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INVESTIGATIONS IN BOUNDARY BAY AND GEORGIA STRAIT FOLLOWING A CHLOROPHENATE SPILL

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By

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ABSTRACT

A series of environmental investigations were conducted following a large freshwater fish kill caused by the 4 March 1984 spill of 45,000 liters of a 2% sodium tetra/pentachlorophenate solution (4CP/5CP) into Hyland Creek and Boundary Bay. This report reviews those studies and presents data collected by the Environmental Protection Service (EPS), Conservation and Protection, Environment Canada.

To assess the residual effects of the spill, EPS sampled sediments, and tissues from fish, crab and shrimp for chlorophenols and chlorinated dibenzo-dioxins and -furans. PCBs were also sampled as an indicator of the general condition of Boundary Bay and because they are a potential source of furans. The Institute of Ocean Sciences (IOS), Department of Fisheries and Oceans, sampled benthic infaunal invertebrates to determine if there was any disruption of community structure in upper Boundary Bay.

No chlorophenols or PCBs were detected in sediments or tissues collected. Dioxins and furans were also not detected in the sediments of Boundary Bay and Georgia Strait, although they were detected at the spill site. When detected at trace levels (parts per trillion) the concentrations of dioxins and furans in tissues are below those that would indicate health or environmental concerns, and are below the levels at a reference site. Only octochloro-p-dioxin was detected in fish, shrimp and crab muscle tissue. A wide range of dioxins and furans were detected in crab hepatopancreas, therefore this organ may be a useful indicator tissue for these contaminants in the marine environment.

No widespread deterioration in the benthic invertebrate community in terms of abundance and diversity of amphipods, isopods, molluscs, nematods, oligochaetes and polychaetes, was observed.

In summary, the chlorophenol spill into Hyland Creek had no measurable residual impact on the benthic invertebrate populations of Boundary Bay, and left no unusually elevated levels of contaminants in sediments or animal tissues collected from Boundary Bay and Georgia Strait. A review of the scientific findings showed no conclusive link between the 1984 gray whale strandings and the chlorophenol spill.

Key Words: chlorophenols, environmental impact, sediments, invertebrates, gray whales, dioxins, furans, PCBs, polychlorinated biphenyls, Boundary Bay, fish kill

RÉSUMÉ

Une série d'investigations environnementales fut conduite à la suite d'une mortalité de poissons d'eaux fraîches causées par un déversement de 45,000 litres de solution de sodium tetra/pentachlorophénate (4CP/5CP) 2% dans le ruisseau Hyland et la baie Boundary le 4 mars 1984. Ce rapport revise ces études et présente les données recueillies par le service de la protection de l'environnement (SPE), conservation et protection, environment Canada.

Afin d'estimer les effets résiduels du déversement, SPE a échantillonné des sédiments ainsi que des tissus de poissons, crabes et crevettes pour chlorophénols, dibenzo-dioxines et -furannes chlorées. BPC furent aussi échantillonnés comme un indicateur de la condition générale de la baie Boundary et parce qu'ils sont une source potentielle de furannes. L'institut des sciences océanographiques (ISO), département des pêches et océans, a échantillonné les invertébrés endofauniques benthiques afin de déterminer si il y a eu une perturbation de la structure communautaire dans la partie supérieure de la baie Boundary.

Aucun chlorophénol ou PCB ne furent détectés dans les sédiments ou tissus collectés. Les dioxines et furannes ne furent pas détectées non plus dans les sédiments de la baie Boundary et le détroit de Georgia, même si ils furent détectées à l'endroit du déversement. Quand détectées à des niveaux de trace (parties par billion), les concentrations de dioxines et furannes dans les tissus sont au-dessous des niveaux qui indiqueraient des inquiétudes regardant la santé ou l'environnement, et sont au-dessous des niveaux à un site de référence. Seulement du octochloro-p-dioxine fut détectée dans les tissus musculaires de poissons, crevettes et crabes. Une grande variété de dioxines et furannes furent détectées dans les hépatopancréas de crabe, par conséquent cet organe peut être un tissu indicateur utile pour ces contaminants dans l'environnement marin.

Aucune détérioration étendue dans la communauté des invertébrés benthiques en terme d'abondance et diversité des amphipodes, isopodes, mollusques, nématodes, oligochètes et polychètes, ne fut observée.

En résumé, le déversement de chlorophénol dans le ruisseau Hyland n'a eu aucun impact résiduel measurable sur les populations d'invertébrés benthiques de la baie Boundary, et n'a laissé aucun niveau anormalement élevé de contaminants dans les sédiments ou tissus animals recueillis dans la baie Boundary et le détroit de Georgia. Une revue des résultats scientifiques a montré qu'il n'y a aucun lien concluant entre les échouages des baleines grises de 1984 et le déversement de chlorophénol.

Mots-clefs: chlorophénols, impact environnemental, sédiments, invertébrés, baleines grises, dioxines, furannes, PBC, biphényles polychlorés, baie Boundary, mortalité de poissons.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

Chlorophenols (CP) used as wood preserving agents, are toxic to a variety of aquatic organisms at low concentrations e.g. < 100 ppb (Jones 1981, Davis and Hoos 1975, Hauch et al. 1980).

On 4 March 1984 about 45,000 liters of (2%) sodium tetra/pentachlorophenate (4CP/5CP) were spilled at the Cloverdale Paint and Chemical plant and entered Hyland Creek. These chemicals were then carried into the Serpentine River which meets Boundary Bay at Mud Bay near Crescent Beach, B.C. (Figure 1). Federal and provincial environmental agencies immediately became involved with clean-up and monitoring. Charges were laid under Section 33(2) of the federal Fisheries Act and the case is presently under appeal by the Crown as the company was acquitted in the initial trial.

This report reviews the findings of various studies on the environmental impact of the spill, and presents data collected by EPS (Environmental Protection Service, Conservation and Protection, Environment Canada). In response to public concern over the incidence of dead gray whales washing ashore from the inland waters of Georgia Strait and Puget Sound, and in order to assess the possible residual effects of the chlorophenate spill, EPS Marine Programs sampled various locations (Figure 2) in Boundary Bay from September 1984 to February 1985. Additional sites in the Strait of Georgia, Burrard Inlet and Indian Arm were sampled by EPS to provide comparative data.

In addition to chlorophenols, EPS also analyzed sediments, fish, crab and shrimp tissues, for chlorinated dibenzo-dioxins and -furans, which are known environmentally persistant contaminants of some chlorophenate solutions. We also sampled for PCBs which can be a source of furans.

This report summarizes those results. Further data collected by EPS on sediment and tissue trace metal levels will be presented in a future report that will focus on environmental quality of the Southern Strait of Georgia (Colodey in prep.).

In conjunction with EPS, the Institute of Ocean Sciences (IOS), Department of Fisheries and Oceans (DFO), participated in portions of the sampling to determine if there was any residual impact of the spill on the nearshore benthic environment. Initial findings are presented and complete results from that study will be published on completion of analysis (R. Brinkhurst pers. comm.).

2 PREVIOUS STUDIES

2.1 Freshwater Impact

A large fish kill was the immediate result of the chlorophenate spill. Over 5,000 fish (juvenile salmonids: steelhead, rainbow trout, coho; lampreys, carp and chub amongst others) were killed in Hyland Creek and the Serpentine River (R. Webb, personal communication).

Although the short-term result of a spill of 4CP/5CP can be catastrophic to some populations, others can recover more quickly. Kathman (1985) described the impact of the spill on the benthic invertebrates of Hyland Creek and concluded that the 5CP/4CP spill had no long-lasting detrimental effect on the benthos. Samples taken about five weeks after the spill indicated a diverse benthic community.

Derksen (1985) compiled data collected by Acres Consultants for Cloverdale Paint and Chemical Ltd. on the initial freshwater spread and dilution of the chlorophenols (Appendix I). Total chlorophenol concentrations in water fell rapidly. At Station C (Figure 1) for example, about 4.5 km downstream from the spill site, total chlorophenols dropped from 11,600 ppb on 4 March 1984 to 406 ppb the following day. This was largely due to clean-up and flushing efforts directed by EPS as described in Wilson (1985). Monthly mean chlorophenol concentrations continued to show a declining trend:

DATE	STATION C CHLOROPHENOLS
April 1984	1.45 ppb
June 1984	0.40 ppb
July 1984	0.12 ppb
August 1984	0.17 ppb

Sediment chlorophenol levels were generally higher than water concentrations including the control sites (Appendix II). Sediment CP levels at Station C fell from 1540 ppb (5 March 1984) to 32 ppb on 7 August 1984. Background levels of chlorophenols upstream of the spill site were 73 ppb (5 March 1984).

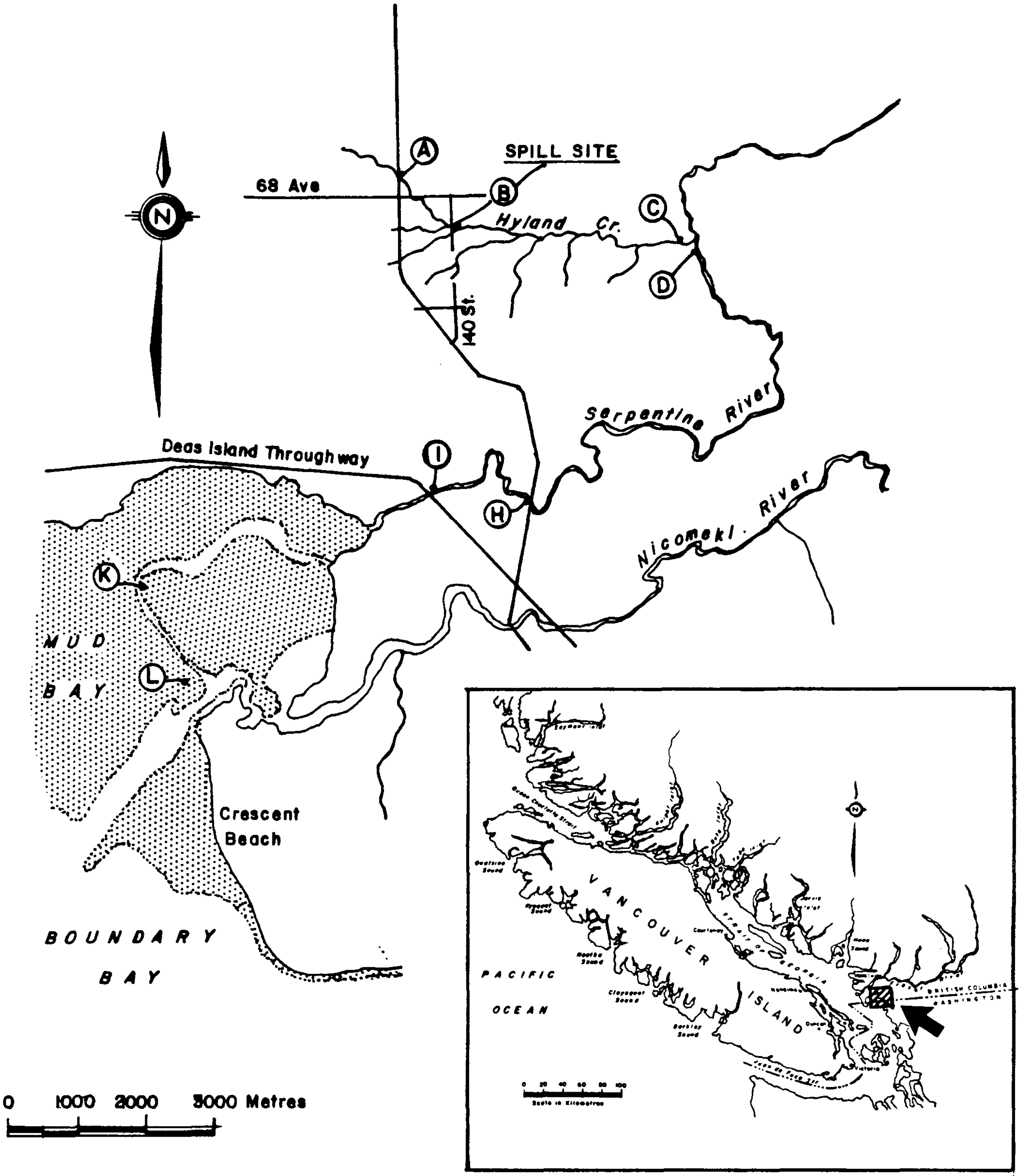

FIGURE I HYLAND CREEK AND MUD BAY SAMPLE STATION LOCATIONS

2.2 Marine Impact

The observed impact of the spill on the marine environment was much less severe than the freshwater impact. Some dead estuarine fish (flounders and sculpins) were found amongst the dead freshwater species that had accumulated near the mouth of the Serpentine River (Department of Fisheries and Oceans [DFO], New Westminster office files).

Chlorophenols from the spill were apparently not adsorbed on the marine sediments: Derksen (1985) reported that chlorophenols in sediments of Mud Bay-Boundary Bay were not detectable at any time following the spill (CP < 4-10 ppb: Appendix II).

The lack of marine environmental damage from the spill likely resulted from the rapid dilution and dispersion of the chlorophenols upon entering Boundary Bay (Figure 1). Total chlorophenol concentrations in water (Appendix I) declined rapidly at sites K and L in Mud Bay throughout the initial sampling period. The first sample of CP-contaminated water was collected on 8 March 1984, when 19-23 ppb were detected in Mud Bay. Concentrations dropped to less than 1 ppb within 4 days. Undetectable concentrations of chlorphenols (CP < 0.1 ppb) predominated from 16 April 1984 to the conclusion of the sampling in March 85.

The maximum water chlorophenol level detected in Mud Bay following the spill (23 ppb), was below the lethal concentrations for sensitive species like salmonids and other less sensitive marine animals and plants:

ORGANISM	5CP (ppb)	REFERENCE
coho salmon	32	Davis & Hoos 1975: 96h LC_{50}
chinook salmon	78	Iwama & Greer 1979: 96h LC_{50}
oyster larvae	70	Davis & Hidu 1968: 14d TLm
copepod	68	Hauch et al. 1980: 96h LC_{50}
estuarine benthic community	140	Tagatz et al. 1981: spp. changes
marine bacteria & phytoplankton	100	Yunker 1981: reduced abundance
marine oligochaetes	150-1700	Chapman et al. 1982: 96h LC_{50}
	4CP (ppb)	
snails	1670	Batte et al. 1951: 24 LT
zooplankton	1000	Kuiper and Hanstveit 1984

However, oysters, crabs and other organisms can concentrate chlorophenols from the water (Truijillo et al. 1982). On 12 April 1984, DFO closed Boundary Bay and Mud Bay to crab and oyster fishing because oysters and crabs were found to be contaminated with 4CP and 5CP. On 9 March 1984 crabs collected from Mud Bay had muscle tissue levels of 67-116 ppb total chlorophenols, while oysters had 171-563 ppb (R. Duncan DFO, unpubl. data). However by 31 May 1984, data indicated that twenty-three Dungeness and Rock crab tissue samples had non-detectable levels of 4CP and 5CP (CP < 0.2 ppb). Four other gill or muscle samples had only trace levels: mean CP = 2.33 ppb. A similarly rapid decline of chlorophenols in oysters was also noted. Consequently, both the commercial and sport crab fisheries were re-opened as annually scheduled 15 July 1984.

Horse clams (*Schizothaerus* sp.) collected by Acres Consultants at Stations K & L (Figure 1) on 9 March 1984 had CP levels of 98 and 83 ppb respectively (Appendix III, Derksen 1985). Tetrachlorophenols were non-detectable in clams from Station L by 10 March 1984 and at Station K by 24 March 1984. Total chlorophenol concentrations were non-detectable in clams at both stations by May 1984.

2.3 Marine Mammals

Each year over 16,000 gray whales migrate up the Pacific coast from Baja California to the Arctic coast. In 1984, the public became concerned when nine gray whales (7 immature) died and washed ashore between 8 March-18 June in the inland waters of Georgia Strait and Puget Sound (Appendix IV). Similarly, six gray whales washed ashore in 1983 (NOAA 1984). The northerly current flow into Boundary Bay, on rising tides, may be one reason why four of the whales washed ashore in the White Rock-Boundary Bay area. Four of the remaining whales washed ashore over 200 km south of the Boundary Bay area. Death of one of the Boundary Bay whales and the Keyport whale, may be attributed to entanglement in rope and a crab trap respectively (Olesiuk & Bigg 1984). Another one of the Boundary Bay whales was so decomposed that its identity as a gray whale is uncertain.

Some of the dead whales were examined and tissue samples were taken for analysis. One gray whale that washed ashore at Semiahmoo Bay near White

Rock, B.C. had 200 ppb 5CP in it's digestive tract. However, Olesiuk & Bigg (1984) sampled the blood, muscle and blubber of this whale to determine if large amounts of 5CP were being assimilated from the digestive tract into the whale's other organs. Only 1.5 ppb chlorophenols were found in muscle tissue, while levels in blubber were undetectable. They concluded that the level of 4CP/5CP in the blood (9.9 ppb) would not be lethal given that terrestrial mammals can tolerate blood levels of 10,000 ppb. People killed by 5CP poisoning have had 16,000 to 100,000 ppb 5CP in their blood or liver (Mason et al. 1965, Wood et al. 1983). In fact up to about 100 ppb 5CP "may be found in the blood and urine of persons having no recognised exposure" to 5CP (Morgan 1976). These very high levels of 5CP known to cause human death are hundreds to thousands of times greater than the levels found in the gray whale. However, caution must be used relating these levels to whales since very little is known about the toxicology of 5CP and other contaminants like pesticides and heavy metals to whales in general (Reijnders 1986).

An autopsy was conducted on another dead gray whale, found 18 June 1984 at Port Angeles, Wa. USA. The autopsy was directed by Dr. T. Gornall (Marine Animal Resource Centre, Seattle) and led by Dr. A. Fouty (Medical Laboratory Associates, Seattle). Gornall et al. (1984) detected 5CP in the stool (800 ppb) and the liver (300 ppb), but not in the fat of the Port Angeles whale. They concluded that the animal died of acute liver failure after "feeding in an area highly contaminated with pesticides, PCB's, heavy metals as well as yet to be identified substances" (Gornall et al. 1984). However, Olesiuk and Bigg (1984) cited data on other whales and marine mammals which led them to conclude that the levels of contaminants listed in the Gornall-Fouty report were within the typical concentrations for marine mammals and probably did not contribute to the animal's death.

A further evaluation of tissues from the Port Angeles gray whale was conducted by Malins et al. 1984. They did not detect 5CP in the blood sample from the whale (detection limit < 15 ppb). They concluded that "concentrations of organic chemicals were too low to have had a bearing on the health of the gray whale." However, relatively high concentrations of aluminum were found in the brain and in the blood (2.2 ppm wet weight).

Malins et al. (1984) reiterated the fact that little is known about whale toxicology, but cited Crapper & DeBoni (1980) inter alia who stated that serious neurological damage and disorientation occurs in mammals when aluminium levels in blood serum are above 0.5 to 1 ppm. Toxic levels of aluminum in brain tissue for cats and rabbits were cited as between 80 and 1600 ppb (Crapper McLaughlin et al. 1983). Malins et al. (1984) mention the need for comparative data from healthy and diseased whales to aid in the interpretation of toxic chemicals data.

Other aquatic mammals, like the large harbour seal population resident in Mud Bay, was apparently not harmed by the spill (M. Bigg, DFO Nanaimo, pers. comm.). Although there was much speculation in the press and electronic news media, no scientific evidence links the whale deaths to the Cloverdale 4CP/5CP spill.

3 METHODS

A series of stations was selected in the Strait of Georgia, Boundary Bay and Mud Bay to examine the residual effect of the 5CP/4CP spill on the near-shore marine environment (Figure 2). Sediments and tissue samples were collected when oceanographic ship-time became available in September and November 1984 (Table 1).

Sediment samples in Boundary Bay and the Strait of Georgia were collected using a 0.1 m^2 Smith-MacIntyre grab and a "Benthos" gravity corer from the CSS VECTOR. Samples from Mud Bay were either collected from the shore at low tide or from a small boat using an Ekman grab at the IOS invertebrate sampling stations. For IOS invertebrate analysis, duplicate grabs were taken and the animals collected on a 500 um screen were preserved in 10% buffered formalin for later enumeration and identification.

Sediment samples for dioxin/furan, CP and PCB analysis were stored in heat-treated glass jars prior to analysis. Chlorophenols and PCBs were analysed at the EPS/DFO West Vancouver Labs using gas liquid chromatography methods described in Swingle and Davidson (1979). Detection limits are given in Table 1. Dioxins and furans in sediments were analyzed at the Environment Canada River Road Environmental Technology Center in Ottawa. Detection limits are listed in Table 3.

Crab and fish tissues were obtained by otter-trawl and from crab traps. Crab samples from Buntzen Bay-Cates Park and Boundary Bay were obtained from commercial fishermen in February 1985 (Figure 2). All samples were frozen prior to analysis. Chlorophenols and PCBs were analysed at the EPS/DFO West Vancouver B.C. Labs using gas liquid chromatography methods described in Swingle and Davidson (1979). Detection limits are listed in Table 2.

Dioxins and furans in tissues were analysed at the Canadian Wildlife Services (CWS) Laboratory in Ottawa with interpretation given by Ross Norstrom (CWS Ottawa). Detection limits are listed in Table 4.

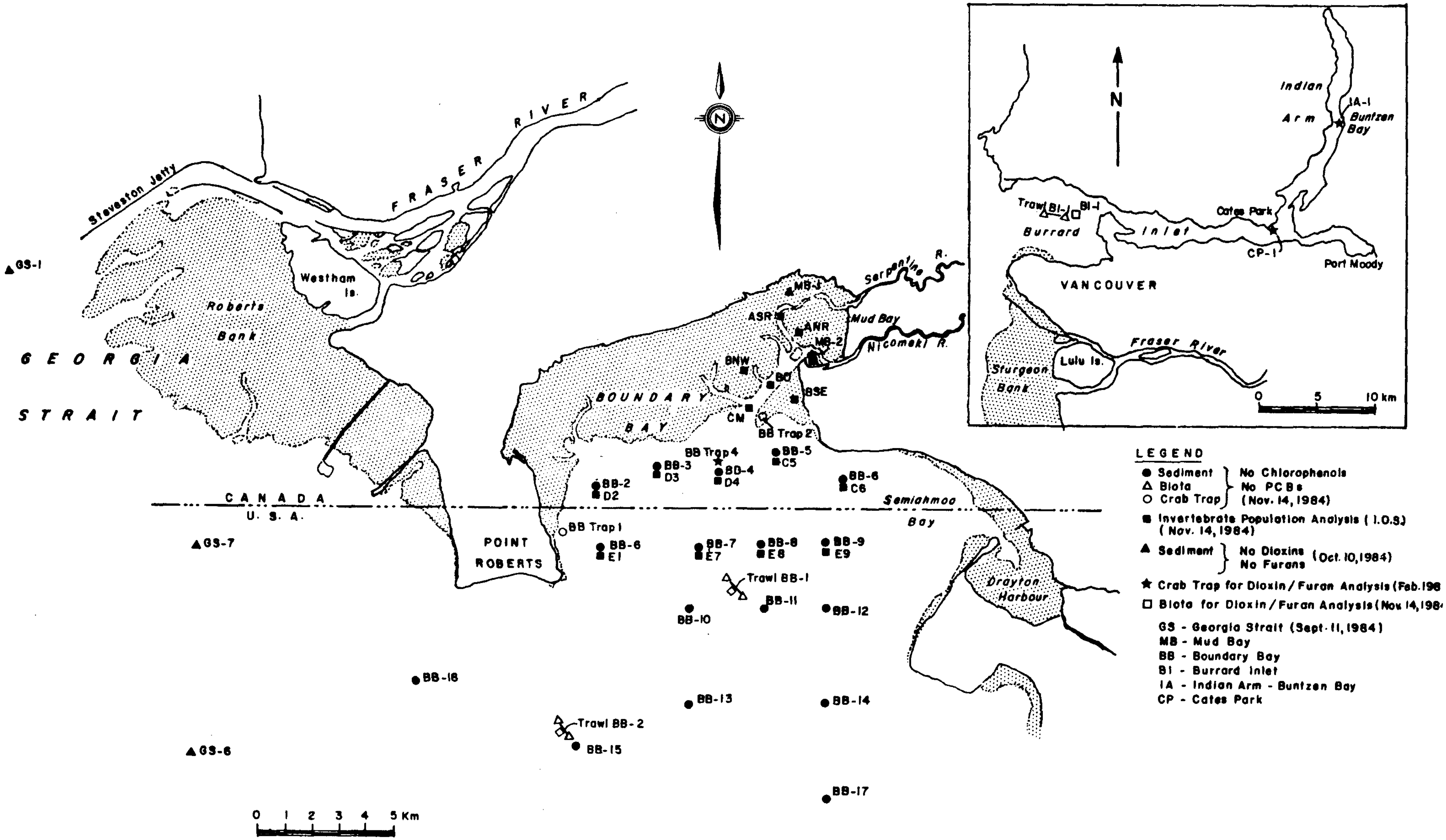

FIGURE 2 LOCATIONS OF SEDIMENT, INVERTEBRATE AND TISSUE SAMPLES COLLECTED - Sept. 1984 to Feb. 1985

TABLE 1 EPS SAMPLING DATES, LOCATIONS, AND ANALYSES, 1984-1985

DATES	LOCATIONS			DEPTH (m)	ANALYSES
	STATION NO.	LATITUDE (N)	LONGITUDE (W)		
11 Sept. 84	GS-1	49 03.70	123 23.60	258	1,2,3,4,5,6
	GS-6	48 52.00	123 07.75	155	1,2,3,4,5,6
	GS-7	48 52.20	123 09.00	107	1,2,3,4,5,6
10 Oct. 84	MB-1	49 05.30	122 53.40	0	5,6
	MB-2	49 03.70	122 52.60	0	5,6
13 Nov. 84	BB-1	49 59.25	122 59.88	7	1,2,3,4,5,d
14	BB-2	49 00.60	123 00.00	3	1,2,3,4,5
	BB-3	49 01.24	122 58.00	6	1,2,3,4,5
	BB-4	49 00.60	122 55.50	6	1,2,3,4,5,d
	BB-5	49 01.20	122 53.60	6	1,2,3,4,5,d
	BB-6	49 00.80	122 51.60	7	1,2,3,4,5
	BB-7	48 59.25	122 56.52	38	1,2,3,4,5,c
	BB-8	48.59.25	122 54.54	37	1,2,3,4,5
	BB-9	48.59.25	122 52.26	27	1,2,3,4,5
	BB-10	48.57.85	122 56.74	28	1,2,3,4,5,d
	BB-11	48 57.85	122 54.33	30	1,2,3,4,5,d
	BB-12	48 57.85	122 52.26	26	1,2,3,4,5,d
	BB-13	48 55.70	122 56.80	48	1,2,3,4,5,6,7,8,9,c,d
	BB-14	48 55.70	122 52.26	30	1,2,3,4,5,d
	BB-15	48 54.50	123 02.70	183	1,2,3,4,5
	BB-17	48 53.50	122 52.26	56	1,2,3,4,5,d
	BB-18	48 56.20	123 06.20	128	1,2,3,4,5
	BB Trawl-1	48 58.40	122 56.00	30	7,8,9,10,d
		48 58.04	122 55.61	30	
	BB Trawl-2	48 54.13	123 00.78	165	7,8,9,10,d
		48 54.62	123 01.49	145	
	BI-1	49 19.80	123 13.20	50	3,4,5
	BI Trawl-1	49 19.95	123 13.33	48	7,8,9,10,d
		49 19.60	123 12.72	45	
	BB Trap-1	49 59.60	123 01.00	3	10,d
	BB Trap-2	49 02.00	122 53.90	3	10,d
8 Feb. 85	BB Trap-3	49 00.60	122 55.50	10	10,d
10 Feb. 85	IA Trap-1	49 23.05	121 51.90	15	10,d
	CP Trap-1	49.18.20	122 57.30	10	10,d

ANALYSES:

*1 Sediment Particle Size
*2 Sediment Volatile Residue
*3 Sediment Trace Metals
4 Sediment Penta/Tetrachlorophenols: Detection Limit = 0.001 ug/g (ppm)
5 Sediment Polychlorinated Biphenyls: Detection Limit = 0.02 ug/g (ppm)
6 Sediment Chlorinated dibenzo-dioxins/furans
*7 Tissue Trace Metals
8 Tissue Penta/Tetrachlorophenols
9 Tissue Polychlorinated Biphenyls
10 Tissue Chlorinated dibenzo-dioxins/furans
c core taken
d duplicate samples taken

STATIONS:
GS Georgia Strait
MB Mud Bay
BB Boundary Bay
BI Burrard Inlet
IA Indian Arm
CP Cates Park

* results to be reported in Colodey (in prep.)

4 RESULTS AND DISCUSSION

No residual evidence of the chlorophenol spill was detected in the sediments or biota collected from Mud Bay, Boundary Bay or the Strait of Georgia. This supports earlier findings of the rapid dispersion, dilution, and biodegradation of the chlorophenate solution.

No pentachlorophenol or tetrachlorophenols were detected from marine sediments (Table 2) or in fish, crab and shrimp tissues (Table 3) sampled by EPS in Boundary Bay in November 1984.

TABLE 2 SEDIMENTS COLLECTED FROM BOUNDARY BAY AND GEORGIA STRAIT FOR CHLOROPHENOL (4CP/5CP) AND PCB ANALYSIS

STATION**	DATE	CONCENTRATION	
		4CP/5CP	PCB
GS-1	11 September 1984	< 0.0001*	< 0.02*
GS-6	11 September 1984	< 0.0001*	< 0.02*
GS-7	11 September 1984	< 0.0001*	< 0.02*
MB-1	10 October 1984	< 0.0001*	< 0.02*
MB-2	10 October 1984	< 0.0001*	< 0.02*
BI-1	13 November 1984	< 0.0001*	< 0.02*
BB-1	14 November 1984	< 0.0001*	< 0.02*
BB-2	14 November 1984	< 0.0001*	< 0.02*
BB-3	14 November 1984	< 0.0001*	< 0.02*
BB-4	14 November 1984	< 0.0001*	< 0.02*
BB-5	14 November 1984	< 0.0001*	< 0.02*
BB-6	14 November 1984	< 0.0001*	< 0.02*
BB-7	14 November 1984	< 0.0001*	< 0.02*
BB-8	14 November 1984	< 0.0001*	< 0.02*
BB-9	14 November 1984	< 0.0001*	< 0.02*
BB-10	14 November 1984	< 0.0001*	< 0.02*
BB-11	14 November 1984	< 0.0001*	< 0.02*
BB-12	14 November 1984	< 0.0001*	< 0.02*
BB-13	14 November 1984	< 0.0001*	< 0.02*
BB-14	14 November 1984	< 0.0001*	< 0.02*
BB-15	14 November 1984	< 0.0001*	< 0.02*
BB-17	14 November 1984	< 0.0001*	< 0.02*
BB-18	14 November 1984	< 0.0001*	< 0.02*

*Below detectable levels
**Refer to Figure 2 for station location

As a further indicator of the general condition of Boundary Bay, EPS sampled for polychlorinated biphenyls (PCBs). However, no PCBs were detected in the sediments (Table 2) or in fish, crab and shrimp tissues sampled (Table 3).

TABLE 3 SPECIES AND TISSUES COLLECTED NOVEMBER 1984 ANALYSED FOR POLYCHLORINATED BIPHENYLS (PCBs)* AND TETRA- AND PENTA-CHLOROPHENOLS (4CP/5CP)*

AREA	SPECIES	TISSUE
Burrard Inlet (Trawl BI-1)**	Sidestripe Shrimp (Pandalopsis dispar)	tail muscle
Boundary Bay (Trawl BB-1)**	Sidestripe Shrimp (Pandalopsis dispar)	tail muscle
	English Sole (Parophrys vetulus)	muscle liver gills
	Starry Flounder (Platichthys stellatus)	muscle liver gills
	Dungeness Crab (Cancer magister)	muscle hepatopancreas gill
(Trawl BB-2)**	Sidestripe Shrimp (Pandalopsis dispar)	tail muscle

*None detected. Detection limits: PCB < 0.02 ug/g
4CP/5CP < 0.0001 ug/g

**Refer to Figure 2 for trawl locations

IOS staff sampled benthic invertebrates from fifteen stations in upper Boundary Bay (Mud Bay) to determine the residual impact of the spill upon the nearshore benthic infaunal community (Appendix III). Brinkhurst and Moore (1985) concluded that results of the preliminary analysis of their sampling did not indicate any widespread deterioration in community structure as reflected in the abundance and diversity of the taxa examined: amphipods, isopods, molluscs, nematods, oligochaetes and polychaetes. More detailed ecological analysis of these samples is pending.

Chlorophenates are known to be contaminated with varying amounts of chlorinated dibenzo-dioxins and -furans (Sachdev and Marvan 1983). Because dioxins and furans are more resistant to environmental breakdown than chlorophenates, EPS also analysed for these compounds.

Samples taken from the railway ditch at the spill site by a Fisheries Officer indicated that dioxins and furans were present in addition to chlorophenols (Table 4). No control samples for dioxins were submitted.

TABLE 4 **CHLOROPHENOL, DIOXIN (D) AND FURAN (F) CONCENTRATIONS FROM SAMPLES COLLECTED AT THE SPILL SITE ON 4 MARCH 1984**

	(ppb)		TETRA		PENTA		HEXA		HEPTA		OCTA	
	4CP	5CP	D	F	D	F	D	F	D	F	D	F
1	n.s.	n.s.	--	--	--	0.2	4.0	10.8	25.7	16.8	21.6	3.2
2	787	292	--	--	--	1.3	16.5	44.6	67.4	54.5		9.9

n.s. = not sampled
-- = not detected < 50 pg/gm (parts per trillion)

No chlorinated dibenzo-dioxins or -furans were detected from sediments collected from the Strait of Georgia or Mud Bay in September or October 1984 (Table 5).

TABLE 5 **SEDIMENTS COLLECTED FROM BOUNDARY BAY AND GEORGIA STRAIT FOR CHLORINATED DIBENZO-DIOXINS AND -FURAN ANALYSIS**

STATION**	DATE	CONCENTRATION
GS-1	11 September 1984	< 50 pg/gm
GS-6	11 September 1984	< 50 pg/gm
GS-7	11 September 1984	< 50 pg/gm
MB-1	10 October 1984	< 50 pg/gm
MB-2	10 October 1984	< 50 pg/gm

< Indicates below detectable levels
** Refer to Figure 2 for station locations

The levels of chlorinated dibenzo-dioxins and -furans found in crab, shrimp and fish tissue sampled in Boundary Bay, Burrard Inlet and Indian Arm are listed in Table 6. No chlorinated dibenzo-furans were detected in any edible muscle tissues. Only OCDD (octochloro-p-dioxin) was found in edible muscle tissues (9-53 parts per trillion). Although this form of dioxin may have a longer half-life in the environment, it is also less toxic than tri- to penta- forms of dioxin (Health and Welfare Canada 1983).

Further results noted by R. Norstrom (Canadian Wildlife Service, Ottawa: pers. comm.) indicate that the crab hepatopancreas accumulated a wide range of dioxins and furans and would therefore be a good indicator-tissue for these compounds in the environment. Levels of 2,3,7,8-T_4CDD, the most toxic form of dioxin, were 2 and 3 ppt (parts per trillion) in Boundary Bay and Cates Park-Buntzen Bay crab hepatopancreas respectively. The Department of Fisheries and Oceans considers 20 ppt to be the "action level" for 2,3,7.8,-T_4CDD, whereby fish products would be deemed unfit for human consumption.

Although fish may have measurable levels of these contaminants, fish consumption is not the major route for human exposure to dioxins. Health and Welfare Canada (1983) ranked various environmental sources responsible for human exposure to dioxins. Direct exposure to chlorophenols, air and airborne particulates from incinerators, soils and dusts contaminated primarily from incinerators, pharmeceuticals and domestic products all ranked as a greater source of exposure to dioxins than the consumption of contaminated fish.

The numerous sources of dioxins and furans such as municipal incinerators and other combustion and industrial sources (Sheffield 1985, Czuczwa and Hites 1986), make interpretation of the limited number of data points from pooled tissue sample-results difficult. The mobile nature of the crabs further complicate the interpretation of the data. Although there are no comparative data on crabs from other areas, the results indicate generally higher levels of dioxins and furans found in Cates Park-Buntzen Bay industrialized area of Indian Arm (Figure 2), compared to levels found in Boundary Bay. Garrett (1983) found very high PCB concentrations at 3 sites near Cates Park (360-2580 ppb sediment dry wt.) and these PCBs could be another source of the furan levels observed.

TABLE 6 CHLORINATED DIBENZO-DIOXIN AND DIBENZO-FURAN LEVELS IN BIOTA FROM BUNTZEN BAY/CATES PARK, BOUNDARY BAY AND BURRARD INLET, 1984-85 (Submitted by EPS/P & Y Region to CWS for analysis.)

YEAR	LOCATION	SPECIES AND TISSUE	NUMBER IN POOL	LIPID (%)	WATER (%)	DIOXINS (ng/kg fresh wt.)					FURANS (ng/kg fresh wt.)*				
						TCDD	PCDD	HxCDD	HpCDD	OCDD	TCDF	PCDF	HxCDF	HpCDF	OCDF
1985	Bunsen Bay Cates Park	CRAB hepatopan.	4	11	77	10	72	360	90	22	281	314	496	63	-
	"	leg muscle	4	0.06	80	-	-	-	-	-	-	-	-	-	-
1985	Boundary Bay	CRAB hepatopan.	4	10	79	tr	24	140	26	9	73	19	21	tr	-
		leg muscle	4	0.07	80	-	-	-	-	-	-	-	-	-	-
1984	Boundary Bay	CRAB**	2	NM	NM	-	-	-	-	53	-	-	-	-	-
1984	Boundary Bay	ENGLISH SOLE muscle	3	NM	NM	-	-	-	-	10	-	-	-	-	-
1984	Boundary Bay	SIDESTRIPE** SHRIMP muscle	2	NM	NM	-	-	-	-	45	-	-	-	-	-
1984	Burrard Inlet	ENGLISH SOLE muscle	4	NM	NM	-	-	-	-	tr	-	-	-	-	-
1984	Burrard Inlet	SIDESTRIPE SHRIMP muscle	8	NM	NM	-	-	-	-	9	-	-	-	-	-

(-) in the table indicates not present at or above the minimum detectable amount: 2 ng/kg for TCDD and TCDF; 5 ng/kg for PCDD, PCDF, HxCDD and HxCDF; 8 ng/kg for HpCDD and HpCDF; 9 ng/kg for OCDD and OCDF.
NM indicates not measured because of small sample size.
* CDF levels were quantitated using the response factor for a CDD with the same number of chlorines.
** Minimum detectable amount for these two samples: 6 ng/kg for TCDD and TCDF; 10 ng/kg for PCDD, PCDF, HxCDD and HxCDF; 15 ng/kg for HpCDD and HpCDF; 25 ng/kg for OCDD and OCDF.

R. Norstrom (pers. comm.) agrees that several sources of contamination could be involved in the dioxin and furan contamination measured in the crab hepatopancreas. However, he reports finding a similar pattern of dioxins and furans in the samples from Boundary Bay and Cates Park-Buntzen Bay, when compared to his data from 5CP-contaminated regions of Surinam (South America).

In summary, no residual effects of the chlorophenol spill into Hyland Creek were detected in Boundary Bay in terms of benthic infaunal invertebrate populations or unusually elevated levels of contaminants in sediments or animal tissues.

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APPENDICES

APPENDIX I

CHLOROPHENOL CONCENTRATIONS IN WATER,
CLAM TISSUE, AND SEDIMENT
MARCH 1984-5
(from Derksen 1985)

APPENDIX I TOTAL PCP PLUS TOTAL TCP (ug/l) (March 4, 1984 to March 11, 1985) WATER CONCENTRATIONS

DATE	STATION							
	HYLAND CREEK			SERPENTINE RIVER			MUD BAY	
	A	B	C	D	H	I	K	L
Mar. 1984								
4	-	-	11600	8200	-	-	-	-
5	< 0.2	344	406	183	< 0.2	< 0.2	-	-
6	< 0.2	154	129	53	-	-	-	-
7	< 0.2	78	71	38	-	-	-	-
8		47	47	19.9	45.2	142	22.9	18.5
9		52	33	13.3	12.5	30	8.7	6.9
10		31.5	42.7	26.4	1.45	10.3	1.43	1.54
11		< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5
12		8.3	3.0	2.36	2.09	-	< 0.18	0.45
13		6.3	3.9	1.9	1.15	-	-	-
14		7.97	1.64	1.22	< 0.11	-	-	-
15		4.1	3.4	2.9	0.23	-	-	-
16		7.2	5.0	2.41	0.27	-	-	-
17		6.0	3.6	1.78	0.77	-	-	-
18		9.1	2.21	1.77	0.40			
19		5.9	4.0	2.7	0.40	-	< 0.10	< 0.10
21		2.09	1.0	-	-	-	-	-
22		2.93	0.95	0.88	0.40	-	0.25	0.86
27*		-	.36	.51	.23	-	-	-
Apr. 1984								
2*		< 0.10	0.52	< 0.10	-	-	-	-
4		43.2	3.4	2.35	-	-	-	-
8		8.29	6.78	4.27	-	-	-	-
9		1.42	0.64	0.27	-	-	-	-
10		1.34	0.65	0.31	0.50	-	0.25	0.86
11	-	2.58	2.02	1.61	-	-	-	-
12	-	1.91	1.25	1.53	-	-	-	-
13	-	4.01	0.55	0.60	-	-	-	-
16	-	1.35	0.73	0.17	0.13	-	< 0.10	< 0.10
19	-	3.21	0.74	0.28	-	-	-	-
23	-	1.43	-	-	0.19	-	-	-
24	-	0.51	-	-	-	-	-	-
26	-	3.21	0.74	0.28	-	-	-	-
27	-	0.90	0.35	< 0.1	< 0.11	-	-	-
28	-	-	-	-	-	-	< 0.1	< 0.1
30	-	2.30	-	-	-	-	-	-

Note: K and L sampled at low ebb
*sampled analyzed May 14, 1985

CONTINUED...

APPENDIX I (Continued)

DATE	STATION							
	HYLAND CREEK			SERPENTINE RIVER			MUD BAY	
	A	B	C	D	H	I	K	L
May 1984								
1	-	1.82	-	-	-	-	-	-
2	-	0.97	-	-	-	-	-	-
3	-	0.57	-	-	-	-	-	-
4	-	2.15	-	-	-	-	-	-
5	-	1.16	0.21	0.37	< 0.10	-	-	-
6	-	0.54	-	-	-	-	-	-
7	-	0.57	-	-	-	-	-	-
8	-	1.73	-	-	-	-	-	-
9	-	0.58	-	-	-	-	-	-
10	-	0.39	0.27	0.25	< 0.14	-	-	-
11	-	1.05	-	-	-	-	-	-
12	-	0.47	-	-	-	-	-	-
13	-	10.02	-	-	-	-	-	-
14	-	8.54	-	-	-	-	< 0.12	< 0.16
15	-	6.52	-	-	-	-	-	-
16	-	1.57	-	-	-	-	-	-
17	-	1.72	-	-	-	-	-	-
18	-	7.0	-	-	-	-	-	-
19	-	0.62	-	-	-	-	-	-
20	-	1.28	-	-	-	-	-	-
21	-	5.0	-	-	-	-	-	-
22	-	0.47	7.0	7.41	0.19	-	-	-
23	-	6.1	-	-	-	-	-	-
24	< 0.15	1.69	-	-	-	-	-	-
27	-	0.52	-	-	-	-	-	-
28	-	0.58	-	-	-	-	-	-
29	-	0.73	0.45	0.44	0.16	-	0.12	< 0.12
30	-	0.56	-	-	-	-	-	-
31	-	0.46	-	-	-	-	-	-
Jun. 1984								
1	-	0.40	-	-	-	-	-	-
2	-	5.2	-	-	-	-	-	-
3	-	0.57	-	-	-	-	-	-
4	-	2.58	0.63	1.04	0.11	-	< 0.1	< 0.1
12	-	0.32	0.17	< 0.12	< 0.1	-	< 0.1	< 0.1
19	-	3.7	-	-	-	-	-	-
26	-	0.29	-	-	-	-	-	-

Note: K and L sampled at low ebb

CONTINUED...

APPENDIX I (Continued)

DATE	STATION							
	HYLAND CREEK			SERPENTINE RIVER			MUD BAY	
	A	B	C	D	H	I	K	L
Jul. 1984								
5	-	0.24	-	-	-	-	-	-
12	-	0.16	0.12	< 0.1	< 0.1	-	-	-
19	-	0.17	-	-	-	-	-	-
25	-	0.18	-	-	-	-	-	-
Aug. 1984								
2	-	0.16	-	-	-	-	-	-
7	-	0.21	0.15	0.17	< 0.1	-	-	-
8	-	-	-	-	-	-	< 0.1	< 0.1
23	-	0.23	-	-	-	-	-	-
Sep. 1984								
10	-	0.19	0.12	0.11	0.33	-	< 0.1	< 0.1
Oct. 1984								
12**	-	0.55	0.22	0.20	0.44	-	-	-
19	-	< 0.11	-	-	-	-	-	-
26	-	0.45	-	-	-	-	-	-
Nov. 1984								
14	-	0.17	0.11	0.10	0.16	-	-	-
Feb. 1985								
13	-	0.16	0.07	0.23	0.25	-	-	-
Mar. 1985								
11	-	-	-	-	-	-	< 0.1	< 0.1

Note: K and L sampled at low ebb
**October 12 - first period of heavy autumn rainfall

APPENDIX I   CLAM TISSUE PCP, TCP, PCP AND TCP (March 9, 1984 to March 11, 1985)

DATE	STATION K (ug/g wet weight)			STATION L (ug/g wet weight)		
	PCP	TCP	Total	PCP	TCP	Total
Mar. 1984						
9	.072	.026	.098	.036	.047	.083
10	.047	.061	.108	.048	< .005	< .053
11	.045	.027	.072	.023	< .005	< .028
24	.019	< .005	< .024	.032	< .005	< .037
Apr. 1984						
3	-	-	-	.006	< .005	< .011
16	-	-	-	.015	< .005	< .020
30	< .005	< .005	< .010	-	-	-
May 1984						
14	< .005	< .005	< .010	< .005	< .005	< .010
29	< .005	< .005	< .010	< .005	< .005	< .010
Jun. 1984						
4	< .005	< .005	< .010	< .005	< .005	< .010
12	< .005	< .005	< .010	< .005	< .005	< .010
Aug. 1984						
8	< .005	< .005	< .010	< .005	< .005	< .010
Sept. 1984						
10	< .005	< .006	< .011	< .005	< .005	< .010
Nov. 1984						
14**	-	-	-	-	-	-
Mar. 1985						
11	< .005	< .005	< .010	< .005	< .005	< .010

*sample analyzed May 14, 1985
**not sampled, daytime tide too high

APPENDIX I SURFICIAL SEDIMENT PCP, TCP, PCP AND TCP (March 5, 1984 to March 11, 1985) (from Derksen 1985)

	STATION (ug/g)						
	A	B	C	D	H	K	L
PCP (1984)							
Mar. 5	.030	.52	.69	.16	.009	-	-
Mar. 8	-	-	-	-	-	< .004	< .004
Aug. 7/8	-	.029	.018	< .005	< .005	< .005	< .005
Nov. 14*	-	.007	.014	.006	< .005	-	-
(1985)							
Feb. 13	-	.031	-	-	-	-	-
Mar. 11	-	-	.006	.011	.021	< .005	< .005
TCP (1984)							
Mar. 5	.043	.45	.85	.22	.007	-	-
Mar. 8	-	-	-	-	-	< .004	< .004
Aug. 7/8	-	.043	.014	< .005	< .005	< .005	< .005
Nov. 14*	-	.030	.019	.006	< .005	-	-
(1985)							-
Feb. 13	-	.040	-	-	-	-	
Mar. 11	-	-	< .005	.009	< .005	< .005	< .005
Total PCP and TCP (1984)							
Mar. 5	.073	.97	1.54	.38	.016	-	-
Mar. 8	-	-	-	-	-	< .008	< .008
Aug. 7/8	-	.073	.032	< .010	< .010	< .010	< .010
Nov. 14*	-	.037	.033	.012	< .010	-	-
(1985)							
Feb. 13	-	.071	-	-	-	-	-
Mar. 11	-	-	< .011	.020	< .026	< .010	< .010

*K and L not sampled as daytime tide too high

DATE	138th St./68th Ave. DITCH STATION		
	PCP	TCP	PCP & TCP
Nov. 14, 1984	.033	.084	.117
Feb. 13, 1985	.235	.350	.585

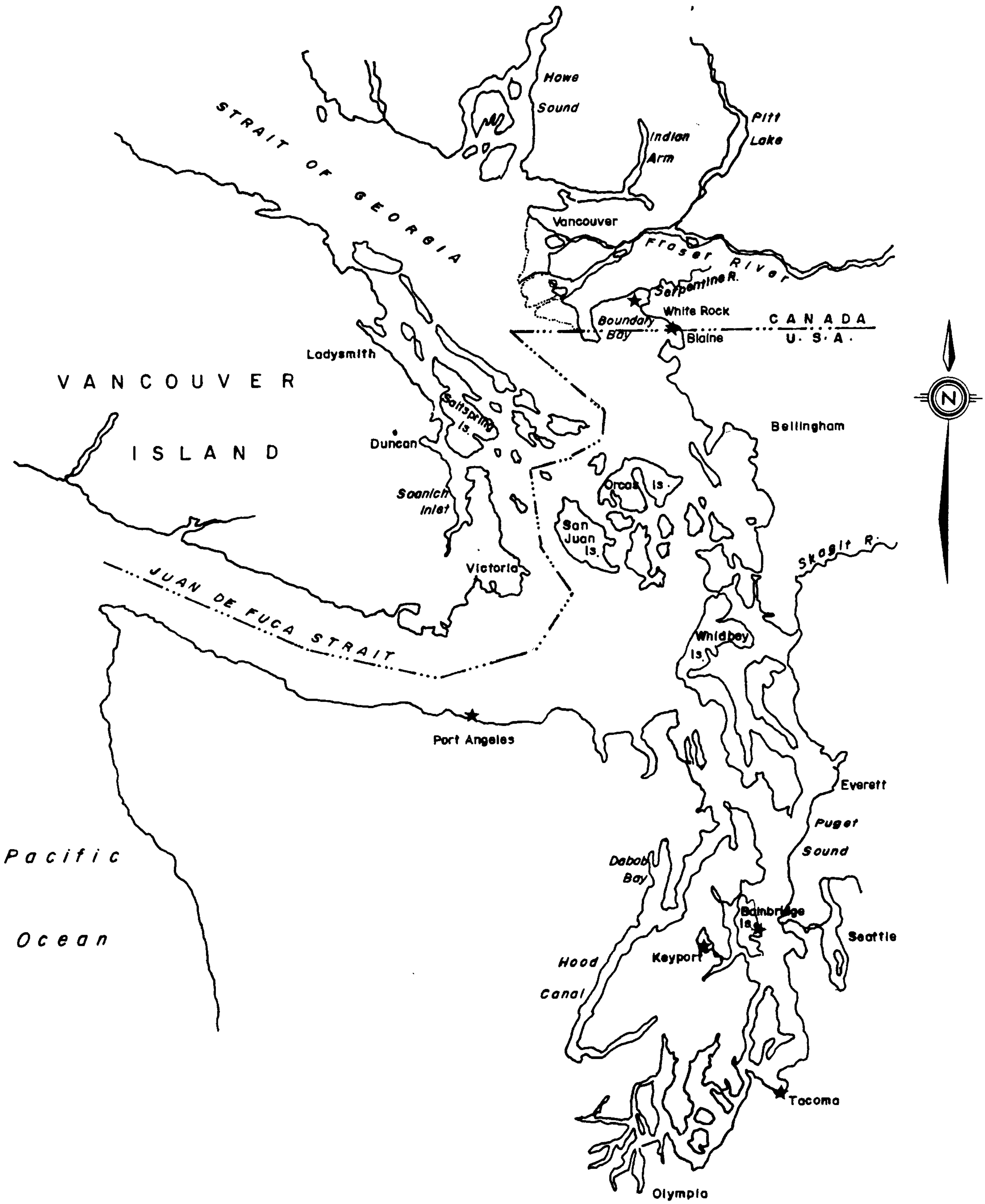
APPENDIX II

SUMMARY OF 1984 GRAY WHALE STRANDINGS IN
SOUTH GEORGIA STRAIT-PUGET SOUND
(from Olesiuk and Bigg 1984)

APPENDIX II SUMMARY OF 1984 GRAY WHALE STRANDINGS IN SOUTH GEORGIA STRAIT-PUGET SOUND (from Olesiuk and Bigg 1984)

DATE FOUND	LOCATION	LENGTH (m)	SEX	CONDITION	FATE
8 March	Victoria, B.C.	8*	F	fresh	buried
11 April	Keyport, Wa.	7*	F	?[1]	buried
24 April	Boundary Bay, B.C.	9.5*	?	dead 1-2 mo.	floated away
26 April	Boundary Bay, B.C.	8.5*	?	dead 2-3 mo.[2]	buried
4 May	Tacoma, Wa.	10	?	?	rendering plant
4 June	White Rock, B.C.	9*	F	dead 1 mo.	examined, left on shore
5 June	Boundary Bay, B.C.	6*	?	dead 3-4 mo.[3]	left on shore
12 June	Bambridge Is. Wa.	12	?	fresh	towed to sea
18 June	Port Angeles, Wa.	8*	M	dead 10 days	necropsied

[1] Death attributed to entanglement in crab trap
[2] Rope found around tail - possible cause of death
[3] Advance state of decomposition - identification as gray whale uncertain
* Likely immature animal (M. Bigg, DFO Nanaimo, pers. comm.)



APPENDIX II
LOCATIONS OF 1984 GRAY WHALE STRANDINGS

APPENDIX III

INVERTEBRATE SAMPLING STATIONS IN UPPER BOUNDARY BAY
13-14 MARCH 1984
(from Brinkhurst and Moore 1985)

APPENDIX III INVERTEBRATE SAMPLING STATIONS IN UPPER BOUNDARY BAY 13-14 MARCH 1984 (from Brinkhurst and Moore 1985)

STATION NUMBER	LATITUDE (N)	LONGITUDE (W)	DEPTH (m)	SUBSTRATE TYPE
ASR	49 04.20	122 53.50	2	sand, eel grass
ANR	49 03.70	122 52.30	5	sand, eel grass, shell
BNW	49 03.60	122 54.33	1.5	sand, eel grass
BO	49 03.30	122 53.80	9	sand
BSE	49 02.90	122 53.20	1	sand
CM	49 02.60	122 55.50	11	sand
C5*	49 01.20	122 53.60	6	sand
C	49 00.80	122 51.60	7	sand
D	49 00.60	122 00.00	3	sand
D	49 01.24	122 58.00	6	sand
D	49 00.60	122 55.50	6	sand
E	49 59.25	122 59.88	7	sand
E	48 59.25	122 56.52	38	mud
E	49 59.25	122 54.54	37	mud
E	48 59.25	122 52.26	27	mud/sand

* Numbered stations correspond to EPS BB-# stations (Table 1).

APPENDIX IV

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APPENDIX IV PERSONAL COMMUNICATION REFERENCES

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