EAST WATERWAY - EVERETT, WASHINGTON
SITE MANAGEMENT PLANNING PROJECT

DOCUMENT REVIEW

Contract No.: C0089007

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1.0 INTRODUCTION

Under Model Toxics Control Act regulations (WAC 173-340), the Washington State Department of Ecology (Ecology), Toxics Cleanup Program, has initiated an investigation of the East Waterway located near the City of Everett, Snohomish County, Washington. A number of active and historic sources of contamination, including industrial and municipal discharges, potentially have contributed to impacts on the natural resources of East Waterway. Information related to these impacts, land use, and past and current conditions in East Waterway has been reported in an extensive collection of documents which at the time of project initiation had not yet undergone a comprehensive review, evaluation, and assimilation within the context of the Model Toxic Control Act.

Recognizing the significance of these documents and the importance of such a review to the development of site management strategies, Ecology initiated a work assignment (#16) with Ecology and Environment, Inc. (E & E) under contract No. C0089007 which included the detailed review of site-related documents. This document presents the final compendium of reviews performed under this task as described by the Ecology scope of work (August 1990) and E & E Work Plan (Document Control Number WD4020.1.1). Details of the review process and a complete listing of review documents are provided in the following section.

2.0 SUMMARY

Documents reviewed as a part of this task include:

Anderson, J.W., May 1985, Final Report, Biological and Chemical Analysis of Sediments for the Design and Construction of the U.S. Navy Homeport Facility at East Waterway - Everett Harbor, Washington, prepared for the U.S. Army Corps of Engineers, Seattle District by Battelle, Pacific Northwest Laboratory, Richland, Washington.

Anderson, J.W. and E.A. Crecelius, February 1985, Analysis of Sediments and Soils for Chemical Contamination for the Design of U.S. Navy Homeport Facility at East Waterway of Everett Harbor, Washington, prepared by Battelle, Marine Research Laboratory, Sequim, Washington.

Battelle Northwest, 1986, Reconnaissance Survey of Eight Bays in Puget Sound, Pacific Northwest Laboratory, December 1986, for U.S. Environmental Protection Agency, Region 10.

Chapman, P.M., R.N. Dexter, J. Morgan, R. Fink, D. Mitchell, R.M. Kocan, and M.L. Landolt, 1984, Survey of Biological Effects of Toxicants Upon Puget Sound Biota, Phase III, Tests in Everett Harbor, Samish and Bellingham Bays, NOAA Technical Memorandum NOS-OMS2, National Oceanic and Atmospheric Administration, Rockville, Maryland.

Crecelius, E.A. and J.W. Anderson, May 1986, Biological and Chemical Analysis of Sediments for the Design and Construction of the U.S. Navy Homeport Facility at East Waterway - Everett Harbor, Washington, Phase III, prepared by Battelle, Marine Research Laboratory, Sequim, Washington.

Crecelius, E.A., N.A. Bloom, and J.M. Gurtisen, May 1985, Distribution of Contaminants in Sediment Cores and Mass Balance of Contaminants Discharged to East Waterway and Port Gardner, Everett, Washington, prepared by Battelle, Marine Research Laboratory, Sequim, Washington.

Hart Crowser, May 1987, Sediment Sampling and Testing Final Report, Proposed Carrier Pier and Breakwater Site, NAVSTA Puget Sound, Contract N62474-85-C-5233, Everett, Washington.

Malins, D.C., B.B. McCain, D.W. Brown, A.K. Sparks, H.O. Hodgins, and S-L Chan, 1982, Chemical Contaminants and Abnormalities in Fish and Invertebrates from Puget Sound, NOAA Technical Memorandum OMPA-19, National Oceanic and Atmospheric Administration, Rockville, Maryland.

Malins, D.C., M.M. Krahn, D.W. Brown, L.D. Rhodes, M.S. Myers, B.B. McCain, and S-L Chan, 1985, Toxic Chemicals in Marine Sediment and Biota from Mukilteo, Washington: Relationships with Hepatic Neoplasms and Other Hepatic Lesions in English Sole (Parophrys vetulus), J. Natl. Cancer Institute, 74:487-494.

PTI Environmental Services, March 1989, Puget Sound Estuary Program, Everett Harbor Action Program: 1989 Action Plan, prepared for United States Environmental Protection Agency, EPA 910/9-89-006.

SAIC, 1989, Summary Technical Memorandum Review of Scott Everett Pulp and Paper Mill, 304 (1) Technical Assistance (Region 10), draft, prepared for U.S. Environmental Protection Agency, Region 10.

Storer, R.S. and P.M. Arsenault, August 1987, Combined Sewer Overflow Receiving Water Sediments Sampling and Analysis Program, Ott Water Engineers, Seattle, Washington.

Tetra Tech, Inc., September 1988, Puget Sound Estuary Program Everett Harbor Action Program: Evaluation of Potential Contaminant Sources, Final Report, prepared for U.S. Environmental Protection Agency, Region 10.

Tetra Tech, Inc. and PTI Environmental Services, September 1988, Everett Harbor Action Program: Analysis of Toxic Problem Areas TC-3338-26 Final Report, September 1988, prepared for United States Environmental Protection Agency, Region 10 - Office of Puget Sound, Seattle, Washington.

URS Consultants, Inc. 1989a, East Waterway Cleanup Reconnaissance Study RI/FS and EIS Workplan - Preliminary Draft, Everett, Washington, prepared for the Washington State Department of Ecology, Olympia, Washington.

URS Consultants, Inc., 1989b, Draft, East Waterway Cleanup Reconnaissance Study - Associated Issues Report, prepared for Washington State Department of Ecology.

United States Army Corps of Engineers, 1985a, Final Report, U.S. Navy Homeport Facility at East Waterway, Everett Harbor, Washington: Biological and Chemical Analyses of Sediments, United States Army Corps of Engineers, Seattle, Washington.

United States Army Corps of Engineers, 1985b, Analysis of Sediments and Soils for Chemical Contamination for the Design and Construction of U.S. Navy Homeport Facility at East Waterway of Everett Harbor, Washington, prepared for U.S. Department of the Navy, Seattle District, U.S. Army Corps of Engineers, Seattle, Washington.

United States Army Corps of Engineers, Seattle District, November 1986, Final Supplement to United States Navy Environmental Impact Statement, Carrier Battle Group, Puget Sound Region Homeporting Project, Volume 1, Chapters 1-12.

United States Department of Navy, 1985, Final Environmental Impact Statement, Carrier Battle Group Puget Sound Region Ship Homeporting Project, Technical Appendices, United States Department of Navy, Western Division, Naval Facilities Engineering Command, San Bruno, California.

Washington State Department of Ecology and City of Everett, 1986, Draft Supplemental Environmental Impact Statement for U.S. Navy's proposed Everett "Homeport", Northwest Regional Office, Washington State Department of Ecology, Redmond, Washington, and City of Everett, Washington.

Washington State Department of Ecology, 1990, Scott Paper Company Everett Plant Draft NPDES Permit and Fact Sheet.

Document review topics were selected to evaluate document contents in terms of requirements established for site investigations and remedial actions under the State of Washington Model Toxics Control Act regulations. These topics, presented in Table 2-1, formed the basis of the review format used to conduct reviews. Review reports, based on this format, were produced for each individual document and in the case of the Navy Homeport EIS (Navy 1985) for each assigned technical appendix. Attachments to the review reports include pertinent summary information, such as data reports and maps providing station locations, which were excerpted directly from the document being reviewed. Review reports for each document have been compiled and incorporated herein to produce this document evaluation report.

Because of the wide variety of document types under review, not all review topics were appropriate to all documents. Table 2-2 summarizes those review topics that were addressed in each document review report. Review comments and evaluations will be used as the base of information for preparation of a comprehensive proposal for an East Waterway site management which is consistent with requirements of the Model Toxics Control Act regulations and relevant/appropriate components of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP, 40 CFR 300).

Table 2-1

REVIEW TOPIC SECTIONS

Section 1.0	INTRODUCTION AND CHRONOLOGY OF EVENTS
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Section 3.0	DEMOGRAPHICS AND LAND USE
Section 4.0	POTENTIALLY LIABLE PERSONS
Section 5.0	IDENTIFICATION OF POLLUTION POINT SOURCES
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Section 9.0	DATA QUALITY
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Section 11.0	DREDGING AND DISPOSAL ISSUES AND DATA
Section 12.0	ENVIRONMENTAL IMPACTS
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Section 14.0	COMMUNITY RELATIONS INFORMATION
Section 15.0	RECOMMENDATIONS
Section 16.0	FINAL COMMENTS

Table 2-2

DOCUMENT REVIEW SUMMARY

Document	Sections 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
A. Anderson, J.W., 1985	√	√					√	√	√		√				√	√
B. Anderson, J.W. and E.A. Crecelius, 1985	√	√						√		√	√	√		√	√	√
C. Battelle Northwest, 1986	√						√	√	√						√	√
D. Chapman, P.M. et al., 1984	√				√	√	√	√	√						√	√
E. Crecelius, E.A. and J.W. Anderson, 1986	√	√			√		√	√	√		√	√			√	√
F. Crecelius, E.A. et al., 1985	√			√	√	√	√		√	√					√	√
G. Hart Crowser, 1987	√	√		√			√			√	√	√			√	√
H. Malins et al., 1982	√				√	√	√	√	√							
I. Malins et al., 1985	√						√	√	√						√	
J. PTI, 1989	√	√	√	√	√	√	√	√	√	√	√	√		√	√	√
K. SAIC, 1989	√	√		√	√	√	√	√	√						√	
L. Storer, R.A. and P.M. Arsenault, 1987	√	√					√			√						√
M. Tetra Tech, 1988a	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
N. Tetra Tech, 1988b	√			√	√	√	√	√	√	√	√	√		√	√	√
O. URS Consultants, 1989a	√	√					√		√					√	√	√
P. URS Consultants, 1989b	√	√	√	√	√	√	√	√	√	√		√			√	√
Q. United States Army Corps of Engineers, 1985a	√	√					√	√	√		√	√		√	√	
R. United States Army Corps of Engineers, 1985b	√	√					√		√		√				√	√
S. United States Army Corps of Engineers, 1986	√	√					√	√	√		√	√	√	√	√	√
T. United States Department of the Navy, 1985																
T1. Appendix A: Sediment Movement Evaluation	√									√	√	√			√	√
T2. Appendix B: Biological Species List	√							√	√						√	
T3. Appendix C: Juvenile Salmonid Study	√		√				√	√	√	√		√			√	√
T4. Appendix D: Correspondence from the Washington State Office of Historic Preservation	√															
T5. Appendix J: Water Quality Data	√	√													√	
T6. Appendix L: Regional Distribution of Waterbirds	√								√						√	√
T7. Appendix M: Guidelines for Specification of Disposal Sites for Dredged or Fill Material	√														√	
T8. Appendix N: Distribution of Contaminants in Everett Harbor	√														√	
T9. Appendix R: Juvenile Salmonid Stomach Analysis	√						√	√	√			√			√	√
T10. Appendix S: Benthics	√	√			√			√	√		√	√	√		√	√
T11. Appendix T: Epibenthics	√	√			√			√	√		√	√			√	√
T12. Appendix U: Demersal Fish	√						√	√	√			√			√	√
T13. Appendix V: Marine Mammal Study	√							√	√			√			√	√
T14. Appendix W: Seabird Survey	√							√	√			√			√	√
U. Washington State Department of Ecology, 1986	√	√					√	√	√	√	√	√	√	√	√	√
V. Washington State Department of Ecology, 1990	√	√			√		√						√			

WD4030.1.0

3. DOCUMENT REVIEWS

Appendix A

EAST WATERWAY - EVERETT, WASHINGTON
SITE MANAGEMENT PLANNING PROJECT

DOCUMENT REVIEW

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Prepared For:

WASHINGTON STATE DEPARTMENT OF ECOLOGY
Toxics Cleanup Program

EAST WATERWAY TECHNICAL DOCUMENT REVIEW

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ATTACHMENTS

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1.0 INTRODUCTION AND CHRONOLOGY OF EVENTS

The report reviewed is one of a number that were prepared by Battelle Northwest for the United States Army Corps of Engineers (COE). The COE was requested by the United States Navy to assist in developing a sediment assessment program for the proposed Homeport facility to be located in the East Waterway of Everett Harbor, Washington. This study evaluates organic, conventional, and trace metal sediment parameters of the East Waterway and focuses on the bioaccumulation of organics and metals by bivalves exposed to East Waterway sediments, toxicity of East Waterway sediments to amphipods, and infaunal analysis of Port Gardner sediments. The report reviewed is presented as Appendix B to the Final Report, U.S. Navy Homeport Facility at East Waterway, Everett Harbor, Washington: Biological and Chemical Analyses of Sediments, which was prepared by the Seattle District, COE, May 3, 1985. Results and findings of the Anderson study are discussed in the COE report.

The following chronological events led to the development of the reviewed report:

- o The COE requests that Battelle, Pacific Northwest Laboratory (PNL) assist the COE with sampling and testing of East Waterway Everett sediments.
- o Sediment samples collected between February 19 and 23, 1985 from Everett East Waterway and surrounding areas.
- o Physical, chemical, and biological testing conducted by Battelle PNL at Sequim, Washington.

2.0 LEGAL AND REGULATORY ISSUES

This study was conducted in order to characterize potential aquatic disposal areas in Port Gardner which could receive contaminated sediments from the East Waterway. Specific regulatory issues pertaining to dredge and disposal of these sediments are not discussed. Comparisons are made of polynuclear aromatic hydrocarbons (PAH) levels at the Fourmile Rock disposal site and potential Port Gardner disposal sites. The information presented was intended for inclusion into the Navy's final environmental impact statement for the proposed Homeport facility.

3.0 DEMOGRAPHICS AND LAND USE

N/A

4.0 POTENTIALLY LIABLE PERSONS

N/A

5.0 IDENTIFICATION OF POLLUTION POINT SOURCES

N/A

6.0 IDENTIFICATION OF POLLUTION NON-POINT SOURCES

N/A

7.0 CHEMICAL DATA

Data Collection

The following sample collection summary includes samples collected for the biological analyses as well as those collected for chemical and physical analyses.

Twenty cores were collected using a 15-foot long Vibracorer with 4-inch diameter coring tubes. Nineteen of the 20 stations were located as near as possible to 19 stations which were sampled previously (Anderson and Crecelius 1985). One additional core was also collected and these cores were composited to yield six separate samples (see Attachment A for Sediment Sampling Locations). Eleven other stations (representing eight potential disposal sites) were sampled using a 0.1 m Van Veen sampler (see Attachment B). Five replicates were collected per station (total of 55 grab samples).

Information was not presented on methods for station positioning or sample collection.

Analytical Testing

Sediment core composites and grab samples were analyzed for selected organics, metals, and conventional parameters.

Results

Analytical data summaries for chemical and physical parameters are provided in Attachment C.

Organics. Gas chromatographic analysis of selected aromatic hydrocarbons at the 11 potential disposal sites showed concentrations ranging from below detection to 59 ppm total PAHs. Subsurface sediments from the East Waterway (six composites) exhibited total PAH concentrations of from 2 to 7 ppm. Polychlorinated biphenyls (PCBs) (only Aroclor 1254 was analyzed) ranged from <1 ppb to 310 ppb in East Waterway sediments and from potential disposal sites.

Conventionals. East Waterway sediments ranged from 0.1 to 0.9 percent gravel, 29 to 56 percent sand, 35 to 50 percent silt, 10 to 20 percent clay and 0.8 to 1.4 percent total organic carbon. Potential disposal sites ranged from 0 to 39 percent gravel, 39 to 97 percent sand, 0.8 to 40 percent silt, 2.1 to 11 percent clay and 0.3 to 31 percent total organic carbon.

Metals. The concentration of trace metals present in sediments from potential disposal sites (only mercury, cadmium, copper, zinc, lead, and arsenic were analyzed) were said to all be below those present in sediments from the Fourmile Rock disposal site. Sediments from lower sections of sediment cores from East Waterway were said to exhibit concentrations that were generally lower than those of surface sediments from potential disposal sites.

Data Quality

Field Methods. The quality of field data collected cannot be verified because no information was presented regarding sample collection methods.

Organics. A quality control/quality assurance (QA/QC) document was presented in the report appendix that identifies the methods and QC procedures followed during analytical testing. Precision and accuracy were said to follow COE guidelines, but QC results were not presented for sediment testing.

Metals. Duplicate and spike quality control sediment analysis results for East Waterway and potential disposal sites were not presented, and therefore, the metals results cannot be verified. Replicate and spike results for metals analysis of tissues indicated acceptable levels of precision and accuracy.

8.0 BIOLOGICAL DATA (FLORA/FAUNA)

Biological data summaries are provided in Attachment D.

Laboratory Testing

Amphipod bioassays were conducted on each of six composites taken from the bottom section of cores in the Everett Harbor Waterway. Bioaccumulation of sediment contaminants by clams (Macoma) and mussels (Mytilis) were evaluated for these sediments. Infaunal analysis was also conducted on replicate (5) grab samples (0.1 m^2) collected at the potential disposal sites.

Results

Bioaccumulation. The bioaccumulation studies of mussels and clams were conducted in two series. The first was conducted as part of studies completed earlier by Anderson and Crecelius (1985) and the second as part of this study. The author reports that the first series (13-day exposure) showed few indications of bioaccumulation but that zinc and lead did accumulate in mussels exposed to East Waterway sediments from two stations (E-4-T and E-11-T), and PAH was accumulated by clams exposed to sediments from one EEW station (E-15-Top). For the

21-day exposure tests, PCBs and PAHs were strongly bioaccumulated by mussels while mercury and copper were strongly accumulated by both bivalves.

Amphipod Toxicity. Amphipod toxicity was exhibited by East Waterway sediments and by control sediments from Sequim Bay. Four of the six East Waterway sediments exhibited significant toxicity to amphipods. The authors state that toxicity of Sequim Bay sediments was a result of grain size (although no grain size data are presented).

Amphipod bioassay tests did not, according to the author, correlate well with the bioaccumulation data or the sediment contaminant analyses. The highest concentrations of sediment PAH were not particularly toxic to the amphipods. However, several sediment composite samples, as well as Sequim Bay sediments, reduced amphipod survival from a mean of 19 for background habitat sand to about 13 individuals (20 organisms, with 4 or 5 replicates) (Table 12 in Attachment E).

Infaunal Analysis. The infaunal analysis results indicate that polychaetes are the dominant species present at potential dredge disposal site stations. Infaunal analysis was not conducted on East Waterway sediments.

The diversity of benthic infauna was observed to be lowest at stations 1 and 2, highest at stations 5 and 7 and intermediate at most others.

Data Quality

For the 13-day bioaccumulation studies, PAH and Aroclor 1254 replicates were analyzed for mussel tissue and indicated acceptable levels of precision (i.e., relative percent difference [RPD] of 18 and 35 percent, respectively). No replicate tissues were tested or analyzed for PAHs for the 21-day bioaccumulation studies. Accuracy was measured through spiking of Cabezon tissue with selected PAHs. Percent recoveries were presented but without control limits; thus it was not possible to determine if acceptable recoveries were obtained. Replicate testing of metals was conducted for clam tissue and standard reference tissue (see Table 5 in Attachment E).

The amphipod bioassay data results indicated that control sediments from Sequim Bay significantly affected the survival of amphipods. Interpretation of the results may not be appropriate based upon simple subtraction of Sequim Bay mean mortalities from East Waterway sediments, thus yielding a statistically significant difference (i.e., significant amphipod mortality) for only one East Waterway station.

QA/QC data were not provided for the infaunal analyses conducted as part of this study.

9.0 DATA QUALITY

As noted previously, the quality of field data collected cannot be verified because no information is presented regarding sample collection methods. This includes station positioning and locations of sample collection.

Because control limits were not identified for the analytical testing performed, it was not possible to fully evaluate the quality of the data presented.

Interpretation of the results of the amphipod bioassays appears to have been influenced by Sequim Bay control sediments which resulted in significant amphipod mortality. Comparison of East Waterway responses to Sequim Bay sediments results in only one East Waterway station having amphipod mortality. However, comparison of native sediments with East Waterway sediments results in five East Waterway stations exhibiting significant toxicity to amphipods.

10.0 HYDROLOGIC AND HYDRODYNAMIC INFORMATION

N/A

11.0 DREDGING AND DISPOSAL ISSUES AND DATA

Dredging and disposal issues are addressed with regard to the suitability of the 11 proposed disposal sites and the six East Waterway composite sites studied. The concentrations of total PAHs present at these sites were compared with United States Environmental Protection Agency (EPA) sediment criteria and Fourmile Rock disposal site levels (see Attachment E). Low Molecular Weight PAHs (LPAH) concentrations from East Waterway exceeded the Fourmile Rock levels for three of six stations, but High Molecular Weight PAHs (HPAH) concentrations at all six sites were below Fourmile Rock levels. For the 11 proposed disposal sites, three exceeded LPAH concentrations at Fourmile Rock, while one station exceeded HPAH concentrations at the existing disposal site.

The only statement made with regard to the biological effects of dredging based on the data results presented was in reference to infauna: "Dredged material disposal options can take these findings into consideration when estimating the potential impacts of disposal and likely recovery rates for the infauna."

12.0 ENVIRONMENTAL IMPACTS

N/A

13.0 INTERIM MEASURES/SPILL AND POLLUTION PREVENTION MEASURES

N/A

14.0 COMMUNITY RELATIONS INFORMATION

N/A

15.0 RECOMMENDATIONS

This document discusses the results of biological testing (amphipod bioassay and bioaccumulation) conducted on East Waterway sediments as part of studies conducted for the Seattle Office of the COE. A stated purpose of the report is to describe the general character of potential disposal sites identified by the Navy within the Port Gardner area. While the general character of such sites is identified with regard to chemistry and biology, the report stops short of providing recommendations that identify the suitability of any of these sites for contaminant disposal.

The data presented in this report should be compared and combined with the entire series of Battelle documents prepared for the Seattle Office of the COE. Cross-referencing between these documents and the resulting reports prepared by the COE can sometimes be confusing.

16.0 FINAL COMMENTS

The report notes that three of the 11 potential disposal sites investigated (EDS-2, 4, and 8) would not be suitable for disposal for contaminated sediments from the East Waterway. This is based upon the concentrations of LPAH and HPAH present at these sites.

The report provides documentation regarding bioaccumulation of metals and organics from organisms exposed to East Waterway contaminated sediments. In addition, amphipod bioassays conducted confirm the toxicity of East Waterway sediments, while the infaunal analyses document the numbers and diversity of those species present within the surrounding Port Gardner area.

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Attachment A

SEDIMENT SAMPLING LOCATIONS (VIBRACORER)

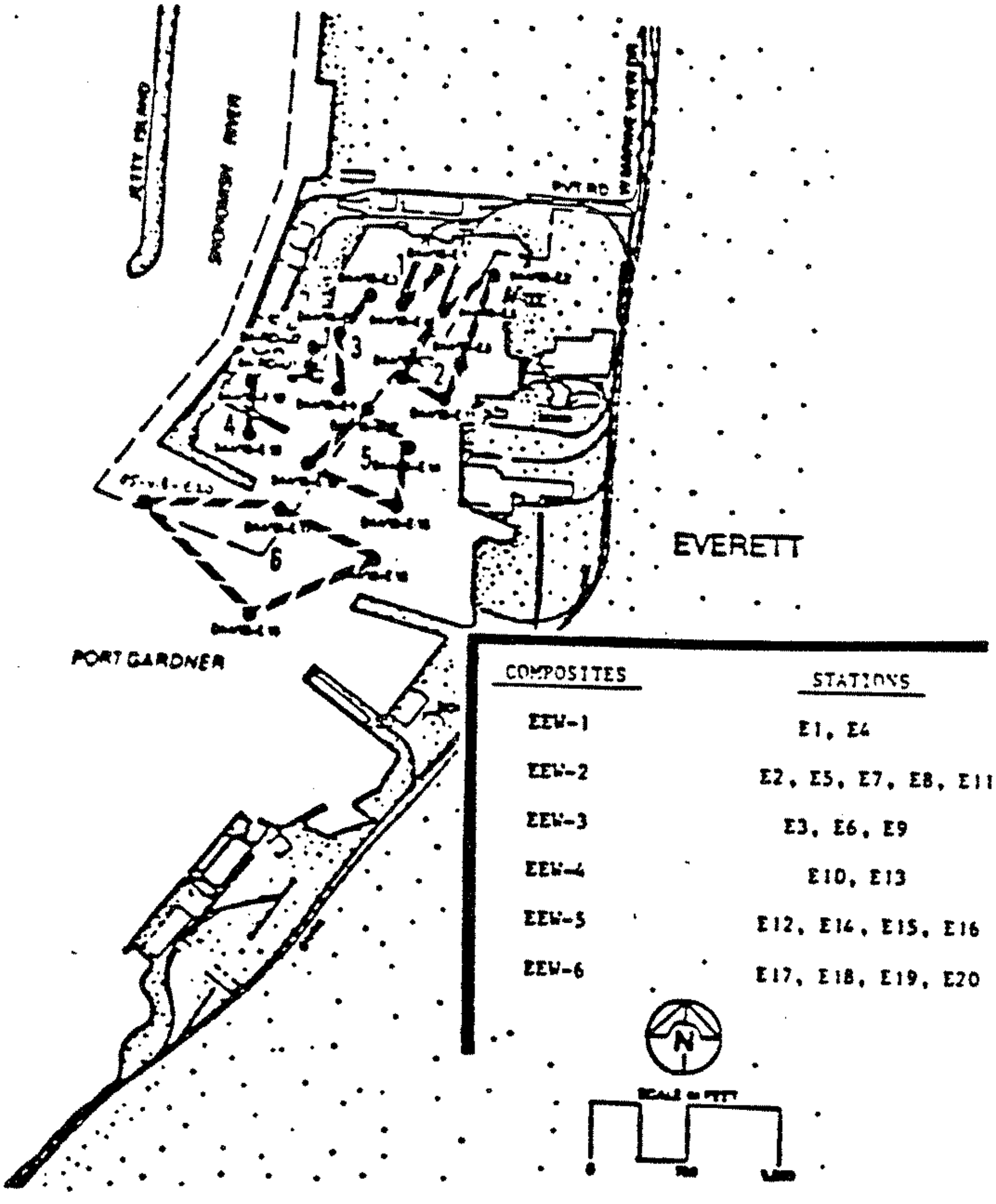

FIGURE 1. Sediment Sampling Locations in the East Waterway

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Attachment B

SEDIMENT SAMPLING LOCATIONS (VAN VEEN GRAB)

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6/7 Deep Delta site

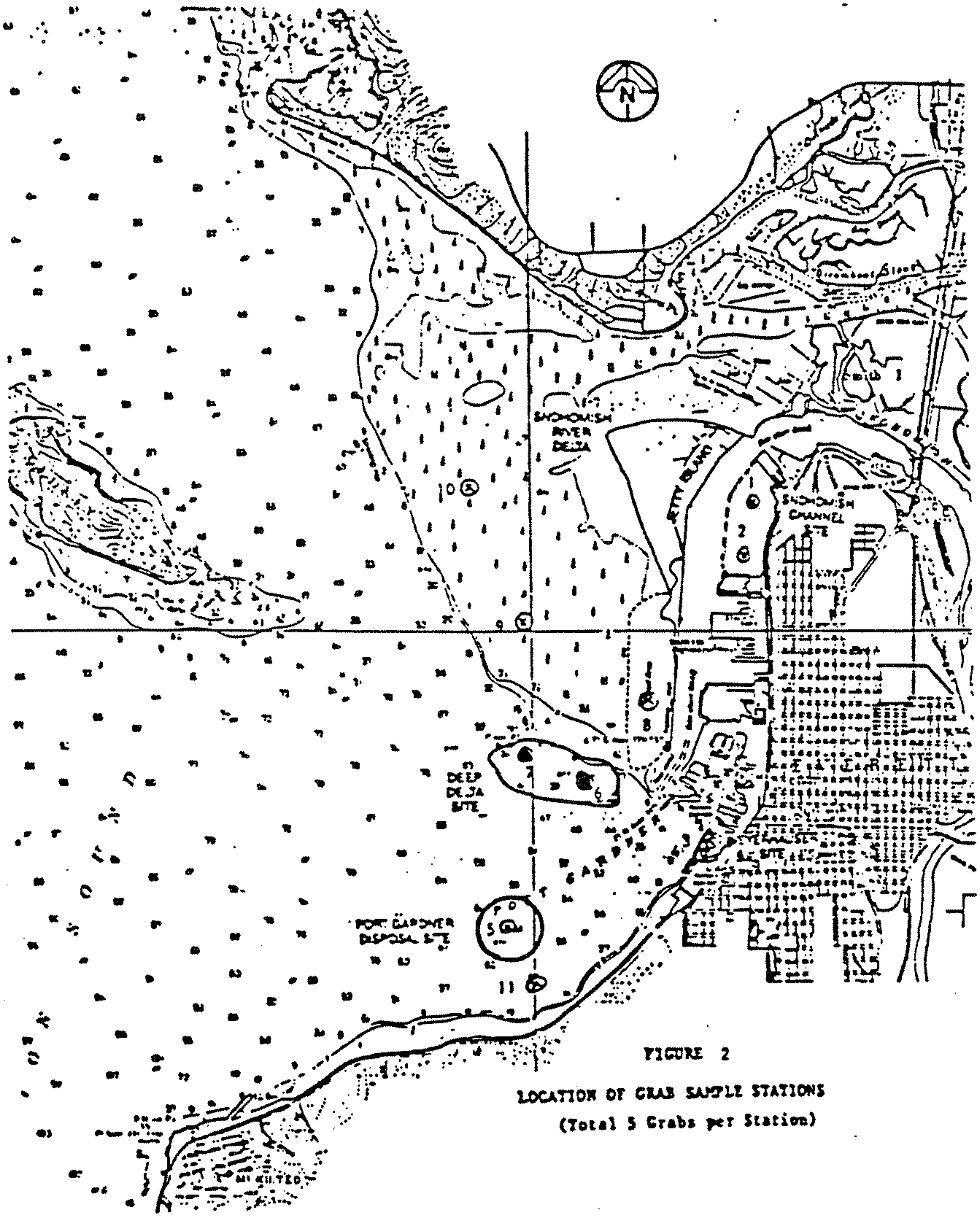

FIGURE 2

LOCATION OF GRAB SAMPLE STATIONS

(Total 5 Grabs per Station)

Attachment C

CHEMICAL AND PHYSICAL ANALYSES DATA SUMMARIES

SNOHOMISH CHANNEL

Table 6.

Everett Disposal Site Sediment

Sample I.D	EDS-1	EDS-2	EDS-3	EDS-4	EDS-5	EDS-6	EDS-7	EDS-8	EDS-9	EDS-10	EDS-
Battelle's I. D. *	1170A	1164A	1168A	1172A	1166A	1158A	1132A	1156A	1130A	1138A	1162A
Wet weight extracted (grams)	50	50	50	50	50	50	50	50	50	50	50
Dry.Wet weight ratio	0,56	0 548	0.424	0.308	0.508	0 628	0.652	0.66	0.674	0.632	0.696
Concentration units µg/kg dry wt.											
Secbutylbenzene	*	*	*	*	*	*	*	*	*	*	*
1-methyl-4-isopropylbenzene	*	621	1081	1320	57	71	31	294	*	*	197
Indan	*	*	*	*	*	*	*	*	*	*	*
Indene	*	*	*	*	*	*	*	*	*	*	*
1-3-dimethyl-5--ethylbenzene	*	*	*	*	*	*	*	*	*	*	*
1-2-diethylbenzene	238	177	*	319	17	*	*	*	*	*	*
1-2-dimethy-4-ethylbenzene	152	7	*	*	4	*	*	5	*	*	*
1,2,3,5-tetrame ethylbenzene	*	8	*	*	*	*	*	3	*	*	*
Naphthalene	132	393	*	467	53	107	115	434	99	*	251
Benzothiophene	*	*	*	*	*	*	*	17	*	*	5
2-methylnaphthalene	49	113	*	107	18	30	39	162	*	*	44
1-methylnaphthalene	31	82	*	561	12	19	27	106	*	*	32
Biphenyl	13	29	*	53	7	6	17	26	*	*	14
2-6-dimethylnaphthalene	12	33	*	*	11	19	24	36	*	*	10
Acenaphthylene	21	66	*	101	8	17	45	48	*	*	37
Acenaphthene	43	53	88	417	24	17	20	60	*	*	31
2,3,6-trimethylnaphthalene	29	52	52	64	9	7	10	26	*	*	12
Fluorene	36	95	95	373	30	30	31	89	*	*	48
Dibenzothiophene	19	86	*	*	5	*	27	77	*	*	38
Phenanthrene	102	380	*	952	8	106	160	455	*	*	307
Anthracene	46	121	*		39	38	52	129	*	*	69
1-methylphenanthrene	140	139	*	*	56	*	*	146	55	*	*
Fluoranthene	204	518	1765	1484	200	181	234	679	110	*	480
Pyrene	426	738	6321	20974	526	422	402	1004	792	*	606
Benzo(A)anthracene	126	319	*	1687	160	109	138	328	*	*	176
Chrysene	154	323	*	*	184	112	145	260	*	*	196
Benzo(b)fluoranthene	290	511	*	*	299	130	286	494	*	*	307
Benzo(k)fluoranthene	181	350	285	5861	519	*	165	448	99	*	190
Benzo(e)pyrene	1788	1991	*	8539	1541	478	640	835	*	*	494
Benzo(a)pyrene	*	1370	*	16090	582	75	765	823	*	*	843
Perylene	475	793	*	*	385	131	457	473	*	*	408
Indeno(1,2,3-c,d)pyrene	703	*	*	*	395	*	*	*	*	*	427
Dibenz(a,h)anthracene	*	853	*	*	*	*	*	*	*	*	*
Benzo(g,h,i)perylene	410	*	*	*	52	*	*	*	*	*	55
TOTAL	5821	10222	9711	59390	5203	2106	3829	7458	1155	*	5276

Table 7.
Everett East Waterway Sediment

Sample I.D.	Comp 1	Comp 2	Comp 3	Comp 4	Comp 5	Comp 6
Battelle's I.D. *	1152A	1154A	1136A	1174A	1128A	1160A
Wet weight extracted (grams)	50	50	50	50	50	50
Dry:Wet weight ratio	0.75	0.73	0.66	0.750	0.69	0.69
Concentration units µg/kg dry wt.						
Secbutylbenzene	*	*	*	*	*	*
1-methyl-4-isopropylbenzene	9	14	4	*	5	119
Indan	*	42	*	*	*	4
Indene	*	30	*	*	*	11
1-3-dimethyl-5-ethylbenzene	*	*	*	*	*	*
1-2-diethylbenzene	*	*	*	*	*	*
1-2-dimethy-4-ethylbenzene	*	3	*	*	*	5
1,2,3,5-tetramethylbenzene	*	*	*	*	*	2
Naphthalene	1045	1762	94	17	76	345
Benzothiophene	70	127	*	*	*	3
2-methylnaphthalene	259	120	27	6	20	93
1-methylnaphthalene	178	67	17	5	13	58
Biphenyl	44	8	11	*	16	18
2-6-dimethylnaphthalene	51	6	11	5	4	21
Acenaphthylene	*	*	18	6	25	43
Acenaphthene	558	64	35	9	25	40
2,3,6-trimethylnaphthalene	8	*	10	4	17	15
Fluorene	315	33	41	16	42	61
Dibenzothiophene	150	9	44	22	*	39
Phenanthrene	779	94	192	92	229	222
Anthracene	168	12	80	26	61	90
1-methylphenanthrene	68	9	77	62	*	96
Fluoranthene	838	74	272	154	246	348
Pyrene	562	110	299	464	1029	447
Benzo(A)anthracene	371	15	117	124	205	320
Chrysene	306	*	134	141	210	252
Benzo(b)fluoranthene	201	9	245	73	579	337
Benzo(k)fluoranthene	73	*	150	38	239	209
Benzo(e)pyrene	295	207	484	255	634	808
Benzo(a)pyrene	170	12	609	103	1030	829
Perylene	470	742	975	394	1184	1026
Indeno(1,2,3-c,d)pyrene	*	*	*	*	*	*
Dibenzo(a,h)anthracene	*	*	*	*	*	*
Benzo(g,h,i)perylene	*	*	*	*	*	*
TOTAL	6988	3569	3944	2016	5889	5861

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TABLE 8. Analyses of PCB (as Arochlor 1254) in Composites From Native Sediments in East Waterway and Potential Disposal Sites.

	SAMPLE	CONCENTRATION OF AROCHLOR 1254 µg/Kg DRY WEIGHT
	EEW-1	*
	EEW-2	*
	EEW-3	*
	EEW-4	12
	EEW-5	12
	EEW-6	9
SNOHOMISH CHANNEL	EDS-1	68
SNOHOMISH CHANNEL	EDS-2	115
	EDS-3	307
	EDS-4	302
	EDS-5	32
DEEP DELTA	EDS-6	43
DEEP DELTA	EDS-7	20
	EDS-8	18
	EDS-9	*
	EDS-10	*
	EDS-11	23

*<1µg/Kg dry sediment

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Attachment D

SEDIMENT CONVENTIONAL PARAMETERS DATA SUMMARY

TABLE 2. Grain Size Distribution and Total Organic Carbon in Sediments from Everett Waterway Composites (EEW) and Potential Disposal Sites (EDS).

Station No.	Grain Size (%) Gravel	Sand	Silt	Clay	TOC(%)
EEW-1	0.5	29.4	50.0	20.1	0.78
EEW-2	0.3 (W)*	54.3	35.3	10.1	0.88
EEW-3	0.9	33.4	50.3	15.5	1.39
EEW-4	0.1 (W)	37.2	51.3	11.3	0.77
EEW-5	0.1 (W)	37.2	48.7	14.0	1.36
EEW-6	0.8 (W)	56.4	30.3	12.5	1.37
EDS-1	4.8 (W)	63.0	26.6	5.6	2.66
EDS-2	11.1 (W)	39.0	40.1	9.7	4.44
EDS-3	38.9 (W)	46.1	8.2	6.8	9.25
EDS-4	39.2 (W)	49.3	4.7	6.8	30.84
EDS-5	4.8 (W)	66.7	17.7	10.8	1.86
EDS-6	0.4 (W)	73.7	19.7	6.2	1.30
EDS-7	0.7 (W)	55.2	33.8	10.3	1.66
EDS-8	0.5 (W)	75.4	16.2	7.5	2.29
EDS-9	0.0	93.2	3.6	3.2	0.49
EDS-10	0.0	97.1	0.8	2.1	0.28
EDS-11	2.7 (W)	75.5	13.3	8.5	1.67

*"W" following the % gravel indicates that wood particles were included.

Table 3. Characteristics of Potential Disposal Sites near Everett Harbor

Station Composite	Depth ft.	Volatiles %	Dry Weight %	Sulfides ug/g	Oil & Grease ppm	Hg ppm	Cd ppm	Cu ppm	Zn ppm	Pb ppm	As ppm
EDS-1	1.1	9.17	57.10	212	625	0.066	0.30	36.1	84.3	58.2	11
EDS-2	0.8	11.11	65.47	<9	930	0.097	0.40	45	90.1	27.3	12.9
EDS-3	12.0	26.80	42.91	1382	1625	0.068	0.46	31.3	141	30.6	8.77
EDS-4	8.0	30.04	30.59	1219	2690	0.045	0.65	20	116.1	18	11.78
EDS-5	350.0	6.93	51.58	<5*, 301	343	0.081	0.24	45.5	85.9	25.2	10.3
EDS-6	114.0	4.79	65.11	115*, 16	178	0.078	0.39	39.8	79.3	32.8	9.1
EDS-7	192.0	5.70	62.07	130	253	0.091	0.53	41.7	82.3	30.8	8.7
EDS-8	3.3	6.11	65.82	64	210	0.072	0.29	34.7	73.8	36.3	8.3
EDS-9	5.7	2.30	69.39	22	66	0.218	0.15	17.2	44.4	46.3	4.3
EDS-10	4.1	2.24	74.99	9	41	0.035	0.04	21.3	56.1	43.2	9.3
EDS-11	234.0	4.71	65.80	8	239	0.074	0.20	25.7	63.1	32.1	6.04

* Replicates taken in the field

Table 4. Characteristics of Composites of Native Material in Everett Harbor - East Waterway.

Station Composite	Stations	Volatiles %	Dry Weight %	Sulfides ug/g	Oil & Grease ppm	Hg ppm	Cd ppm	Cu ppm	Zn ppm	Pb ppm	As ppm
EEW-1	E1 E4	3.06	70.90	<7	85	0.08	0.30	41.6	80.5	14.6	7.9
EEW-2	E2 E5 E7 E8 E11	3.14	72.70	67	64	0.06	0.26	39.9	72.5	14.7	8.6
EEW-3	E3 E6 E9	4.89	65.78	56	166	0.09	0.42	47.2	81.0	14.9	12.5
EEW-4	E10 E13	3.30	72.43	37	128	0.06	0.37	37.2	71.2	16.1	10.0
EEW-5	E12 E14 E15 E16	4.67	67.30	14	373	0.10	0.46	59.6	80.2	21.5	9.1
EEW-6	E17 E18 E19 E20	4.90	68.79	30	204	0.08	0.36	36.0	69.4	18.8	9.2

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Attachment E

BIOLOGICAL DATA SUMMARIES

7. Analyses of Trace Metals and PAH in Clams and Mussels Exposed to Everett East Waterway Sediments in Aug., 1984. Values are in mg/Kg dry weight (ppm).

	PCB (1254)	TOTAL PAH	Cu	Zn	Pb	As	Hg	Cd
MACOMA								
Sequim Bay								
Control	1.02	2.74	33.8	337	3.23	13.27	0.21	1.07
E-1-B	0.72	5.11	21.2	340	<1.7	13.48	0.13	1.13
E-4-T	0.0	3.39	27.3	357	4.71	12.11	0.16	1.97
E-4-B	0.71	2.28	22.7	291	2.27	12.46	0.17	0.96
E-15-T	0.0	36.61	R1 21.1	312	4.17	12.08	0.13	1.07
			R2 22.3	301	4.22	11.96	0.12	0.96
			R3 22.6	307	3.78	11.71	0.13	1.07
E-18-T*	0.55	0.80	17.5	358	<1.7	13.73	0.15	1.13
MYTILUS								
Sequim Bay								
Control	0.93	6.02	8.18	169	<1.7	10.58	0.22	3.21
E-1-B	0.30	0.82	7.32	158	<1.9	11.58	0.16	3.72
E-4-T	0.80	6.22	7.60	146	191	5.90	0.13	4.11
E-4-B	0.51	15.50	7.69	177	<1.7	12.90	0.15	3.72
E-11-T	0.78	10.45	7.09	245	332	<3.1	0.12	3.49
E-15-T	R1 1.04	1.23						
	R2 0.73	1.47	7.21	192	<1.9	11.53	0.13	3.55
E-18-T*	0.68	2.75	6.92	118	<1.8	8.53	0.12	4.00

*Since surface layer was very thin this is essentially a bottom sediment

TABLE 10. Total PAH and PCB Concentrations (mg/kg dry) in Bivalves Exposed to Everett East Waterway Native Sediments for 21 Days

	Sediment		Macoma		Mytilus	
	PAH	PCB	PAH	PCB	PAH	PCB
Initial Samples	--	-	2.18	**	5.50	**
Sequim Bay Controls	0.20	*	16.13	**	4.43	**
Composite 1	7.00	*	254.80	**	20.74	1.41
Composite 2	3.57	*	2.90	**	16.91	1.42
Composite 3	3.94	*	1.66	**	2.40	0.47
Composite 4	2.02	0.012	5.01	**	20.83	0.70
Composite 5	5.89	0.012	36.09	**	4.71	1.80
Composite 6	5.86	0.009	19.54	1.23	87.95	1.49

* <1 μg/kg.

** <10μg/kg.

TABLE 11. Metal Concentrations in Bivalves Exposed for 21 Days to Everett Harbor Native Sediments

Station Composites	Sample Type	Dry Weight %	Hg ppm	Cd ppm	Cu ppm	Zn ppm	Pb ppm	As ppm
EEW-1	*Mytilus*	7.11	0.342	2.63	8.7	168.7	8.2	7.3
	Macoma	10.45	0.202	1.10	12.2	245.0	<4.5	13.0
EEW-2	*Mytilus*	7.09	0.295	2.85	8.7	194.0	5.7	10.7
	Macoma	9.85	0.193	1.41	11.2	266.0	<4.1	14.2
EEW-3	*Mytilus*	14.82	0.321	3.00	7.2	159.4	<5.4	9.6
	Macoma	10.91	0.188	1.30	11.3	212.0	<4.3	15.6
EEW-4	*Mytilus*	7.07	0.278	3.58	7.5	182.9	5.8	10.6
	Macoma	10.76	0.197	1.87	12.3	326.0	<4.1	16.0
EEW-5	*Mytilus*	7.58	0.182	3.18	8.2	199.0	<5.0	9.0
	Macoma	10.82	0.141	1.42	14.4	326.0	4.1	12.8
EEW-6	*Mytilus*	9.04	0.220	3.10	7.2	196.0	<4.5	9.9
	Macoma	8.10	0.196	1.43	17.2	231.0	<3.7	17.7
Sequim Bay Control	*Mytilus*	8.64	0.215	3.44	11.5	136.4	8.5	11.1
	Macoma	11.16	0.161	1.19	35.6	247.0	<4.5	20.4
Initial Samples	*Mytilus*	8.48	0.106	3.00	7.7	156.1	5.5	12.8
	Macoma	12.40	0.107	1.12	9.6	237.0	<3.6	13.7

TABLE 5. Results of Replicate Metals Analyses of *Macoma* and Standard Reference Samples

Sample	Replicate	Hg	Cd	Cu	Zn	Pb	As
MESS-1* (March, 1985)	1	0.170	0.55	23.9	178.0	42.5	10.6
	2	0.174	0.56	25.2	171.2	39.0	11.2
Mean ± (S.D.)		0.173 (0.003)	0.58 (0.05)	25.3 (1.45)	172 (5.6)	40.5 (1.8)	10.3 (1.1)
Certified Value		0.171	0.59	25.1	191.0	34.0	10.6
Oyster* STD-1566 (March, 1985)	1	0.047	3.66	62.1	864	<1.4	13.58
	2	0.044	3.77	62.8	864	1.57	13.10
	3	0.040	3.55	62.8	871	<114	13.54
Mean ± (S.D.)		0.044 (0.004)	3.66 (0.11)	62.6 (0.4)	866 (4.0)	<1.46	13.41 (0.27)
Oyster STD-1566 (April, 1985)	1	0.053	3.43	61.4	825	<2.8	14.0
	2	0.052	3.24	63.0	819	<2.8	12.6
	3	0.042	2.91	62.6	805	<3.4	12.8
Mean ± (S.D.)		0.047 (0.006)	3.19 (0.26)	62.3 (0.83)	816 (10.3)	<3.0 (0.4)	13.1 (0.8)
Certified Value (S.D.)		0.057 (0.015)	3.5 (0.4)	63.0 (3.5)	852 14	0.48 (0.04)	13.4 (1.9)
Macoma Exposed to EWW-5 Composite	1	0.131	1.37	15.3	322	<3.8	12.5
	2	0.151	1.47	13.7	337	4.1	12.6
	3			14.1	320	4.4	13.3
Mean (S.D)		0.141 (0.014)	1.42 (0.07)	14.4 (0.83)	326 (9.3)	4.1 (0.3)	12.8 (0.4)

*[illegible]S-1 standard supplied by the National Research [illegible]uncil of Canada and the oyster standard tissue supplied by the National Bureau of Standards.

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TABLE 12. Summary of Results of Amphipod Bioassays of Everett East Waterway Native Sediments.

Sediment	Rep	Survivors (20 max)	Mean & SD Survival	%Mortality	# Reburied After 1 hr	% Reburial
Sequim Bay	1	15	16.5(1.9)	25	15	100
	2	15		25	15	100
	3	17		15	17	100
	4	19		5	19	100
Sequim Bay (repeat)	1	13	12.6(1.1)	35	11	85
	2	12		40	12	100
	3	14		30	13	93
	4	13		35	13	100
	5	11		45	11	100
Habitat Sed.	1	19	19.3(0.5)	5	19	100
	2	19		5	18	95
	3	20		0	20	100
	4	19		5	18	95
Habitat Sed. (repeat)	1	19	19.7(0.6)	5	19	100
	2	20		0	20	100
	3	20		0	20	100
EEW-1	1	17	14.8(2.6)	15	14	82
	2	17		15	16	94
	3	12		40	10	83
	4	13		35	13	100
EEW-2	1	15	13.8(5.3)	25	14	93
	2	16		20	14	88
	3	18		10	18	100
	4	6		70	5	83
EEW-3	1	19	15.8(2.9)	5	18	95
	2	12		40	10	83
	3	16		20	13	81
	4	16		20	12	75
EEW-4	1	17	13.8(3.2)	15	17	100
	2	11		45	11	100
	3	11		45	10	91
	4	16		20	15	94
EEW-5	1	10	12.0(2.9)	50	10	100
	2	9		55	9	100
	3	14		30	14	100
	4	15		25	13	87
EEW-5 (repeat)	1	13	13.2(2.7)	35	12	92
	2	16		20	13	81
	3	15		25	15	100
	4	13		35	12	92
	5	9		55	8	89
EEW-6	1	16	16.5(2.9)	20	16	100
	2	13		35	12	92
	3	17		15	16	94
	4	20		0	20	100

Note: With 4 replicates, a difference of 3.35 in survival is needed to be 75% certain of detecting a statistically significant ($p < 0.05$) difference between conditions. Using Sequim Bay as a fine sediment control (16.50 - 3.35 = 13.15), only EEW-5 shows a significant reduction in survival. The repeat test does not show this reduction.

TABLE 13. Summary of Infaunal Species at the Potential Dredge Material Disposal Sites

Station	No. Spp.	No. Polychaetes	Percent Polychaetes
EDS 1	16	9	56
EDS 2	12	5	42
EDS 3	32	14	44
EDS 4	31	12	39
EDS 5	66	47	71
EDS 6	42	25	60
EDS 7	47	30	64
EDS 8	40	18	45
EDS 9	32	13	41
EDS 10	29	11	38
EDS 11	71	45	63

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Table 5. Comparison of PAH totals from 4-mile Rock Disposal Site and the proposed Everett Site (EDS).

All units are µg/kg dry sediment or PPB

	4 mile Rock	EDS 1	EDS 2	EDS 3	EDS 4	EDS 5	EDS 6	EDS 7	EDS 8	EDS 9	EDS 10	EDS 11
Battelle (Σ Naththalene–Benzo(g,h,i)perylene)		5821	10222	9711	59390	5203	2106	3829	7458	1155	ND	527
EPA Sediment Criteria (Σ light PAHs)	683	337	713	95	1893	148	298	378	1155	99	ND	712
EPA Sediment Criteria (Σ heavy PAHs)	11,200	4282	6974	8371	54635	4406	1673	2775	4071	1001	ND	3774

List #1 Acenaphthene, Naphthalene, Acenaphthylene, Anthracene, Fluorene
List #2 Dibenzo(A-H)Anthracene, Benzo(A)Anthracene, Benzo(A)pyrene, Benzo(B)Flouranthene, Indeno(1-2-3-C-D)Pyrene
Pyrene, Benzo(G-H-I)Perylene

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Attachment F

EPA CRITERA COMPARISONS

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TABLE 16. Comparison of PAH totals from 4-mile Rock Disposal Site and composited sediments from sampling sites within the Everett East Waterway

All units are µg/kg dry sediment or PPB

	4 mile Rock	Comp 1	Comp 2	Comp 3	Comp 4	Comp 5	Comp 6
Battelle (Σ Neththalene- Benzo(g,h,i)perylene)		6988	3569	3944	2016	5889	5861
EPA Sediment Criteria (Σ light PAHs)	683	2865	1965	460	166	458	801
EPA Sediment Criteria (Σ heavy PAHs)	11,200	2816	427	2310	1643	4326	3550

List #1 Acenaphthene, Naphthalene, Acenaphthylene, Anthracene
List #2 Dibenzo(A-H)Anthracene, Benzo(A)Anthracene, Benzo(A)pyrene, Benzo(B)Flouranthene, Indeno(1-2-3-C-D)Pyrene Pyrene, Benzo(G-H-I)Perylene

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Appendix B

EAST WATERWAY, EVERETT, WASHINGTON
TECHNICAL DOCUMENT REVIEW

Review of:

Anderson, J.W. and E.A. Crecelius, 1985, Analysis of Sediments and Soils for Chemical Contamination for the Design of U.S. Navy Homeport Facility at East Waterway of Everett Harbor, Washington. Prepared by Battelle, Marine Research Laboratory, Sequim, WA. February 1985. 34 pp. and appendices.

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EAST WATERWAY TECHNICAL DOCUMENT REVIEW

TABLE OF CONTENTS CHECKLIST

ATTACHMENTS

1.0 INTRODUCTION AND CHRONOLOGY OF EVENTS

The United States Department of the Navy (Navy) requested that the Seattle District United States Army Corps of Engineers (COE) assist in developing a contaminated sediments assessment program for the East Waterway, Everett. The COE contracted with Battelle, Marine Research Laboratory (MRL), to conduct the initial analysis of the extent of horizontal and vertical sediment contamination in East Waterway. The report reviewed documents the results of that analysis.

- o Field sampling conducted in July 1984:
  - Nineteen aquatic sediment cores,
  - Four aquatic sediment grabs, and
  - Two upland cores;
- o Analytical testing:
  - Chemical testing of organics, metals and bulk chemistry conducted by Battelle, MRL, and
  - Interlaboratory comparison testing by New York Testing Laboratory;
- o Bioaccumulation studies:
  - Conducted at Battelle, MRL, using clams and mussels;
- o Recommendations:
  - Further chemical and biological testing needed to identify the acceptability of unconfined aquatic disposal of contaminated sediments.

2.0 LEGAL AND REGULATORY ISSUES

The report reviewed was intended to provide information with which to respond to the National Environmental Policy Act/State Environmental Policy Act process for the proposed Navy Homeport facility at Everett. Regulatory issues addressing dredging and disposal of contaminated sediments and soils are addressed and discussed indirectly. The document summary states that "approximately 500,000 c.y. of material exhibits elevated chemical contamination compared to Puget Sound background (Main Basin Puget Sound sediments) and requires biological testing before the acceptability of unconfined disposal can be concluded." A comparison of East Waterway sediments is made with two deep water Puget Sound disposal sites (Four-Mile Rock and Port Gardner) and Main Basin Puget Sound sediments. The report does not, however, identify or discuss specific regulatory criteria that must be met.

3.0 DEMOGRAPHICS AND LAND USE

N/A

4.0 POTENTIALLY LIABLE PERSONS

N/A

5.0 IDENTIFICATION OF POLLUTION POINT SOURCES

The report notes that cadmium is a metal of concern in surface sediments of the East Waterway, the source of which should be of concern to the United States Environmental Protecton Agency, Region X EPA. No potential sources are discussed.

6.0 IDENTIFICATION OF POLLUTION NON-POINT SOURCES

N/A

7.0 CHEMICAL DATA

Only a single recommendation is made with regard to aquatic disposal of East Waterway sediments. The recommendation being that "...more consideration be given to aquatic disposal using clean native material as a cap to contain contaminants...." The document summary indicates that biological testing is necessary before the acceptability of unconfined disposal of sediments from the East Waterway can be identified.

8.0 BIOLOGICAL DATA (FLORA/FAUNA)

Data Collection. A total of 19 marine sediment cores, 4 aquatic sediment grab samples, and 2 upland cores were collected in July of 1984. Sediment cores (1.3 to 3.0 m) were collected using a Vibricore and were sectioned into two or three sections based upon physical appearance (i.e., surficial sediments typically black, sulfide containing mud vs. subsurface sediments appearing as gray sand). Grab sediment samples were collected using a Van Veen grab sampler to collect the top 10 to 15 cm of sediment. The two upland cores (48 ft long) were drilled using a 4-in. rotary drill with steel casing. Three composite samples (12 to 18 ft in length) were analyzed for each upland core. Station locations are noted in Figure 1 (Attachment A).

Analytical Testing. Sediment samples were analyzed for 30 selected organic chemicals, 13 toxic metals, and for conventional parameters including: grain size, total and volatile solids, oil and grease, total organic carbon, and sulfides. The organics included selected polycyclic aromatic hydrocarbons (PAHs) and Aroclor 1254. Metals included chromium (Cr), nickel (Ni), copper (Cu), zinc (Zn), selenium (Se), lead (Pb), arsenic (As), mercury (Hg), cadmium (Cd), silver (Ag), beryllium (Be), thallium (Tl), and antimony (Sb).

Bioaccumulation testing was conducted using clams (Macoma inquinata) and mussels (Mytilus edulis) which were placed in aquaria with surface sediments from the 22 East Waterway stations. However, analytical testing of tissue was not conducted as part of this study.

Marine Sediments-Organics. The highest concentrations (230 ppm) of those aromatic compounds measured (total PAHs) were found at Station E5 and in the upper waterway near loading dock facilities. These areas were generally more contaminated than the middle and southern portions of the waterway. A relatively high concentration of aromatics was also found in the grab sample from Station A4 at the southern tip of the waterway. Thickness of the surface contaminated layer was also greatest (150 cm) at Station E4.

A total of 18 specific aromatics were summed together for those stations sampled to produce a contour of total PAHs present in the East Waterway (Figure 6 in Attachment A). The other 12 lower molecular weight compounds tested were quantified but not characterized as to distribution within the waterway.

Aroclor 1254, the only polychlorinated biphenyl (PCB) analyzed, was highest in the upper waterway, (Stations E1, E4, and E5 at 590, 580, and 670 ppb), while the highest concentration observed (720 ppb) was at Station E11. A contour of surficial Aroclor 1254 contamination is presented in Figure 9 (Attachment A).

Marine Sediments-Metals. Concentrations of toxic metals in Everett Harbor sediment ranged from: 44 to 170 ppm for Cr; 15 to 220 ppm for Cu; 5 to 140 ppm for Pb; 0.2 to 2.6 ppm for Cd; and 0.03 to 3.5 ppm for Hg. All sediment metal results are presented in Table A4 (Attachment B). Generally, surface sections of cores exhibited Hg concentrations that were nearly an order of magnitude greater than the bottom or subsurface sediments. The following metals were elevated in core sections of surface sediments over bottom core sections: As, Ag, Cd, Cu, Pb, Hg, and Zn.

Contours of surface concentrations of Pb and Hg are presented for the East Waterway (Figures 10 and 11 in Attachment A). The distribution of As, Cd, Cu, Zn were reportedly similar.

Higher concentrations of metals occur in the northern region of the waterway, a pattern which is also true of the organic contaminants present.

Marine Sediments-Conventional Parameters. Native sediment (i.e., sediment at the bottom of the cores) contained less water, mud, carbon, oil and grease, and sulfides than surface sediment.

Comparative Analysis. A comparative analysis was made between sediments of the East Waterway, the Main Basin of Puget Sound, and sediments from potential open water disposal sites in Puget Sound (Table 7 in Attachment B and Figures 4.4 and 4.5 in Attachment A).

The percentage of volatile organics was higher in top and middle sediment cores and grab samples from the East Waterway than at the Four-Mile Rock disposal site and Main Basin Puget Sound. Dichloro-diphenyl-trichloroethane and PCB concentrations in the East Waterway were approximately equal to those in sediments at Four-Mile Rock and the Puget Sound Main Basin. PAH concentrations in top and middle core sections and grabs were three to seven times higher in the East Waterway than at the Four-Mile Rock disposal site. (Four-Mile Rock PAH sediment concentrations are approximately three times higher than Port Gardner and Main Basin Puget Sound).

The metals data indicate that top and middle sections of sediment cores are contaminated with As, Cd, Cu, Pb, Hg, and Zn compared to the bottom core sections, the Port Gardner and Four-Mile Rock disposal sites, and Main Basin Puget Sound sediments.

The percentages of total solids and mud (silt and clay) did not differ widely between locations. Total organic carbon was higher in surface sections of cores than at comparison locations. Oil and grease were considerably higher (i.e., 7 to 50 times) in top and middle sections of cores and grabs from the East Waterway than at other sites and than in bottom core samples. A lack of sulfide data at other disposal sites did not allow comparison of this analyte.

Field Methods. Except for the split spoon sampling of upland sediments, it is not clear from the methods presented what type of field sampling equipment (i.e., stainless steel) was used to collect the cores and grab samples. Decontamination procedures are also not discussed for marine sediment sampling utensils, core liners, and Van Veen grab.

Organics. Low percent recoveries (<35 percent) were observed for some of the PAHs analyzed. Other recoveries averaged 55 to 80 percent. (Percent recoveries were used to correct gas chromatograph (GC) peaks to actual values for PAHs recovered).

In the analysis of Aroclor 1254 it was noted that an envelope of unresolved material was present in the GC chromatogram region of Aroclor 1254. The authors state that the values presented for Aroclor 1254 should be considered high since they may include other minor amounts of unresolved organics with the same GC retention time.

Replicate analyses (interlaboratory comparison) indicated that when PAHs were detected by both labs, PAH values varied from 20 to 460 percent between labs. In many cases, compounds were not detected by both labs. In the case of Aroclor 1254, values were 1.5 to 12 times lower for one laboratory.

High concentrations of unresolved complex mixtures (UCM) were present in 20 of the samples and remain unidentified.

Metals. Sample variability was tested using triplicate analyses. The results indicated generally good precision for all but Hg and Cr (Relative Percent Difference > 30 percent). Method accuracy was tested through analysis of standard, certified sediments. Results showed generally good accuracy except for Hg for one standard sediment sample (i.e., < 10 percent recovery).

Upland Sediments. For all analytes, upland sediments were said to be generally less contaminated than surficial aquatic sediments and similar to "native" sediments in the waterway. However, the large increment of sample analyzed (i.e., 12 to 18 feet) does not provide the same resolution as that afforded to sediments collected as part of this study (i.e. 1 to 2 feet).

Supporting Documentation. The authors cite three sediment studies previously conducted on the East Waterway. These are:

- Crecelius, E.A., N.S. Bloom and J.M. Gurtisen. 1984. Chemical analysis of sediment cores from the East Waterway (Everett, Washington). Final Report to U.S. Army Corps of Engineers, PNL-5045, UC-11. Seattle, Washington.

- Malins, D.C., B.B. McCain, D.W. Brown, A.K. Sparks, H.O. Hodgins and S. Chen. 1982. Chemical contaminants and abnormalities in fish and invertebrates from Puget Sound. NOAA Technical Memorandum OMPA-19. Boulder, Colorado.

- U.S. EPA, 1985, In press. (No reference provided.)

9.0 DATA QUALITY

N/A

10.0 HYDROLOGIC AND HYDRODYNAMIC INFORMATION

Methods

A bioaccumulation study was initiated using clams (*Macoma inquinata*) and mussels (*Mytilus edulis*). These organisms were placed in aquaria and exposed to surficial sediments from each of the 22 East Waterway stations. Specific procedures for this bioaccumulation study were not identified in the report.

Results

Mortality of the mussels occurred during the study. The degree of mortality was not identified except for one aquarium where 90 percent mortality was observed after 13 days. Because of the mortality that occurred the study was stopped at day 13.

Chemical analysis for the presence of tissue contaminants was not conducted and therefore no bioaccumulation information was presented in the report. (One of the report recommendations was that these tissues, which were frozen for preservation, be analyzed for chemical contaminants as part of a follow-up study).

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Data Quality

Due to the lack of information presented and lack of analytical data, it was not possible to determine the validity of these biological tests.

11.0 DREDGING AND DISPOSAL ISSUES AND DATA

Organics

Based upon the poor replicate chemistry results for PAHs and low recovery of known mixtures obtained in this study, the levels of PAH and PCB recovered from sediments associated with the East Waterway remain unclear.

Metals

Triplicate analyses indicated generally good precision for most metals of concern. Exceptions were Hg and Cr. Analytical accuracy was low for Hg in one of two standard reference sediments tested.

The data presented can be considered to represent the extent of relative contamination in the waterway. However, because of the apparent uncertainties with regard to specific concentrations of those organic contaminants present, the application of these waterway sediment data to dredge/disposal or sediment cleanup criteria may not be valid. In addition, because no positioning information is presented, the station locations cannot be verified.

12.0 ENVIRONMENTAL IMPACTS

During the bioaccumulation studies initiated in the study, it was noted that mortality occurred for mussels exposed to sediments from the East Waterway. The degree of mortality (90 percent) was reported for only one of 22 aquaria.

The report recommends that "where potential disposal strategies may lead to impacts on aquatic species, the material should be tested for effects on bioassay organisms." Amphipod and oyster larvae are the recommended bioassay species.

13.0 INTERIM MEASURES/SPILL AND POLLUTION PREVENTION MEASURES

N/A

14.0 COMMUNITY RELATIONS INFORMATION

Dredging and dredged disposal criteria are not specifically discussed. Sediments from the East Waterway are compared with sediments from two open water disposal sites in Puget Sound (Four-Mile Rock and

Port Gardner) and with Main Basin Puget Sound sediments (see Table 7 and discussion in Section 8).

The report recommends that, after sediment disposal options have been determined, analytical methods to assess each option be designed and finally, that more consideration should be given to aquatic disposal using clean native material as a cap.

15.0 RECOMMENDATIONS

The document reviewed is a preliminary assessment of sediment quality in the East Waterway. Based upon the data presented and QA limitations of the data, this information should only be considered to provide an estimate of the general level of contamination present. Other later documents should be consulted to determine if more definitive data are available with which to make cleanup decisions. This document does not provide the level of detail necessary for identification of dredge/disposal suitability for sediments of the East Waterway.

The presence of unresolved complex mixtures of organics appears to have been responsible for interferences and lack of resolution of some compounds. Resolution of these complex mixtures may help to quantify the levels and nature of contamination present in sediments of the East Waterway as well as the potential sources of these contaminants.

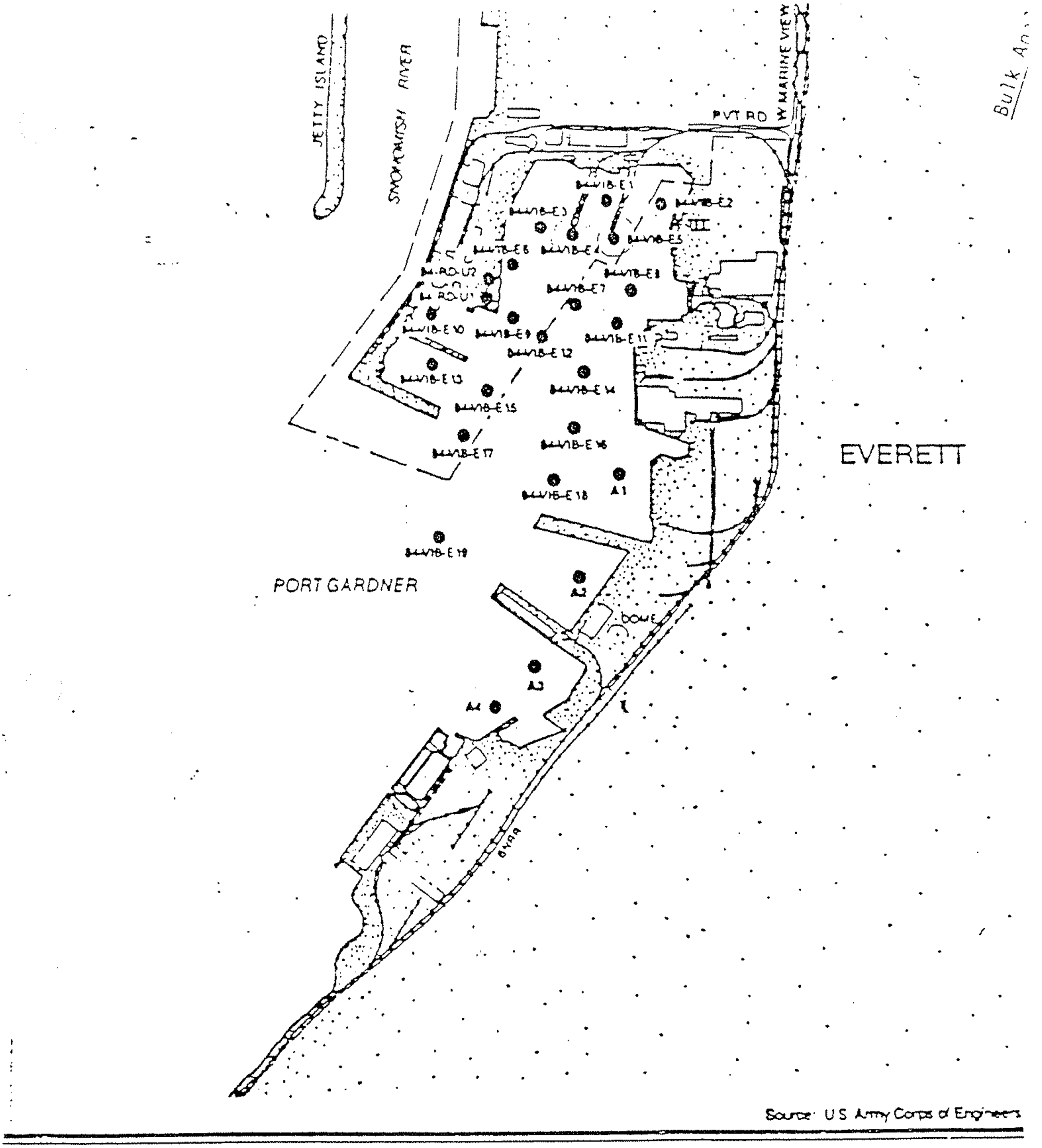
16.0 FINAL COMMENTS

This document serves as a preliminary assessment document for sediments of the East Waterway, Everett. As such, the document should be used for the general characterization and distribution of those selected contaminants analyzed during the study. The presence of other sediment contaminants (including other PCBs and PAHs) and the exact concentrations of those contaminants require further investigation. Finally, the lack of station positioning information may preclude replication of sample stations and thus contaminant locations if followup studies are conducted.

The additional references cited in this report (see Section 8) should be reviewed with regard to their applicability to contaminated sediments of the East Waterway (e.g., Romberg et al. 1984).

Attachment A

MAPS



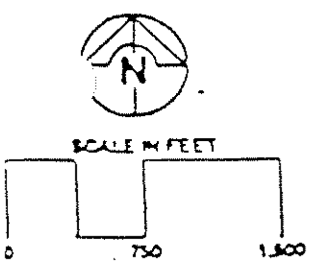


Figure 1
Sediment sampling locations in the East Waterway.

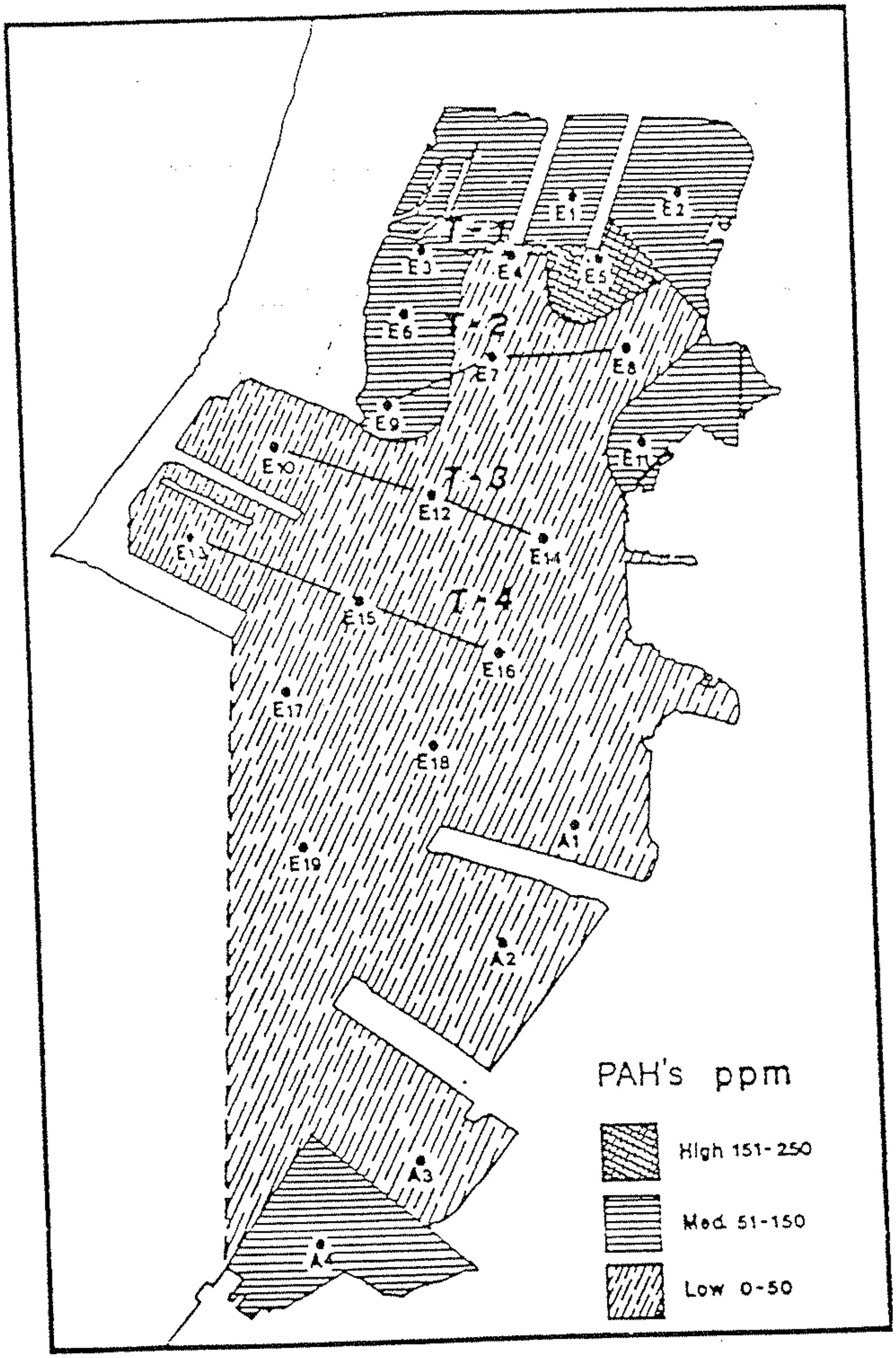


FIGURE 6. Distribution of ppm PAH (dry wt.) in surface sections of sediment cores and surface grab samples of the East Waterway. Transects shown in Figures 7 and 8 are T-1 through T-4.

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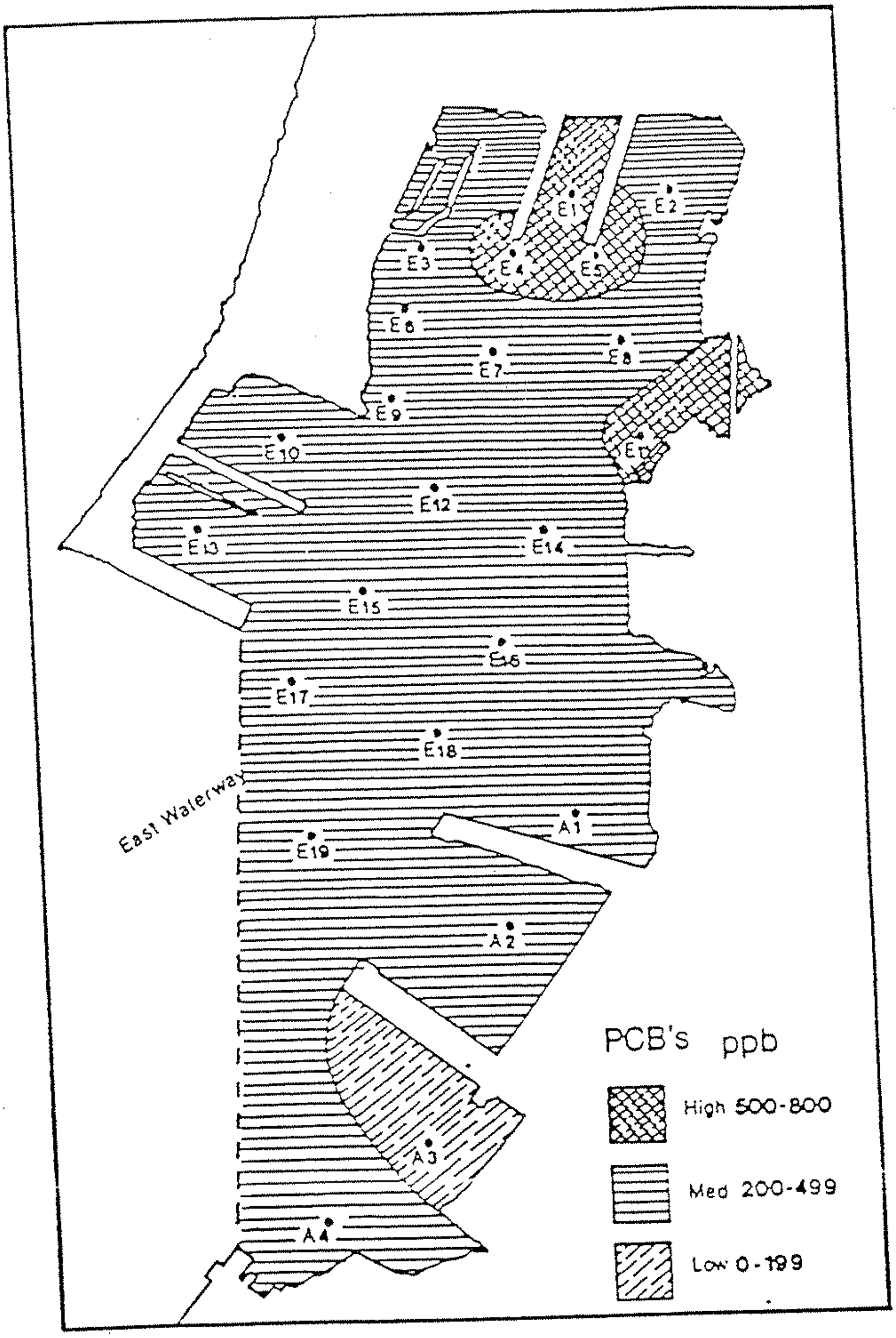

FIGURE 9. Distribution of ppb PCB (dry wt.) in surface sections of sediment cores and surface grab samples of the East Waterway.

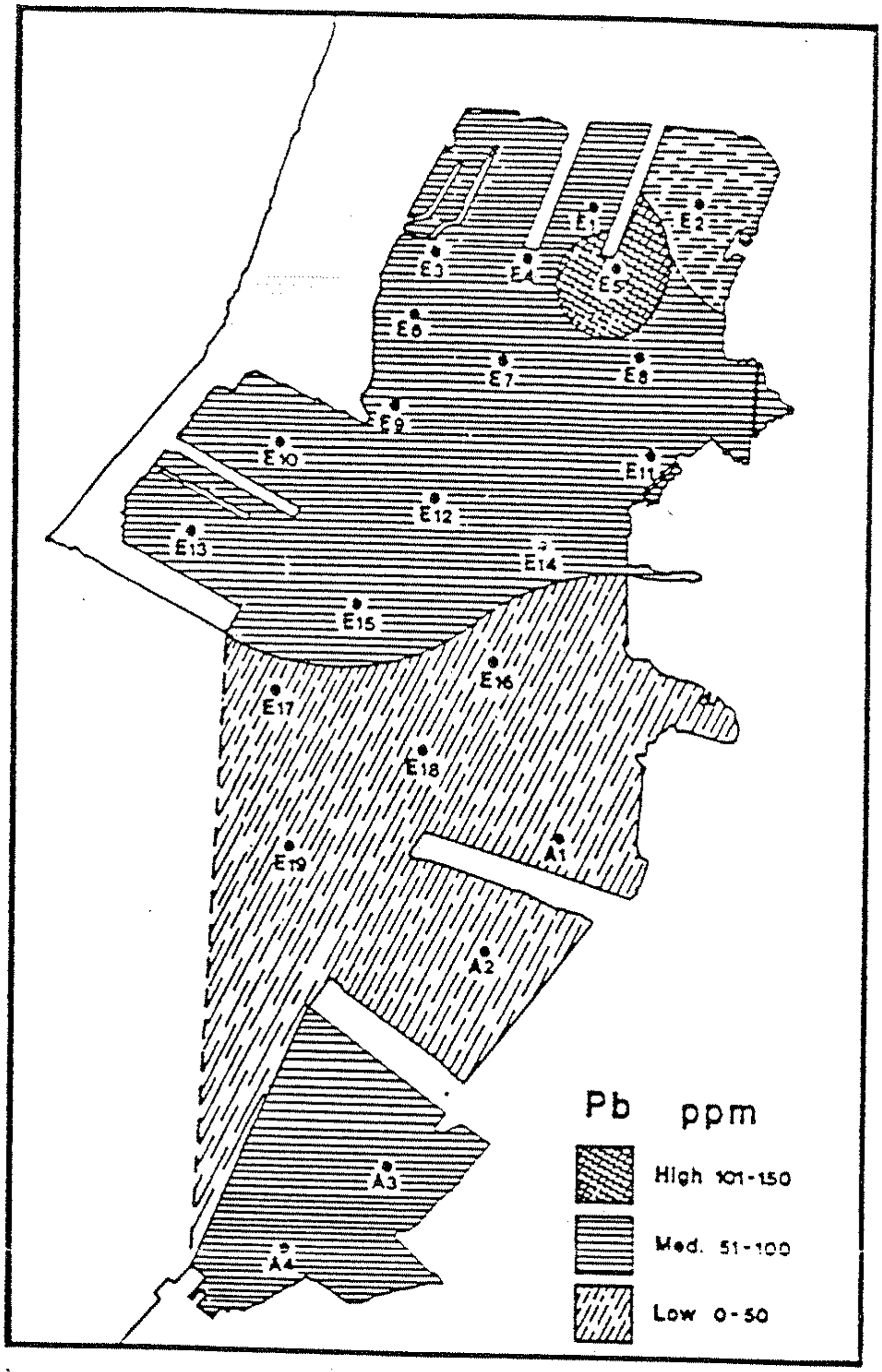

FIGURE 10. Distribution of ppm Pb (dry wt.) in surface sections of sediment cores and surface grab samples of the East Waterway.

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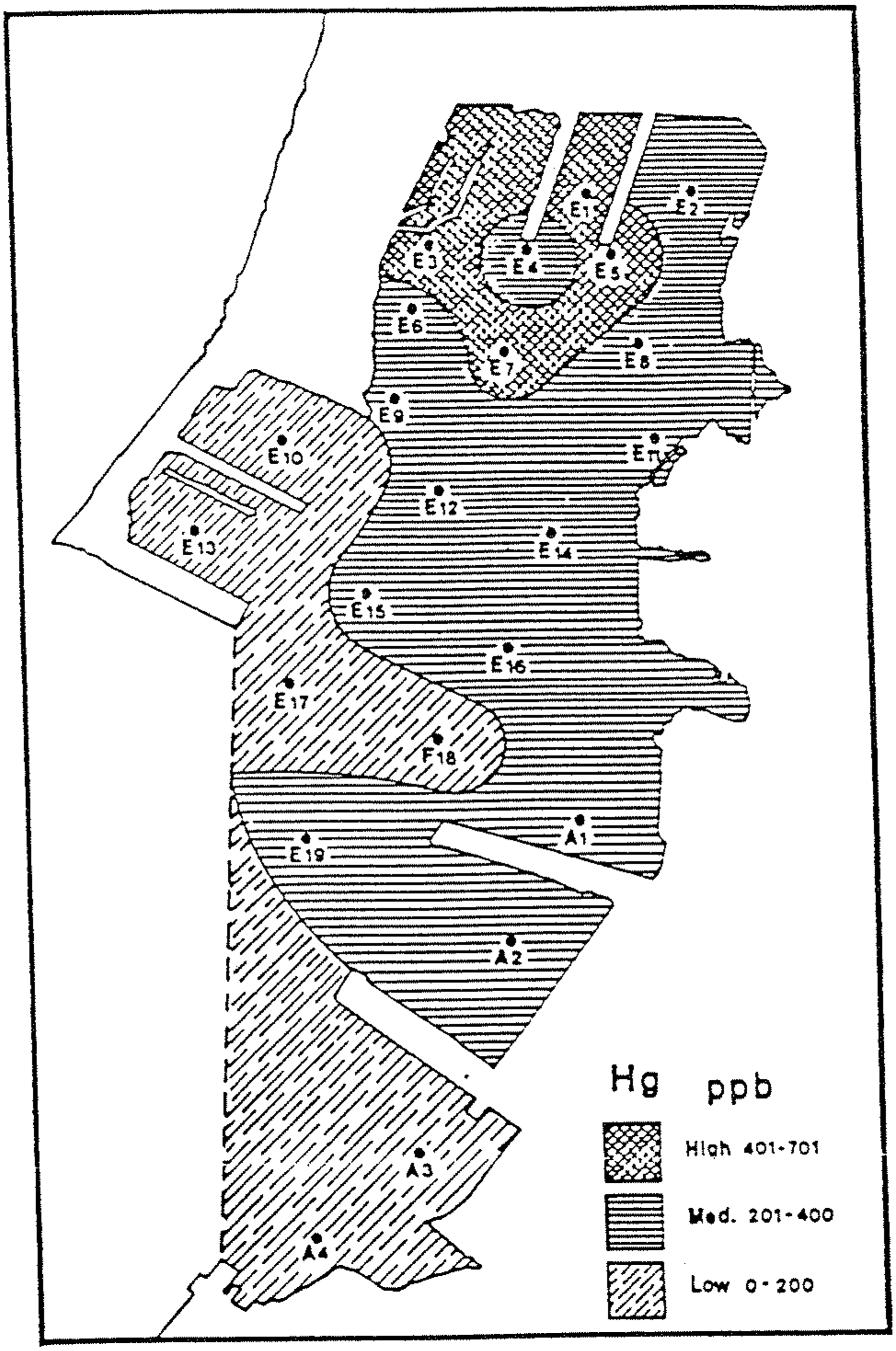

FIGURE 11. Distribution of ppb Hg (dry wt.) in surface of sediment cores and surface grab samples of the East Waterway.

ex: Puget Sound Dredged Disposal Analysis.
Management Plan Report.
Unconfined Open-Water Disposal of Dredged Material, Phase I (Central Puget Sound) June 1988.

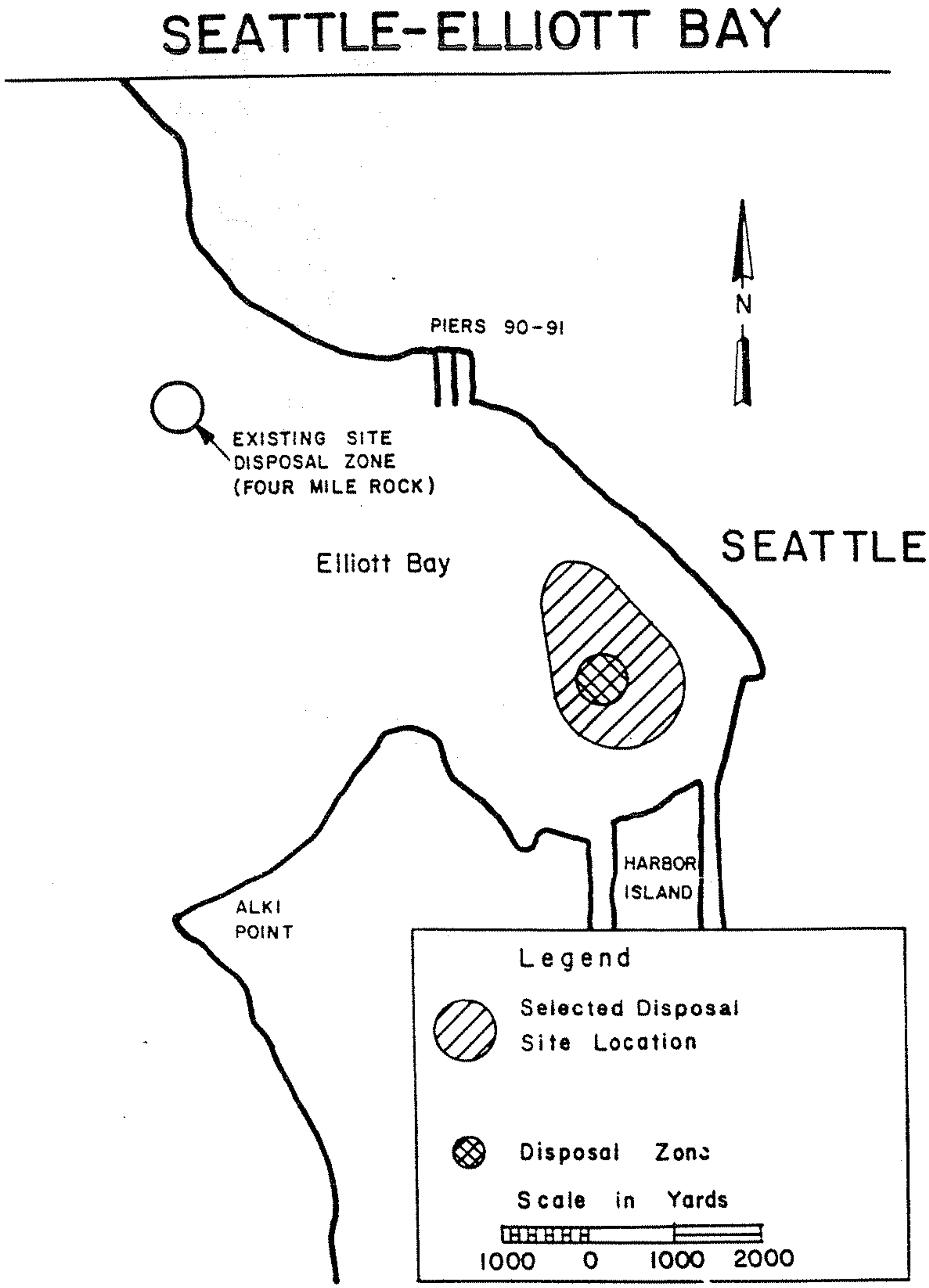

Figure 4.4 Elliott Bay Disposal Site

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ex: Puget Sound Dredged Disposal Analysis.
Management Plan Report.
Unconfined Open-Water Disposal of Dredged Material, Phase I (Central Puget Sound) June 1988.

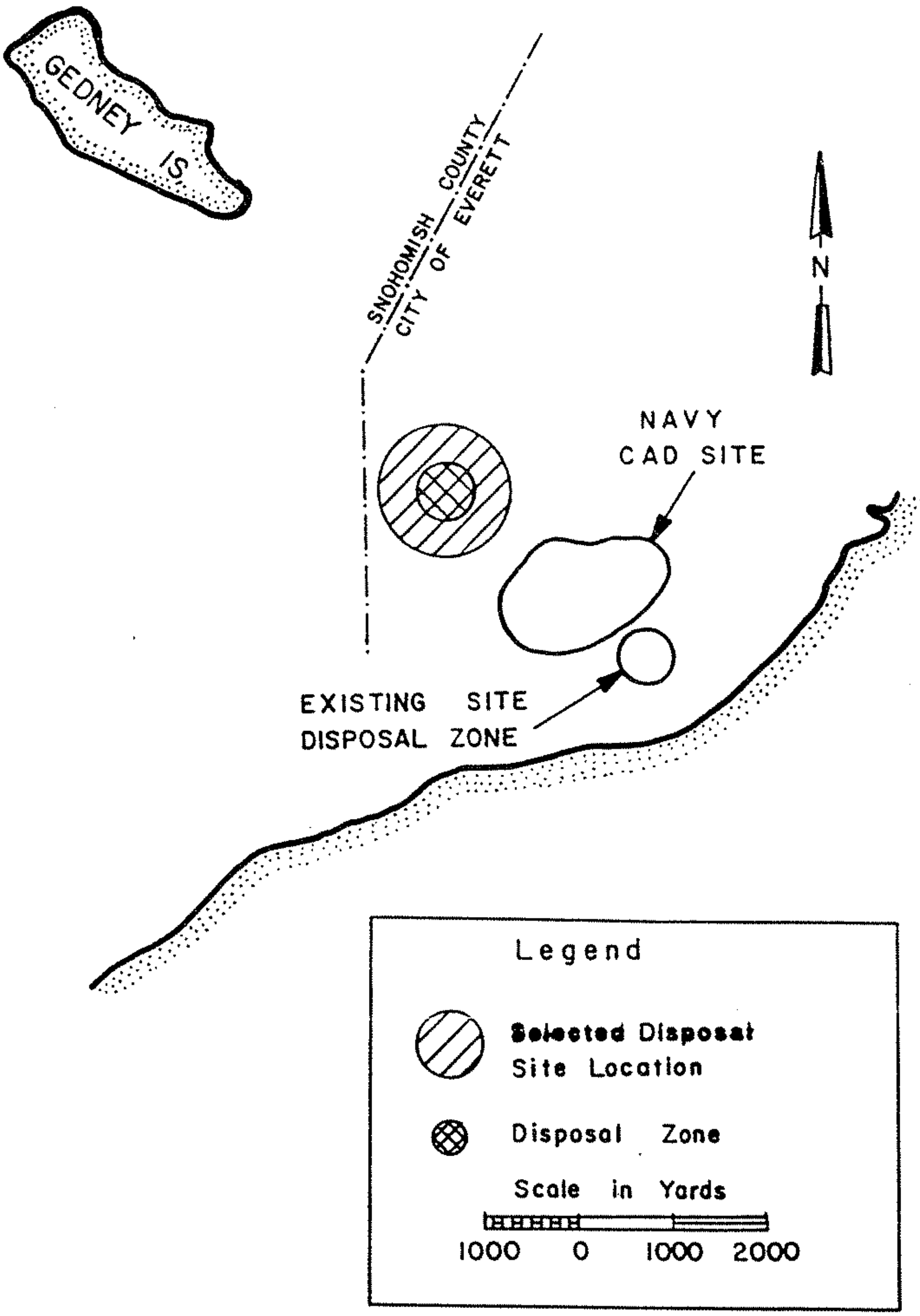

Figure 4.5 Port Gardner Disposal Site

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Attachment B

DATA SUMMARIES

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NCE . .ATION OF METALS IN EVERETT HARBOR SEDIMENT

ation No.	Ppm (Dry Weight Basis)												
	Cr	Ni	Cu	Zn	Se	Pb	As	Hg	Cd	Ag	Be	Tl	Sb
1-T	123	82.2	127.4	317	1.20	85.0	10.7	0.608	1.55	0.338	0.878	1.61	<4.4
1-B	153	63.9	44.8	80.5	<0.93	9.0	8.99	0.053	0.200	-	-	-	-
2-T	98	60.3	89.2	118.4	<0.90	49.4	4.9	0.348	1.31	0.203	0.788	0.803	4.8
2-B	100	53.0	36.3	67.9	<0.92	10.1	9.19	0.031	0.325	-	-	-	-
3-T	113	70.6	112.9	255	<0.93	90.6	7.2	0.445	2.05	-	-	-	-
3-B	141	52.5	35.6	64.2	<0.92	11.6	6.94	0.055	0.532	-	-	-	-
-4-T	119	67.4	97.8	240	<0.97	55.8	8.5	0.264	2.44	-	-	-	-
-4-M	149	72.4	165.4	205	1.03	73.4	13.6	3.482	1.47	-	-	-	-
-4-B	163	72.5	52.7	92.4	<0.97	10.1	9.3	0.073	0.273	-	-	-	-
-5-T	136	63.1	110.1	286	<0.96	138.7	<2.5	0.652	2.36	-	-	-	-
-5-B #1	122	61.4	38.9	74.4	1.23	8.3	7.80	0.064	0.222	-	-	-	-
-5-B #2	-	-	-	-	-	-	-	0.053	0.222	-	-	-	-
-5-B #3	-	-	-	-	-	-	-	0.040	0.236	-	-	-	-
-6-T	113	66.3	154.2	202	<0.94	74.4	12.8	0.287	2.18	0.424	0.810	<0.803	<4.3
-6-B	142	57.2	37.7	64.4	1.09	9.9	15.6	0.064	0.399	-	-	-	-
-7	111	61.6	106.3	198	<0.92	55.6	7.6	0.529	1.14	-	-	-	-
-7-B	150	61.2	35.5	71.2	<0.94	5.7	9.93	0.047	0.236	-	-	-	-
-8-T	119	63.0	121.6	319	<0.92	68.5	7.5	0.370	1.97	-	-	-	-
-8-B	121	48.3	35.8	64.6	<0.91	16.3	6.10	0.077	0.325	-	-	-	-
-9-T	155	70.2	114.9	364	<1.0	67.9	7.4	0.318	1.42	-	-	-	-
-9-B	173	91.0	82.4	118.3	<1.0	20.1	15.0	0.134	0.650	-	-	-	-
E-10-T	124	65.8	88.1	520	1.04	55.9	7.4	0.194	1.65	-	-	-	-
E-10-B	141	58.5	44.2	76.8	<0.94	11.0	6.94	0.062	0.406	-	-	-	-
E-11-T #1	82.5	45.2	101.2	170.6	<0.84	64.8	3.16	0.335	1.03	0.165	0.315	1.61	<4.4
E-11-T #2	62.1	42.0	103.0	167.0	<0.82	59.9	4.83	0.383	1.05	0.168	0.383	1.61	<4.3
E-11-T #3	67.2	41.9	105.2	158.8	<0.79	64.1	3.22	0.300	1.09	0.180	0.360	1.61	<4.2
E-11-B #1	143	57.1	41.1	72.3	<0.93	10.5	7.50	0.064	1.03	0.029	0.900	0.803	<4.2
E-11-B #2	135	54.5	41.2	73.5	1.14	7.6	9.29	-	0.281	0.029	0.900	0.803	<4.6
E-11-B #3	108	61.0	40.2	75.4	<0.92	11.2	7.38	-	-	-	-	-	<4.4
E-12-T	115	69.0	104.2	185.7	<0.92	56.9	8.9	0.344	1.57	-	-	-	-
E-12-B	161	69.5	46.7	83.9	1.12	9.6	8.29	0.058	0.273	-	-	-	-
E-13-T	111	74.6	107.9	226	1.10	59.7	10.0	0.194	1.71	-	-	-	-
E-13-M	146	67.4	224	166.7	1.04	69.9	39.2	2.603	1.52	-	-	-	-
E-13-B	151	52.3	37.1	70.8	1.23	9.8	7.01	0.053	0.370	-	-	-	-
E-14-T	108	87.4	92.3	157.8	1.01	56.4	6.2	0.376	1.91	-	-	-	-
E-14-B	155	59.7	41.5	76.6	<0.93	8.8	10.9	0.061	0.303	-	-	-	-
E-15-T	111	73.9	96.9	145.8	<1.0	67.3	7.7	0.389	1.55	-	-	-	-
E-15-B	130	61.8	42.9	77.0	<0.92	10.4	6.84	0.064	0.259	-	-	-	-
E-16-T #1	158	61.4	54.8	87.8	<0.94	21.0	8.9	0.204	0.739	0.085	0.743	1.61	<4.5
E-16-T #2	-	-	-	-	-	-	-	0.201	0.746	0.085	-	-	-
E- #3	-	-	-	-	-	-	-	0.206	0.665	0.088	-	-	-
E-16-B	152	65.5	44.1	80.1	<0.94	8.8	8.63	0.066	0.296	-	-	-	-

Station No.	Ppm (Dry Weight Basis)												
	Cr	Ni	Cu	Zn	Se	Pb	As	Hg	Cd	Ag	Be	Tl	Sb
:-17-T	97	59.8	77.2	696	<0.89	31.6	14.9	0.129	1.62	-	-	-	-
:-[illegible]7-B	104	36.0	21.2	47.7	<0.91	8.1	3.92	0.035	0.229	-	-	-	-
:-18-T	97	37.6	20.0	44.9	<0.89	6.1	5.33	0.028	0.244	-	-	-	-
:-19-T	95	50.6	66.9	113.1	1.19	34.4	8.36	0.276	1.48	0.235	0.720	0.803	<4.2
:-19-B	104	38.9	20.1	44.8	0.96	5.0	5.62	0.028	0.214	-	-	-	
\1 Grab	133	63.3	76.7	441	1.01	75.3	16.1	0.301	1.90	-	-	-	-
\2 Grab	149	63.1	75.3	237	<0.93	55.7	13.5	0.234	2.60	-	-	-	-
\3 Grab	94	30.2	15.0	53.2	<0.85	14.5	6.41	0.030	0.244	-	-	-	-
\4 Grab #1	43.7	22.3	33.0	141.3	0.81	19.2	10.29	0.079	1.12	0.088	0.248	2.41	<3.8
\4 Grab #2	50.8	23.1	31.5	146.9	<0.71	21.0	10.90	0.129	1.14	0.097	-	-	-
\4 Grab #3	59.4	22.9	31.9	144.0	<0.71	19.3	10.47	0.081	1.04	0.088	-	-	<4.1
J-1-T	97	40.0	42.9	111.1	<0.85	135.1	A.7	0.048	0.288	-	-	-	-
J-1-M #1	123	54.1	38.4	73.7	<0.92	10.3	9.96	0.060	0.421	-	-	-	-
J-2-M #2	-	-	-	-	-	-	-	0.057	0.362	-	-	-	-
J-1-M #3	-	-	-	-	-	-	-	0.055	0.362	-	-	-	-
J-1-B	137	54.3	44.4	72.0	0.92	11.0	10.22	0.064	0.310	-	-	-	-
J-2-T	149	50.2	35.5	85.7	<0.92	43.1	4.84	0.044	0.340	-	-	-	-
J-2-M	117	45.4	30.4	64.7	<0.91	7.0	7.37	0.044	0.303	-	-	-	-
J-2-B	100	51.1	42.3	71.8	1.12	7.5	10.80	0.060	0.325	-	-	-	-
IESS-1 #1	68	29.3	28.1	197	1.05	31.1	11.4	0.178	0.683	0.085	2.00	0.803	-
IESS-1 #2	61	29.1	28.9	185.8	<0.92	33.1	11.0	0.178	0.683	0.088	2.12	0.803	-
IESS-1 #3	61	35.1	25.3	174.3	1.15	30.4	9.7	0.178	0.695	0.085	1.94	0.803	-
IBS #1	92	34.1	20.4	127.5	<0.99	27.8	11.4	0.079	0.348	-	-	-	-
IBS #2	93	41.8	21.6	126.4	1.61	28.6	10.4	0.071	0.398	-	-	-	-
IBS #3	98	37.2	22.7	134.5	<0.96	31.9	9.2	0.073	0.378	-	-	-	-
CSS-1 #1	-	-	-	-	-	-	-	0.135	-	-	-	-	-
CSS-1 #2	-	-	-	-	-	-	-	0.133	-	-	-	-	-
CSS-1 #3	-	-	-	-	-	-	-	0.136	-	-	-	-	-
Blank #1	-	-	-	-	-	-	-	N.D.	0.015	<0.003	0.045	<0.803	-
Blank #2	-	-	-	-	-	-	-	N.D.	0.015	<0.003	0.045	<0.803	-
Blank #3	-	-	-	-	-	-	-	N.D.	0.015	<0.003	0.045	<0.803	-

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Table 7. Mean Concentrations of Bulk Physical and Chemical Properties and Organic Contaminants in Everett and Puget Sound Sediments

	East Waterway Sediment Cores			Grabs	Port Gardner Disposal Site	Four Mile Rock Disposal Site	Puget Sou Main Bas
	Top	Mid	Bottom	Surface	Surface	Surface	Surface
Thickness (cm)	132	47	>140	10	10	10	10
	% dry weight						
Solids	39	49	71	42	62	58	35
Mud[1]	59	82	52	31	38	37	94
Volatiles	23	13	3.1	21	3.5	4.7	7.4
TOC	12.7	3.6	1.0	10.7	---[2]	1.7	2.5
	ppm (mg/kg dry weight)						
Oil and Grease	4950	4610	92	1850	111	251	41
Sulfides	408	179	31	370	---[2]	---[2]	--[2]
PAH	54	72	2	27	3	11	4
PCB	0.4	0.4	<0.01	0.2	0.1	0.6	0.1
DDTs	<0.02	<0.02	<0.02	<0.02	<0.02	0.007	0.002

Mud = silt and clay combined

Data not available

app

hyd

recycled paper

ecology and environment

Appendix C

EAST WATERWAY, EVERETT, WASHINGTON
TECHNICAL DOCUMENT REVIEW

Review of:

Battelle Northwest, 1986, Reconnaissance Survey of Eight Bays in Puget Sound, Pacific Northwest Laboratory, December 1986, for U.S. Environmental Protection Agency, Region 10.

Contract No. C0089007

Document Control No. WD4030.1.0-C

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Prepared For:

WASHINGTON STATE DEPARTMENT OF ECOLOGY
Toxics Cleanup Program

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EAST WATERWAY TECHNICAL DOCUMENT REVIEW

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ATTACHMENTS

Attachment A: Sampling Location Maps
Attachment B: Organic Analytical Results for East Waterway
Attachment C: PCB Analytical Results for East Waterway
Attachment D: Marine Amphipod Bioassay Results for East Waterway
Attachment E: Oyster Larvae Bioassay Results for East Waterway
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1.0 INTRODUCTION AND CHRONOLOGY OF EVENTS

The final report represents a cooperative effort between the United States Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration to examine the impact of urbanization of various bays of Puget Sound from July 1983 through April 1985. The work reported by this study was, in large part, conducted and written by Pacific Northwest Laboratory. This review focuses on the information pertaining to Everett Harbor - Port Gardner sampling stations, especially in East Waterway.

The study was designed as an initial screening effort in 1983. Additional sampling in 1984 was conducted to characterize identified "hot spots." Sampling was not replicated for detailed statistical tests or rigorous quantitative analysis. Multiple testing, chemical analyses, biological analyses, and bioassays, of the same sediment sample were the prime goals of this reconnaissance study to determine the relative degradation of bay sediments from urban bays. Four reference bays were chosen for baseline comparisons with 80 sampling stations, and four urban bays were chosen as urban-industrialized water bodies with 101 sampling stations.

Chronology of Events

August 2 to September 15, 1983 - Sampling conducted at all 181 stations for analysis of sediments for screening purposes. Analyses performed were grain size, percent water, percent loss on ignition (percent volatile solids), silver, mercury, lead, oil and grease, and bioassays with amphipods.

April 23 to May 29, 1984 - Detailed sampling of the most contaminated of the contaminated stations and cleanest of clean stations. Thirty-two stations were sampled in the urban bays (8 each), and 16 stations in the reference bays (4 each). Samples were analyzed for priority pollutant metals, base/neutral/acid extractables (BNAs), volatile organics, and pesticides/polychlorinated biphenyls (PCBs); benthic infauna; amphipod and larval oyster bioassays; sediment grain size, total organic carbon (TOC), and percent water; and incidence of fish and shellfish disease.

2.0 LEGAL AND REGULATORY ISSUES

N/A

3.0 DEMOGRAPHICS AND LAND USE

N/A

4.0 POTENTIALLY LIABLE PERSONS

N/A

5.0 IDENTIFICATION OF POLLUTION POINT SOURCES

N/A

6.0 IDENTIFICATION OF POLLUTION NON-POINT SOURCES

N/A

7.0 CHEMICAL DATA

Data and interpretations summarized in this section considered only the Everett Harbor-Port Gardner sampling stations, specifically stations S1 to S6, which were set up in the East Waterway area.

The physical and chemical analyses of the sediments for the East Waterway area (stations S1 to S6) have been calculated by the reviewer as a subset of the 25 stations sampled in Everett Harbor. The results for the East Waterway area were averaged, if possible, from the data presented in the original report and are summarized below. Tables extracted from the original report are included as attachments to this review.

Sediment samples for chemical and biological analyses were retrieved from a composite of replicate benthic grab samples at each sampling station. Benthic grab samples were collected using a 0.1 m^2 Van Veen grab sampler. Composite samples were collected from each station to equal 26 liters in the 1983 analysis and 5 liters in the 1984 analysis. All analyses were performed using recognized, published methods from several sources. The bioassay techniques for larval oysters were modified to determine sediment toxicity. Quality assurance /quality control (QA/QC) protocol and recovery values also generally conformed with industry standards and are detailed in the text of the report.

The results reported below represent average values for all six East Waterway stations.

Grain-Size Results

Sediments in the East Waterway area of Everett Harbor are comprised of 6% gravel, 37% sand, 42% silt, and 15% clay, as averaged over 6 sampling stations (see Attachment A). Sediments also had 66% water, indicative of silty sediments, and high (20%) percent volatile solids, indicative of the organic debris found on the sediments. The most likely source of the organic debris was identified as coming from the activities of the logging industry.

Metals Results

The samples were analyzed using EPA furnace and Atomic Absorption (AA) methods. Specific analytical details were not provided other than AA methods which included spectrophotometry using a Zeeman flame furnace. Mercury was determined using an equivalent of EPA Method 245.5 (40 CFR Part 136). Results are presented as dry weight. Average metals values were calculated to be low to moderate for silver (0.369 ppm), mercury (0.329 ppm), cadmium (1.59 ppm), arsenic (11.5 ppm), copper (84.8 ppm), nickel (44.2 ppm), and zinc (348.7 ppm) and moderate to high for lead (56.9 ppm) and chromium (52.5 ppm).

Oil and Greases

Infared spectrophotometry was used to analyze sediments for heavy hydrocarbons in 1983. Sediments in East Waterway have high (5,880 ppm) concentrations of hydrocarbons.

Extractable And Volatile Organic Compounds

Gas chromatography-mass spectrometry methods were used to determine volatile organic compound concentrations and were reported as equivalent to EPA Method 624 (40 CFR Part 136). Results are presented in Attachment B.

Pesticides/PCBs

Methods equivalent to EPA Method 608 (40 CFR Part 136) were were used to analyze sediments for Pesticides and PCBs. Results are presented in Attachment C.

Results of each chemical analysis were compared between the urban bays, and between urban bays and reference bays. Although the analytical methods used in this study have been refined over the last 7 years, the QA/QC protocol was similar to that required of current Contract Laboratory Program laboratories today.

8.0 BIOLOGICAL DATA (FLORA/FAUNA)

The investigators sampled benthic infauna and looked for indications of disease in benthic dwelling flounder and invertebrates to correlate chemical and physical sediment analyses with biological parameters.

Methods

Benthic cores were collected during the 1984 sediment sampling effort. Six cores (5 cm by 15 cm each) were collected at each station and collectively sieved through a 1.0 mm mesh sieve. No replicates were taken since all six cores were sieved together. All organisms were identified and counted. Ten percent (5 of 48 stations) of the samples were sent to an independent expert for species verification.

Flounder and English sole were collected using an otter trawl. When possible, up to six fish were collected per size class (five size classes). Fish were measured for total length, weighed, and tissues excised from the following organs: liver, kidney, spleen, gall bladder, small intestines, gonad, heart, and gill. Tissues were examined microscopically for indications of lesions. Similar analyses were performed on crab (*Cancer magister* and *C. gracilis*) and shrimp (*Pandalus platyceros* and *Pandalopsis dispar*) collected using an otter trawl and baited crab ringnets. Tissues examined include: antennal gland, bladder, cardiac and pyloric stomachs, epidermis, esophagus, eye, gill, gonad, hemopoietic tissue, hepatopancreas, hindgut, midgut, and midgut ampulla.

Bioassays using sediment collected from the sampling stations were used to determine toxicity to the marine amphipod, *Rhepoxynius abronius*, and oyster larvae (see Attachment D). Methods developed by Swartz *et al*. (1984) and the American Society for Testing and Materials (Method E 724-80, 1980), were used. Amphipods and control sediments were collected weekly from Whidbey Island, Washington, refrigerated, and transported to the laboratory. The tests run in 1983 were without replication, and those conducted in 1984 had five replicates per treatment. Both test runs used 850 mL of sediment per beaker using Clam Bay seawater, and 20 amphipods per beaker. Survivorship was examined over a 10-day period.

Larval oyster bioassays were conducted using 2-hour old embryos from oysters spawned in the laboratory. Sediment toxicity was examined at 0.01, 0.1, 1.0, 10, and 100 grams of sediment for each treatment (see Attachment E). Each treatment was replicated three times. Approximately 30,000 embryos were placed in each beaker for 46 to 50 hours. Sediment controls and sea water controls were used. Percent normal and abnormal larvae were determined for each treatment.

Results and Discussion

Benthic fauna. Raw benthic sampling data were not provided in the report for this reviewer to examine infaunal population parameters for the East Waterway area; but the stations sampled in 1984 were composed of all six East Waterway stations and two others in Everett Harbor. An average of seven species and 114 individuals were identified. These numbers, when compared to other bays, are indicative of a stressed environment with few species, of which one or more are dominant. In the case of this area of Everett Harbor, capitellids and nematodes are the dominant infauna. These species are also indicative of the high organic levels found in the sediments (both natural and man-made pollution).

The large sieve size may be a problem in giving accurate results for the benthic survey. There are many polychaete species which, in the adult stage would pass through a 1.0 mm sieve (e.g., syllids). The large sieve size and the fact that a small area was sampled to quantify the infaunal community (236 cm^2) lead the reviewer to accept the data as only a qualitative study of the area. Most studies of infaunal communities take 10 to 12, 15 by 15-cm cores and collect only 80% of the infaunal species (3,535 cm^2). The number of cores to take is usually determined by plotting cumulative species number versus area sampled (number of cores), and involves taking many cores before the beginning of the study to determine the proper number of cores to take during the study.

Fish and Shellfish Disease Incidence. No fish, shrimp, or crabs were collected from the Everett Harbor bay. The samples collected from other urban bays indicated a high incidence of some cancer lesions in both fish and shellfish.

Bioassays. Amphipod - The 1983 screening tests performed with sediments from Everett Harbor indicate a low mean survival rate for amphipods living in these sediments (15 out of 20 survived). The 1984 tests paralleled the results from 1983. Sediments from the East Waterway area had mean survival rates of 44%, 71%, 67%, 42%, 14%, and 89% in 1984. All but the last station had significantly lower survival rates compared to the controls. However, as pointed out by the investigators, the results may indicate either a response to sediment grain-size (fine-grained sediments also detrimentally affect amphipod survival), the contaminants present in the sediments, or both. Inadequate sediment controls were run to examine survival in different sediment grain-sizes.

Oyster Larvae - The 1983 analyses using sediments from Everett harbor indicated that only sediment concentrations (by weight) of 10 and 100 grams resulted in significant levels of abnormal larvae developed. The 1984 tests, using only the 100 grams sediment treatment, but replicated, showed no significant differences between control and Everett Harbor sediments with respect to percent of larvae developing abnormally.

General Findings

Many statistical comparisons between bays were made for all parameters measured. However, for the purposes of this review, an effort will be made to concentrate on the relevance of these comparisons to Everett Harbor.

In general, coarse-grained sediments were not heavily contaminated unless there was a high organic content in the sediments. Although urban bays were more contaminated (chemically) than references bays, differences in the physical make-up of the bays also contributed a significant portion of the variance found, as did the presence of chemical pollution. The investigators thought it would be better to establish reference stations within a bay instead of reference bays.

This would help control differences in sediment granulometry, infaunal community structure, and natural sediment chemistry found in comparing different bays.

Comparisons of the concentrations of PCBs and organic compounds found in Everett Harbor with other bays indicated a high level of contamination for these pollutants. Biological indicators of this pollution did not always reflect this contamination and may be the result of the physical differences in sediments themselves and not the presence of contaminants.

9.0 DATA QUALITY

In general, the report was well documented with respect to QA/QC methods employed for each analyses. Validation procedures reported did fall within accepted standards. The methods used, although dated, were recognized methods at the time of the study. Therefore, the results found in this study provide an indication of the contaminants found in the East Waterway area during the mid-1980's and serve as a useful pollution baseline.

The validity and usefulness of future studies similar to the work under review would be improved by incorporating the following technical recommendations. The benthic infaunal sampling would be improved by using a 0.5 mm sieve as a maximum. Cores should be replicated to develop a species-area curve to determine the proper number of cores to collect at each sampling station. These procedures would give investigators a more robust data set to use in station comparisons. Replication of sampling would provide a better estimate of the natural variability found at each station. This additional information would be useful in future studies, if necessary, which would examine the ecological risk of the contaminated sediments.

The amphipod and larval oyster bioassays would be improved by having better sediment controls to examine the influence of sediment grain size to apparent sediment toxicity. Possible control options could include three different sediment grain sizes as well as sea water controls.

10.0 HYDROLOGIC AND HYDRODYNAMIC INFORMATION

N/A

11.0 DREDGING AND DISPOSAL ISSUES AND DATA

N/A

12.0 ENVIRONMENTAL IMPACTS

N/A

13.0 INTERIM MEASURES/SPILL AND POLLUTION PREVENTION MEASURES

N/A

14.0 COMMUNITY RELATIONS INFORMATION

N/A

15.0 RECOMMENDATIONS

If determined appropriate, additional studies could be designed to improve on the data collected in the East Waterway area. A more extensive benthic survey is required to more fully characterize the infaunal assemblages found in the East Waterway area. Sediment chemistry methods should be consistent between years. The study reviewed here varied analytical methods for the 1983 and 1984 sampling analysis. Therefore additional sampling may be needed to confirm the levels of contamination found in the study area.

An effort should be made to collect sole, flounder, other benthic fishes, and invertebrates from the East Waterway area to examine the incidence of disease in this area of Everett Harbor. These biological parameters were not examined for the East Waterway area in this study.

Future sediment toxicity bioassays studies would benefit by examining the toxicity of East Waterway sediments to amphipods, larval and juvenile fishes (preferably salmonids), and either oyster larvae or another bivalve more likely to occur in the East Waterway area. The possibility of performing in situ toxicity tests should also be evaluated to eliminate the common problems associated with static bioassays using the controls in this study. As a minimum, the bioassays should be conducted in flow-through conditions if they cannot be run in the field. Trophic analyses of the community should also be considered to determine potential pathways of bioaccumulation.

The information provided in this study established a strong data base which should be used during the design of any future studies in the East Waterway area.

16.0 FINAL COMMENTS

As suggested by the investigators, the 3-pronged approach (chemical, biological, and toxicological) introduced in this study is ideal for determining the toxicity of sediments in any bay or water body. Concurrently examining sediment chemistry, toxicity, and the biological communities within each sampling event provides investigators with sufficient information to address the requirements of major studies requiring risk assessment and clean-up level development.

If necessary, future work in the East Waterway area of Everett Harbor would benefit by this triad approach to sample sediment chemistry, toxicity, and biology, performed concurrently, several times over the study period (e.g., 1 or 2 years). The data base provided in this report could be used to assist in the design of such a study.

Attachment A

SAMPLING LOCATION MAPS

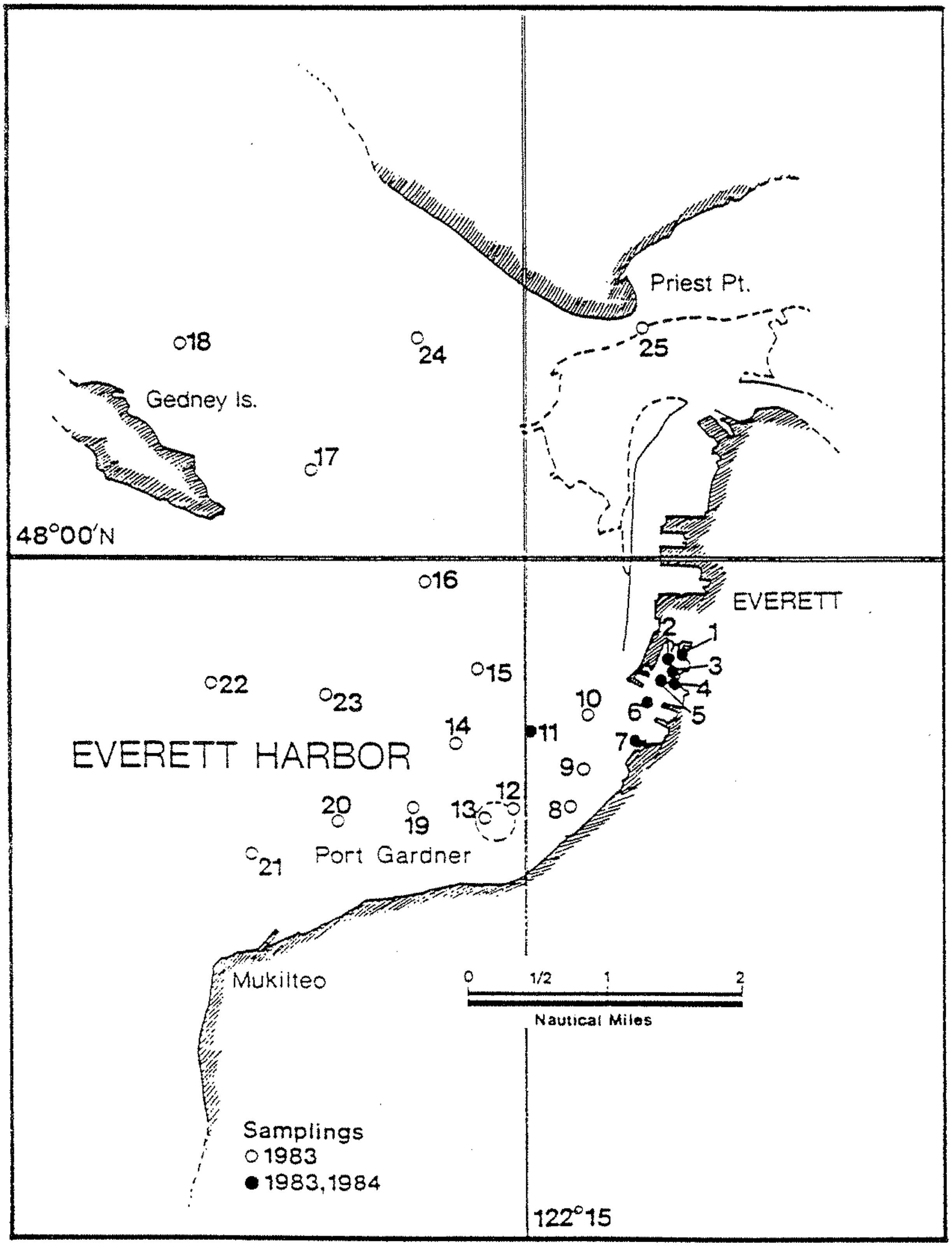

FIGURE 4. Port Gardner - Everett Harbor Sampling Stations

Attachment B

ORGANIC ANALYTICAL RESULTS FOR EAST WATERWAY

TABLE B-19. Concentrations of Priority Pollutants in Sediments Sampled from Port Gardner - Everett Harbor 5/1/84, µg/kg dry weight

Station	B-4 S-1	B-4 S-2	B-4 S-3	B-4 S-4
BASE/NEUTRAL COMPOUNDS				
acenaphthene	370	110	280	3300
fluoranthene	4800	770	830	4100
naphthalene	1300	750	1800	5900
bis(2-ethylhexyl) phthalate				
butyl benzyl phthalate				440
di-n-octyl phthalate			60	
benzo(a)anthracene	810	160		370
benzo(a)pyrene	250			
benzo(k)fluoranthene and/or benzo(b)fluoranthene	620	150		310
chrysene	650	160	210	340
acenaphthylene				770
anthracene	700	27	110	410
benzo(ghi)perylene				
fluorene	410	140	290	2100
phenanthrene	1900	380	970	4700
dibenzo(a,h)anthracene				
indeno(1,2,3-cd)pyrene				
pyrene	2500	510	880	2100
ACID COMPOUNDS				
phenol	250	190		1400
VOLATILES				
benzene				
chloroform				18m
1,1 dichloroethylene				
ethylbenzene				18m
tetrachloroethylene				
toluene				
trichloroethylene				

"m" indicates that a concentration falls between the detection level and the quantitation level for that compound

TABLE B-20. Concentration of Priority Pollutants in Sediments Sampled from Port Gardner - Everett Harbor 5/7/85, µg/kg dry weight

Station	B-4 S-5	B-4 S-6	B-4 S-7	B-4 S-11
BASE/NEUTRAL COMPOUNDS				
acenaphthene	240	120	480	
fluoranthene	1800	790	1400	200
napnthalene	590	790	1400	
bis(2-ethylhexyl) phthalate	830	190	290	870
butyl benzyl phthalate				
di-n-octyl phthalate				
benzo(a)anthracene	910		540	
benzo(a)pyrene				
benzo(k)fluoranthene and/or benzo(b)fluoranthene	1000		460	
chrysene	750		460	
acenaphthylene			120	
anthracene	890		480	
benzo(ghi)perylene				
fluorene	250		400	
phenanthrene		630	1600	370
dibenzo(a,h)anthracene				
indeno(1,2,3-cd)pyrene				
pyrene	1500	630	1600	200
ACID COMPOUNDS				
phenol				
VOLATILES				
benzene				
chloroform				
1,1 dichloroethylene				
ethylbenzene				
tetrachloroethylene				
toluene				
trichloroethylene				

"m" indicates that a concentration falls between the detection level and the quantitation level for that compound

Attachment C

PCB ANALYTICAL RESULTS FOR EAST WATERWAY

TABLE B-26. PCB Concentrations in Sediment from Four Urban and Four Baseline Bays in Puget Sound Collected 4/23/84 through 5/29/84, µg/kg dry weight.

Station Location	Battelle Number	PCB 1254 µg/kg	PCB 1260 µg/kg
Bellingham Bay	B-1 S-3	74	20µ*
	B-1 S-4	54	20µ
	B-1 S-5	27	20µ
	B-1 S-7	31	20µ
	B-1 S-11	54	20µ
	B-1 S-12	53	20µ
	B-1 S-23	20µ	20µ
	B-1 S-24	20µ	20µ
Fourmile Rock-Elliott Bay Dump Site Vicinity	B-5 S-9	273	57
	B-5 S-10	245	34
	B-5 S-12	78	20µ
	B-5 S-17	501	145
	B-5 S-20	640	20µ
	B-5 S-22	608	79
	B-5 S-23	148	20µ**
	B-5 S-24	59	20m
Port Gardner-Everett Harbor	B-4 S-1	445	20µ
	B-4 S-2	74	20m
	B-4 S-3	485	31
	B-4 S-4	800	165
	B-4 S-5	352	42
	B-4 S-6	114	20m
	B-4 S-7	130	25
	B-4 S-11	134	37
Sinclair Inlet	B-6 S-6	1080	173
	B-6 S-7	431	157
	B-6 S-8	507	139
	B-6 S-14	1210	462
	B-6 S-17	400	430
	B-6 S-18	200	280
	B-6 S-19	320	380
	B-6 S-20	480	260

Station Location	Battelle Number	PCB 1254 µg/kg	PCB 1260 µg/kg
Case Inlet	B-8 S-1	20µ	20µ
	B-8 S-11	20µ	20µ
	B-8 S-15	20µ	20µ
	B-8 S-17	20µ	20µ
Dabob Bay	B-7 S-1	20µ	20µ
	B-7 S-5	20µ	20µ
	B-7 S-7	20µ	20µ
	B-7 S-15	20µ	20µ
Samish Bay	B-2 S-1	20µ	20µ
	B-2 S-3	20µ	20µ
	B-2 S-7	20µ	20µ
	B-2 S-20	20µ	20µ
Sequim Bay	B-3 S-14	20µ	20µ
	B-3 S-17	20µ	20µ
	B-3 S-18	20µ	20µ
	B-3 S-20	20µ	20µ

* "µ" Denotes concentration is less than detection limit

** "m" Indicates that a concentration falls between the detection level and the quantitation level for that compound.

Attachment D

MARINE AMPHIPOD BIOASSAY RESULTS FOR EAST WATERWAY

TABLE C-4. Responses of the Marine Amphipod, *Rhepoxynius abronius*, to Sediments Collected from Port Gardner - Everett Harbor 8/19/83 through 8/21/83 (continued)

Sampling Area	Collection Date	Battelle Sample No.	EPA Sample Number	Assay Number	Amphipod Responses[a]: No. of Amphipods Out of Sediment	Amphipod Survival: No. of Survivors	Amphipod Survival: (%)	No. of Surviving Amphipods not Reburying	Chemical Characteristics of Sediments: pH	Eh(mv)	Interstitial Water S‰
EVERETT HARBOR	8/21/83	4-16-1	34443	4	1	15	75	0	7.06	73	30
		4-17-1	34445	4	0	13	65	0	7.25	63	30
		4-18-1	34447	4	0	15	75	0	7.04	29	30
		4-19-1	34449	4	1	17	85	0	7.07	83	30
		4-20-1	34451	4	0	19	95	0	7.25	90	30
		4-21-1	34453	4	0	19	95	0	7.21	53	31
		4-22-1	34455	4	0	17	85	0	7.45	49	30
		4-23-1	34457	4	1	17	85	0	7.21	190	30
		4-24-1	34459	4	0	20	100	0	7.08	291	_[b]
		4-25-1	34461	4	0	19	95	0	8.03	386	_[b]

Note: Refer to page 19 for footnote explanations and other details.

TABLE C-4. Responses of the Marine Amphipod, Rhepoxynius abronius, to Sediments Collected from Port Gardner - Everett Harbor 8/19/83 through 8/21/83 (continued)

Sampling Area	Collection Date	Battelle Sample No.	EPA Sample Number	Assay Number	Amphipod Responses[a]: No. of Amphipods Out of Sediment	Amphipod Survival: No. of Survivors	Amphipod Survival: (%)	No. of Surviving Amphipods not Reburying	Chemical Characteristics of Sediments: pH	Eh(mv)	Interstitial Water S‰
EVERETT HARBOR	8/21/83	4-16-1	34443	4	1	15	75	0	7.06	73	30
		4-17-1	34445		0	13	65	0	7.25	63	30
		4-18-1	34447		0	15	75	0	7.04	29	30
		4-19-1	34449		1	17	85	0	7.07	83	30
		4-20-1	34451		0	19	95	0	7.25	90	30
		4-21-1	34453		0	19	95	0	7.21	53	31
		4-22-1	34455		0	17	85	0	7.45	49	30
		4-23-1	34457		1	17	85	0	7.21	190	30
		4-24-1	34459		0	20	100	0	7.06	291	-[b]
		4-25-1	34461		0	19	95	0	8.03	306	-[b]

Note: Refer to page 19 for footnote explanations and other details.

TABLE C-13. Individual Replicate Responses of the Marine Amphipod, *Rhepoxynius abronius*, to Sediments Collected from Everett Harbor, 5/1/84 and 5/7/84.

Battelle Number	Assay Number	Replicate	Survivors	Survivors not Reburying	$\bar{X}$ No. Out of Sediment/Day[a]
B-4 S-1	2	1	13	1	6.1
		2	9	2	1.8
		3	9	1	4.7
		4	7	0	1.3
		5	6	1	3.4
B-4 S-2	2	1	16	0	0.1
		2	14	0	0.3
		3	14	0	0.0
		4	14	0	0.2
		5	13	1	0.5
B-4 S-3	2	1	15	0	0.2
		2	15	2	0.1
		3	15	1	1.2
		4	11	0	0.3
		5	11	1	1.2
B-4 S-4	2	1	6	3	4.8
		2	11	6	6.6
		3	8	3	5.8
		4	7	0	4.5
		5	10	2	6.5
B-4 S-5	3	1	3	0	2.3
		2	2	0	1.0
		3	0	0	0.9
		4	8	1	2.8
		5	1	1	0.6
B-4 S-6	3	1	18	0	0.3
		2	16	0	0.2
		3	19	0	0.2
		4	18	0	0.0
		5	18	0	0.2
B-4 S-7	3	1	20	0	0.0
		2	18	0	0.3
		3	19	0	0.2
		4	19	0	0.0
		5	14	0	0.6
B-4 S-11	3	1	15	0	0.0
		2	14	1	0.0
		3	14	0	0.0
		4	17	0	0.0
		5	14	0	0.0

a Mean number of amphipods floating on the surface each day.

Attachment E

OYSTER LARVAE BIOASSAY RESULTS FOR EAST WATERWAY

TABLE D-4. Environmental Conditions for Oyster Larval Bioassay No. 2 Performed May 10-12, 1984

Initial Observations

	C-D[1]	1-23[2]	4-3	1-12	1-24	C-C[1]	1-11	4-4	4-2	4-1
D.O.	7.4	6.7	6.3	6.6	6.0	7.2	5.9	7.0	6.1	5.1
pH	8.08	8.04	7.79	7.80	7.95	8.12	7.86	7.78	7.80	7.73
S°/₀₀	31	31	31	31	31	31	31	31	31	31
°C	20.0	20.1	20.0	20.1	20.0	20.0	20.0	20.0	20.0	20.0

Final Observations

	C-D[1]	1-23[2]	4-3	1-12	1-24	C-C[1]	1-11	4-4	4-2	4-1
D.O.	7.0	6.6	6.6	6.8	6.7	7.5	7.2	7.4	7.3	7.4
pH	8.25	8.17	8.17	8.12	8.16	8.25	8.17	8.20	8.20	8.13
S°/₀₀	34	32	32	32	32	32	32	32	32	33
°C	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0

1 Control.
2 Code (Bay-Station): Bay 1 is Bellingham Bay, Bay 4 is Port Gardner - Everett Harbor.

Attachment F

AMBIENT CONDITIONS DURING OYSTER LARVAE BIOASSAYS

TABLE D-5. Environmental Conditions for Oyster Laval Bioassay No. 3 Performed May 10-12, 1984

	C-F[1]	4-5[2]	4-6	4-7	4-11	C-G[1]	5-9	5-10	5-12	5-17
Initial Observations										
D.O	7.1	6.9	6.9	6.9	6.9	7.1	6.9	6.9	6.9	6.9
pH	8.12	8.12	8.09	8.08	8.05	8.07	8.03	7.94	8.07	8.04
S°/₀₀	30	30	30	30	30	30	30	30	30	30
°C	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2
Final Observations										
D.O	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4
pH	8.28	8.21	8.18	8.17	8.17	8.21	8.17	8.17	8.05	8.11
S°/₀₀	32	32	32	32	32	32	32	32	32	32
°C	20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5

1 Control.
2 Code (Bay-Station): Bay 4 is Port Gardner - Everett Harbor, Bay 5 is Fourmile Rock - Elliott Bay dump site vicinity.

Appendix D

EAST WATERWAY, EVERETT, WASHINGTON
TECHNICAL DOCUMENT REVIEW

Review of:

Chapman, P.M., R.N. Dexter, J. Morgan, R. Fink, D. Mitchell, R.M. Kocan, and M.L. Landolt, 1984, Survey of Biological Effects of Toxicants Upon Puget Sound Biota, Phase III, Tests in Everett Harbor, Samish and Bellingham Bays, NOAA Technical Memorandum NOS-OMS2, National Oceanic and Atmospheric Administration, Rockville, Maryland, 44 pp.

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Prepared For:

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EAST WATERWAY TECHNICAL DOCUMENT REVIEW

TABLE OF CONTENTS CHECKLIST

<u>ATTACHMENTS</u>

1.0 INTRODUCTION AND CHRONOLOGY OF EVENTS

The document reviewed was produced at the conclusion of a study conducted by the National Oceanic and Atmospheric Administration (NOAA) as part of the Marine Ecosystems Analysis (MESA) Puget Sound Project, to determine if marine sediment samples collected from Bellingham Bay and Everett Harbor were toxic to biota, relative to other areas within the Puget Sound ecosystem.

The analytical results from composite sediment grab samples collected from 22 stations were presented. The samples were tested for acute lethal, sublethal, partial life cycle, cell reproduction and genotoxic effects. Two of the stations were located in Samish bay, a nonindustrialized area; these results were used to provide reference data. The relative toxicity of the sediment samples to representative Puget Sound biota were evaluated, and the results were compared to similar data from other (previously tested) areas of Puget Sound.

Attachments to this review have been excerpted directly from the NOAA document.

Chronology of Events

- o Sediment samples were collected May 1983.
- o Sediment sample analysis results were compiled in the review document dated May 1984.

2.0 LEGAL AND REGULATORY ISSUES

N/A

3.0 DEMOGRAPHICS AND LAND USE

N/A

4.0 POTENTIALLY LIABLE PERSONS

N/A

5.0 IDENTIFICATION OF POLLUTION POINT SOURCES

Sampling stations selected for Bellingham Bay and Everett Harbor were situated near potential sources of toxic substances (e.g., industrial locations, sewer discharges). Precise station location information was provided in Figures 2 and 3 (Attachment A).

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The following point sources were identified during discussion of sediment characterization:

- **Pulp and paper mills** - Inner Everett Harbor sediments showed high levels of organic enrichment, which were attributed to inputs of wood and other organic debris from local pulp and paper mills. Sediment in Bellingham was rich in organic matter only in the inner harbor area, near the pulp and paper mills.

Various sediment toxic effects were found in specified stations and it was recommended that the sources of contamination be determined. The report includes a table of "Summary of Contaminant Distribution Data Related to the Study Area". In this table, primary pollutants were identified and possible pollutant inputs (pulp and paper mill, mercury cell chlor-alkali plant, light industry inputs, municipal sewage) were suggested. Supporting references or documentation for these suggestions were not provided in the report.

6.0 IDENTIFICATION OF POLLUTION NON-POINT SOURCES

As discussed above, various sediment toxic effects were found in specified stations, and the authors recommended that the sources of contamination be determined. Specific non-point sources were not identified in the report.

7.0 CHEMICAL DATA

Chemical analyses performed in this study were designed to characterize the sediment. Analyses included grain size, percents of clay, silt, gravel, sand, water, digestable organic carbon (DOC), total volatile solids (TVS), and extractable organic matter. Results for the aforementioned analytes were described and the data were tabulated; methodologies were referenced and summarized in the report. The report stated that 10 percent of all samples for grain size, DOC, and TVS were analyzed in duplicate. No sample raw data or quality control (QC) data were provided in the report, so data quality could not be evaluated. According to the authors, results were within the ranges observed for other areas of Puget Sound, with the exceptions of a high clay content in Bellingham Bay sediments and a high percentage of TVSs in inner Everett Harbor sediments. No specific data were provided to support this statement.

The report included a table of "Summary of Contaminant Distribution Data Related to the Study Area". In this table, metals (mercury, copper, lead, zinc), polychlorinated biphenyl compounds, and polycyclic aromatic hydrocarbons were identified and related to possible pollutant inputs. No information except identification of the chemical contaminants was provided in the report, so the data quality or the relevance of the data to the toxicity studies could not be evaluated. In the report preface, it was stated that "chemical analyses of sediment samples from many other bays and harbors around the Sound showed that Bellingham Bay and Everett Harbor were relatively highly contaminated." No specific data were provided to support this statement.

8.0 BIOLOGICAL DATA (FLORA/FAUNA)

Methods

Sediment Collection. A 0.1 m^2 Van Veen grab modified with top screens and rubber flaps was utilized for sediment collection. Six to ten grabs were collected at each station. Subcores were removed from the grab by inserting the aluminum barrel of an aluminum cookie press into the sediment. Seven to ten subcores were taken from each grab sample. The subcores were combined and homogenized in a polyethylene bag, to yield approximately 10 L (15 kg wet weight) of sample. Sediment aliquots were transferred to solvent-rinsed glass jars with Teflon-lined caps, or to polyethylene bags for subsequent testing. All samples, except those for sediment characterization, were frozen within 24 hours of collection and kept frozen until analysis. Samples for sediment characterization were maintained at 4°C until analysis.

Sample Preparation and Analysis. The following sediment direct exposure test methods were employed:

- Acute lethal, using the amphipod Rheopoxynius abronius;
- Sublethal, using the respiration rate of the oligochaete Monopylephorus cuticulatus;
- Partial lifecycle, using larve from the Pacific oyster, Crassostrea gigas; and
- Cell reproduction and genotoxic effects, using cultured fish cells.

Collection, preparation, exposure, and analysis procedures for all tests were described in the report.

Acute lethal test (Amphipod lethality) - Five replicate tests were run for each test sediment and for the control tests. Four control series were run; three control were unfrozen sediment from the collection site and one control was frozen sediment from the control site. Amphipod avoidance response also was determined at the time each mortality check was made. Procedure references were not provided.

Sublethal test (Oligochaeta repiration rate) - Oligochaeta oxygen consumption was determined potentiometrically. Between three and five series of measurements were taken for each sample; three consecutive aliquots were analyzed for each measurement. Procedure references were not provided, except for a conversion table used for the percent oxygen determination.

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Partial lifecycle (oyster larvae toxicity) - Prepared sediment samples were innoculated with developing oyster embryos. After incubation, the oyster larvae were concentrated, preserved, examined, and counted for percent survival and for percent abnormalities. Percent survival was determined relative to seawater control survivals. All analyses were run in duplicate. Quality assurance (QA) procedures included blind counts. Two control bioassays were prepared and run concurrently; one control used clean sediment from West Beach, Whidbey Island, and the other control contained clean seawater. No data were provided to support the assumption that the controls were "clean". The bioassay procedure reference was provided.

Cell reproduction and genotoxicity (fish cells) - Sediment samples were extracted with methanol and dichloromethane. The extract was dried with sodium sulfate and the volume reduced to dryness to determine the weight of extractable organic material. The soluble portion of the extracts were then reconstituted to 1 mL with dimethyl sulfoxide (DMSO).

Cell cultures from two fish species were employed: rainbow trout gonad cells, and bluegill fry cells. The gonad cells enzymatic activity processes and activates many toxins that require metabolic activation. Fry cells are relatively unaffected by toxins requiring metabolic activation. Both cells types are susceptible to direct acting toxins. Both cultures were incubated in the presence of the sediment extracts for 96 hours to evaluate cell reproduction inhibition and cytotoxicity. Six dilutions of each extract were prepared, ranging from nontoxic to 100 percent toxic.

Each concentration of each extract was tested against both cell types in triplicate, and against the control cultures of both untreated cells and solvent-treated cells. To test the activity of the enzyme systems and the sensitivity of the cells, positive controls of three replicates of six concentrations of benzo(a)pyrene were run for each cell type. For all cultures, live cells were removed after the 96-hour incubation, and counted using a coulter electronic particle counter. Any concentration which reduced the final cell count by 20 percent was considered inhibitory; the extract was considered cytotoxic when the cell count was less than the seeding cell density.

Two extracts were chosen for genotoxicity testing: the highest concentration which did not inhibit nitosis in trout gonad cells and a second concentration one dilution lower. After incubation with sediment extracts (two cultures per dilution of each extract) for 48 hours, the cells were fixed, stained, and examined for normal and aberrant anaphases. Controls were run with each series of extracts, consisting of a set of untreated cells and set of cells treated with DMSO. A set of three positive controls were treated with benzo(a)pyrene.

Sample Results

Acute Lethal Test. The report concluded that exposure of the amphipod to one station in each Bellingham Bay (Station 3) and Everett Harbor (Station 14) resulted in a significant ($P < 0.05$) decrease in survival rate relative to controls. Data for avoidance did not correspond with the survival data. The report concluded that sublethal test-significant respiratory anomalies compared to controls were detected in 3 of the 10 sediments from Bellingham Bay, in 4 of the 10 sediments from Everett Harbor, and in none of the sediments from Samish Bay.

Partial Lifecycle. Three stations in Bellingham Bay and three stations in Everett Harbor exceeded the single sample marine quality criterion (proposed by Woelke 1972) of 20 percent abnormality. Six of the stations at each location exceeded the multiple sample marine quality criterion of 5 percent abnormality (proposed by Woelke 1972). The survival rate data was concluded to be in agreement with the observed abnormality rate. Based on the combined abnormality and survival rate data, all of the stations in Bellingham Bay and Everett Harbor except one were evaluated as either of low, intermediate or high toxicity. Both Lake Samish stations showed no partial lifecycle toxicity.

Cell Reproduction and Genotoxicity. The report stated that neither the DMSO solvent nor the extraction blank affected cell proliferation; no data were provided to support this conclusion. The positive control (benzo[a]pyrene) was concluded to affect cell reproduction in trout gonad cells but not in fry cells; no data were provided to support this conclusion. Positive cell culture responses (a statistically significant in cell number) were observed in gonad cells at eight stations, including both stations at the reference location. Fry cell cultures exhibited positive responses at three stations, including one station at the reference location. The report summarized that 8 of the 22 tested stations induced statistically significant increases in the number of anaphase aberrations relative to control cultures. One of the stations was a station in the reference location.

General Findings

Both Bellingham Bay and Everett Harbor sediments demonstrated acute lethal, sublethal, and partial lifecycle toxicities relative to Lake Samish. Based on previous reports (referenced) and the results of the aforementioned toxicity studies, both areas were concluded to be less toxic than the Duwamish River or Commencement Bay.

The results of the cell reproduction studies and geotoxic effects were inconclusive without specific chemical data. The report concluded that comparisons between present sediment bioassay data for Everett Harbor and Bellingham Bay indicate that Everett Harbor sediments are more toxic overall than Bellingham Bay sediments. The report further concluded that the highest sediment toxicity in Everett Harbor was found in the inner harbor; in Bellingham Bay, the highest toxicity was found in the inner bay.

9.0 DATA QUALITY

Information included in the report was insufficient to evaluate overall data quality. Summaries of toxicity results and sediment characterization were provided; no raw data were provided. All methods used and statistical analysis performed were described or referenced. All toxicity studies performed appropriate control studies or blank studies, and all tests were performed in duplicate or triplicate, to provide statistically significant results. Chemical analyses data previously collected for the two areas of concern were discussed, but specific analytical results or raw data were not provided, so data quality could not be assessed.

10.0 HYDROLOGIC AND HYDRODYNAMIC INFORMATION

N/A

11.0 DREDGING AND DISPOSAL ISSUES AND DATA

N/A

12.0 ENVIRONMENTAL IMPACTS

N/A

13.0 INTERIM MEASURES/SPILL AND POLLUTION PREVENTION MEASURES

N/A

14.0 COMMUNITY RELATIONS INFORMATION

N/A

15.0 RECOMMENDATIONS

As a stand-alone document, information presented in the report should be considered a preliminary evaluation of relative sediment toxicities in Bellingham Bay, Everett Harbor, and Lake Samish. Sampling was limited (10 sampling stations in Bellingham Bay, 10 sampling stations in Everett Harbor, and 2 sampling stations in Lake Samish) and a number of the toxicity results could not be explained with existing information. Chemical contaminant data were available for only Bellingham Bay and Everett Harbor; the data were historical, and not directly relevant to the sample set used for toxicity studies. An attempt to identify point sources or non-point sources of chemical contaminants would require further investigation.

16.0 FINAL COMMENTS

The purpose of the study was to determine if sediment samples of two urban areas were toxic. Results of the overall study do demonstrate toxicities, which were reported to be of a lesser degree than toxicities observed at three other locations in highly industrialized urban areas, previously demonstrated to be highly contaminated. Report findings indicated that all studies provided useful information regarding sediment toxicity.

Attachment A

STATION LOCATIONS

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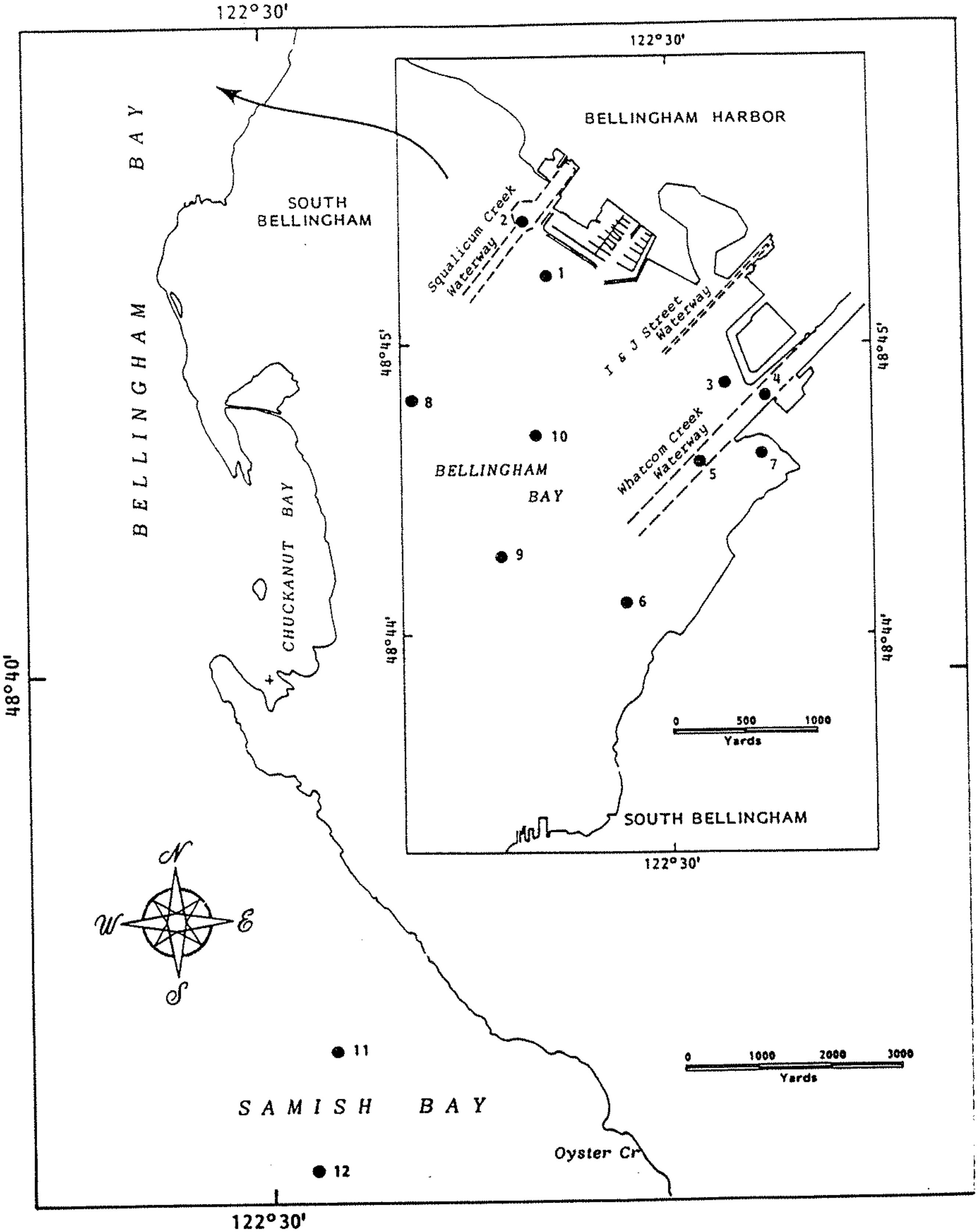

Figure 2 Station Locations in Bellingham and Samish Bays

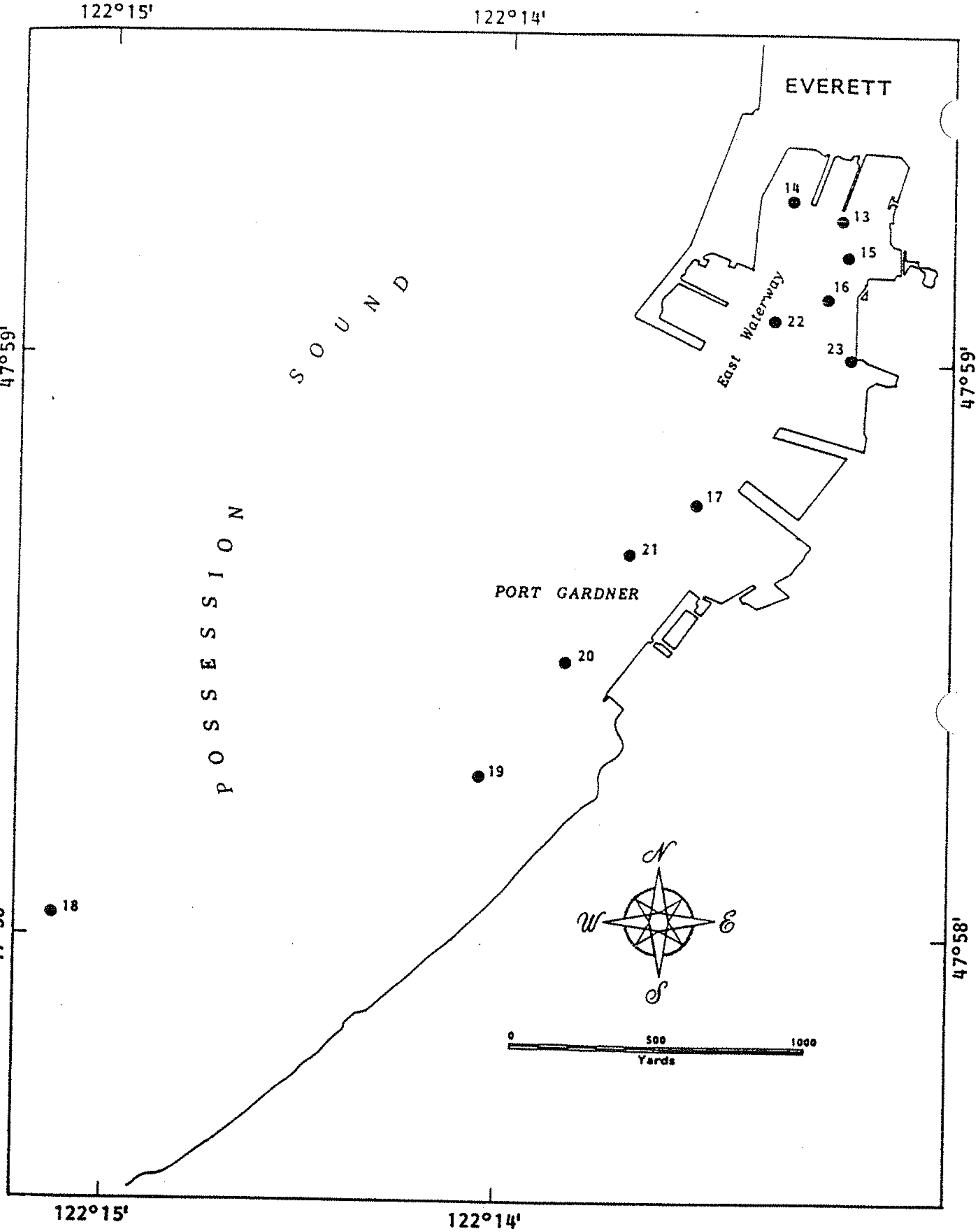

Figure 3 Station Locations in Everett Harbor

TABLE I Sediment Physical and Chemical Parameters

Station Number	Gravel %	Sand[a] %	Silt[a] %	Clay[a] %	Water %	DOC[b] %	TVS[b] %	Extractables[b] %	Soluble[c] %
Bellingham Bay									
01	0.00	1.72	53.58	44.70	43.28	1.42	5.9	0.0693	84
02	0.00	2.31	68.93	28.76	49.08	2.25	8.7	0.0603	98
03*[d]	3.48	18.08	44.30	34.14	61.21	3.32	14.8	0.1746	66
04*	0.64	5.29	66.80	27.28	58.35	1.03	11.9	0.1965	76
05	0.00	2.98	49.83	47.19	55.33	1.22	8.1	0.1113	83
06	0.00	2.18	62.94	34.88	58.39	1.54	8.7	0.1493	82
07*	0.14	7.17	48.37	44.38	60.19	1.50	9.8	0.1875	72
08	1.26	23.13	43.56	32.04	45.56	1.02	5.6	0.0944	78
09	0.00	5.46	49.11	45.43	63.11	1.35	7.6	0.1393	85
10	1.06	23.46	44.48	31.00	47.04	1.29	6.4	0.1065	85
Samish Bay									
11	0.28	78.40	11.08	10.25	31.62	0.38	3.0	0.0334	68
12*	0.00	8.76	59.76	31.48	64.32	1.32	7.9	0.0789	67

Table I (Cont'd)

Station Number	Gravel %	Sand[a] %	Silt[a] %	Clay[a] %	Water %	DOC[b] %	TVS[b] %	Extract-ables[b] %	Soluble[c] %
Everett Harbor									
13*	0.23	28.35	50.17	21.25	62.91	5.72	18.6	0.4257	78
14*	2.51	9.04	54.77	33.67	74.59	7.20	18.9	0.4158	65
15*-[d]	11.01	32.30	45.36	11.33	56.86	7.06	18.7	0.4021	43
16*	0.80	34.00	47.38	17.82	66.22	7.69	23.1	0.3691	42
17	1.30	38.57	40.58	19.54	51.82	3.43	11.4	0.1894	53
18	3.06	60.18	24.15	12.61	36.01	1.36	4.2	0.0658	58
19	0.04	81.63	12.72	5.61	27.15	0.78	2.6	0.0464	77
20	0.07	40.31	42.97	16.64	47.62	1.23	7.9	0.1114	78
21*	1.77	40.90	37.12	20.20	51.61	1.26	9.9	0.1737	49
22*	8.55	16.60	42.95	31.90	64.54	2.45	17.3	0.3503	38
23*	3.13	42.15	37.24	17.48	66.19	6.34	25.6	0.3148	43

a. Phi size ranges: sand, -2 to +4; silt, >4 to 8; clay, >8.
b. Percent of dry weight of sediments.
c. Material which dissolved in DMSO during genotoxicity testing. Expressed as percent of extractable organic matter (extractables).
d. A minus (-) sign after the station number indicates that no living organisms were observed in the sediments during sampling. A star (*) indicates that a bad odor, e.g. H_2S, was noted in the sample during collection.

TABLE 2 Oyster Larvae Bioassay Data

Station	Replicate	Total Larvae	Normal Larvae Total	Normal Larvae %	Abnormal Larvae Total	Abnormal Larvae %	Mean Values: Number of Larvae	Mean Values: Percent Abnormal	Mean Values: % Relative Survival[a]	Relative Toxicity[b]
1	A	66	48	72.7	18	27.3	110	25.1	26	3
	B	153	116	75.8	37	24.2				
2	A	140	128	91.4	12	8.6	166	11.8	40	2
	B	191	164	85.9	27	14.1				
3	A	181	165	91.2	16	8.8	250	6.0	60	1
	B	318	304	95.6	14	4.4				
4	A	100	89	89.0	11	11.0	67	11.3	16	2
	B	33	29	87.9	4	12.1				
5	A	84	64	76.2	20	23.8	65	26.2	16	3
	B	46	32	69.6	14	30.4				
6	A	192	176	91.7	16	8.3	232	6.5	56	1
	B	272	258	94.9	14	5.1				
7	A	47	39	83.0	8	17.0	32	18.8	8	3
	B	17	13	76.5	4	23.5				
8	A	90	59	65.6	31	34.4	106	24.6	25	3
	B	121	100	82.6	21	17.4				
9	A	181	168	92.8	13	7.2	184	6.3	44	1
	B	186	176	94.6	10	5.4				
10	A	69	64	92.8	5	7.2	136	4.4	33	1
	B	203	196	96.6	7	3.4				
11	A	266	257	96.6	9	3.4	245	2.7	59	0
	B	224	220	98.2	4	1.8				

Table 2 (Cont'd)

Station	Replicate	Total Larvae	Normal Larvae Total	Normal Larvae %	Abnormal Larvae Total	Abnormal Larvae %	Mean Values: Number of Larvae	Mean Values: Percent Abnormal	Mean Values: % Relative Survival[a]	Relative Toxicity[b]
12	A	400	395	98.8	5	1.2	307	1.8	74	0
	B	214	208	97.2	6	2.8				
13	A	19	8	42.1	11	57.9	32	46.7	8	3
	B	44	27	61.4	17	38.6				
14	A	55	48	87.3	7	12.7	96	31.7	23	3
	B	136	92	67.6	44	32.4				
15	A	119	104	87.4	15	12.6	124	12.5	30	2
	B	128	112	87.5	16	12.5				
16	A	66	56	84.8	10	15.2	105	15.8	25	2
	B	143	120	83.9	23	16.1				
17	A	184	163	88.6	21	11.4	189	10.1	45	2
	B	193	176	91.2	17	8.8				
18				not tested						
19	A	319	312	97.8	7	2.2	311	2.1	75	0
	B	302	296	98.0	6	2.0				
20	A	123	104	84.6	19	15.4	147	12.9	35	2
	B	171	152	88.9	19	11.1				
21	A	248	232	93.5	16	6.5	236	8.1	57	1
	B	223	201	90.2	22	9.8				

Table 2 (Cont'd)

Station	Replicate	Total Larvae	Normal Larvae Total	Normal Larvae %	Abnormal Larvae Total	Abnormal Larvae %	Mean Values: Number of Larvae	Mean Values: Percent Abnormal	Mean Values: % Relative Survival[a]	Relative Toxicity[b]
22	A	179	163	91.1	16	8.9	119	11.3	29	2
	B	59	48	81.4	11	18.6				
23	A	56	35	62.5	21	37.5	57	26.5	14	3
	B	57	48	84.2	9	15.8				
Sediment Control	A	408	402	98.5	6	1.5	382	1.6	92	-
	B	356	350	98.3	6	1.7				
Seawater Control	A	449	438	97.6	11	2.4	415	2.2	100	-
	B	381	374	98.2	7	1.8				
Combined Sediment and Seawater Controls							396 (n=4; S.D.=42; x±2S.D.=312-480)			

a. In terms of mean seawater control survivals which, following standard (Cummins, 1973, 1974; APHA, 1980) procedures, are assigned a survival value of 100%.

b. Relative toxicity of sediment extracts was scored on the following scale:

>20% abnormalities = 3 - high toxicity
10-19% abnormalities = 2 - intermediate toxicity
4-9% abnormalities = 1 - low toxicity
<3% abnormalities = 0 - no toxicity

TABLE 3 Amphipod Bioassay Data

Station	Survival[a] Mean	Survival[a] S.D.	Avoidance[b] Mean	Avoidance[b] S.D.
1	18.6	0.5	1.3	2.9
2	18.6	1.7	3.8	5.1
3	17.2	1.3	1.1	2.1
4	18.4	0.9	2.1	3.3
5	19.2	0.8	0.4	1.3
6	17.4	2.2	2.8	4.9
7	18.0	1.6	0.6	1.6
8	18.8	1.3	2.0	3.0
9	19.2	1.3	0.4	1.5
10	18.4	1.5	1.4	3.2
11	19.0	1.2	3.3	2.5
12	19.2	1.3	0.7	1.6
13	19.4	0.5	3.3	3.0
14	15.0	2.0	1.6	2.3
15	18.4	1.5	1.5	2.2
16	18.6	1.1	1.3	1.9
17	18.6	0.9	1.9	2.5
18	19.0	0.7	1.2	2.0
19	19.6	0.5	3.1	2.6
20	19.2	0.8	1.4	2.4
21	19.2	0.8	1.6	2.3
22	19.4	0.9	0.7	1.3
23	19.4	0.5	2.4	3.0
C1[c]	19.2	1.3	0.3	0.6
C2[c]	19.4	0.9	0.4	0.7
C3[c]	19.0	0.7	0.3	0.6
FC[d]	18.6	0.5	0.1	0.4

a. 5 replicates; seeded with 20 amphipods per replicate
b. number of amphipods on the surface per jar per day
c. controls with fresh sediment
d. control with frozen sediment

TABLE 4 Oligochaete Respiration Rate Data

Station	Mean Respiration ($\mu L O_2$/mg dry wt/h)	S.D.	n	Level of Significance[a]
1	0.32	0.10	7	**
2	0.23	0.05	7	n.s.
3	0.19	0.03	7	*
4	0.20	0.04	7	n.s.
5	0.28	0.06	7	n.s.
6	0.19	0.02	7	*
7	0.25	0.05	7	n.s.
8	0.26	0.04	7	n.s.
9	0.26	0.06	7	n.s.
10	0.22	0.04	7	n.s.
11	0.22	0.02	6	n.s.
12	0.24	0.05	7	n.s.
13	0.22	0.03	7	n.s.
14	0.31	0.05	7	**
15	0.29	0.07	6	*
16	0.21	0.03	6	n.s.
17	0.28	0.04	6	*
18	0.27	0.05	7	n.s.
19	0.19	0.03	7	*
20	0.20	0.03	6	n.s.
21	0.24	0.06	6	n.s.
22	0.20	0.03	6	n.s.
23	0.21	0.05	6	n.s.
Control	0.24	0.04	29	

a. Level of significance of difference compared to control value:
n.s. = not significant; * = $0.05>P>0.01$; ** = $0.01>P>0.001$

TABLE 5 Fish Cell Reproduction Data

Station	Lowest Organic Concentration Giving Significant Response[a]		Relative Toxicity[b]	
	RTG-2	BF-2	RTG-2	BF-2
1	10	50	+	n.s.
2*	25	25	(+)	(+)
3	25	10	(+)	+
4*	50	50	n.s.	n.s.
5	25	50	(+)	n.s.
6*	50	50	n.s.	n.s.
7*	50	50	n.s.	n.s.
8	50	25	n.s.	(+)
9	25	50	(+)	n.s.
10	25	50	(+)	n.s.
11	25	10	(+)	+
12*	5	10	+	+
13	10	50	+	n.s.
14	10	50	+	n.s.
15*	50	50	n.s.	n.s.
16	25	50	(+)	n.s.
17	10	50	+	n.s.
18		not tested		
19	10	25	+	(+)
20	2	25	+	(+)
21	10	25	+	(+)
22	25	50	(+)	n.s.
23	25	50	(+)	n.s.

a. values in µg sediment extract/mL culture medium
b. n.s. = negative; significant response ($P<0.05$) only at 50 µg/mL
(+) = questionable; significant response ($P<0.05$) only at 25 µg/mL
\+ = positive; significant response ($P<0.05$) at 10 µg/mL or less

* = same rating for both RTG-2 and BF-2 cells

TABLE 6 Fish Cell Anaphase Aberration Data

Station	Number of Abnormalities Per 100 Cells	P< a
1	11	n.s.
2	6	n.s.
3	17	0.01
4	12	n.s.
5	13	n.s.
6	21	0.01
7	10	n.s.
8	26	0.01
9	16	0.05
10	48	0.01
11	18	0.01
12	6	n.s.
13	7	n.s.
14	8	n.s.
15	23	0.01
16	2	n.s.
17	9	n.s.
18	Not Tested	
19	10	n.s.
20	8	n.s
21	11	n.s.
22	18	0.01
23	7	n.s.

Controls:

5 cultures; 100 anaphase cells/culture = 500 cells
Mean = 10.8% abnormalities
S.D. = 1.92

a. Significance is determined based on the confidence limits (C.L.) for abnormalities in 500 anaphase cells from control cultures: upper 95% C.L. = 15 abnormal cells/100; upper 99% C.L. = 17 abnormal cells/100.

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Appendix
E

EAST WATERWAY, EVERETT, WASHINGTON
TECHNICAL DOCUMENT REVIEW

Review of:

Crecelius, E.A. and J.W. Anderson, May 1986, Biological and Chemical Analysis of Sediments for the Design and Construction of the U.S. Navy Homeport Facility at East Waterway - Everett Harbor, Washington, Phase III, prepared by Battelle, Marine Research Laboratory, Sequim, Washington, 26 pp. and appendices.

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Prepared For:

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EAST WATERWAY TECHNICAL DOCUMENT REVIEW

TABLE OF CONTENTS CHECKLIST

ATTACHMENTS

1.0 INTRODUCTION AND CHRONOLOGY OF EVENTS

The document reviewed provides a preliminary assessment of sediment quality and toxicity in East Waterway. Physical, chemical, and biological tests were performed on two composite sediment samples collected from the waterway. One sample was composited from the upper, surface, "contaminated" sediment layer, and one sample was composited from the lower, bottom, "native" sediment layer. The report does not state precisely when the sampling occurred nor the location of sampling sites from which composites were derived. Some comparisons between the native and contaminated samples are made. In addition, some of the data are compared to "background" Puget Sound sediments from Sequim Bay.

The United States Navy requested that the Seattle District United States Army Corps of Engineers (COE) assist in developing a contaminated sediments assessment program for East Waterway. This assessment builds on previous East Waterway sediment characterization performed in 1984 and 1985 by Battelle (see Section 7.0 for complete reference citations). The assessment consisted of:

- Field sampling
  - Presumably conducted in 1985 or 1986, although not stated in report
  - One "contaminated" sediment composite sample
  - One "native" sediment composite sample
- Analytical testing (Waterways Experiment Station)
  - EP-toxicity (EP-tox) test for metals; analysis of selected organics, including all those on the United States Environmental Protection Agency (EPA) priority pollutant list (analysis also by U.S. Testing Company, Hoboken, New Jersey, and Pacific Northwest Laboratory, Richland, Washington)
- Biological studies
  - Amphipod (Rhepoxynius abronius) bioassay to determine sediment toxicity
  - Juvenile geoduck (Panopea generosa) bioassay to determine sediment toxicity
  - Microtox bacteria bioassay on sediment extracts
  - Oyster larvae (Crassostrea gigas) water column bioassay to determine potential water quality effects
  - Toxicity and bioaccumulation of contaminant sediments using shrimp, clams, and mussels

2.0 LEGAL AND REGULATORY ISSUES

Regulatory issues addressing dredging and disposal of contaminated sediments and soils only are addressed indirectly, in a very general sense. The report states that concentrations of contaminants found in the sediment composites are similar to those reported in previous studies of East Waterway. The report does not identify or discuss specific regulatory criteria that must be met to dredge and dispose of contaminated sediments.

3.0 DEMOGRAPHICS AND LAND USE

N/A

4.0 POTENTIALLY LIABLE PERSONS

N/A

5.0 IDENTIFICATION OF POLLUTION POINT SOURCES

Polycyclic aromatic hydrocarbons (PAHs) are noted as the primary contaminants with small amounts of polychlorinated biphenyls (PCB) (Aroclor 1254) and heavy metal contamination. No possible point sources of these contaminants are discussed.

6.0 IDENTIFICATION OF POLLUTION NON-POINT SOURCES

N/A

7.0 CHEMICAL DATA

Methods

Data Collection. Two composite sediment samples were collected from East Waterway. "A large grab-sampler" was used to collect sediments. The type of grab-sampler is not specified. No information is presented on collection methods or sampling locations.

Analytical Testing. The steps used to determine levels of PAHs and PCBs were digestion (or soxhlet extraction), followed by phase separation of solvents, column chromatography, and capillary gas chromatography (GC).

Three methods were used to measure trace metals in tissues and sediments. X-ray fluorescence was used to analyze for copper (Cu), zinc (Zn), lead (Pb), nickel (Ni), chromium (Cr), and arsenic (As). Atomic absorption spectroscopy was used for cadmium (Cd), silver (Ag), selenium (Se), antimony (Sb), beryllium (Be), thallium (Th), and cold vapor analysis was used for mercury (Hg). The EP-tox test determined concentrations of metals leachable from sediment into freshwater at pH 5.0. Atomic absorption using a Zeeman graphite furnace was used to quantify concentrations of the soluble metals Zn, As, Cd, Cu, and Pb. Cold vapor atomic absorption was used to quantify mercury.

Results

Bulk Analyses. The contaminated composite contained less silt and more clay than the native sediment. The contaminated sediment also contained more water, volatile components, total hydrocarbons (oil), and sulfides than the native sediment composite sample. High concentrations of oil (5,700 ppm) were observed in East Waterway contaminated sediments and in native sediments (1,200 ppm) (see Attachment A).

Metals. The contaminated sediment exhibited higher levels of Cu, Zn, Pb, Hg, Ag, and Sb than the native sediment. The concentrations of metals present were compared to Washington State Department of Ecology (Ecology) criteria for dangerous wastes and were shown to be 100 to 1,000 times lower than the criteria. These results are presented in Table 3 of Attachment A.

It should be noted that comparison of these sediments to dangerous waste criteria is only meaningful if upland disposal of these sediments is contemplated, in which case, if the criteria were exceeded, disposal at an approved site is required.

Organics. GC analyses results for PAHs are shown in Table 4 of Attachment A. The total PAH level recorded for the native sample is considerably higher (24 ppm) than levels recorded in previous studies (2 ppm). The authors indicated that this was likely due to the fact that their sampling technique included a thin layer of contaminated sediment from outer harbor sites in the native sediment sample. Additional laboratory analysis was conducted to ensure that PAH compounds were identified correctly; 20 of the 23 PAH compounds confirmed by GC-MS had the proper molecular weights.

The scan of EPA priority pollutants only quantified a few compounds because detection limits are high for the approved EPA methods. The highest volatile organic compound quantified was acetone at 1,200 µg/kg. Dioxin was at or below 0.04 ppt and cyanide was less than 1.3 mg/kg. The contaminated sediment contained about 300 ppb of Aroclor 1254 compared to 66 ppb in the native sediment (other PCB congeners were not tested).

Pesticide resolution was not possible due to the overlapping of chromatogram peaks for PCBs, endrin, endrin aldehyde, dichlorodiphenyl-dichloroethylene (DDE), dieldrin, and dichlorodiphenyldichloroethane (DDD). Based on total peak heights for all pesticides, the authors stated that no single pesticide concentration would exceed 10 ppb and, therefore, no significant environmental concern exists.

Data Quality

Field Methods. No information is presented on how the sediment samples were collected and composited. An extensive quality control (QC) plan for analysis procedures and custody of samples is included as an appendix, but sampling techniques and sampling locations are not discussed.

Laboratory Methods. Organics: Percent recovery data were not presented for the PAH analyses. Confirmatory analysis of GC testing was conducted using GC/MS. Three of 20 compounds identified in the GC analysis (acenaphthylene, 2,3,6-trimethylnapthalene, and 1-methylphenanthrene) could not be confirmed using GC/MS.

Aroclor 1254 was the only PCB congener analyzed.

Metals: Percent recovery data were good for all standard conditions. Precision was good for all but total Hg and dissolved Pb.

Biological Testing: Replicate test results were generally good for all biological testing conducted.

Supporting Documentation. The report cites two additional sediment studies conducted on the East Waterway:

Anderson, J.W. and E.A. Crecelius, 1985, Analysis of Sediments and Soils for Chemical Contamination for the Design of the U.S. Navy Homeport Facility at East Waterway of Everett Harbor, Washington, prepared for U.S. Army Corps of Engineers, Seattle District, PNL-5383, Pacific Northwest Laboratory, Richland, Washington.

Anderson, J.W., E.A. Crecelius, and J.Q. Word, 1986, Biological and Chemical Analysis of Sediments for the Design and Construction of the U.S. Navy Homeport Facility at East Waterway - Everett Harbor, Washington, Phase II, prepared for U.S. Army Corps of Engineers, Seattle District, PNL-5494, Pacific Northwest Laboratory, Richland, Washington.

8.0 BIOLOGICAL DATA (FLORA/FAUNA)

Methods

Several different sediment bioassays were conducted using the amphipod Rhepoxynius abronius, and juvenile geoducks.

The amphipod and geoduck bioassays were conducted by adding wet sediment and filtered Sequim Bay seawater to a plastic beaker. A known number of organisms were added to each beaker and exposed for 10 days. The geoducks were fed marine algae every other day. Water temperature and aeration were maintained during the test. After 10 days, the organisms were wet-sieved out of the sediment and the living organisms were counted.

The oyster larvae bioassays and Microtox (bacteria bioassay) were conducted using elutrates from East Waterway sediments and Sequim Bay sediments. Control filtered seawater and two negative controls using added concentrations of cadmium also were used to assess the larvae responses.

The bioaccumulation and chronic toxicity studies utilized clams (Macoma), mussels (Mytilus), and shrimp (Pandalus). Clams and mussels were exposed to sediments for 21 days and shrimp were exposed for 15 days. Clams were placed in the sediment, mussels were suspended in the water column above the sediment, and shrimp were placed in suspended sediment in separate aquaria.

Results

Amphipod. The native sediment and contaminated sediment composite samples did not produce significantly higher mortality than the control Sequim Bay sediment for the amphipod test. This result reportedly does not agree with earlier tests; but the animals did spend much more time out of the sediment, particularly in the contaminated sample. Thus, according to the authors, abnormal behavioral responses to East Waterway sediment were demonstrated but not toxicity.

Geoduck. No juvenile geoducks survived in the contaminated sediment while the native sediments were not toxic to juvenile geoducks. No previous bioassays have been done with geoducks, so there is no frame of reference for this result. It appears geoducks may be useful as a toxicity indicator; however, geoduck bioassays are not presently an approved Puget Sound Protocol toxicity testing procedure.

Oyster Larvae. The oyster larvae tests also showed a significant difference between the native and contaminated sediments. Survival was 100 percent in the native sediments but less than 50 percent in the contaminated sediments and in the standard toxicant (cadmium) sediments. The percentage of abnormal larvae also rose sharply in contaminated sediments.

Microtox. Both East Waterway sediments were more toxic than Sequim Bay sediments, according to the Microtox response. Sequim Bay sediments have been found to have an above average toxicity for this test.

Bioaccumulation. The bioaccumulation results were somewhat surprising and inconclusive. The East Waterway composites appeared slightly less toxic than the Sequim Bay control sediments. Only PAHs were bioaccumulated by all three species tested, but PAH concentrations were highest (10.4 ppm) in mussels exposed to Sequim Bay control sediments. Clams and mussels also accumulated detectable PCBs, while metals were not accumulated significantly. The authors reported that the bioaccumulation results obtained in this study were similar to results obtained in the Phase II study (Anderson et al. 1986).

Tables presenting the biological test result data from the report are attached to this document (see Attachment B).

Data Quality. The quality assurance (QA) plan appears to be adequate and the replicate sample results are generally agreeable. The tests clearly show that the contaminated sediments are more toxic than native sediments. However, the bioaccumulation studies indicate that further testing and analysis may be appropriate. (The senior author has recently indicated in a personal communication that subsequent studies have not demonstrated a similar toxicity response for Sequim Bay sediments.)

9.0 DATA QUALITY

Although it is not clear how the sediment samples were collected or composited originally, an extensive QA plan is included in the report as an appendix. The procedures outlined in this plan are adequate for both chemical and biological data. However, whether the procedures presented were followed cannot be verified because little or no laboratory QA/QC data are provided.

Testing results of dissolved metals (EP-tox) may not be applicable to marine systems because fresh water (at pH 5.0) rather than seawater was used to determine leachable metals concentrations.

10.0 HYDROLOGIC AND HYDRODYNAMIC INFORMATION

N/A

11.0 DREDGING AND DISPOSAL ISSUES AND DATA

No recommendations are made regarding the suitability of these sediments for dredging and/or open water disposal.

12.0 ENVIRONMENTAL IMPACTS

The biological tests show that, in some cases, East Waterway sediments cause organism mortality (particularly geoduck) and affect organism behavior (e.g., amphipods). The report does not make recommendations concerning mitigating these effects or the possible effects of dredging and open-water disposal on marine organisms.

13.0 INTERIM MEASURES/SPILL AND POLLUTION PREVENTION MEASURES

N/A

14.0 COMMUNITY RELATIONS INFORMATION

N/A

15.0 RECOMMENDATIONS

The report presents only a brief summary of results with little comparison between native and contaminated sediments and no recommendations regarding dredging and subsequent open-water disposal. Metal concentrations are well below Ecology dangerous waste limits. The major contaminants are PAH compounds. Other organic priority pollutants are near or below detection limits. The bioassays indicate differing levels of toxicity to different organisms.

The primary conclusion drawn by the authors is that sediments of East Waterway "have different degrees of toxicity to different organisms".

It is clear from the data that the upper layer of sediment is more contaminated than the lower layer. However, this is discussed only briefly, and it is unclear whether differences between the samples are significant enough to identify a clear line of demarcation for purposes of dredging.

16.0 FINAL COMMENTS

Although a significant amount of data is presented, very few conclusions or recommendations are presented. The data could be compared with results from other sediments to determine the sediments' suitability for dredging. The biological testing results could be used to make at least an initial assessment of the impacts of dredging and disposal on the marine organisms studied and on other marine life associated with East Waterway.

The locations of the sediment sampling sites should be identified in order to compare these results with others from East Waterway.

Attachment A

CHEMICAL AND PHYSICAL TEST RESULTS

TABLE 1. Bulk Properties of Everett Composites

	Grain Size							Oil	Sulfides
	% Gravel	% Sand	% Silt	% Clay	% Solids	% Volatiles	% TOC	(ppm)	(ppm)
Everett rep.1	4	27	43	26	36.5	22.1	9.60	5710	446
Composite rep.2	9	28	40	23	37.1	22.0	8.32	--	587
Dirty rep.3	5	27	42	26	37.4	22.0	8.33	--	508
Everett rep. 1	2	28	50	20	50.4	11.8	4.37	1180	246
Composite rep.2	1	27	54	18	49.7	10.9	--	--	234
Native rep.3	1	28	52	19	47.6	12.6	--	--	170

TABLE 2. Metals in Everett Composite Sediments ppm (dry weight)

		Cr	Ni	Cu	Zn	Pb	As	Cd	Hg	Ag	Sb	Tl	Be	Se
Everett Contaminated Composite	Rep. 1	135	64	92	224	60	11.3	0.72	0.456	0.36	1.6	<0.4	0.9	<1.1
	2	109	63	109	199	59	9.7	0.71	1.08	0.34	0.8	<0.4	1.0	<1.1
	3	130	64	100	225	64	12.0	0.73	0.467	0.35	1.6	<0.4	0.7	<1.2
Everett Native Composite	Rep. 1	123	58	66	112	29	12.0	1.03	0.330	0.24	<0.8	<0.4	0.71	<1.2
	2	138	66	68	113	28	11.0	0.74	0.239	0.25	--	--	--	<1.2
	3	146	63	67	110	29	11.0	1.03	0.231	0.26	--	--	--	<1.9
BNW Value for Standard (NBS 1646)		72	35	19	131	25	11.0	0.37	0.075	0.083	--	--	--	<1.2
Certified Value		76	32	18	138	28	11.0	0.36	0.063	none	none	none	none	0.6

TABLE 3. Concentrations of Dissolved Trace Metals in EP Toxicity Test Solutions of Everett East Waterway Sediment Composites

		ppb or g/L					
		Cu	Zn	Pb	As	Hg	Cd
EEW Native		0.67	25	0.26	7.00	0 .0009	0.36
EEW Contaminated	Rep. 1	0.94	175	2.08	3.87	0.001	1.16
	Rep. 2	0.74	168	0.76	5.35	0.001	0.71
	Rep. 3	1.12	92	1.05	3.54	0.001	0.43
Washington State Department of Ecology Criteria for Dangerous Waste		5000	5000	5000	5000	200	1000

TABLE 5. Analysis of PCBs as Arochlor 1254 in Sediments from the East Waterway of Everett Harbor, Washington

Sample Identification	Concentration Arochlor 1254 (µg/kg dry weight)
Native Sed.	66
Contam. #1	289
Contam. #2	305
Contam. #3	304

TABLE 6. Analyses of Pesticides in Everett Harbor

Sample	Pesticide	Concentrations (g/kg dry)
Native Sediment	alpha BHC	0.4
	Heptachlor Epoxide	0.3
Contaminated Sediment		
rep #1	alpha BHC	0.6
	Heptachlor Epoxide	0.6
	Endolsulfan Sulfate	0.9
rep #2	Heptachlor Epoxide	2.2
	Endolsulfan Sulfate	2.2
rep #3	Heptachlor Epoxide	1.7

Attachment B

BIOLOGICAL TEST RESULTS

TABLE 7. Summary of Amphipoda Bioassay with Everett Harbor Sediments (collected 6/6/85)

Treatments	Rep.	No. Surviving	$\bar{X}$ No. Surviving (± S.D.)	$\bar{X}$ % Survival	$\bar{X}$ % Emerged Per Day	Overall Mean (± S.D.)	No. Reburied	$\bar{X}$ % Reburied
Sediment Sequim Bay	1	19	18.8 ± 0.45	94 ± 2.2	4 ± 4	8.2 ± 4.6	19	98 ± 3
	2	18			12 ± 13		18	
	3	19			4 ± 7		19	
	4	19			14 ± 18		18	
	5	19			7 ± 12		18	
Amphipod Habitat from Whidbey Island	1	20	21.0 ± 2.12	98 ± 4.5	0 ± 0	0 ± 0	19	97 ± 3
	2	21			0 ± 0		20	
	3	23			0 ± 0		22	
	4	23			0 ± 0		23	
	5	18			0 ± 0		18	
Clean Native Sediment Everett Harbor	1	20	18.4 ± 1.52	92 ± 7.6	16 ± 7	26 ± 6.6	18	92 ± 8
	2	19			26 ± 13		18	
	3	16			23 ± 16		16	
	4	18			33 ± 16		17	
	5	19			30 ± 16		15	
Contaminated Sediment Everett Harbor	1	18	18.0 ± 1.41	88 ± 8.4	29 ± 20	33.8 ± 4.6	11	87 ± 14
	2	16			33 ± 22		15	
	3	18			30 ± 18		17	
	4	20			39 ± 13		18	
	5	18			38 ± 13		17	

TABLE 7. Summary of Amphipoda Bioassay with Everett Harbor Sediments (collected 6/6/85)

Treatments	Rep.	No. Surviving	$\bar{X}$ No. Surviving (± S.D.)	$\bar{X}$ % Survival	$\bar{X}$ % Emerged Per Day	Overall Mean (± S.D.)	No. Reburied	$\bar{X}$ % Reburied
Sediment Sequim Bay	1	19			4 ± 4		19	
	2	18			12 ± 13		18	
	3	19	18.8 ± 0.45	94 ± 2.2	4 ± 7	8.2	19	98 ± 3
	4	19			14 ± 18	± 4.6	18	
	5	19			7 ± 12		18	
Amphipod Habitat from Whidbey Island	1	20			0 ± 0		19	
	2	21			0 ± 0		20	
	3	23	21.0 ± 2.12	98 ± 4.5	0 ± 0	0	22	97 ± 3
	4	23			0 ± 0	± 0	23	
	5	18			0 ± 0		18	
Clean Native Sediment Everett Harbor	1	20			16 ± 7		18	
	2	19			26 ± 13		18	
	3	16	18.4 ± 1.52	92 ± 7.6	23 ± 16	26	16	92 ± 8
	4	18			33 ± 16	± 6.6	17	
	5	19			30 ± 16		15	
Contaminated Sediment Everett Harbor	1	18			29 ± 20		11	
	2	16			33 ± 22		15	
	3	18	18.0 ± 1.41	88 ± 8.4	30 ± 18	33.8	17	87 ± 14
	4	20			39 ± 13	± 4.6	18	
	5	18			38 ± 13		17	

TABLE 8. Amphipod Bioassay with Aged (30-day) Sediments

Treatments	Rep.	No. Surviving	$\bar{X}$ No. Surviving (± S.D.)	$\bar{X}$ % Survival	$\bar{X}$ % Emerged Per Day	Overall Mean (± S.D.)	No. Reburied	$\bar{X}$ % Reburied
Sediment Sequim Bay	B-1	20			16.3 ± 16.2		19	
	-2	20			10.6 ± 14.5		20	
	-3	20	19 ± 2.0	95 ± 11.2	15.0 ± 16.5	18.06	20	98 ± 3.0
	-4	15			28.8 ± 18.1	± 6.82	15	
	-5	20			19.6 ± 14.1		19	
Native Habitat Sediment from Whidbey Island	B-1	20			0.6 ± 1.8		20	
	-2	21			0.6 ± 1.8		20	
	-3	21	20 ± 0.6	100 ± 0	1.3 ± 2.3	0.62	21	100 ± 0
	-4	20			0.6 ± 1.8	± 0.46	20	
	-5	20			0 ± 0		20	
Everett Harbor <u>Clean</u> Native Sediment	B-1	19			21.3 ± 9.9		19	
	-2	20			23.1 ± 20.2		20	
	-3	19	19 ± 0.5	96 ± 2.2	20.6 ± 12.9	21.76	19	99 ± 2.2
	-4	19			21.9 ± 15.1	± 0.92	18	
	-5	19			21.9 ± 11.3		19	
Everett Harbor <u>Contaminated</u> Sediment	B-1	18			33.1 ± 12.5		18	
	-2	18			27.5 ± 22.0		15	
	-3	20	19 ± 1.0	95 ± 5.0	34.4 ± 17.2	32.12	18	94 ± 6.5
	-4	19			33.1 ± 13.4	± 2.67	19	
	-5	20			32.5 ± 15.8		19	

TABLE 9. Geoduck Bioassay with Sequim Bay and Everett Harbor Sediments

Treatments	Rep	No. Surviving	X No. Surviving (± S.D.)	X % Survival
Sequim Bay Control Sediment	1	20	16 ± 8	80 ± 40
	2	20		
	3	20		
	4	0		
	5	20		
Everett Harbor Clean Native Sediment	1	20	19 ± 0.9	95 ± 4
	2	18		
	3	20		
	4	19		
	5	18		
Everett Harbor Contaminated Sediment	1	0	0 ± 0	0 ± 0
	2	0		
	3	0		
	4	0		
	5	0		

TABLE 10. Oyster Larvae Bioassay Results Testing The Effects of Elutrates[a] Made from Everett Harbor Sediments (10-ml Aliquots Counted from the 1000-ml Exposure for each Count, 8/8/85)

Treatment	Rep.	Total No. Counted	Mean (± S.D.)	No. Normal	No. Abnormal	No. Normal	Mean (± S.D.)
Control Filtered Lab Seawater	1	104		94	10	90	
	2	192	118 ± 68	150	42	78	85 ± 6
	3	59		51	8	86	
Sequim Bay Station #17 Sediment Elutrate	1	157		142	15	90	
	2	99	133 ± 30	72	27	72	79 ± 9
	3	144		110	34	76	
Everett Harbor Native Sediment "Clean"	1	65		8	57	12	
	2	68	81 ± 25	3	65	4	7 ± 5
	3	109		4	105	4	
Everett Harbor Contaminated "Dirty"	1	61		2	59	3	
	2	41	48 ± 11	0	41	0	1 ± 2
	3	42		0	42	0	
Standard Toxicant 1 ppm Cadmium	1	30		4	26	13	
	2	66	51 ± 19	6	60	10	17 ± 9
	3	57		12	45	27	
Standard Toxicant 10 ppm Cadmium	1	26		0	26	0	
	2	23	34 ± 17	0	23	0	0.7 ± 1.0
	3	53		1	52	2	

(a) One liter of sediment was mixed with 4-liters seawater and the water was then passed through a 0.45-micron filter.

TABLE 11. Comparison of Toxicity of Organic Extracts Everett East Waterway and Sequim Bay Sediment Using Microtox Test

Sample Identification	Dry wt[a] (g)	µg/mL Acute toxicity[b]	Upper C.I.[c]	Lower C.I.[c]
EWW Native				
Rep. 1	2.19	0.28	0.30	0.26
Rep. 2	2.41	0.82	0.91	0.75
Rep. 3	1.95	0.29	0.33	0.26
EWW Contaminated				
Rep. 1	1.61	0.11	0.13	0.10
Rep. 2	1.98	0.13	0.15	0.12
Rep. 3	2.05	0.12	0.13	0.11
Sequim Bay Control				
Rep. 1	1.92	1.6	1.80	1.39
Rep. 2	1.90	0.4	0.39	0.33
Rep. 3	1.94	0.3	0.34	0.26

(a) Dry weight of sediment extracted.
(b) 15 minutes, EC 50% in units of µL of sediment extract per mL of test solution.
(c) 95% confidence interval.

TABLE 12. Survival of Animals and Bioaccumulation of Trace Metals, PAHs and PCBs in Tissues of Clams, Mussels, and Shrimp Exposed to Everett East Waterway Sediment Composites and Sequim Bay Sediment

Animal and Exposure	ppb Wet Weight			ppm Dry Weight					
	% Survival	PCB's (1254)	Total PAHs	Cu	Zn	Pb	As	Hg	Cd
Clam (Macoma)									
Pre-exposed animals	--	0.1	53	11.2	235	0.75	15.8	0.070	0.8
Sequim Bay	100	0.1	1,414	14.7	262	1.09	17.3	0.108	1.0
EEW native	100	0.1	1,789	11.5	244	2.19	16.1	0.122	0.8
EEW contaminated Rep. 1	--	0.7	2,560	10.4	246	1.50	14.9	0.115	0.8
Rep. 2	--	--	--	10.1	249	1.44	15.4	0.115	0.9
Rep. 3	--	--	--	10.9	252	1.44	15.1	0.113	0.8
Mussel (Mytilius)									
Pre-exposed	--	0.1	593	7.7	139	0.57	10.2	0.042	2.5
Sequim Bay	95	0.1	10,415	7.8	182	0.51	9.2	0.086	3.9
EEW Native	95	0.1	3,837	8.0	156	0.70	8.9	0.099	3.6
EEW Conta	95	0.5	3,041	8.0	177	0.57	8.4	0.076	3.6
Shrimp (Pandalus)									
Pre-exposed	--	0.1	10	--	--	--	--	--	--
Sequim Bay	75	0.1	10	62	63	5.66	8.2	0.072	7.0
EEW Native	85	0.1	78	87	92	17.70	10.5	0.079	13.6
EEW Contaminated Rep. 1	85	0.1	747	71	71	7.89	7.3	0.072	6.0
Rep. 2	90	--	--	101	89	4.15	9.6	0.076	6.0

Appendix F

EAST WATERWAY, EVERETT, WASHINGTON
TECHNICAL DOCUMENT REVIEW

Review of:

Crecelius, E.A., N.A. Bloom, and J.M. Gurtisen, May 1985, Distribution of Contaminants in Sediment Cores and Mass Balance of Contaminants Discharged to East Waterway and Port Gardner, Everett, Washington, prepared by Battelle, Marine Research Laboratory, Sequim, Washington, 27 pp. and appendices.

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EAST WATERWAY TECHNICAL DOCUMENT REVIEW

TABLE OF CONTENTS CHECKLIST

ATTACHMENTS

1.0 INTRODUCTION AND CHRONOLOGY OF EVENTS

The report reviewed evaluates the sources and fate of contaminants in Everett Harbor-Port Gardner. Existing data on pollutant sources (i.e., municipal and industrial discharges, combined sewer overflows, urban runoff, groundwater, atmospheric deposition, and seawater transport) were used to estimate contaminant mass loadings. Six sediment cores were collected and analyzed for selected organic compounds, metals, and lead-210 to quantify the rate of accumulation of contaminants in local sediments.

Chronology of Events

Based on previous studies in Port Gardner and East Waterway in which elevated concentrations of metals, petroleum hydrocarbons, and chlorinated organic compounds were discovered in offshore sediments (Malins et al. 1982; Crecelius et al. 1984; Anderson and Crecelius 1985; Strand et al. 1985), the United States Environmental Protection Agency (EPA) and the United States Army Corps of Engineers (COE) contracted with Battelle Pacific Northwest Laboratory to conduct a study to define the sources and fate of these contaminants in Everett Harbor-Port Gardner. This report describes the results of that study. Field sampling was conducted in November 1983.

2.0 LEGAL AND REGULATORY ISSUES

N/A

3.0 DEMOGRAPHICS AND LAND USE

N/A

4.0 POTENTIALLY LIABLE PERSONS

The report identifies the following active dischargers as contributors of contaminants to East Waterway-Port Gardner:

- City of Everett: Operates a municipal wastewater treatment plant (WWTP) that discharges to the Snohomish River and has multiple combined sewer overflows (CSO) outfalls discharging to the Snohomish River and East Waterway-Port Gardner.
- Scott Paper Company (Scott): Discharges treated wastewater from their paper mill to Port Gardner and East Waterway.
- Weyerhaeuser: Discharges treated wastewater from their Kraft mill to lower Steamboat Slough.

5.0 IDENTIFICATION OF POLLUTION POINT SOURCES

The study evaluated pollutant loadings from the point sources described below. Contaminant concentration data and estimated loadings were summarized in tables which are included in Attachment A.

Everett Wastewater Treatment Plant

The Everett WWTP discharges to the Snohomish River. Effluent data from a Washington State Department of Ecology (Ecology) study (1982) were used to estimate annual pollutant loadings for cadmium, chromium, copper, mercury, nickel, lead, silver, and zinc. The report does not describe how many or what type of samples were collected during the Ecology study. Loadings for arsenic, polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) were calculated using the average annual discharge from the plant and average concentrations measured in effluent from Metro's West Point WWTP in Seattle.

Under its National Pollution Discharge Elimination System (NPDES) permit, the Everett WWTP is required to monitor effluent for chromium, copper, and zinc on a quarterly basis. Ecology periodically conducts Class II inspections at permitted facilities, during which samples of plant influent and effluent are collected and analyzed for metals. These data apparently were not used in this evaluation. In addition, since this report was completed, 24-hour composite samples of plant effluent have been collected and analyzed for the complete list of priority pollutants.

Scott Paper Mill

The Scott mill has two outfalls in East Waterway and one in Port Gardner. Plant effluent data for mercury and zinc were obtained from Ecology's Northwest Regional office. No description of the data (e.g., number of samples, sampling location, quality assurance procedures) is provided. Data for other contaminants were obtained from the "U.S. EPA 1983 report on water quality management for Puget Sound" (no citation provided). It is not clear whether these data are specific to the Scott mill.

Priority pollutant data for all three outfalls were provided in Scott's 1980 NPDES permit application. These data are based on a single sample collected from each outfall.

Weyerhaeuser Kraft Mill

The Weyerhaeuser mill discharges into lower Steamboat Slough on the outgoing tide. Available data from a single, 1-day sampling event were used to evaluate pollutant loadings.

6.0 IDENTIFICATION OF POLLUTION NON-POINT SOURCES

The study evaluated pollutant loadings from the non-point sources listed below.

Snohomish River

Annual pollutant loadings for metals in the Snohomish River were calculated using unpublished data from Bloom and Crecelius (no citation provided). No description of the data (i.e., number of samples, sampling location, quality assurance procedures) is provided in the report. Annual loadings for organic contaminants were not estimated because data on these contaminants in the Snohomish River were unavailable.

Combined Sewer Overflows

Annual pollutant loadings from city CSOs were calculated based on estimates of total annual CSO discharge from the Everett service area using available data on the chemical composition of influent to the Everett plant and urban runoff from samples collected in Bellevue (Galvin et al. 1984).

Total annual pollutant loading from CSOs was estimated based on the following assumptions:

- CSOs occur when precipitation exceeds 1.25 cm/day.
- Precipitation exceeds 1.25 cm/day approximately 20 days each year. Each of these storms deposits 2.5 cm of rainfall. With a 18.1 km^2 drainage area, each storm generates approximately 120 by 106 gal of runoff.
- The combined sewer system has a capacity of 40 by 106 gal/day, of which 10 by 106 gal/day is baseflow.
- Approximately 90 percent of the total annual CSO discharge (1,800 by 106 gal) is comprised of urban runoff. The remaining 10 percent consists of municipal wastewater.

Atmospheric Deposition

The total atmospheric deposition rate (wet plus dry fallout) of particulates on the surface of Port Gardner was estimated based on data from studies conducted in Seattle (no reference provided). Chemical composition of deposited material was assumed to be similar to those from central Puget Sound. Chemistry data from Romberg et al. (1984) was used in the calculations.

Groundwater

Groundwater, particularly in the industrial waterfront area in Everett, was identified as a potential source of contaminants to East Waterway-Port Gardner. However, because data describing the chemical composition and groundwater flow rates were not available, this potential source was not evaluated.

7.0 CHEMICAL DATA

Methods

Data Collection. Six sediment cores (two in East Waterway and four in Port Gardner) were collected in November 1983. Cores (1.1 to 2.0 m in depth) were collected using a large diameter (15 by 15 cm cross-section) Kasten-type gravity corer. Composite samples from 5 cm intervals in each core were submitted for chemical analysis. Station locations are shown in Attachment B.

Analytical Testing. Sediment samples were analyzed for 18 aromatic hydrocarbons, Aroclor 1254, lead-210, and 16 inorganic constituents (silver, aluminum, arsenic, calcium, cadmium, chromium, copper, iron, mercury, potassium, manganese, nickel, lead, silicon, titanium, and zinc). Analytical methods are summarized below:

Inorganic Compounds

- o Energy dispersive x-ray fluorescence for all inorganics except mercury, silver, and cadmium which were by atomic absorption.

Organic Compounds

- o Soxlet extraction followed by column chromatographic fractionation and capillary column gas chromatographic analysis.

The analytical laboratory that performed the analyses is not identified in the report. The report references Riley et al. (1980, 1981) and Crecelius et al. (1984) for a detailed description of analytical methods.

Results

Marine Sediments-Organics. The highest concentrations of the 18 aromatic compounds measured were found at Stations 29 (1,130 to 49,900 ppb total PAH) and 30 (1,980 to 258,800 ppb total PAH) in East Waterway. PAH contamination at Station 30 extended to a depth of approximately 120 cm. PAH concentrations at Stations 25 (<90 to 21,800 ppb) and 28 (<90 to 52,700 ppb) near the mouth of East Waterway also were elevated. The concentrations of PAHs at Stations 26 (400 to 4,900 ppb) and 27 (160 to 3,300 ppb) in Port Gardner were comparable to the concentrations detected in the main basin of Puget Sound (4,000 ppb).

PCB (Aroclor 1254) concentrations were also higher in the cores collected from East Waterway than those collected from Port Gardner. However, the PCB contamination was shallower than the PAH contamination, which indicates that PCB input has occurred for a shorter period of time (40 years) than the PAH input (80 to 100 years).

Marine Sediments-Metals. The concentrations of silver, mercury, and lead were 2 to 10 times greater in the upper sections of the sediment cores than in the lower, subsurface sections at all stations in

Port Gardner and East Waterway. Concentrations range from 0.03 to 0.64 ppm for silver, 0.05 to 3.0 ppm for mercury, and 5.1 to 177 ppm for lead. Metals data are included in Attachment C.

Stations 29 and 30 in East Waterway also exhibited greater concentrations of zinc and cadmium in the surface sections than in the subsurface sections of the cores. Concentrations range from 91 to 365 ppm for zinc and 0.5 to 4.7 ppm for cadmium. Station 30 exhibited subsurface peaks of copper (193 ppm), mercury (3 ppm), and lead (177 ppm) at depths of approximately 120 cm.

Marine Sediments-Conventional Parameters. Conventional parameters were not analyzed. The sediment collected from East Waterway was described as a mixture of black, poorly consolidated sand, mud, wood chips, and tree bark.

Sedimentation Rate. Sedimentation rates in the cores collected from Stations 25 (0.73 $g/cm^2/yr$) and 26 (0.43 g/cm2yr) were estimated from lead-210 dating analysis. Lead-210 analysis was not applicable to the other stations because these cores either contained insufficient lead-210 activity or lead-210 activity did not change significantly with depth.

Sedimentation rates for Stations 27 (0.27 $g/cm^2/yr$) and 28 (0.74 $g/cm^2/yr$) were estimated based on the depth at which lead, mercury, and silver began to increase above baseline. Calculations were not provided in the report; therefore, these rates could not be verified. Sedimentation rates in East Waterway (5.0 $g/cm^2/yr$) were estimated from dredging records.

Comparative Analysis. Surficial sediments from East Waterway-Port Gardner were compared with sediments from the main basin of Puget Sound and the Fourmile Rock disposal site (see Attachment D). Contaminant concentrations measured in Port Gardner sediments were comparable to those found in background stations from the main basin of Puget Sound.

Concentrations of cadmium, copper, mercury, zinc, PAHs, and PCBs in sediments from East Waterway were 2 to 10 times greater than background and were similar to those measured at the Fourmile Rock disposal site.

Contaminant accumulation in the surface sediments (0 to 10 cm) was calculated from the sedimentation rates and contaminant concentration data. An "excess" accumulation, defined as "the difference between concentrations in surface sediment and those in sediments deposited during pre-industrial periods, approximately 100 years ago" also was calculated to determine anthropogenic effects on pollutant loading. The results, summarized in Attachment E, show that loadings of PAHs and PCBs exhibited the largest increase (i.e., 10 times). Cadmium, lead, mercury, and silver loadings are 2 to 4 times greater than pre-industrial loadings.

Sediment accumulation rates were compared with estimated loadings from point and non-point sources. Snohomish River loadings were not included in the comparisons because it was assumed that contaminants transported by the river are from natural sources. The mass balance determinations showed that for some metals, the estimated source loadings minus losses due to advection are approximately equal to the accumulation rate in the sediments (see Attachment F). However, the organic compounds evaluated (PAH, PCB, and oil) do not balance. These differences have been attributed to the limited amount of data available to define pollutant sources.

8.0 BIOLOGICAL DATA (FLORA/FAUNA)

N/A

9.0 DATA QUALITY

Field Methods

Field sampling methods are not described in detail in the report. A Kasten-type gravity corer was used to collect the sediment samples. Decontamination procedures are not provided. Station location was reported in latitude/longitude to the nearest 0.1 minute.

Organics

A duplicate analysis was performed on one section from two of the cores to evaluate sample variability. The Relative Percent Difference (RPD) ranged from 9 to 40 percent for PAHs and from 0 to 62 percent for PCBs. No project control limits were presented for these analysis and results of the duplicate analysis were not evaluated by the authors.

No other quality assurance (QA) tests (e.g., analysis of surrogate or analyte spikes) were performed. Consequently, it is difficult to evaluate the validity of the results for the organic compounds.

Metals

Three certified reference standards were analyzed to evaluate method accuracy. The results showed generally good accuracy (85 to 117 percent recovery).

One sample from each core was analyzed in triplicate to evaluate sample variability. Precision was relatively high (RPD < 20 percent).

10.0 HYDROLOGIC AND HYDRODYNAMIC INFORMATION

A study of circulation patterns within East Waterway-Port Gardner was not conducted as part of this study. To quantify transport of suspended solids out of the basin for the mass balance calculations, it was assumed that the concentrations of contaminants in the surface water

(0 to 10 m) are equal to those measured in central Elliott Bay and that the concentrations in deeper water in Port Gardner (i.e., > 10 m) are equal to those for 100 m depths in the Puget Sound main basin.

11.0 DREDGING AND DISPOSAL ISSUES AND DATA

N/A

12.0 ENVIRONMENTAL IMPACTS

N/A

13.0 INTERIM MEASURES/SPILL AND POLLUTION PREVENTION MEASURES

N/A

14.0 COMMUNITY RELATIONS INFORMATION

N/A

15.0 RECOMMENDATIONS

This report provides sediment quality data for a limited number of stations in East Waterway-Port Gardner. Based on the QA information provided in the report, it appears that the metals data are adequate. However, the organic data should be qualified.

Although several pollutant sources are identified and discussed, no additional contaminant loading information was generated by this study. Additional pollutant source loading data are available from other, more recent studies that could be used to update the mass balance analysis. Contributions from groundwater sources should be evaluated in any future studies which will necessitate an adequate sampling and analysis program to characterize this resource.

16.0 FINAL COMMENTS

This document provides sediment quality data that can be used to evaluate the horizontal and vertical distribution of contaminants in East Waterway-Port Gardner sediments. However, because of QA limitations, further investigation is needed to quantify the extent of contamination from organic compounds. Lead-210 analysis also provides estimates of sedimentation rates for Port Gardner area sediments. References for previous work cited in the document that should be considered in future work on the East Waterway include:

- Anderson, J.W. and E.A. Crecelius, 1985, Analysis of Sediments and Soils for Chemical Contamination for the Design of U.S. Navy Homeport Facility at East Waterway of Everett Harbor, Washington, prepared for U.S. Army Corps of Engineers, PNL-5383, Pacific Northwest Laboratory, Richland, Washington.

- Crecelius, E.A., N.S. Bloom, and J.M. Gurtisen, 1984, Chemical Analysis of Sediment Cores for East Waterway (Everett, Washington), Final report to U.S. Army Corps of Engineers, PNL-5045, UC-11, prepared by Battelle Marine Research Laboratory, Sequim, Washington.

- Galvin, D.V., G.P. Romberg, D.R. Houck, and J.H. Lesniak, 1984, Toxicant Pretreatment Planning Study Summary Report, Water Quality Division, Municipality of Metropolitan Seattle, Seattle, Washington.

- Malins, D.C., B.B. McCain, D.W. Brown, A.K. Sparks, H.O. Hodgins, and S. Chen, 1982, Chemical Contaminants and Abnormalities in Fish and Invertebrates from Puget Sound, NOAA Technical Memorandum OMPA-19, Boulder, Colorado.

- Riley, R.G., E.A. Crecelius, D.C. Mann, K.H. Abel, B.L. Thomas, and R.M. Bean, 1980, Quantitation of Pollutants in Suspended Matter and Water from Puget Sound, NOAA Technical Memorandum, ERL MESA-49, National Oceanic and Atmospheric Administration, Boulder, Colorado.

- Riley, R.G., E.A. Crecelius, M.L. O'Malley, K.H. Abel, and D.C. Mann, 1981, Organic Pollutants in Waterways Adjacent to Commencement Bay, NOAA Technical Memorandum OMPA-12, National Oceanic and Atmospheric Administration, Boulder, Colorado.

- 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, Metro Toxicant Program Report No. 6A, Water Quality Division, Municipality of Metropolitan Seattle, Seattle, Washington.

- Strand, J.A., E.A. Crecelius, R.A. Elston, G.W. Fellingham, and W.H. Pearson, 1985, Detailed Chemical and Biological Analyses of Selected Sediments from Puget Sound, PNL-5471, Pacific Northwest Laboratory, Richland, Washington.

- Washington State Department of Ecology, 1982, Water Quality of the Snohomish River Estuary and Possible Impacts of a Proposed Hewlett Packard Manufacturing Plant, EDOW 82-2, Olympia, Washington.

Attachment A

CONTAMINANT CONCENTRATION AND ANNUAL LOADING

TABLE 30. Concentrations of Contaminants in Snohomish River and Waste Water

Stream	Annual flow liters	μg L⁻¹ (dissolved plus suspended solids)											
		Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn	Oil	PAH	PCBs
Snohomish River[(a)]	8.6×10^{12}	0.014	0.9	0.05	NR	2.6	0.003	NR	0.8	NR	NR	NR	NR
Snohomish River[(b)]		<1	NR	<0.06	<3	<5	<0.2	<2	<2	8			
Everett STP influent[(b)] before treatment	1.76×10^{10}	24	NR	1	10	410	0.28	34	43	460	NR	NR	NR
Everett STP effluent[(b)] after treatment	1.76×10^{10}	3	NR	<1	<10	25	<0.2	17	9	55	NR	NR	NR
METRO West Point[(c)] effluent	1.4×10^{11}	7.3	3.7	4.4	64	88	0.28	51	74	140	29,000	15	0.26
Urban run-off[(c)] Bellevue		NR	13	0.7	7	20	<1	12	210	120	NR	NR	NR
Weyerhaeuser paper mill[(b)]	2.9×10^{10}	3	NR	<1	<10	25	<0.2	9	9	80	NR	NR	NR
Scott paper mill[(d)]	3.8×10^{10}	NR	NR	NR	NR	NR	0.23	NR	NR	117	NR	NR	NR

(a) Bloom and Crecelius (Unpublished data)
(b) Wash. DOE 82-2
(c) Galvin et al. 1984
(d) Wash. DOE, Redmond office
NR = not reported

TABLE 31. Annual Loading of Contaminants to Port Gardner and East Waterway

Source	kg y^{-1}											
	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn	Oil	PAH	PCBs
Snohomish River	121	7921	438	4562	55800	7	60200	33900	73000	NR	NR	NR
Municipal Waste Water	53	65[(a)]	18[(b)]	176[(b)]	440	3.5[(b)]	300	158	968	510,000[(a)]	264[(a)]	4.6[(a)]
Combined Sewer Overflows 6.84 x 10^9 L y^{-1} 8% STP influent 92% urban runoff	13[(b)]	25(a)	4.9	49	343	6.4[(b)]	94	1348	1001	199,000[(a)]	103[(a)]	1.8[(a)]
Industrial Waste Water	30[(b)]	7.3	73	1440	7500	15.7	1460	1825	1180	154,000	NR	NR
Atmospheric Deposition	0.4	52	1.4	11.7	184	0.4	14.7	1100	108	NR	9.0[(c)]	NR
Total excluding Snohomish River	61	149	97	1678	8467	26	1869	4431	3257	863,000	376	6.4

(a) Assumed METRO West Point effluent concentrations.
(b) Assumed the less than concentration.
(c) Metro Task C1 (Romberg et al. 1983).
NR = not reported.

Attachment B

STATION LOCATIONS

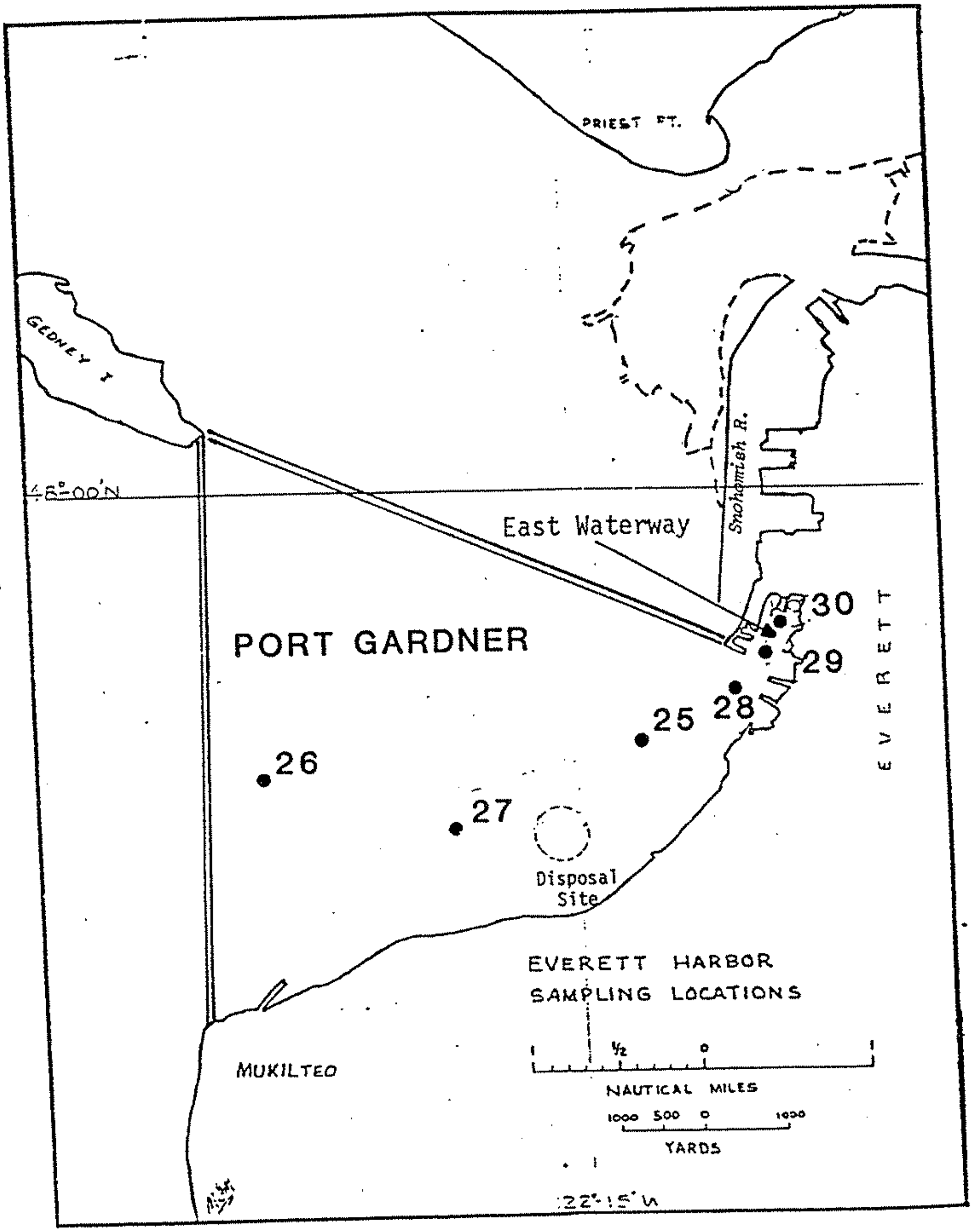

FIGURE 1. Boundaries of the Area of Study and the Locations of Sediment Coring Stations

Attachment C

ELEMENT CONCENTRATIONS IN SEDIMENT CORES

TABLE 9. Concentration of Elements in Sediment Core No. BPS-25

47° 58.4'N 122° 14.6 W
WATER DEPTH 105 m DATE: 11-7-83

Depth, cm	Major Metals, Percent[a]						Trace Elements, Parts per Million[a]									
	Al	Si	K	Ca	Ti	Fe	Mn	Cr	Ni	Cu	Zn	Hg	Ag	Cd	Pb	As
0-2	6.7	28.6	1.16	1.97	0.363	3.40	521	147	49.8	37.1	81	0.049	0.143	0.329	14.4	10.0
2-4												0.089	0.311	0.563	15.9	
4-6	6.6	26.3	1.20	1.91	0.405	3.69	530	141	62.3	52.6	109	0.111	0.362	0.648	24.1	10.6
6-10												0.110	0.337	0.820	18.7	
10-15												0.147	0.437	1.23	24.3	
15-20	7.2	25.0	1.22	1.78	0.413	3.94	495	132	71.3	55.9	114	0.134	0.433	1.47	28.9	9.9
20-25												0.153	0.363	1.47	22.3	
25-30	6.4	26.0	1.17	1.76	0.350	3.41	481	113	54.9	47.8	93	0.105	0.258	0.992	26.5	7.6
30-35												0.119	0.258	0.856	18.6	
35-40	7.0	26.9	1.20	1.79	0 338	3.36	465	109	56.5	158.8	89	0.530	0.202	0.729	20.9	8.5
40-45												0.133	0.176	0.697	45.6	
45-50	6.2	24.8	1.12	1.78	0.355	3.26	460	135	51.1	39.9	85	0.169	0.178	0.549	23.4	10.5
55-60												0.344	0.178	0.329	19.9	
75-80	7.0	26.4	1.33	1.72	0.419	4.19	550	136	66.7	53.6	102	0.169	0.136	0.199	22.3	12.2
95-100												0.072	0.044	0.212	7.2	
115-120[b]	6.8	27.5	1.29	1.86	0.419	3.86	519	122	62.4	32.7	84	0.064	0.043	0.206	8.5	9.5
135-140												0.059	0.037	0.212	5.1	
165-170	6.7	27.5	1.29	1.87	0.410	3.89	529	151	60.2	33.1	83	0.057	0.052	0.280	9.7	10.2
175-180												0.059	0.046	0.231	5.1	
195-200	6.3	27.3	1.28	1.89	0.409	3.80	544	126	59.8	33.6	84	0.065	0.046	0.228	7.3	8.4

(a) Calculated on a dry-weight, salt-free basis.
(b) Represents the mean of a triplicate analysis.

Bo-

TABLE 10. Concentration of Elements in Sediment Core No. BPS-26

47° 58.4'N 122° 18.0 W
WATER DEPTH 164 m DATE: 11-7-83

	Major Metals, Percent[a]						Trace Elements, Parts per Million[a]									
Depth, cm	Al	Si	K	Ca	Ti	Fe	Mn	Cr	Ni	Cu	Zn	Hg	Ag	Cd	Pb	As
0-5	6.5	24.6	1.32	1.57	0.402	4.55	855	130	68.0	52.5	118	0.151	0.454	0.274	34.3	16.1
5-10												0.153	0.403	0.228	31.0	
10-15[b]	6.7	26.0	1.32	1.68	0.391	4.56	706	119	63.9	47.2	111	0.151	0.428	0.246	34.5	11.0
15-20												0.106	0.301	0.203	26.1	
20-25	7.1	27.1	1.30	1.68	0.398	4.06	555	110	65.0	44.8	106	0.144	0.335	0.241	31.0	10.7
25-30												0.180	0.440	0.254	31.3	
30-35	6.8	26.3	1.39	1.71	0.427	4.42	573	122	71.5	49.2	116	0.172	0.371	0.235	32.4	10.9
35-40												0.195	0.292	0.250	29.3	
40-45	6.7	26.2	1.38	1.57	0.422	4.55	522	134	72.9	50.0	116	0.187	0.231	0.243	34.5	12.8
45-50												0.161	0.208	0.254	28.1	
55-60	7.2	26.0	1.38	1.55	0.425	4.54	557	114	68.9	43.8	101	0.120	0.092	0.254	19.9	12.7
65-70												0.058	0.069	0.242	14.5	
75-80	6.1	27.4	1.39	1.57	0.425	4.35	591	110	69.9	37.1	94	0.044	0.052	0.264	12.1	9.6
95-100												0.046	0.052	0.275	7.6	
115-120	6.7	27.2	1.39	1.62	0.410	4.27	691	109	62.3	35.6	93	0.046	0.048	0.237	9.4	8.4
135-140												0.041	0.057	0.239	8.0	
165-170	6.3	25.5	1.36	1.62	0.404	4.36	542	119	66.1	34.8	94	0.040	0.065	0.267	11.2	8.4
175-180												0.042	0.065	0.308	8.0	
185-190												0.042	0.069	0.289	7.6	
195-200	6.5	27.4	1.35	1.58	0.421	4.21	530	103	63.6	34.8	91	0.046	0.083	0.308	8.7	10.3

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

(b) Represents the mean of a triplicate analysis.

TABLE 11. Concentration of Elements in Sediment Core No. BPS-27

Depth, cm	Major Metals, Percent[a]						Trace Elements, Parts per Million[a]									
	Al	Si	K	Ca	Ti	Fe	Mn	Cr	Ni	Cu	Zn	Hg	Ag	Cd	Pb	As
0-5	6.5	26.6	1.26	1.83	0.369	3.77	597	129	57.9	40.0	92	0.065	0.269	0.227	21.7	9.8
5-10												0.083	0.230	0.203	17.4	
10-15	5.4	29.9	1.13	1.96	0.306	2.87	466	135	50.0	24.4	63	NA	0.128	0.169	15.1	7.5
15-20												0.089	0.180	0.230	14.7	
20-25	6.6	28.0	1.21	1.89	0.363	3.46	488	129	55.7	31.9	80	0.099	0.142	0.217	18.1	9.6
25-30												0.070	0.051	0.247	8.8	
30-35	6.2	26.6	1.29	1.73	0.393	3.97	505	123	59.1	34.4	86	0.059	0.062	0.258	10.3	12.3
35-40												0.139	0.081	0.249	7.2	
40-45												0.061	0.047	0.231	6.8	
45-50[b]	6.4	27.3	1.29	1.80	0.401	3.93	553	132	60.0	34.6	86	0.070	0.082	0.218	12.3	11.3
55-60												0.066	0.047	0.225	7.5	
65-70	6.7	27.8	1.33	1.76	0.421	4.12	538	119	62.7	36.8	87	0.059	0.043	0.256	10.0	10.0
75-30												0.050	0.047	0.232	6.8	
95-100	6.8	27.9	1.35	1.77	0.425	4.22	558	142	63.4	39.9	91	0.048	0.051	0.196	8.8	13.4
115-120												0.078	0.047	0.238	6.9	
135-140	6.7	27.6	1.34	1.80	0.417	4.08	536	125	60.0	34.6	88	0.055	0.047	0.236	8.2	8.9
155-160												0.059	0.039	0.235	6.8	
175-180	6.5	27.3	1.38	1.72	0.437	4.30	556	143	64.8	34.2	95	0.061	0.047	0.245	8.2	12.4
185-190												0.066	0.047	0.238	7.5	
195-200	6.9	27.4	1.38	1.68	0.429	4.35	547	137	64.4	36.2	91	0.053	0.051	0.292	8.5	10.1

(a) Calculated on a dry-weight, salt-free basis.
(b) Represents the mean of a triplicate analysis.
NA = Not analyzed

TABLE 12. Concentration of Elements in Sediment Core No. BPS-28

47° 58.8'N 122° 13.6W
WATER DEPTH 20 m DATE: 11-8-83

	Major Metals, Percent[a]						Trace Elements, Parts per Million[a]									
Depth, cm	Al	Si	K	Ca	Ti	Fe	Mn	Cr	Ni	Cu	Zn	Hg	Ag	Cd	Pb	As
0-2.5	5.9	24.7	1.11	1.88	0.390	3.51	503	143	62.4	55.3	123	0.306	0.218	1.73	31.2	10.3
2.5-5												0.209	0.315	2.00	37.2	
5-10	7.0	23.9	1.20	1.87	0.404	3.73	534	137	67.4	67.4	113	0.357	0.334	1.97	36.1	10.1
10-15												0.231	0.225	1.27	31.7	
15-20	6.2	27.0	1.18	2.01	0.414	3.62	535	165	62.3	54.8	101	0.254	0.160	1.09	29.7	7.3
20-25												0.225	0.182	0.884	23.7	
25-30	6.8	26.6	1.19	1.97	0.428	3.83	550	132	63.9	62.2	97	0.184	0.155	0.983	24.3	11.4
30-35												0.126	0.131	0.682	17.7	
35-40	6.7	27.2	1.20	2.00	0.411	3.66	520	113	57.4	49.3	97	0.127	0.095	0.514	20.1	11.6
40-45												0.193	0.116	0.438	13.8	
45-50												0.116	0.126	0.443	14.6	
55-60[b]	6.9	27.2	1.20	1.99	0.422	3.84	549	147	56.6	52.6	86	0.088	0.093	0.378	14.8	14.3
65-70												0.122	0.087	0.333	12.2	
75-80	6.7	27.7	1.16	2.07	0.408	3.39	507	141	50.7	46.4	72	0.083	0.081	0.385	11.8	11.6
95-100												0.054	0.042	0.309	5.5	
115-120	5.7	32.4	1.07	2.07	0.268	2.49	404	85	39.8	22.4	51	0.050	0.031	0.173	8.9	6.7
125-130												0.111	0.144	0.288	12.9	
135-140	6.6	28.0	1.14	2.06	0.398	3.52	516	125	53.6	42.6	82	0.183	0.107	0.290	11.6	12.4
145-150												0.035	0.032	0.214	5.9	
160-165	7.2	26.9	1.20	1.98	0.412	3.79	530	140	60.2	56.2	90	0.100	0.102	0.272	13.2	15.3

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

(b) Represents the mean of a triplicate analysis.

TABLE 13. Major Metals and Trace Element Content of Core BPS-29,[a] Everett Harbor

Depth, cm	Major Metals, Percent[a]						Trace Elements, Parts per Million[a]									
	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(b)	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) Calculated on a dry-weight, salt-free basis.

(b) Represents the mean of a triplicate analysis.

TABLE 14. Major Metals and Trace Element Content of Core BPS-30,[a] Everett Harbor

Depth, cm	Major Metals, Percent[a]						Trace Elements, Parts per Million[a]									
	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[b]	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) Calculated on a dry-weight, salt-free basis.

(b) Represents the mean of a triplicate analysis.

Attachment D

CONTAMINANT CONCENTRATION IN SURFACE SEDIMENT

TABLE 15. Concentration of Contaminants in Everett and Puget Sound Surface Sediments

Contaminant	East Waterway[a]	Port Gardner (STA 25, 26, & 27)	Fourmile Rock Disposal Site[b]	Puget Sound Main Basin[b]
	ppm ($\mu g\ g^{-1}$ dry weight)			
As	7.9	10	15	10
Cd	1.5	0.3	0.7	0.3
Cu	97	40	92	36
Pb	57	17	126	38
Hg	0.33	0.14	1.1	0.14
Zn	245	85	359	100
PAH	54	3	11	4
PCB	0.4	0.1	0.6	0.1

(a) Anderson and Crecelius 1985.
(b) Romberg et al. 1984

Attachment E

ANNUAL "EXCESS" CONTAMINANT ACCUMULATION RATES

TABLE 35. Annual "Excess" Contaminant Accumulation Rates and Pre-industrial Accumulation Rates in Sediments for Regions of Port Gardner and East Waterway. "Excess" Contaminant Accumulation Calculated from Excess Contaminants (Table 33) and Sedimentation Rates (Table 32).

	kg y^{-1}											
Region	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn	Oil	PAH	PCBs
Port Gardner												
muddy sand	8.7	38	33	0	646	4.6	38	722	570	8970	3720	2.1
sandy mud	14.0	58	21	409	701	1.8	0	642	642	15880	315	5.1
mud	6.4	138	0	344	310	1.5	34	430	413	877	58	1.4
East Waterway	7.6	82	61	0	608	2.4	0	627	3960	60170	451	12.1
Total "Excess"	36.7	316	115	753	2265	10.3	72	2421	5585	85900	4544	20.8
Total Region Pre-industrial Accumulation Rates	8.0	1064	35	14630	4655	5.3	8780	1064	12500	3900	<13	<1.3

Attachment F

CONTAMINANT MASS BALANCE

TABLE 36. Mass Balance of Contaminants in Port Gardner and East Waterway.

	Kg y^{-1}		
Contaminant	Annual Loading[a] of Contaminants	Accumulation in Sediments of "Excess" Contaminants	Removal by Seawater Transport
Ag	61	37	0.11
As	149	316	21
Cd	97	115	1.3
Cr	1,678	753	5.7
Cu	8,467	2,265	26
Hg	26	10.3	0.014
Ni	1,869	72	9.9
Pb	4,431	2,421	5.7
Zn	3,257	5,585	54
Oil	863,000	89,900	132
PAH	376	4,544	1.1
PCB	6.4	20.8	0.0028

(a) Excluding Snohomish River.

Appendix G

EAST WATERWAY, EVERETT, WASHINGTON
TECHNICAL DOCUMENT REVIEW

Review of:

Hart Crowser, May 1987, Sediment Sampling and Testing Final Report, Proposed Carrier Pier and Breakwater Site, NAVSTA Puget Sound, Contract N62474-85-C-5233, Everett, Washington, 13 pp. and appendices.

Contract No. C0089007

Document Control No. WD4030.1.0-G

January 1991

Prepared For:

WASHINGTON STATE DEPARTMENT OF ECOLOGY
Toxics Cleanup Program

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101 YESLER WAY, SEATTLE, WASHINGTON, 98104, TEL. 206/624-9537
International Specialists in the Environment
recycled paper

EAST WATERWAY TECHNICAL DOCUMENT REVIEW

TABLE OF CONTENTS CHECKLIST

ATTACHMENTS

1.0 INTRODUCTION AND CHRONOLOGY OF EVENTS

The report reviewed provides physical and chemical test data regarding sediments at Port Gardner. Core samples were collected at ten locations around the proposed Homeport breakwater and carrier pier site. Two subsamples from each core were analyzed and the results compared to an earlier study by Anderson and Crecelius (1985) and to the Puget Sound Dredged Disposal Analysis (PSDDA) ML-1 criteria for sediment disposal practices developed by the United States Army Corps of Engineers (COE). Based on these comparisons and on the definitions of "uncontaminated" and "native" sediment from Anderson et al. (1985), the report concludes that the subject sediments are suitable for open-water disposal without capping.

Project chronology was as follows:

- Early February 1987: Hart Crowser, Inc. was retained by Abam Engineers on behalf of the United States Department of the Navy (Navy) to analyze the sediments in Port Gardner in the vicinity of the proposed carrier pier and breakwater.

- February 11, 1987 to February 14, 1987: Samples were collected by Nortec, Inc., under the supervision of Hart Crowser, Inc., using Vibracore sampling methods.

- February 16, 1987: Samples are submitted to Laucks Testing Laboratories, Inc. for chemical analysis.

- Late February - early March 1987: Hart Crowser performed physical tests to classify sediments as to soil type.

- May 14, 1987: Final report submitted to Navy.

2.0 LEGAL AND REGULATORY ISSUES

The author stated that "the results presented in this report are intended to satisfy the requirements of Section D-1, Page 11, of the March 2, 1987, Water Quality Certification (Washington State Department of Ecology, 1989)." However, the report did not explain said requirements or discuss how the results of the analysis satisfied them.

3.0 DEMOGRAPHICS AND LAND USE

N/A

4.0 POTENTIALLY LIABLE PERSONS

This report did not discuss specific businesses or persons who might be responsible for the chemicals found in the subject sediments. Furthermore, it did not show the sediments to be significantly polluted compared to the adopted ML-1 standards. However, the report did note that "most samples contained some amount of wood fragments with the upper foot exhibiting abundant wood chips and fragments." The authors suggested that the abundance of wood is likely due to the use of the waterway for log transport and to a lesser extent, for short term log storage.

5.0 IDENTIFICATION OF POLLUTION POINT SOURCES

N/A

6.0 IDENTIFICATION OF POLLUTION NON-POINT SOURCES

N/A

7.0 CHEMICAL DATA

Information presented in the report was based on 10 sediment cores collected over 4 consecutive days (Attachment A). The samples were 2-inch-diameter Vibracore samples. Each core typically provided two subsamples. Sample depths ranged from about 1 foot to 4 feet below sediment surface. Chemical and related analysis were performed by Laucks Testing Laboratories. Eight of the 10 cores were analyzed for the following parameters:

- o Total Solids;
- o Total Volatile Solids;
- o Total Organic Carbon;
- o Oil and Grease;
- o Sulfide;
- o Trace Metals (arsenic, cadmium, copper, lead, mercury, zinc);
- o Volatile Organic Compounds;
- o Semivolatile Organic Compounds; and
- o Polychlorinated Biphenyl Compounds.

The remaining two cores consisted mostly of wood fragments and were evaluated only for total solids and percent wood.

The report states: "Analysis of the sediment subsamples indicates the presence of trace metals, three volatile chlorinated hydrocarbons, thirteen polycyclic aromatic hydrocarbons, and two phthalate esters at various concentrations in several of the samples tested...."

Attachment B presents the applicable 1986 PSDDA ML-1 threshold limits and results of the 1985 sediment analysis by Anderson and Crecelius. Based on these data, Hart Crowser found the sediments in question suitable for open-water disposal without capping, because 1) there were relatively low concentrations of contaminants present when compared to the ML-1 criteria and 2) the sediments sampled exhibited similar levels of contaminants as those sediments analyzed by Anderson et al. in 1985 which were considered "uncontaminated."

No further evaluation or discussion of transportability, chemical reactivity, decomposition or biologic toxicity of these sediments was included.

Overall, the quality of the data presented in this report appears high. The text describes standard sampling techniques, responsible handling and storage, clean laboratory preparation and analysis that includes duplicates, standards and spikes. In summary, the appendix covering the chemical analysis lab report states:

> "Analysis of standard reference materials indicates excellent accuracy for metals and volatile organic compounds and lower accuracy for semivolatile organic compounds.
>
> Based on the indications of sampling handling and the results of quality control measurements, the results of the tests performed are of high quality. There are no indications that would limit the use of the results for their intended purpose of sediment characterization."

This report contains supporting documentation in its appendices which generally corroborates the above statements regarding data quality (see Section 10.0, Data Quality).

The only significant problem with the report was the lack of data available for Cores V-1 and V-2. These samples were not analyzed because they were mostly wood and "the amount of sediment recovered was not sufficient for testing requirements." These two samples are closer to the existing shoreline than the other samples (see maps provided in Attachment A) and also closer to the interior harbor where Anderson et al. found contaminated sediments in 1985. Whatever sources brought the highest concentrations of wood to these sample sites may have also brought contaminants. Near-shore sediments should have been analyzed.

The date of the report should also be considered when evaluating its usefulness. The sampling events on which it is based occurred in February 1987, almost 4 years prior to this review. Also, based upon the findings of the study, the subject area has since been dredged.

8.0 BIOLOGICAL DATA (FLORA/FAUNA)

N/A

9.0 DATA QUALITY

N/A

10.0 HYDROLOGIC AND HYDRODYNAMIC INFORMATION

The quality of data presented in this report appears to be high overall. The methods of analysis used for this work were based on United States Protection Agency document SW-846, Test Methods for Evaluating Solid Waste (1985). All methods were selected to closely correspond to those used for analysis in the earlier referenced work by Anderson et al. Only sediment cores were analyzed. The methods of sampling, handling, storage, preparation and analysis described in the report appear to be valid, based on the quality assurance/quality control (QA/QC) data presented. However, the laboratory package, attached as appendices to the reviewed report, does not include all the documentation considered necessary for a complete data review as defined in the 1989 PSDDA Guidance manual (Washington Department of Ecology).

Also, some of the QA/QC data given are not evaluated or summarized. Spikes for instance, show a low percent recovery for acids and no control limits are cited.

11.0 DREDGING AND DISPOSAL ISSUES AND DATA

The reviewed report was used as a decision making document to permit dredging, which has since been completed. The report was intended to satisfy part of the requirements of the Water Quality Certification issued by the Washington State Department of Ecology to the Navy on March 2, 1987. It provided a chemical and physical analysis of sediments to a maximum depth of 4.1 feet below the sediment surface. It is based on ten Vibracore samples of which eight received chemical analysis. All samples were collected from around the proposed breakwater and carrier pier at Port Gardner. The report concludes that the sediments appear suitable for disposal in open water without capping. This finding is based on a comparison of contaminant levels found in the sediment with the corresponding threshold criteria established by the COE in PSDDA ML-1 and on a comparison with sediments considered uncontaminated in the 1985 report by Anderson and Crecelius.

12.0 ENVIRONMENTAL IMPACTS

The report evaluated the sediments without discussing sources of pollution or the potential aquatic or biological impacts the contaminants found could have on the local marine environment. The report does conclude that the sediments appear suitable for disposal in open water without capping. However, this finding is based solely on a comparison of contaminant levels found in the sediment with the corresponding threshold criteria established by the COE in PSDDA ML-1 and on a comparison with sediments considered uncontaminated in the 1985 report by Anderson and Crecelius (see Attachment A, Table 2).

13.0 INTERIM MEASURES/SPILL AND POLLUTION PREVENTION MEASURES

N/A

14.0 COMMUNITY RELATIONS INFORMATION

N/A

15.0 RECOMMENDATIONS

The intended scope and use of this report is limited. It was meant to satisfy specific requirements for obtaining a Water Quality Certification from the Washington State Department of Ecology. It concludes only that:

- o The sediments analyzed are similar to other local sediments considered "native" or "uncontaminated" in a 1985 report by Anderson and Crecelius.
- o The sediments show chemical concentrations below the PSDDA ML-1 criteria.
- o The sediments in the vicinity of the proposed carrier pier and breakwater appear suitable for open water disposal without capping.

The only significant data gap in the report is the lack of analysis on two near-shore core samples because the samples were reported to be composed of mostly wood fragments. The report does not address the possibility that these near-shore deposits may be more contaminated than the deeper, less organic rich sediments. In future sediment studies in Port Gardner which include near shore environs, care should be taken to collect enough mineral sediment (vs. wood fragments) to allow for thorough chemical analysis.

16.0 FINAL COMMENTS

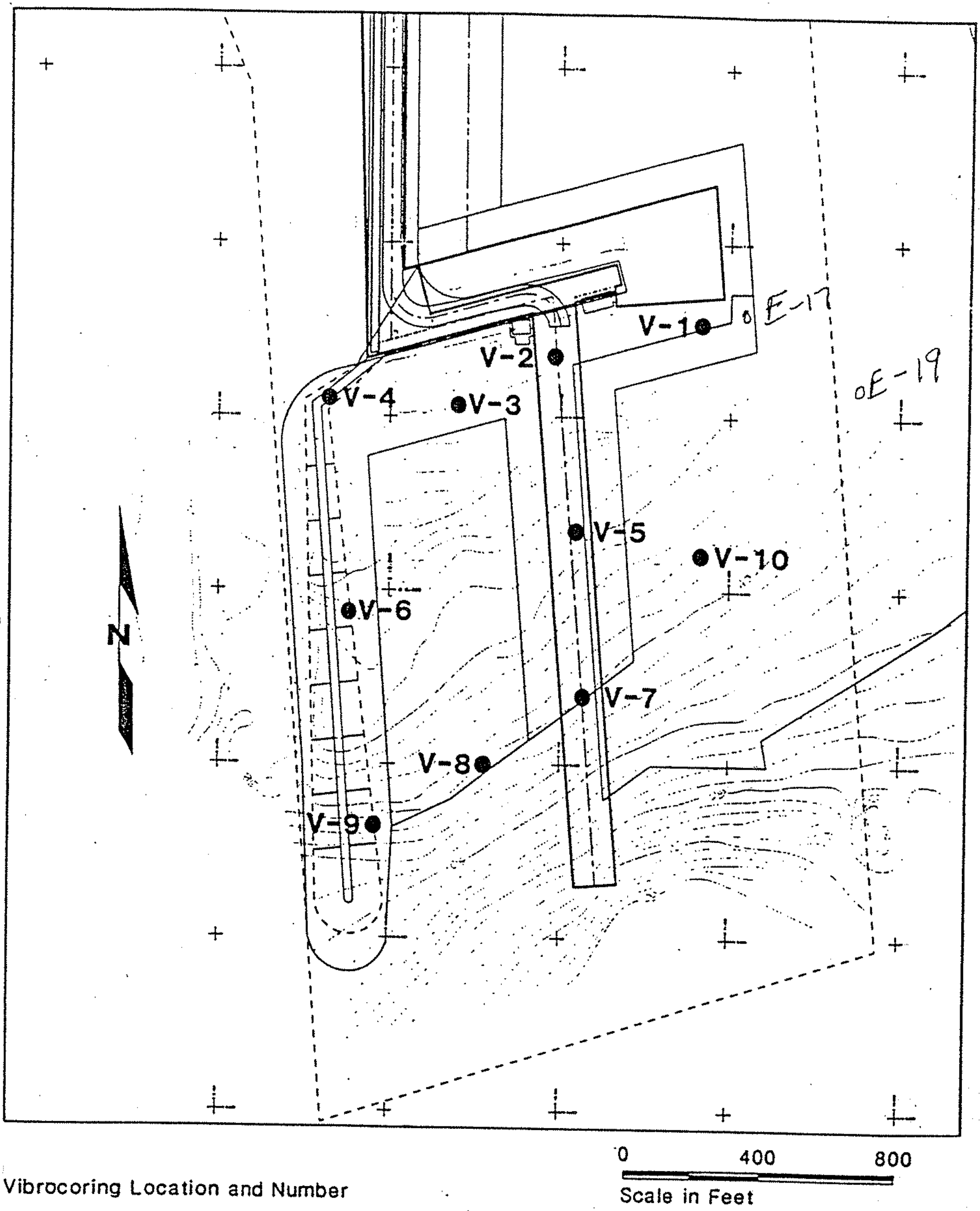
This report provides good quality baseline chemical data for the sediments around the proposed breakwater and carrier pier at Port Gardner. The limited scope of the report, however, prevents it from providing any comprehensive or detailed guidance or recommendations. The fact that the study area has already been dredged also limits the future usefulness of the report.

This report was, in part, the basis for the dredging permit issued by the Seattle District COE. Dredging of the site took place from November 1, 1989 through March 14, 1990. The limits of that dredging are shown on the attached map (Attachment A). The dredged sediments were deposited at the Port Gardner multi-user, unconfined open-water disposal site (Attachment B).

Attachment A

SITE AND EXPLORATION PLANS

Site and Exploration Plan



Vibrocoring Location and Number

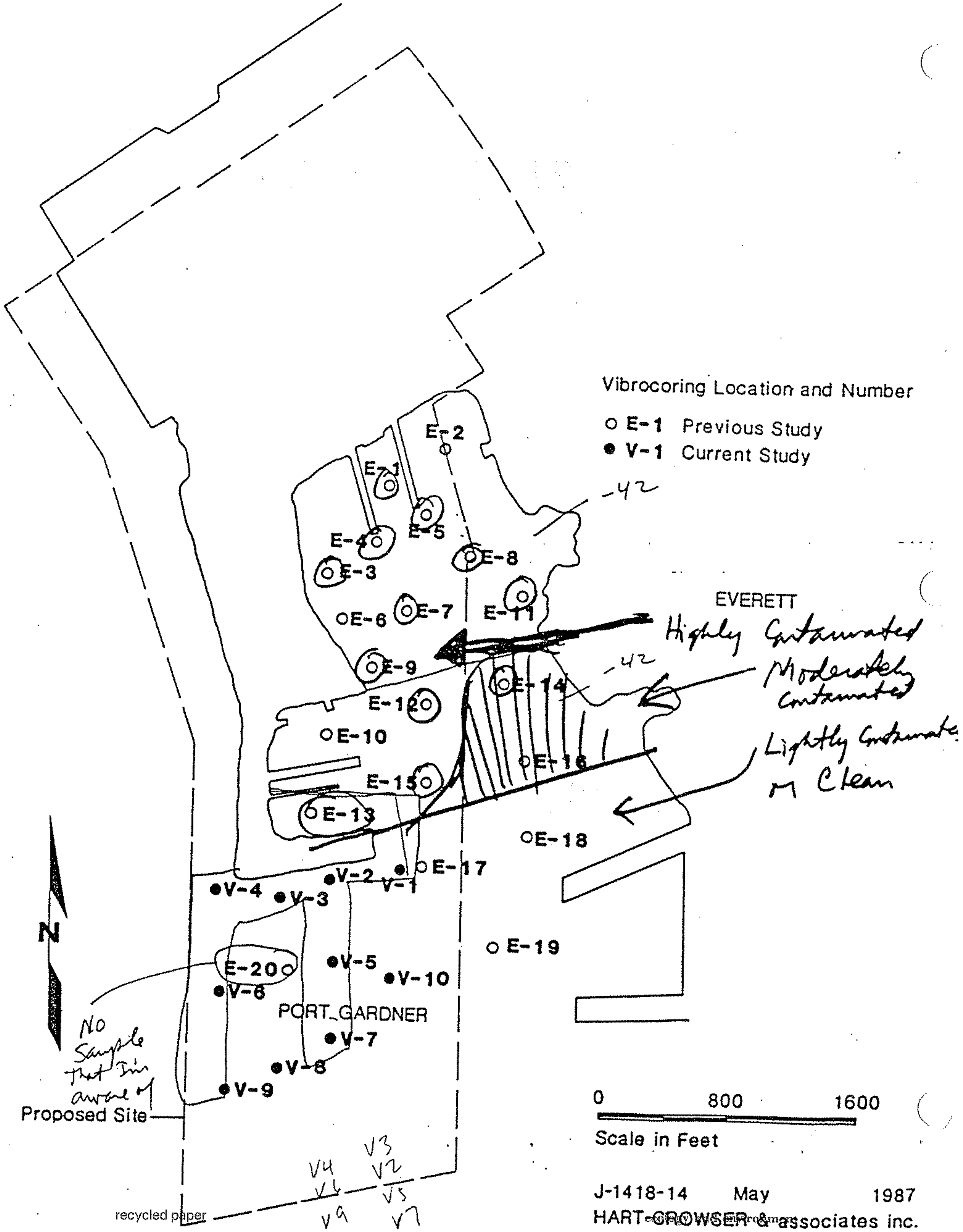
● V-1 Current Study

J-1418-14 May 1987

HART-CROWSER & associates inc.

Revised Figure 1

Vibrocoring Exploration Plan



J-1418-14 May 1987

HART-CROWSER & associates inc.

Revised Figure 2

Attachment B

SITE SEDIMENT CHEMISTRY

Anderson and Crecelius (1985) [illegible]th PSDDA ML-1 Criteria

Proposed Carrier and Pier and Breakwater Site - NAVSTA Puget Sound

ANALYTE	ML-1 CRITERIA	RESULTS OF THIS WORK (SOUTH OF SOUTH MOLE) AVERAGE VALUES	% OF ML-1 CRITERIA	LOWEST VALUE	HIGHEST VALUE	% OF ML-1 CRITERIA	AVERAGE S-1	AVERAGE S-2	RESULTS OF WORK BY ANDERSON AND CRECELIUS, 1985 (EAST WATERWAY) AVERAGE TOP	AVERAGE MIDDLE	AVERAGE BOTTOM	AVERAGE GRABS
INDEX PARAMETERS												
Retained on No. 8 sieve (% AR)	NC	5		2 U	23		6	2				
Total Solids (% AR)	NC	62.3		42.7	77.3		56	69	41.28	61.44	71.35	47.17
Total Volatile Solids (% DB)	NC	9.2		4.0	23.4		13	5	24.66	7.62	3.15	13.4
Total Organic Carbon (% DB)	NC	3.5		0.4	9.7		5	2	8.80	2.28	1.07	5.86
Oil and Grease (% DB)	NC	0.005		0.005 U	0.006		0.01	0.01	4.41	2.73	0.103	1.88
Sulfide as S (% DB)	NC	0.018		0.001	0.055		0.02	0.02	0.38	0.096	0.037	0.35
TRACE METALS (mg/kg)												
Arsenic	85	9.9	11.7	8.4	15	17.6	9	11	7.9	26.4	8.6	12
Cadmium	5.8	0.4	6.5	0.1	1.0	17.2	0.5	0.3	1.5	1.5	0.4	1.5
Copper	310	43	13.7	27	55	17.7	43	42	97	205	41	50
Lead	300	11	3.6	10 U	20	6.7	11	10	57	71	9	41
Mercury	0.41	0.09	21.5	0.05 U	0.15	36.6	0.1	0.1	0.33	3	0.06	0.16
Zinc	260	67	25.8	55	100	38.5	72	62	245	186	74	218
VOLATILE ORGANIC COMPOUNDS (ug/kg)												
Methylene Chloride	NC	3		3 U	3 J		3	3				
Trichloroethene	1600	3	0.2	3 U	3 J	0.2	3	3				
Tetrachloroethene	140	4	2.8	3 U	19	13.6	3	3				
SEMIVOLATILE ORGANIC COMPOUNDS (ug/kg)												
Naphthalene	2100	99	4.7	50 U	230	11.0	100	98				
Acenaphthylene	560	78	14.0	50 U	220	39.3	96	61				
Phenanthrene	1500	94	6.3	50 U	160	10.7	108	80				
Anthracene	960	72	7.5	50 U	130	13.5	83	60				
SUM OF LPAH	5200	343	6.6	200	630	12.1	387	299				
Fluoranthene	1700	114	6.7	50 U	350	20.6	150	79				
Pyrene	2600	111	4.3	50 U	340	13.1	142	80				
Benzo(a)anthracene	1300	100	7.7	57	440	33.8	129	71				
Chrysene	1400	105	7.5	50 U	440	31.4	139	71				
Benzo(b)fluoranthene	3200	84	2.6	50 U	260	8.1	108	61				
Benzo(k)fluoranthene	CE	82		50 U	350		104	60				
Benzo(a)pyrene	1600	131	8.2	50 U	560	35.0	160	103				
Indeno(1,2,3-cd)pyrene	600	72	11.9	50 U	130	21.7	83	60				
Benzo(ghi)perylene	670	71	10.6	50 U	120	17.9	82	60				
SUM OF HPAH	12000	871	7.3	457	2990	24.9	1098	644				
SUM OF LPAH AND HPAH	17200	1214	7.1	657	3620	21.0	1485	943	54525 T	72390 T	1575 T	27230 T
Dibutylphthalate	1400	102	7.3	50 U	310	22.1	129	75				
Bis(2-ethylhexyl)phthalate	1900	133	7.0	50 U	820	43.2	121	145				

NOTES:

1. Results of work by Anderson and Crecelius are from "Final Report, Analysis of Sediments and Soils for Chemical Contamination for the Design of U.S. Navy Homeport Facility at East Waterway of Everett Harbor, Washington, "Anderson, J.W. and Crecelius, E.A., 1985, U.S. Army Corps of Engineers.
2. PSDDA ML-1 criteria from "Preliminary Draft Report, Puget Sound Dredged Disposal Analysis (PSDDA) Technical Appendix- Evaluation Procedures, 1986," U.S. Army Corps of Engineer
3. AR indicates a result expressed on an as received basis.
4. DB indicates a result expressed on a dry basis.
5. U indicates analyte not detected. Value expressed is the detection limit.
6. J indicates an estimated value.
7. T indicates a sum of analytes including some not listed in this table.
8. [illegible]