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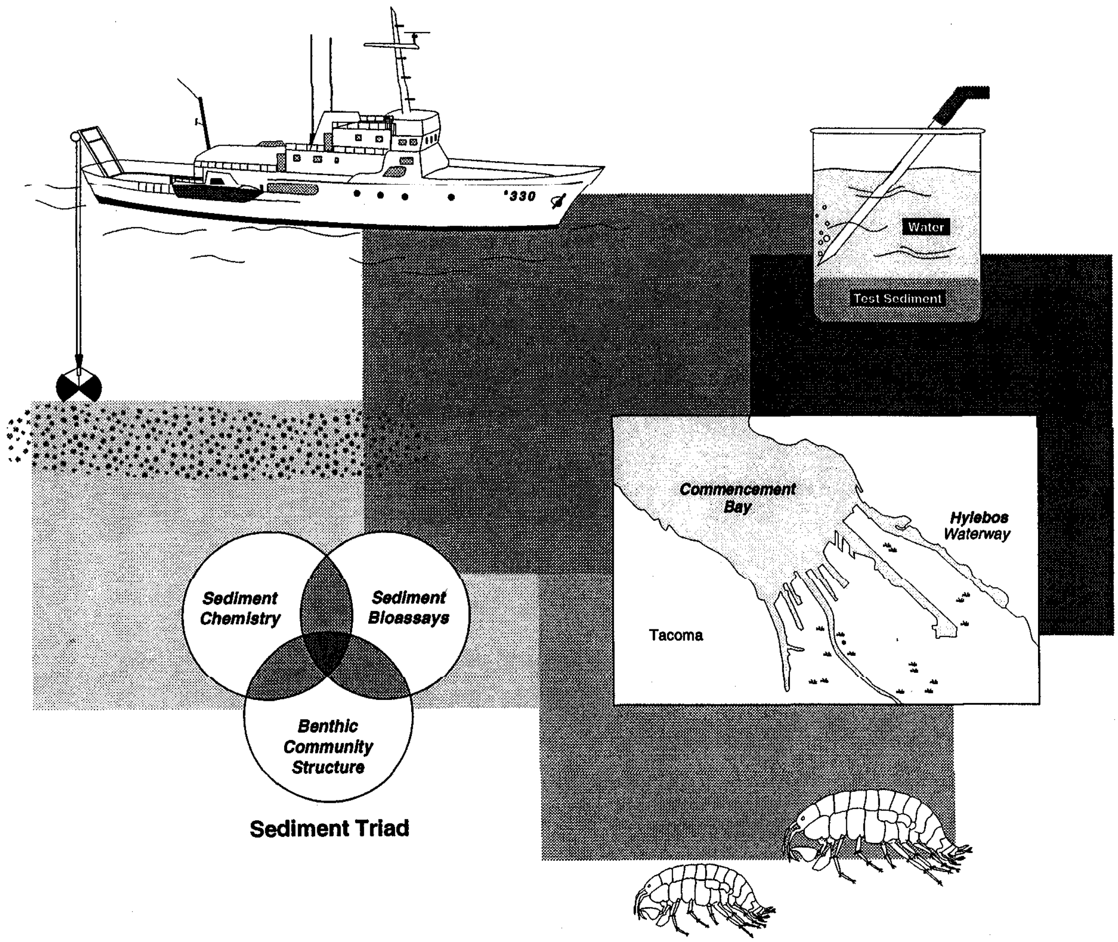
COMMENCEMENT BAY DAMAGE ASSESSMENT STUDIES

HYLEBOS WATERWAY DATA AND DATA ANALYSIS REPORT



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The National Oceanic and Atmospheric Administration of the U.S. Department of Commerce; the U.S. Department of the Interior, including the U.S. Fish and Wildlife Service; the Washington Department of Ecology, Washington Department of Fish and Wildlife, and Washington Department of Natural Resources; the Puyallup Tribe of Indians; and the Muckleshoot Indian Tribe

HYLEBOS WATERWAY DATA AND DATA ANALYSIS REPORT

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LIST OF ACRONYMS

ARI	Analytical Resources, Inc.
CBDAS	Commencement Bay Damage Assessment Study
COC	contaminant of concern
DGPS	differential global positioning system
DNR	Washington Department of Natural Resources
DOI	Department of the Interior
DW	dry weight
Ecology	Washington State Department of Ecology
ER	enrichment ratio
EVS	EVS Environment Consultants, Inc.
HCC	Hylebos Cleanup Committee
HPAH	high molecular weight polycyclic aromatic hydrocarbons
LOEL	lowest observed effects level
LPAH	low molecular weight polycyclic aromatic hydrocarbons
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
OC	organic carbon
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PSDDA	Puget Sound Dredged Disposal Analysis
PSEP	Puget Sound Estuary Program
QA/QC	quality assurance/quality control
QAPP/LAP	quality assurance project plan/laboratory analysis plan
RI	remedial investigation
ROD	record of decision
SAP	sampling and analysis plan
SMS	sediment management standards
SQO	sediment quality objective
SQS	sediment quality standards
SVOC	semivolatile organic compound
TOC	total organic carbon
Trustees	Commencement Bay Natural Resources Trustee Council

VOC	volatile organic compound
U.S. EPA	U.S. Environmental Protection Agency

1.0 INTRODUCTION

The Hylebos Waterway (Figure 1-1) is one of the many waterways that compose the Commencement Bay Superfund site. During the Commencement Bay Near Shore/Tideflats remedial investigation (RI) conducted in 1985, the degree and spatial extent of chemical contamination, adverse biological effects, and potential threats to natural resources were assessed (Tetra Tech 1985). Subsequent efforts included a feasibility study that identified alternatives for sediment remedial action (Tetra Tech 1988) and development of sediment quality objectives (SQOs) based on sediment clean up goals (PTI 1989). The results of past studies (Tetra Tech 1985; Striplin et al. 1995) indicate that sediments in the Hylebos Waterway are contaminated with a number of hazardous substances. Based on results of laboratory bioassay tests, these sediments may be toxic to natural resources. These previous data also indicate that the benthic community may be impacted. When compared to reference areas, statistically significant reductions in the abundance of various taxonomic groups, including crustaceans, polychaetes, and molluscs were apparent for many stations in the Hylebos Waterway (Tetra Tech 1985).

The Commencement Bay Natural Resource Trustee Council (Trustees) is concerned that hazardous substances present in the sediments of the Hylebos Waterway have caused and are continuing to injury to natural resources. Members of this council include the National Oceanic and Atmospheric Administration (NOAA), the U.S. Department of the Interior, including the U.S. Fish and Wildlife Service; the Washington Department of Ecology (Ecology), Washington Department of Natural Resources (DNR), the Puyallup Tribe of Indians, and the Muckelshoot Indian Tribe. The Trustees cooperatively initiated the Commencement Bay Damage Assessment Study (CBDAS) to assess natural resource injury for Commencement Bay. Between May 23 and June 1, 1994, as part of the CBDAS, the Trustees conducted an investigation that specifically addressed the natural resource injury issues for the Hylebos Waterway. The purpose of this investigation was to verify and further define the presence of hazardous substances in Hylebos Waterway sediments, to determine the potential toxicity associated with surficial sediments based on standardized bioassays, and to assess the status of benthic infauna communities. During this investigation, chemical analyses were used to further delineate the magnitude and extent of chemical contaminants within the upper strata of soft-bottom sediments, and laboratory bioassays were used to estimate the degree of toxicity associated with exposure to these surficial sediments.

Abundance and enumeration data were used to assess the status of benthic infaunal communities and to determine the extent to which benthic community structure may be injured from continued exposure to hazardous substances. The data generated in this investigation were interpreted as per the sediment quality triad methodology, an approach that utilizes a weight-of-evidence type analysis of sediment chemistry, toxicity results from laboratory bioassays, and benthic species abundance data to identify potential effects.

This report summarizes the data obtained during the Hylebos Waterway investigation conducted in the summer of 1994. The methods used during all phases of the project (i.e., field collection, chemical analyses, laboratory bioassays, and data analysis) will be reviewed. There were no deviations from the sampling and analysis plan (SAP; EVS 1994a).

2.0 SUMMARY OF THE STUDY DESIGN AND METHODS

A detailed account of the study design can be found in the SAP (EVS 1994a), the combined quality assurance project plan/laboratory analysis plan (QAPP/LAP; EVS 1994b), and the laboratory procedures of the NOAA/National Marine Fisheries Service (NMFS) Montlake Laboratory (NOAA 1995). The SAP identifies the potential sampling locations for both the Hylebos Waterway and reference stations, methods of sample collection and handling, procedures for the chemical analysis of volatile organic compounds (VOCs) in sediments samples, laboratory bioassay procedures, benthic community analysis procedures, and proposed methods for data reduction, validation, and analysis. The QAPP/LAP contains explicit information for each procedure that was used during the investigation, as well as procedures to ensure that the data are of sufficient quality to be used in support of any litigation that might ensure from a natural resource damage assessment. NOAA and NMFS were the primary agencies involved in this investigation; technical support was provided by EVS Environment Consultants (EVS).

The surface sediment samples were collected from the Hylebos Waterway, Carr Inlet, and Commencement Bay between May 23 and June 1, 1994, and processed in accordance with the SAP and QAPP/LAP. Sections 2.1 through 2.6 of this data analysis report summarize the major aspects of the methods as provided in the SAP.

2.1 SAMPLING STATIONS

A total of 32 stations were sampled for this study. Twenty-eight stations were in the Hylebos Waterway (Figure 2-1), two reference stations were in Carr Inlet (Figure 1-1), and two reference stations were along the north shore of Commencement Bay (Figure 1-1). Latitude and longitude coordinates for the sampling stations were established using the differential global positioning system (DGPS; Table 2-1).

2.1.1 Hylebos Waterway Stations

The Hylebos Waterway stations were selected on the basis of the following project objectives:

- To verify the presence and further delineate the distribution of contaminants of concern (COCs) and sediment problem areas. A sediment problem area is defined as an area in which the concentration of one or more hazardous substances is causing injury to natural resources, thereby reducing the level of services provided to other resources.

- To supplement the sediment chemistry studies undertaken by the Hylebos Cleanup Committee (HCC; Striplin et al. 1995), a consortium of responsible parties. Studies were conducted at the direction of the U.S. Environmental Protection Agency (U.S. EPA). Station locations were chosen to accomplish the following objectives: 1) to increase the spatial resolution of sediment quality by decreasing the distances among adjacent sampled sediment locations; 2) to collect bioassessment/injury data from areas not sampled previously; and 3) to further delineate the extent of previously identified problem areas.

The Hylebos Waterway was divided into six approximately equal-sized segments based on reach length (Figure 2-1). The segments are numbered 1 through 6, with Segment 1 located at the head of the waterway and Segment 6 located at the mouth. In general, these segments are comparable with those used in the RI.

Five stations were located in Segment 1 (Figure 2-1). All five stations were located near areas identified by historical data as exhibiting resource injuries based on toxicity and impacted benthic communities as documented in the RI (Tetra Tech 1985).

Five stations were located in Segment 2 (Figure 2-1). Stations were located near areas of known resource injury, as documented in RI data, or in areas where resource injury was suspected. Stations DAC-HY-21, DAC-HY-20, and DAC-HY-19 were located near the Elf Atochem facility; Stations DAC-HY-23 and DAC-HY-22 were located near the General Metals of Tacoma facility.

Four stations were located in Segment 3 (Figure 2-1) near areas of known resource injury, based on historical data. Station DAC-HY-18 was adjacent to the Hylebos Marina. Stations DAC-HY-18, DAC-HY-17, and DAC-HY-16 increased the spatial resolution of the data on sediment quality; Station DAC-HY-15 was co-located with a station proposed by the HCC (Striplin 1994).

Two stations were located in Segment 4 (Figure 2-1). This portion of the waterway has historically contained relatively low concentrations of contaminants in surface sediment, and previous assessment of biological resources has indicated little adverse impact (Tetra Tech 1985). Station DAC-HY-14 was located near the area identified by historical data as an area of potential resource injuries (Tetra Tech 1985).

Six stations were located in Segment 5 (Figure 2-1), all near the Occidental Chemical Company facility. These stations were located near areas that were identified in the RI as exhibiting resource injuries, or in locations that would increase the spatial resolution of sediment quality in the segment. Station DAC-HY-09 was co-located with a station proposed by the HCC (Striplin et al. 1994).

Six stations were located in Segment 6 (Figure 2-1), where little historical data have been generated. All six stations were located near potential nearshore sources of contamination, including AK-WA Shipbuilding, Ole & Charlie's Marina, and the Commencement Bay Marina. Stations DAC-HY-03, DAC-HY-04, and DSC-HY-05 are co-located with stations utilized by the HCC (Striplin et al. 1994).

2.1.2 Reference Stations

Reference sediment samples were collected from two stations in Carr Inlet and two stations on the north shore of Commencement Bay (Figure 1-1). Latitude and longitude coordinates for the reference stations are provided in Table 2-1. The Carr Inlet sediments were used as reference sediment for the toxicity tests. The Commencement Bay sediments were used as the reference benthic community and as the comparative basis for the abundance of major taxa found in Hylebos Waterway.

The two Carr Inlet reference stations were within 200 m of each other, located on the north side of Raft Island. Carr Inlet was chosen for reference sediment collection because it was recommended and approved by local regulatory agencies as a reference station for sediment bioassays. In addition, there is a substantial amount of historical data for this area that could be used in analysis of the chemical and biological test results. Only Carr Inlet sediments were used as reference sediments in the laboratory toxicity tests. Reference sediments were used to account for bioassay test responses that may be due to natural characteristics of the sediment, such as sediment grain size or total organic carbon (TOC) content.

The Commencement Bay stations were located along the southern shore of Browns Point (Figure 1-1). Sediments were collected from two areas because each was predominated by different sediment grain-size characteristics. Grain size, TOC, and water depth were used to select the appropriate Commencement Bay reference stations for analysis of benthic abundance data. Sediments from the Commencement Bay reference stations were not used in the laboratory toxicity tests because they have been neither recommended nor approved by local regulatory agencies for that use.

2.2 SAMPLING METHODS

A 0.1-m^2 van Veen grab sampler was used to collect all sediment samples submitted for chemical analysis and toxicity tests; a 0.06-m^2 van Veen was used for sediments submitted for benthic community analysis. A minimum of nine grab samples of surficial sediments was collected from each test and reference station. The uppermost 10 cm of surface sediment was removed from each sample with a stainless-steel spoon. Samples were placed into the appropriate containers and processed as specified in the SAP and QAPP/LAP. Four replicates were collected at each station for samples submitted for chemical analysis and bioassay testing; seven replicates were collected at each station for samples submitted for benthic community analysis. The sediment samples collected for benthic analyses were sieved through 1-mm screens while aboard the sampling platform. Organisms retained on the screen were placed into a jar and preserved with 10 percent buffered formalin. They were later identified to the lowest practical taxonomic level and enumerated at the laboratory.

2.3 LABORATORY ANALYSIS

2.3.1 Sediment Conventionals

All sediment samples were analyzed for the following parameters: grain size, TOC, total solids, total volatile solids, ammonia, and sulfides. Analytical Resources Incorporated (ARI) of Seattle, Washington, conducted these analyses in accordance with the procedures identified in the project plans (EVS 1994a,b; NOAA 1995).

2.3.2 Hazardous Substance Analysis

The primary COCs included 12 trace elements, polychlorinated biphenyls (PCBs), 4 VOCs, and 18 semivolatile organic compounds (SVOCs) that were identified as COCs in the Commencement Bay Damage Assessment Phase I Report (EVS 1995). The substances measured in the current Hylebos Waterway study extended beyond these 35 compounds. Table 2-2 lists all analytes included in the CBDAS and the laboratory that performed the analyses. Analyses of the VOCs and selected chlorinated hydrocarbons were performed by ARI following the procedures specified in the QAPP/LAP (EVS 1994b). The NOAA/NMFS Northwest Fisheries Center in Seattle, Washington, analyzed the sediments for all analytes except VOCs. Analytical procedures used by the NMFS laboratory were specified by NOAA (1995). PCBs were analyzed by congener and were reported as total PCBs as well as by "chlorobiphenyl A/B," where A equals the number of chlorines and B equals the typical BZ number.

2.3.2.1 Method Comparison

Trace elements were analyzed by the NMFS laboratory using two different methods: strong acid digestion and total acid digestion. A discussion of both methods appears in the Puget Sound Estuary Program (PSEP) protocols (PSEP 1989). Because data in the past have been collected by both methods, these samples were used as an opportunity to determine whether the methods yielded substantial differences in results for the COCs for Commencement Bay. Only results based on the total acid digestion method were used in this study. Because the total acid digest is considered to provide a more exhaustive recovery of the metals and metalloids, the Trustees determined that only the results using this method would be used in the report. (The results of measurements made using both strong acid and total acid digests on the same samples are compared in Section 3.2.1.1.)

2.3.3 Toxicity Testing

Three standardized sediment toxicity tests were conducted: a 10-day amphipod mortality test using *Rhepoxynius abronius*; a 20-day juvenile polychaete growth test using *Neanthes* *arenaceodentata*; and a 48-hour echinoderm larval combined mortality test using *Dendraster excentricus*. Toxicity testing was conducted by EVS. PSEP (1991) and ASTM (1993) guidelines were followed for all bioassays, except for the deviations as noted in the project plans (EVS 1994a,b). Two of the toxicity tests used in the present study, the amphipod and the echinoderm larval test, are similar to the tests conducted during the RI (Tetra Tech 1985). Although the bivalve larval test was used in the RI, the echinoderm larval test was used in the current study because bivalve larvae were not available when the tests were performed. Comparable results from these two tests are expected for two reasons. First, local regulatory agencies consider the tests interchangeable, and review of the LC_{50} data generated from reference toxicity tests indicates that the two groups have similar sensitivities. The LC_{50} value is a tool used within the scientific community that allows the relative toxicities of contaminants to be compared. It represents the concentration of contaminant in water that is estimated to be lethal to 50 percent of the test organisms. The LC_{50} is usually expressed as a time-dependent value (i.e., 96-hour or 10-day) to provide an estimate of toxicity at both the acute and chronic levels. The juvenile polychaete growth test was not used during RI, but was added to the CBDAS to be consistent with present requirements of the Washington State Sediment Management Standards (SMS; Ecology 1991).

Testing was conducted in two series for each bioassay to ensure that sediment holding times were not exceeded. For amphipod and polychaete bioassays, the first test series was conducted on sediment collected from 12 Hylebos Waterway stations; the second test series was conducted on sediment from the remaining 16 Hylebos Waterway stations and the two Carr Inlet reference stations. For the echinoderm larval tests, each test series was conducted on sediment from 15 stations. The two test series overlapped (i.e., the second test series was initiated before completion of the first test series), and the toxicity response data for the two reference sediments were used in all statistical comparisons for both test series.

Sediment from Carr Inlet served as the reference sediment for all laboratory toxicity tests. Control sediment was collected from West Beach, Whidbey Island, Washington.

2.3.4 Benthic Organism Identification and Abundance

After preliminary processing in the field, the benthic infauna samples were delivered to the EVS Benthic Laboratory, Seattle, Washington, for identification and enumeration. Biota were sorted, identified, and enumerated according to the project plans (EVS 1994a,b). Of the seven replicate samples collected at each station, four samples were randomly selected for analyses and the remaining three samples were archived.

Upon arrival in the laboratory, all samples were reinventoried and checked against the chain of custody forms. Samples were rinsed with fresh water to remove formalin and then rescreened with a 0.5-mm mesh to retain smaller organisms and fragments. All biota retained on the screen were stored in 70 percent ethanol until further processing. Taxonomists counted and identified all organisms to the lowest practical taxonomic level, which was generally species. Only the anterior portions of fragments were identified and counted.

The enumeration data were entered into a computerized database. Numeric abundance for the major classes of benthos (i.e., crustaceans, polychaetes, and molluscs) and total abundance data were determined for each station.

Quality assurance and quality control (QA/QC) was conducted for both sorting and taxonomy. In compliance with the methods provided in the SAP and QAPP/LAP (EVS 1994a,b), 20 percent of the samples were resorted by an independent processor to check for sorting efficiency and accuracy. Taxonomic QA/QC was achieved by independent re-identification of 5 percent of all samples.

2.4 DATA QUALITY AND STATUS SUMMARY

EcoChem, Inc., Seattle, Washington, performed QA/QC review of all data. EcoChem provided validation reports for each of the categories of analyses conducted for this project. These validation reports (Appendix A) are the source for the data quality and status information presented in Appendix B. All data, as qualified, were found to be acceptable for use.

2.5 DATA ANALYSIS AND USE

The data analysis approaches used during this study were similar to those used in the RI (Tetra Tech 1985). This approach permits direct comparison of data generated as part of this study with results obtained during the RI, and evaluation of the status of resource conditions relative to those observed in 1984. Sediment chemistry data from each station were used with the sediment toxicity data and the benthic species abundance data to perform a sediment quality triad analysis, using a weight-of-evidence approach.

2.5.1 Hazardous Substances

Concentrations of analytes were compared with the SQOs identified in the Commencement Bay Nearshore/Tideflats Record of Decision (ROD; EPA 1989). The data were also compared with the sediment quality standards (SQS) as defined in the Washington State sediment management standards (SMS). Exceedance of the SQS was considered indicative of injury to the sediment as defined by the U.S. Department of Interior (DOI) Natural Resource Damage Assessment regulations (43 CFR Part 11).

To allow comparison with SQS and SQO, the concentrations of organic compounds were normalized to both dry weight (DW) and organic carbon (OC) content. Two enrichment ratios (ERs), in which both the SQS and SQO were used as the criteria concentration, were calculated for each analyte detected at each station, according to the following equation:

$$ER = \frac{\text{normalized contaminant concentration}}{\text{criteria concentration}}$$

2.5.2 Toxicity Data

Laboratory toxicity data were analyzed by the following process:

1. The results for each sample from the Hylebos Waterway was matched, on the basis of sediment grain size, to results for an appropriate Carr Inlet reference sediment.

2. Homogeneity of variance for these two data sets was tested using an F-test.

3. Based on the results of the test for homogeneity of variance, the appropriate *t*-test, which tests for equal or unequal variances, was used to determine the statistical significance between the Hylebos Waterway data set and the data set for the selected reference station.

This approach is consistent with that used for analysis of the RI data (Tetra Tech 1985).

2.5.3 Benthic Data

Benthic taxonomic and abundance data were analyzed by the following process:

1. The results for each sample from the Hylebos Waterway was matched, on the basis of sediment grain size, TOC, and water depth, to the results for an appropriate Commencement Bay reference sediment.

2. Abundance data for the major classes of benthos as well as total abundance data were log-transformed.

3. Numeric abundance for major classes of benthos and total abundance data for the Hylebos Waterway and the appropriate reference stations were statistically compared with a *t*-test.

The approach used to analyze the benthic data is consistent with that used for analysis of the RI data (Tetra Tech 1985).

2.5.4 Sediment Quality Triad Analysis

The sediment quality triad analysis was used to evaluate the impact of chemical contamination in the Hylebos Waterway. The sediment quality triad uses a weight-of-evidence approach to assess the effects of contamination by combining chemical and biological measurements (Chapman 1992). Three complementary measures are used to identify pollution-induced degradation: sediment chemistry to determine contamination, sediment bioassays to determine toxicity, and *in situ* bioeffects (e.g., benthic infaunal community structure) to determine alteration of resident communities. The combination of these three separate measures allows for the differentiation of effects related to contamination from natural variability and/or laboratory artifacts. In general, impacted or degraded habitats are those which have positive "hits" for all of the three measures. Summary statistics for the triad approach commonly include rankings or an index of severity for the respective measurement parameters, ratio-to-reference values, and generation of triaxial plots for the different indices. This process permits a station-by-station analysis to establish whether conditions at the station are degraded and whether the degradation is consistent among the independent measures.

In conducting the triad analysis for the CBDAS, stations were placed into one of three classifications — adversely affected, potentially adversely affected, or not adversely affected — based on a qualitative evaluation of the data from each station. The following definitions were used; a classification matrix is shown in Table 2-3:

- ***Adversely Affected*** — The data from a station included contaminants at concentrations that were elevated above the SQS, the sediments were toxic in at least one of the three tests, and there were significant reductions in at least one of the abundance indices.

- ***Potentially Adversely Affected*** —

  A) The data from a station included contaminants at concentrations that were elevated above the SQS and exhibited either toxicity in at least one of the toxicity tests or significant reduction in at least one of the abundance indices.

  B) The data from a station did not include any contaminants at concentrations above the SQS, but exhibited either toxicity in at least one of the toxicity tests or significant reduction in at least one of the abundance indices. This status is assigned to stations that exhibited impact but whose measured contaminants did not exceed the SQS, because not all potential contaminants are analytically measured, and the responses measured during toxicity testing or analysis of benthic abundance data may be due to one of these unmeasured contaminants.

- ***Not Adversely Affected*** — The data from a station includes contaminants at concentrations above or below the SQS or SQO, but there were no significant responses observed in any of the toxicity tests, nor any significant reduction in any of the benthic abundance indices.

3.0 RESULTS

The results are summarized separately for each parameter measured, beginning with the analytical data. Because of the vast amount of data generated during this study, summary tables have been prepared and are presented in this section. Detailed data reports are presented in Appendices C, D, and E.

3.1 SEDIMENT: CONVENTIONAL PARAMETERS

The highest fractions of silt and clay were found in sediments from the head of the Hylebos Waterway; the mouth of the waterway was predominantly sand (Table 3-1). Sediments at the four reference stations covered a wide range of grain-size composition; sediments with high fractions of silt and clay (i.e., fines, consisting of particles which pass through a 62.5 μ mesh) were found in both Carr Inlet and Commencement Bay. A summary of all conventional parameters measured is provided in Table 3-2 for surface sediments from the Hylebos Waterway, and Table 3-3 for surface sediments from Carr Inlet and Commencement Bay.

3.2 HAZARDOUS SUBSTANCES

Analytical results for trace elements and organotin compounds measured in sediments from the reference stations are provided in Table 3-4; comparable results for organic compounds measured in the reference sediment samples are provided in Table 3-5. None of the analytes exceeded their respective SQS or SQO concentrations at either the Carr Inlet or Commencement Bay reference stations. Monobutyltin and tetrabutyltin were not detected at any of the reference stations. Dibutyltin (19.9 μg/kg) and tributyltin (25.5 μg/kg) were both detected at Reference Station DAC-HY-30 (Table 3-4). There are no SQS or SQO for organotin compounds. Nearly all of the SVOCs were detected in the reference station sediments, but none of these compounds were found at concentrations that exceeded SQS or SQO concentrations. None of the VOCs were detected in any of the reference stations sediments (Table 3-5).

Analytical results for trace elements and organotin compounds for the Hylebos Waterway sediment samples are summarized in Table 3-6 and Table 3-7. Table 3-6 presents results obtained by the total acid digestion method; Table 3-7 presents results obtained by the strong acid digestion method. These tables provide information on the frequency øf detection; minimum, median, and maximum concentration normalized to both dry weight and organic carbon content; the SQO and SQS concentrations, and the frequency of exceeding these values. Comparable data for organic compounds in the Hylebos Waterway sediment samples are presented in Table 3-8. Figure 3-1 shows which analytes were detected at concentrations exceeding the SQS and SQO on a station-by-station basis. No reference stations are depicted in Figure 3-1 because there were no exceedances at these stations.

Detailed results for each sediment sample, along with appropriate qualifiers are provided in Appendix C. No significant data quality issues were identified by the QA/QC review of the data (see Appendix B).

3.2.1 Trace Elements and Organotin Compounds: Comparison to Criteria

In the Hylebos Waterway samples, mercury was detected at 1 of 28 stations (Table 3-6), but the measured concentration was below both the SQS and SQO. However, the detection limits for mercury exceeded the SQS in eight samples and the SQO in six samples (Appendix C); all of these samples were collected from Segments 1 and 2. Cadmium was detected at 21 of the 28 stations, but none of the measured concentrations exceeded the SQS and SQO. The remainder of the trace elements were detected at all 28 Hylebos Waterway stations, but only arsenic and zinc were found at concentrations exceeding the criteria concentrations. Arsenic exceeded both the SQS and SQO at three stations in Segment 1; zinc exceeded both the SQS and SQO at one station in Segment 2 and one station in Segment 3 (Figure 3-1).

Neither monobutyltin nor tetrabutyltin were detected in sediments from any of the Hylebos Waterway stations. Dibutlytin was detected at 24 of the 28 stations, and tributyltin was detected at all 28 stations (Table 3-6). Concentrations of tributyltin ranged from 14.9 to 238 μg/kg DW. There is no SQS or SQO for tributyltin, although concentrations at 26 of 28 Hylebos Waterway stations exceeded the Puget Sound Dredged Disposal Analysis (PSDDA) screening concentration of 30 μg/kg DW.

3.2.1.1 Trace Element Method Comparison

Total-to-strong acid ratios calculated for the trace elements analyzed in this study are presented in Appendix C. For most trace elements the concentrations generated by the total acid method were higher than that generated by the strong acid method by a factor of about 1.2, as shown below:

Average of total to strong acid ratios:

- Antimony — 5.85
- Arsenic — 0.82
- Cadmium — 1.07
- Chromium — 1.14
- Copper — 1.09
- Lead — 1.32
- Mercury — 0.85
- Nickel — 1.49
- Silver — 0.75
- Zinc — 1.17

As measured by total acid digestion, arsenic concentrations exceeded the SQS at three stations and exceeded the SQO at three stations; zinc concentrations exceeded the SQS at two stations and exceeded the SQO at two stations (Table 3-6). In comparison, as measured by strong acid digestion, arsenic and zinc concentrations exceeded SQS at one station and the SQO at one station (Table 3-7). These data indicate that for most elements analyzed, both methods yield comparable results.

3.2.2 Organic Compounds: Comparison to Criteria

Table 3-8 summarizes the concentrations of organic compounds in surface sediments collected from the Hylebos Waterway. All polycyclic aromatic hydrocarbons (PAHs) on the analyte list were detected at all 28 of Hylebos Waterway stations, but none of the concentrations exceeded SQS. However, the concentrations of anthracene and phenanthrene exceeded their SQO. There was at least one exceedance of SQO for each of the high molecular weight PAHs (HPAHs), but no exceedances of SQS. All exceedances occurred in Segments 1 and 2 (Figure 3-1). All HPAH compounds were detected at Station DAC-HY-24 (Segment 1) at concentrations exceeding the SQO.

All of the measured phenols except 2-methylphenol were detected at all of the Hylebos Waterway stations. Only pentachlorophenol exceeded the SQS and SQO, at one station in Segment 5 (DAC-HY-09).

Concentrations of 1,4-dichlorobenzene exceeded the SQS at two stations, and concentrations of 1,2,4-trichlorobenzene exceeded the SQS at 15 stations and the SQO at 4 stations (Figure 3-1). The concentration of neither 1,3- nor 1,2-dichlorobenzene exceeded SQS or SQO at any station.

Hexachlorobutadiene was detected at all 28 Hylebos Waterway stations. Concentrations exceeded both the SQS and SQO at five stations in Segments 5 and 6 (DAC-HY-06 through -10). With the exception of Station DAC-HY-17, the concentration of hexachlorobutadiene exceeded the SQO at all stations in Segments 2 through 6 (Figure 3-1).

Concentrations of bis(2-ethylhexyl)phthalate exceeded the SQS at Station DAC-HY-09, and the SQO at Station DAC-HY-24 (Figure 3-1). Concentrations of butylbenzylphthalate exceeded the SQS at Station DAC-HY-23 in Segment 2 (Figure 3-1). No other phthalates exceeded SQS or SQO concentrations.

All pesticides, except for aldrin, were detected at most of the Hylebos Waterway stations. Concentrations of hexachlorobenzene exceeded the SQS at 21 of 28 stations, and the SQO at 12 of 28 stations. The exceedances of the SQS occurred at every station mouthward of and including Station DAC-HY-21, which is midway in Segment 2 (Figure 3-1). Sediments from all stations in Segment 5 contained hexachlorobenzene at concentrations exceeding the SQO. The remaining exceedances occurred at various stations throughout the Hylebos Waterway.

Concentrations of p,p'-DDE exceeded the SQO at three stations, and concentrations of p,p'-DDD exceeded the SQO at two stations. All five exceedances occurred in Segment 1 (Figure 3-1). p,p'-DDT was detected at nearly all Hylebos Waterway stations, but none of the measured concentrations exceeded the SQO criterion. There are no SQS criteria for DDT or its metabolites. No SQS or SQO criteria exist for the other pesticides. The only comparison criteria available are the PSDDA screening guidelines; there were no exceedances of these concentrations for other pesticides.

PCBs were detected in all sediment samples from the Hylebos Waterway. Total PCBs were determined by measuring the concentrations of 17 chlorobiphenyl congeners, summing the concentrations, and multiplying by 2, as specified in NOAA (1995). The concentration of total PCBs determined in this manner exceeded the SQS at 19 of the 28 Hylebøs Waterway stations, but did not exceed the SQO at any station (Figure 3-1). Segment 1 was the only segment that had no samples with total PCB concentrations exceeding the SQS.

Trichloroethene was the only VOC detected in any sample. It was measured in sediments from one station, but the SQO was not exceeded. Currently no SQS concentrations exist for VOCs.

3.3 TOXICITY TESTING

Sufficient sediment was collected from all 28 Hylebos Waterway stations and the two Carr Inlet reference stations to conduct the three standardized laboratory toxicity tests. Sediment from Carr Inlet Station DAC-CR-2 was used as reference sediment in all bioassay tests conducted on sediments collected from Hylebos Waterway Stations DAC-HY-01, -02, -06, -07, -13, -14, and -22. Sediment from Carr Inlet Station DAC-CR-2A was used as reference sediment in all bioassay tests for the remaining Hylebos Waterway stations. Sediment grain size was the criterion used to select the appropriate reference station for each Hylebos Waterway station. The tests proceeded without incident, and no major data quality issues were identified by the QA/QC review of the data (see Appendix B). Those stations at which toxicity was observed, following the criteria of Section 2.6.2 and the SAP, are summarized in Figure 3-2. No stations had sediments that were toxic in all three laboratory bioassays. Sediments from Stations DAC-HY-04, -05, -10, and -24 were toxic in both the amphipod mortality and echinoderm larval tests. The laboratory bioassay data sheets are provided in Appendix D.

3.3.1 Amphipod Mortality Test

Results of the 10-day mortality test with the amphipod *Rhepoxynius abronius* are presented in Table 3-9 for Carr Inlet reference stations and the control stations and in Table 3-10 for Hylebos Waterway stations. Mean mortality in the West Beach control sediment (Table 3-9) was 3 and 7 percent for the two test series, respectively. Mortality in the controls was below the acceptability limit of 10 percent. Therefore, the amphipod bioassay tests were considered successful.

Mean mortality in the two Carr Inlet reference sediment samples was 14 and 15 percent, for Stations DAC-CR-2 and DAC-CR-2A, respectively. The percent mortality determined for reference sediment sample DAC-CR-2A is based on only four replicate samples rather than five as were used in all other tests, because an unusually high mortality of 90 percent was observed in one of the five replicates when compared to the mortality observed in the other four replicates (i.e., $\bar{x}$ = 15 percent). For this report, the one replicate with high mortality was considered an outlier datum and was not included when calculating the mean mortality for Station DAC-CR-2A, nor subsequently when making statistical comparisons with Hylebos Waterway sediment toxicity test data.

Table 3-10 summarizes mean percent mortality measured for each Hylebos Waterway station, the reference station used in the statistical comparison, and whether mortalities were significantly different than reference. Mean mortality for all tests conducted with Hylebos Waterway sediment ranged from 3 percent for sediments from Station DAC-HY-14 to 44 percent for sediments from Station DAC-HY-10. Sediments from six stations exhibited statistically significant mortality when compared to results from reference sediments. Most of these stations are located in Segments 5 and 6.

3.3.2 Echinoderm Larval Combined Mortality Test

Results of the 48-hour echinoderm larvae (*Dendraster excentricus*) combined mortality test are presented in Table 3-9 for Carr Inlet reference stations and control stations, and Table 3-11 for Hylebos Waterway stations. Combined mortality in the seawater control ranged from approximately -20 percent to -6 percent, while the combined mortality in the sediment control ranged from -1 percent to approximately -17 percent (Table 3-9). Negative mortality results when the number of larvae counted at the end of the exposure period is greater than the number of fertilized eggs that were estimated to have been originally placed into the exposure chamber. Larval density was estimated at the start of the test by counting the number of larvae in a well-mixed sample from the batch of fertilized eggs used to initiate the test exposures. Established protocols do not address the issue of overseeding; according to the acceptability criteria, these echinoderm larval tests were successful.

Table 3-11 summarizes mean percent combined mortality measured for each Hylebos Waterway station, the reference station used in the statistical comparison, and whether combined mortalities were significantly different than reference. Combined mortality for all tests conducted with Hylebos Waterway sediment ranged from -28 percent for Station DAC-HY-21 to 57 percent for Station DAC-HY-20. Of the 28 Hylebos Waterway sediment samples tested, 10 samples were found to exhibit a statistically significant increase in combined mortality when compared to the appropriate reference sediment. Significant mortalities were found for sediments collected from all segments of the Hylebos Waterway.

3.3.3 Juvenile Polychaete Growth Test

Results of the 20-day juvenile polychaete (*Neanthes arenaceodentata*) growth test for Carr Inlet reference stations are presented in Table 3-9; data for the Hylebos Waterway stations are presented in Table 3-12. Table 3-12 summarizes mean individual biomass measured for each Hylebos Waterway station, the reference station used in the statistical comparison, and whether measured mortalities were significantly different than reference. Mean end-of-test biomass of juvenile worms maintained in control sediment ranged from 9.7 to 11.7 mg DW, while the end-of-test biomass of worms from the reference sediments ranged between 9 and 10 mg DW. Mean biomass of juvenile worms exposed to Hylebos Waterway sediments ranged from 7 to 14 mg DW. There were no statistical differences in the biomass of worms exposed to in Hylebos Waterway sediment when compared to the appropriate reference sediment.

3.4 BENTHIC ABUNDANCE

3.4.1 Total Abundance

The total abundances of benthic organisms in sediment from the Hylebos Waterway stations and Commencement Bay reference stations are presented in Table 3-13. The occurrence of statistically significant depressions in total benthic abundances are also summarized in Table 3-13. A complete listing of the species found and their densities is provided in Appendix E. Table 3-14 provides the data for grain size, TOC, and depth, which were used to pair the Hylebos Waterway station with the appropriate Commencement Bay reference station, and the results of the pairing process. Sediments from Commencement Bay Station DAC-HY-35 were used as reference sediments in the benthic invertebrate analysis for Hylebos Waterway Stations DAC-HY-01, -02, -03, -04, -05, -06, -07, -09, -12, -13, -14, -17, and -23. Sediments from Commencement Bay Station DAC-HY-30 were used as reference sediment for the remaining Hylebos Waterway stations. Statistical comparisons for individual abundances of crustaceans, molluscs, and polychaetes are tabulated in Tables 3-15, 3-16, and 3-17, respectively.

When compared to the appropriate Commencement Bay reference station, the total abundances of benthic organisms were statistically lower at 22 of the 28 stations located in Hylebos Waterway. Stations where total abundance exceeded the total abundance at the reference station are shown in Figure 3-3. Of the six stations at which the total benthic abundance was not significantly depressed, one station was in Segment 1, four stations were in Segment 2, and one station was in Segment 3. Total benthic abundance was statistically lower than reference at all stations in Segments 4 and 5.

3.4.2 Crustacean Abundance

The mean abundance of crustaceans at the Commencement Bay reference stations were approximately 1,083 and 1,466 individuals per m^2 (Table 3-15), while the mean abundance at Hylebos Waterway stations ranged from approximately 33 to 1,229 per m^2 (Table 3-15). Crustaceans represented between 5 and 18 percent of the total abundance of benthic organisms in reference area samples, whereas crustaceans were less abundant, ranging from >1 percent to approximately 9 percent in the Hylebos Waterway benthic communities.

Numerically abundant benthic crustaceans found at the reference stations include the ostracods *Euphilomedes carcharodonta* and *E. producta*, the amphipod *Rhepoxynius abronius*, and the pinnotherid crab *Pinnixa schmitti.* Numerically abundant benthic crustaceans found in the Hylebos Waterway include the ostracods *Euphilomedes carcharodonta* and *E. producta*, the tanaid *Leptochelia savignyi*, and the cumacean *Eudorella pacifica.*

Results of the statistical comparisons for abundance of crustaceans found in Hylebos Waterway sediments relative to reference sediments are found in Table 3-15. The abundance of crustaceans was statistically lower at 23 of the 28 stations located in the Hylebos

Waterway. Stations where abundance of crustaceans exceeded that of the reference stations are shown in Figure 3-3.

3.4.3 Molluscan Abundance

The mean abundance of molluscs for the Commencement Bay reference stations were approximately 937 and 2,087 per m^2 (Table 3-16). The mean abundance of molluscs from the Hylebos Waterway stations ranged from approximately 125 to 4,204 per m^2 (Table 3-16). Molluscs represented between 3 and 50 percent of the total abundance of benthic organisms in reference area samples. Molluscs in the Hylebos Waterway samples accounted for approximately 2 to 39 percent of the total abundance of benthic organisms.

Numerically abundant benthic molluscs found in the Hylebos Waterway include the bivalve molluscs *Axinopsida serricata*, *Lyonsia californica*, and *Psephidia lordi* and the gastropod *Turbonilla* sp. Numerically abundant molluscs found at the reference stations include *Crepipatella lingulata*, *Parvilucina tenuisculpta*, and *Turbonilla sp.*

Results of the statistical comparisons for abundance of molluscs found in Hylebos Waterway sediments relative to reference sediments are found in Table 3-16. The abundance of molluscs was statistically lower at 14 of the 28 stations located in the Hylebos Waterway. Stations where abundance of molluscs exceeded reference are shown in Figure 3-3.

3.4.4 Polychaete Abundance

The mean abundance of polychaetes for the Commencement Bay reference stations was approximately 13,970 and 16,012 per m^2 (Table 3-17). The mean abundance of polychaetes from the Hylebos Waterway stations ranged from approximately 1,575 to 17,496 per m^2 (Table 3-17). Polychaetes represented between 30 and 86 percent of the total abundance of benthic organisms in reference area samples. Polychaetes in the Hylebos Waterway samples accounted for approximately 55 to 98 percent of the total abundance of benthic organisms.

Numerically abundant polychaetes found at the reference stations include the cirratulid *Aphelochaeta* sp., the spionid *Prionospio steenstrupi*, and the lumbinerid *Scoletoma luti*. Numerically abundant polychaetes found in the Hylebos Waterway include the cirratulids

Aphelochaeta sp. and *Chaetozone acuta*, the spionids *Polydora socialis* and *Prionospio steenstrupi*, the lumbinerids including *Scoletoma luti*, and the sabellid *Euchone limnicola.*

Results of the statistical comparisons for abundance of polychaetes found in Hylebos Waterway sediments relative to reference sediments are found in Table 3-17. The abundance of polychaetes was statistically lower at 21 of the 28 stations located in the Hylebos Waterway. Stations where abundance of polychaetes exceeded reference are shown in Figure 3-3.

4.0 DATA ANALYSIS

The chemistry, toxicity, and benthic abundance data for Hylebos Waterway sediments were analyzed using the sediment quality triad approach. The first step in the analysis was to calculate ERs for each compound that exceed either the SQS or the SQO criteria (Table 4-1). Using the sediment chemistry data which consist of exceedances of SQS and SQO criteria and ER values, laboratory bioassay results, and benthos data, the stations were placed into one of three classifications — adversely affected, potentially adversely affected, or not adversely affected — as defined in Section 2.5.4. The results of this classification, based on the sediment quality triad rankings (Table 4-2), indicate that one station was classified as not adversely affected, 15 stations were classified as potentially adversely affected, and 12 stations were classified as adversely affected. The majority of stations that were classified as adversely affected were located in Segments 1 and 5.

5.0 SUMMARY

Between May 23 and June 1, 1994, surface sediment samples were collected from 28 locations in Hylebos Waterway, 2 reference stations in Carr Inlet, and 2 reference locations in Commencement Bay. Sediment samples were submitted for chemical analysis, laboratory toxicity testing, and benthic invertebrate enumeration. Results were compared with chemical and biological SQS, and with chemical criteria presented in the ROD (U.S. EPA 1989). Chemical, bioassay, and benthic data were used to perform a sediment quality triad analysis. Data quality evaluations were performed on all data. No significant data quality issues were found for either the chemical or biological data. All data, as qualified, were acceptable for use.

5.1 TRACE ELEMENTS AND ORGANOTIN

Arsenic concentrations exceeded both SQS and SQO concentrations at three stations in Segment 1, at the head of the waterway. Zinc concentrations exceeded the SQS and SQO at one station in Segment 2 and at one station in Segment 3. Mercury was detected at one station, but the concentration did not exceed either the SQS or SQO. Detection limits for mercury exceeded the SQS for eight samples and exceeded the SQO for five samples. No other trace elements were detected at concentrations exceeding either SQS or SQO concentrations.

Monobutyltin and tetrabutyltin were not detected at any Hylebos Waterway stations; dibutyltin was detected at 24 of 28 stations; tributyltin was detected at all 28 stations. Tributyltin concentrations exceeded the PSDDA screening level of 30 μg/kg dry weight at 26 of the 28 stations.

None of the trace elements or organotin compounds in sediments collected from either the Carr Inlet or Commencement Bay reference stations exceeded the SQS or SQO.

5.2 ORGANIC COMPOUNDS

PAHs were detected at all 28 Hylebos Waterway stations. No concentrations exceeded respective SQS concentrations. LPAH concentrations exceeded the SQO concentrations at two stations in Segment 2, and HPAH concentrations exceeded the SQO concentrations at eight stations in Segments 1 and 2. All ERs were less than 2, except for fluoranthene, which was 2.44 at Station DAC-HY-22.

Exceedances of SQS and SQO concentrations by phthalates and phenols were limited to a small number of compounds at a few stations. SQO concentrations of p,p'-DDD and p,p'-DDE were exceeded at four stations in Segment 5, and all exceedance ratios were less than 1.5.

Hexachlorobenzene concentrations exceeded the SQS at 21 stations: from Station DAC-HY-1, located at the mouth of Hylebos Waterway, through Station DAC-HY-21, located midway in Segment 2. Hexachlorobenzene concentrations exceeded the SQO at 12 Hylebos Waterway stations; these included six stations in Segment 5 and six stations throughout the remaining segments of the waterway. Concentrations of 1,2,4-trichlorobenzene exceeded the SQS at 15 stations and exceeded the SQO at four stations. Concentrations of 1,4-dichlorobenzene exceeded the SQS at two stations.

Hexachlorobutadiene concentrations exceeded both the SQS and SQO at Stations DAC-HY-06 through DAC-HY-10. Hexachlorobutadiene concentrations exceeded only the SQO at all other stations mouthward of DAC-HY-24, with the exception of DAC-HY-17.

Although total PCBs did not exceed the SQO concentration at any Hylebos Waterway station, the SQS was exceeded at 19 of the 28 stations, distributed in all segments except Segment 1.

None of the organic compounds in sediments collected from either the Carr Inlet or Commencement Bay reference stations exceeded the SQS or SQO.

5.3 TOXICITY TESTING

In amphipod mortality bioassays, statistically different percent mortalities were observed for the following six stations: DAC-HY-04, -05, -08, -10, -12, and -24. Station DAC-HY-24 was near the head of the waterway; the remainder were near the mouth.

Statistical differences in echinoderm combined mortality was observed at 10 of the 28 Hylebos Waterway stations. There were no statistical differences in growth of juvenile polychaete worms exposed to Hylebos sediments when compared to the appropriate reference sediment.

5.4 BENTHIC ABUNDANCE

Total benthic abundance was statistically lower at 22 of the 28 stations when compared to the appropriate reference station. Total benthic abundance was not depressed in Segments 4, 5, and 6, which are located near the head of the waterway.

Numerically, crustaceans accounted for up to 9 percent of the Hylebos Waterway benthic community. Crustacean abundance was statistically lower at 23 of the 28 Hylebos stations when compared to the appropriate reference station. The five stations where abundance of crustaceans was not depressed were distributed irregularly throughout the Hylebos Waterway.

Polychaetes accounted for approximately 55 percent to 98 percent of the Hylebos Waterway benthic population. Polychaete abundance was statistically lower at 21 of the 28 Hylebos stations when compared to the appropriate reference station. These 21 stations were distributed among all of the waterway segments.

Molluscs represented up to 50 percent of the Hylebos Waterway benthic population. Molluscs abundance was statistically less at 14 of the 28 Hylebos stations when compared to the appropriate reference station. Significant depressions of molluscan abundance occurred primarily in Segment 1, at the head of the waterway, and in Segments 5 and 6, at the mouth of the waterway.

5.5 SEDIMENT QUALITY TRIAD ANALYSIS

Sediment quality at each of the Hylebos Waterway stations was evaluated by a triad approach that took into account the results of chemical analyses, toxicity tests, and benthic enumeration. Stations were classified as adversely affected, potentially adversely affected, or not adversely affected. The results of this classification were as follows: one station was classified as not adversely affected, 15 stations were classified as potentially adversely affected, and 12 stations were classified as adversely affected. Each of the 6 waterway segments contained at least one station that was classified as adversely affected.

6.0 REFERENCES

ASTM. 1993. ASTM standards on aquatic toxicology and hazard evaluation. Prepared by American Society for Testing and Materials, Philadelphia, PA.

Chapman, P.M. 1992. Chapter 10; sediment quality triad approach. *In*: EPA 823-R-92-006. Sediment classification methods compendium. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

EVS 1994a. Commencement Bay damage assessment studies: sampling and analysis plan. Prepared for National Oceanic and Atmospheric Administration Damage Assessment and Restoration Center, Seattle, WA.

EVS 1994b. Commencement Bay damage assessment studies: Draft combined quality assurance project plan and laboratory analysis plan. Prepared for National Oceanic and Atmospheric Administration Damage Assessment and Restoration Center, Seattle, WA.

EVS 1995. Commencement Bay phase I damage assessment. Prepared for Commencement Bay Natural Resource Trustees. EVS Environment Consultants, Inc., Seattle, WA.

NOAA. 1995. Commencement Bay Damage Assessment Quality Assurance Plan. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Environmental Conservation Division, Seattle, WA.

PSEP. 1989. Recommended protocols for metals in Puget Sound water, sediment, and tissue samples. Final Report TC-3090-04. Prepared for U.S. Army Corps of Engineers, Seattle District. Puget Sound Estuary Program, Seattle, WA.

PSEP. 1991. Recommended guidelines for conducting laboratory bioassays on Puget Sound sediments. Final Report. Prepared by PTI Environmental Services, Inc. for EPA, Region 10, Office of Puget Sound, and U.S. Army Corps of Engineers, Seattle District.

PTI. 1989. Commencement Bay nearshore/tideflats feasibility study: development of sediment cleanup goals. Public Review Draft. Prepared for Tetra Tech, Inc., the Washington State Department of Ecology, and the U.S. Environmental Protection Agency. PTI Environmental Services, Bellevue, WA.

Striplin Environmental Associates, Science Applications International Corporation, D.M.D., Dalton, Olmsted, & Fuglevand, and Converse Consultants NW. 1994. Combined sampling and analysis plan and quality assurance project plan for the Commencement Bay nearshore/tideflats Superfund site - Hylebos Waterway problem areas. Prepared for the Hylebos Cleanup Committee. Striplin Environmental Associates, Seattle, WA.

Striplin Environmental Associates, Dalton Olmsted & Fuglevand, D.M.D., Aura Nova Consultants, and R.P. Feins. 1995. Hylebos waterway pre-remedial design program-event 1a and 1b data report. Prepared for the Hylebos Cleanup Committee. Striplin Environmental Associates, Seattle, WA.

Tetra Tech. 1985. Commencement Bay nearshore/tideflats remedial investigation. Tetra Tech, Inc., Bellevue, WA.

Tetra Tech. 1988. Commencement Bay nearshore/tideflats feasibility study. Public Review Draft. Prepared for U.S. EPA, Region 10 and Washington State Department of Ecology. Tetra Tech, Bellevue, WA.

U.S. EPA. 1989. Commencement Bay nearshore/tideflats record of decision. U.S. Environmental Protection Agency, Region 10, Seattle, WA.

Washington State Department of Ecology. 1991. Sediment cleanup standards user manual. First edition. Washington State Department of Ecology, Sediment Management Unit. Olympia, WA.

Wolotira, R. 1995. Personal communication (telephone conversation with Dennis Hanzlick, EVS Environment Consultants, Inc., Seattle, WA), June 28, 1995. Oceanographer, National Oceanic and Atmospheric Administration Damage and Restoration Center, Seattle, WA.

FIGURES

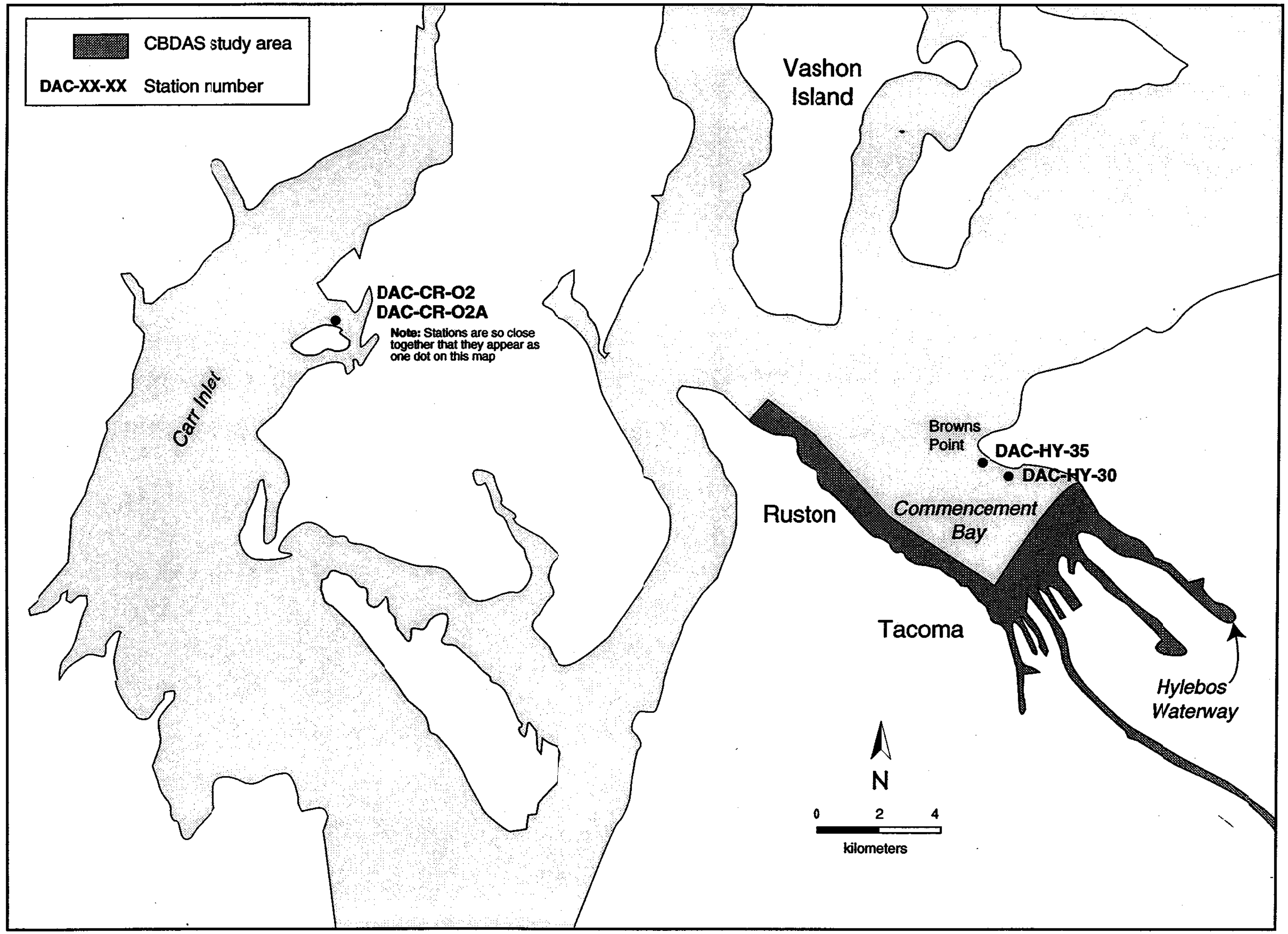

Figure 1-1. South and southcentral Puget Sound; locations of the CBDAS, the Hylebos Waterway, and reference stations in Carr Inlet and Commencement Bay.

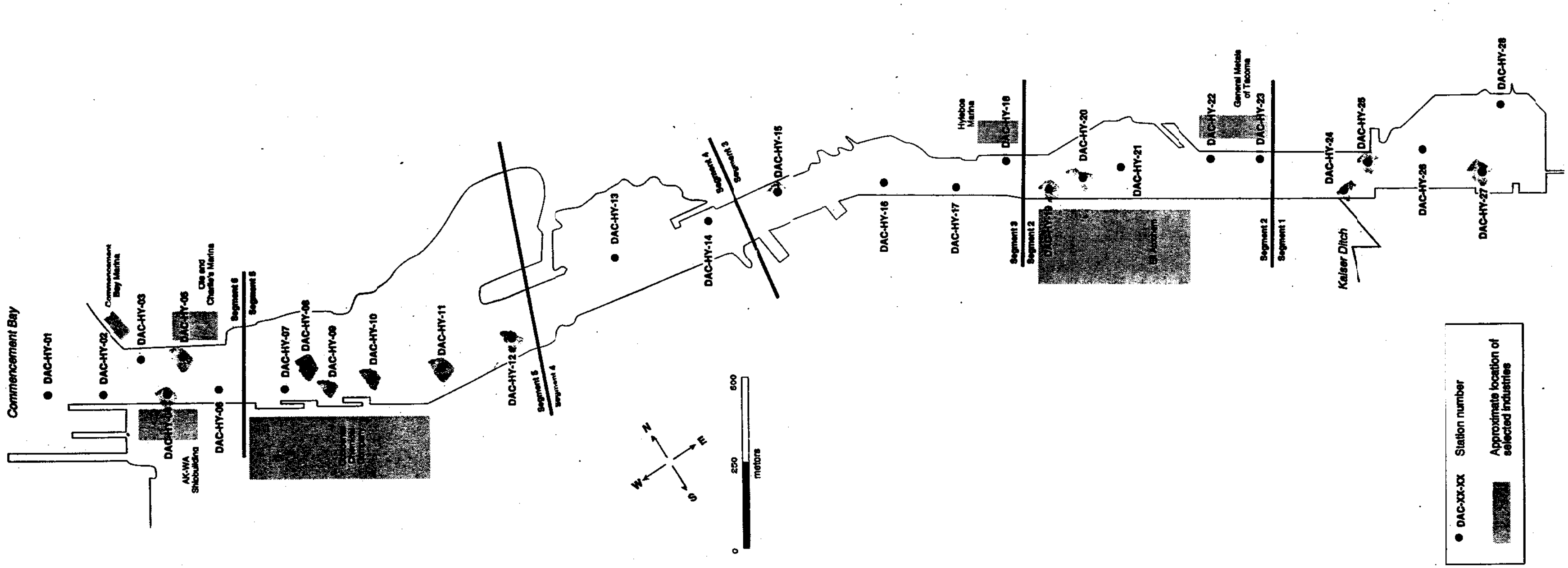

Figure 2-1. Approximate station locations and locations of selected industries in Hylebos Waterway.

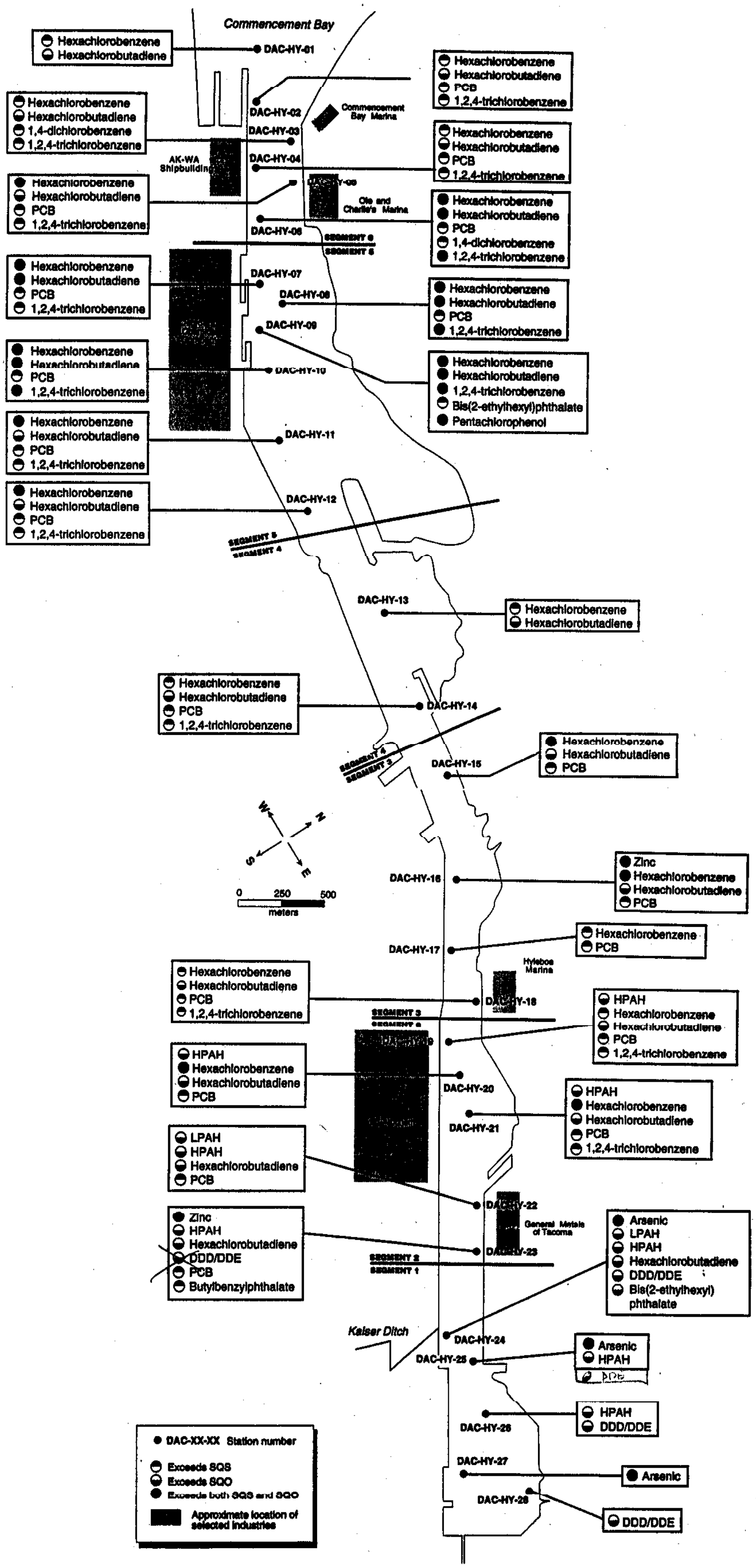

Figure 3-1. Contaminants of concern that exceeded SQS and/or SQO concentrations at Hylebos Waterway stations.

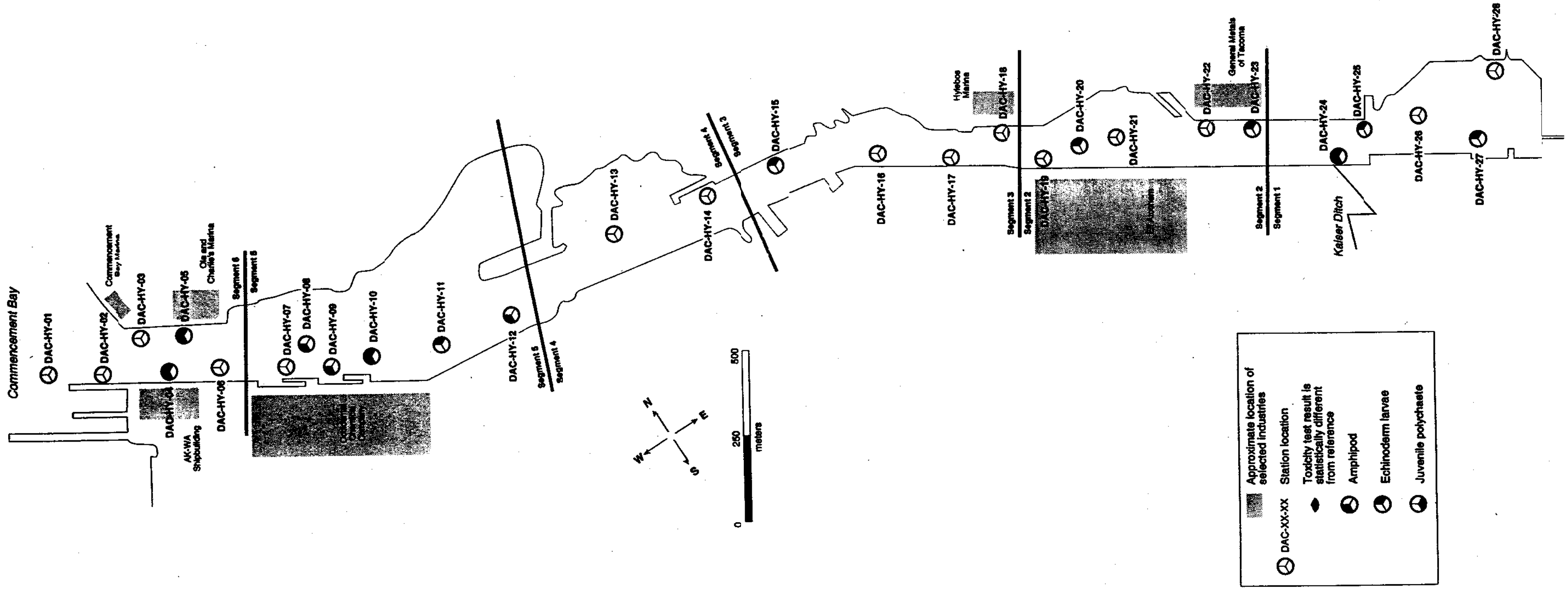

Figure 3-2. Summary of toxicity test results and locations of selected industries in Hylebos Waterway.

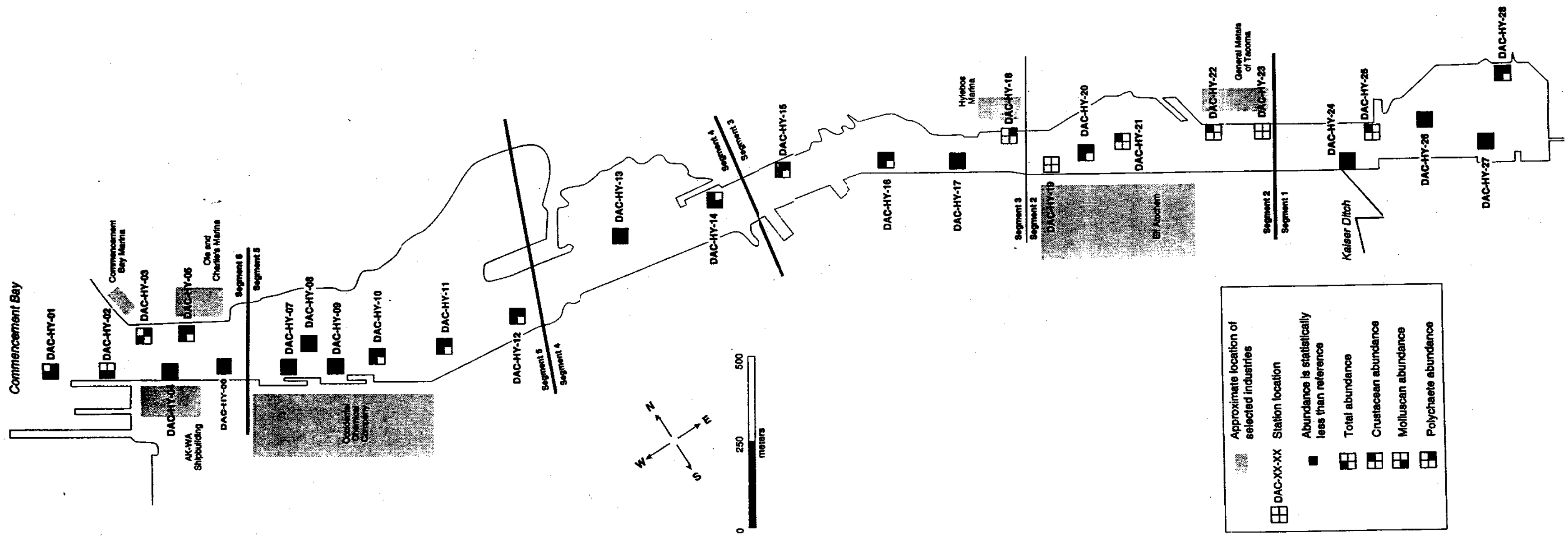

Figure 3-3. Summary of benthic abundance results and locations of selected industries in Hylebos Waterway.