0	9.8	111.0
		5	13.1	24.5	9.5	108.0
		10	12.2	27.0	7.5	85.0
CS-2	1230	0	13.1	23.0	10.0	112.6
		5	13.4	23.5	10.0	113.6
		10	13.0	25.5	9.0	102.7
CS-3	1410	0	13.0	23.5	10.0	112.7
		5	13.2	23.5	9.9	112.0
		10	13.2	25.0	10.1	115.4
CS-4	1425	0	13.0	23.5	10.3	116.1
		5	13.5	23.5	10.9	124.1
		10	12.9	25.5	8.3	94.5
		20	12.0	30.5	7.3	84.3
CS-5	1200	0	12.6	24.0	9.9	110.9
		5	13.5	24.0	10.0	114.2
		10	13.0	26.5	7.9	90.8
		20	13.2	30.5	6.8	80.6
		30	13.2	31.5	6.9	82.3
CS-6	1520	0	13.0	23.5	11.9	134.1
		5	13.0	23.5	11.6	130.7
		10	12.6	27.0	8.7	99.4
		20	11.5	31.5	7.1	81.6
		30	11.8	31.5	6.8	78.7
		40	11.5	32.0	6.5	75.0
CS-7	1445	0	13.0	24.0	11.5	130.0
		5	13.1	24.0	10.7	121.2
		10	12.8	26.0	8.9	101.5
		20	11.9	31.5	7.1	82.3
		30	11.7	32.0	6.8	78.8
		40	12.2	31.5	6.7	78.2
Discharge Cove	1335	0	13.2	23.0	10.0	112.8
		2	13.2	23.5	9.5	107.5

Results of Chatham Sound Water Quality Survey - August 7, 1974

Station	Time	Sample Depth (m)	Temperature °C	Salinity °/oo	Dissolved Oxygen mg/l	% Saturation Oxygen
CS-1	2055	0	12.1	22.0	10.6	116.0
		5	12.0	25.5	10.3	115.0
		10	11.1	29.0	7.7	86.3
CS-2	2000	0	12.0	21.5	9.8	106.7
		5	12.0	26.0	9.2	103.1
		10	11.5	27.5	7.4	82.8
CS-3	1820	0	12.2	21.5	8.5	92.9
		5	12.0	25.0	9.4	104.6
		10	11.4	29.5	7.8	88.3
CS-4	1725	0	12.2	21.5	9.5	103.9
		5	12.2	25.0	9.4	105.1
		10	11.8	27.5	8.0	90.1
		20	10.4	31.5	7.1	79.6
CS-5	2030	0	12.5	22.0	7.7	85.0
		5	12.2	26.5	9.7	109.5
		10	11.5	28.0	8.0	89.8
		20	10.5	32.0	6.8	76.7
		30	9.8	32.0	6.1	67.7
CS-6	1840	0	12.1	21.5	9.3	101.5
		5	11.9	26.5	8.9	99.8
		10	11.2	29.5	7.7	86.7
		20	10.6	31.5	6.7	75.5
		30	10.2	32.0	6.4	71.7
		40	10.0	32.0	6.0	66.9
CS-7	1755	0	12.2	21.5	10.2	111.5
		5	12.2	25.5	9.7	108.8
		10	12.0	27.0	8.5	95.9
		20	10.8	31.5	6.7	75.8
		30	10.6	32.0	6.5	73.5
		40	10.5	32.0	6.3	7.10
DC-1	1810	0	12.1	21.5	9.0	98.7
	Bottom	2	12.0	23.5	8.6	94.8

APPENDIX II

SPECIES LIST - CHATHAM SOUND BENTHIC STATIONS

APPENDIX II. SPECIES LIST - CHATHAM SOUND BENTHIC STATIONS.

Taxa	Discharge Cove	CS-2	CS.3	CS.4	CS.6	CS.7
FORAMINIFERA						
Rhabdamina abyssorum					Many	
COELENTERATA						
Hydroidae		Some				
Ptilosarcus gurneyi						1
NEMERTEA		1	3	3	6	
NEMATODA		2				
POLYCHAETA						
Harmothoe lunulata				1		1
Peisidice aspera				1		
Pholoe minuta						
Eteone longa		1				
Eteone pacifica					1	
Eteone spetsbergensis			1			
Eulalia bilineata						1
Eulalia sp				1		
Phyllodocidae (unidentified)					1	
Hesionidae (unidentified)				1		
Pilargis berkleyae					1	1
Exogone lourei		6	2	9	12	
Odontosyllis phosphorea				1		
Sphaerosyllis sp.				1		
Syllis heterochaeta		1	1	1	5	1
Nephtys ferruginea		3				
Nephtys punctata		2				3
Nephtys sp.		1	1			2
Sphaerodoropsis sphaerulifer				1		
Sphaerodorum papillifer						2
Glycera capitata				1		
Glycinde picta	5					
Lumbrinereis bicirrata		4				
Lumbrinereis luti		4	4	8	4	4
Lumbrinereis sp.				1		
Ninoe gemmea				1		1
Drilonereis falcata minor		2				
Dorvillea pseudorubrovittata		1				1
Orbiniidae (unidentified)		1				
Scoloplos pugettensis		4	5	2		
Scoloplos acmeceps						3
Scoloplos armiger		1				

Taxa	Discharge Cove	CS-2	CS.3	CS.4	CS.6	CS.7
Paraonidae (unidentified)			1			
Aricidea minuta						2
Aricidea quadrilobata			1			
Aricidea ramosa				1		
Paraonis gracilis		11	3	9	5	3
Laonice cirrata			2		1	
Polydora socialis				1		
Prionospio steenstrupi		1	1			
Spio cirrifera			1			
Spiophanes berkeleyorum				6	4	6
Spiochaetopterus costarum					1	
Chaetozone setosa		2	3		5	
Cirratulus cirratus spectabilis	50				1	
Tharyx sp.		4	6			
Cirratulidae (unidentified)	5	20	23	47	14	13
Cossura sp.			2	1		
Pherusa plumosa			2	2		3
Scalibregmidae (unidentified)		1				
Scalibregma inflatum			1		2	
Sternaspis scutata		1	8			4
Ammotrypane aulogaster				1		
Capitella capitata	20					
Decamastus gracilis		3	3	9	3	8
Mediomastus capensis		9	3	5	2	2
Maldane glebifex		2		1	16	
Praxillella gracilis		2				
Rhodine bitorguata		2			1	3
Maldanidae (unidentified)		4	18		5	7
Myriochele oculata			1			
Idanthyrsus armatus						1
Pectinaria granulata				1		
Ampharete acutifrons		3				
Amphicteis mucronata				2		
Amphicteis scaphobranchiata					2	2
Anabothrus gracilis					2	
Melinna cristata			1			
Ampharetidae (unidentified)		1		1		
Artacama conifera			1		2	
Polycirrus sp.		7	11			
Proclea graffi		15	9		1	
Terebellidae (unidentified)				2	1	2
Terebellides stroemi		17	3		14	
Laonome kroyeri		3	1			1
Sabellidae (unidentified)		1				
Potamilla neglecta				1		
OLIGOCHAETA	10					

Taxa	Discharge Cove	CS-2	CS.3	CS.4	CS.6	CS.7
MOLLUSCA-BIVALVIA						
Mya sp		1				
Cardita ventricosa		2		11	1	2
Acila castrensis				73		35
Clinocardium californiense				1		1
Nucula minuta				14		10
Solamen columbianum			1	1	1	1
Rictacyma esquimalti						1
Thyasira sp.		1				
Thyasira gouldii			2	2		
Crenella sp.		1				
Cryptomya sp.			1			
Nucula sp.			7			1
Paruilucina sp.			1		8	
Cyclocardium sp.				3		
Propriomusum davidosoni				1		
Yoldia sp.				1	1	
Nucula tennis				6		
Macoma sp.				1		
Unidentified Bivalues		2	1		1	
GASTROPODA						
Polinices pallida		1				
Trachydermon sp.		1		3		1
Unidentified Gastropod				1		
CRUSTACEA						
Amphipoda	10	8	13	14	24	7
Cumacea			1			
Cladocera			2		1	
Decapoda-Pagurus sp.				2		
Isopoda				2		
SIPUNCULIDA				1		1
ECHINODERMATA-HOLOTHUROIDEA						
Eupentacta quinquesemita		1		1	1	1
Leptosynapta sp.				1		
Pentamera sp.						1
Unidentified Holothurian		1				
OPHIUROIDEA						
Ophiura sp.				1		1
ASCIDIACEA						
Solitary Ascidian				10		

APPENDIX III

INTERTIDAL FAUNA AND FLORA

APPENDIX III

FAUNA AND FLORA - INTERTIDAL STATION 3.

Phaeophyta	-	Laminaria sp.		
		Fucus sp.		
Chlorophyta	-	Ulva sp.		
		Enteromorpha sp.		
Rhodophyta	-	encrusting red algae		
Cnidaria	-	Anthozoa	-	Xanthograminus sp
Nemertea				
Mollusca	-	Amphineura	-	Katharina tunicata
				Mopalia sp.
		Gastropoda	-	limpets
			-	Thais
			-	Littorina sp.
		Bivalvia	-	Mytilus edulis
Arthropoda	-	Crustacea	-	Balanus sp.
			-	Pagurus sp.
			-	Hemigrapsus sp.
			-	Isopoda
			-	Amphipoda
Echinodermata	-	Asteroidea	-	Leptasterias sp.
Chordata	-	Pisces	-	Stichaeidae
			-	Cottidae

FAUNA AND FLORA - INTERTIDAL STATION 4.

Algae	-	Phaeophyta	-	Fucus sp.
				Laminaria sp.
		Chlorophyta	-	Ulva sp.
			-	Enteromorpha sp.
			-	Other unidentified Genera
		Rhodophyta	-	a number of unidentified Genera
		Porifera	-	a number of unidentified encrusting sponges.
Cnidaria	-	Anthozoa	-	Xanthograminus sp.
Nemertea				
Mollusca	-	Amphineura	-	Katherina tunicata
			-	Mopalia sp.
		Gastropoda	-	Littorina sp.
			-	Thais sp
			-	number of unidentified Limpets
		Bivalvia	-	Mytilus sp.
Arthropoda	-	Cirripedia	-	Balanus glandula
			-	Balanus cariousus
		Decapoda	-	Pagurus sp.
			-	Hemigrapsus sp.
		Amphipoda		
		Isopoda		
Echinodermata		Leptasterias sp.		
Pisces		Stichaeidae		
		Cottidae		

APPENDIX III

FAUNA AND FLORA - INTERTIDAL STATION 6.

Algae

Phaeophyta	-	Fucus sp.
Chlorophyta	-	Enteromorpha sp.
		Shale on beach generally coated with single cell chlorophytes

Annelida

Polychaeta	-	Capitella sp.

Mullusca

Pelecypoda	-	Mytilus sp.
Gastropoda	-	Limpets

Arthropoda

Cirripedia	-	Balanus glandula
	-	Balanus cariosus
Amphipoda	-	Gammarus sp.
Decapoda	-	Hemigrapsus sp.