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REVIEW OF OCEANOGRAPHIC DATA RELATING TO OCEAN DUMPING IN THE PRINCE RUPERT AREA WITH COMMENTS ON PRESENT AND ALTERNATE DUMP SITES

E.V.S. CONSULTANTS LTD.

REVIEW OF OCEANOGRAPHIC DATA RELATING TO OCEAN DUMPING IN THE PRINCE RUPERT AREA WITH COMMENTS ON PRESENT AND ALTERNATE DUMP SITES

Prepared for

DEPARTMENT OF FISHERIES & OCEANS
Institute of Ocean Sciences
9860 West Saanich Road
Sidney, B. C.

Prepared by

E. R. McGreer, P. W. Delaney and G. A. Vigers

E.V.S. Consultants Ltd.
195 Pemberton Avenue
North Vancouver, B. C.
V7P 2R4

J. W. McDonald
ESL Environmental Sciences Limited
34 - 1035 Richards Street
Vancouver, B. C.
V6B 3E4

E. H. Owens
Woodward-Clyde Consultants
16 Bastion Square
Victoria, B. C.
V8W 1H9

Project 645

March, 1980

E.V.S. consultants ltd.

Our File: 645

March 31, 1980

Dr. C. D. Levings
Department of Fisheries and Oceans
4160 Marine Drive
West Vancouver, B. C.
V7V 1N6

Dear Dr. Levings:

Re: Review of Oceanographic Data Relating to Ocean Dumping in the Prince Rupert Area with Comments on Present and Alternate Dump Sites

We are pleased to present to you our final report on the review of oceanographic data from the Prince Rupert area of British Columbia. This project has been a challenging one which we have enjoyed working on during the past months.

The most common finding during the study was the lack of long-term and site specific data for the proposed ocean dumping sites. This was the case for information on physical oceanography and biological resources, and was particularly evident for at-bottom current data needed to predict bedload and suspended sediment transport. We have included in the report recommendations of the types of data required for evaluating potential dump sites more precisely. Using a relative rating system, Tuck Inlet was identified as the site most suitable for dumping of contaminated materials, and Ogden Channel as the preferred site for clean materials.

We trust that this report meets your requirements at this time, and that it completes our assignment to your satisfaction.

Yours very truly,

E.V.S. Consultants Ltd.

E R McGreer

E. R. McGreer, M.Sc.
Project Manager,
Marine/Estuary Studies

ERM/les

195 Pemberton Avenue, North Vancouver, B.C. V7P 2R4 Telephone (604) 986-4331

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SUMMARY

A review of oceanographic data in the Prince Rupert region of British Columbia was undertaken to evaluate suitable sites for ocean dumping. Eight sites were proposed after an initial review of the data and, from these, final site selections were made. Tuck Inlet was considered the site most suitable for dumping of contaminated dredge spoil material, and Ogden Channel was recommended as the site for disposal of uncontaminated material. The review included assessment of data on historic use of dump sites in the region, physical oceanography, biological resources, sediment bedload transport, the extent of PCB and heavy metal contamination in the area, towing economics and logistics, and information obtained from personal interviews with former proponents of ocean dumping, Fisheries Canada and a Prince Rupert fisherman. Many data gaps were identified, particularly long-term, site-specific information on biological resources, and data necessary to predict sediment bedload transport. Recommendations for future studies included evolving a more realistic criterion for ocean disposal of organohalogen contaminated material.

CONCLUSIONS

Based on the reviews of the data for the disciplines presented within this report the following conclusions can be drawn:

1. The site most highly recommended for disposal of contaminated material was Tuck Inlet. It was the most suitable site according to biological resource data and the second most suitable site in terms of physical oceanography criteria.

2. The dump site in North Prince Rupert Harbour was the second most favourable site for dumping of contaminated material in a combined rating of biological and physical oceanographic criteria. North Porpoise Harbour was third in the overall rating system, but concerns related to salmon enhancement projects scheduled in the area mitigate against its continued use for ocean dumping.

3. The site most suitable for dumping of clean materials was Ogden Channel. It rated third overall for biological criteria and fourth for physical oceanography.

4. Brown Passage was the second most suitable site for dumping clean material. North Prince Rupert Harbour could also be considered providing some detailed study of the currents and bottom sediment transport in the area was conducted.

5. At present, the criteria for ocean dumping of PCB contaminated material do not allow dumping of spoil from Porpoise Harbour. Until research to establish more realistic criteria is developed, land disposal is recommended.

6. Specific data for many of the dump sites were missing. Information which was available was most often the result of single samplings providing no data on seasonal variations on changes from one year to another. In particular, relevant data on bottom currents within 1 m of the sea bed, which are essential for assessing sediment bedload transport, were nonexistent.

RECOMMENDATIONS

1. Future scientific cruises should endeavour to collect data which would be useful in assessing the suitability of designated ocean dumping sites. Specifically, more consideration should be given to: collecting data to fill information gaps (e.g. at-bottom currents and fisheries stock assessment data), collecting data at the same sites over a period of years, developing a numbering system for sampling sites in the Prince Rupert area so that data from different cruises can be readily compared, collecting complementary data (e.g. contaminants in sediments and organisms at any one site), and ensuring that the limit of detection for chemical analyses allows reporting of concentrations less than criteria specified in the Ocean Dumping Act.

2. Consideration should be given to evolving a more realistic criterion for ocean dumping with respect to organohalogen compounds.

3. Until research to establish more realistic criteria for ocean dumping of PCB contaminated material is developed, spoil from contaminated areas of Porpoise Harbour should be disposed on land.

4. The sources of mercury pollution in Prince Rupert Harbour and Tuck Inlet should be identified and reduced or eliminated.

1.0 INTRODUCTION

1.1 Purpose and Scope of Investigation

In addition to routine dredging for harbour maintenance in the Prince Rupert area, a major port development is planned (i.e. grain elevators, bulk loading facilities) which may result in a substantial increase in dredging activity. The possible increase in the quantity of dredged spoils would require the establishment of suitable ocean dump sites in the Prince Rupert area. A problem with pollution and contamination of sediments in Porpoise Harbour which requires occasional dredging also exists. Concern over the present and future impact of ocean dumping in the Prince Rupert area prompted the Department of Fisheries and Oceans to examine the situation.

The objectives of this project were to review the existing data base and to make recommendations on present and future dump sites. Information was collected on historic dump sites, physical oceanography, resources species (spawning grounds, locations of fishing areas), bottom sediment transport, disposal of contaminated material and the economics and logistics of ocean dumping in the area. Rating of proposed dump sites for disposal of different types of material was performed, and consideration given to alternative locations. Information was also obtained through interviews with various key personnel in Prince Rupert during a field trip by two members of the study team in December, 1979.

1.2 Historical Perspective on Dump Sites and Permit Applications in the Prince Rupert Area

1.2.1 Historical dump sites

Existing information, compiled by Department of Fisheries and Oceans personnel, regarding historical dump sites in the Prince Rupert region is summarized in Table 1. There have been seven

TABLE 1

SUMMARY OF DATA ON HISTORICAL DUMP SITES

PRIOR TO 1976 - PRINCE RUPERT AREA*

Area	Location	Depth	Useage	Material	Comments
Porpoise Harbour, Prince Rupert	54°14.5'N 130°18.6'W	10.5 fm 1.75 miles NW of dock	25,000 yd^3/yr	mud, silt, wood waste	Columbia Cellulose (later Cancel) dredging and dumping from 1950 to 1976
Casey Cove, Digby Island, Prince Rupert Harbour	54°16.9'N 130°22.2'W	11 fm	not known	wood waste from log booming	1,500-2,000 yd^3 dredged out over last three years
Prince Rupert Harbour	south of Digby Is.			city garbage	ceased in 1930's; a sanitary land site established
Inverness Passage	54°11'N 130°11.5W	<6 fm	1953/54 - .25 million yd^3 dredged annually until 1970's - 2-3000 yd^3 every few years	silt	
Horsey Island, Inverness Channel	54°8.2'N 130°7'W	4 fm to surface	1953 - 750,000 yd^3	gravel and mud	inactive; used once
Brown Passage, Chatham Sound	54°18.5'N 130°45.5'W	100+ fm	undetermined	heavy steel wire mesh, fish offal, ammunition	- site established by MOT (1946), but officially disused now
Port Simpson, Tsimpsean Peninsula	just off cannery	>20 fm	unknown but limited; 1967/68 104,000 yd^3; 1971 - some	silt, mud, gravel, rock	

*Permit numbers not included with historic data on dumpsites examined.

sites in the area which have been used for dumping in the past. Dumping at most of the sites has been discontinued for one reason or another with the exception of Digby Cove and Porpoise Harbour. Biological recovery in Porpoise Harbour has resulted in a re-evaluation of this area as a suitable dump site.

1.2.2 Application for dumping permits

According to the Environmental Protection Service files, from 1976-1980, there have been six applications for ocean dumping in the Prince Rupert region. This information is summarized in Table 2.

Throughout this period, correspondence between various government agencies suggested various potential ocean dumping sites. Briefly, commencing with application in 1976 by Canadian Cellulose Co. Ltd. (Permit #0034) to dispose of dredged material, it was suggested to either dispose on land or utilize a site in Chatham Sound (54°9.3'N, 130°26.7'W). Prior to this, RODAC had recommended a site midway between Kinahan Islands and Flora Banks. Both of these sites were later deemed unacceptable due to the biological productivity of Chatham Sound and nearby Flora Banks. Towing of dredged material to these locations was also considered impractical. In 1976, RODAC decided to retain Porpoise Harbour (54°14.5'N, 130°18.4'W) as the dump site (Permit #0034).

Later in 1976, the "deep hole" in Browns Passage (54°18'N, 130°45'W) was suggested as a potential site for future dumping. However, the extended towing distance from dredging to dump site proved this recommendation to be unrealistic. Due to indecision in designating a multi-use dumping site, the Porpoise Harbour location was again retained for 1977 on application by

TABLE 2

OCEAN DUMPING APPLICATIONS - 1976 TO PRESENT

Permit No.	Permittee	Dredge Site	Material	Quantity	Dumpsite	Status	Dumping Date
0034	Canadian Cellulose Co. Ltd.	-maintenance dredging in front of plant	-nonfloatable dredge material; 65% mud and silt; 35% wood wastes -insoluble	-5000 m^3 -expected frequency of dumping 2 loads/day 380 m^3/load	-Porpoise Harbour 54°14.5'N 130°18.4'W ~18 m deep	issued	May 1976
0207	Canadian Cellulose Co. Ltd.	-maintenance dredging	-as above (#0034)	7700 m^3		rejected April/78 due to high PCBs	
0459	B.C. Packers Ltd. (Port Edward)	-maintenance dredging at dock	-nonfloatable dredge material comprised of silt, mud and clay	2294 m^3	-Porpoise Harbour 54°14.5'N 130°18.4'W ~24 m deep	issued	Feb. 1978
0615	National Harbours Board	-Ocean Dock, Prince Rupert	-mud and gravel	535 m^3		rejected (side casted material into deeper waters adjacent to dock)	late '78 -early '79

TABLE 2 (continued)

Permit No.	Permittee	Dredge Site	Material	Quantity	Dumpsite	Status	Dumping Date
0632	Public Works Canada	-Seal Cove, P.R. 54°19.9'N 130°16.6'W -dock area	-nonfloatable dredge material comprised of mud and loose rock	5000 m^3 (1000 m^3/day)	-Prince Rupert Harbour 54°22.1'N 130°15.7'W >50 m deep	-issued Jan.'79	-permit expired (not used)
0802	Canadian Cellulose Co. Ltd.	-maintenance dredging	-as above (permit #0034)	3060 m^3		-rejected due to high PCBs	-1979 (land disposal)

B. C. Packers (Permit (#0459). In 1977, a PCB spill into Porpoise Harbour restricted further dumping of dredged material by Canadian Cellulose Co. Ltd.; land disposal was enforced (Permit #0207, 0802) and is continued annually to this date.

On application by the National Harbours Board (Permit #0615) to dredge in front of their dock, the deepest basin in the Prince Rupert Harbour (54°18.8'N, 130°21.4'W) was suggested as a dump site. Prior to dredging operations, the dumping permit was rejected due to sediment contamination. Fisheries Service approved side-casting of "clean" dredge spoil into deeper waters adjacent to the Ocean Dock. Finally, Public Works Canada applied (Permit #0632) in 1978 to ocean dump non-floatable dredged material, comprised of mud and loose rock. Approval was granted for dumping at a site in Prince Rupert Harbour (54°22.1'N, 130°15.7'W), however the permit expired January 1979 before dredging operations were undertaken.

1.3 Preliminary Selection of Possible Ocean Dumping Sites

Members of the study team were called together in January after all information and data collection were completed. The meeting took the form of a workshop in which everyone presented a summary for their particular discipline. After discussion of the findings, a listing of all potential coean dumping sites was prepared. Eight sites were identified and are shown in Figure 1. The sites were:

Site No.	Name	Depth Range	Approximate Location
1	Chatham Sound - deep trench	90-120 m	54°12'N, 130°25'W
2	Porpoise Harbour - deep hole	17-20 m	54°14'N, 130°18'W
3	Prince Rupert Harbour - deep hole	36-50 m	54°13'N, 130°21'W
4	Tuck Inlet	55-60 m	54°25'N, 130°17'W
5	Upper Prince Rupert Harbour	55 m	54°22'N, 130°16'W
6	Chatham Sound - Malacca Passage	90-140 m	54°06'N, 130°22'W
7	Brown Passage	90-100 m	54°18'N, 130°45'W
8	Ogden Channel	145-190 m	53°53'N, 130°18'W

Assessment of existing and required data was made with reference to those sites and they are discussed throughout this report.

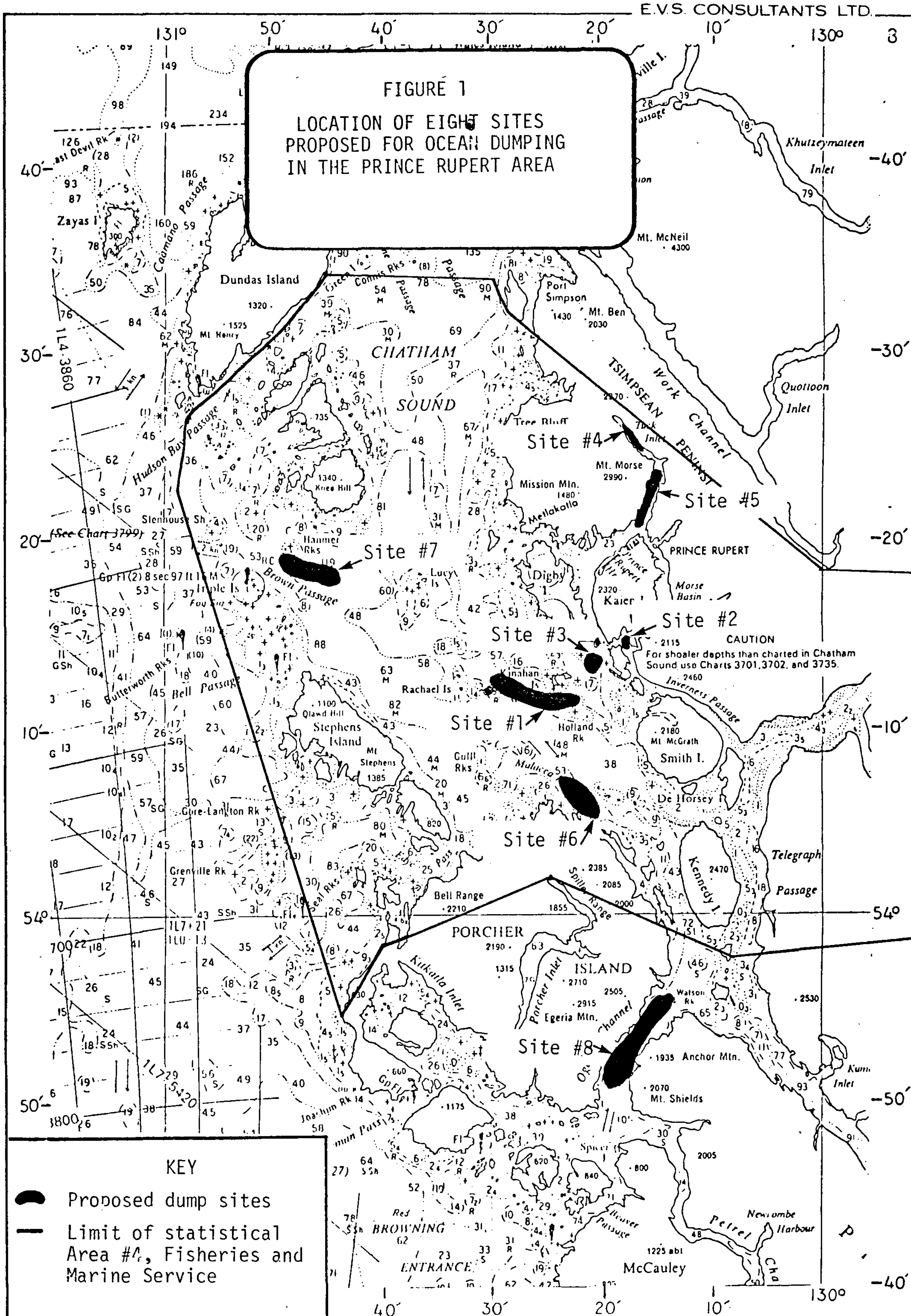


FIGURE 1
LOCATION OF EIGHT SITES
PROPOSED FOR OCEAN DUMPING
IN THE PRINCE RUPERT AREA
KEY
Proposed dump sites
Limit of statistical Area #4, Fisheries and Marine Service
Site #1
Site #2
Site #3
Site #4
Site #5
Site #6
Site #7
Site #8
CHATHAM SOUND
Dundas Island
Zayas I.
Stephens Island
PORCHER ISLAND
PRINCE RUPERT
Kaien
Digby I.
Smith I.
Kennedy I.
Port Simpson
TSIMPSEAN PENINSULA
Work Channel
Khutzeymateen Inlet
Quottoon Inlet
Telegraph Passage
Inverness Passage
Brown Passage
Hudson Bay Passage
Bell Passage
BROWNING ENTRANCE
McCauley
Petrel Channel
CAUTION
For shoaler depths than charted in Chatham Sound use Charts 3701, 3702, and 3735.
131°
130°
54°

2.0 PHYSICAL OCEANOGRAPHY

2.1 Background

The main purpose in reviewing the physical oceanography of the Prince Rupert area was to compile and synthesize pertinent physical/chemical data available for areas under consideration as future ocean dumping sites. Most information was gathered from the Institute of Ocean Sciences (IOS), Patricia Bay, and the Environmental Protection Service (EPS), West Vancouver. A detailed list of the principals contacted is given in the Acknowledgments section.

A description of the oceanographic conditions of the major water bodies within the study area is followed by specific oceanographic information for each of the eight proposed dump sites in the sections below. The parameters most relevant to ocean dumping are circulation, vertical stratification, levels of dissolved oxygen and variations in suspended solids.

2.2 General Oceanographic Conditions - Prince Rupert Area

2.2.1 Chatham Sound

The circulation and general water chemistry of Chatham Sound are determined primarily by the discharge of the Skeena River. South Chatham Sound is essentially a large estuary with a fresh surface layer moving northwards under the influence of the Coriollis force and prevailing winds. As a result, most water is transported north along the nearshore of the Tsimpsean Peninsula with a relatively small volume escaping through Brown Passage (NEAT, 1975). Due to entrainment of seawater from beneath, the surface salinity increases as the fresh water moves seaward. To make up the volume of seawater entrained into the surface fresh layer, a compensating shoreward movement of bottom saline water occurs (i.e. a classic "salt wedge").

The Nass River also discharges through Portland Inlet (Fig. 2) into North Chatham Sound. Under normal conditions the Nass fresh water mass mixes with the northward-moving Skeena waters and moves northwest into Dixon Entrance. During unusually heavy Nass River discharges, the Nass surface waters can spread into Chatham Sound and effectively block Skeena River water from moving northward beyond Tugwell Island (Trites, 1952). Figures 2 and 3 show the effects of normal runoff and freshet on the amount of fresh water found in the upper 60 ft (18.3 m) of Chatham Sound.

Current measurements taken on 24 August 1948 at a point in Chatham Sound near the entrance to Prince Rupert Harbour, showed that the average current at all depths was in a direction of 315^{O}True (northwest), and ranged from 0.57 knots at the surface to 0.10 knots at a depth of 20 m (NEAT, 1975).

Figure 4 shows the surface salinity under normal river conditions. The water column in South Chatham Sound is usually moderately stratified and very sensitive to the effects of changing flow rates in the Skeena River (Packman, 1977). Near the entrance to Prince Rupert Harbour, vertical salinity differences are typically 7 to 9°/₀₀ from surface to bottom. Vertical water temperature gradients range from 2 to 4°C (Packman, 1977; Packman, 1979). Levels of dissolved oxygen are typically saturated or super-saturated at the surface and decrease slowly with depth. Packman (1977) reported dissolved oxygen saturation as low as 66.9% southwest of Coast Island.

Representative oceanographic conditions in the Prince Rupert area for the months of April, June/July and October are shown in Figures 5, 6, and 7. Figure 7 also shows selected monthly information for salinity, turbidity and dissolved oxygen.

FIGURE 2.
PERCENTAGE OF FRESH WATER IN UPPER 60 FEET DURING
FRESHET CONDITIONS, SKEENA RIVER ESTUARY, JUNE 8-18, 1948
(From Cameron, 1948a)

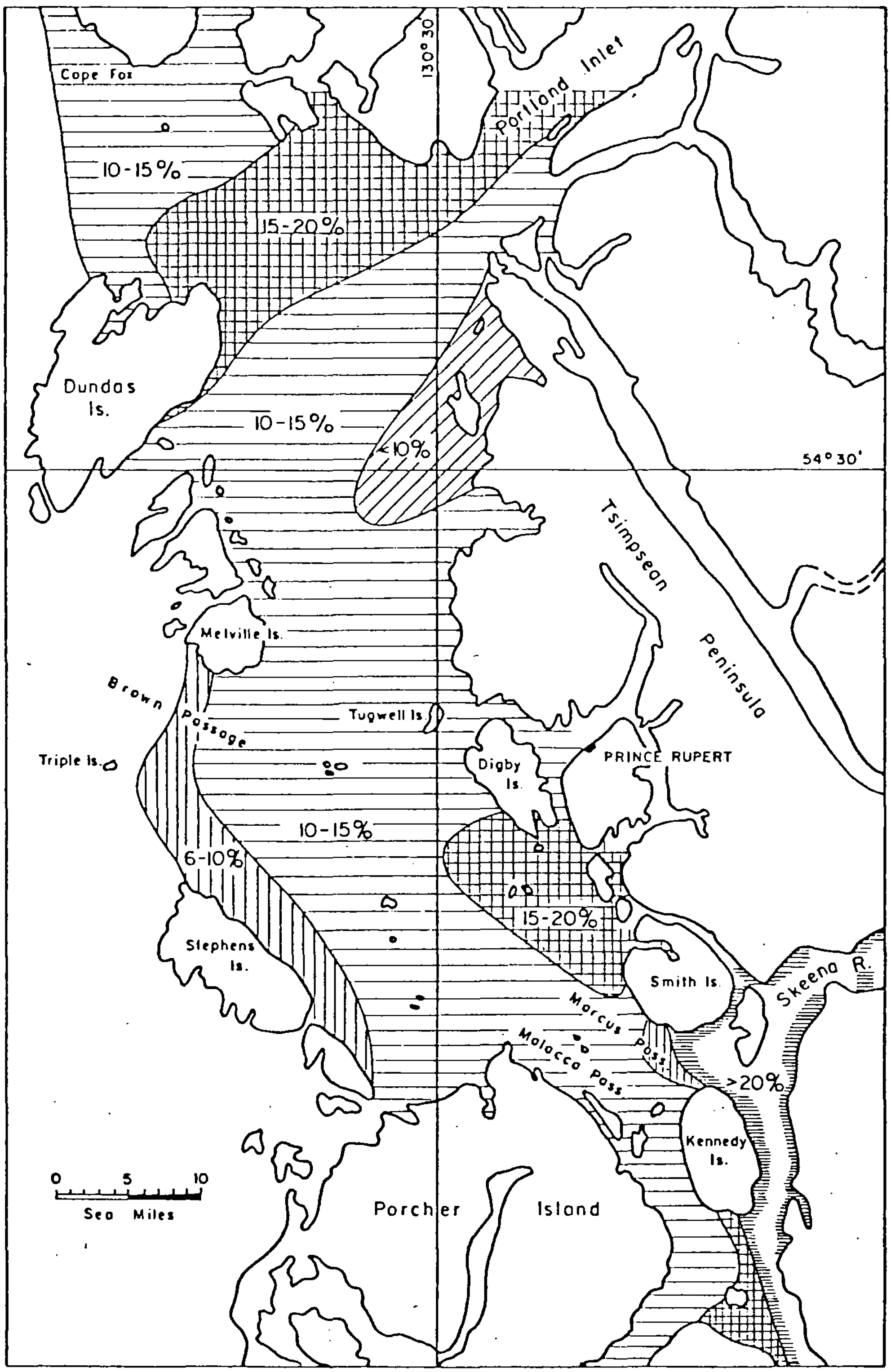


FIGURE 3.
PERCENTAGE OF FRESH WATER IN UPPER 60 FEET DURING NORMAL RIVER CONDITIONS, SKEENA RIVER ESTUARY, AUGUST 10-19, 1948
(From Cameron, 1948a)

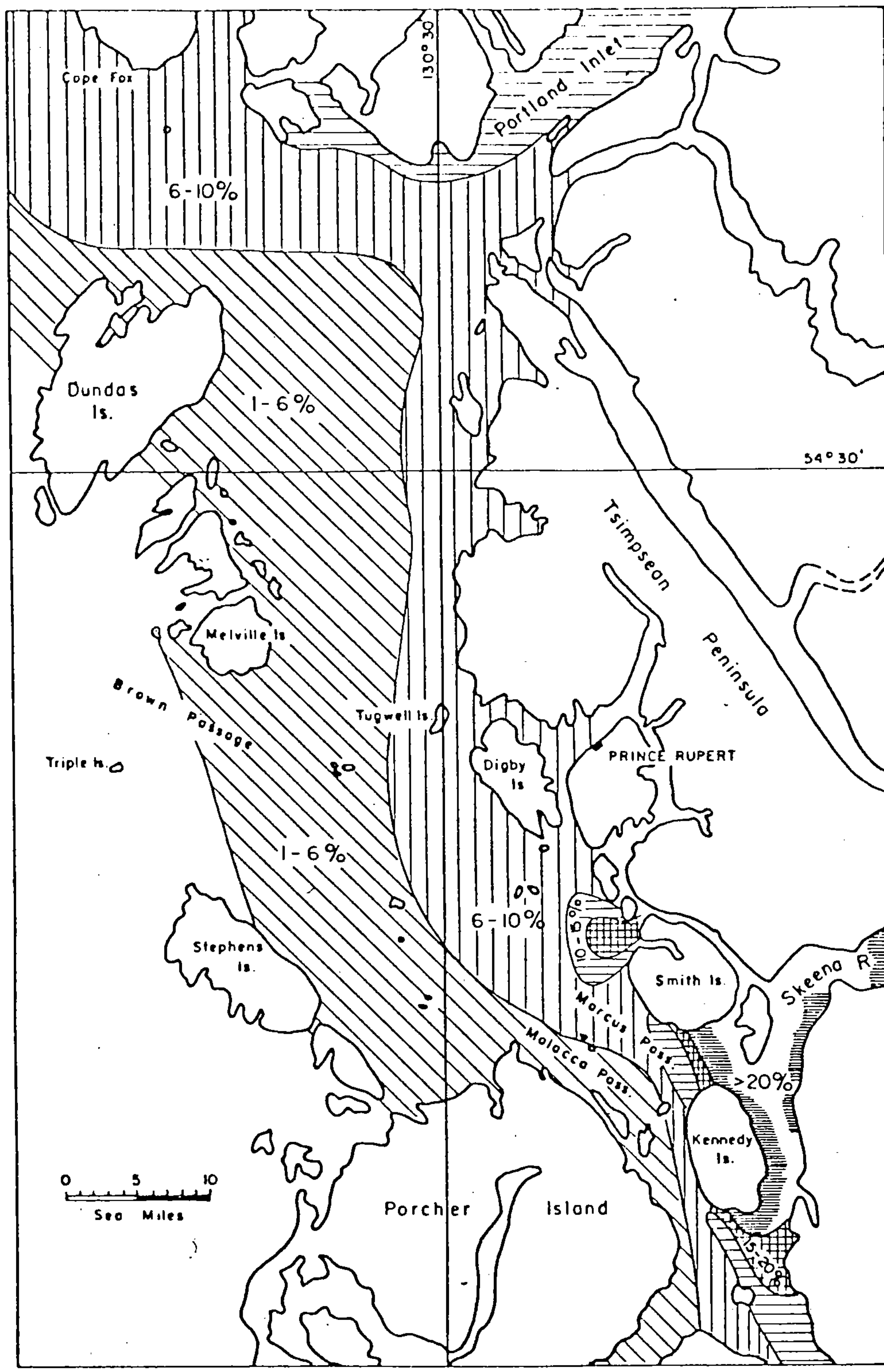
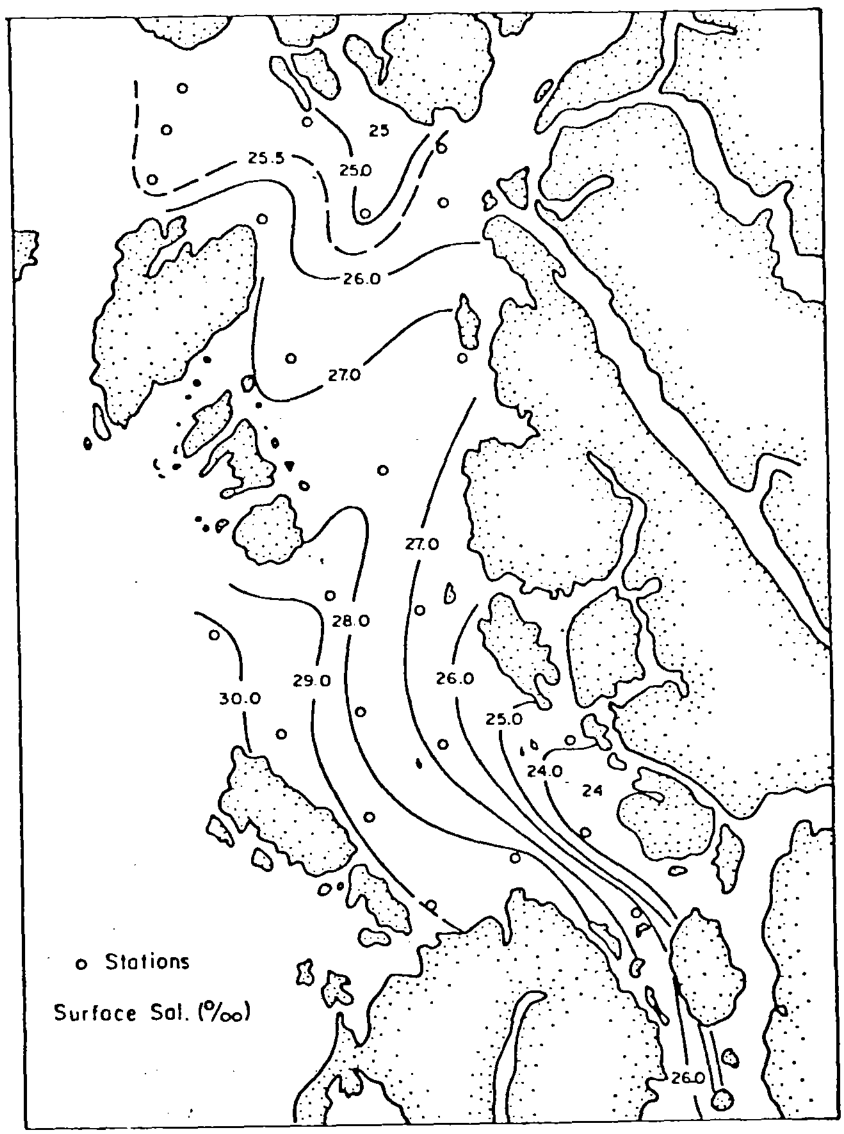


FIGURE 4.
SURFACE SALINITY PATTERN (°/₀₀) IN THE SKEENA RIVER ESTUARY
DURING NORMAL RIVER CONDITIONS, AUGUST 10-19, 1948
(From Trites, 1956)



The Skeena River outflow is highly turbid, especially during freshet in June (Hoos, 1975). As a result, turbidity and suspended load are increased significantly in the Chatham Sound estuarine waters at this time. Salt water flocculation aids in deposition of these silts, forming large shallow deltaic areas in the nearshore Skeena River mouth.

2.2.2 Tuck Inlet

Tuck Inlet is a narrow fjord extending about 6 km beyond the northern end of Prince Rupert Harbour (Fig. 5). A shallow sill (Tuck Narrows) with maximum depths of about 10 m separates the two bodies of water. Depths within the approximately 0.6 km wide Tuck Inlet exceed 60 m. The only known oceanographic survey was conducted by the Environmental Protection Service in June, 1979. Temperature, conductivity and dissolved oxygen profiles were taken at three representative stations in Tuck Inlet. Moderate stratification was observed at all stations. Surface-to-bottom differences in temperature were about 3.5°C, and in conductivity about 9,000 μmhos/cm. Vertical differences in dissolved oxygen values ranged from 4 mg/L near the head to 1-3 mg/L near the mouth. Surface dissolved oxygen was near saturation at all stations. It was also noted that quantities of surface debris tended to collect in Tuck Inlet (Glen Packman, EPS, pers. comm.), indicating poor surface circulation in the inlet. This assumption is based on the preliminary investigation by EPS, and the minimum input of fresh water entering the area (i.e. lack of driving force for true estuarine circulation patterns) at any time. Figure 5 shows some results of the EPS June 1979 sampling.

2.2.3 Prince Rupert Harbour

Prince Rupert Harbour is bounded to the north by Tuck Narrows and can be assumed to extend approximately 18 km southwest to Frederick Point at the entrance to Chatham Sound (Fig. 5). Its width is an average 1 to 2 km and there are two other main passages leading from it: Venn Passage to the northwest into Metlakatla Bay and Fern Passage to the southeast into Morse Basin. The deepest portions of its basin appear to be adjacent to Fern Passage (Seal Cove) where depths can exceed 65 m.

Prince Rupert Harbour has no major river influents, consequently, its surface salinity usually decreases towards the mouth of the inlet where there is dilution by Skeena River water (NEAT, 1975). Measurements of salinity and temperature within the harbour confirm this (Figs. 5, 6, and 7), and the fact that the waters are stratified. The surface mixed layer is usually less than 10 m deep. The low transmissibility in the surface waters demonstrates the turbid effects of Skeena River water, especially near the harbour mouth. In October 1974 the surface transmissibility was less than 10% in the harbour and less than 1% near the mouth (NEAT, 1975). The deeper water (below 10 m) was clearer with transmissibility of about 50%.

Vertical stratification is also evident in the concentrations of dissolved oxygen within the harbour, especially during early fall. Measurements in October 1974 (NEAT, 1975) showed surface dissolved oxygen levels near 10 mg/L and bottom concentrations near 8 mg/L at the mouth decreasing to less than 6.5 mg/L at the head. These low bottom levels in fall are thought to be caused either by limited mixing, stagnation and rapid oxygen consumption near the bottom; by surface shading by higher turbidities reducing photosynthesis; or, by organic wastes in surface layers and

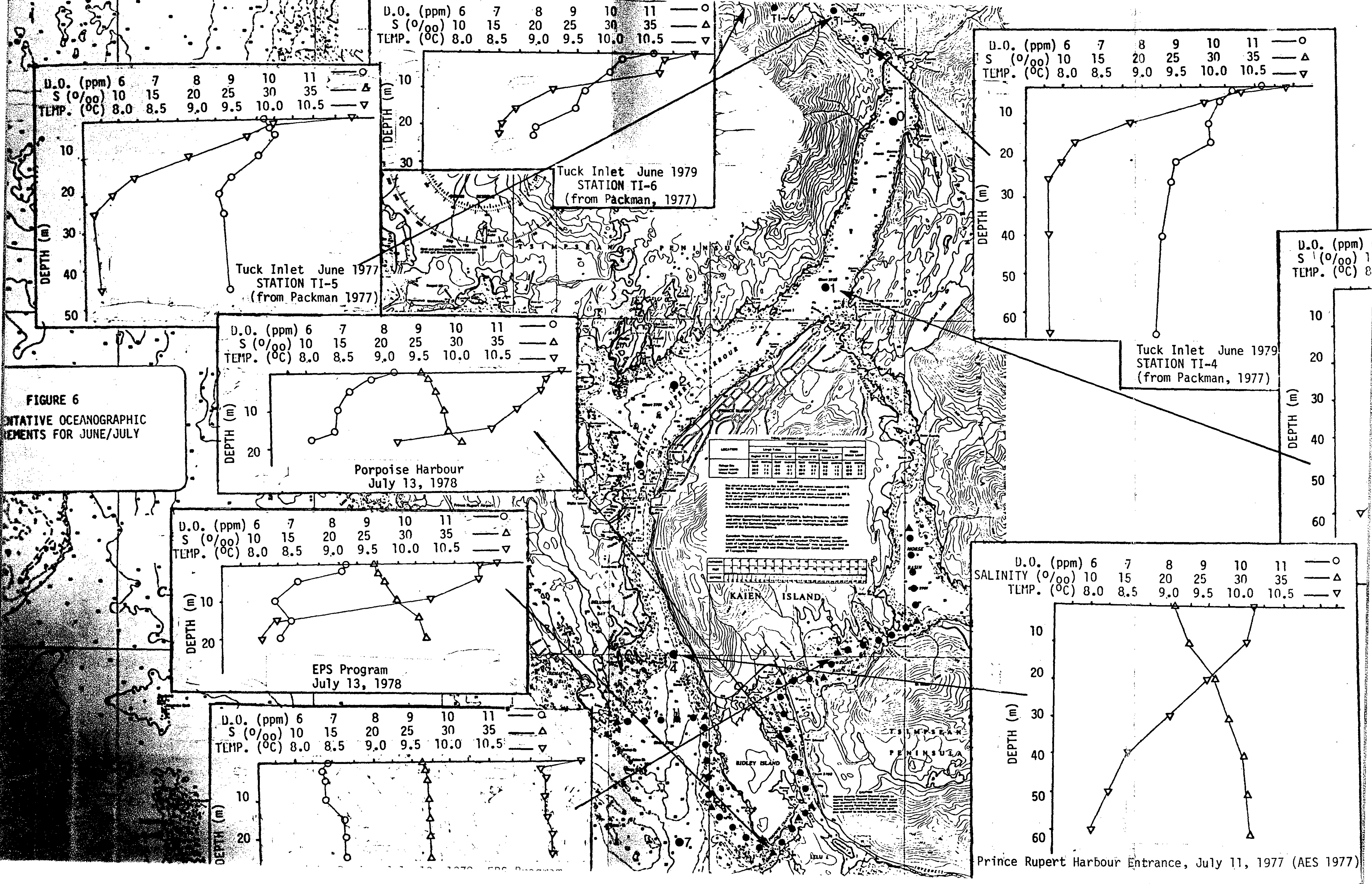


FIGURE 6

...NTATIVE OCEANOGRAPHIC ...EMENTS FOR JUNE/JULY

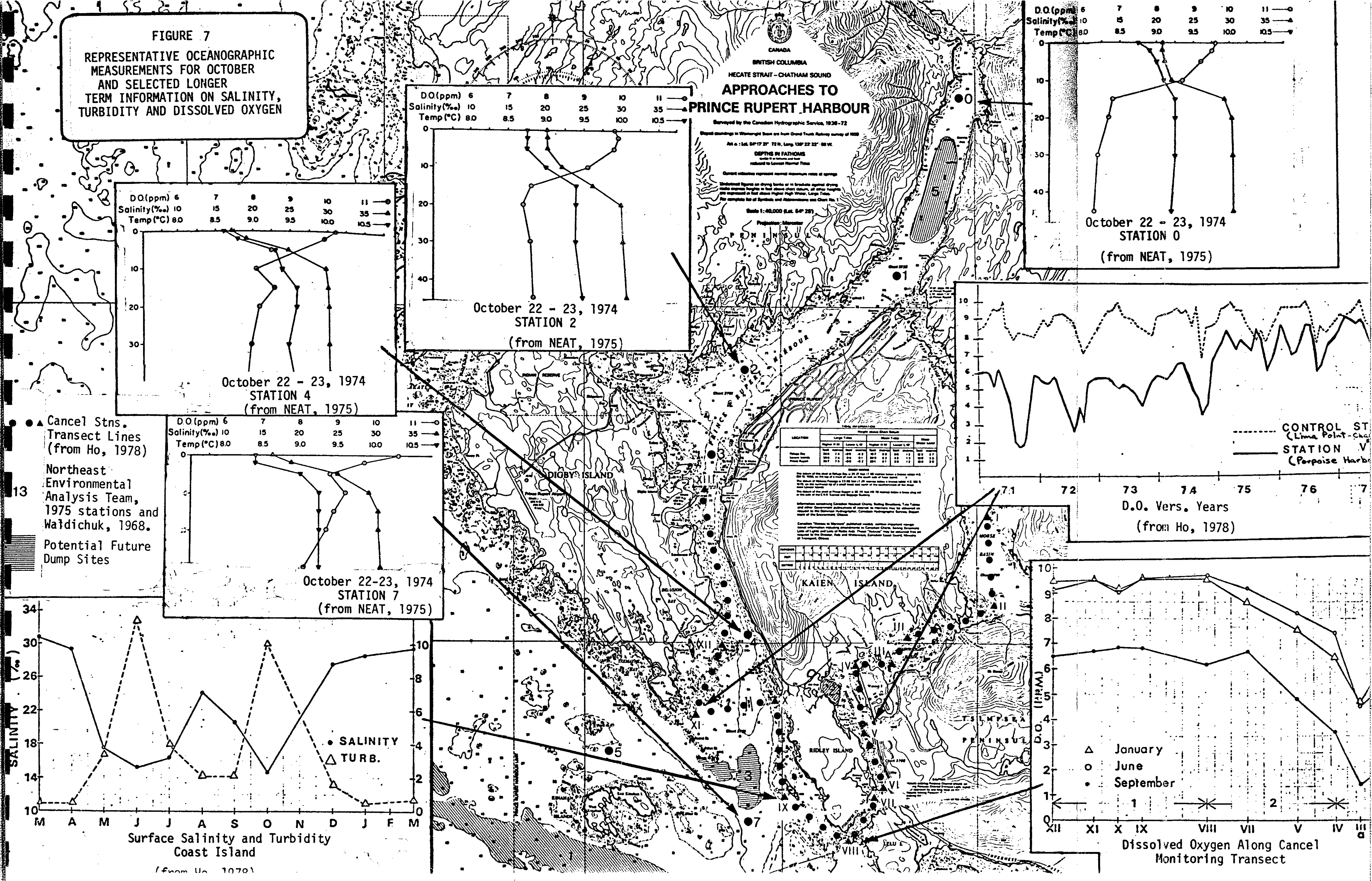


FIGURE 7

REPRESENTATIVE OCEANOGRAPHIC MEASUREMENTS FOR OCTOBER AND SELECTED LONGER TERM INFORMATION ON SALINITY, TURBIDITY AND DISSOLVED OXYGEN high oxygen consumption by bacteria (NEAT, 1975). Measurements in spring (April, 1962) showed much less stratification in dissolved oxygen. Surface to bottom differences were always less than 1 mg/L (Waldichuk, 1968).

The tidal amplitude in Prince Rupert Habour varies from 16.0 ft (4.9 m) at average tides to 24.9 ft (7.6 m) at large tides (Associated Engineering Services, 1977). An estimated 96% of the total tidal range volume is supplied through the harbour entrance (near Barrett Rock) and the remaining 4% by flow through Venn Passage (Associated Engineering Services, 1977). The tidal flushing volume of the harbour, Tuck Inlet and Morse Basin is estimated at 10 billion cubic feet (2.83 x 10^7 cubic metres). At the mouth of Prince Rupert Harbour Waldichuk (1968) demonstrated a north-south oscillation of surface currents in phase with the rise and fall of the tides. Surface speeds approached 1 to 2 knots. Bottom currents were much weaker and also oscillated north to south. However, the northerly currents were stronger suggesting the possibility of a net inflow at depth. Measurements of bottom currents in Prince Rupert Harbour from July 4 to July 15, 1977, showed net current movements out of the harbour (southwest) 60% of the time and into the harbour 30% of the time. These percentages represent the long term water movements only and not the tidal current periods. Highest speeds of about 0.4 knots (33 cm/sec) were observed for current directions in the range of 170°-190°True (Associated Engineering Services, 1977).

An internal review by the Environmental Protection Service (G. Packman, pers. comm.) of the Associated Engineering Services report (1977) recognized a significant onshore component in the surface circulation and the possibility for surface water convergence in the upper end of Prince Rupert Harbour, trapping surface debris there.

2.2.4 Porpoise Harbour, Wainwright Basin and Morse Basin

Porpoise Harbour is a relatively narrow body of water oriented north-south and linked to Chatham Sound to the south by Porpoise Channel (Fig. 5). Depths in Porpoise Harbour are less than 18 m except for a small basin in its northwest and near its southern connection to Propoise Chanel. Wainwright and Morse Basins lie to the northeast connected to Porpoise Basin by a series of narrow, constricted channels, Zanardi Rapids and Galloway Rapids, respectively. Several different types of waste are discharged into these waters associated with the CanCel Kraft Mill, fish processing and Port Edward domestic wastes. A general summary of these wastes and their discharge locations is provided in Ho (1978) and Hoos (1975).

The water column in Porpoise Harbour is moderately stratified. Fresh Skeena River water is introduced into the harbour during tidal exchanges through Porpoise Channel. However, the net flow of water from Morse Basin is north through Btuze Rapids while the main flow through Wainwright Basin and Porpoise Harbour is out through Porpoise Channel (Ho, 1978; Packman, 1979). Flushing rates have been calculated by Ker et al. (1970).

Two very distinct low salinity troughs appear for surface waters in the months of June and October. These are due to peak annual Skeena River outflow and increased rainfall, respectively (Ho, 1978). Turbidity peaks are also observed in these same periods. The effects are less intense in Wainwright Basin than Porpoise Harbour.

Levels of dissolved oxygen in Porpoise Harbour declined significantly after the introduction of the sulphite mill, so much so that numerous fish kills have been reported. However, since the shutdown of the sulfite mill in 1976, a yearly improvement in levels of dissolved oxygen have been reported by CanCel and the Environmental Protection Service. A comparison of surface dissolved oxygen from 1971 to 1978 at a station inside Porpoise Harbour and a control station in south Chatham Sound indicated a dramatic recovery to within about 80% of natural levels within the harbour (see Fig. 7). An annual variation is also evident for all areas. From November to July, levels of dissolved oxygen are near saturation in most nearshore areas unaffected by industry. In the period August to October, surface levels of dissolved oxygen usually decrease from means of about 9 ppm to about 6.5 ppm. This is apparently due to wind-induced upwelling which occurs primarily in the fall and brings bottom water masses to the surface. The bottom waters are lower in dissolved oxygen, and this phenomenon has been suggested as occurring along the north coast (Ho, 1978).

2.3 Initial Physical Oceanographic Assessment of Eight Proposed Dump Sites

A workshop review of the physical, chemical and biological information available in the Prince Rupert area identified eight potential areas for consideration as future ocean dump sites. It was determined that the final relative rating of each site would, in part, depend upon the toxic nature of the materials to be dumped. "Dirty" materials were described as those containing PCBs, heavy metals and/or other toxic chemicals. "Clean" materials were described as those which would have no direct toxic effects.

The important physical oceanographic criteria for dump site selection are essentially water depth and circulation/dispersion potential. The preferred locations for "dirty" wastes would be deep stagnant basins where circulation and dispersion potential were minimal. In such areas the "dirty" materials would potentially have severe long term effects on bottom sediments and organisms but would be restricted to as small an area as possible. The preferred locations for "clean" dump materials would be deeper basins already subject to large annual turbidity variations and where circulation was maximized. Examples of such areas would be those with large tidal flushing, long fetches for wind/wave activity, and where there was significant net water transport or net river influence.

On the basis of these physical oceanographic criteria, an evaluation was made of the eight potential dumping sites (Table 3). The relative ratings (numbers 1 → 8 indicate order of decreasing preference) are separated into two classifications, one for "clean" materials and the other for "dirty" materials. Such a separation determines whether widespread or limited dispersion is wanted. Using this system, the preferred sites in terms of physical oceanographic criteria were North Porpoise Harbour for "dirty" material, and southeast Chatham Sound for "clean" materials.

2.4 Oceanography Field Studies Conducted Near Prince Rupert

A review of the pertinent oceanographic literature for the Prince Rupert area yielded the following chronological list of representative field studies:

1948 (June, August and September) - Oceanographic studies by Pacific Oceanographic Group in Chatham Sound (summary of findings in Cameron, 1948).

1954-57 - Hecate Oceanographic Project in Hecate Strait and part of Chatham Sound (described in Barber, F. G. and S. Tabata, 1954).

1961 (September) - Oceanographic measurements in Prince Rupert Harbour, Chatham Sound, Porpoise Harbour and Wainwright Basin (summary provided in Waldichuk, 1961).

TABLE 3

RELATIVE RATINGS FOR EIGHT POTENTIAL DUMPSITES BASED ON PHYSICAL OCEANOGRAPHIC CRITERIA

Physical Oceanographic Criteria	SITE 1 Kinahan Island Basin	SITE 2 N. Porpoise Harbour Basin	SITE 3 Pr. Rupert Harbour Entrance Basin	SITE 4 Tuck Inlet Basin	SITE 5 N. Prince Rupert Harbour Basin	SITE 6 Southeast Chatham Sound (Malacca Psg)	SITE 7 Brown Passage	SITE 8 Ogden Channel
Depth Ranges	90 - 120 m	17 - 20 m	36 - 50 m	55 - 60 m	55 m	90 - 140 m	90 - 100 m	145 - 190 m
Tidal Flushing Approximations	1-2 knots	1 knot	2 - 2 1/2 knots	NI	NI	1-2 knots	2 knots	2 knots
Net Water Transport (wind-river influence)	YES NW	YES S	YES NW	NI	YES NE at surface, SW at Bottom	YES NW	YES NW	YES SW
Prevailing Wind Fetch Estimates (illustrates potential for wind/wave mixing)	20 km SE	2 km SE	8 - 15 km SE	1 - 2 km SE	8 km SE	12 - 16 km SE	30 - 50 km SE	4 - 8 km SE
Skeena River Influence	Moderate	Minimum	Moderate	Minimum	Minimum	Moderate	Minimum	Strong (Major Outflow Channel)
Surface Turbidity Variations	Moderate levels & moderate annual variations	Moderate levels & moderate annual variations	Moderate to high levels & large annual variations	NI	Low to Moderate levels & moderate to low annual variations	Moderate to high levels & low to moderate annual variations	Moderate to low levels & moderate variations	Extremely high levels & little variation due to direct Skeena River influence
Surface Dissolved Oxygen Variations	≈7 to 10 mg/L	≈6 - 9 mg/L but historically much lower	≈7 - 10 mg/L	LI ≈7 - 10 mg/L	LI ≈8.5 - 9.5 mg/L	LI ≈7 - 10 mg/L	NI but probably 8 - 11 mg/L	NI

B LI 8 to 9.5

Relative Ratings* for	SITE 1	SITE 2	SITE 3	SITE 4	SITE 5	SITE 6	SITE 7	SITE 8
CLEAN MATERIALS DUMPED (Wide-spread dispersion wanted)	2	7	5	8	6	1	3	4
DIRTY MATERIALS DUMPED (Limited dispersion wanted)	5	1	6	2	3	4	8	7

KEY: NI - No information
LI - Limited information
* - 1 = most suitable
8 = least suitable

1962 (April and July) - Oceanographic measurements in Prince Rupert Harbour, Chatham Sound, Porpoise Harbour, Wainwright Basin, Morse Basin and Inverness Passage (summary provided in Waldichuk, 1963).

1964 (October) - Oceanographic measurements in Porpoise Harbour, Wainwright Basin and Morse Basin after a reported fish kill (summarized in Kussat, 1968).

1969 (May to November) - Oxygen surveys in waters contiguous to Porpoise Harbour (summarized in Brothers, 1970).

1970 - Current studies in Porpoise Harbour (summarized in Ker et al., 1970).

1973 (March) - Spot oceanographic measurements near proposed superport sites at Fairview, Ridley Island and Kitson Island (summarized in Slaney, 1973).

1974 (July and August) - Oceanographic measurements by Marine Studies Group of the Environmental Protection Service in Prince Rupert Harbour Entrance, Porpoise Harbour and Wainwright Basin (summarized in Packman, 1977).

1974 (October and November) - Oceanographic measurements in Prince Rupert Harbour and Entrance for assessment of proposed bulk loading facilities (summary provided in Northcoast Environmental Analysis Team, 1975).

1974 to Present - Oceanographic monitoring program by Canadian Cellulose of waters potentially affected by wastes discharge (summarized in Ho, 1978).

1977 (June) - Oceanographic measurements by Environmental Protection Service in Porpoise Harbour and Channel (summarized in Packman, 1979a).

1977 (July) - Oceanographic measurements in Prince Rupert Harbour during assessment of sewage disposal options (summarized in Associated Engineering Services Ltd., 1977).

1977 - Current studies in Porpoise Harbour and Chatham Sound (summarized in Simons, 1977).

1978 (July) - Oceanographic measurements by Environmental Protection Service in Porpoise Harbour and Wainwright Basin (summarized in Packman, 1979a).

1979 (June) - Oceanographic measurements by Environmental Protection Service in Tuck Inlet, Prince Rupert Harbour and Propoise Harbour (summarized in Packman, 1979b).

1979 (August) - Water quality observations in the mouth of the Skeena River and Inverness Passage (manuscript in production by A. Ages, Institute of Ocean Sciences, Patricia Bay).

3.0 BIOLOGICAL RESOURCES

3.1 Background

Numerous biological surveys have been conducted by various organizations in conjunction with development in the Prince Rupert region, but these surveys have been carried out on an *ad hoc* basis and assessments of the impact of ocean dumping on the biological resources of the eight proposed dump sites have not been made. Both qualitative and quantitative date would be desirable, but as with other components in this review, much information relevant to biological impact assessment is lacking.

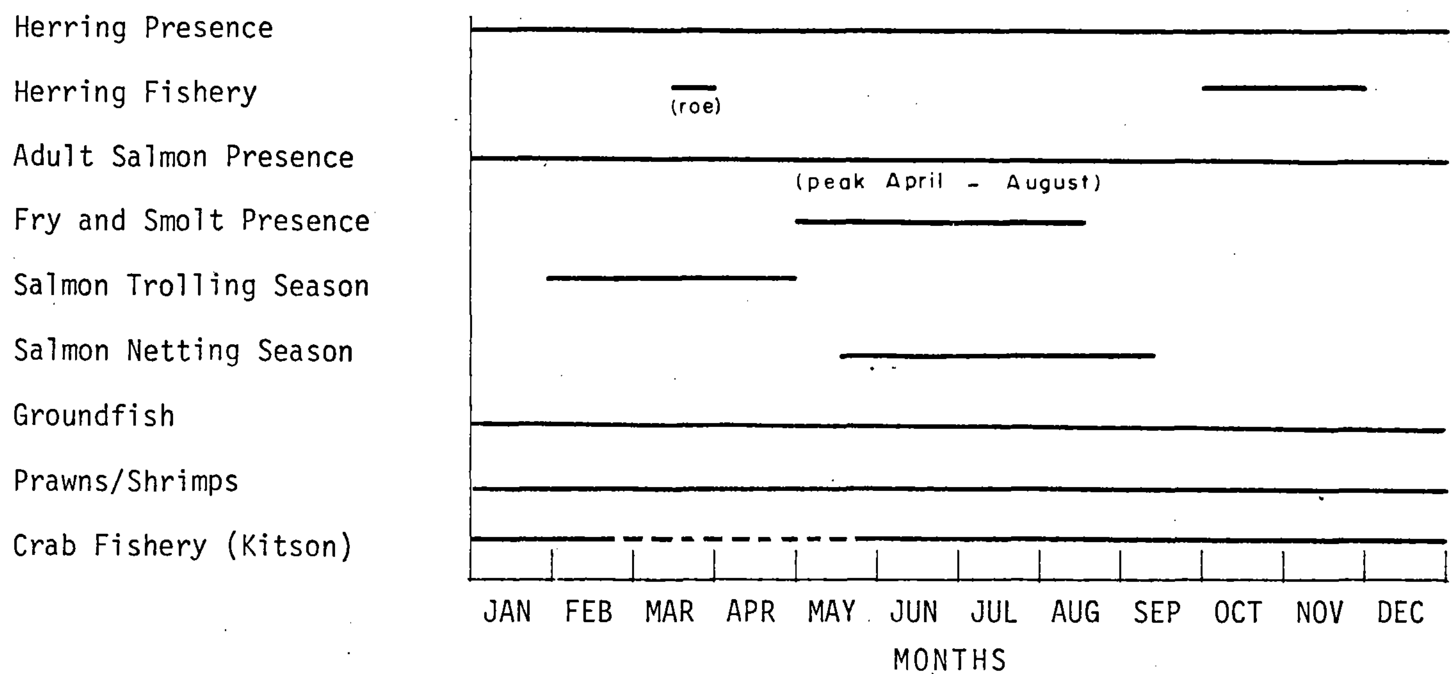
The fishery resources of prime concern in the Prince Rupert region are:

1) Salmon (juveniles and adults)
2) Herring
3) Groundfish
4) Crustaceans (shrimps, prawns, crabs).

The presence and abundance of these stocks vary seasonally (Fig. 8), thus dumping activity must work within certain time constraints. The available data allow for general presence/absence assessment, but not rigorous quantitative population estimates. A general review and assessment of the relevant biological information for the proposed dumping sites follows.

FIGURE 8

SEASONAL VARIATION IN COMMERCIAL FISHERIES ASSOCIATED WITH PRINCE RUPERT - SKEENA ESTUARY REGION
(Modified from F. F. Slaney and Company Limited, 1973)



3.1.1 Critical review of existing biological data for the Prince Rupert study area

Evident throughout the biological data is the conspicuous absence of site specific information on the various fish stocks for the proposed dumping areas. Catch statistics are available for salmon, herring and groundfish resources; however, they apply to the Fisheries and Marine Service Statistical Area 4, which includes the Skeena River (Fig. 1), and not specifically to any of the proposed sites. Similarly, there is a considerable amount of information for salmon utilizing the Skeena River (Table 4), however the annual catch is an average for the Skeena system only and not directly related to any area proposed for ocean dumping. Data from shrimp/prawn tows are available for this region of the B. C. coast (e.g. Butler and Dubokovic, 1955), but there is no recent information for areas under consideration as potential dump sites in the Chatham Sound region. Therefore the emphasis for the Biological Resource Section can only be qualitative in its attempt to relate available fisheries data to the proposed dump site areas.

3.2 Chatham Sound (Sites 1, 3 and 6)

Due to its close proximity to the Skeena River, the second major producer of salmon in B. C., Chatham Sound is a principal thoroughfare for juvenile and adult salmon. Certain areas (e.g. Flora Banks, Kitson Island; Fig. 9) are extremely productive rearing habitats for juvenile salmonids (Higgins and Schouwenburg, 1973; Hoos, 1975). Commercial harvesting of adults in the area between the Kinahans and Kitson Island (site 1; Fig. 9) has been documented by Schouwenburg (1976). Dredge spoils dumped in these areas may reduce the effectiveness of gillnetting operations.

TABLE 4

SALMONID FISHERIES DATA FOR SKEENA RIVER

(From Hoos, 1975)

	Average Annual Catch	Spawning	Emergence	Estuary Residence	Commercial Fishing
Sockeye	881,000 (1908-67)	late summer-autumn 2 peaks: - July-Aug. - Sept.-Oct.	spring - 1-3 yr f/w residence	- some on beaches - majority: - river mouth - Flora Bank - Kitson Island ∿1 mon → seaward	- mid-June to mid-August - peak catches during last 2 weeks of July and first week of August
Pink	odd-year 953,000 (1951-63) even-year 707,000	- closer to sea (Lakelse) - late Aug.-late Oct.	April-May → sea	peak - mid-May - do not remain in river mouth - move out into shallow estuary channels along beaches and sand banks - esp. Flora and De Horsey Bank ∿1 mon → seaward	- mid-July and peak in early Aug.

TABLE 4 (continued)

	Average Annual Catch	Spawning	Emergence	Estuary Residence	Commercial Fishing
Coho	100,000 (1951-63)	- close to sea - Oct.-Nov.	spring - usually remain 1 yr in f/w	- longer estuary residence - early June - remain in shallow waters of sand banks for week to 2 mon - esp. Inverness Passage	peak catches late July-early August
Chum	50,000 (1951-63)	Aug.-early Sept.	spring - directly to sea	- long estuary life - mainly Inverness Passage - peak numbers in estuary mid-July - move out of estuary late Aug.-Sept..	- late Aug.
Chinook	50,000 (1951-63)	Sept.	spring - spend few days to yr in stream	Inverness Passage for summer - peak numbers mid-June	late Feb.-late Aug. - peak - mid-July
Steelhead	10,000-12,000	Jan.-June	June-Sept. - spend 1-5 yr in f/w		

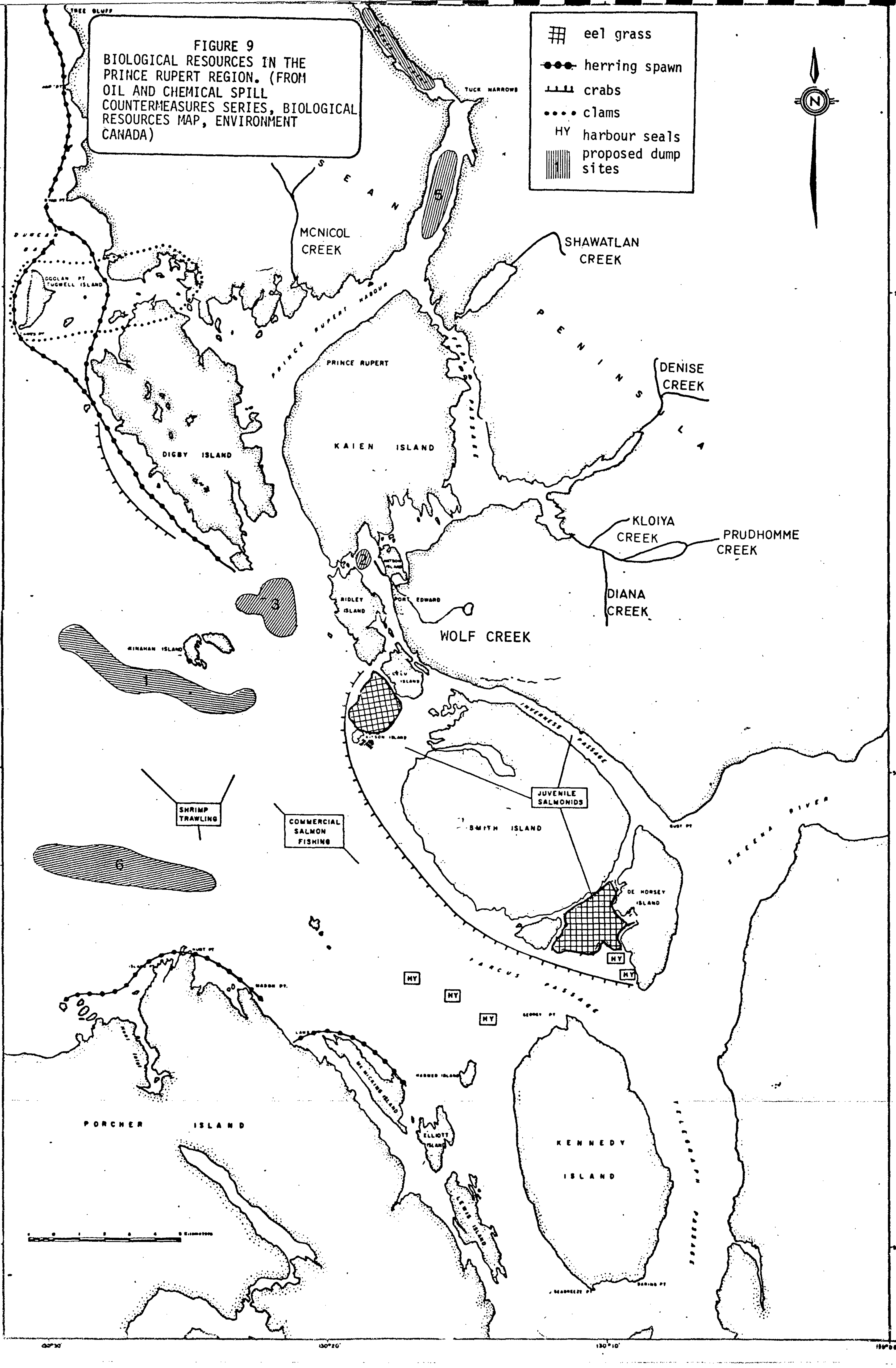
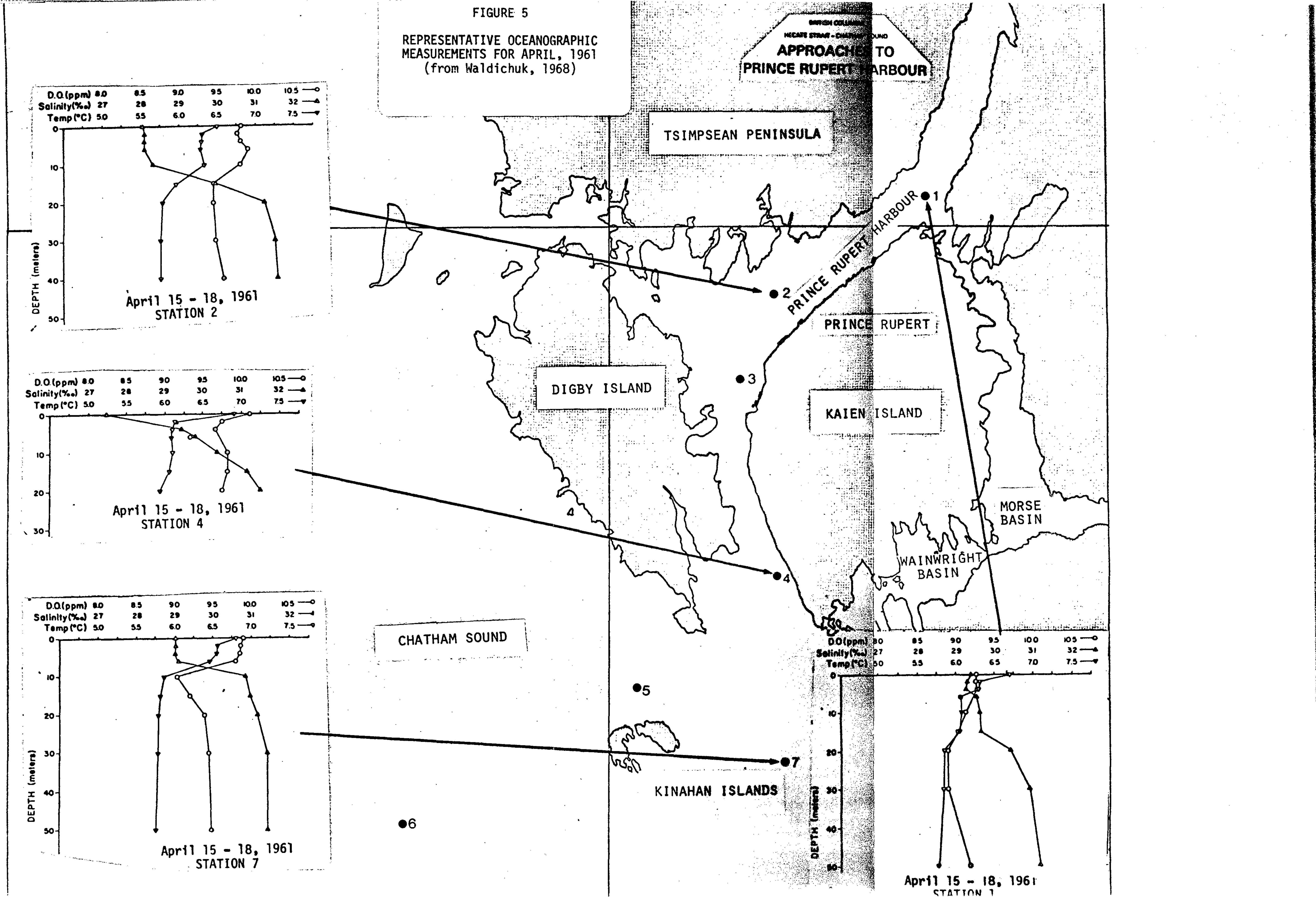


FIGURE 9
BIOLOGICAL RESOURCES IN THE PRINCE RUPERT REGION. (FROM OIL AND CHEMICAL SPILL COUNTERMEASURES SERIES, BIOLOGICAL RESOURCES MAP, ENVIRONMENT CANADA)

E.V.S. CONSULTANTS LTD.

FIGURE 5

REPRESENTATIVE OCEANOGRAPHIC MEASUREMENTS FOR APRIL, 1961 (from Waldichuk, 1968)



Herring spawning and fishing areas vary in size and location from year to year. Spawning areas extend from Port Simpson south to Porcher Island (Fig. 9). Bays and inlets along this coastline provide highly productive rearing habitats for larval and juvenile herring. Surveys and seine catches show largest returns of adult herring for areas west of Ridley Island (site 3) and south of Kinahan Island (sites 1 and 6) (Higgins and Schouwenburg, 1973; Hoos, 1975; Knapp and Cairns, 1978).

The groundfish fishery within Chatham Sound is of minor significance compared to the total catch for Statistical Area 4 (Fig. 1; Smith, 1977). Areas south of Kinahan Island (sites 1 and 6; Fig. 1), Smith Island, Lucy Island and Edge Passage produce the most significant quantities of groundfish (Leaman, 1977). Shrimp trawls (Carmichael and Boutillier, 1979) yielded no groundfish south of Kinahan Island; however, the area north of Porcher Island (site 6) and west of Rachael Island (site 1) was relatively productive for black cod.

The current crustacean (crab, shrimp, prawn) fishery occurs primarily in Chatham Sound. The result of shrimp and prawn surveys in the 1950s (Butler and Legare, 1954; Butler and Dubokovic, 1955) indicated that Chatham Sound could support a moderate shrimp fishery, the trench south of Kinahan Island (site 1) yielding the largest catches. Shrimp were most abundant in January, and inhabited deeper waters in September (Butler and Dubokovic, 1955). Surveys conducted in 1978 (Carmichael and Boutillier, 1979; Cooper and Boutillier, 1979) found the areas northeast of Rachael and south of Kinahan Island (site 1) to be most productive, but in general the catches were very low compared to those of Butler and Dubokovic (1955).

3.3 Porpoise Harbour (Site 2)

Beach seine monitoring programs over the past few years have documented the utilization of Porpoise Harbour by salmonids, herring and crabs (Birtwell, 1978). Juvenile salmonids from the local streams (Denise, Diana, Kloiya, Prudhomme and Shawatlan) migrate through, and possibly rear in Propoise Harbour. These streams produce all the sockeye and chinook originating from the small coastal streams in Fisheries Statistical Area 4 (Knapp and Cairns, 1978). Historically, this basin has been important for herring spawning and rearing of juveniles (Waldichuk, 1962; Birtwell, 1978). Beach seining in 1978 found the highest catches of herring in the northwest corner (near site 2) of the harbour (Nelson, 1978). Although there is no commercial fishery of Dungeness crabs, there is some recreational harvesting within Porpoise Harbour. Any dumping or dredging activity should be restricted from March to August when salmon and herring migrate and rear in this area.

3.4 Prince Rupert Harbour (Site 4) and Tuck Inlet (Site 5)

Limited fisheries resource information is available for this area. Relatively small populations of coho, chum and pink salmon spawn in McNicol (Tsimpsean Peninsula, south of site 5) and Silver (head of Tuck Inlet, site 4) Creeks (Knapp and Cairns, 1978). Dolly Varden, coastal cutthroat trout and steelhead have been reported in McNicol Creek (Hinton et al., 1975). The estuaries for both of these creeks will support rearing salmonids. A salmon sport fishery exists throughout this region, and commercial herring catches are made within Prince Rupert Harbour (Knapp and Cairns, 1975). Surveys conducted in 1979 showed the presence of crabs and prawns in the Prince Rupert Harbour region (Packman, 1979). Both herring and crustaceans have been reported in Tuck Inlet, however there are no estimates of population size.

3.5 Brown Passage (Site 7) and Ogden Channel (Site 8)

Again, information is limited. Brown Passage is adjacent to the productive groundfish area of Hecate Strait. Ogden Channel is known to be a major thoroughfare for the Skeena River salmon (Hoos, 1975).

3.6 Assessment of Eight Proposed Dump Sites with Respect to Biological Resource Data

Although a site specific, complete fisheries inventory is lacking, a relative and, by necessity, somewhat subjective rating system has been developed for assessment purposes (Table 5). The important biological criteria for dump site selection were the spatial and temporal distribution of the various fish stocks and their food items. Salmonids and herring utilize significant areas of the Prince Rupert region. Chatham Sound, Prince Rupert Harbour and Porpoise Harbour are all major thoroughfares for various stocks of salmonids from spring to fall. Throughout the spring and summer associated estuaries and offshore banks (Flora, Kitson Banks) are productive rearing habitats for salmon and herring. Thus unregulated dumping activity could release dredge spoils in habitats valued for rearing and spawning, or soil and snag nets during commercial fishing. The tides in Chatham Sound are large and move in several different directions, thus possibly enabling dumped material to reach productive rearing areas if the timing of dumping activities is not closely scrutinized.

TABLE 5

RELATIVE RATINGS FOR EIGHT PROPOSED DUMP SITES BASED ON BIOLOGICAL CRITERIA

	Site 1 Kinahan Island Basin	Site 2 N. Porpoise Harbour Basin	Site 3 Pr. Rupert Harbour Entrance Basin	Site 4 Tuck Inlet Basin	Site 5 N. Prince Rupert Harbour Basin	Site 6 Southeast Chatham Sound (Malacca Psg)	Site 7 Brown Passage	Site 8 Ogden Channel
Salmon								
Juveniles	+++	++	+++	+	+	++	+	++
Adults	+++	++	+++	+	+	+++	++	+++
Herring								
Spawn/Juveniles	+++	++	+++	+	+	+++	LI/-	LI/-
Adults	+++	++	+++	+	+	++	LI/-	LI/-
Groundfish	++	-	++	+	+	++	+++	+
Crustaceans	+++	+	++	+	+	+++	++	+
Relative Ratings* for materials dumped	8	5	7	1	2	6	4	3

+++
++ } degree of importance, most to least; LI/- , limited information/probably not important;
+ -, not important at this site; *1 = most suitable, 8 = least suitable.

Groundfish and crustaceans are present year round and dispersed throughout Chatham Sound. Depending upon the type and quantity of material being disposed, these fish resources are mobile enough to avoid relatively confined dump sites.

On the basis of these biological criteria, an evaluation of the proposed dump sites was made (Table 5). The relative ratings (number 1 → 8) are in order of decreasing preference. Using this system, Tuck Inlet was the preferred site for both "clean" and "dirty" materials.

3.7 Combined Ratings for Dump Sites Based on Biological Resource and Physical Oceanographic Data

The relative ratings of each site from the physical oceanographic (Table 3) and biological resource data (Table 5) can be summed to form a single, combined rating for both clean and contaminated materials. For "dirty" materials, the site with the lowest overall score (i.e. most suitable) was Tuck Inlet (score of 3). The second lowest score (5) was for North Prince Rupert Harbour Basin, and the third (6) for North Porpoise Harbour Basin. As Tuck Inlet ranked first in biological ratings and second in physical oceanography, it would appear to be the obvious choice for dumping of contaminated materials.

Three sites (Malacca Passage, Brown Passage and Ogden Channel) were tied with 7 points in the overall rating for clean materials. However, although ranking first in physical oceanography (i.e. for most widespread dispersion), Malacca Passage ranked sixth in the biological ratings. Protection of the biological resources should outweigh the need for widespread dispersion of clean material, therefore Brown Passage or Ogden Channel would be favoured. Due to the greater towing distance to Brown Passage and its lower biological score, Ogden Channel would seem to be the best choice for dumping of clean material.

The sites with the second and third lowest scores for clean materials were North Prince Rupert Harbour (8) and Tuck Inlet (9), respectively. If a stronger weighting of the biological over physical criteria was deemed appropriate, both these sites might also be considered for dumping of clean materials. Tuck Inlet scored first and North Prince Rupert Harbour second in the biological ratings (Table 5). However, choice of these latter two sites would result in very little dispersion of the dumped material (Table 3).

4.0 DISPERSION AND BOTTOM TRANSPORT OF DUMPED MATERIAL

4.1 Results of Initial Review of Existing Data

A literature review pertaining to the eight sites considered in this project revealed a significant lack of even general relevant information. The existing data base would allow calculation of the approximate dimensions (vertical height and horizontal extent) of a deposit of dumped material of known volume and particle size distribution. The only additional input for this determination would be the water depth (Krishnappen, 1975). An example of these calculations has not been included here as it was felt that dispersion was more important than just the form and size of dumped material on the sea bed. Also, specific data on the volume and sediment characteristics of the dumped material would be required. Development of a scenario for a hypothetical dredge spoil did not seem to be worthwhile.

No data on bottom current velocities or gross and net bottom current direction (Table 6) exist for the eight proposed dump sites. Reference has been made to "bottom current data" in the section of this report dealing with physical oceanography, but these data were not the type of bottom data required. "Bottom" used in the previous section was a relative term referring to the vertical water column from surface to sediments. The bottom data were collected 10 or even 20 feet above the sea bed. Such data are of little or no value for bedload movement calculations, which require data at a *maximum* of 1 m (100 cm) above the sea bed. The use of the word "bottom" current data in the present section refers specifically to those collected within 1 m of the sea bed.

TABLE 6

PHYSICAL DATA AVAILABLE TO ASSESS DISPERSION AND BOTTOM TRANSPORT OF DREDGE SPOIL AT PROPOSED OCEAN DUMP SITES - PRINCE RUPERT AREA

Site No.	Site Location	Water Depth	Bottom Sediments	Bottom Currents (+100 cm)	
				Velocity	Direction(s)
1	Kinahan Island Basin	x	-	-	-
2	North Porpoise Harbour Basin	x	o	-	-
3	Prince Rupert Harbour Entrance Basin	x	-	-	-
4	Tuck Inlet Basin	x	o	-	-
5	North Prince Rupert Harbour Basin	x	o	-	-
6	Southeast Chatham Sound (Malacca Passage)	x	-	-	-
7	Brown Passage	x	-	-	-
8	Ogden Channel	x	-	-	-

x known (adequate)

o partly known (inadequate)

- not known (inadequate)

Because of the lack of at-bottom current data, calculations of possible bedload or suspended transport of any dumped material could not be carried out. Current data for sites located in an open basin with oceanographic conditions can often be extrapolated from one site to the next, but in the complex topography of the Prince Rupert study areas such extrapolation would not be valid.

The dispersion is of particular importance in assessing either containment or spreading by natural processes. The stability of dumped material may be a critical factor in assessing the suitability of a particular site. If the predicted dispersion is low (i.e. the materials are contained in a small geographical area of the sea bed) contaminants would not spread out and affect adjacent areas. If the predicted dispersion is high it would be necessary to know the direction of the material movement to evaluate the potential impact of spreading to adjacent biological habitats.

It is not possible to produce any reliable estimates of probable current velocities, sediment characteristics, or sediment transport rates without precise scientific data. Such estimates would be general, and would probably not indicate any significant differences among sites. Current velocity and sediment characteristics in this regard are two totally unrelated variables. Two similar sites can have a mud bottom in one case and a sand/pebble sediment in another, simply as a result of differences in local geology, sediment sources, or some other factor. It is, therefore, not possible from the knowledge of sediment type alone to infer bottom dispersion conditions. Only in a case where the sea bed is characterized by sand with an abundant supply of silt/clay fed into the area would it be safe to speculate that the fine-grained sediments would be removed (or not deposited) by bottom currents.

The distribution of bottom sediments is poorly documented for the Prince Rupert region as a whole and for the proposed dump sites in particular. No systematic surveys have been carried out to map bottom sediments or to collate available unpublished information (D. Tiffin, B. Bronhold, R. Macdonald, pers. comm.). Information presented on existing hydrographic charts provides the only information of sediment size and distribution characteristics. *The density of the information on the charts is so low as to preclude meaningful interpretation.*

The review of existing data undertaken for this component of the study focused on the availability of at-bottom (i.e. 1 m) current and sediment data. In addition to the absence of sound data or information on bottom sediments, no oceanographic or current surveys of bottom velocities have been undertaken. Existing current data (e.g. Waldichuk et al., 1968) were largely obtained during profiled measurements of the water column rather than from bottom-mounted instruments. Bottom current velocities near the sea bed over any one area fluctuate considerably due to frictional effects. Sediment transport calculations require accurate measurements at depths of 100 cm or less above the sediment-water interface.

Due to the absence of defined sources of information (e.g. detailed bottom sediment maps) considerable time was applied to a careful search through ancillary sources (e.g. Hoos, 1975; Waldichuk et al., 1968; Waldichuk, 1972) in an attempt to locate data on bottom sediments and at-bottom currents. No systematic, relevant data sets were found from this search except for the near-bottom current velocity data discussed in the following section.

4.2 Assessment of Possible Fate of Dumped Material at Eight Proposed Dump Sites

Inasmuch as the physical data base is equally poor for each of the sites (Table 3), no single site can be recommended above the others in terms of predicted movement of dumped material. It would appear that movement is more likely to occur in areas of constricted tidal current flow such as parts of Porpoise Channel and at the entrance to Prince Rupert Harbour (site 3). Site specific assessments must be made to document local conditions as bottom currents as sediment dispersion can vary markedly within small geographic areas. For example, within Porpoise Harbour there are areas where expected dispersion rates would be low (as in the dump site presently in use: site 2), whereas adjacent constricted channels may have relatively high dispersion conditions. Near-bottom current velocity data from Waldichuk et al. (1968) for single locations within Porpoise Harbour (54°14.6'N, 130°18.4'W), and the entrance to Prince Rupert Harbour (54°14.0'N, 130°20.8'W) indicate that velocities greater than 20 cm/s can be expected at these two locations. These velocities are in excess of that required for entrainment of suspended sediments (silts and clays), however, the velocities reported are not at-bottom currents, but rather near-bottom measurements taken 10 to 60 feet above the sea floor. The remaining sites would be expected to have low natural dispersion rates, although this statement must be qualified due to the lack of *any* bottom or near-bottom current data.

The present dump site in Porpoise Harbour (site 2) is located in a relatively deep part of the basin. Unfortunately no studies have been conducted on changes in the distribution of material dumped at this site. Therefore, it is not possible to apply site specific data to assess dispersion or non-dispersion of bottom sediments and the suitability of this location as a dump site.

In general deep, open ocean sites would be recommended over shallow (<50 m) channel or bay sites, as current velocities would likely be higher in the latter environments. This recommendation applies most stringently to dumping of contaminated material which should not be allowed to spread into areas adjacent to the dump site.

4.3 General Requirements for Impact Assessment of Ocean or Coastal Dumping

Since such few data to assess the dispersion of dumped material exist for the Prince Rupert area, it was felt that a summary of the general requirements was in order. It is hoped that such a summary will serve as a guide to scientists collecting data during future studies in this area.

The physical factors involved in dredge spoil disposal have been discussed by several authors (e.g. Bowen, 1976; Sternberg et al., 1979; Smith, 1979). The information necessary to assess the impact of ocean or coastal dumping can be categorized into (a) the disposal method and the disposal material, and (b) the disposal site environment.

To assess the behaviour of the dump material requires a knowledge of:

i) the types and amounts of material,
ii) the degree of packing,
iii) the methods of release (clam-shell; barge tipping, etc.)

From this information it is possible to model how the dumped material would behave and how it would be deposited on the sea floor (Bowen, 1976).

To a large degree the character of the disposal material controls the final form that the material would assume on the sea floor. The settling and dispersion rates are a function not only of the size of the material but also of the character of the material and the degree of packing. For example, fine-grained sediments such as silts or clays could settle at the same velocity as pebbles or cobbles if they were in a dry, semi-consolidated and compacted state. The same sediments released as a slurry would settle very slowly and would probably disperse over an extensive area before deposition. Figure (i) indicates this point of inflection and shows that consolidated clays and silts can be deposited in fast currents (up to 500 cm/s at 15 cm above bottom), whereas unconsolidated sediments of the same size with a 90% water content would settle out only if the velocity is less than 10 cm/s.

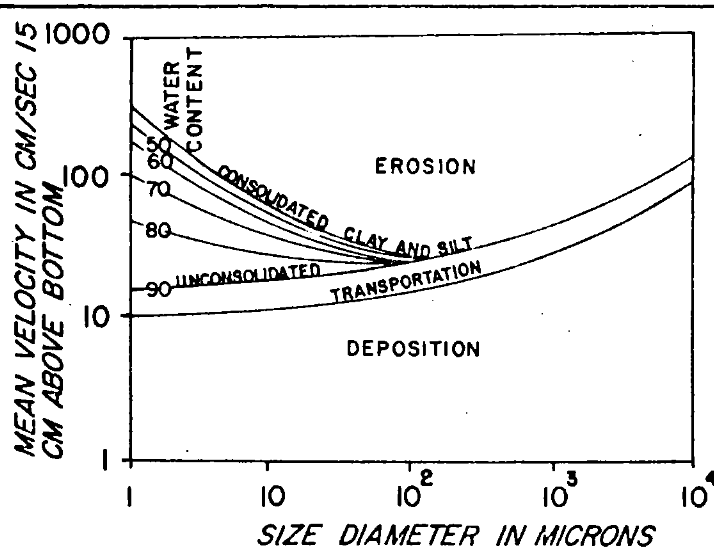


Figure (i). Erosion, transportation, and deposition velocities for different grain sizes. The diagram indicates possible values for various stages of consolidation. (*Source unknown.*)

The method of disposal is also a parameter which must be taken into account as it determines the initial surface area through which the sediment or material enters the water. The pertinent data required would be values on volume per unit area.

To assess the dispersion or spreading of dumped material requires data on:

iv) bottom current velocity and direction (at 100 cm above the sea bed),
v) bottom pressure,
vi) water depth, and
vii) bottom sediment characteristics.

The movement of dumped material on the sea floor can take place by bed-load transport or by suspended sediment movement. The threshold for the initiation of transport for fine sand is in the order of 20 cm/s, whereas silts and clays can be suspended by simple bottom pressure fluctuations. Prediction of bottom current velocities necessary to initiate transport is based primarily on laboratory studies. The results of these experiments (Fig. (ii)) provide a general guide to the size-current velocity relationship. Data on other factors such as the degree of consolidation and the duration of velocities sufficient to entrain sediments are also required.

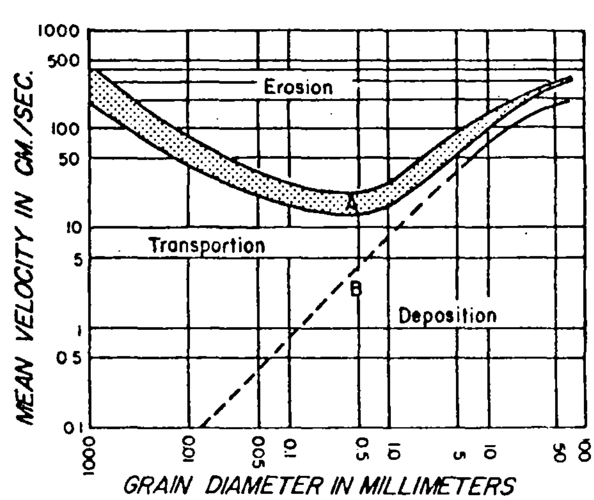


Figure (ii). Hjulstrom's diagram (1935) of the relation between water velocity and particle size.

A critical factor in assessing dispersion of dumped materials is knowledge of the importance of storm-generated hydraulic processes on the sea bed. Sternberg et al. (1979) noted that sand-sized material dumped off the Washington-Oregon coast in approximately 30 m water depths was dispersed up to 0.4 km/yr. In this experiment the importance of storm-generated bottom currents was emphasized as a critical element in the movement of sediments coarser than 0.18 mm. Material finer than 0.15 mm was dispersed primarily by currents and by wave-induced bottom motion.

The single most important data set for the assessment of dispersion rates is bottom current velocities (at 100 cm above the sea bed). The use of bottom-mounted standard Savonius-Rotor meters (with threshold velocities of 2 cm/s and response times in the order of 30 s) would provide adequate data. In general, these types of data are obtained only as the result of specific studies and are rarely part of standard oceanographic surveys.

The basic data inputs required to develop an adequate assessment of dump spoil dispersion are sediment size and bottom currents. With these data it is possible to determine direction and distance of transport using existing modelling techniques. Actual bed-load and suspended-load volumes, however, cannot be estimated without detailed site-specific data. As these data are lacking for the proposed dump sites around Prince Rupert, it has not been possible to compute meaningful values which would be useful in the development of impact assessment.

5.0 REVIEW OF CONTAMINANTS IN SEDIMENTS AND BIOTA FROM THE PRINCE RUPERT AREA AND IMPLICATIONS FOR OCEAN DUMPING

5.1 Polychlorinated Biphenyls (PCBs)

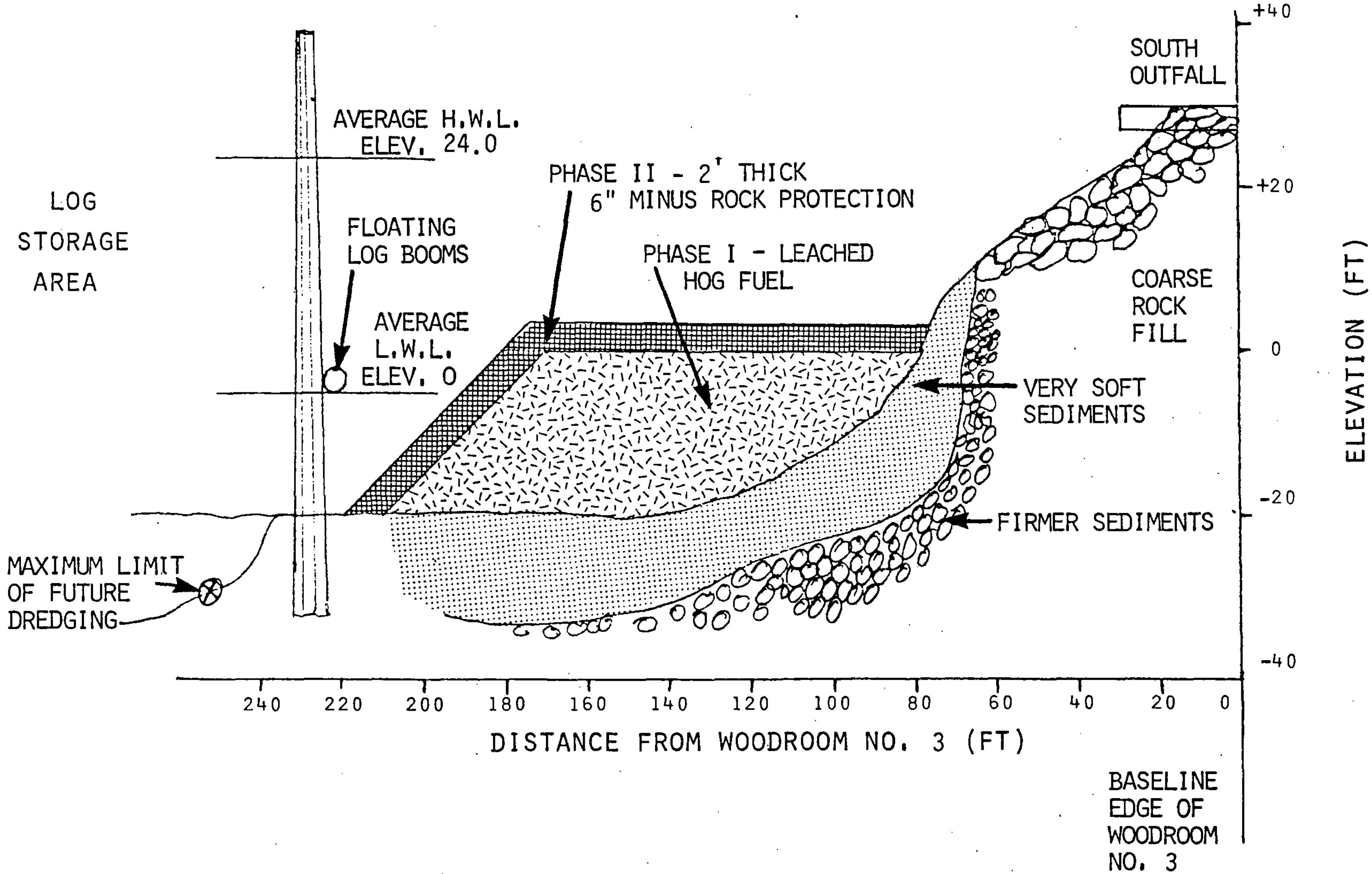
5.1.1 Source of PCBs and levels in sediments and biota

In January, 1977, an electrical transformer at the Cancel Mill, Prince Rupert, exploded resulting in the spillage of approximately 300 gallons of PCBs into Porpoise Harbour. Contaminated bottom sediments were subsequently covered over with layers of leached hog fuel, gravel and rock to a depth of over 20 feet. A schematic cross section showing the relative thickness and dimensions of the covering is given in Figure 10a. Levels of PCBs in sediments of Porpoise Harbour have been monitored periodically by the Environmental Protection Service and the most recent results are shown in Figure 10b. Concentrations of PCBs in crabs collected from Porpoise Harbour are presented in Table 7.

Levels of PCBs in sediments declined at most sites between 1978 and 1979 in the immediate vicinity of the mill (Fig. 10b). However, site P2-18, which showed an increase from 0.37 to 0.49 ppm PCB in six months during 1978, was not resampled in 1979. The levels recorded are relatively low compared to concentrations found in sediments from other industralized areas in B. C. (Vigers, 1977; Garrett, 1976). Concern has previously been expressed over the possibility of contaminated material spreading farther into Porpoise Harbour (G. Packman, pers. comm.). However, there is not sufficient data with which to confirm or refute this suggestion at present. Future monitoring programs should include a larger number of samples extending into the centre of Porpoise Harbour. At present, E.P.S. recommended that dredging should not take place inside the floating log boom (Fig. 10b), some 250 feet from shore.

FIGURE 10a

CROSS SECTION OF BURIED PCB CONTAMINATED MATERIAL OFFSHORE OF CANCEL MILL, PRINCE RUPERT, B. C.
(Source: Environmental Protection Service, 1980)



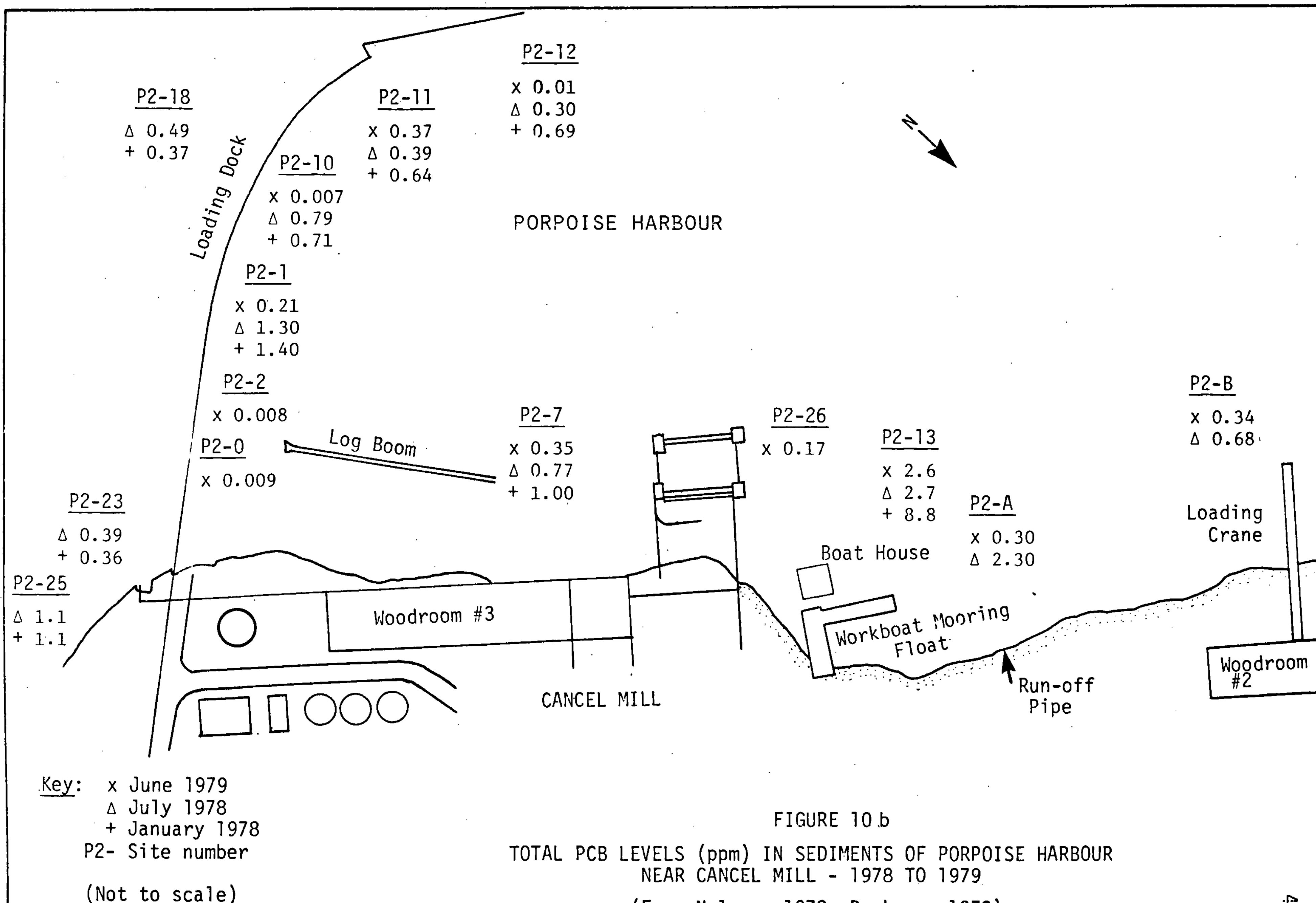


FIGURE 10 b

TOTAL PCB LEVELS (ppm) IN SEDIMENTS OF PORPOISE HARBOUR NEAR CANCEL MILL - 1978 TO 1979

(From Nelson, 1978; Packman, 1979)

TABLE 7

CONCENTRATION (PPM DRY WEIGHT) OF POLYCHLORINATED BIPHENYLS (PCB'S) IN CRAB *(Cancer magister)* TISSUE FROM PORPOISE HARBOUR - 1978 AND 1979 (SEE FIGURE 11 FOR SITE LOCATIONS)

Station	Carapace Width (cm)	Concentration of Arochlor 1254 (ppm)	
		1978	1979
1	18.5	0.073	
	17.0	0.210	
	12.0		<0.005
	17.5		<0.005
2		not analyzed	
	16.5		0.20
	13.0		<0.005
3	17.5	0.260	
	17.0	0.240	
	17.5		<0.005
	17.5		0.046
4	16.0	0.150	
	18.0	0.056	
	18.0		0.019
	20.0		<0.005
5	16.0	0.070	
	17.0	0.030	
	17.5		0.028
	18.0		0.025
6	20.0		0.030
	19.5		0.009
7		no catch	
8	17.0	0.050	
	12.5	0.088	
9	19.0	0.120	
	17.0	0.340	
10	17.0	0.290	
	17.5	0.090	
11	17.5	0.024	
	16.5	0.048	
12	17.5	0.280	
	17.5	0.064	

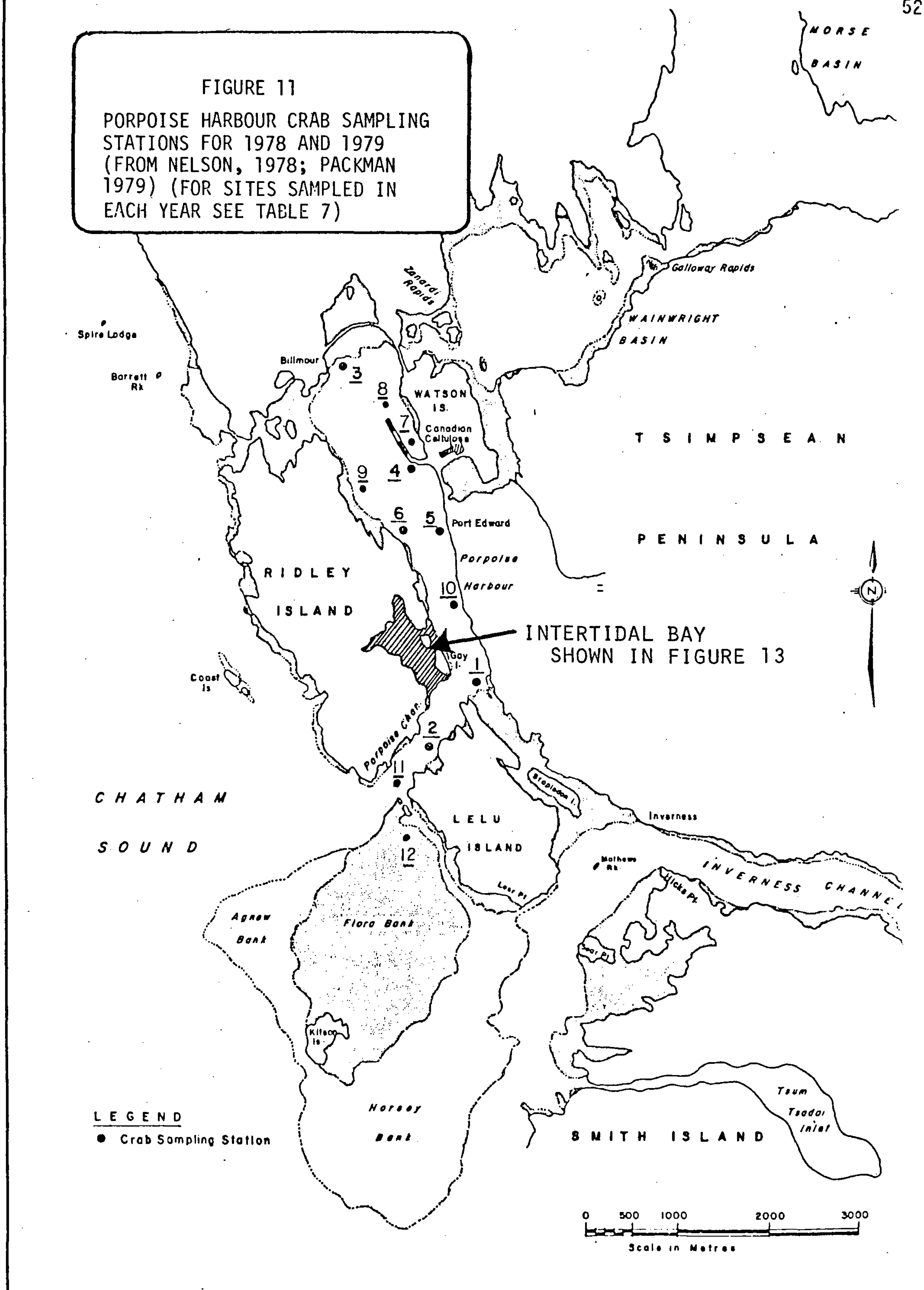
The concentration of PCBs in crab tissue (Table 7) from sites in the Porpoise Harbour area (Fig. 11) also show a general decrease between 1978 and 1979. Unfortunately, crabs collected in 1979 were not obtained from as many sites as 1978 (Table 7). No explanation (e.g. sites not sampled or crabs not present at sites) was given for this in the orginal data (Packman, 1979). Placement of traps in the same locations (i.e. all 12 sites on Fig. 11) in future monitoring studies would provide valuable information on distribution and contamination. Also, the values reported (<0.005 to 0.20 ppm for 1979) are by dry weight. Since guidelines established by the Food and Drug Directorate for PCBs (Environmental Contaminants Committee, 1976) are by wet weight, it would be useful to have values expressed as wet weight as well. For *Cancer magister*, division by five can be used to convert concentrations from a dry to wet weight basis (Bawden et al., 1973). Thus concentrations recorded in 1979 range from <0.001 to 0.04 ppm wet weight. These values are well below the 2.0 ppm wet weight guideline for PCBs in commercial seafood recommended by the Food and Drug Directorate (Environmental Contaminants Committee, 1976). Indeed, after initial closure following the Cancel spill, recreational crab fishing was re-opened several years ago (Nelson, 1978). PCB levels in other marine fauna from Porpoise Harbour have not been measured. It would be of interest, for example, to know concentrations in certain benthic invertebrate species which live close to the sediment. Amphipods and other infaunal benthos were shown to have levels of PCB almost 20 times higher than sediment values in Port Alberni (Vigers, 1977).

5.1.2 Significance of PCB levels in sediments to ocean dumping criteria

Under the Ocean Dumping Control Act of 1975 (Government of Canada, 1975), the maximum quantities and concentrations of PCBs that may be contained in another substance as described in Schedule 1 [para 9(5)(b)] to the Act are:

FIGURE 11

PORPOISE HARBOUR CRAB SAMPLING STATIONS FOR 1978 AND 1979 (FROM NELSON, 1978; PACKMAN 1979) (FOR SITES SAMPLED IN EACH YEAR SEE TABLE 7)



a) for organohalogen compounds, that quantity not exceeding 0.01 parts of a concentration shown to be toxic to marine animal and plant sensitive organisms in a bioassay sample and test carried out in accordance with procedures established or approved by the Minister.

Levels of PCBs in sediments from Porpoise Harbour in 1979 (Fig. 10) showed a range from 7 to 2,600 ppb. Comparison of these analytical results from Porpoise Harbour with toxicity data in Table 8 indicates that the above criterion for permitting ocean dumping cannot be met. Since incipient LC50 values for PCBs may be as low as 3.4 ppb for local species, application of the criterion of 0.01 yields a maximum acceptable concentration in sediments to be dumped of 0.034 ppb. Strict application of this section of the Act would prohibit ocean dumping of any sediment from this area, and to date, applications for ocean dumping of material from Porpoise Harbour have been refused (Table 2).

Given the ubiquitous nature of PCBs in harbour sediments (Garrett, 1976; Vigers, 1977), the present extremely low values restricting ocean dumping appear to be unrealistic. The regulations, however, cannot be changed easily because much of the fundamental information on biological effects of organohalogen residues in sediments is lacking (E.V.S. Consultants Ltd., 1978).

TABLE 8

TOXICITY OF PCBs TO SOME AQUATIC ORGANISMS

Species	Fresh-water Marine	LC50 ppb	Duration (days)	Procedure: static or flow-through	EC50 ppb	Chronic Bioassay Procedure	Aroclor	Reference
Daphnia magna (water flea)	f	67	21	static	63	50% reproductive impairment	1242	Nebeker & Puglisi, 1974
	f	25	21	static	24	" " "	1248	" " "
	f	31	21	static	28	" " "	1254	" " "
	f	36	21	static	33	" " "	1260	" " "
	f	2.6	14	flow	2.1	" " "	1248	" " "
	f	1.8	14	flow	1.1	" " "	1254	" " "
	f	1.3	21	flow	1.3	" " "	1254	" " "
	f	24	14	-	-	-	1254	Maki & Johnson, 1975
Oronectes nais (crayfish)	f	30	7	static	-	-	1242	Stalling & Mayer, 1972
	f	100	7	static	-	-	1254	" " "
	f	80	7	flow	-	-	1254	" " "
Gammarus fasciatus (scud)	f	10	4	flow	-	--	1242	" " "
	f	5	10	flow	-	-	1242	" " "
	f	52	4	static	-	-	1248	" " "
	f	2400	4	static	-	-	1254	" " "
Tanytarsus dissimilis (midge)	f	0.65	21	-	0.45	Survival and growth	1254	Nebeker & Puglisi, 1974
Palaemonaetes kadiakensis (grasshrimp)	m	3	7	flow	-	-	1254	Stalling & Mayer, 1972
Panaeus duorarum (pink shrimp)	m	3.5	35	-	-	-	1254	Nebeker & Puglisi, 1972
Salmo clarki (cutthroat)	f	5430	4	static	-	-	1242	Stalling & Mayer, 1972
Salmo gairdneri (rainbow trout)	f	67	5	flow	-	-	1242	Walker, 1976 ; Mayer et al, 1976
	f	48	10	flow	-	-	1242	
	f	18	15	flow	-	-	1242	
	f	10	20	flow	-	-	1242	
	f	12	25	flow	-	-	1242	Mayer et al, 1976
Salmo clarki (cutthroat)	f	5750	4	static	-	-	1248	Stalling & Mayer, 1972

TABLE 8 (continued)

Species	Fresh-water Marine	LC50 ppb	Duration (days)	Procedure: static or flow-through	EC50 ppb	Chronic Bioassay Procedure	Aroclor	Reference
Salmo gairdneri (rainbow trout)	f	54	5	flow	-	-	1248	Walker, 1976; Mayer et al, 1976
	f	38	10	flow	-	-	1248	
	f	16	15	flow	-	-	1248	
	f	6.4	20	flow	-	-	1248	
	f	3.4	24	flow	-	-	1248	
Salmo clarki (cutthroat)	f	42500	4	static	-	-	1254	Stalling and Mayer, 1972.
Salmo gairdneri (rainbow trout)	f	156	5	flow	-	-	1254	Walker, 1976; Mayer et al, 1976
		160	10	flow	-	-	1254	
		64	15	flow	-	--	1254	
		39	20	flow	-	-	1254	
		27	25	flow	-	-	1254	
Salmo clarki (cutthroat)	f	60900	4	static	-	-	1260	Stalling and Mayer, 1972
Salmo gairdneri (rainbow trout)	f	326	10	flow	-	-	1260	Walker, 1976; Mayer et al, 1976
	f	143	15	flow	-	-	1260	
	f	78	20	flow	-	-	1260	
	f	49	25	flow	-	-	1260	
	f	51	30	flow	-	-	1260	

5.2 Heavy Metals

5.2.1 Sediment concentrations

The most recent data on concentrations of cadmium and mercury in sediments from the Prince Rupert area are given in Table 9. The locations of sites B-1 to B-38 sampled for heavy metals are shown in Figure 12.

Cadmium in sediments ranged from <1.15 ppm at site B-9 to 7.3 ppm at site B-28. Only two areas showed abnormally high values. One was Wainwright Basin (1.97 ppm), and the other was Prince Rupert Harbour (B-24, 1.81 ppm; B-26, 2.67 ppm; and B-28, 7.3 ppm). The source or extent of the elevated levels for cadmium were not discussed in the preliminary reporting of these data (Packman, 1979).

Levels for mercury in the sediments sampled ranged from 0.194 ppm at site B-16 to a high of 2.66 ppm at site B-28. The concentration of mercury at sites sampled in the Prince Rupert area was considerably higher than background levels (0.02-0.04 ppm) recorded in other coastal areas of B. C. such as the Fraser River estuary (McGreer and Vigers, 1979). Two areas which showed relatively high levels of contamination were Prince Rupert Harbour (B-5, 1.46 ppm; B-21A, 1.69 ppm; B-26 and B-27, 1.27 ppm; B-28, 2.66 ppm) and sites within Tuck Inlet (0.977-1.42 ppm). The high levels recorded in Prince Rupert Harbour may be due to industrial effluent discharge, street run-off, or historical activities such as the shipyards operating in this area during World War II, but the source of mercury in Tuck Inlet is unknown.

TABLE 9

CONCENTRATIONS OF CADMIUM AND MERCURY IN SEDIMENTS COLLECTED JUNE, 1979 FROM THE PRINCE RUPERT AREA

(From Packman, 1979)

(See Fig. 12 for Station Locations)

Station	Cd (ppm)	Hg (ppm)
B-1'	<1.24	0.503
B-4	<1.18	0.366
B-5		1.46
B-6	1.2	0.293
B-7	<1.16	0.425
B-8	<1.23	0.413
B-9	<1.15	0.459
B-10	<1.15	0.287
B-11'	1.18	0.813
B-13	<1.19	0.234
B-14	<1.23	0.269
B-15	<1.23	0.551
B-16	<1.21	0.194
B-17	<1.17	0.657
B-18	<1.21	0.457
B-19	<1.21	0.312
B-20	<1.21	0.356
B-21	<1.22	0.578
B-21A	<1.22	1.69
B-22	<1.22	0.378
B-23	<1.24	0.883
B-24	1.81	0.538
B-25	<1.22	0.393
B-26	2.67	1.27
B-27	<1.17	1.27
B-28	7.3	2.66
B-29	<1.2	0.378
B-30	<1.23	1.36
B-31	<1.17	
B-32	1.61	0.305
B-33	<1.23	0.513
B-34	<1.19	0.425
B-35	<1.22	0.256
B-36	<1.24	0.488
B-37	<1.23	0.539
B-38	<1.22	0.403
Tuck Inlet 1	<1.23	1.42
Tuck Inlet 2	<1.23	0.977
Tuck Inlet 3	<1.22	0.704
Tuck Inlet 4	<1.18	1.11
Wainwright Basin 1	1.97	0.259

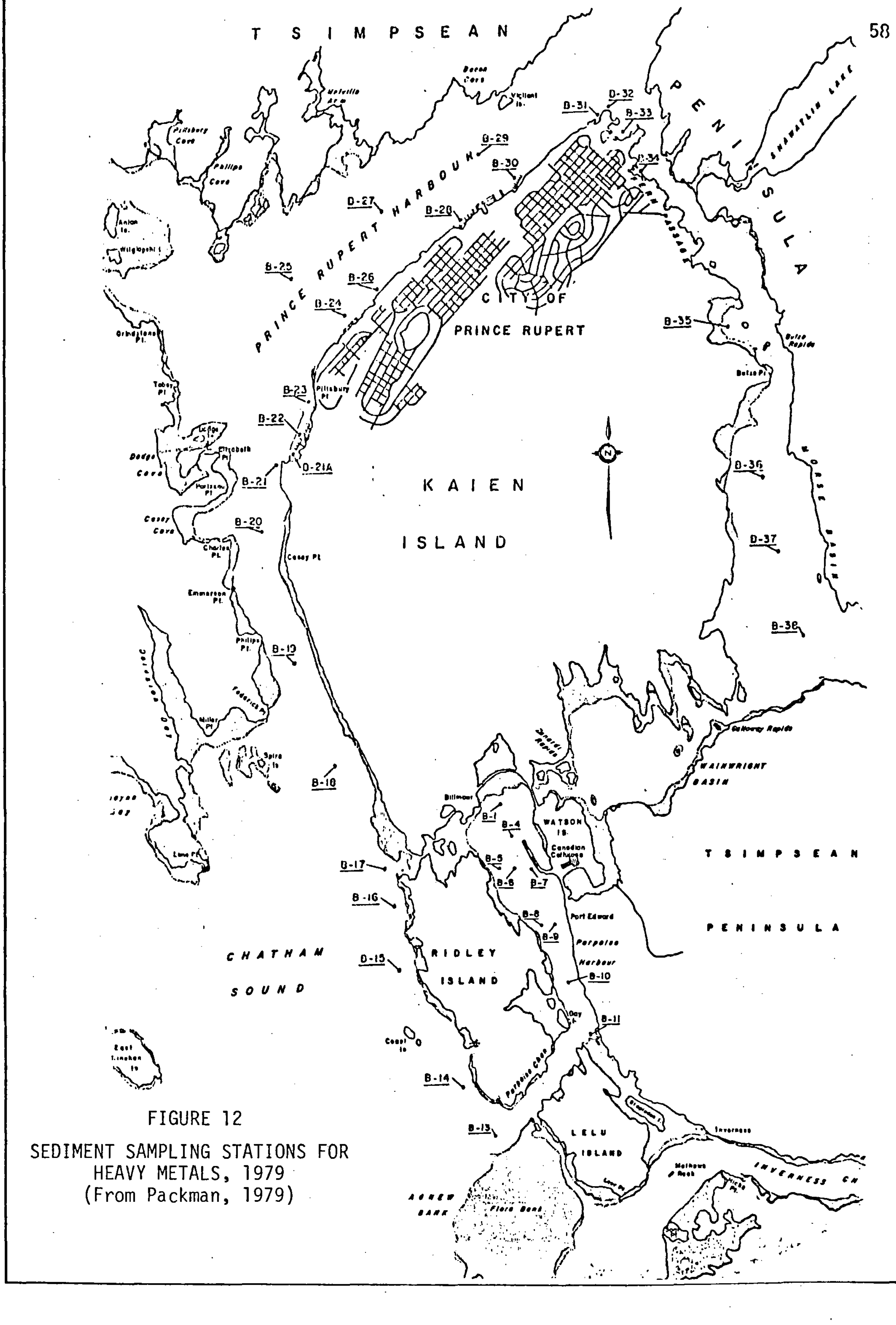


FIGURE 12

SEDIMENT SAMPLING STATIONS FOR HEAVY METALS, 1979 (From Packman, 1979)

5.2.2 Significance of sediment metal levels to ocean dumping

Mercury and cadmium are both prohibited substances under Schedule 1 of the Ocean Dumping Act (Government of Canada, 1975). The maximum concentrations prescribed under the Act are 0.75 ppm for mercury and 0.6 ppm for cadmium in sediments. For mercury, sediments from select areas of Porpoise Harbour, Prince Rupert Harbour and Tuck Inlet with concentrations over 0.75 ppm (see Table 9 and Fig. 12) should not be ocean dumped.

Alternatively, one of the three areas mentioned above would seem appropriate as a site for dumping moderately contaminated material. In this way, the contamination would be confined to one area. Given the data on physical oceanography, biological resources and sediment transport, Tuck Inlet would appear the most suitable area for deposition of contaminated dredge spoil.

Concentrations of cadmium exceeding the Ocean Dumping Act limit of 0.6 ppm are found in sediments from Porpoise Harbour and Prince Rupert Harbour (Table 9 and Fig. 12). If current studies in Tuck Inlet confirmed the containment of sediments in this area, some of this cadmium contaminated material could be disposed in this area. Unfortunately, the analytical detection limit did not permit accurate readings below 1.15 ppm (Table 9). The limit of detection for cadmium using Atomic Absorption Spectrophotometry is generally closer to 0.2 ppm when an adequate portion of sample ($\sim$5.0 g wet wt) is used. In future, care should be taken in carrying out chemical analyses to ensure that the limits of detection for substances of concern are below the levels specified in the Ocean Dumping Act.

Levels of contaminants in other areas considered as potential dump sites are unknown, but as these sites are not near industrialized areas, it is assumed they are low in contamination.

6.0 INFORMATION COLLECTED FROM INTERVIEWS CONDUCTED IN PRINCE RUPERT

6.1 Future Plans for Disposal of Dredge Spoil by Firms Involved in Ocean Dumping in Prince Rupert Area

6.1.1 National Harbours Board - Ridley Island Development

Although the extent of development at the Ridley Island site is unknown at present, NHB plans to firm up dredging requirements by June of 1980 (A. Nesbitt, pers. comm.). Previous estimates of up to ten million cubic metres of peat material to be dredged and dumped may have been premature. Tentative plans now call for designed galleries to carry ship loading conveyors out to berths in deeper water on the west side of Ridley Island. Very little dredging would be required in this case. If any peat material is to be dredged, NHB plans to pile the material in wind rows on the island, as it may be required as fill for later expansion. Further, they feel that, if required, dredged material could be dumped in a lagoon on the east side of Ridley Island (Fig. 13). The area is a former booming ground and is fully exposed on a low tide. Preliminary engineering designs call for placing a dyke across the open end of the bay and then filling it in as required. Such a plan might alleviate the need for ocean dumping, but a permit would have to be obtained before any dumping could occur in an intertidal area. Work on an alternative to ocean dumping was begun in part from a desire to avoid conflict with local fishermen. Any large-scale dumping in a highly visible area (e.g. Chatham Sound) would precipitate a "barrage" (estimate of 60) of phone calls which no one really wished to handle.

6.1.2 Cancel

Disposal of waste at the Cancel Mill is a continuing problem due to the different types and substantial quantities of wastes generated. There are five main types of waste from the mill operation (D. Ho, pers. comm.):

Harbour Dredge Spoil - wood waste from ship loading areas and booming grounds (Fig. 14). Routine maintenance dredging required each year consisting of 3,000 to 8,000 m^3 of material. This area was site of PCB spill and sediments are contaminated (Fig. 10). Currently being disposed of on land (see Table 2).

Hog Fuel - bark and coarse wood waste generated from de-barkers in two woodrooms is currently disposed of in hog fuel piles on the site. Some sawdust material, wood chips and other inorganics are also dumped in the piles.

In-Plant Control Waste - "reject" wood waste including chips is gathered by an in-plant collection system and transferred to outside depots to be picked up for disposal. Approximately 15 Tons (wet) per day is produced by the two mills. The control waste is dumped in a land fill by permission of a PCB permit but space is limited and the present site will be almost filled in about 2 years.

Refuse - plastics, paper, etc., scrap metal etc., nonorganic material. Presently being put in land fill alternated with layers of soil, or elsewhere on site.

Garbage - general organic waste from cafeteria operation which serves 1000 plant personnel. Also being disposed in land fill.

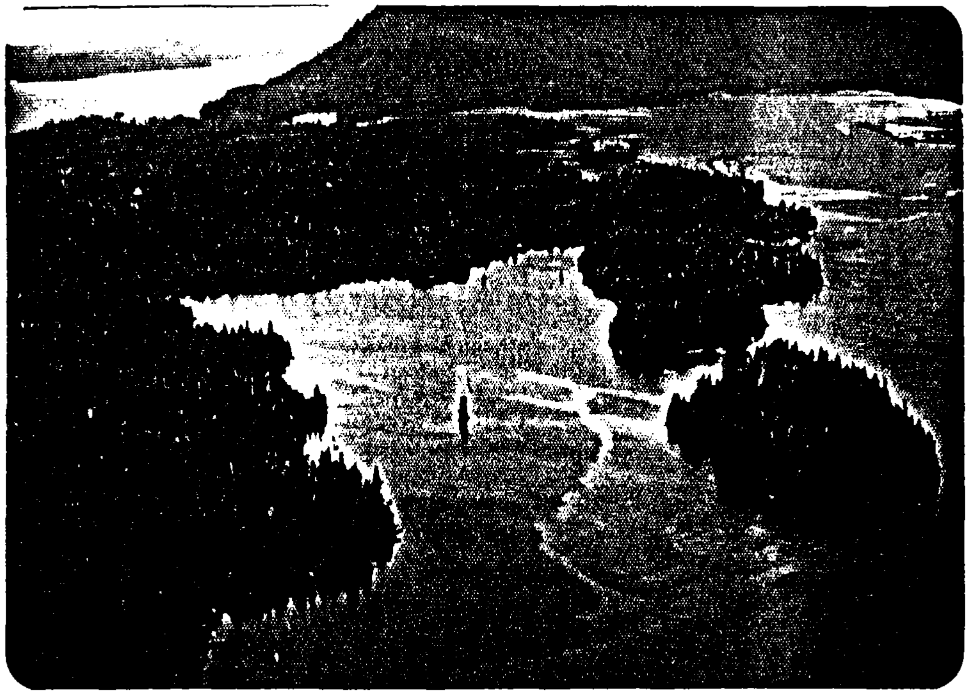


FIGURE 13

INTERTIDAL BAY AT SOUTHEAST END OF RIDLEY ISLAND (54°13'N, 130°18'W)
PROPOSED AS DUMP SITE FOR PORT DEVELOPMENT
(EXACT LOCATION IS SHOWN ON FIGURE 11)

FIGURE 14

CANCEL LOG STORAGE AREA - PORPOISE HARBOUR
(VIEW IS FROM WOODROOM #3 LOOKING TOWARDS LOG BOOM - SEE FIGURE 10)

The volume and type of material to be generated by Cancel in the near future will be similar to that being generated at present (D. Rowse, pers. comm.). Dredging in Porpoise Harbour about once per year will continue but plans are to dispose of the material in a new land fill site being considered east of the mill. The new site (Fig. 15) will be used for in-plant control waste, refuse, garbage and any harbour sediments not suitable for ocean dumping.

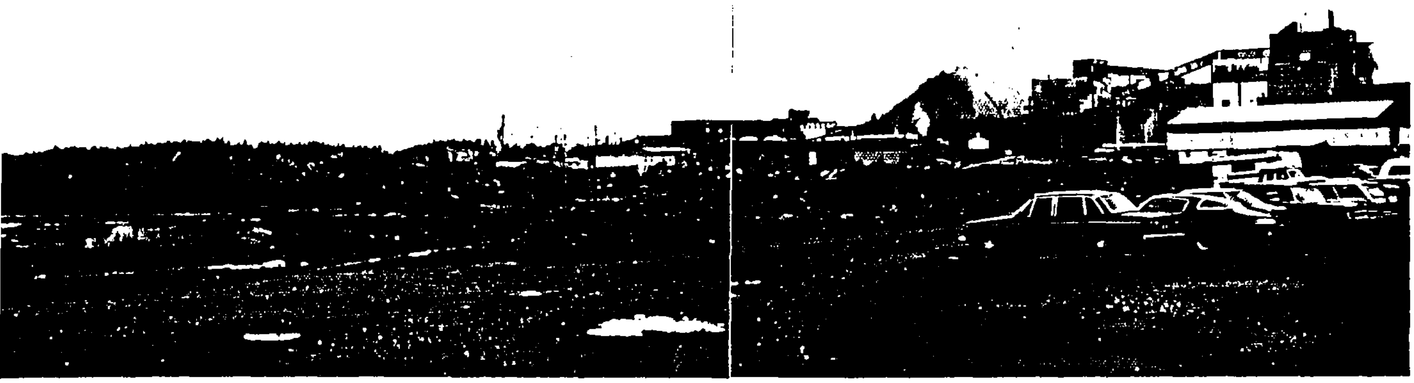
Hog fuel output represents the greatest volume of waste material produced and space limitations for disposal on site are becoming critical. Ocean dumping of this material would be the most cost effective means of disposal. Consideration is being given, however, to purchase of a new boiler for incineration of the hog fuel produced. Hog fuel does not burn easily and energy costs run about $36/T for incineration. If an efficient burning process can be perfected there would be a net saving in energy. One problem is that the heavy rains in the area keep the hog fuel continually soaked. Plans are to have a new boiler in operation within about 12 months. The net consumption of hog fuel would be greater than the amount being produced so that current stockpiles would currently be reduced. If improvements in waste disposal methods can be completed on schedule, it should eliminate the need for ocean dumping of material from the Cancel operation in the future.

6.2 Economic and Logistical Considerations

During the field trip in Prince Rupert, we interviewed Mr. Mike Stevenson, dispatcher for Rivtow Straits Ltd., the main dredging/ towing company in the region. He provided us with costs for rental of equipment normally used in towing dredge spoil to sea from Prince Rupert. The two main units used are:

FIGURE 15

LOCATION PROPOSED AS FUTURE LANDFILL SITE. PORT EDWARD IS ON



THE LEFT OF THE PHOTOGRAPH AND CANCEL MILL IS ON THE RIGHT.

1. Small tug @ \$90/h with a "50" series barge (∿1000 short ton capacity) @ \$250/day.

2. Large tug @ \$200/h with a "100" series barge (∿2000 short ton capacity) @ \$300/day.

The speed for the larger "100" series barge is about 7.5-8.5 knots. Thus a round trip from Cancel to Tuck Inlet would take approximately 8 h plus 2 h for pick-up and return of barge = 10 h. The cost for a "50" series barge and companion tug for the trip would be about \$1150.00. At three to four barge loads per year the annual costs for towing spoil exclusive of dredging costs would be approximately \$5600.00. [Note: In 1978, Cancel spent approximately \$35,000 for dredging and land disposal of spoil from Porpoise Harbour (D. Rowse, pers. comm.); thus the costs for ocean dumping at any of the sites recommended in this study would not appear to be prohibitive.]

With regards to restrictions on their operating radius or problems with weather, we were told that only the length of time for towing would be affected. Some shallow water areas or parts of Hecate Strait could present problems for tug operators in rough weather, but these were the only exceptions mentioned. Only extreme weather conditions would affect the operation, and no particular time of the year was considered worse than another. Dumping is by means of a front end loader pushing material off the end of the barge.

6.3 Concerns of Fisheries Canada, Prince Rupert

The general concerns of Fisheries Canada for ocean dumping in the region centred on utilization of areas by commercial species of fish and invertebrates (T. Turnbull, pers. comm.). There was agreement that Porpoise Harbour should be abandoned as a dump site because of the increase in biological productivity in recent years. Also, there are plans by the Salmon Enhancement Program to restore salmon runs to Wolf Creek which flows into Wainwright Basin. Concern was also expressed that dredging in Porpoise Harbour near the Cancel mill was disturbing the PCB contaminated sediment in the area.

A number of comments were made on the use of Tuck Inlet as a disposal site for contaminated material. Spring salmon have been observed holding outside Tuck Narrows in December. These are thought to be springs from Qualicum, B. C., California and Oregon which use the northern waters as winter feeding grounds. However, no study or confirmation of the identity of the fish observed has been made. They have also been observed in Delusion Bay on Digby Island. Use of Tuck Inlet as an area for shrimp and prawn fishing has been increasing over the past several years. Tuck Inlet may be a site for future residential expansion as new roads are constructed around Tsimpsean Peninsula. However, these are only tentative plans at the present time.

With respect to Chatham Sound, Fisheries Canada confirmed that very little groundfishing is carried out in the area (T. Turnbull, pers. comm.). Dumping in the area was not considered to be physically harmful to salmon migrating through the area. The greatest concern was over the psychological reaction of commercial fishermen if they saw barge loads of spoil being dumped into the ocean. No one at Fisheries Canada wished to answer forty or fifty telephone calls a day from irate fishermen! Thus, in addition to physical and biological effects from ocean dumping, there can be the social impacts to be considered.

6.4 Comments from Local Fishermen

During our trip to Prince Rupert, we were fortunate to have the opportunity of interviewing Mr. Robert Johnson, a local fisherman for many years. In addition to fishing, Mr. Johnson has served as an oceanographic technician for many of the Kitimat Oil Port studies and for Fisheries Canada. Mr. Johnson confirmed that the only groundfishing in Chatham Sound was the occasional use by fish boats returning to Prince Rupert from other areas. There are, however, about 40 boats which go out from Prince Rupert regularly for prawning and shrimping in Chatham Sound. Any dumping in the area would arouse suspicion and some vociferous action. If dumping occurs, some prior warning and information to these local fishermen would be advisable. Also, any spoil to be dumped should not contain material which would clog or foul fishing gear. Mr. Johnson also noted the need for more accurate soundings to be taken in Chatham Sound if one wished to locate a deep hole for dumping. Several areas which read 65 fathoms on the present charts are actually about 80 fathoms in depth. Similarly, fishing gear has been found to scrape bottom in areas which the chart indicated should have been 10-20 fathoms deeper. From scraping of the bottom by his nets, Mr. Johnson described the bottom of Chatham Sound as varying from soft mud to very coarse, sandy material. His recommendation for a deep hole in a relatively quiet area for deposition of contaminated material was Ogden Channel. We have included this site in our assessment on his recommendation.

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