FINAL REPORT

**Chemical Analysis of Sediment
Cores from the East Waterway
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Sequim, Washington**

June 1984**Prepared for
U.S. Army Corps of Engineers
under a Related Services Agreement
with the U.S. Department of Energy
Contract DE-AC06-76RLO 1830****Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute**

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PACIFIC NORTHWEST LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC06-76RLO 1830

Printed in the United States of America
Available from
National Technical Information Service
United States Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161

NTIS Price Codes
Microfiche A01

Printed Copy

Pages	Price Codes
001-025	A02
026-050	A03
051-075	A04
076-100	A05
101-125	A06
126-150	A07
151-175	A08
176-200	A09
201-225	A010
226-250	A011
251-275	A012
276-300	A013

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CHEMICAL ANALYSIS OF SEDIMENT
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Pacific Northwest Laboratory
Richland, Washington 99352

SUMMARY

Chemical data for two sediment cores from the East Waterway of Everett, Washington, indicate that 20 to 30 cm of contaminated sediments are accumulating per year. The concentrations of several heavy metals (Pb, Hg and Cu), polychlorinated biphenyls (PCBs) and petroleum hydrocarbons increase with depth in the sediments suggesting contamination of this waterway has varied by as much as a factor of 10 during the last 5 years.

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CHEMICAL ANALYSIS OF SEDIMENT CORES
FROM THE EAST WATERWAY (EVERETT, WASHINGTON)

INTRODUCTION

The Seattle District, U.S. Army Corps of Engineers is conducting a general investigation study for improvements to navigation for the existing federal project in Everett Harbor, Washington. The improvement focuses on deepening the East Waterway from its currently authorized -30 feet mean lower low water (MLLW) to a depth between -35 and -45 feet MLLW. Previous studies conducted by the National Oceanic and Atmospheric Administration (NOAA) indicate that surface sediments in the East Waterway are chemically contaminated (Malins et al. 1982). Sediment bioassays conducted by the U.S. Environmental Protection Agency (EPA) Region X have determined that sediments in the East Waterway are toxic to amphipods. The EPA is presently conducting additional sediment toxicity bioassays and chemical analyses on sediments from the Everett area. The work reported here is a subcomponent of the larger study funded by EPA. Other reports that have addressed water quality in Everett included one by the Washington State Department of Ecology (Singleton et al. 1982) and one by the EPA (1983). Currently no data exist regarding the deeper sediments from this harbor.

The principal objective of the work reported here was to determine the extent of chemical contamination at depth compared to surface sediment in the East Waterway. These data will be used to assist in the evaluation of methods for disposing of dredged material.

FIELD SAMPLING

Sediment cores were collected in duplicate at two locations (Stations BPS-29 and BPS-30) in the East Waterway on November 8, 1983 (Figure 1). Latitude, longitude, water depth (referenced to mean lower low water [MLLW]) and core length are listed below:

	<u>BPS-29</u>	<u>BPS-30</u>
Latitude	47° 59.0'N	47° 59.2'N
Longitude	122° 13.3 6W	122° 13.2W
Water depth	14 m	9.8 m
Core length	110 cm	150 cm

One core from each station was sectioned for chemical analysis. The other core was sectioned and stored for back up. The cores were collected using a large diameter Kasten-type gravity corer. The cross section of the barrel was 15 x 15 cm.

CHEMICAL ANALYSES

The methods for chemical analyses were described in detail by Riley et al. 1980, 1981 and Crecelius et al. (in press) and are summarized here. All concentrations are reported on a salt-free, dry-weight basis. Selected petroleum hydrocarbons that were quantified include 20 saturate hydrocarbons with carbon numbers from C₁₂ to C₃₁ and 18 aromatic hydrocarbon components. Six sediment samples were analyzed for several chlorinated organic compounds including polychlorinated biphenyls (PCBs) and chlorinated butadienes (CBDs). For organic chemical analysis, the sediments were soxhlet extracted, subjected to column chromatographic fractionation and the isolated fractions subjected to capillary column gas chromatographic analysis. Inorganic analysis was by either energy dispersive X-ray fluorescence or atomic absorption.

To ensure the quality of the chemical analyses, three sediment standards were analyzed for inorganic elements and our results compared to certified values for these standards (Table 1). Also, for the determination of precision of replicate analyses of homogenized sediment two sediment samples from Everett were analyzed in triplicate. The results from triplicate analyses are shown in Table 2.

TABLE 1. Results of Triplicate Analyses of Standard Marine Sediments

Sediment Standard ^(a)	Major Metals, Percent						Trace Elements, Parts per Million									
	Al	Si	K	Ca	Ti	Fe	Mn	Cr	Ni	Cu	Zn	Hg	Ag	Cd	Pb	As
MESS-1	5.6	27.8	1.91	0.52	0.485	3.02	452	68	30.8	20.7	172	0.171	0.101	0.685	33.4	10.6
(Estuarine mud)	5.7	28.2	1.91	0.53	0.478	2.98	449	98	29.5	22.3	183	0.149	0.097	0.645	34.3	7.9
	5.7	27.3	1.89	0.49	0.503	2.96	430	83	33.3	21.3	174	0.154	0.084	0.688	28.6	9.7
$\bar{x}$	5.7	27.8	1.90	0.51	0.489	2.99	444	83	31.2	21.4	176	0.158	0.094	0.673	32.1	9.4
S	0.1	0.5	0.01	0.02	0.013	0.03	12	15	1.9	0.8	6	0.012	0.009	0.024	3.1	1.4
Certified	5.8	31.6	1.85	0.48	0.543	3.09	513	71	29.5	25.1	191	0.171	(b)	0.59	34.0	10.6
$\pm$	0.2	1.0	0.03	0.04	0.016	0.15	25	11	2.7	3.8	17	0.014		0.10	6.1	1.2
BCSS-1	5.2	27.5	1.93	0.61	0.412	3.37	207	136	58.1	15.3	106	0.130	0.055	0.289	22.5	10.6
(Estuarine mud)	5.4	27.5	1.84	0.59	0.394	3.29	199	116	55.4	13.4	105	0.108	0.047	0.309	21.8	12.2
	6.3	26.8	1.87	0.63	0.392	3.28	195	119	58.5	17.0	106	0.127	0.059	0.290	20.8	11.7
$\bar{x}$	5.6	27.3	1.89	0.61	0.399	3.31	200	124	57.3	15.2	106	0.122	0.054	0.296	21.7	11.5
S	0.6	0.4	0.05	0.02	0.011	0.05	6	11	1.7	1.8	0.6	0.012	0.006	0.011	0.9	0.8
Certified	6.3	30.9	1.80	0.54	0.440	3.28	229	123	55.3	18.5	119	0.129	(b)	0.25	22.7	11.1
$\pm$	0.2	0.5	0.03	0.05	0.013	0.10	15	14	3.6	2.7	12	0.012		0.04	3.4	1.4
NBS-1646	6.3	28.1	2.03	0.85	0.463	3.36	301	69	31.4	14.9	121	0.064	0.101	0.369	25.5	10.8
(Estuarine mud)	5.8	28.1	2.00	0.85	0.456	3.38	314	80	36.6	14.0	126	0.063	0.073	0.387	29.4	10.2
	5.4	27.7	2.01	0.82	0.462	3.34	316	70	32.2	15.6	120	0.071	0.081	0.380	22.4	9.3
$\bar{x}$	5.8	28.0	2.01	0.84	0.460	3.36	310	73	33.4	14.8	122	0.066	0.085	0.379	25.8	10.1
S	0.5	0.2	0.02	0.02	0.004	0.02	8	6	2.8	0.8	3	0.004	0.014	0.009	3.1	0.8
Certified	6.3	(b)	(b)	0.83	(b)	3.35	375	76	32	18	138	0.063	(b)	0.36	28.2	11.6
$\pm$	0.2			0.03		0.10	20	3	3	3	6	0.012		0.07	1.8	1.3

(a) Standards MESS-1 and BCSS-1 were provided by the National Research Council of Canada. Standard NBS-1646 was provided by the U.S. National Bureau of Standards. $\bar{x}$ = mean of triplicate analyses reported for this study; S = one standard deviation, certified value for standard; $\pm$ = one standard deviation about the certified value.

(b) Not certified for these elements.

TABLE 2. Results of Triplicate Analyses for Metals in Two Everett Harbor Sediments

Sediment Sample(a) (Core & Depth)	Major Metals, Percent ^(b)						Trace Elements, Parts per Million ^(b)									
	Al	Si	K	Ca	Ti	Fe	Mn	Cr	Ni	Cu	Zn	Hg	Ag	Cd	Pb	As
BPS-29	4.9	16.7	0.94	1.54	0.314	3.14	392	116	55.2	75.6	200	0.180	0.383	2.53	55.7	14.7
20-25 cm	4.3	16.3	0.93	1.43	0.302	3.08	386	107	56.4	75.7	172	0.175	0.589	2.40	44.9	11.0
	4.8	16.6	0.91	1.52	0.301	3.06	381	100	59.9	77.8	171	0.170	0.366	2.53	45.2	10.3
$\bar{x}$	4.7	16.5	0.93	1.50	0.306	3.09	386	108	57.2	76.3	181	0.175	0.446	2.49	48.6	12.0
S	0.3	0.2	0.02	0.06	0.007	0.04	6	8	2.4	1.2	16	0.005	0.124	0.08	6.2	2.4
RSD(%)	6.8	1.3	1.6	3.9	2.4	1.4	1.4	7.4	4.3	1.6	9.1	2.9	27.8	3.0	12.7	19.7
BPS-30	6.9	26.0	1.21	1.95	0.465	4.45	615	135	70.4	54.8	94.7	0.096	0.114	0.477	14.1	10.3
135-140 cm	7.2	26.5	1.24	1.92	0.475	4.42	578	162	73.1	51.8	98.2	0.108	0.101	0.491	12.5	11.4
	7.5	26.4	1.24	1.93	0.471	4.45	609	158	69.9	51.6	98.6	0.090	0.121	0.494	12.7	11.4
$\bar{x}$	7.2	26.3	1.23	1.93	0.470	4.44	601	152	71.3	52.7	97.2	0.098	0.112	0.487	13.1	11.0
S	0.3	0.3	0.02	0.02	0.005	0.02	20	15	1.7	1.8	2.2	0.009	0.010	0.009	0.9	0.6
RSD(%)	4.2	1.0	1.4	0.8	1.1	0.4	3.3	9.6	2.4	3.4	2.2	9.4	9.1	1.9	6.7	5.8

(a) $\bar{x}$ = mean of three analyses of one homogenous sample; S = one standard deviation; RSD (%) = percent relative standard deviation.

(b) Calculated on a dry-weight, salt-free basis.

RESULTS AND DISCUSSION OF SEDIMENT CORES

The sediments cored in the East Waterway were primarily a mixture of poorly consolidated sand, mud, wood chips and tree bark. However the bottom of each core contained compact mud, indicating the core barrel had penetrated through the sediments that have accumulated since the East Waterway was dredged. The sediments, except for the bottom two sections, were black in color, contained hydrogen sulfide gas and smelled of petroleum. The sources of the wood chips and bark are the wood products industries and log boom storage area in East Waterway. The chemical and physical properties of the sediments indicate the lengths of the cores, 110 cm for Core 29 and 150 cm for Core 30, were long enough to penetrate through the sediments deposited since the waterway was dredged. The sedimentation rate in the East Waterway ranges from 20 to 30 cm per year assuming 100 to 150 cm of sediment has accumulated in the last 5 years. According to dredging records (personal communication with Steven Dice, U.S. Army Corps of Engineers, Seattle District) the East Waterway was last maintenance dredged by the Corps in 1978 under Contract DACW67-78-C-0081. This dredging was completed on October 9, 1978. Under that contract the East Waterway navigation channel was dredged to -34 feet MLLW.

MAJOR METALS

The concentrations of major metals and trace elements in sections of the cores are shown in Tables 3 and 4. The concentrations of the major metals are typical of fine-grained marine sediment. These concentrations generally increase with depth in the cores, probably due to dilution of the sediment with wood chips and bark. The greatest change in these metals occurs in the bottom section of Core 29 and the bottom two sections of Core 30. These three sections were gray in color and did not contain wood and bark. Also, the sediment density was much greater than the less consolidated sediments above.

TABLE 3. Major Metals and Trace Element Content of Core BPS-29, ^(a) Everett Harbor

Depth, cm	Major Metals, Percent ^(b)						Trace Elements, Parts per Million ^(b)									
	Al	Si	K	Ca	Ti	Fe	Mn	Cr	Ni	Cu	Zn	Hg	Ag	Cd	Pb	As
0-5	5.0	17.5	1.00	1.57	0.322	3.33	418	98	57.2	70.7	221	0.177	0.392	2.37	40.2	13.2
5-10												0.207	0.403	2.39	34.1	
10-15	5.5	17.8	0.94	1.52	0.303	3.27	427	126	57.3	71.2	182	0.188	0.372	2.26	40.4	13.0
15-20												0.288	0.368	2.47	46.0	
20-25 ^(c)	4.7	16.5	0.93	1.50	0.306	3.09	386	108	57.2	76.3	181	0.175	0.446	2.49	48.6	12.0
25-30												0.232	0.416	2.37	45.7	
30-35	4.5	18.6	0.98	1.65	0.307	3.14	412	101	59.5	72.4	127	0.235	0.352	2.22	46.7	6.1
35-40												0.163	0.285	1.73	35.1	
40-45	5.0	20.1	0.92	2.17	0.282	3.20	419	107	52.5	60.5	93	0.205	0.243	1.62	35.3	6.3
45-50												0.383	0.336	1.93	44.7	
50-55	6.6	21.9	1.06	1.80	0.364	3.35	480	121	59.9	90.1	125	0.767	0.327	1.86	55.0	9.1
55-60												0.533	0.249	1.53	42.4	
60-65	5.9	25.5	1.14	1.96	0.381	3.59	523	147	56.9	87.0	110	0.804	0.238	1.49	45.2	10.5
65-70												0.153	0.178	0.755	16.1	
70-75												0.201	0.203	1.15	26.1	
75-80	6.5	24.2	1.29	1.80	0.456	4.43	582	158	71.7	75.6	119	0.220	0.225	1.17	29.7	11.9
80-85												0.142	0.215	0.909	20.7	
90-95	7.4	23.5	1.28	1.76	0.451	4.57	579	155	78.2	82.8	124	0.198	0.253	1.05	29.2	14.0
100-105												0.157	0.232	0.673	16.7	
105-110	8.3	22.8	1.44	1.64	0.531	5.98	699	192	97.9	87.5	133	0.121	0.221	0.592	17.5	16.5

^(a) Latitude 47° 59.0'N, longitude 122° 13.3'W; water depth 14 m; Datum MLLW; core length 110 cm, date 11-8-83.

^(b) Calculated on a dry-weight, salt-free basis.

^(c) Represents the mean of a triplicate analysis.

TABLE 4. Major Metals and Trace Element Content of Core BPS-30,^(a) Everett Harbor

Depth, cm	Major Metals, Percent ^(b)						Trace Elements, Parts per Million ^(b)									
	Al	Si	K	Ca	Ti	Fe	Mn	Cr	Ni	Cu	Zn	Hg	Ag	Cd	Pb	As
0-5	6.1	20.8	1.20	1.77	0.372	3.85	518	148	69.4	89.5	365	0.213	0.537	4.63	55.5	15.2
5-10												0.210	0.594	4.73	52.4	
10-15	5.3	20.2	1.16	1.67	0.364	3.86	506	132	68.9	89.3	344	0.174	0.580	4.27	57.4	10.2
15-20												0.325	0.643	3.79	53.8	
20-25	5.6	20.5	1.07	1.61	0.359	3.69	470	120	64.8	90.3	229	0.276	0.562	2.85	61.9	6.6
25-30												0.263	0.339	1.77	48.3	
30-35	6.3	23.3	1.11	1.87	0.397	3.99	513	142	67.3	78.9	184	0.432	0.297	1.58	76.1	5.8
35-40												0.371	0.366	2.10	48.9	
45-50												0.278	0.706	3.44	73.3	
55-60	5.3	21.2	1.08	1.53	0.355	3.74	467	122	68.2	96.7	183	0.324	0.781	3.51	74.8	5.3
65-70												0.315	0.443	1.60	72.7	
75-80												0.791	0.605	2.59	91.2	
85-90	5.7	18.6	1.04	1.57	0.329	3.67	462	125	68.5	156.6	182	0.727	0.713	2.43	92.2	2.7
95-100												1.80	0.524	2.40	86.2	
100-105	5.0	18.5	0.96	1.58	0.318	3.93	443	108	72.8	165.3	206	1.14	0.410	2.57	100.9	4.5
105-110												3.01	0.290	3.25	176.9	
115-120	5.2	19.8	1.05	1.84	0.338	3.94	484	118	78.6	192.9	312	2.18	0.514	2.53	175.3	4.2
125-130												1.33	0.512	2.39	122.0	
135-140 ^(c)	7.2	26.3	1.23	1.93	0.470	4.44	597	151	71.2	52.8	97	0.098	0.112	0.487	13.1	11.0
145-150	7.0	26.1	1.25	1.96	0.456	4.25	585	149	68.6	50.2	91	0.075	0.090	0.432	13.8	10.0

(a) Latitude 47° 59.2'N, longitude 122° 13.2'W; water depth 9.8 m; Datum MLLW; core length 150 cm, date 11-8-83.

(b) Calculated on a dry-weight, salt-free basis.

(c) Represents the mean of a triplicate analysis.

TRACE ELEMENTS

Of the ten trace elements that were analyzed in the cores, Cu, Zn, Hg, Ag, Cd and Pb are significantly elevated compared to other sediments deposited in Puget Sound more than 100 years ago (Pavlou et al. 1983). The profiles of concentration with depth of four heavy metals (Hg, Cd, Pb and Cu) in the cores are shown in Figures 2 through 7. Three conclusions can be made from these data. First, the sediments of East Waterway contain significantly high concentrations of these five heavy metals compared to the bottom of Core 30. Second, the maximum Hg, Pb and Cu contamination occurs at a depth of 100 to 130 cm in Core 30. A subsurface maximum in Hg, Pb and Cu is also present at a depth of 60 cm in Core 29 indicating these metals were probably discharged at a much higher rate in past years than presently in the inner region of East Waterway. Finally, the concentrations of Cd in surface sediments are higher than at depth, suggesting a different history of contamination for Cd than for the other metals.

HYDROCARBONS

Qualitative examination of GC chromatograms of sediment core extracts indicated hydrocarbon patterns that are characteristic of a petroleum distillate. The patterns were similar for both cores. The concentration of 20 saturate hydrocarbons ($C_{12} - C_{31}$) and 18 aromatic hydrocarbons were determined at 10 depths in each core (Tables 5 through 10). Total concentrations of aromatic hydrocarbons with sediment depth are depicted in Figure 8. In both cores the concentrations of hydrocarbons increase with depth, reaching a maximum in the lower third of the core, then decreasing to the lowest concentrations in the bottom sections. The subsurface maximum concentrations are three to eight times greater than the hydrocarbon concentrations in the surface sediment. Although Core 30 is more heavily contaminated than Core 29, the similar vertical distributions in both cores suggest sediments from the entire East Waterway have been heavily contaminated with hydrocarbons. Maximum contamination appears to have occurred following the last dredging at these coring stations. Total

FIGURE 2. Profiles of Mercury (Hg) and Cadmium (Cd) Concentrations with Depth

FIGURE 3. Profile of Lead (Pb) Concentration with Depth in Core BPS-29

FIGURE 4. Profile of Copper (Cu) Concentration with Depth in Core BPS-29

FIGURE 5. Profiles of Mercury (Hg) and Cadmium (Cd) Concentrations with Depth in Core BPS-30

FIGURE 6. Profile of Lead (Pb) Concentration with Depth in Core BPS-30

FIGURE 7. Profile of Copper (Cu) Concentration with Depth in Core BPS-30

TABLE 5.

CONCENTRATION OF SATURATE HYDROCARBONS IN SECTIONS OF CORE BPS-29, CONCENTRATIONS IN MICROGRAMS PER KILOGRAM OF DRY SEDIMENT (PPB).

SATURATE COMPONENT FACTOR	29T 105-110	29S 100-105	29Q 80-85	29N 65-70	29L 55-60	29I 40-45	29G 30-35	29E 20-25	29C 10-15	29A 0-5
DEPTH INTERVAL (CM)										
SAMPLE DRY WT./WET WT.	0.50	0.47	0.53	0.43	0.52	0.50	0.27	0.23	0.32	0.30
DODECANE	10	6	1327	3187	463	3358	2614	913	423	291
TRIDECANE	6	5	954	2545	977	2059	2702	921	153	83
TETRADECANE	8	7	559	1796	640	1096	1200	459	150	225
PENTADECANE	14	16	396	746	805	1007	1632	277	257	88
HEXADECANE	8	11	515	725	772	1059	167	92	92	1631
HEPTADECANE	23	26	746	622	2014	1761	641	823	1083	704
PHYTANE	0	0	644	1605	3010	8044	1579	1278	747	187
OCTADECANE	9	12	688	1118	1972	1239	238	225	160	276
PRISTANE	0	0	599	1494	2801	7484	1469	1189	695	174
NONADECANE	38	54	664	1353	996	726	144	442	1686	419
EICOSANE	27	40	777	1096	2078	1410	411	463	525	414
HENTRICOSANE	74	117	763	1006	2072	1280	454	532	606	269
DOCOSANE	64	78	578	714	1374	995	225	597	366	608
TRICOSANE	183	242	821	1241	1859	1612	449	545	117	232
TETRACOSANE	68	107	877	910	1789	2550	154	256	223	437
PENTACOSANE	602	745	2857	3494	4523	2780	412	650	707	280
HEXACOSANE	161	208	2150	2802	5403	3687	522	166	480	1164
OCTACOSANE	131	222	1497	1513	2606	2359	564	565	731	406
TRICOSANOL	75	230	1693	2392	3276	4169	1203	1411	633	467
HENTRICOSANE	768	992	3161	3799	5889	5745	722	1168	1292	767
TOTAL SELECT SATURATES C11 THRU C31, INCLUDES PHYTANE AND PRISTANE	2270	3118	22265	34157	45321	54419	17500	12973	11145	9122

TABLE 6.

CONCENTRATIONS OF AROMATIC HYDROCARBONS IN SECTIONS OF CORE BPS 29

CONCENTRATIONS ARE IN MICROGRAMS PER KILOGRAM DRY SEDIMENT (PPB).

CORE DEPTH(CM)	40-45	30-35	20-25	10-15	0-5
DRY WEIGHT:WET WEIGHT	0.50	0.27	0.28	0.32	0.30
NAPHTHALENE	774	1353	653	505	535
BENZOTHIOPHENE	N.D.	N.D.	N.D.	N.D.	N.D.
2-METHYLNAPHTHALENE	177	190	116	115	113
1-METHYLNAPHTHALENE	80	86	0	34	34
BIPHENYL	158	303	169	200	255
2,6-DIMETHYLNAPHTHALENE	44	92	N.D.	N.D.	N.D.
2,3,6-TRIMETHYLNAPHTHALENE	81	74	55	45	55
FLUORENE	317	423	309	266	292
DIBENZOTHIOPHENE	62	95	35	0	929
PHENANTHRENE	937	1617	826	872	937
ANTHRACENE	290	400	366	316	346
1-METHYLPHENANTHRENE	631	1098	989	1061	833
FLUORANTHENE	2441	4273	3366	3059	2903
PYRENE	394	1864	1372	1282	1284
CHRYSENE	552	728	413	920	1449
B(E)PYRENE	134	731	207	192	215
B(A)PYRENE	391	630	362	337	474
PERYLENE	271	300	167	156	121
TOTAL SELECT AROMATICS					
NAPHTHALENE - PERYLENE	7733	14254	9406	9359	10775

N.D.-CONCENTRATION IS <5 MICROGRAMS/KILOGRAM DRY SEDIMENT.

TABLE 7.

CONCENTRATIONS OF AROMATIC HYDROCARBONS IN SECTIONS OF CORE DPS 29

CONCENTRATIONS ARE IN MICROGRAMS PER KILOGRAM OF DRY SEDIMENT (PPB).

CORE DEPTH(CM)	105-110	100-105	80-85	65-70	55-60
DRY WGT:WET WEIGHT	0.50	0.47	0.53	0.43	0.52
NAPHTHALENE	59	109	865	992	3212
BENZOTHIOPHENE	N.D.	N.D.	33	48	116
2-METHYLNAPHTHALENE	26	46	195	227	640
1-METHYLNAPHTHALENE	9	17	101	189	405
BIPHENYL	21	24	112	207	360
2,6-DIMETHYLNAPHTHALENE	14	27	73	116	302
2,3,6-TRIMETHYLNAPHTHALENE	5	9	81	142	442
FLUORENE	27	54	336	750	1291
DIBENZOTHIOPHENE	N.D.	10	336	456	1306
PHENANTHRENE	126	241	1213	1736	4167
ANTHRACENE	40	83	494	1142	1749
1-METHYLPHENANTHRENE	68	85	290	800	2162
FLUORANTHRENE	236	406	2319	4015	8233
PYRENE	160	279	1321	2008	4340
CHRYSENE	103	248	1238	2705	3793
B(E)PYRENE	61	52	1326	3122	3930
B(A)PYRENE	127	338	9062	6244	10573
PERYLENE	51	40	2244	3123	2888
TOTAL SELECT AROMATICS NAPHTHALENE - PERYLENE	1132	2067	21647	28101	49908

N.D.-CONCENTRATION IS <5MICROGRAMS/KILOGRAM DRY SEDIMENT

TABLE 8.

CONCENTRATION OF SATURATE HYDROCARBONS IN SECTIONS OF CORE BPS-30. CONCENTRATIONS ARE IN MICROGRAMS PER KILOGRAM OF DRY SEDIMENT (PPB).

DEPTH INTERVAL (CM)	145-150	135-140	115-120	100-95	80-75	40-45	30-35	20-25	10-15	0-5
SAMPLE DRY WT./WET WT.	0.76	0.67	0.42	0.26	0.31	0.30	0.64	0.28	0.26	0.27
DODECANE	0	0	259231	232830	17214	3903	3177	3938	3103	5510
TRIDECANE	0	0	145751	145463	22173	12455	1982	6537	5368	4128
TETRADECANE	0	0	69480	65437	14612	2726	962	3659	2324	3467
PENTADECANE	0	26	157325	162566	22622	2094	1025	2924	2427	5205
HEXADECAN	0	0	19621	34804	13588	481	44	4113	251	377
HEPTADECAN	24	41	23532	9357	12735	1345	127	5439	783	1457
PHYTANE	35	75	142968	19270	20319	3055	226	2686	1529	1439
OCTADECAN	0	16	9015	3493	10458	1062	64	4045	1211	4552
PRISTANE	33	69	133023	17929	18906	2842	210	2499	1422	1338
NONADECANE	4	48	60898	16011	21474	827	323	2976	2173	4955
EICOSANE	22	44	16830	3080	5903	2006	128	7047	4238	6365
HENTRICOSANE	54	83	9305	2392	2551	2351	161	9084	5281	9319
DOCOSANE	41	64	7645	1705	2197	1881	112	5274	5644	5693
TRICOSANE	96	167	9212	1469	1506	2762	226	8344	5673	7844
TETRACOSANE	41	68	8662	838	1672	2284	92	8354	4043	15072
PENTACOSANE	305	470	13834	1447	3676	5721	592	6584	8503	10141
HEXACOSANE	78	139	15429	957	5536	5479	231	13246	2066	17484
OCTACOSANE	43	84	20182	2592	5994	7853	224	9497	997	6507
TRICOSANE	36	75	27610	2524	8590	5941	192	9612	1614	11026
HENTRICOSANE	351	578	20140	1524	11171	11487	577	16538	2084	11226
TOTAL SELECT SATURATES C11 THRU C31, INCLUDES PHYTANE AND PRISTANE	1163	2045	1169692	725688	222897	78553	10674	132397	60734	133228

TABLE 9.

CONCENTRATIONS OF AROMATIC HYDROCARBONS IN SECTIONS OF CORE BPS 30

CONCENTRATIONS ARE IN MICROGRAMS PER KILOGRAM DRY SEDIMENT (PPB).

CORE DEPTH(CM)	45-50	30-35	20-25	10-15	0-5
DRY WEIGHT:WET WEIGHT	0.30	0.64	0.28	0.26	0.27
NAPHTHALENE	831	7495	918	521	3143
BENZOTHIOPHENE	N.D.	1172	N.D.	N.D.	N.D.
2-METHYLNAPHTHALENE	212	210	239	248	434
1-METHYLNAPHTHALENE	73	271	97	95	162
BIPHENYL	40	89	241	203	291
2,6-DIMETHYLNAPHTHALENE	146	48	127	133	169
2,3,6-TRIMETHYLNAPHTHALENE	93	30	112	82	188
FLUORENE	550	485	682	798	1018
DIBENZOTHIOPHENE	146	80	211	284	424
PHENANTHRENE	1697	1158	2332	2214	2629
ANTHRACENE	1090	335	1248	1332	1019
1-METHYLPHENANTHRENE	878	317	2742	1915	1817
FLUORANTHENE	7050	3040	12465	14091	13715
PYRENE	3106	1573	6077	6612	6788
CHRYSENE	2555	578	4601	6060	1276
B(E)PYRENE	882	185	709	560	845
B(A)PYRENE	4303	818	4277	2111	4778
PERYLENE	949	1387	683	347	842
TOTAL SELECT AROMATICS NAPHTHALENE - PERYLENE	24607	19273	37761	37604	37536

N.D.-CONCENTRATION IS <5 MICROGRAMS/KILOGRAM DRY SEDIMENT.

TABLE 10.

CONCENTRATIONS OF AROMATIC HYDROCARBONS IN SECTIONS OF CORE BPS 30.

CONCENTRATIONS ARE IN MICROGRAMS PER KILOGRAM DRY SEDIMENT (PPB).

SAMPLE INTERVAL (CM)	145-150	135-140	115-120	95-100	75-80
DRY WEIGHT:WET WEIGHT	0.42	0.67	0.42	0.26	0.31
NAPHTHALENE	59	91	25378	4348	2619
BENZOTHIOPHENE	N.D.	N.D.	2494	653	385
2-METHYLNAPHTHALENE	N.D.	15	7936	4241	1205
1-METHYLNAPHTHALENE	N.D.	N.D.	5847	2803	1049
BIPHENYL	N.D.	N.D.	3086	3145	995
2,6-DIMETHYLNAPHTHALENE	N.D.	N.D.	2609	2920	465
2,3,6-TRIMETHYLNAPHTHALENE	N.D.	10	4261	6315	1656
FLUORENE	N.D.	44	12258	8481	3342
DIBENZOTHIOPHENE	182	N.D.	9195	5558	3591
PHENANTHRENE	N.D.	148	35817	8408	7440
ANTHRACENE	287	45	7800	41524	4369
1-METHYLPHENANTHRENE	N.D.	151	7069	3294	3267
FLUORANTHENE	176	360	37968	33219	15511
PYRENE	137	223	20954	16772	8260
CHRYSENE	N.D.	81	20077	12364	9271
B(E)PYRENE	N.D.	N.D.	12075	19862	2669
B(A)PYRENE	N.D.	N.D.	33193	39422	7369
PERYLENE	1135	871	10773	10510	1053
TOTAL SELECT AROMATICS					
NAPHTHALENE - PERYLENE	1976	2041	258790	223840	74516

N.D.-CONCENTRATION IS <5 MICROGRAMS/KILOGRAM DRY SEDIMENT.

FIGURE 8. Concentration of total selected aromatic hydrocarbons in sediment cores.

concentrations of selected aromatic hydrocarbons in some core sections appear to be similar to concentrations in some sediment cores analyzed from Waterways adjacent to Commencement Bay (Riley et al. 1981). A similar pattern was observed for Hg, Pb and Cu.

CHLORINATED ORGANICS

Six sediment samples were analyzed for PCBs and scanned for other chlorinated organic compounds in a semiquantitative manner. The identification of these other compounds was based on GC retention time relative to a known analytical standard only and to comparison to distribution patterns of the compound from our previously reported work.

The results of the PCBs analyses are listed in Table 11 and vertical profiles in sediment cores plotted in Figure 9. The maximum concentrations of PCBs was 1610 µg/Kg (as Arochlor 1254) at depth interval 95-100 cm in Core 30. Less than 10 µg/Kg PCBs were detected in the bottom sections of each core. Chlorinated butadienes (CBDs) were the other chlorinated organic compounds detected in the surface and mid-depth core sections. The only CBD compound that was quantified was hexachlorobutadiene which was approximately 100 µg/Kg in the mid-depth section of each core and <13 µg/Kg in the bottom section.

TABLE 11. Concentrations of PCBs as Arochlor 1254 in Sediments (µg/Kg dry wt)

<u>Core Stations</u>	<u>Depth (cm)</u>	<u>PCBs</u>
BPS-29	0-5	210
	65-70	320
	105-110	<10
BPS-30	0-5	1040
	95-100	1610
	145-150	<10

FIGURE 9. Concentration of PCBs as Arochlor 1254 in Sediment Cores

CONCLUSIONS

Based on the results of two cores, it appears that approximately 1 to 1.5 meters of sediment has been deposited in East Waterway since it was last dredged by the Corps in 1978.

The sediments of East Waterway are contaminated with Hg, Ag, Zn, Cd, Pb, Cu, saturated hydrocarbons, aromatic hydrocarbons and PCBs. Malins et al. (1982) reported similar concentrations for Hg, Cd, Pb, As and aromatic hydrocarbons in a surface sediment collected near our Station BPS-29. Their results, compared to those reported in this study, are compared in Table 12.

The subsurface sediments contain as much as five times greater concentrations of contaminants than surface sediments. The thickness of contaminated sediments was between 0-110 cm at Station BPS-29 and 0-130 cm at Station BPS-30. The sediments for deeper than 135 cm at Station BPS-30 contain lower concentrations of contaminants than surface sediments in Possession Sound or the main basin of Puget Sound (Pavlou et al. 1983).

TABLE 12. Comparison of the Concentration of Contaminants in East Waterway Surface Sediment ($\mu\text{g/g}$ dry wt)

<u>Contaminant</u>	<u>This Study BPS-29, $\mu\text{g/g}$</u>	<u>Malins et al. 1982 Station 2(05215), $\mu\text{g/g}$</u>
Hg	0.19	0.26
Cd	2.4	1.7
Pb	37	36
As	13	19
Aromatic hydrocarbons	10.8	5.1

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