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PUGET SOUND SEDIMENT TRAP DATA: 1980-1985

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Puget Sound Sediment Trap Data: 1980–1985

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1.0 INTRODUCTION

In 1979, scientists at the Pacific Marine Environmental Laboratory began investigating the sources, transformation, transport and fate of pollutants in Puget Sound and its watershed under Sec. 202 of the Marine Protection, Research and Sanctuaries Act of 1971 (P.L. 92–532) which called in part for "...a comprehensive and continuing program of research with respect to the possible long range effects of pollution, overfishing, and man-induced changes of ocean ecosystems..." The effort was called the Long-Range Effects Research Program (L-RERP) after language in the Act and was later called the PMEL Marine Environmental Quality Program. Building on research then underway at PMEL on estuarine circulation, laboratory scientists began a coordinated study that began with the description of the distribution of properties (salinity, temperature, trace metals and trace organics) in the water column and underlying sediments. The objectives of the Marine Environmental Quality Trace Metal and Organics Program were 1) to quantify the sources and sinks of selected trace metals and organics for Puget Sound, 2) to determine geochemical mechanisms that transform trace metals between the dissolved and particulate phases and 3) to determine to what extent these geochemical mechanisms alter the fate of trace metals and organics entering Puget Sound. Work began in rivers discharging into Puget Sound and process studies were undertaken to understand the role of flocculation in trace metal transport. Subsequently the research centered on the role of suspended sediments in transporting and redistributing trace metals and organics in the main basin of the Sound. Research activities included deployment of long-term current meter moorings, acquisition of a library of sediment cores, deployment of sediment traps and the analyses of dissolved and particulate chemical constituents of the water column and sediments. The scientific results of these activities have been reported in over 100 publications (see Section 6).

The Long-Range Effect Research Program consisted of 1) sampling dissolved and particulate constituents in the water column by bottle sampling, 2) sampling settling particles by sediment trap and 3) sampling sediments by grab, box, gravity and Kasten corers. All three type of samples collected between 1979 and 1985 for the two urban embayments (Elliott and Commencement Bays) are reported in Paulson *et al.* (1991a). All the water column data in the

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open waters of Puget Sound collected between 1981 and 1985 are reported in Paulson *et al.* (1991 b). Water column data collected from a single cruise in 1986 in both the open waters and embayments of Puget Sound are reported in Paulson *et al.* (1991c). In this Data Report, a variety of data from particles collected in 104 traps deployed on 34 moorings in open waters between 1980 and 1985 are presented (Table 1).

Because these measurements constitute the most extensive data base of trace metal and trace organic observations in Puget Sound, many of which have been unavailable to other investigators, we feel that they should be widely available to the local scientific community as well as others interested in estuarine geochemistry. The text of this data report begins with the sampling and analytical methods with the accompanying quality control/quality assurance data. The text of the data sections are a summary of the available data and published literature in which the data is interpreted along with a catalogue of the data available in the Appendix (on microfiche located in the back pocket of this data report).

A catalogue of sediment data for the open waters of Puget Sound is not available at this time. Therefore, below you will find a description of citations in which PMEL's sediments collected by PMEL's L-RERP sampling program have been analyzed and reported. Sedimentation rates in Puget Sound are reported in Lavelle *et al.* (1985, 1986). Baker *et al.* (1985) discuss the carbon and pigment content and sedimentation rates in Puget Sound. Trace metal content, geochemistry and sedimentation rates are discussed in Romberg *et al.* (1984), Feely *et al.* (1986), Bloom and Crecelius (1987) and Paulson *et al.* (1988a). Bates *et al.* (1984, 1987) and Murphy *et al.* (1988) present and discuss trace organic content in the sediments. All ancillary data collected from the cores associated with the publications cited above have been submitted in uncollated form to the data management team of the Puget Sound Water Quality Authority.

Table 1. Summary of Sediment Traps Recovered

Sampling Year	Number of Moorings	Number of Traps	Cylinder Collection Time (hr)	Dates (Inclusive)	Region
1981	5	22	144–168	5 Dec 80 – 2 Feb 81 2 Feb 81 – 16 Apr 81 22 Apr 81 – 5 Jul 81 21 Jul 81 – 29 Sep 81 7 Oct 81 – 19 Dec 81	Time series in CMB
1982	5	17	137–168	Feb 82 – 25 Apr 82	AI, CMB, EP
1983	7	21	91	18 Mar 82 – 24 Apr 82	Transect across EP, COL
	1	6	24	13 Apr 83 – 29 Apr 83	EP
	3	6	288	26 Apr 83 – 29 Aug 83	AI, CMB, EP
	3	6	228	29 Aug 83 – 7 Dec 83	AI, CMP, EP
1984	6	16	288	1 Dec 83 – 30 May 84	SJF, AI, CMB, EP, WB
	3	6	264	5 Apr 84 – 23 Jul 84	AI, CMB, EP
1985	1	3	204	29 Mar 85 – 22 Jun 85	CMB
		1	4	10 Apr 85 – 12 Apr 85	CMB

SJF Strait of Juan de Fuca
AI Admiralty Inlet
CMB Central Main Basin
EP East Passage
WB Whidbey Basin
COL Colvos Passage

2.0 METHODS

2.1 Collection and Processing

Settling particles were trapped using the cylindrical Sequentially Sampling Sediment Trap described by Baker and Milburn (1983). The smooth polyethylene collection funnel has a collection cross-sectional area of 324.3 cm^2 and an aspect ratio of 3.0:1 (Fig. 1). Settling particles collect in the funnel and are directed in turn to one of 10 acrylic containers (200 ml each). The acrylic containers have been filled with a dense filling solution to minimize loss of particles by turbulence. Toxins such as sodium azide are added to the dense filling solution brine to prevent organic growth. After a preset time, the next acrylic container on the sampling unit is rotated under the funnel. The sediment traps are kept upright during collection and are closed during the recovery process. In each sampling year, sediment traps were deployed in different locations throughout Puget Sound for different durations. A summary of the number and duration of deployments for each sampling year is presented in Table 1.

Upon recovery, the sampling containers were transported to the laboratory and the contents split. Approximately half of the supernatant (100 ml) was first decanted from the sampling containers. This liquid was stored in high-density linear polyethylene bottles or discarded. The remaining sample of particles and supernatant was then thoroughly mixed and split into separate aliquots for measurement of total dry weight, pigments, total carbon and nitrogen, trace metals and trace organic measurements.

2.2 Analyses

2.2.1 Total Sedimentation Rate

The contents of each aliquot for total dry weight analysis were filtered onto a pre-tared, 47 mm, 0.2 μm Nuclepore filter and vacuum desiccated. After at least a week of drying, the filters were re-weighed on electrobalances. The total dry weight was calculated by difference. Sedimentation rates were calculated from the total dry weight, the duration of the collection period and the collection cross-sectional area.

2.2.2 Size Fractionation

Particles were separated according to size and density and collected on 0.4 μm membrane filters for weighing. A separation scheme (Fig. 2) was designed to isolate fine and coarse mineral grains, fecal pellets and coarse low-density particles. In step (1), aliquots from each trap were gently washed through a 38 μm sieve. The large particles retained on the sieve were then segregated at step (2) into density classes by flotation in carbon tetrachloride with density ρ = 1.6 g/cm^3 (Dillon, 1964). The low-density fraction at step (3) was vigorously rewashed through a 38 μm sieve using hot soapy water to disaggregate fecal pellets. Sedimented particles were density segregated by centrifugation on a saturated zinc chloride solution (ρ = 1.9 g/cm^3).

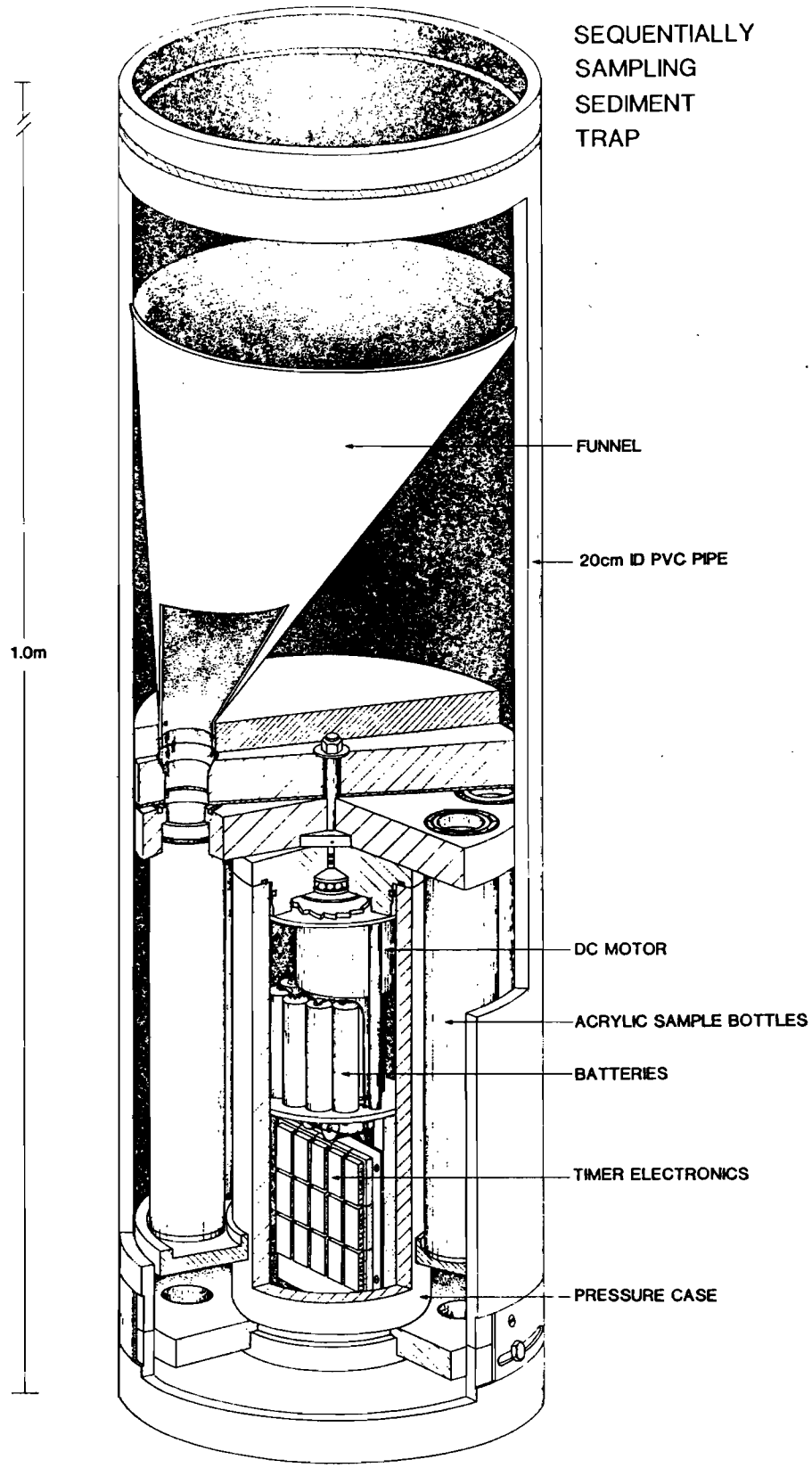

Fig. 1. Mechanical design of the sediment trap. The electronic timing components are accessible after removing the pressure-case end cap at the base of the unit.

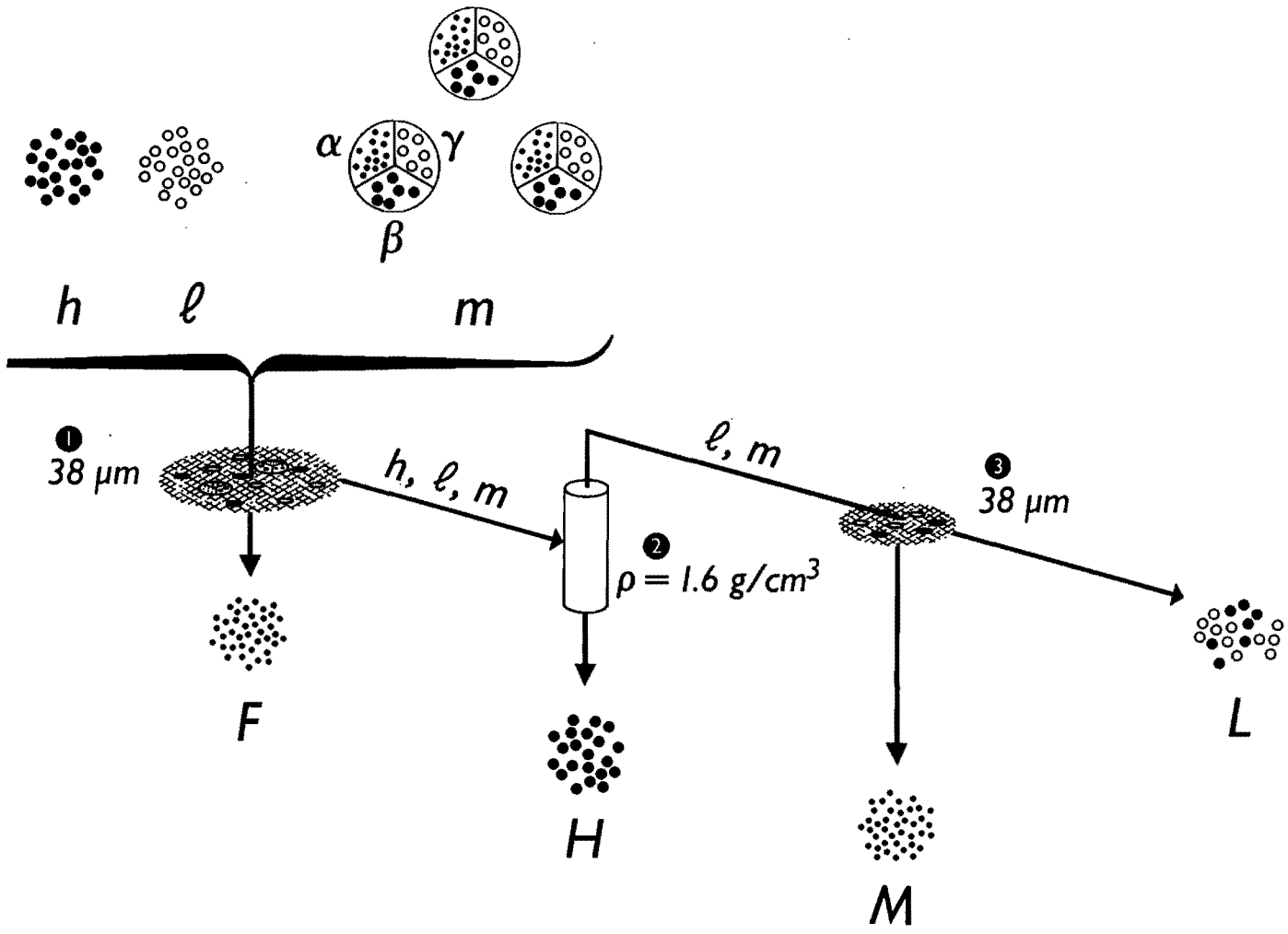

Fig. 2. Fractionation scheme for sediment trap particles. At the first step, fine particles F were mechanically separated by washing through a 38 μm sieve. Particles retained on the sieve were segregated according to density at step (2), with high-density coarse particles H being separated out. At step (3), low-density coarse particles L and intact macroaggregates were vigorously rewashed through a 38 μm sieve. The fine fraction (α) of the disaggregated macroaggregates passing through the sieve was collected as fraction M. The particles retained on the sieve at step (3) consisted of low-density coarse particles, including the fraction γ disaggregated from macroaggregates, as well as the high-density coarse fraction β disaggregated from macroaggregates.

2.2.3 Pigments

Pigments in trapped particles were measured in aliquots filtered onto glass-fiber filters, stored frozen, and analyzed by fluorometry as described by Holm-Hansen *et al.* (1965). The total pigment in a sample (chl_T) is expressed in terms of chlorophyll *a* equivalents, calculated as chlorophyll *a* + (1.51) pheophorbide (Shuman and Lorenzen, 1975).

2.2.4 Organic Carbon and Nitrogen

Total particulate C and N was measured in aliquots filtered onto silver filters, stored frozen, and combusted in a Perkin-Elmer 240B CHN analyzer. Acid treatment of selected samples indicates that particulate C was typically 95% organic.

2.2.5 Trace Metals

Several different analytical procedures were used to determine the trace metal content of the settling particles for each sampling period.

2.2.5.1 Trace Metals – 1981. The trace metal aliquots from the ten cylinders from each sediment trap were combined to give one sample representing the entire trap deployment. The combined sample was then sieved through a 64 μm polyethylene screen and the <64 μm material was collected on a 142 or 47 mm, 0.4 μm Nuclepore filter and vacuum desiccated. The <64 μm fraction was analyzed for trace metals.

Trace elements associated with the poorly structured hydrous oxide phases of the suspended matter and sediment trap samples were determined by the method of Chester and Hughes (1967) with slight modifications. Desiccated samples were leached with 5 ml of a mixed reagent containing 0.04 hydroxylamine hydrochloride in 25% Ultrex® acetic acid at 50°C for 2 h. The resulting supernatant was filtered through an acid-cleaned polypropylene-glass filtration unit containing a 0.2 μm Nucleopore filter. The residue was rinsed with quartz-distilled water, then filtered; the supernatant was then combined with the original supernatant, acidified with 0.5 ml of concentrated Ultrex® HCl diluted to 20 g weight, and analyzed for trace elements by the graphite furnace atomic absorption spectrometer (GFAAS) procedures described by Feely *et al.* (1981).

Trace elements associated with particulate organic matter were determined using the procedures of Landing and Feely (1981). Separate 100-mg aliquots of sediment trap material were heated in 10% H_2O_2 for 18 h at 65°C and then sonicated with continued heating for another 24 h. The samples were decanted and filtered through an acid-cleaned 0.2-μm Nucleopore filter. The samples were rinsed with two portions of quartz-distilled water, acidified with 0.5 ml of concentrated Ultrex® HCl, diluted with quartz-distilled water to 20 g total weight, and analyzed for trace elements by flameless atomic absorption.

Total metal concentrations for Al, Fe, Mn, Ni, Cu, Zn, Pb, Cr, Cd and Co in OMPA1 and OMPA4 samples were determined by dissolution in a HF-HCl-HNO_3 acid digestion according to the method of Eggiman and Betzer (1976) followed by analysis of the digested acid solution by GFAAS. The precision of total analysis of samples is given in Table 2. Arsenic in OMPA1 samples and Fe, Mn, Cu, Zn, Pb, Cr, V and As in OMPA2 and OMPA3 samples were analyzed by XRF according to the method of Nielson (1977). Ag, Se and Hg were determined according to the method of Bloom and Crecelius (1987).

2.2.5.2 Trace Metals – 1982. The trace metal aliquots from the ten cylinders from each trap were combined in the manner described for the 1981 trace metal samples. Total Cu, Pb, Ag and Hg were determined by the method of Bloom and Crecelius (1984).

2.2.5.3 Trace Metals – 1983 to 1984. The trace metal aliquots from the ten cylinders from each trap were combined and processed in the manner described for the 1981 trace metal samples. Total Mn, Cu, Pb and Cd concentrations were determined by dissolution in a HF-HCl-HNO_3 acid digestion according to the method of Eggiman and Betzer (1976) followed by analyses of the digested acid solution by GFAAS. Quality assurance/quality control data for this set of analyses is given in Table 2.

2.2.5.4 Trace Metals – 1985. For the 1985 sediment trap deployments, trace metal aliquots from each cylinder were filtered onto separate filters. The Mn concentrations in <63 μm fraction and the >63 μm fraction for each cylinder were analyzed separately. The Mn associated with the oxide phase of the sediment trap particles was selectively extracted with hydroxylamine hydrochloride according to the method of Robbins *et al.* (1984). The extractant from the selective extraction procedure was analyzed by GFAAS. The Mn in the residual phase was determined by the dissolution in a HF-HCl-HNO_3 acid digestion according to the method of Eggiman and Betzer (1976) followed by analyses of the digested acid solution by GFAAS.

2.2.6 Trace Organics

In most cases, the trace organic aliquots from each cylinder were combined and processed in the manner described for the 1981 trace metal samples. In some cases, a sediment trap contained enough material to combine aliquots from less than the ten cylinders (usually 3–4 cylinders) to produce several samples from the same sediment trap.

The analytical procedure for trace organics included Soxhlet extraction with methanol/dichloromethane, silica gel adsorption chromatography to separate the aliphatic and aromatic fractions, and Sephadex gel permeation chromatography to further concentrate the polycyclic aromatic hydrocarbons (PAH) (Hamilton *et al.*, 1984). Compounds were quantified with a Hewlett-Packard 5880 gas chromatograph and a Hewlett-Packard 5993 gas chromatograph-

Table 2. Quality Control/Quality Assurance Data for Trace Metals

		Al	Fe	Mn	Ni	Cu	Zn	Pb	Cd	Co
1981	Sample Precision (%CV; n=3)	1–6%	1–4%	0.5–4%	10–11%	4%	3–25%	6–16%		5–10%
	AGV SRM Observed	6.9		942	7	56	51	33		19
	AGV SRM Literature	4.5		774	15	64	86	33		16
	BCR SRM Observed	5.4		1660	19	22	110	15		36
	BCR SRM Literature	3.6		1400	10	16	125	14		36
	MAG SRM Observed	7.1		935	74	32	153	21		25
	MAG SRM Literature	4.3		774	52	33	140	27		18
1982–1984	Determination Limit (ppm)			12		2		2	0.15	
	Sample Precision (%CV, n=3)			4		9		1	19	
	BCSS-1 SRM Observed			227 ±13		18 ±1		24 ±2	0.35 ±0.07	
	BCSS-1 SRM Certified			229 ±15		18 ±3		23 ±3	0.25 ±0.07	
	MAG SRM Observed			651 ±15		28 ±1		29 ±3	0.33 ±0.06	
	MAG SRM Literature			770		27		24	N/A	
	MESS-1 SRM Observed			472 ±78		32 ±5		32 ±1	0.60 ±0.01	
	MESS-1 SRM Certified			513 ±25		25 ±4		34 ±6	0.59 ±0.1	

mass spectrometer using either an OV-1 (aliphatic) or SE-54 (PAH) fused silica column with temperature programmed from 70 to 270°C at 4°C/min. Recovery standards were used to correct volatilization losses (Barrick *et al.*, 1980) (Table 3). Analytical precision for the individual hydrocarbons was ± 10% (one standard deviation expressed as a percentage of the mean) and the limit of detection for each individual compound was generally less than 5 μg/g. PAH compounds derived from combustion processes are designated combustion PAH (COMB PAH) and represent the sum of nine compounds—fluoranthene, pyrene, benz[a]anthracene, chrysene, benzofluoranthenes, benzo[e]pyrene, benzo[a]pyrene, indeno[c,d]pyrene, and benzoperylene. All concentrations are expressed in nanograms per gram dry weight of sediment.

Table 3. Organic Recovery Data (%); 1981

	Alphatic	PAH
OMPA 1	73 ± 4	54 ± 6
range	(68–78)	(48–56)
OMPA 2	97 ± 7	55 ± 12
range	(85 ± 100)	(42–67)
OMPA 4	85 ± 14	93 ± 33
range	(67–99)	(78–139)
OMPA 5	10 ± 6	83 ± 19
range	(6–14)	(40–103)

3.0 RESULTS

The data from recovered sediment traps is organized by sampling year in the following sections. For each section, a brief description of the locations and deployment intervals of the sediment traps for the sampling year is given. This is followed by the citations where interpretations of the data can be found. Each section also contains two tables. The first table gives sampling data for each sediment trap in the following order: sediment trap name, serial number (S/N), mooring name, latitude, longitude, water depth, depth of sediment trap deployment, collection start time, duration of collection time for each cylinder, collection stop time and comments. The second table indicates what type of data is available in the Appendix for each sediment trap such as pigment, carbon and nitrogen content, size fractionation, trace metal (TM) or trace organic (Org.) data. The last column of this table indicates the page number in the Appendix that a particular type of data for the given trap can be found. The Appendix is organized in sets. Firstly, individual tables for each sediment trap within the set are presented with data for the ten cylinders organized by rows. The total sedimentation rate is always given for each cylinder. Pigment, carbon and nitrogen and size fractionation data for each cyclinder can also found in these tables for the individual sediment traps, if available. For trace metal and trace organic analysis, the samples from the ten cylinders from each trap were usually combined. Therefore, the data for trace metals and trace organics from each set of sediment traps is presented in two tables in the Appendix following the set of individual sediment trap tables. In the table for trace metal and trace organic data, data from each sediment trap is given by rows.

3.1 1981 Sampling Year

The 1981 sampling program consisted of a time series at a central main basin location with almost continuous sampling between 5 December 1980 and 19 December 1981 (Table 4). Usually traps were deployed at depths of 50, 100, 160 and 200 m. During the summer deployment (OMPA4), a trap was placed at 20 m.

The total sedimentation rates, pigment and carbon data (Table 5) are presented and discussed in Baker *et al.* (1985). Feely *et al.* (1986) presents and discusses the data for total trace metal content and for trace metal content of electively extracted phases of the settling particles. Further discussion of the trace metal data can be found in Paulson *et al.* (1988a). Mn concentrations on settling particles at the central main basin location are discussed in Cudaback *et al.* (1991). The trace organic data is presented and discussed in Bates *et al.* (1984, 1987) and Murphy *et al.* (1988).

Table 4. Sediment Trap Location and Sampling Data for 1981

0 Trap Name	1 S/N	2 Mooring	3 Lat. N	4 Long. W	5 Water Depth	6 Sample Depth	7 Start: Date/	8 Duration Cylinder	9 Stop: Date/	10 Comments
PS811-50	4	OMPA1	47 41.9	122 27.2	210	50	5 DEC 80 00:00	144	2 FEB 81 00:00	
PS811-100	6	OMPA1	47 41.9	122 27.2	210	100	5 DEC 80 00:00	144	2 FEB 81 00:00	
PS811-160	1	OMPA1	47 41.9	122 27.2	210	160	5 DEC 80 00:00	144	2 FEB 81 00:00	1 of Triple
PS811-200	5	OMPA1	47 41.9	122 27.2	210	205	5 DEC 80 00:00	144	2 FEB 81 00:00	
PS812-50	1	OMPA2	47 41.9	122 27.2	202	42	2 FEB 81 17:00	161	16 APR 81 02:00	
PS812-100	2	OMPA2	47 41.9	122 27.2	202	92	2 FEB 81 17:00	161	16 APR 81 02:00	1 of Triple
PS812-200	6	OMPA2	47 41.9	122 27.2	202	197	2 FEB 81 17:00	161	16 APR 81 02:00	
PS813-50	1	OMPA3	47 41.5	122 27.5	220	50	22 APR 81 16:00	168	5 JUL 81 12:00	1 of Triple
PS813-100	2	OMPA3	47 41.5	122 27.5	220	100	22 APR 81 16:00	168	5 JUL 81 12:00	
PS813-160	3	OMPA3	47 41.5	122 27.5	220	160	22 APR 81 16:00	168	5 JUL 81 12:00	
PS813-200	4	OMPA3	47 41.5	122 27.5	220	200	22 APR 81 16:00	168	5 JUL 81 12:00	
PS814-20	3&7	OMPA4	47 41.7	122 27.2	210	20	21 JUL 81 13:00	161	29 SEP 81 02:00	Averaged
PS814-100	5	OMPA4	47 41 7	122 27.2	210	100	21 JUL 81 13:00	161	29 SEP 81 02:00	
PS814-160	2	OMPA4	47 41.7	122 27.2	210	160	21 JUL 81 13:00	161	29 SEP 81 02:00	
PS814-200	1	OMPA4	47 41.7	122 27.2	210	200	21 JUL 81 13:00	161	29 SEP 81 02:00	
PS815-20	1&2	OMPA5	47 41.7	122 27.3	200	20	7 OCT 81 16:00	176	19 DEC 81 00:00	Averaged
PS815-50	3	OMPA5	47 41.7	122 27.3	200	50	7 OCT 81 16:00	176	19 DEC 81 00:00	
PS815-100	4	OMPA5	47 41.7	122 27.3	200	100	7 OCT 81 16:00	176	19 DEC 81 00:00	
PS815-160	5	OMPA5	47 41.7	122 27.3	200	160	7 OCT 81 16:00	176	19 DEC 81 00:00	
PS815-200	7	OMPA5	47 41.7	122 27.3	200	200	7 OCT 81 16:00	176	19 DEC 81 00:00	

Table 5. Availability of Sediment Trap Data for 1981

0 Trap Name	1 S/N	2 Mooring	3 Pig-ments	4 Carbon	5 Size Frac.	6 TM	7 Org.	8 Page
PS811-50	4	OMPA1	X	X				6
PS811-50						X		10
PS811-50							X	11
PS811-100	6	OMPA1	X	X				7
PS811-100						X		10
PS811-100							X	11
PS811-160	1	OMPA1	X	X				8
PS811-160						X		10
PS811-160							X	11
PS811-200	5	OMPA1	X	X				9
PS811-200						X		10
PS811-200							X	11
PS812-50	1	OMPA2	X	X	X			12
PS812-50							X	16
PS812-100	2	OMPA2	X	X	X			13
PS812-100						X		15
PS812-100							X	16
PS812-200	6	OMPA2	X	X	X			14
PS812-200							X	16
PS813-50	1	OMPA3	X	X	X			17
PS813-50						X		21
PS813-50							X	22
PS813-100	2	OMPA3	X	X	X			18
PS813-100							X	22
PS813-160	3	OMPA3	X	X	X			19
PS813-160						X		21
PS813-160							X	22
PS813-200	4	OMPA3	X	X	X			20
PS813-200						X		21
PS813-200							X	22
PS814-20	3&7	OMPA4	X	X	X			23
PS814-20						X		27
PS814-20							X	28
PS814-100	5	OMPA4	X	X	X			24
PS814-100						X		27
PS814-100							X	28
PS814-160	2	OMPA4	X	X	X			25
PS814-160						X		27
PS814-160							X	28
PS814-200	1	OMPA4	X	X	X			26
PS814-200						X		27
PS814-200							X	28
PS815-20	1&2	OMPA5	X	X	X			29
PS815-20							X	34
PS815-50	3	OMPA5	X	X	X			30
PS815-50							X	34
PS815-100	4	OMPA5	X	X	X			31
PS815-100							X	34
PS815-160	5	OMPA5	X	X	X			32
PS815-160							X	34
PS815-200	7	OMPA5	X	X	X			33
PS815-200							X	34

3.2 1982 Sampling Year

The 1982 sampling program consisted of 5 moorings deployed between 8 February 1982 and 25 April 1982 (Table 6). In the Admiralty Inlet area, a mooring off Foulweather Bluff (PS821) held two sediment traps (50 and 100 m) while PS825 off Point No Point contained 4 sediment traps (19, 50, 90 and 175 m). A mooring at the central main basin location held two traps (175 and 195 m). In the northern end of East Passage, four sediment traps (20, 90, 147 and 177 m) were deployed on mooring PS8213. In Poverty Bay, mooring PS8214 held four sediment traps at approximately the same depth.

The trace organic data (Table 7) is presented and discussed in Bates *et al.* (1987) and Murphy *et al.* (1988).

Table 6. Sediment Trap Location and Sampling Data for 1982

0 Trap Name	1 S/N	2 Mooring	3 Lat. N	4 Long. W	5 Water Depth	6 Sample Depth	7 Start: Date/	8 Duration Cylinder	9 Stop: Date/	10 Comments
PS821-50	4	PS821	47 57.0	122 34.2	108	50	8 FEB 82 17:00	168	25 APR 82 15:00	
PS821-100	2	PS821	45 57.0	122 34.2	108	100	8 FEB 82 17:00	168	25 APR 82 15:00	
PS825-50	4	PS825	47 54.0	122 28.2	200	50	8 FEB 82 13:00	168	25 APR 82 15:00	
PS825-19	13	PS825	47 54.0	122 28.2	200	19	8 FEB 82 13:00	168	25 APR 82 15:00	
PS825-90	6	PS825	47 54.0	122 28.2	200	90	8 FEB 82 13:00	168	25 APR 82 15:00	
PS825-175	12	PS825	47 54.0	122 28.2	200	175	8 FEB 82 13:00	168	25 APR 82 15:00	
PS825-195	7	PS825	47 54.0	122 28.2	200	195	8 FEB 82 13:00	168	25 APR 82 15:00	
PS8210-175	9	PS8210	47 41.4	122 27.0	203	175	9 FEB 82 15:00	168	25 APR 82 15:00	
PS8210-195	11	PS8210	47 41.4	122 27.0	203	195	9 FEB 82 15:00	168	25 APR 82 15:00	
PS8213-20	8	PS8213	47 29.4	122 24.0	184	20	25 FEB 82 14:00	137	25 APR 82 02:00	
PS8213-90	19	PS8213	47 29.4	122 24.0	184	90	25 FEB 82 14:00	137	25 APR 82 02:00	1 of Triple
PS8213-147	10	PS8213	47 29.4	122 24.0	184	147	25 FEB 82 14:00	137	25 APR 82 02:00	
PS8213-177	15	PS8213	47 29.4	122 24.0	184	177	25 FEB 82 14:00	137	25 APR 82 02:00	
PS8214-20	16	PS8214	47 21.6	122 24.0	175	20	24 FEB 82 14:00	137	25 APR 82 02:00	
PS8214-90	17	PS8214	47 21.6	122 24.0	175	90	24 FEB 82 14:00	137	25 APR 82 02:00	
PS8214-149	18	PS8214	47 21.6	122 24.0	175	149	24 FEB 82 14:00	137	25 APR 82 02:00	
PS8214-177	20	PS8214	47 21.6	122 24.0	180	177	24 FEB 82 14:00	137	25 APR 82 02:00	

Table 7. Availability of Sediment Trap Data for 1982

0 Trap Name	1 S/N	2 Mooring	3 Pig-ments	4 Carbon	5 Size Frac.	6 TM	7 Org.	8 Page
PS821-50	4	PS821	X					35
PS821-50						X		51
PS821-100	2	PS821	X					36
PS821-100						X		51
PS825-50	4	PS825					X	54
PS825-100							X	54
PS825-19	13	PS825	X					37
PS825-19						X		51
PS825-19							X	54
PS825-90	6	PS825	X					38
PS825-90						X		51
PS825-90							X	54
PS825-175	12	PS825	X					39
PS825-175						X		51
PS825-175							X	54
PS825-195	7	PS825	X					40
PS825-195						X		51
PS825-195							X	54
PS8210-175	9	PS8210	X					41
PS8210-175						X		51
PS8210-195	11	PS8210	X					42
PS8210-195						X		51
PS8213-20	8	PS8213	X		X			43
PS8213-20						X		51
PS8213-20							X	54
PS8213-90	19	PS8213	X		X			44
PS8213-90							X	54
PS8213-147	10	PS8213	X					45
PS8213-147						X		51
PS8213-147							X	54
PS8213-177	15	PS8213	X		X			46
PS8213-177						X		51
PS8213-177							X	54
PS8214-20	16	PS8214	X					47
PS8214-20						X		51
PS8214-20							X	54
PS8214-90	17	PS8214	X					48
PS8214-90						X		51
PS8214-90							X	54
PS8214-149	18	PS8214	X					49
PS8214-149						X		51
PS8214-149							X	54
PS8214-177	20	PS8214	X					50
PS8214-177						X		51
PS8214-177							X	54

3.3 1983 Sampling Year

The 1983 sampling program consisted of two sets of sediment trap deployments (Table 8). A short term experiment (18 March 1983 to 24 April 1983) emphasized sediment transport in East Passage. An across-axis transect consisting of 4 moorings (PS833–PS836) stretched across East Passage east of Three Tree Point. Each mooring held a sediment trap at 50 and 100 m while the center mooring (PS835) also contained sediment traps at 30, 148 and 214 m. Sediment traps on moorings in Poverty Bay (PS838; 50, 100 and 188 m), off Brown's Point (PS8310; 50, 100 and 177 m) and Colvos Passage (PS8312; 88 m) also were part of the short term experiment. A single mooring (PS8324) with a cylinder duration of one day was deployed in Poverty Bay with double sediment traps deployed at 30, 90 and 155.

Between 13 April 1983 and 29 August 1983, sediment trap were deployed at 30 and 100 m off Point No Point (PS8329), in central main basin (PS83-26) and off Three Tree (PS83–27). A second set of sediment traps at 30 and 100 m at the same locations were deployed between 29 August 1983 and 7 December 1983 (PS8333, PS8330 and PS8331, respectively).

Mn concentrations on settling particles at the central main basin location (Table 9) are discussed in Cudaback *et al.* (1991). Trace organic data for the 1983 sediment trap program is presented and discussed in Bates *et al.* (1987) and Murphy *et al.* (1988)

Table 8. Sediment Trap Location and Sampling Data for 1983

0 Trap Name	1 S/N	2 Mooring	3 Lat. N	4 Long. W	5 Water Depth	6 Sample Depth	7 Start: Date/	8 Duration Cylinder	9 Stop: Date/	10 Comments
PS833-50	26	PS833	47 26.9	122 25.5	177	50	18 MAR 83 00:00	91	24 APR 83 22:00	1 of Double
PS833-50B		PS833	47 26.9	122 25.5	177	50	18 MAR 83 00:00	91	24 APR 83 22:00	2 of Double
PS833-100	27	PS833	47 26.9	122 25.5	177	100	18 MAR 83 00:00	91	24 APR 83 22:00	
PS834-50	28	PS834	47 26.8	122 24.9	183	50	18 MAR 83 00:00	91	24 APR 83 22:00	
PS834-100	29	PS834	47 26.8	122 24.9	183	100	18 MAR 83 00:00	91	24 APR 83 22:00	
PS835-31	14	PS835	47 27.0	122 24.3	221	31	18 MAR 83 00:00	91	24 APR 83 22:00	
PS835-50	15	PS835	47 27.0	122 24.3	221	50	18 MAR 83 00:00	91	24 APR 83 22:00	1 of Triple
PS835-50B	16	PS835	47 27.0	122 24.3	221	50	18 MAR 83 00:00	91	24 APR 83 22:00	2 of Triple
PS835-50C	17	PS835	47 27.0	122 24.3	221	50	18 MAR 83 00:00	91	24 APR 83 22:00	3 of Triple
PS835-100	18	PS835	47 27.0	122 24.3	221	100	18 MAR 83 00:00	91	24 APR 83 22:00	
PS835-148	20	PS835	47 27.0	122 24.3	221	148	18 MAR 83 00:00	91	24 APR 83 22:00	
PS835-214	23	PS835	47 27.0	122 24.3	221	214	18 MAR 83 00:00	91	24 APR 83 22:00	
PS836-50	24	PS836	47 27.0	122 23.7	201	50	18 MAR 83 00:00	91	24 APR 83 22:00	
PS836-100	25	PS836	47 27.0	122 23.7	201	100	18 MAR 83 00:00	91	24 APR 83 22:00	
PS838-50	2	PS838	47 21.7	122 22.0	172	50	18 MAR 83 00:00	91	24 APR 83 22:00	
PS838-100	6	PS838	47 21.7	122 22.0	172	100	18 MAR 83 00:00	91	24 APR 83 22:00	
PS838-166	7	PS838	47 21.7	122 22.0	172	166	18 MAR 83 00:00	91	24 APR 83 22:00	
PS8310-50	11	PS8310	47 19.7	122 26.5	174	50	18 MAR 83 00:00	91	24 APR 83 22:00	
PS8310-100	12	PS8310	47 19.7	122 26.5	174	100	18 MAR 83 00:00	91	24 APR 83 22:00	
PS8310-170	13	PS8310	47 19.7	122 26.5	174	170	18 MAR 83 00:00	91	24 APR 83 22:00	
PS8312-88	30	PS8312	47 25.8	122 31.2	174	88	18 MAR 83 00:00	91	24 ARP 83 22:00	
PS8324-30	31	PS8324	47 21.6	122 22.0	173	35	13 APR 83 00:00	24	29 APR 83 00:00	1 of Double
PS8324-30B	32	PS8324	47 21.6	122 22.0	173	35	13 APR 82 00:00	24	29 APR 83 00:00	2 of Double
PS8324-90	33	PS8324	47 21.6	122 22.0	173	95	13 APR 83 00:00	24	29 APR 83 00:00	1 of Double
PS8324-90B	34	PS8324	47 21.6	122 22.0	173	95	13 APR 83 00:00	24	29 APR 83 00:00	2 of Double
PS8324-155	35	PS8324	47 21.6	122 22.0	173	153	13 APR 83 00:00	24	29 APR 83 00:00	1 of Double
PS8324-155B	36	PS8324	47 21.6	122 22.0	173	153	13 APR 83 00:00	24	29 APR 83 00:00	2 of Double
PS8326-30	17	PS8326	47 41.6	122 27.3	202	30	26 APR 83 10:00	288	29 AUG 83 00:00	
PS8326-100	15	PS8326	47 41.6	122 27.3	202	100	26 APR 83 10:00	288	29 AUG 83 00:00	
PS8327-30	14	PS8327	47 26.9	122 24.3	222	30	25 APR 83 13:30	288	29 AUG 83 00:00	
PS8327-100	18	PS8327	47 26.9	122 24.3	222	100	25 APR 83 13:30	288	29 AUG 83 00:00	
PS8329-30	16	PS8329	47 53.4	122 28.8	198	30	26 APR 83 10:00	288	29 AUG 83 00:00	
PS8329-100	20	PS8329	47 53.4	122 28.8	198	100	26 APR 83 10:00	288	29 AUG 83 00:00	
PS8330-30	2	PS8330	47 41.9	122 27.4	200	30	29 AUG 83 10:00	228	7 DEC 83 00:00	
PS8330-100	6	PS8330	47 41.9	122 27.4	200	100	29 AUG 83 10:00	228	7 DEC 83 00:00	
PS8331-30	7	PS8331	47 26.9	122 22.4	223	30	29 AUG 83 10:00	228	7 DEC 83 00:00	
PS8331-100	11	PS8331	47 26.9	122 22.4	223	100	29 AUG 83 10:00	228	7 DEC 83 00:00	
PS8333-30	13	PS8333	47 53.8	122 28.9	198	30	29 AUG 83 10:00	228	7 DEC 83 00:00	
PS8333-100	23	PS8333	47 53.8	122 28.9	198	100	29 AUG 83 10:00	228	7 DEC 83 00:00	

Table 9. Availability of Sediment Trap Data for 1983

0 Trap Name	1 S/N	2 Mooring	3 Pig-ments	4 Carbon	5 Size Frac.	6 TM	7 Org.	8 Page
PS833-50	26	PS833	X					56
PS833-50B		PS833	X					57
PS833-100	27	PS833	X					58
PS834-50	28	PS834	X					59
PS834-100	29	PS834	X					60
PS835-31	14	PS835	X		X			61
PS835-31						X		95
PS835-50	15	PS835	X					62
PS835-50						X		95
PS835-50B	16	PS835	X					63
PS835-50C	17	PS835	X					64
PS835-100	18	PS835	X		X			65
PS835-100						X		95
PS835-148	20	PS835	X					66
PS835-148						X		95
PS835-214	23	PS835	X					67
PS835-214						X		95
PS836-50	24	PS836	X					68
PS836-100	25	PS836	X					69
PS838-50	2	PS838	X					70
PS838-50						X		95
PS838-100	6	PS838	X					71
PS838-100						X		96
PS838-166	7	PS838	X					72
PS838-166						X		95
PS8310-50	11	PS8310	X					73
PS8310-50						X		95
PS8310-100	12	PS8310	X					74
PS8310-100						X		95
PS8310-170	13	PS8310	X					75
PS8310-170						X		95
PS8312-88	30	PS8312	X					76
PS8312-88						X		95
PS8324-30	31	PS8324	X					77
PS8324-30B	32	PS8324	X					78
PS8324-90	33	PS8324	X					79
PS8324-90B	34	PS8324	X					80
PS8334-155	35	PS8324	X					81
PS8324-155B	36	PS8324	X					82
PS8326-30	17	PS8326	X					83
PS8326-30							X	97
PS8326-100	15	PS8326	X					84
PS8326-100							X	97
PS8327-30	14	PS8327	X		X			85
PS8327-30							X	97
PS8327-100	18	PS8327	X		X			86
PS8327-100							X	97
PS8329-30	16	PS8329	X					87
PS8329-30							X	97
PS8329-100	20	PS8329	X					88
PS8329-100							X	97
PS8330-30	2	PS8330	X		X			89
PS8330-30							X	97
PS8330-100	6	PS8330	X		X			90
PS8330-100							X	97
PS8331-30	7	PS8331	X					91
PS8331-30							X	97
PS8331-100	11	PS8331	X					92
PS8331-100							X	97
PS8333-30	13	PS8333	X					93
PS8333-100	23	PS8333	X					94
PS8333-100							X	97

3.4 1984 Sampling Year

The sampling at 30 and 100 m at the locations off Point No Point (PS8402), in central main basin (PS8403) and off Three Tree Point (PS8405) that began in 1983 continued in 1984 between 1 December 1983 and 30 March 1984 (Table 10) and between 5 April 1984 and 23 July 1984 (PS8413, PS8414 and PS8415, respectively). During the 1 December 1983 to 30 March 1984 period, sediment traps were also deployed at 30, 160 and 195 m at the central main basin location (PS8403), at 32 and 88 m in the Strait of Juan de Fuca (PS8401), at 108 and 165 m in Whidbey Basin (PS8407) and at 30 and 100 m off Browns Point (PS8406).

The trace organics data (Table 11) is interpreted in Murphy *et al.* (1988).

Table 10. Sediment Trap Location and Sampling Data for 1984

0 Trap Name	1 S/N	2 Mooring	3 Lat. N	4 Long. W	5 Water Depth	6 Sample Depth	7 Start: Date/	8 Duration Cylinder	9 Stop: Date/	10 Comments
PS8401-32	15	PS8401	48 13.9	122 57.8	128	32	1 DEC 83 20:00	288	30 MAR 84 20:00	
PS8401-88	16	PS8401	48 13.9	122 57.8	128	88	1 DEC 83 20:00	288	30 MAR 84 30:00	
PS8402-30	17	PS8402	47 53.9	122 28.5	194	30	1 DEC 83 20:00	288	30 MAR 84 20:00	
PS8402-98	18	PS8402	47 53.9	122 28.5	194	98	1 DEC 83 20:00	288	30 MAR 84 20:00	
PS8403-32	33	PS8403	47 41.7	122 27.4	201	32	1 DEC 83 20:00	288	30 MAR 84 20:00	
PS8403-50	24	PS8403	47 41.7	122 27.4	201	50	1 DEC 83 20:00	288	30 MAR 84 20:00	
PS8403-98	25	PS8403	47 41.7	122 27.4	201	98	1 DEC 83 20:00	288	30 MAR 84 20:00	1 of Double
PS8403-98B	25	PS8403	47 41.7	122 27.4	201	98	1 DEC 83 20:00	288	30 MAR 84 20:00	2 of Double
PS8403-160	26	PS8403	47 41.7	122 27.4	201	160	1 DEC 83 20:00	288	30 MAR 84 20:00	
PS8403-195	27	PS8403	47 41.7	122 27.4	201	195	1 DEC 83 20:00	288	30 MAR 84 20:00	
PS8405-32	28	PS8405	47 27.0	122 24.3	221	32	1 DEC 83 20:00	288	30 MAR 84 20:00	
PS8405-98	29	PS8405	47 27.0	122 24.3	221	98	1 DEC 83 20:00	288	30 MAR 84 20:00	
PS8406-32	30	PS8406	47 19.9	122 26.5	172	32	1 DEC 83 20:00	288	30 MAR 84 20:00	
PS8406-98	31	PS8406	47 19.9	122 26.5	172	98	1 DEC 83 20:00	288	30 MAR 84 20:00	
PS8407-108	12	PS8407	47 55.3	122 20.5	221	108	1 DEC 83 20:00	288	30 MAR 84 20:00	
PS8407-165	34	PS8407	47 55.3	122 20.5	221	165	1 DEC 83 20:00	288	30 MAR 84 20:00	
PS8413-32	2	PS8413	47 53.8	122 28.8	194	32	5 APR 84 16:00	264	23 JUL 84 16:00	
PS8413-98	7	PS8413	47 53.8	122 28.8	194	98	5 APR 84 16:00	264	23 JUL 84 16:00	
PS8414-32	13	PS8414	47 41.7	122 27.4	200	32	5 APR 84 16:00	264	23 JUL 84 16:00	
PS8414-98	20	PS8414	47 41.7	122 27.4	200	98	5 APR 84 16:00	264	23 JUL 84 16:00	
PS8415-32	32	PS8415	47 27.0	122 24.3	221	32	5 APR 84 16:00	264	23 JUL 84 16:00	
PS8415-98	36	PS8415	47 27.0	122 24.3	221	98	5 APR 84 16:00	264	23 JUL 84 16:00	

Table 11. Availability of Sediment Trap Data for 1984

0 Trap Name	1 S/N	2 Mooring	3 Pig-ments	4 Carbon	5 Size Frac.	6 TM	7 Org.	8 Page
PS8401-32	15	PS8401	X					98
PS8401-32						X		120
PS8401-32							X	122
PS8401-88	16	PS8401	X					99
PS8401-88						X		120
PS8401-88							X	122
PS8402-30	17	PS8402	X					100
PS8402-30						X		120
PS8402-98	18	PS8402	X					101
PS8402-98						X		120
PS8403-32	33	PS8403	X					102
PS8403-50	24	PS8403	X					103
PS8403-50						X		120
PS8403-98	25	PS8403	X					104
PS8403-98						X		120
PS8403-98B	25	PS8403	X					105
PS8403-160	26	PS8403	X					106
PS8403-160						X		120
PS8403-195	27	PS8403	X					107
PS8403-195						X		120
PS8405-32	28	PS8405	X					108
PS8405-32						X		120
PS8405-98	29	PS8405	X					109
PS8405-98						X		120
PS8406-32	30	PS8406	X					110
PS8406-32						X		120
PS8406-98	31	PS8406	X					111
PS8406-98						X		120
PS8407-108	12	PS8407	X					112
PS8407-108						X		120
PS8407-108							X	122
PS8407-165	34	PS8407	X					113
PS8407-165						X		120
PS8407-165							X	122
PS8413-32	2	PS8413	X					114
PS8413-98	7	PS8413	X					115
PS8414-32	13	PS8414	X					116
PS8414-32							X	122
PS8414-98	20	PS8414	X					117
PS8414-98							X	122
PS8415-32	32	PS8415	X					118
PS8415-32							X	122
PS8415-98	36	PS8415	X					119

3.5 1985 Sampling Year

A single mooring (PS8509) was deployed in the central main Basin between 29 March 1985 and 22 June 1985 at depths of 30, 100 and 175 m (Table 12). A second sediment trap at 100 m (100s) had a cylinder duration time of 4 hours.

Sedimentation rates and Mn concentrations on settling particles (Table 13) are discussed in Cudaback *et al.* (1991).

Table 12. Sediment Trap Location and Sampling Data for 1985

0 Trap Name	1 S/N	2 Mooring	3 Lat. N	4 Long. W	5 Water Depth	6 Sample Depth	7 Start: Date/	8 Duration Cylinder	9 Stop: Date/	10 Comments
PS8509-30	25	PS8509	47 42.0	122 27.1	195	30	29 MAR 85 00:00	204	22 JUN 85 00:00	
PS8509-100	26	PS8509	47 42.0	122 27.1	195	100	29 Mar 85 00:00	204	22 JUN 85 00:00	
PS8509-177	27	PS8509	47 42.0	122 27.1	195	175	29 MAR 85 00:00	204	22 JUN 85 00:00	
PS9809-100S	11	PS8509	47 42.0	122 27.1	195	100	10 APR 85 09:00	4	12 APR 85 01:00	

Table 13. Availability of Sediment Trap Data for 1985

0 Trap Name	1 S/N	2 Mooring	3 Pig-ments	4 Carbon	5 Size Frac.	6 TM	7 Org.	8 Page
PS8509-30	25	PS8509						123
PS8509-30						X		127
PS8509-100	26	PS8509						124
PS8509-175	27	PS8509						125
PS8509-175						X		127
PS8509-100S	11	PS8509						126
PS8509-100S						X		127

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5.0 REFERENCES

Baker, E.T., and H.B. Milburn (1983): An instrument system for the investigation of particle fluxes. *Continental Shelf Research, 1*, 425–435.

Baker, E.T., R.A. Feely, M.R. Landry, and M.F. Lamb (1985): Temporal variations in the concentration and settling flux of carbon and phytoplankton pigments in a deep fjordlike estuary. *Estuarine, Coastal and Shelf Science, 21*, 859–877.

Barrick, R.C., J.I. Hedges, and M.L. Peterson (1980): Hydrocarbon geochemistry of the Puget Sound region-I. Acyclic sedimentary hydrocarbons. *Geochim. Cosmochim. Acta, 44*, 1349–1362.

Bates, T.S., S.E. Hamilton, and J.D. Cline (1984): Vertical transport and sedimentation of hydrocarbons in the central main basin of Puget Sound, Washington. *Environmental Science and Technology, 18*, 299–305.

Bates, T.S., P.P. Murphy, H.C. Curl, Jr., and R.A. Feely (1987): Hydrocarbon distributions and transport in an urban estuary. *Environmental Science and Technology, 21*(2), 193–198.

Bloom, N.S., and E.A. Crecelius (1987): Distribution of silver, mercury, lead, copper and cadmium in central Puget Sound sediments. *Mar. Chem., 21*, 377–390.

Chester, R., and M.J. Hughes (1967): A chemical treatment for the separation of ferro-manganese minerals, carbonate minerals and adsorbed trace elements from peleagic sediments. *Chem. Geol., 2*, 249–262.

Cudaback, C.N., A.J. Paulson, and J.W. Lavelle (1991): A modeling study of the vertical distribution and transport of manganese in Puget Sound. NOAA Technical Memorandum, ERL PMEL-93.

Dillon, W.P. (1964): Flotation technique for separating fecal pellets and small marine organisms from sand. *Limnol. Oceanogr., 9*, 601–602.

Eggimann, D.W., and P.R. Betzerm (1976): Decomposition and analysis of refractory oceanic suspended materials. *Anal. Chem., 48*, 849–890.

Feely, R.A., G.J. Massoth, and A.J. Paulson (1981): The distribution and elemental composition of suspended particulate matter in Norton Sound and the north-eastern Bering Sea Shelf: Implications for Mn and Zn recycling in the coastal waters. In *The Eastern Bering Sea Shelf, Oceanography and Resources*, Vol. 1 (Hood, D.W. and J.A. Calder, eds.). U.S. Dept. of Commerce, Washington, D.C., pp. 321–338.

Feely, R.A., G.J. Massoth, E.T. Baker, J.F. Gendron, A.J. Paulson, and E.A. Crecelius (1986): Seasonal and vertical variations in the elemental composition of suspended and settling particulate matter in Puget Sound, Washington. *Estuarine, Coastal and Shelf Science, 22*, 215–239.

Hamilton, S.E., T.S. Bates, and J.D. Cline (1984): Sources and transport of hydrocarbons in the Green-Duwamish River, Washington. *Environmental Science and Technology, 18*, 72–79.

Holm-Hansen, O., C.J. Lorenzen, R.W. Holmes, and J.D. Strickland (1965): Fluorometric determination of chlorophyll. *J. du Conseil, Conseil International pour l'Exploration de la Mer, 30*, 3–15.

Landing, W.M., and R.A. Feely (1981): The chemistry and vertical flux of particles in the northeastern Gulf of Alaska. *Deep-Sea Res., 28*, 19–37.

Lavelle, J.W., G.J. Massoth, and E.A. Crecelius (1985): Sedimentation rates in Puget Sound from ^{210}Pb measurements. NOAA Technical Memorandum ERL PMEL-61, 43 pp.

Lavelle, J.W., G.J. Massoth, and E.A. Crecelius (1986): Accumulation rates of recent sediments in Puget Sound, Washington. *Marine Geology, 72*, 59–70.

Murphy, P.P., T.S. Bates, H.C. Curl, Jr., R.A. Feely, and R.S. Burger (1988): The transport and fate of particulate hydrocarbons in an urban fjord-like estuary. *Estuarine, Coastal and Shelf Science, 27*, 461–482.

Nielson, K.K. (1977): Matrix corrections for energy dispersive X-ray fluorescence analysis of environmental samples with coherent/incoherent scattered X-rays. *Anal. Chem., 49*, 641–648.

Paulson, A.J., R.A. Feely, H.C. Curl, Jr., E.A. Crecelius, and T. Geiselman (1988a): The impact of scavenging on trace metal budgets in Puget Sound. *Geochimica et Cosmochimica Acta, 52*(7), 1765–1779.

Paulson, A.J., H.C. Curl, Jr., R.A. Feely, G.J. Massoth, K.A. Krogslund, T. Geiselman, M.F. Lamb, K. Kelly, E.A. Crecelius and J.F. Gendron (1991a): Trace metal and ancillary data in the watersheds and urban embayments of Puget Sound. NOAA Data Report ERL PMEL-30.

Paulson, A.J., H.C. Curl, Jr., R.A. Feely, T. Geiselman, K.A. Krogslund, G.J. Massoth, M.F. Lamb and K. Kelly (1991b): Trace metal and ancillary data in the open waters of Puget Sound: 1981–1985. NOAA Data Report ERL PMEL-31.

Paulson, A.J., H.C. Curl, Jr., R.A. Feely, K.A. Krogslund and S. Hanson (1991c): Trace metal and ancillary data in Puget Sound: August 1986. NOAA Data Report ERL PMEL-32.

Robbins, J.M., M. Lyle, and G.R. Heath (1984): A sequential extraction procedure for partitioning elements among co-existing phases in marine sediments. Ref. 84–3. College of Oceanography, Oregon State Univ., Corvallis, OR, 45 pp.

Romberg, G.P., S.P. Pavlou, R.F. Shokes, W. Hom, E.A. Crecelius, P. Hamilton, J.T. Gunn, R.D. Muench, and J. Vinelli (1984): Toxicant Pretreatment Planning Study Technical Report C1: Presence, Distribution and Fate of Toxicants in Puget Sound and Lake Washington. Municipality of Metropolitan Seattle (METRO), Seattle, WA, 231 pp.

Shuman, F.R., and C.J. Lorenzen (1975): Quantitative degradation of chlorophyll by a marine herbivore. *Limnol. Oceanogr., 20,* 580–586.

6.0 PUGET SOUND BIBLIOGRAPHY

Entries are by year starting in 1972.

1972

Cannon, G.A. (1972): Wind effects on currents observed in Juan de Fuca submarine canyon. *Journal of Physical Oceanography, 2*, 281–285.

Cannon, G.A., and N.P. Laird (1972): Observations of currents and water properties in Puget Sound, 1972. NOAA Technical Report, ERL 247-POL 14, 42 pp.

Cannon, G.A., N.P. Laird, and T.V. Ryan (1972): Currents observed in Juan de Fuca submarine canyon and vicinity, 1971. NOAA Technical Report, ERL 252-POL 14, 57 pp.

1973

Cannon, G.A. (1973): Observations of currents in Puget Sound, 1970. NOAA Technical Report, ERL 260-POL 17, 77 pp.

1975

Cannon, G.A. (1975): Observations of bottom-water flushing in a fjord-like estuary. *Estuarine and Coastal Marine Science, 3*, 95–102.

Laird, N.P., and J.A. Galt (1975): Observations of currents and water properties in Puget Sound, 1973. NOAA Technical Report, ERL 327-PMEL 23, 141 pp.

Schumacher, J.D., and R.M. Reynolds (1975): STD, current meter, and drogue observations in Rosario Strait, January–March 1974. NOAA Technical Report, ERL 333-PMEL 24, 212 pp.

Tracy, D.E. (1975): STD and current meter observations in the north San Juan Islands October 1973. NOAA Technical Memorandum, ERL PMEL-4, 77 pp.

1976

Charnell, R.L., and G.A. Krancus (1976): A processing system for Aanderaa current meter data. NOAA Technical Memorandum, ERL PMEL-6, 50 pp.

Pacific Marine Environmental Laboratory (1976): Physical Oceanography in Puget Sound Main Basin. Project Report: Fiscal Year 1976 and 1976T. NOAA Technical Memorandum, ERL MESA-18, 110 pp.

1977

Chester, A.J., D.M. Damkaer, D.B. Dey, and J.D. Larrance (1977): Seasonal distributions of plankton in the Strait of Juan de Fuca. NOAA Technical Memorandum, ERL MESA-24, 71 pp.

1978

Apel, J.R., and G.A. Cannon (1978): Recent studies in the Strait of Juan de Fuca. In: *Comments on vessel traffic management in Puget Sound waters and environmental factors entering therein*, U.S. Coast Guard hearings, Docket Number CGD 78-041, Seattle.

Baker, E.T., J.D. Cline, R.A. Feely, and J. Quan (1978): Seasonal distribution, trajectory studies, and sorption characteristics of suspended particulate matter in the northern Puget Sound region. DOC/EPA Interagency Energy/Environment R&D Program Report, EPA-600/7-78-126, 140 pp.

Cannon, G.A., and C.C. Ebbesmeyer (1978): Winter replacement of bottom water in Puget Sound. In: *Estuarine Transport Processes*, B. Kjerfve, ed., Univ. of South Carolina Press, Columbia, 229–238.

Cannon, G.A., ed., J.R. Holbrook, and R.A. Feely, ed. assts. (1978): Circulation in the Strait of Juan de Fuca: Some recent oceanographic observations. NOAA Technical Report, ERL-PMEL 29, 49 pp.

Cannon, G.A., and N.P. Laird (1978): Variability of currents and water properties from year-long observations in a fjord estuary. In: *Hydrodynamics of Estuaries and Fjords,* J.C.J. Nijoul, ed., Elsevier, Amsterdam, 515–535.

Chester, A.J. (1978): Microzooplankton in the surface waters of the Strait of Juan de Fuca. NOAA Technical Report, ERL 403-PMEL 30, 29 pp.

Schumacher, J.D., C.A. Pearson, R.L. Charnell, and N.P. Laird (1978): Regional response to forcing in southern Strait of Georgia. *Estuarine and Coastal Marine Science, 7*, 79–91.

Smyth, C.S. (1978): Report on FY 1977 numerical modeling in Puget Sound. NOAA Technical Memorandum, ERL MESA-30, 47 pp & 1 microfiche.

1979

Cannon, G.A., N.P. Laird, and T.L. Keefer (1979): Puget Sound circulation: Final Report for FY77–78. NOAA Technical Memorandum, ERL MESA-40, 55 pp.

Cline, J., L. Codispoti, H. Curl, C. Ebbesmeyer, H.S. Harris, S.P. Pavlou, M. Rattray, W. Schell, M. Waldichuk, and D.W.S. Westlake (1979): Puget Sound. In: *Assimilative Capacity of U.S. Coastal Waters for Pollutants*, E.D. Goldberg, ed. Working Paper No. 1: Federal

Plan for Ocean Pollution Research Development and Monitoring, FY 1981–1985. NOAA Environmental Research Laboratories, Boulder, 243–280.

Feely, R.A., and H.C. Curl, Jr., eds. (1979): Trace metal and marine production processes. NOAA Special Report, Environmental Research Laboratories, Boulder, 22 pp.

Feely, R.A., and M.F. Lamb (1979): A study of the dispersal of suspended sediments from the Fraser and Skagit Rivers into Northern Puget Sound using LANDSAT imagery. DOC/EPA Interagency Energy/Environment R&D Program Report, EPA-600/7-79-165, 46 pp.

Krancus, G.A., C.A. Pearson, and R.L. Charnell (1979): A one-pass processing system for Aanderaa current meter data. In: *Proceedings, Second Working Conference on Oceanography Data Systems 1978*, C.D. Tollios, ed., Woods Hole Oceanographic Institution, 96–111.

Overland, J.E., M.H. Hitchman, and Y.J. Han (1979): A regional wind model for mountainous coastal areas. NOAA Technical Report, ERL 407-PMEL 32, 34 pp.

Pashinski, D.J., and R.L. Charnell (1979): Recovery record for surface drift cards released in the Puget Sound-Strait of Juan de Fuca system during calendar years 1976–1977. NOAA Technical Memorandum, ERL PMEL-14, 30 pp.

Pearson, C.A., G.A. Krancus, and R.L. Charnell (1979): R2D2: An interactive graphics program for rapid retrieval and display of oceanographic data. In: *Proceedings, Second Working Conference on Oceanographic Data Systems 1978*, C.D. Tollios, ed., Woods Hole Oceanographic Institution, 318–329.

Pease, C.H., R.J. Stewart, and J.E. Overland (1979): Report on FY-78 numerical modeling in the Strait of Juan de Fuca and Puget Sound. NOAA Technical Memorandum, ERL MESA-38, 32 pp.

1980

Cannon, G.A., and N.P. Laird (1980): Characteristics of flow over a sill during deep-water renewal. In: *Fjord Oceanography*, H.J. Freeland, D.M. Farmer, and C.D. Levings, eds., Plenum Press, New York, 549–556.

Chester, A.J., D.M. Damkaer, D.B. Dey, G.A. Heron, and J.D. Larrance (1980): Plankton of the Strait of Juan de Fuca, 1976–1977. DOC/EPA Interagency Energy/Environment R&D Program Report, EPA-600/7-80-032, 64 pp & 4 microfiche.

Curl, H.C., Jr., J. Cline, R.A. Feely, and E.T. Baker (1980): Annual Report for FY80, Long-Range Effects Research Program: Coastal and Estuarine Pollutant Transport. Pacific Marine Environmental Laboratory, Seattle, Washington.

Frisch, A.S., and J.R. Holbrook (1980): HF radar measurements of circulation in the eastern Strait of Juan de Fuca (August 1978). DOC/EPA Interagency Energy/Environment R&D Report, EPA-600/7-80-096, 267 pp.

Helseth, J.M., L.R. Hinchey, R.M. Reynolds, J.M. Cox, C.C. Ebbesmeyer, D.M. Browning (1980): Observations from the Washington State ferry Walla-Walla of near surface temperature and salinity across Puget Sound's main basin. NOAA Technical Memorandum, ERL MESA-50, 40 pp & 3 microfiche.

Holbrook, J.R., R.D. Muench, and G.A. Cannon (1980): Seasonal observations of low-frequency atmospheric forcing in the Strait of Juan de Fuca. In: *Fjord Oceanography*, H.J. Freeland, D.M. Farmer, and C.D. Levings, eds., Plenum Press, New York, 319–328.

Holbrook, J.R., R.D. Muench, D.G. Kachel, and C. Wright (1980): Circulation in the Strait of Juan de Fuca: Recent oceanographic observations in the eastern basin. NOAA Technical Report, ERL 412-PMEL 33, 33 pp.

Muench, R.D., and J.R. Holbrook (1980): Vertical structure of fluctuating currents in the Strait of Juan de Fuca. In: *Fjord Oceanography*, H.J. Freeland, D.M. Farmer, and C.D. Levings, eds., Plenum Press, New York, 329–332.

Pease, C.H. (1980): An empirical model for tidal currents in Puget Sound, Strait of Juan de Fuca, and southern Strait of Georgia. DOC/EPA Interagency Energy/Environment R&D Program Report, EPA-600/7-80-185, 33 pp.

Stewart, R.J., and C.H. Pease (1980): A comparison of the MESA-Puget Sound oil spill model with wind and current observations from August 1978. DOC/EPA Interagency Energy/Environment R&D Program Report, EPA-600/7-80-168, 54 pp.

1981

Cannon, G.A., and J.R. Holbrook (1981): Wind-induced seasonal interactions between coastal and fjord circulation. In: *The Norwegian Coastal Current*, R. Saetre and M. Mork, eds., Univ. of Bergen, Norway, 131–152.

Cox, J.M., C.C. Ebbesmeyer, C.A. Coomes, L.R. Hinchey, J.M. Helseth, G.A. Cannon, and C.A. Barnes (1981): Index to observations of currents in Puget Sound, Washington, from 1908–1980. NOAA Technical Memorandum, OMPA-5, 51 pp.

Curl, H.C., Jr., E.T. Baker, J.D. Cline, and R.A. Feely (1981): Estuarine and coastal pollutant transport and transformation: The role of particulates. NOAA/OMPA Section 202 Research Program, FY81 Annual Report, Pacific Marine Environmental Laboratory, 104 pp.

Ebbesmeyer, C.C., G.A. Cannon, and J.M. Cox (1981): Reply on Sound sewage. *Seattle Times*, July 8, p. A1.

Frisch, A.S., J.R. Holbrook, and A.B. Ages (1981): Observations of a summer-time reversal in circulation in the Strait of Juan de Fuca. *Journal of Geophysical Research, 86*, 2044–2048.

Hamilton, S.E., and J.D. Cline (1981): Hydrocarbons associated with suspended matter in Green River, WA. NOAA Technical Memorandum, ERL PMEL-30, 116 pp.

Holbrook, J.R., and A.S. Frisch (1981): A comparison of near-surface CODAR and VACM measurements in the Strait of Juan de Fuca, August 1978. *Journal of Geophysical Research, 86*, 10908–10920.

Overland, J.R., and B.A. Walter, Jr. (1981): Gap winds in the Strait of Juan de Fuca. *Monthly Weather Review, 109*, 2221–2233.

Pearson, C.A. (1981): Guide to R2D2—Rapid Retrieval Data Display. NOAA Technical Memorandum, ERL PMEL-29, 148 pp & Nov. 81 addendum.

Sillcox, R.L., W.R. Geyer, and G.A. Cannon (1981): Physical transport processes and circulation in Elliott Bay. NOAA Technical Memorandum, OMPA-8, 45 pp.

1982

Baker, E.T. (1982): Suspended particulate matter in Elliott Bay. NOAA Technical Report, ERL 417-PMEL 35, 44 pp.

Baker, E.T., and S.L. Walker (1982): Suspended particulate matter in Commencement Bay. NOAA Technical Memorandum, OMPA-26, 47 pp.

Cannon, G.A., and M.W. Grigsby (1982): Observations of currents and water properties in Commencement Bay. NOAA Technical Memorandum, OMPA-22, 35 pp.

Curl, H.C., Jr., ed. (1982): Estuarine and coastal pollutant transport and transformation: The role of particulates. NOAA/OMPA Section 202 Research Program, FY80–82 Final Report, Pacific Marine Environmental Laboratory, 228 pp.

Geyer, W.R., and G.A. Cannon (1982): Sill processes related to deep-water renewal in a fjord. *Journal of Geophysical Research, 87*, 7985–7996.

Holbrook, J.R., and D. Halpern (1982): Winter-time near-surface currents in the Strait of Juan de Fuca. *Atmosphere-Ocean, 20*, 327–339.

Massoth, G.J., R.A. Feely, and M.F. Lamb (1982): Trace element composition of suspended particulate matter in the lower Duwamish River and Elliott Bay, Washington. NOAA Technical Memorandum, OMPA-17, 41 pp.

Walter, B.E., Jr., and J.E. Overland (1982): Response of stratified flow in the lee of the Olympic Mountains. *Monthly Weather Review, 110*, 1458–1473.

1983

Bates, T.S., S.E. Hamilton, and J.D. Cline (1983): Collection of suspended particulate matter for hydrocarbon analyses: continuous flow centrifugation vs. filtration. *Estuarine, Coastal and Shelf Science, 16*, 107–112.

Baker, E.T., G.A. Cannon, and H.C. Curl, Jr. (1983): Particle transport processes in a small marine bay. *Journal of Geophysical Research, 88*, 9661–9669.

Baker, E.T., and H.B. Milburn (1983): An instrument system for the investigation of particle fluxes. *Continental Shelf Research, 1*, 425–435.

Cannon, G.A. (1983): An overview of circulation in the Puget Sound estuarine system. NOAA Technical Memorandum, ERL PMEL-48, 30 pp.

Cannon, G.A., and G.S.E. Lagerloef (1983): Topographic influences on coastal circulation (a review). In: *Coastal Oceanography*, H. Gade, A. Edwards, and H. Svendsen, eds., Plenum Press, New York, 235–252.

Feely, R.A., G.J. Massoth, and M.F. Lamb (1983a): The effect of sewage effluents on the flocculation of major and trace elements in a stratified estuary. In: *Trace Metals in Sea Water*, C.S. Wong, E.A. Boyle, K.W. Bruland, J.D. Burton and E.D. Goldberg, eds., Plenum Press, New York, 227–244.

Feely, R.A., G.J. Massoth, A.J. Paulson and J.F. Gendron (1983b): Possible evidence for enrichment of trace elements in the hydrous manganese oxide phases of suspended matter from an urbanized embayment. *Estuarine, Coastal and Shelf Science, 17*, 693–708.

Holbrook, J.R., G.A. Cannon, and D.G. Kachel (1983): Two-year observations of coastal-fjord interactions in the Strait of Juan de Fuca. In: *Coastal Oceanography*, H. Gade, A. Edwards, and H. Svendsen, eds., Plenum Press, New York, 411–426.

Lavelle, J.W., and H.O. Mofjeld (1983): Effects of time-varying viscosity on oscillatory turbulent channel flow. *Journal of Geophysical Research, 88*, 7607–7616.

Overland, J.E., and B.A. Walter, Jr. (1983): Marine weather of the inland waters of western Washington. NOAA Technical Memorandum, ERL PMEL-44, 62 pp.

Reed, R.K. (1983): Oceanic warming off the U.S. west coast following the 1982 El Niño. *Tropical Ocean-Atmosphere Newsletter, No. 22*, 10–12.

Schoenberg, S.A. (1983): Regional wind patterns of the inland waters of western Washington and southern British Columbia. NOAA Technical Memorandum, ERL PMEL-43, 61 pp.

Young, A.W., and J.D. Cline (1983): Super-speed centrifugation at sea using a gimballed platform. *Estuarine, Coastal and Shelf Science, 16*, 145–150.

1984

Baker, E.T. (1984): Patterns of suspended particle distribution and transport in a large fjord-like estuary. *Journal of Geophysical Research, 89*, 6553–6566.

Baker, E.T., and J.W. Lavelle (1984): The effect of particle size on the light attenuation coefficient of natural suspensions. *Journal of Geophysical Research, 89*, 8197–8203.

Bates, T.S., S.E. Hamilton, and J.D. Cline (1984): Vertical transport and sedimentation of hydrocarbons in the central main basin of Puget Sound, Washington. *Environmental Science and Technology, 18*, 299–305.

Cannon, G.A., D.E. Bretschneider, and J.R. Holbrook (1984): Transport variability in a fjord. In: *The Estuary as a Filter*, V.S. Kennedy, ed., Academic Press, New York, 67–78.

Coomes, C.A., C.C. Ebbesmeyer, J.M. Cox, J.M. Helseth, L.R. Hinchey, G.A. Cannon, and C.A. Barnes (1984): Synthesis of current measurements in Puget Sound, Washington—Volume 2: Indices of mass and energy inputs into Puget Sound: Runoff, air temperature, wind, and sea level. NOAA Technical Memorandum, NOS OMS-4, 45 pp & 2 microfiche.

Cox, J.M., C.C. Ebbesmeyer, C.A. Coomes, J.M. Helseth, L.R. Hinchey, G.A. Cannon, and C.A. Barnes (1984): Synthesis of current measurements in Puget Sound, Washington—Volume 1: Index to current measurements in Puget Sound from 1908–1980, with daily and record averages for selected measurements. NOAA Technical Memorandum, NOS OMS-3, 38 pp & 4 microfiche.

Ebbesmeyer, C.C., C.A. Coomes, J.M. Cox, J.M. Helseth, L.R. Hinchey, G.A. Cannon, and C.A. Barnes (1984): Synthesis of current measurements in Puget Sound, Washington—Volume 3: Circulation in Puget Sound: An interpretation based on historic records of currents. NOAA Technical Memorandum, NOS OMS-5, 73 pp & 1 microfiche.

Hamilton, S.E., T.S. Bates, and J.D. Cline (1984): Sources and transport of hydrocarbons in the Green-Duwamish River, Washington. *Environmental Science and Technology, 18*, 72–79.

Lavelle, J.W., H.O. Mofjeld, and E.T. Baker (1984): An *in situ* erosion rate for a fine-grained marine sediment. *Journal of Geophysical Research, 89*, 6543–6552.

Mofjeld, H.O., and L.H. Larsen (1984): Tides and tidal currents of the inland waters of western Washington. NOAA Technical Memorandum, ERL PMEL-56, 52 pp.

Mofjeld, H.O., and J.W. Lavelle (1984): Setting the length scale in a second-order closure model of the unstratified bottom boundary layer. *Journal of Physical Oceanography, 14*, 833–839.

Ozturgut, E.O., and J.W. Lavelle (1984): A new method of wet density and settling velocity determination for waste water effluent. *Environmental Science and Technology, 18*, 947–952.

Paulson, A.J., R.A. Feely, H.C. Curl, Jr., and J.F. Gendron (1984): Behavior of Fe, Mn, Cu and Cd in the Duwamish River estuary downstream of a sewage treatment plant. *Water Research, 18*, 633–641.

* Romberg, G.P., S.P. Pavlou, R.F. Shokes, W. Hom, E.A. Crecelius, P. Hamilton, J.T. Gunn, R.D. Muench, and J. Vinelli (1984): Toxicant Pretreatment Planning Study Technical Report C1: Presence, Distribution and Fate of Toxicants in Puget Sound and Lake Washington. Municipality of Metropolitan Seattle (METRO), Seattle, WA, 231 pp.

---

* Associated with a PMEL sampling program.

1985

Baker, E.T., R.A. Feely, M.R. Landry, and M.F. Lamb (1985): Temporal variations in the concentration and settling flux of carbon and phytoplankton pigments in a deep fjordlike estuary. *Estuarine, Coastal and Shelf Science, 21*, 859–877.

Bretschneider, D.E., G.A. Cannon, J.R. Holbrook, and D.J. Pashinski (1985): Variability of subtidal current structure in a fjord estuary: Puget Sound, Washington. *Journal of Geophysical Research, 90*, 11949–11958.

Cannon, G.A., R.K. Reed, and P.E. Pullen (1985): Comparison of El Niño events off the Pacific Northwest. In: *El Niño North: Niño Events in the Eastern Subarctic Pacific Ocean*, W.S. Wooster and D.L. Fluharty, eds., Washington Sea Grant, Seattle, 75–84.

Cokelet, E.D., and R.J. Stewart (1985): The exchange of water in fjords: The efflux/reflux theory of advective reaches separated by mixing zones. *Journal of Geophysical Research, 90*, 7287–7306.

Cokelet, E.D., R.J. Stewart, and C.C. Ebbesmeyer (1985): The exchange of water in fjords: a simple model of two-layer advective reaches separated by mixing zones. *Proceedings 19th International Coastal Engineering Conference, 3–7 Sept. 1984, Houston, TX*, 3124–3133.

* Crecelius, E.A., R.G. Riley, N.S. Bloom, and B.L. Thomas (1985): History of contamination of sediments in Commencement Bay, Tacoma, Washington. NOAA Tech. Memo. NOS OMA-14, Rockville, MD, 44 pp.

Hamilton, P., J.T. Gunn, and G.A. Cannon (1985): A box model of Puget Sound. *Estuarine, Coastal and Shelf Science, 20*, 673–692.

Lavelle, J.W., G.J. Massoth, and E.A. Crecelius (1985): Sedimentation rates in Puget Sound from ^{210}Pb measurements. NOAA Technical Memorandum ERL PMEL-61, 43 pp.

Pashinski, D.J. (1985): Comparison of current meters in a tidally dominated flow. Oceans '85, Ocean Engineering and the Environment: Conference Record, November 12–14, 1985, Marine Technology Society, IEEE Ocean Engineering Society, San Diego, CA, 738–741.

Paulson, A.J., and R.A. Feely (1985): Dissolved trace metals in the surface waters of Puget Sound. *Marine Pollution Bulletin, 16*, 285–291.

1986

Cannon, G.A., and D.E. Bretschneider (1986): Interchanges between coastal and fjord circulation. In: *Contaminant Fluxes through the Coastal Zone*, G. Kullenberg, ed., Rapp. P.-v. Reun. Cons. int. Explor. Mer, *186*, 38–48.

---

* Associated with a PMEL sampling program.

Curl, H.C., Jr., E.T. Baker, T.S. Bates, G.A. Cannon, R.A. Feely, T.L. Geiselman, P.P. Murphy, D.J. Pashinski, A.J. Paulson, M.F. Roberts, and D.A. Tennant (1986): Contaminant transport from Elliott and Commencement Bays—Final Report, August 1987. PMEL report to EPA, 269 pp.

Ebbesmeyer, C.C., C.A. Coomes, J.M. Cox, E.T. Baker, C.S. Smyth, and C.A. Barnes (1986): Dynamics of Commencement Bay and approaches. NOAA Technical Memorandum NOS OMA 24, 79 pp.

Feely, R.A., G.J. Massoth, E.T. Baker, J.F. Gendron, A.J. Paulson, and E.A. Crecelius (1986): Seasonal and vertical variations in the elemental composition of suspended and settling particulate matter in Puget Sound, Washington. *Estuarine, Coastal and Shelf Science, 22*, 215–239.

Lavelle, J.W., G.J. Massoth, and E.A. Crecelius (1986): Accumulation rates of recent sediments in Puget Sound, Washington. *Marine Geology, 72*, 59–70.

Ozturgut, E., and J.W. Lavelle (1986): Settling analysis of fine sediment in salt water at concentrations low enough to preclude flocculation. *Marine Geol., 69*, 353–362.

Paulson, A.J. (1986): The effects of flow rate and pre-treatment on the extraction of trace metals from estuarine and coastal seawater by Chelex-100. *Analytical Chemistry, 58*, 183–187.

1987

Bates, T.S., P.P. Murphy, H.C. Curl, Jr., and R.A. Feely (1987): Hydrocarbon distributions and transport in an urban estuary. *Environmental Science and Technology, 21*(2), 193–198.

* Bloom, N.S., and E.A. Crecelius. 1987. Distribution of silica, mercury, lead, copper and cadmium in central Puget Sound sediments. *Marine Chem., 21*, 377–390.

Lavelle, J.W., and W.R. Davis (1987): Measurements of benthic sediment erodibility in Puget Sound, Washington. NOAA Tech. Memo. ERL PMEL-72, 32 pp.

Lavelle, J.W., and H.O. Mofjeld (1987): Bibliography on sediment threshold velocity. *J. Hydr. Eng., 113*(3), 389–393.

Lavelle, J.W., and H.O. Mofjeld (1987): Do critical stresses for incipient motion and erosion really exist? *J. Hydr. Eng., 113*(3), 370–385.

Murphy, P.P., T.S. Bates, and H.C. Curl, Jr. (1987): Geochemical history of hydrocarbons in Puget Sound. *Eos, Transactions of the American Geophysical Union, 68*, 1758.

Tennant, D.A., S.L. Walker, J.W. Lavelle, and E.T. Baker (1987): A practical manual for determining settling rates of ocean disposed sewage sludge. NOAA Tech. Memo. ERL PMEL-69, 29 pp.

---

* Associated with a PMEL sampling program.

1988

Baker, E.T., H.B. Milburn, and D.A. Tennant (1988): Field assessment of sediment trap efficiency under varying flow conditions. *Journal of Marine Research, 46*, 573–592.

Cannon, G.A. (1988): Flow variations through sections across Puget Sound. In: First Annual Meeting on Puget Sound Research, Puget Sound Water Quality Authority, March 18–19, 103–107.

Cannon, G.A. (1988): Time variations of bottom-water inflow at the mouth of an estuary. In: *Understanding the Estuary. Advances in Chesapeake Bay Research*. Chesapeake Research Consortium, Gloucester Point, VA (in press).

Cokelet, E.D., R.J. Stewart, and C.C. Ebbesmeyer (1988): The annual mean transport and refluxing in Puget Sound. In: First Annual Meeting on Puget Sound Research, Puget Sound Water Quality Authority, March 18–19, 108–119.

Crecelius, E.A., and H.C. Curl, Jr. (1988): Temporal trends of contamination recorded in sediments of Puget Sound. In: First Annual Meeting on Puget Sound Research, Puget Sound Water Quality Authority, March 18–19, 21–32.

Curl, H.C., Jr. (1988): Assimilative capacity: a "discredited" idea whose time is yet to come. In: First Annual Meeting on Puget Sound Research, Puget Sound Water Quality Authority, March 18–19, 247–255.

Curl, H.C., Jr., E.T. Baker, T.S. Bates, G.A. Cannon, R.A. Feely, T.L. Geiselman, M.F. Lamb, P.P. Murphy, D.J. Pashinski, A.J. Paulson, and D.A. Tennant (1988): Contaminant transport from Elliott and Commencement Bays. NOAA Tech. Memo. ERL PMEL-78, 136 pp.

Ebbesmeyer, C.C., C.A. Coomes, J.M. Cox, G.A. Cannon, and D.E. Bretschneider (1988): Decade-long regimes of a fjord basin's oceanography, hydrology, and climatology: Puget Sound, 1916–1987. In: First Annual Meeting on Puget Sound Research, Puget Sound Water Quality Authority, March 18–19, 50–57.

Feely, R.A., A.J. Paulson, H.C. Curl, Jr., and D.A. Tennant (1988): The effect of the Duwamish River plume on horizontal versus vertical transport of dissolved and particulate trace metals in Elliott Bay. In: First Annual Meeting on Puget Sound Research, Puget Sound Water Quality Authority, March 18–19, 172–184.

Lavelle, J.W. (1988): A laterally averaged model of currents in Admiralty Inlet and the main basin of Puget Sound. In: First Annual Meeting on Puget Sound Research, Puget Sound Water Quality Authority, March 18–19, 89–92.

Lavelle, J.W., H.O. Mofjeld, E. Lempriere-Doggett, G.A. Cannon, D.J. Pashinski, E.D. Cokelet, L. Lytle, and S. Gill (1988). A multiply-connected channel model of tides and tidal currents in Puget Sound, Washington, and a comparison with updated observations. NOAA Tech. Memo. ERL PMEL-84, 103 pp.

Lavelle, J.W., E. Ozturgut, E.T. Baker, D.A. Tennant, and S.L. Walker (1988): Settling speeds of sewage sludge in seawater. *Env. Sci. Technol., 22*(10), 1201–1207.

Mofjeld, H.O. (1988): Depth dependence of bottom stress and quadratic drag coefficient for barotropic pressure-driven currents. *J. Phys. Oceanogr., 18*(11), 1658–1669.

Mofjeld, H.O. (1988): Seasonal and interannual variations of tidal mixing and excursions in Admiralty Inlet. In: First Annual Meeting on Puget Sound Research, Puget Sound Water Quality Authority, March 18–19, 99–102.

Murphy, P.P., T.S. Bates, H.C. Curl, Jr., R.A. Feely, and R.S. Burger (1988): Retention of organic pollutants in Puget Sound. In: First Annual Meeting on Puget Sound Research, Puget Sound Water Quality Authority, March 18–19, 195–199.

Murphy, P.P., T.S. Bates, H.C. Curl, Jr., R.A. Feely, and R.S. Burger (1988): The transport and fate of particulate hydrocarbons in an urban fjord-like estuary. *Estuarine, Coastal and Shelf Science, 27,* 461–482.

Paulson, A.J., R.A. Feely, H.C. Curl, Jr., E.A. Crecelius, and T. Geiselman (1988a): The impact of scavenging on trace metal budgets in Puget Sound. *Geochimica et Cosmochimica Acta, 52*(7), 1765–1779.

Paulson, A.J., R.A. Feely, H.C. Curl, Jr., E.A. Crecelius, and G.P. Romberg (1988b): Contrasting sources and fates of Pb, Cu, Zn and Mn in the main basin of Puget Sound. In: First Annual Meeting on Puget Sound Research, Puget Sound Water Quality Authority, March 18–19, 185–194.

Paulson, A.J., R.A. Feely, H.C. Curl, Jr., E.A. Crecelius, and G.P. Romberg (1988c): Sources and sinks of Pb, Cu, Zn and Mn in the main basin of Puget Sound. NOAA Tech. Memo. ERL PMEL-77, 26 pp.

1989

Cannon, G. (1989): Puget Sound Circulation: What have observations taught us, and what is still to be ascertained. Oceans '89 Proceedings, September 18–21, 1989, Seattle, WA, Vol. 1: Fisheries, Global Ocean Studies, Marine Policy and Education, Oceanographic Studies, Marine Technology Society, IEEE Publication Number 89CH2780-5, 77–80.

Curl, H.C., Jr. (1989): Marine ecology: the water column. Proceedings of a Conference/Workshop on Recommendations for Studies in Washington and Oregon: Offshore Oil and Gas Development. Minerals Management Service, Dept. of Interior, May 23–25, 1988, Portland, OR, 65–72.

Ebbesmeyer, C.C., C.A. Coomes, G.A. Cannon, and D.E. Bretschneider (1989): Linkage of ocean and fjord dynamics at decadal period. In: *Aspects of Climate Variability in the Pacific and Western Americas,* D.J. Peterson (ed.), Amer. Geophys. Un., Geophys. Monogr. 55, Washington, D.C., 399–417.

Mofjeld, H.O. (1989): Long-term trends and interannual variations of sea level in the northwestern region of the United States. Proceedings of the Oceans '89 Conference, September 18–21, 1989, Seattle, WA, Vol. 1, 228–230.

Paulson, A.J., H.C. Curl, Jr., and R.A. Feely (1989a): Estimates of trace metal inputs from non-point sources discharged into estuaries. *Marine Pollution Bulletin, 20*(11), 549–555.

Paulson, A.J., R.A. Feely, H.C. Curl, Jr., E.A. Crecelius, and G.P. Romberg (1989b): Separate dissolved and particulate trace metal budgets for an estuarine system: a possible management tool. *Environmental Pollution, 57*, 317–339.

Paulson, A.J., R.A. Feely, H.C. Curl, Jr., and D.A. Tennant (1989c): Estuarine transport of trace metals in a buoyant riverine plume. *Estuarine, Coastal and Shelf Science, 28*, 281–248.

Paulson, A.J., T.P. Hubbard, H.C. Curl, Jr., R.A. Feely, T.E. Sample and R.G. Swartz (1989d): Decreased fluxes of Pb, Cu and Zn from Elliott Bay. Proceedings of the Sixth Symposium on Coastal and Ocean Management, ASCE, July 11–14, 1989, Charleston, SC, Vol. 4, 3916–3930.

Perillo, G.M.E. and J.W. Lavelle (1989): Sediment transport processes in estuaries: An introduction. *J. Geophys. Res., 94*(C10), 14,287–14,288.

1990

Cannon, G.A. (1990): Variations in horizontal density gradient forcing at the mouth of an estuary. In: Physics of Estuaries and Shallow Bays, R. Chen (ed.), Coastal and Estuarine Studies, Vol. 38, Springer-Verlag, N.Y., 375–388.

Cannon, G.A., J.R. Holbrook and D.J. Pashinski (1990): Variations in the onset of bottom-water intrusions over the entrance sill of a fjord. *Estuaries, 13*(1), 31–42.

Cokelet, E.D., R.J. Stewart and C.C. Ebbesmeyer (1990): The annual mean transport in Puget Sound. NOAA Tech. Memo. ERL PMEL-92 (NTIS NA), 59 pp.

1991

Cokelet, E.D. (1991): Axial and cross-axial winter winds over Puget Sound. *Mon. Wea. Rev.* (in press).

Cokelet, E.D., R.J. Stewart and C.C. Ebbesmeyer (1991): The exchange of water in fjords. Part II: The annual mean transport in Puget Sound. (submitted).

Cokelet, E.D., R.J. Stewart and C.C. Ebbesmeyer (1991): The exchange of water in fjords III: The annual mean efflux/reflux coefficients in Puget Sound. (submitted).

Cokelet, E.D., R.J. Stewart and C.C. Ebbesmeyer (1991): The exchange of water in fjords. Part IV: Tracer concentrations and ages in Puget Sound. (submitted).

Cokelet, E.D., R.J. Stewart and C.C. Ebbesmeyer (1991): Unit input response matrices for the Puget Sound reflux model. NOAA Data Report ERL PMEL (in preparation).

Cokelet, E.D., R.J. Stewart and C.C. Ebbesmeyer (1991): Concentrations and ages of conservative pollutants in Puget Sound. In: Proceedings of the Puget Sound Research '91, Puget Sound Water Quality Authority, Seattle, Washington, 1:99–108.

Cudaback, C.N., A.J. Paulson, and J.W. Lavelle (1991): A modeling study of the vertical distribution and transport of manganese in Puget Sound. NOAA Technical Memorandum, ERL PMEL-93.

Curl, Jr., H.C. and A.J. Paulson (1991): The biogeochemistry of oxygen and nutrients in Hood Canal. In: Proceedings of Puget Sound Research '91. Puget Sound Water Quality Authority, Seattle, Washington, 1, 109–115.

Lavelle, J.W., E.D. Cokelet, and G.A. Cannon (1991): A model study of density intrusions into and circulation within a deep, silled estuary: Puget Sound. *J. Geophys. Res., 96(C9)*, 16,779–16,800.

Lavelle, J.W., C. Cudaback, A.J. Paulson and J.W. Murray (1991): A rate for the scavenging of fine particles by macroaggregates in a deep estuary. *J. Geophys. Res., 96*(C1), 783–790.

Paulson, A.J. and H.C. Curl, Jr. (1991): The biogeochemistry of trace metals in Hood Canal. In: Proceedings of Puget Sound Research '91, Puget Sound Water Quality Authority, Seattle, Washington, 1, 116–122.

Paulson, A.J., H.C. Curl, Jr., R.A. Feely, G.J. Massoth, K.A. Krogslund, T. Geiselman, M.F. Lamb, K. Kelly, E.A. Crecelius and J.F. Gendron (1991a): Trace metal and ancillary data in the watersheds and urban embayments of Puget Sound. NOAA Data Report ERL PMEL-30.

Paulson, A.J., H.C. Curl, Jr., R.A. Feely, T. Geiselman, K.A. Krogslund, G.J. Massoth, M.F. Lamb and K. Kelly (1991b): Trace metal and ancillary data in the open waters of Puget Sound: 1981–1985. NOAA Data Report ERL PMEL-31.

Paulson, A.J., H.C. Curl, Jr., R.A. Feely, K.A. Krogslund and S. Hanson (1991c): Trace metal and ancillary data in Puget Sound: August 1986. NOAA Data Report ERL PMEL-32.

Paulson, A.J., H.C. Curl, Jr., and E.D. Cokelet (1991d): Remobilization of Cu from marine particulate organic matter and from sewage. *Mar. Chem., 33*, 41–60.

1992

Paulson, A.J.: The effect of cell adsorption on the determination of Cu complexation by adsorptive cathodic stripping voltammetry. *Anal. Chim. Acta* (submitted).

Paulson, A.J., H.C. Curl, Jr., and R.A. Feely: The biogeochemistry of nutrients and trace metals in Hood Canal, a Puget Sound Fjord. *Mar. Chem.* (submitted).

Paulson, A.J., H.C. Curl, Jr., and J.F. Gendron: Biological control of Cu partitioning in estuaries. *Mar. Chem.* (submitted).

Paulson, A.J., H.C. Curl, Jr., and J.F. Gendron: The equilibration of 64Cu with natural Cu in marine water samples. *Env. Sci. Tech.* (submitted).