NOAA Data Report ERL PMEL-32

TRACE METAL AND ANCILLARY DATA IN PUGET SOUND: AUGUST 1986

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NOTICE

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Trace Metal and Ancillary Data in Puget Sound: August 1986

A.J. Paulson[1], H.C. Curl, Jr.[1], R.A. Feely[1], K.A. Krogslund[2], and S. Hanson[1]

1. INTRODUCTION

In the first of three data reports on the trace metal and ancillary data in Puget Sound and its watersheds (Paulson *et al.*, 1991a), all water column, sediment and sediment trap data from the urban embayments and the watersheds discharging into Puget Sound between 1979 and January 1986 were reported. In the second data report (Paulson *et al.*, 1991b), the complete data set between 1980 and January 1985 for the open waters of Puget Sound was presented. In this third data report, data from a single cruise in the urban embayments and open waters of Puget Sound during August 1986 are listed. The data are presented geographically in the following manner: Elliott and Commencement Bays, the main basin of Puget Sound, South Puget Sound, Whidbey Basin and Hood Canal. The information gained from these data has been interpreted by PMEL scientists and is published in a variety of scientific journals that are listed within each section.

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 the 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 program were 1) to quantify the sources and sinks of selected trace metals 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 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

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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 analysis 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 Puget Sound Bibliography at the end of this document).

Because these measurements constitute the most extensive data base of trace metal 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. Twenty-eight cruises were undertaken between 1979 and 1986 to accomplish these objectives. Besides the dissolved and particulate trace metals data, salinity, temperature data and concentrations of dissolved oxygen, methane, nutrients, particulate organic carbon and particulate organic nitrogen were sometimes obtained.

The text of this data report consists of the sampling and analytical methods with the accompanying quality control/quality assurance data. The text of the data sections are a summary of the data and published literature in which the data is interpreted along with a catalogue of the data available on microfiche located in the back pocket of this data report. In most cases, a table consists of one station with the parameters as columns and the depths as rows. The tables on microfiche were produced from hardcopies of files in a grouphome of the data management program RS1 (Version 4.2) on a VAX mainframe computer at PMEL. Those wishing a copy of the RS grouphome on tape should contact the senior author by letter. ASCII text files of each RS1 data file have been produced with fields separated by commas. Those wishing IBM compatible ASCII text files on either high density 3.5" or 5.25" diskettes may contact the senior author by letter. Under no circumstances will hardcopies of the files be available from PMEL.

2. METHODS

2.1 Sampling and Processing

2.1.1 Water Column

Surface samples in the Elliott, Commencement and Skagit Bays were collected by lowering acid-cleaned, 1-L linear polyethylene bottle (LPE) from the bow of a small boat with a nylon line. Surface samples from Hood Canal fresh waters were collected in a similar manner from bridges or from the shore. Open water seawater samples (Fig. 1) taken for dissolved oxygen, nutrient analyses and particulate trace metal were collected in 10-liter standard Niskin bottles attached to a General Oceanics rosette. Once on deck, water for dissolved oxygen analyses was transferred to clean glass-stoppered bottles in such a way that air bubbles were not trapped. The oxygen samples were collected in standard 125 milliliter D.O. bottles. Nutrient samples were placed in ice or dry ice onboard and transferred to a low-temperature freezer prior to analysis. Salinity and temperature data were taken from CTD (conductivity-temperature-depth) instrumentation or from discrete samples collected from the Go-Flo® bottles for analyses and from reserving thermometer data, respectively. Analysis of discrete Go-Flo® samples allows comparisons with the CTD data to detect mistripping of Go-Flo® bottles.

Open water dissolved trace metal samples were collected in specially-modified Teflon®-coated Go-Flo® bottles attached to a Kevlar® line. Standard Go-Flo® bottles were modified by replacing all O-rings with silicone O-rings and replacing the spigot with a Teflon® stopcock. The ends of the bottles were covered with new clean plastic bags whenever they are not on the Kevlar line. Discrete salinity samples from all Go-Flo samples were taken to insure proper collection. Samples for dissolved trace metal analyses were filtered through acid-cleaned 0.2 μm Nuclepore filters using 50 mm filters held in the all-Teflon® Savillex® filtering apparatus, collected in LPE bottles, preserved by adding Ultrex nitric acid to a pH < 2 and refrigerated or frozen until analysis. Prior to each sampling period, all-Teflon® Savillex® filtering apparatus and 50 mm 0.2 μm Nuclepore filters were acid-cleaned, assembled and rinsed by processing 1 L of 0.1 N nitric acid through each apparatus. Quartz-distilled water was then processed through each apparatus; the first 500 ml was discarded before collection of seawater for analysis. All procedures requiring exposure of the sample to the atmosphere were performed in the class 100 laminar flow hood. If the filtering apparatus is reused, a new acid-cleaned filter is placed in the apparatus and the apparatus is then cleaned by rinsing with 1 L of 0.1 M HNO_3. Surface samples in 1-L LPE bottles were filtered using 50 mm filters held by the Teflon® Savillex® apparatus within a laminar flow hood.

Suspended matter for TSM and particulate trace metal analyses was collected on pre-tared, acid-cleaned 37-mm, 0.4 μm Nuclepore filters. Suspended matter for both the TSM and particulate trace metal analysis was filtered inline using 37-mm Nuclepore filters held in modified, Teflon® Savillex® filtering apparatus. Filters for particulate trace metals were loaded and unloaded in a laminar flow hood. All samples were rinsed with Milli-Q water (pH 8), placed

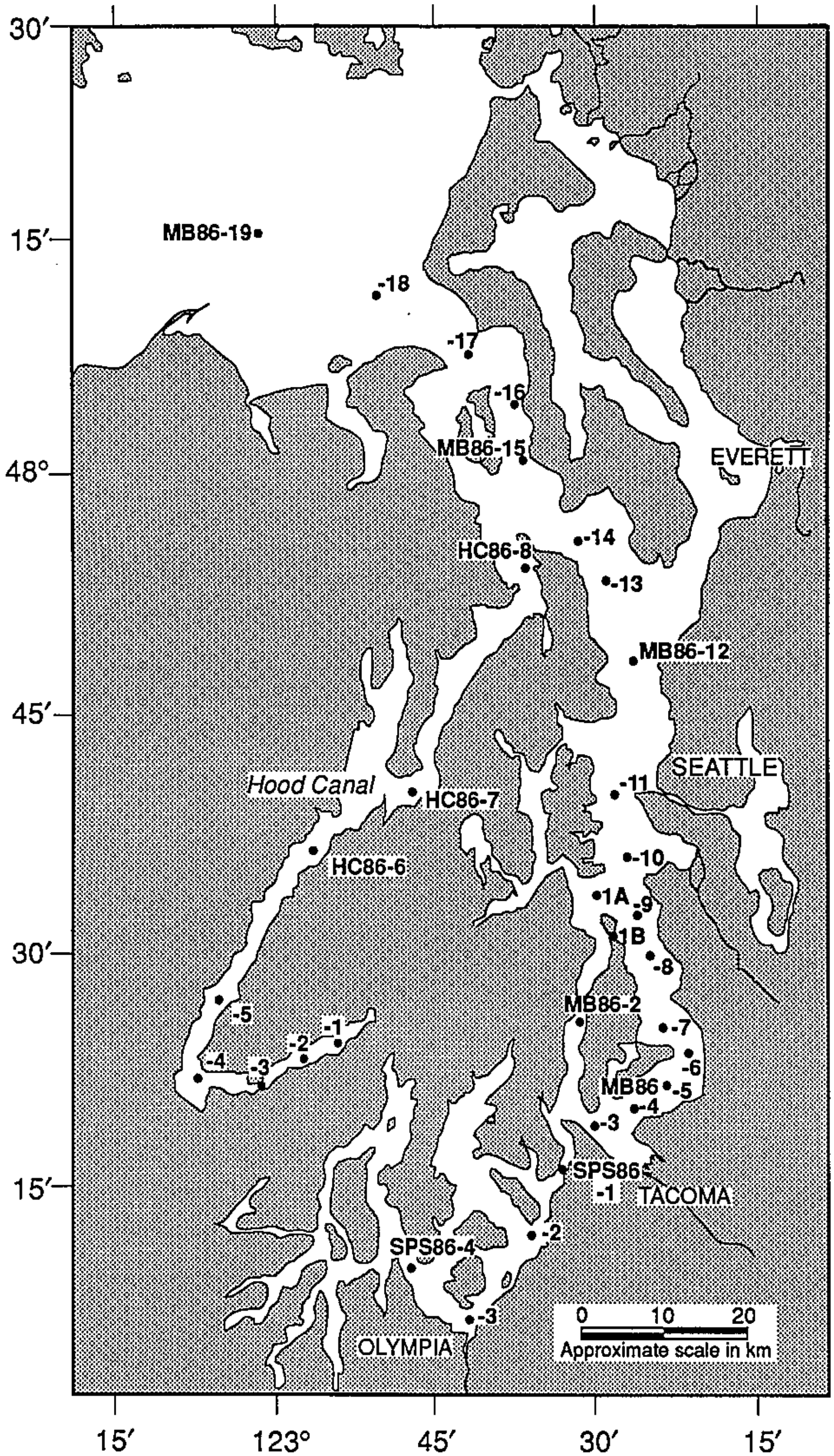

Fig. 1. Sampling locations.

in acid-cleaned polycarbonate petri dishes with Teflon® holders and vacuum-desiccated over sodium hydroxide. Reference filters from the same filter lot were stored and desiccated along with the samples to evaluate changes in weight by the filters due to humidity.

By convention, samples collected by hand (small boat, shore, bridge) were assigned a depth of 0 m. The depths of samples collected in 10-L Go-Flo bottles attached at a rossette sampler during a CTD cast were usually recorded as sampling bottles were being tripped. The depths of sub-surface samples taken by hydroccast were calculated by the length of hydrowire or Kevlar® cable in the water at the time the bottle was tripped. No correction was made for wire angle. A non-metallic pinger was installed at the end of the kevlar line to more accurately collect near-bottom samples by Kevlar® hydrocast.

2.2 Analyses

2.2.1 Temperature and Salinity

Salinity and temperature data for open waters were obtained from conductivity-temperature-depth (CTD) instrumentation. The Plessey CTD was calibrated in accordance with procedures NOIC-CP-04A. Digitally recorded data from CTD were converted to engineering units by applying the calibration relations determined by the Northwest Regional Calibration Center. The salinity was calculated based on the depth, temperature and conductivity. A temperature and salinity offset was applied to the field CTD data based on the differences between the discrete measurements of salinity and temperature and those calculated from the CTD calibrations. Data converted through calibrations were field checked to provide salinity to ±0.01 and pressure to ±1.0 decibars. The bench salinometers used for the discrete samples provided salinity measurements to 0.003 ppt for discrete samples.

2.2.2 Dissolved Oxygen

Dissolved oxygen concentrations were determined by Winkler titrations (Winkler, 1888) as modified by Carpenter (1965) and reported in Strickland and Parsons (1972) and Parsons *et al.* (1984). The procedure was standardized with oven-dried KIO_3 while blanks were determined by the difference method.

2.2.3 Nutrients

All nutrient analyses reported in this document were performed under the direction of Ms. Kathy Krogslund of the Marine Chemistry Laboratory of the Department of Oceanography, University of Washington. Nutrient analyses were performed using the procedures of Whitledge *et al.* (1981) using a Technicon Autoanalyzer 2.

2.2.4 Dissolved Trace Metal Analyses

The trace metal analyses were performed by graphite furnace atomic absorption spectrometry (GFAAS) using a Perkin-Elmer Zeeman 500 spectrometer equipped with a HGA-500 graphite furnace and an AS-40 automatic sampler using standard conditions (Perkin-Elmer, 1977) with slight modifications when necessary. A modification of the Chelex-100®, ion-exchange, pre-concentration procedure following the method of Kingston *et al.* (1978) was used as described in Paulson (1986). All apparatus were made of polyethylene or Teflon® and were acid-cleaned. Reagents were made by diluting Ultrex® acid (HNO_3), base (NH_4OH) or salt mixtures (NH_4OH and acetic acid) with Q-H_2O to the appropriate molarity.

Ion-exchange columns were prepared by soaking 5.0 g of 200–400 mesh Chelex-100® in 2.5 M HNO_3 for two hours, and then decanting and soaking in clean 2.5 M HNO_3 for another two hours. This slurry mixture was poured into a fritted polyethylene Isolab column, allowed to drain, washed with 30 mL of 2.5 M HNO_3, rinsed with 30 mL of Q-H_20, and then converted to the ammonium form by eluting with 10 mL of 2 M NH_4OH. Excess NH_4OH was removed by rinsing with 30 mL of Q-H_2O. The prepared columns were placed in a plexiglass rack and the effluent end of the column was attached to a peristaltic pump (Manostat®) with silicon tubing. The weighed samples were neutralized to pH 2 with concentrated NH_4OH, buffered with 10 mL of 1 M NH_4Ac, adjusted to pH 5.4 with concentrated NH_4OH and transferred to 1000-ml Teflon separatory funnels (Nalgene). Five mL of the sample was placed in the prepared column and an air-tight seal was formed between the column and the funnel by placing the tip of the separatory funnel through a hole in a #5 hollow stopper (Nalgene) and firmly inserting the stopper into the top of the column. The stopcock was opened and the flow rate of the pump is adjusted to 0.15 mL/minute. When no solution remains above the column, the column was rinsed with 10 mL of Q-H_2O, rinsed with 30 mL of 10 M NH_4Ac in order to remove excess sea salts and eluted with 20 mL of 2 M HNO_3 into a pre-weighed 30-mL (LPE) bottle. The eluate was analyzed by GFAAS using calibration against standards prepared in a similar HNO_3 matrix.

Quality control was based on measurements of procedural blanks and measurement of standard seawater (Table 1). The field filtering blanks suggest that the analyses of these metals reported in this report were not jeopardized by field or laboratory contamination. The analytical imprecision was generally less than 10% (Paulson, 1986). Variations in the extraction efficiency, natural variability and random contamination by sampling, filtration or analytical procedures can combine to limit our ability to define the concentration of a trace metal at a particular depth at an exact station location. In 1980, ten samples from 100 m were collected during four casts at a single station in the main basin of Puget Sound using four different Go-Flo® bottles in order to determine the overall precision of our measurements. The sampling and processing precisions for dissolved Mn, Cu, Ni and Cd were 4%, 3%, 8% and 1%, respectively. Similar results were

TABLE 1. Quality control data for dissolved trace metals (in μg/l).

	Cd	Mn	Fe	Ni	Cu	Zn	Pb	n
Filtering Blank	0.0019 ±0.0007	0.025 ±0.009	0.035 ±0.009	<0.005	<0.008	0.053 ±0.006	<0.010	3
Determination Limit	0.002	0.03	0.03	0.01	0.01	0.02	0.01	
CASS-1 Observed	0.029 ±0.0004	2.33 ±0.06		0.094 ±0.009	0.285 ±0.045	0.953 ±0.030	0.220 ±0.006	3
CASS-1 Certified	0.026 ±0.005	2.27 ±0.17	0.873 ±0.076	0.290 ±0.031	0.291 ±0.077	0.98 ±0.09	0.251 ±0.027	
MF 86-3 MB 86-11-T1 50 m[1]	0.078 ±0.02	1.02[3] ±0.31	0.22 ±0.07	0.37 ±0.02	0.34 ±0.01	0.35 ±0.07	0.054[3] ±0.021	3
RSTD	3%	30%	32%	5%	3%	20%	39%	
MF 86-3 MB 86-11 50 m T1-T5[2]	0.075 ±0.005	0.99 ±0.06	0.31 ±0.14	0.37 ±0.01	0.33 ±0.01	0.34 ±0.02	0.033[4] ±0.027	5
RSTD	7%	6%	45%	3%	3%	6%	82%	

[1] 3 samples collected between 45 and 55 m at the same time
[2] 5 samples collected over 24 hours.
[3] Strong vertical gradient.
[4] Strong low tide-high tide correlations.

found in 1986. However, large sampling and temporal variability were found for Fe and Pb. The large Pb variability was partially a result of a strong tidal correlation.

2.2.5 Total Suspended Matter (TSM)

The filters with collected suspended matter were re-weighed after desiccation on Cahn electrobalance models 26, 29 or 4700. The weight of suspended matter on the filters was corrected for changes in weight of the filters determined from re-weighing the reference filters. Given the corrected net weight of suspended matter and the volume of water filtered, the total suspended matter concentrations were calculated. The accuracy and precision of the Cahn balances are ±0.0012% and ±0.001 mg, respectively. The precision of total suspended matter measurements is nominally 0.01%. The shipboard sampling precision for total suspended matter is highly dependent on location, depth and elapsed time. Sampling precisions for total suspended matter reported for the main basin of Puget Sound have ranged between 1.0% and 17%.

2.2.6 Particulate Trace Metal

Total elemental compositions (Al, Si, Mn, Fe, Ni, Cu, Zn, Pb, Cr, V and P) in suspended particulate matter were determined by X-ray primary- and secondary-emission spectrometry using the thin-film technique (Baker and Piper, 1976; Feely *et al.*, 1981, 1986; Holmes, 1981). A Kevex Model 770-8000 X-ray energy spectrometer with a rhodium X-ray tube was used in the direct and secondary-emission (Ge and Zr targets) modes to obtain maximum efficiency for excitation of individual elements in the sample. Thin-film standards were prepared from suspensions of finely ground U.S. Geological Survey Standard Rocks (BCR-1, BHVO-1, MAG-1, GXR-1, GXR-4, GXR-6; GSD-4, GSD-5, GSD-6, and GSD-7; 90 percent by volume less than 15 μm in diameter), and National Research Council of Canada Standard Reference Material BCSS-1. The reference values for the thin-film standards used in the calibration are shown in Table 2. Calibrations for Al, Si, Mn, Fe, Cu and V were effected using standard regression techniques. Ni, Zn, Pb, and Cr calibrations were effected using East Pacific ocean mid-depth suspended matter whose elemental composition was determined by graphite furnace atomic absorption spectrometry following 3 M HCl dissolution. P calibration was effected using East Pacific Ocean mid-depth suspended matter whose elemental composition was determined by flow injection analysis following 3 M HCl dissolution.

The reported values for trace metals in suspended particulates were calculated in the following manner:

$$\text{conc (sample)} = \frac{C * A}{WT * S}$$

where: conc (sample) is concentration of sample in ppm,
C is net counts/(sec cm^2)

TABLE 2. X-ray fluorescence spectrometry: Standards and values used in calibration wherever values are given.

	Al Wt. %	Si Wt. %	Mn ppm	Fe Wt. %	Cu	V
MAG[1]	9.23	25.33	820	5.17		
BCSS-1[1]			240	3.20		
BHVO-1			1320	8.46	137	
GSD-1			900	5.14		120
GSD-4			850	4.07		120
GSD-5			1150	4.08		110
GSD-6			1000	4.10	380	140
GSD-7			700	4.55		
GXR-1			900	24.7	1300	
GXR-4			140	2.98	6500	
GXR-6				5.59	105	180
SGR			900	2.09		5.4
BCR-1				9.39		

1) Concentrations corrected for sea salt content.

TABLE 3. X-ray fluorescence spectrometry: Determination limits and precision using 37-mm Nuclepore™ aerosol polycarbonate membrane filters.

	Al Wt. %	Si Wt. %	Mn ppm	Fe Wt. %	Ni ppm	Cu ppm	Zn ppm	Pb ppm	Cr ppm	V ppm	P Wt. %
Determination Limit	0.06	0.06	24	0.02	15	18	15	48	33	25	0.02
Average	0.25	3.72	288	35.9	19	385	244	177	830	674	3.92
Precision RSTD (%)	13	2.1	24	1.1	47	4	5	28	7	5	2.1

Wt is weight of particulates on filter in mg,
A is effective area of filter, and
S is slope of net counts/sec cm^2 vs. ng/cm^2

The precision is given in terms of coefficient of variation (C.V. = $\frac{1\sigma \text{ error}}{\text{mean value}} \cdot 100$). For particulate major and trace metal results from 26 replicate measurements of an East Pacific Ocean mid-depth sample, each of which was obtained on a different analysis day (Table 3), the precision was less than 10% except for Ni and Pb, which had low concentrations, and Mn, which was affected by the low Mn/Fe ratio of this sample.

The determination limits are based on counting statistics and are defined as:

$$\text{Determination Limit} = 3 \times \text{Minimum Detection Limit}$$
$$= 3\left(2 \cdot K \cdot \frac{1}{\sqrt{T}} \frac{\sqrt{I_B}}{I_p}\right)$$

where: K = standard concentration in desired units (Wt.% or ppm),
T = counting or analysis time in seconds,
I_B = background intensity in counts-per-second, and
I_p = net peak intensity in counts-per-second.

The precision and determination limits are given in Table 3. Because the high organic content of Hood Canal surface samples prevented accurate XRF analysis for some trace metals, some filters from stations HC86-1 through HC86-5 were dissolved in a HCl-HNO_3-HF solution according to the method of Eggimann and Betzer (1976). The acid solution was measured by graphite furnace atomic absorption spectrometry (GFAAS). The detection limits were determined by analyses of unused filters. The detection limits for Cu, Ni and Cd calculated with a typical 800 μg mass loading were 1 ppm, 9 ppm and 0.18 ppm based on instrumental detection limits (Cu and Ni) and based on three standard deviations of the results for unused filters (Cd). The analyses of the standard BCSS-1 (2.3 mg) (National Research Council of Canada) resulted in Cu, Ni, and Cd determinations of 17.4, 59 ppm and 0.22 ppm, respectively. These values were within the tolerance limits of the certified values. In addition, deeper particulate samples from HC86–5 were dissolved and the concentration of Cd in the acid solution was measured by GFAAS.

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3. RESULTS

3.1 Water Column

The water column data is listed in 34 columns grouped in the following manner:

Column	Data
0–1	Sample identification
2–3	Temperature and Salinity Data
4–5	Methane and Oxygen Data
6–10	Nutrient Data
11	Temperature, Salinity, Methane, Oxygen, Nutrient Comments
12–13	Depth and Salinity for Dissolved Trace Metal Samples
14–20	Dissolved Trace Metal Data
21	Dissolved Trace Metal Comments
22	Depth for Particulate Samples
23	Total Suspended Matter (TSM) Data
24–33	Particulate Trace Metal Data
34	Particulate Trace Metal Comments
35	Availability of Coulter Counter Data

Separate samples for the different analyses were taken during small boat sampling in Elliott, Commencement and Skagit Bays and during sampling from bridges or the shore of the Hood Canal rivers. In the open waters of Puget Sound, a CTD/rosette sampler aboard the *Miller Freeman* was used to collect the temperature data in column 2 and column 3. When salinity data is not from discrete salinity samples that were collected from the same sampling bottle used to collect other chemical samples, column 11 is marked "*". Dissolved trace metal samples in open waters were always taken from casts with a special winch that was mounted on the bows of the *Miller Freeman* and was distinct from the CTD casts. Discrete salinity samples were always taken in conjunction with every dissolved trace metal sample. Inferences about the possibility of mistripping of sampling bottles can be made from examination of discrete salinity, oxygen and nutrient data.

3.1.1 Elliott and Commencement Bays

Nine surface stations in Elliott Bay (EB86-1 to -9) and 10 surface stations in Commencement Bay (CB86-1 to -10) were occupied during August 1986 (Table 4). In addition, three vertical profiles were taken in Elliott Bay (EB86-10 to -12).

Dissolved trace metal data from Elliott Bay have been reported and discussed by Paulson *et al.* (1989).

Table 4. Sampling Locations and Sampling Data for Commencement and Elliott Bays

0 Cruise Name	1 Sta. Name	2 Lat. N	3 Long. W	4 Date	5 Cast Type	6 Time Loc.	7 O2	8 CH4	9 Nut	10 Dis TM	11 Part TM	12 POC PON	13 Page
1 MF86-2	CB-1	47 15.6	122 26.3	19 Aug 86	SB	08:54			X	X			A-2
2 MF86-2	CB-2	47 16.1	122 25.9	19 Aug 86	SB	09:08			X	X			A-2
3 MF86-2	CB-5	47 16.2	122 25.8	19 Aug 86	SB	09:38			X	X			A-2
4 MF86-2	CB-6	47 16.6	122 25.9	19 Aug 86	SB	10:10			X	X			A-2
5 MF86-2	CB-4	47 16.2	122 25.7	19 Aug 86	SB	10:46			X	X			A-2
6 MF86-2	CB-7	47 16.8	122 25.9	19 Aug 86	SB	11:24			X	X			A-2
7 MF86-2	CB-8	47 16.8	122 24.9	19 Aug 86	SB	11:43			X	X			A-2
8 MF86-2	CB-9	47 17.2	122 24.8	19 Aug 86	SB	11:59			X	X			A-2
9 MF86-2	CB-10	47 15.4	122 22.6	19 Aug 86	SB	12:37			X	X			A-2
10 MF86-2	CB-3	47 15.7	122 25.1	19 Aug 86	SB	13:37			X	X			A-2
11 MF86-2	EB-2	47 34.0	122 20.8	20 Aug 86	SB	12:20			X	X	X		A-4
12 MF86-2	EB-3	47 34.5	122 21.5	20 Aug 86	SB	12:35			X	X	X		A-4
13 MF86-2	EB-4	47 35.2	122 21.5	20 Aug 86	SB	12:50			X	X	X		A-4
14 MF86-2	EB-5	47 35.4	122 21.0	20 Aug 86	SB	13:00			X	X	X		A-4
15 MF86-2	EB-6	47 35.4	122 20.6	20 Aug 86	SB	13:10			X	X	X		A-4
16 MF86-2	EB-1	47 30.8	122 18.2	20 Aug 86	SB	13:30			X	X	X		A-4
17 MF86-2	EB-7	47 36.0	122 21.5	20 Aug 86	SB	14:05			X	X	X		A-4
18 MF86-2	EB-8	47 36.4	122 21.5	20 Aug 86	SB	14:15			X	X	X		A-4
19 MF86-2	EB-9	47 36.8	122 22.3	20 Aug 86	SB	16:35			X	X	X		A-4
20 MF86-2	EB-10	47 39.0	122 26.9	20 Aug 86	SB	17:15			X		X		A-6
21 MF86-2	EB-11	47 39.6	122 26.9	20 Aug 86	SB	18:00			X		X		A-7
22 MF86-2	EB-12	47 40.5	122 26.9	20 Aug 86	SB	18:30			X		X		A-8

3.1.2 South Puget Sound

Four stations in South Puget Sound (SPS86-1 to -4) were occupied in August 1986 (Table 5).

No data from South Puget Sound have been previously reported.

Table 5. Sampling Location and Sampling Data for South Puget Sound

	0 Cruise Name	1 Sta. Name	2 Lat. N	3 Long. W	4 Date	5 Cast Type	6 Time Loc.	7 O2	8 CH4	9 Nut	10 Dis TM	11 Part TM	12 POC PON	13 Page
1	MF86-2	SPS86-1	47 17.2	122 32.5	18 Aug 86	TM	19:15				X			B-2
2	MF86-2	SPS86-1	47 17.2	122 32.5	18 Aug 86	CTD	19:21	X		X		X		B-2
3	MF86-2	SPS86-2	47 10.0	122 36.7	18 Aug 86	TM	20:48				X			B-3
4	MF86-2	SPS86-2	47 09.8	122 36.7	18 Aug 86	CTD	21:46	X		X		X		B-3
5	MF86-2	SPS86-3	47 07.5	122 44.0	18 Aug 86	CTD	23:08	X		X		X		B-5
6	MF86-2	SPS86-4	47 10.6	122 47.5	19 Aug 86	TM	00:16				X			B-6
7	MF86-2	SPS86-4	47 10.3	122 48.1	19 Aug 86	CTD	00:31	X		X		X		B-6

3.1.3 Main Basin of Puget Sound

Three stations in Colvos Passage (Table 6) were occupied in August 1986 (Sta. MF86-1a, -1b and -2). Between Dalco Passage (MB86-3) and outer Admiralty Inlet (MB86-18), 15 stations were occupied in the main Basin of Puget Sound. In addition, one station in eastern Strait of Juan de Fuca (MB86-19) was occupied.

No data from the main basin of Puget Sound have been previously reported.

Table 6. Sampling Location and Sampling Data for the Main Basin of Puget Sound

0 Cruise Name	1 Sta. Name	2 Lat. N	3 Long. W	4 Date	5 Cast Type	6 Time Loc.	7 O2	8 CH4	9 Nut	10 Dis TM	11 Part TM	12 POC PON	13 Page
1 MF86-2	MB86-1A	47 33.9	122 29.9	18 Aug 86	CTD	12:12	X		X		X		C-2
2 MF86-2	MB86-1B	47 31.5	122 28.9	18 Aug 86	TM	14:07				X			C-3
3 MF86-2	MB86-1B	47 31.7	122 28.6	18 Aug 86	CTD	14:30	X		X		X		C-3
4 MF86-2	MB86-2	47 24.5	122 31.4	18 Aug 86	TM	16:28				X			C-4
5 MF86-2	MB86-2	47 24.9	122 31.4	18 Aug 86	CTD	17:08	X		X		X		C-4
6 MF86-2	MB86-3	47 19.2	122 29.7	19 Aug 86	TM	08:11				X			C-5
7 MF86-2	MB86-3	47 19.8	122 30.8	19 Aug 86	CTD	09:03	X		X		X		C-5
8 MF86-2	MB86-4	47 19.7	122 26.7	19 Aug 86	TM	10:50				X			C-7
9 MF86-2	MB86-4	47 19.9	122 26.8	19 Aug 86	CTD	11:44	X		X		X		C-7
10 MF86-2	MB86-5	47 20.9	122 24.5	19 Aug 86	TM	14:10				X			C-9
11 MF86-2	MB86-5	47 20.9	122 24.6	19 Aug 86	CTD	14:48	X		X		X		C-9
12 MF86-2	MB86-6	47 22.7	122 21.8	19 Aug 86	CTD	17:02	X		X		X		C-11
13 MF86-2	MB86-7	47 25.3	122 23.3	19 Aug 86	TM	18:29				X			C-13
14 MF86-2	MB86-7	47 25.2	122 23.5	19 Aug 86	CTD	19:14	X		X		X		C-13
15 MF86-2	MB86-8	47 30.3	122 25.5	19 Aug 86	CTD	21:24	X		X		X		C-15
16 MF86-2	MB86-9	47 33.6	122 26.7	20 Aug 86	TM	09:00				X			C-17
17 MF86-2	MB86-9	47 33.9	122 26.5	20 Aug 86	CTD	09:53	X		X		X		C-17
18 MF86-2	MB86-10	47 36.9	122 27.6	20 Aug 86	TM	14:05				X			C-19
19 MF86-2	MB86-10	47 36.9	122 27.4	20 Aug 86	CTD	14:53	X		X		X		C-19
20 MF86-2	MB86-12	47 48.7	122 27.2	20 Aug 86	CTD	17:35							C-21
21 MF86-2	MB86-12	47 48.7	122 27.3	20 Aug 86	TM	17:56				X			C-21
22 MF86-2	MB86-12	47 48.7	122 27.5	20 Aug 86	CTD	18:19	X		X		X		C-21
23 MF86-2	MB86-11	47 42.3	122 27.3	20 Aug 86	TM	20:23				X			C-23
24 MF86-2	MB86-11	47 42.4	122 27.4	20 Aug 86	CTD	20:48	X		X		X		C-23
25 MF86-2	MB86-14	47 56.7	122 32.3	21 Aug 86	TM	10:26				X			C-25
26 MF86-2	MB86-14	47 55.6	122 31.2	21 Aug 86	CTD	11:06	X		X		X		C-25
27 MF86-2	MB86-15	48 01.3	122 37.7	21 Aug 86	TM	13:25				X			C-26
28 MF86-2	MB86-15	48 01.2	122 37.5	21 Aug 86	CTD	14:02	X		X		X		C-26
29 MF86-2	MB86-16	48 05.2	122 37.7	21 Aug 86	CTD	16:01	X		X		X		C-27
30 MF86-2	MB86-16	48 05.1	122 38.0	21 Aug 86	TM	17:43				X			C-27
31 MF86-2	MB86-17	48 08.6	122 43.3	21 Aug 86	CTD	19:58	X		X		X		C-29
32 MF86-2	MB86-17	48 08.3	122 43.4	21 Aug 86	TM	20:28				X			C-29
33 MF86-2	MB86-18	48 12.5	122 53.2	21 Aug 86	CTD	22:30	X		X		X		C-30
34 MF86-2	MB86-19	48 14.4	123 01.1	22 Aug 86	CTD	00:17	X		X		X		C-31
35 MF86-2	MB86-19	48 14.5	123 01.9	22 Aug 86	TM	01:01				X			C-31

3.1.4 Whidbey Basin

One station in Possession Sound (WB86-1), one station in Port Susan (WB86-2) and three stations in Saratoga Passage (WB86-3 to 5) were occupied during August 1986 (Table 7). In addition, 6 surface surface stations were sampled in Skagit Bay by small boat (SB86-1 to -6).

No Whidbey Basin data have been previously report.

Table 7. Sampling Location and Sampling Data for Whidbey Basin

0 Cruise Name	1 Sta. Name	2 Lat. N	3 Long. W	4 Date	5 Cast Type	6 Time Loc.	7 O2	8 CH4	9 Nut	10 Dis TM	11 Part TM	12 POC PON	13 Page
1 MF86-2	WB86-1	47 55.5	122 25.6	23 Aug 86	CTD	10:52	X		X		X		D-2
2 MF86-2	WB86-1	47 55.9	122 25.6	23 Aug 86	TM	11:57				X			D-2
3 MF86-2	WB86-4	48 06.6	122 29.5	23 Aug 86	CTD	13:40	X		X		X		D-4
4 MF86-2	WB86-4	48 06.7	122 29.7	23 Aug 86	TM	14:35				X			D-4
5 MF86-2	WB86-3	48 02.7	122 22.9	23 Aug 86	CTD	16:09	X		X		X		D-6
6 MF86-2	WB86-3	48 02.9	122 22.9	23 Aug 86	TM	17:42				X			D-6
7 MF86-2	WB86-2	48 07.9	122 23.6	23 Aug 86	CTD	19:31	X		X		X		D-7
8 MF86-2	WB86-2	48 07.6	122 23.5	23 Aug 86	TM	20:45				X			D-7
9 MF86-2	WB86-5	48 14.1	122 34.8	24 Aug 86	CTD	06:53	X		X		X		D-9
10 MF86-2	WB86-5	48 14.1	122 34.2	24 Aug 86	TM	07:29				X			D-9
11 MF86-2	SB-1	48 18.3	122 21.0	23 Aug 86	SB	07:30			X	X	X		D-10
12 MF86-2	SB-2	48 20.8	122 21.0	23 Aug 86	SB	07:50			X	X	X		D-10
13 MF86-2	SB-3	48 16.6	122 23.0	23 Aug 86	SB	09:45			X	X	X		D-10
14 MF86-2	SB-4	48 16.0	122 25.5	23 Aug 86	SB	10:05			X	X	X		D-10
15 MF86-2	SB-5	48 17.1	122 27.7	23 Aug 86	SB	10:34			X	X	X		D-10
16 MF86-2	SB-6	48 14.3	122 35.3	23 Aug 86	SB	12:55			X	X	X		D-10

3.1.5 Hood Canal

Eight station in Hood Canal (HC86-1 to -8) were occupied during August 1986 (Table 8). In addition, 4 rivers that flow into Hood Canal and the receiving waters of the Hoodsport power station were sampled from the shore or bridges.

The nutrient data from Hood Canal is discussed in Curl and Paulson (in press) while trace metal data is discussed in Paulson and Curl (in press).

Table 8. Sampling Location and Sampling Data for Hood Canal

	0 Cruise Name	1 Sta. Name	2 Lat. N	3 Long. W	4 Date	5 Cast Type	6 Time Loc.	7 O2	8 CH4	9 Nut	10 Dis TM	11 Part TM	12 POC PON	13 Page
1	MF86-2	HC86-7	47 41.2	122 45.1	22 Aug 86	CTD	07:36	X		X		X		E-2
2	MF86-2	HC86-6	47 35.8	122 57.6	22 Aug 86	TM	09:40				X			E-3
3	MF86-2	HC86-6	47 35.5	122 57.9	22 Aug 86	CTD	10:34	X		X		X		E-3
4	MF86-2	HC86-5	47 26.4	123 06.1	22 Aug 86	CTD	12:54	X		X		X		E-5
5	MF86-2	HC86-5	47 26.4	123 06.1	22 Aug 86	TM	13:39				X			E-5
6	MF86-2	HC86-1	47 24.2	122 54.9	22 Aug 86	CTD	15:30	X		X		X		E-6
7	MF86-2	HC86-2	47 22.9	122 59.1	22 Aug 86	TM	17:06				X			E-7
8	MF86-2	HC86-2	47 22.9	122 59.1	22 Aug 86	CTD	17:30	X		X		X		E-7
9	MF86-2	HC86-3	47 21.3	123 01.9	22 Aug 86	CTD	19:44	X		X		X		E-8
10	MF86-2	HC86-4	47 22.2	123 08.1	22 Aug 86	TM	20:49				X			E-9
11	MF86-2	HC86-4	47 22.7	123 07.8	22 Aug 86	CTD	21:28	X		X		X		E-9
12	MF86-2	HC86-8	47 54.3	122 36.5	23 Aug 86	CTD	08:07	X		X		X		E-10
13	MF86-2	HC86-8	47 54.3	122 36.8	23 Aug 86	TM	08:48				X			E-10
14	MF86-2	SKOK	47 18.4	123 10.1	22 Aug 86	SHORE					X	X		E-12
15	MF86-2	DOSR	47 41.3	122 53.2	22 Aug 86	BRIDG					X	X		E-12
16	MF86-2	HAMA	47 32.6	123 02.6	22 Aug 86	SHORE					X	X		E-12
17	MF86-2	DUCK	47 39.0	122 56.4	22 Aug 86	SHORE					X	X		E-12
18	MF86-2	POWST	47 22.5	123 10.1	22 Aug 86	SHORE					X	X		E-12

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