

# **PTI**

*ENVIRONMENTAL SERVICES*

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## **Puget Sound Dredged Disposal Analysis**

### **BASELINE SURVEY OF PHASE II DISPOSAL SITES**

For

**Washington Department of Ecology  
Olympia, Washington**

June 1989

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PUGET SOUND DREDGED DISPOSAL ANALYSIS  
BASELINE SURVEY OF PHASE II DISPOSAL SITES

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Washington Department of Ecology  
Olympia, Washington 98504-8711

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## CONTENTS

	<u>Page</u>
LIST OF FIGURES	iv
LIST OF TABLES	v
SUMMARY	vii
1. INTRODUCTION	1
2. SAMPLING APPROACH AND DATA STATUS	4
PHYSICAL MAPPING	5
Sampling Approach	5
Data Quality and Status	5
SEDIMENT CHEMISTRY	8
Sampling Approach	8
Data Quality and Status	8
BIOASSAYS	11
Testing Approach	11
Data Quality and Status	11
BENTHIC INFAUNA	11
Sampling Approach	12
Data Quality and Status	12
BIOACCUMULATION	12
Sampling Approach	12
Data Quality and Status	12
MODIFICATIONS TO SAMPLING PLAN	13
SUMMARY OF DATA COMPLETENESS	13
3. DATA SUMMARY FOR BELLINGHAM BAY	14
OVERVIEW OF SAMPLING	14
REMOTS® DATA	14
Physical Characteristics	14
Biological Characteristics	25

SEDIMENT CHEMISTRY	25
BIOASSAYS	36
BENTHIC INFAUNA	36
BIOACCUMULATION	39
SUMMARY	39
4. DATA SUMMARY FOR ANDERSON/KETRON ISLANDS DISPOSAL SITE AND CARR INLET REFERENCE STATION	42
OVERVIEW OF SAMPLING	42
REMOTS® DATA	42
Physical Characteristics	42
Biological Characteristics	52
SEDIMENT CHEMISTRY	52
BIOASSAYS	59
BENTHIC INFAUNA	59
BIOACCUMULATION	62
SUMMARY	62
5. CONCLUSIONS	64
ACCOMPLISHMENTS	64
CHANGES TO SAMPLING PLAN	64
RECOMMENDATIONS	64
REFERENCES	67
APPENDIX A - SAMPLING CRUISE SAFETY PLAN AND SAMPLING AND ANALYSIS PROCEDURES	
APPENDIX B - BELLINGHAM BAY DISPOSAL SITE DATA	
APPENDIX C - ANDERSON/KETRON ISLANDS DISPOSAL SITE DATA	
APPENDIX D - QUALITY ASSURANCE/QUALITY CONTROL REPORTS	
APPENDIX E - BELLINGHAM BAY STATION LOGS	
APPENDIX F - ANDERSON/KETRON ISLANDS DISPOSAL SITE STATION LOGS	

## LIST OF FIGURES

	<u>Page</u>
Figure 1. Locations of PSDDA Phase II disposal sites in Puget Sound	2
Figure 2. Transponder locations in Bellingham Bay	20
Figure 3. Location of REMOTS® stations in Bellingham Bay	24
Figure 4. Location of chemistry, bioassay, infauna, and bioaccumulation stations in Bellingham Bay	26
Figure 5. Transponder locations at Anderson/Ketron islands disposal site	47
Figure 6. REMOTS® stations at the Anderson/Ketron islands disposal site	51
Figure 7. Location of chemistry, bioassay, infauna, and bioaccumulation stations at the Anderson/Ketron islands disposal site	53

## LIST OF TABLES

	<u>Page</u>
Table 1. Modifications to PSDDA Phase II baseline monitoring plan	6
Table 2. PSDDA Phase II baseline sampling schedule	7
Table 3. PSDDA chemicals of concern	9
Table 4. Sampling station locations and types of data collected in Bellingham Bay	15
Table 5. Sampling information for Bellingham Bay	16
Table 6. Analysis codes and laboratories	19
Table 7. Clark's Point transponder location	21
Table 8. The Marine Park transponder location	22
Table 9. The Squalicum Marina transponder location	23
Table 10. Concentrations of conventional variables in surface sediments from Bellingham Bay	27
Table 11. Concentrations of PSDDA chemicals of concern detected in surface sediments from Bellingham Bay	28
Table 12. Concentrations of PSDDA chemicals of concern detected in surface sediments from Bellingham Bay site and perimeter stations	30
Table 13. Concentrations of PSDDA chemicals of concern detected in surface sediments from Bellingham Bay at benchmark stations	32
Table 14. Chemicals exceeding PSDDA screening level and maximum level values in Bellingham Bay and frequency of exceedance	34
Table 15. Exceedances of PSDDA screening level and maximum level values in Bellingham Bay sediment chemistry data	35
Table 16. Bioassay summary for Bellingham Bay	37
Table 17. Benthic infauna summary for Bellingham Bay	38
Table 18. Concentrations of detected PSDDA chemicals of concern and detection frequency in <i>Compsomyax subdiaphana</i> tissue from Bellingham Bay	40

	<u>Page</u>
Table 19. Sampling station locations and types of data collected at Anderson/ Ketron islands disposal site	43
Table 20. Reference station locations and types of data collected in Carr Inlet	44
Table 21. Sampling information for Anderson/Ketron islands disposal site	45
Table 22. Sampling information for Carr Inlet reference station	46
Table 23. Dupont powderworks transponder location	48
Table 24. Riviera pier transponder location	49
Table 25. Johnston transponder location	50
Table 26. Concentrations of conventional variables in surface sediments from Anderson/Ketron islands disposal site	54
Table 27. Concentrations of PSDDA chemicals of concern detected in surface sediments from Anderson/Ketron islands disposal site	55
Table 28. Concentrations of PSDDA chemicals of concern detected in surface sediments from Anderson/Ketron islands benchmark, site, and perimeter stations	57
Table 29. Bioassay summary for Anderson/Ketron islands disposal site	60
Table 30. Benthic infauna summary for Anderson/Ketron islands disposal site	61
Table 31. Concentrations of detected PSDDA chemicals of concern and detection frequency in <i>Compsomyx subdiaphana</i> tissue from the Anderson/Ketron islands disposal site	63
Table 32. Numbers of samples collected during PSDDA Phase II baseline survey	65

## SUMMARY

Puget Sound Dredged Disposal Analysis (PSDDA) is an interagency program which includes the U.S. Army Corps of Engineers, Seattle District as lead agency, supported by the U.S. Environmental Protection Agency Region 10, the Washington Department of Ecology, and the Washington Department of Natural Resources. The goal of PSDDA is to provide the basis for publicly acceptable guidelines governing environmentally safe unconfined, open-water disposal of dredged material, and to provide Puget Sound-wide consistency and predictability in decisions concerning dredged material disposal.

A baseline field survey was conducted at the PSDDA Phase II disposal sites between 11 April and 4 May 1989. During this period, 445 samples were collected various data types from the disposal sites in north Puget Sound in Bellingham Bay and in the south sound between Anderson and Ketron islands. The purpose of the baseline survey was to characterize physical, chemical, and biological conditions in and near the disposal sites. These data will provide a basis for later assessment of the distribution and impact, if any, of material disposed of at each site.

Specific data collected at each of the disposal sites includes:

- Physical site mapping using REMOTS® sediment vertical profile images
- Chemical testing of sediments for the PSDDA chemicals of concern and tributyltin
- Bioassay testing of sediment samples using three bioassays (amphipod acute toxicity test, oyster larvae abnormality test, and Microtox)
- Benthic infauna abundances
- Tissue body burden data for a macrobenthic species (bivalve *Compsomyax subdiaphana*) found at the site.

Several changes to the Phase I monitoring plan and Phase II sampling and analysis plan were implemented during this study. Changes to the Phase I monitoring plan were based on the recommendations contained in the Phase I baseline report that were approved by the PSDDA agencies. Changes to the Phase II sampling plan were necessitated by conditions noted during field sampling. Specific changes included:

- Addition of a fourth benchmark station in Bellingham Bay (based on no bio-accumulation samples at benchmark station BBB02)
- Use of a van Veen sampler to collect benthic infauna at Anderson/Ketron Station AKT06 (based on the presence of sandy sediments)
- Enumeration of benthic infauna to major taxa level only (per Phase I recommendations)
- Collection of a single composite bioaccumulation sample at each station (per Phase I recommendations)

- Analysis of bioaccumulation in tissues collected at the Bellingham Bay zone station (BBZ01) (based on the presence of this organism at the zone station)
- Use of one reference station (Carr Inlet) (per Phase I recommendations)
- Deletion of plan view photographs from the physical monitoring plan (per Phase I recommendations)
- Collection of triplicate sediment vertical profiling system images (per Phase I recommendations)
- Chemical analysis of sediments using strong acid digestion only (per Phase I recommendations).

## BELLINGHAM BAY

The most notable physical feature of the Bellingham Bay disposal site was the presence of low-reflectance material located several centimeters below the sediment/water interface at the southeast portion of the site. Possible sources of this layer include recent construction activity in the Post Point area, relict dredged material, or disturbance caused by trawler activity. No other data were correlated with the presence of the low-reflectance sediment.

Sediment concentrations of several PSDDA chemicals of concern exceeded the screening level (SL) values in Bellingham Bay. The maximum level values for phenol were exceeded at a station at the southern perimeter of the site (Station BBP04). Organic chemicals with sediment concentrations that exceeded the SL include phenol, 4-methylphenol, and benzoic acid. Mercury was the only metal to exceed the SL.

Seven stations located throughout Bellingham Bay had sediment concentrations exceeding the SL for mercury: Stations BBB01, BBB02, BBP01, BBP02, BBP03, BBP04, and BBZ01. The highest mercury concentration (0.56 mg/kg dry weight) was found in sediments collected northeast of the site.

The Bellingham Bay study area is biologically similar to many Puget Sound habitats. Macro-benthic abundance is typical of nearshore regions. Molluscs were the most abundant major taxon at all stations sampled except Station BBB01. At Station BBB01, polychaetes were the most abundant taxon, averaging 1,229 individuals per box core. Cirratulid polychaetes, a taxonomic family frequently associated with areas of organic enrichment, were responsible for the high density of organisms at this station. Station BBB01 is adjacent to a pulp mill discharge, the probable source of the organic enrichment.

All bioassays performed on Bellingham Bay sediments met PSDDA Phase II disposal guidelines.

## ANDERSON/KETRON ISLANDS

The sediments in and near the Anderson/Ketron islands disposal site in south Puget Sound consist of a mixture of silt, clay, and very fine to fine sand. Stations along the eastern, western, and northern borders of the area are characterized by very fine sands, while stations along the

southern border and in the central portion of the site are characterized by sediments having a high silt-clay fraction. One chemical, zinc, exceeded the SL by a factor of 1.69

Crustaceans were the most abundant major taxon at the Anderson/Ketron islands disposal site. Densities of infaunal organisms at the transect stations were generally higher than at the benchmark station.

All sediments tested met PSDDA Phase II disposal guidelines based on amphipod mortality, oyster larvae abnormality, and Microtox bioassays.

## 1. INTRODUCTION

Puget Sound Dredged Disposal Analysis (PSDDA) is an interagency program which includes the U.S. Army Corps of Engineers, Seattle District (Corps) as lead agency, supported by the U.S. Environmental Protection Agency Region 10 (EPA), the Washington Department of Ecology (Ecology), and the Washington Department of Natural Resources. The goal of PSDDA is to provide the basis for publicly acceptable guidelines governing environmentally safe unconfined, open-water disposal of dredged material, and to provide Puget Sound-wide consistency and predictability in decisions concerning dredged material disposal. The objectives of PSDDA are as follows:

- Identify acceptable unconfined, open-water disposal sites
- Define consistent and objective evaluation procedures for the dredged material to be discharged at those sites
- Develop site use management plans.

Part of the Phase II effort is to establish two nondispersive disposal sites for the north and south regions of Puget Sound, located in Bellingham Bay and in waters between Anderson and Ketron islands (Figure 1). The sites are described in PSDDA (1987).

Management of site use depends upon the evaluation of the site condition prior to and during the course of disposal activities. The study described in this report was undertaken to identify baseline conditions at both of the sites. The purpose of the baseline sampling is to characterize physical, chemical, and biological conditions in and near each of the Phase II disposal sites to provide a sufficiently complete and accurate basis for later assessment of the distribution and impact, if any, of dredged material disposed of at each site.

The primary functions of the disposal site monitoring plan are to ensure compliance with the Section 404(b)(1) guidelines of the Clean Water Act and to field-verify PSDDA study predictions of site conditions following dredged material disposal (PSDDA 1988). Monitoring will provide the data needed for direct response to agency and public concerns regarding site conditions and environmental impacts.

The management plan for PSDDA disposal sites focuses on verifying assumptions regarding site conditions and provides an evaluation of the transport of dredged material or chemicals of concern across the site boundary. Adverse impacts on biological communities beyond the site boundary are of principal concern. Biological changes and physical and chemical changes within the site boundary will also be assessed.

To clearly evaluate the issues related to dredged material disposal in Puget Sound, the monitoring plan was developed based on the following six testable hypotheses (PSDDA 1988):

- **Hypothesis 1:** Dredged material stays within the disposal site boundary.
- **Hypothesis 2:** Chemical concentrations at the offsite monitoring stations do not measurably increase over time due to dredged material disposal.

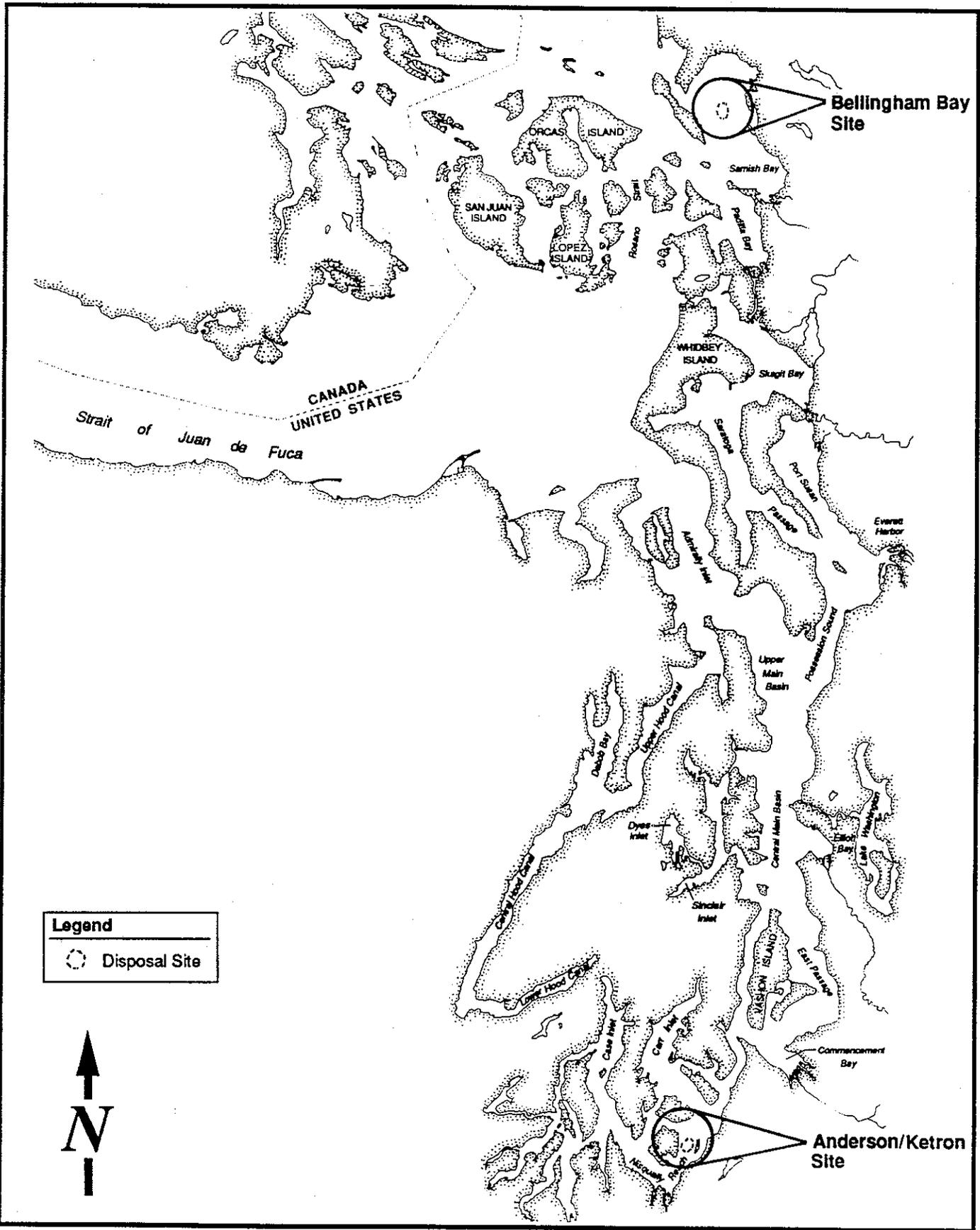


Figure 1. Locations of PSDDA Phase II disposal sites in Puget Sound

- **Hypothesis 3:** Sediment chemical concentrations at onsite monitoring stations do not exceed the chemical concentrations associated with Site Condition II chemical disposal guidelines due to dredged material disposal.
- **Hypothesis 4:** Sediment toxicity within the disposal site does not exceed Site Condition II chemical disposal guidelines due to dredged material disposal.
- **Hypothesis 5:** No significant increase in chemical body burden of benthic infauna species collected downcurrent of the disposal site occurs due to dredged material disposal.
- **Hypothesis 6:** No significant decrease in the abundance of dominant benthic infauna species occurs downcurrent of the disposal site due to dredged material disposal.

The monitoring plan requires that area-specific changes independent of disposal activities (i.e., background conditions) be identifiable in order to test these hypotheses. These constraints require that a wide variety of locations and measurements be used, as illustrated by baseline sampling methods. Benthic infauna species abundance and tissue bioaccumulation were chosen by PSDDA as monitors for adverse impacts on biological communities outside the disposal site. Infauna and bioaccumulation samples were collected at stations in the presumed downcurrent direction from the disposal site (transect stations) and at other stations within each area remote from the disposal site (benchmark stations). Data to evaluate transport of dredged material across the site boundary and physical conditions within the site were collected with a REMOTS® sediment profiling camera. Data to evaluate transport of chemicals of concern across the site boundary were evaluated by analysis of chemical concentrations and bioassay response at stations located 0.125 nautical mile from the site (perimeter stations). Chemical and bioassay analyses were conducted within the disposal site to determine if the site management goal is being met. Chemical and bioassay analyses were also conducted at benchmark stations to later assess background changes within each bay, and at a reference station in an uncontaminated area of Puget Sound (Carr Inlet). The purpose of the reference station is to provide an additional bioassay control and to further define Site Condition II guidelines.

This report is divided into several sections. Analytical methods, including quality assurance steps and their results, are briefly described in Section 2 of the report. Sections 3 and 4 provide summaries of the findings for the proposed Bellingham Bay and Anderson/Ketron islands disposal sites, respectively. Section 5 contains results of the Phase II baseline survey summarized in terms of accomplishments and changes to the sampling plan.

This report also contains Appendices A-F and a supplement. Sampling methods and equipment used during the study are described in detail in Appendix A. Tables of all analytical results are contained in Appendices B and C. Detailed quality assurance reviews of these data are included in Appendix D. Station logs for the Bellingham Bay and Anderson/Ketron islands disposal sites are contained in Appendices E and F, respectively. REMOTS® photographs are included in a separate supplement.

## 2. SAMPLING APPROACH AND DATA STATUS

An important aspect of disposal site monitoring is evaluating the transport of material or chemicals of concern across the site boundary. Six station types were established:

- *Zone* stations, within the disposal target zone, are intended to characterize the composition of the dredged material deposited at the center of the site. Zone station names are coded with the letter Z throughout this report.
- Other *site* stations, outside the disposal zone but within the disposal site, are also intended to characterize the composition of the dredged material deposited at the site but outside the direct impact area. Site station names are coded with the letter S throughout this report.
- *Perimeter* stations, located at a distance of 0.125 nautical mile from the site boundary, are intended to establish whether or not dredged material has drifted outside the disposal site. Perimeter station names are coded with the letter P throughout this report.
- *Transect* stations, located in the downcurrent direction from each site, are intended to establish if dredged material or chemicals of concern from the dredged material have moved offsite. Transect station names are coded with the letter T throughout this report.
- *Benchmark* stations, located in the general vicinity of each disposal site but outside the influence of currents passing over the site, are intended to identify long-term changes in the background conditions in each basin or to identify changes in the area that are due to sources other than dredged material placed at the disposal site. Benchmark station names are coded with the letter B throughout this report.
- *Reference* stations, located in uncontaminated areas of Puget Sound, were used for bioassay comparisons under the PSDDA evaluation procedures. Carr Inlet was selected as the reference area for sediment collection based on the results of baseline studies at the PSDDA Phase I disposal sites (PTI 1988). Reference station names are coded with the letter R throughout this report.

The PSDDA environmental monitoring plan (included in PSDDA 1988) calls for the collection of specific data at each of the disposal sites. These data include:

- Physical mapping of the disposal sites using REMOTS® sediment vertical profile images (site, perimeter, and transect stations were sampled)
- Sediment chemistry data from disposal zone, perimeter, benchmark, and reference stations
- Bioassay data using sediment from disposal zone, benchmark, and reference stations
- Benthic infauna abundances and tissue body burden data from transect and benchmark stations.

Appendix A describes the procedures used to collect and process PSDDA Phase II baseline samples for each of these data types. A brief summary of these procedures is provided here to assist the reader in interpreting the data as they are presented.

Baseline sampling was conducted at the proposed Bellingham Bay and Anderson/Ketron islands disposal sites between 11 April and 4 May 1989. Several changes in the Phase II monitoring plan were made based on findings of the Phase I baseline studies (PTI 1988). The changes incorporated into the Phase II baseline study are listed in Table 1. During the Phase II baseline study a total of 445 samples was collected for various data types. Sampling was carried out in the sequence shown in Table 2. Station positioning was achieved through the use of a microwave navigation system at each of the disposal sites and by radar ranges at the reference station in Carr Inlet.

## **PHYSICAL MAPPING**

Physical mapping of the disposal sites was accomplished by taking sediment vertical profile images using a REMOTS® camera. Variables measured from the REMOTS® images included grain-size, surface boundary roughness, the apparent redox potential discontinuity (RPD) depth, and infauna successional stage.

### **Sampling Approach**

Sediment grain-size was estimated from REMOTS® images by overlaying a grain-size comparator on the color REMOTS® image and matching grain-size of the image to one of seven grain-size classes on the comparator.

Surface boundary roughness, a measure of small-scale topographic relief, was determined by measuring the vertical distance between the highest and lowest points of the sediment/water interface. The RPD depth was measured at the boundary between the more highly reflective oxygenated sediment and the underlying reduced sediment. The area is measured to scale and divided by the prism window width to obtain the mean depth for the apparent RPD.

Infauna successional stage was determined by examining the REMOTS® images for the presence of invertebrates belonging to specific functional types. Depending upon the presence of organisms belonging to certain types, the infauna community was classified as either a Stage I, II, or III community. Stage I communities are composed primarily of organisms living at the sediment-water interface that filter feed or feed on surficial material, while Stage III communities are composed primarily of organisms living deep in the sediment and exhibiting characteristics that indicate deep sediment feeding. Stage II is intermediate between I and III. Stage I communities are typical of recently disturbed or physically harsh environments, while Stage III communities are found in more physically quiescent areas.

### **Data Quality and Status**

Triplicate profile photographs were collected at all sampling stations at both disposal sites. Two images were analyzed at 20 percent of the stations, and one image was analyzed at each of the remaining stations. Unanalyzed images have been archived for later analysis if necessary.

**TABLE 1. MODIFICATIONS TO PSDDA PHASE II  
MONITORING PLAN**

Parameter	Original Approach	Revised Approach
Benthos	Species identification	Total abundance Abundance of major taxa
	Use mini-Soutar box corer at all stations	Sample Station AKI06 with van Veen grab sampler
Bioaccumulation	Replicate composites at each station	Single composite sample
Reference stations	Carr Inlet Port Susan	Carr Inlet only
SVPS <sup>a</sup>	Plan view photographs	No plan view
	Single image at all stations	Triplicate images at all stations
Sediment metals analysis	Total digestion Strong acid digestion	Strong acid digestion only

<sup>a</sup> SVPS - sediment vertical profile system.

TABLE 2. PSDDA PHASE II BASELINE SAMPLING SCHEDULE

Date		Sample Type	Location
April	11	REMOTS®	Anderson/Ketron islands
	13	REMOTS®	Bellingham Bay
	14	Infauna	Bellingham Bay
	17	Infauna	Bellingham Bay
	18	Infauna/bioaccumulation	Bellingham Bay
	19	Bioaccumulation	Bellingham Bay
	20	Bioaccumulation	Bellingham Bay
	21	Bioaccumulation	Bellingham Bay
	24	Chemistry/bioassay	Bellingham Bay
	25	Chemistry/bioassay/infauna	Bellingham Bay
	28	Chemistry/bioassay	Carr Inlet, Anderson/Ketron islands
May	1	Chemistry/bioassay/infauna	Anderson/Ketron islands
	2	Infauna	Anderson/Ketron islands
	3	Bioaccumulation	Anderson/Ketron islands
	4	Bioaccumulation	Anderson/Ketron islands

## SEDIMENT CHEMISTRY

### Sampling Approach

The concentrations of contaminants were determined for sediments collected from zone, perimeter, and benchmark stations. Sediment chemistry included metals, pesticides, polychlorinated biphenyls (PCB), acid/base/neutral (A/B/N) extractable organics, volatiles, and tributyltin.

Sediment was collected for chemical and bioassay testing using a dual 0.1-m<sup>2</sup> van Veen grab sampler. Sample depths were 10 cm at the disposal zone station and 2 cm at all other stations (perimeter, benchmark, and reference). Each sample was formed of material composited from a minimum of six grabs. Additional grabs were necessary at benchmark stations because the 2-cm sample depth did not provide enough material for bioassays as well as chemical analyses.

Chemical analyses of sediment samples were performed for all PSDDA chemicals of concern (Table 3) and tributyltin. Conventional sediment variables were also measured, including grain-size, total organic carbon (TOC), total volatile solids, total solids, and total sulfides (PSEP 1986). Sediments collected for bioassays were analyzed for total ammonia using the technique described by Plumb (1981). Bioassay sediments were also analyzed for grain-size and TOC.

### Data Quality and Status

All chemical data were reviewed according to guidelines of the Puget Sound Estuary Program (PSEP) and PSDDA for quality assurance and quality control (QA/QC) (PSEP 1986). A summary of reasons for any data rejection or qualification and caveats regarding data quality is provided in this section. More complete details of the QA review and discussion are given in Appendix D.

Sediment data for hexachloroethane were rejected as a result of QA review because of zero surrogate recovery (laboratory reanalysis for hexachloroethane could not be performed). In addition, some organic compounds reported by the laboratory as detected in sediments were reclassified as undetected during QA review of mass spectra (e.g., data for some phthalates originally reported at levels near or below nominal detection limits were classified as undetected). Several PCB reported as detected below the detection limit were reclassified as undetected because too few peaks matched those of Aroclor mixtures.

Of the accepted data, selected values for sediment samples have been qualified during QA review as estimates (*E* qualifier code). Data qualified as estimates are acceptable but have a greater uncertainty associated with them than data that have not been qualified. Reasons for qualifying sediment data as estimates include:

- Values were reported at levels below the lower range of calibration standards for A/B/N compounds (typically 1 ng on-column). This qualification affected less than 10 percent of the values.
- The PSEP control limits of 25 percent relative percent difference for ongoing calibration was occasionally exceeded for phenol, benzyl alcohol, benzoic acid, 2-methylnaphthalene, and dimethyl phthalate.

TABLE 3. PSDDA CHEMICALS OF CONCERN

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Metals		
antimony	copper	nickel
arsenic	lead	silver
cadmium	mercury	zinc

Phenol and Substituted Phenols	
phenol	2,4-dimethylphenol
2-methylphenol	pentachlorophenol
4-methylphenol	

**Low Molecular Weight Polycyclic Aromatic Hydrocarbons (LPAH)**

naphthalene	fluorene
2-methylnaphthalene	phenanthrene
acenaphthylene	anthracene
acenaphthene	

**High Molecular Weight Polycyclic Aromatic Hydrocarbons (HPAH)**

fluoranthene	benzo(a)pyrene
pyrene	indeno(1,2,3-c,d)pyrene
benz(a)anthracene	di-benz(a,h)anthracene
chrysene	benzo(g,h,i)perylene
benzofluoranthenes (b and k)	

**Chlorinated Benzenes**

1,2-dichlorobenzene	1,2,4-trichlorobenzene
1,3-dichlorobenzene	hexachlorobenzene (HCB)
1,4-dichlorobenzene	

**Polychlorinated Biphenyls**

total polychlorinated biphenyls (PCB)

**Chlorinated Aliphatic Hydrocarbons**

hexachlorobutadiene	hexachloroethane
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TABLE 3. (Continued)

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Phthalate Esters	
dimethyl phthalate	butyl benzyl phthalate
diethyl phthalate	bis(2-ethylhexyl)phthalate
di-n-butyl phthalate	di-n-octyl phthalate

Miscellaneous Oxygenated Compounds	
benzyl alcohol	benzoic acid
dibenzofuran	

Organonitrogen Compounds	
N-nitrosodiphenylamine	

Pesticides	
total DDT (p,p' isomers)	aldrin
heptachlor	dieldrin
$\alpha$ -chlordane	$\gamma$ -hexachlorocyclohexane (lindane)

Volatile Organic Compounds	
trichloroethene	ethylbenzene
tetrachloroethene	total xylenes

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- Mass spectral interferences for approximately 12 percent of the A/B/N compounds reported at relatively low concentrations were judged to produce some uncertainty in the quantified result, although the interferences were not sufficient to cause rejection of the data.

In addition, blank correction of sediment data resulted in qualifiers (i.e., *B* or *Z* qualifier codes) for some A/B/N values. Among metals, results for precision and accuracy [standard reference materials (SRM) and predigestion spikes] for antimony were typically outside PSEP limits. Because there was a low bias for SRM and predigestion spikes, all antimony values were qualified with a *G* code, indicating concentration is greater than the value shown.

Analyses by total acid digestion (TAD) during the Phase I study resulted in matrix spike recoveries that were outside PSEP control limits for antimony, lead, and silver. The modified strong acid digestion used during the Phase II study was designed to overcome certain problems with interferences using the TAD technique. The modified strong acid procedure used during Phase II resulted in acceptable matrix spike recoveries and SRM results for all metals except antimony. Therefore, better performance was demonstrated using the modified digestion technique as required by PSDDA guidelines for substitution of analytical techniques for metals.

## BIOASSAYS

Three sediment bioassays were conducted: 10-day amphipod (*Rhepoxynius abronius*) bioassay, 48-hour bivalve larvae bioassay using the oyster *Crassostrea gigas*, and Microtox bioassay using the saline extraction method.

### Testing Approach

The bioassays were conducted within 14 days of sediment collection in accordance with PSEP (1986) protocols. For the amphipod and oyster larvae bioassays, five replicates were used for each sediment type. For the Microtox test, a serial dilution was made of each sediment type. Each dilution was replicated. Sediment from West Beach on Whidbey Island was used as a negative control for all four bioassays.

### Data Quality and Status

Based on QA/QC review, the data for the amphipod, oyster larvae, and Microtox bioassays were considered acceptable. Although mortality (including abnormality) in the negative controls for the oyster larvae bioassay was high (i.e., 51 percent), the data were accepted. Under new recommendations being considered by PSDDA, up to 50 percent mortality is allowable in the negative control. The exceedance of this proposed limit is considered minor. Abnormality in the negative controls (i.e., 1.7 and 8.4 percent) was below the recommended maximum level of 10 percent.

## BENTHIC INFAUNA

Abundances of major taxa (i.e., polychaetes, molluscs, and crustaceans) were determined for samples collected from transect and benchmark stations.

## Sampling Approach

Benthic infauna samples were collected using a 0.06-m<sup>2</sup> mini-Soutar box corer and were sieved through a 1.0-mm screen. Material remaining on the screen was washed into a sample container and fixed with a 10 percent solution of buffered formalin. In the laboratory the benthic samples were transferred to isopropanol within 96 hours of collection, then sorted and counted to determine the abundance of major taxa (i.e., polychaetes, molluscs, and crustaceans).

## Data Quality and Status

Replicate samples were collected at all biological stations identified in the monitoring plan (PSDDA 1988). Re-sorting of samples indicated that PSEP sorting guidelines were met in every case. All benthic infauna data were considered acceptable for use.

## BIOACCUMULATION

The concentrations of contaminants were determined in organisms collected from transect and benchmark stations. The collected tissue was analyzed for metals, pesticides, PCB, and A/B/N compounds.

## Sampling Approach

The van Veen grab sampler was used to collect organisms for bioaccumulation analysis. At both the Bellingham Bay and Anderson/Ketron islands disposal sites, the bivalve *Compsomyax subdiaphana* was selected for bioaccumulation analysis based on the abundance and biomass of organisms in infauna samples. One sample was collected at each sampling station. This sample was composited from up to 24 grabs (12 deployments of the van Veen sampler). A bioaccumulation sample was not successfully collected at Station AKB02. Neither *C. subdiaphana* nor any other suitable organisms were found in the 24 grabs taken at this station. For all other stations, a minimum of 5 grams (wet weight) of tissue was collected for analysis (total sample sizes ranged from 5 to 173 grams wet weight).

## Data Quality and Status

Tissue samples were analyzed for all the PSDDA chemicals of concern except volatile organic compounds and tributyltin. All chemical data were reviewed according to PSEP/PSDDA guidelines for QA/QC (U.S. EPA 1986). A summary of reasons for any data rejection or qualification and caveats regarding data quality are provided in this section. More complete details of the QA review and discussion are given in Appendix D.

Of the accepted data, selected values for tissue have been qualified during QA review as estimates (*E* qualifier). Data qualified as estimates are acceptable but have a greater uncertainty associated with them than data that have not been qualified. Reasons for qualifying tissue data as estimates include:

- Benzoic acid values were reported at levels above the highest range of calibration standards for A/B/N compounds (120 ng on-column)

- The PSEP control limit of 25 percent relative percent difference for ongoing calibration was exceeded for benzoic acid
- Silver and arsenic exceeded PSEP control limits for serial dilution.

## MODIFICATIONS TO SAMPLING PLAN

All stations designated in the cruise plan were sampled for the selected types of data with the following exceptions:

- Bioaccumulation sampling at Station BBB02 resulted in an insufficient number of the selected organism (*C. subdiaphana*). A brief survey of alternative benchmark sites resulted in the establishment of a new station, BBB04. Bioaccumulation, sediment chemistry, and infauna data were collected at Station BBB04.
- Field observations of the distribution of abundance of *C. subdiaphana* in Bellingham Bay suggested that this clam occurred at the center of the site as well as the peripheral transect stations. Although not included in the original sampling plan, two casts were made at the center of the site after all other bioaccumulation samples had been collected for Bellingham Bay. Over 200 grams (wet weight in shell) were collected in these two casts. These samples were retained and the tissue was analyzed.
- Sediment at Station AKT06 was too sandy to permit adequate penetration with the mini-Soutar box corer. Infauna samples were therefore taken using the dual van Veen grab sampler. Samples from this station were archived. Data obtained from these samples will not be directly comparable to data from other samples collected with the mini-Soutar sampler.

## SUMMARY OF DATA COMPLETENESS

All sampling was conducted in the sequence specified in the cruise plan. All samples specified in the cruise plan were collected, with the exception of tissue for bioaccumulation analyses from Stations AKB02 and BBB02. No *C. subdiaphana* were found in 24 grabs taken at either station.

At 2 of the 20 other stations the amount of tissue was insufficient for all analyses and only metals concentrations were determined. For all other tissue samples, tissue chemical concentrations were determined for metals, PCB, pesticides, and A/B/N compounds.

### 3. DATA SUMMARY FOR BELLINGHAM BAY

#### OVERVIEW OF SAMPLING

One zone station, 4 perimeter stations, 12 transect stations, and 4 benchmark stations were sampled in Bellingham Bay. REMOTS® photographs were collected at additional site and perimeter stations. Coordinates of these stations and the types of data collected at each station are listed in Table 4. A summary of the data collected from each sample is shown in Table 5. The analysis codes used in Table 5 are listed in Table 6.

Station positioning was achieved using shore-based microwave transponders located at Clark's Point, Marine Park, and the observation tower of the Squalicum marina. These locations are shown in Figure 2. Detailed descriptions are provided in Tables 7, 8, and 9. The navigation system is described in Appendix A.

Sediment texture throughout the site was a mixture of silt and clay, with higher proportions of silt around the center of the site. Wood particles were observed at some stations, particularly those near the eastern edge of the site. Adequate penetration depths were consistently achieved with both the van Veen and mini-Soutar samplers using either no or little additional weight. Infauna were evident in all samples screened; tube-dwelling polychaetes were particularly evident. The clam *C. subdiaphana* was the only large organism consistently observed, and was selected for bioaccumulation studies. *Molpadia intermedia*, the organism used during the Phase I baseline survey, was not found.

An absence of sufficient *C. subdiaphana* at Station BBB02 resulted in the assignment and sampling of another benchmark station, BBB04.

#### REMOTS® DATA

A total of 56 sediment profile stations were occupied at the Bellingham Bay disposal site, including one at the center of the site (Z), 16 within the site (S), 16 at the perimeter of the site (P), 20 along transects (T), and 3 from benchmark (B) stations (Figure 3). Three REMOTS® images were obtained at each station. At least one image was analyzed at each station. Also, an additional replicate image was analyzed at Stations BBP01, BB902, BBT01, BBT02, BBT03, BBT10, BBT11, BBT13, BBT14, BBB01, and BBB02. The remaining replicates were archived.

#### Physical Characteristics

Fine-grained sediments, predominantly silt and clay, were found at all stations. Analysis of the REMOTS® images using the grain-size comparator indicated that the median grain-size was  $>4$  phi (Supplement, Plate 1). Based on the deep and relatively uniform camera prism penetration depth across the site, the surveyed area is characterized by sediments of low shear strength. The frequency distribution of sediment surface boundary roughness values indicates that most surface relief is  $\leq 1.0$  cm in extent. In nearly all images, this surface relief is biogenic in origin, reflecting features such as fecal mounds, burrows, and near-surface macro and meiofaunal sediment reworking (Supplement, Plate 2).

TABLE 4. SAMPLING STATION LOCATIONS AND TYPES  
OF DATA COLLECTED IN BELLINGHAM BAY

Station	Latitude	Longitude	REMOTS*	Sediment Chemistry	Bioassay	Infauna Abundance	Bioaccumu- lation
BBZ01	48 42 49.80	122 33 01.80	R	C	B		
BBS01	48 42 37.20	122 33 01.80	R				
BBS02	48 42 36.80	122 32 54.40	R				
BBS03	48 42 39.00	122 32 47.90	R				
BBS04	48 42 42.80	122 32 43.30	R				
BBS05	48 42 49.80	122 32 41.30	R				
BBS06	48 42 54.60	122 32 43.10	R				
BBS07	48 42 58.80	122 32 46.90	R				
BBS08	48 43 01.20	122 32 52.20	R				
BBS09	48 43 01.90	122 33 01.80	R				
BBS10	48 43 01.20	122 33 09.50	R				
BBS11	48 42 58.80	122 33 15.90	R				
BBS12	48 42 54.60	122 33 21.40	R				
BBS13	48 42 49.80	122 33 22.20	R				
BBS14	48 42 42.80	122 33 21.40	R				
BBS15	48 42 39.00	122 33 15.90	R				
BBS16	48 42 36.80	122 33 09.50	R				
BBP01	48 43 23.40	122 33 01.80	R	C			
BBP02	48 42 49.80	122 32 23.70	R	C			
BBP03	48 42 14.40	122 33 01.80	R	C			
BBP04	48 42 49.80	122 33 42.60	R	C			
BBP05	48 42 24.60	122 32 46.90	R				
BBP06	48 42 29.80	122 32 34.20	R				
BBP07	48 42 37.10	122 32 26.10	R				
BBP08	48 43 01.20	122 32 26.10	R				
BBP09	48 43 08.40	122 32 34.20	R				
BBP10	48 43 13.50	122 32 46.90	R				
BBP11	48 43 13.50	122 33 16.30	R				
BBP12	48 43 08.40	122 33 29.20	R				
BBP13	48 43 01.20	122 33 37.60	R				
BBP14	48 42 37.10	122 33 37.60	R				
BBP15	48 42 29.80	122 33 29.20	R				
BBP16	48 42 24.60	122 33 16.30	R				
BBT01	48 42 14.70	122 33 01.80	R			I	A
BBT02	48 42 06.00	122 33 01.80	R			I	A
BBT03	48 41 57.00	122 33 01.80	R			I	A
BBT04	48 43 23.70	122 33 01.80	R			I	A
BBT05	48 43 32.40	122 33 01.80	R			I	A
BBT06	48 43 42.00	122 33 01.80	R			I	A
BBT07	48 42 49.80	122 33 57.80	R			I	A
BBT08	48 42 49.80	122 34 09.50	R			I	A
BBT09	48 42 49.80	122 34 22.50	R			I	A
BBT10	48 42 49.80	122 32 09.00	R			I	A
BBT11	48 42 49.80	122 21 55.80	R			I	A
BBT12	48 42 49.80	122 21 42.00	R			I	A
BBT13	48 42 09.80	122 33 01.80	R				
BBT14	48 42 01.50	122 33 01.80	R				
BBT15	48 43 29.00	122 33 01.80	R				
BBT16	48 43 37.80	122 33 01.80	R				
BBT17	48 42 49.80	122 34 02.40	R				
BBT18	48 42 49.80	122 34 15.50	R				
BBT19	48 42 49.80	122 32 02.00	R				
BBT20	48 42 49.80	122 31 47.90	R				
BBB01	48 43 49.80	122 31 04.40	R	C	B	I	A
BBB02	48 42 49.80	122 31 34.20	R	C	B	I	A
BBB03	48 41 00.00	122 33 01.80	R			I	A
BBB04	48 42 00.00	122 35 00.00		C	B	I	A

TABLE 5. SAMPLING INFORMATION FOR BELLINGHAM BAY

Station	Sample	Field Replicates	Date	Time	No. of Grabs	Analysis Codes <sup>a</sup>
BBT03	BBT03I	1	04/14/89	0913	1	I,G
BBT03	BBT03I	2	04/14/89	0925	1	I
BBT03	BBT03I	3	04/14/89	0935	1	I
BBT03	BBT03I	4	04/14/89	0943	1	I
BBT03	BBT03I	5	04/14/89	0953	1	I
BBT02	BBT02I	1	04/14/89	1002	1	I,G
BBT02	BBT02I	2	04/14/89	1013	1	I
BBT02	BBT02I	3	04/14/89	1021	1	I
BBT02	BBT02I	4	04/14/89	1029	1	I
BBT02	BBT02I	5	04/14/89	1035	1	I
BBT01	BBT01I	1	04/14/89	1044	1	I,G
BBT01	BBT01I	2	04/14/89	1054	1	I
BBT01	BBT01I	3	04/14/89	1107	1	I
BBT01	BBT01I	4	04/14/89	1122	1	I
BBT01	BBT01I	5	04/14/89	1131	1	I
BBT09	BBT09I	1	04/14/89	1212	1	I,G
BBT09	BBT09I	2	04/14/89	1226	1	I
BBT09	BBT09I	3	04/14/89	1244	1	I
BBT09	BBT09I	4	04/14/89	1255	1	I
BBT09	BBT09I	5	04/14/89	1304	1	I
BBT08	BBT08I	1	04/14/89	1312	1	I,G
BBT08	BBT08I	2	04/14/89	1321	1	I
BBT08	BBT08I	3	04/14/89	1330	1	I
BBT08	BBT08I	4	04/14/89	1339	1	I
BBT08	BBT08I	5	04/14/89	1348	1	I
BBT07	BBT07I	1	04/14/89	1406	1	I,G
BBT07	BBT07I	2	04/14/89	1415	1	I
BBT07	BBT07I	3	04/14/89	1423	1	I
BBT07	BBT07I	4	04/14/89	1432	1	I
BBT07	BBT07I	5	04/14/89	1439	1	I
BBB03	BBB03I	1	04/17/89	0908	1	I,G
BBB03	BBB03I	2	04/17/89	0930	1	I
BBB03	BBB03I	3	04/17/89	0940	1	I
BBB03	BBB03I	4	04/17/89	0950	1	I
BBB03	BBB03I	5	04/17/89	1002	1	I
BBB02	BBB02I	1	04/17/89	1030	1	I,G
BBB02	BBB02I	2	04/17/89	1040	1	I
BBB02	BBB02I	3	04/17/89	1050	1	I
BBB02	BBB02I	4	04/17/89	1102	1	I
BBB02	BBB02I	5	04/17/89	1112	1	I
BBT12	BBT12I	1	04/17/89	1128	1	I,G
BBT12	BBT12I	2	04/17/89	1141	1	I
BBT12	BBT12I	3	04/17/89	1151	1	I
BBT12	BBT12I	4	04/17/89	1201	1	I
BBT12	BBT12I	5	04/17/89	1225	1	I
BBT11	BBT11I	1	04/17/89	1323	1	I,G
BBT11	BBT11I	2	04/17/89	1333	1	I
BBT11	BBT11I	3	04/17/89	1343	1	I
BBT11	BBT11I	4	04/17/89	1400	1	I
BBT11	BBT11I	5	04/17/89	1410	1	I

TABLE 5. (Continued)

Station	Sample	Field Replicates	Date	Time	No. of Grabs	Analysis Codes <sup>a</sup>
BBT10	BBT10I	1	04/17/89	1434	1	I,G
BBT10	BBT10I	2	04/17/89	1452	1	I
BBT10	BBT10I	3	04/17/89	1503	1	I
BBT10	BBT10I	4	04/17/89	1514	1	I
BBT10	BBT10I	5	04/17/89	1524	1	I
BBT04	BBT04I	1	04/17/89	1552	1	I,G
BBT04	BBT04I	2	04/17/89	1605	1	I
BBT04	BBT04I	3	04/17/89	1614	1	I
BBT04	BBT04I	4	04/17/89	1624	1	I
BBT04	BBT04I	5	04/17/89	1634	1	I
BBT05	BBT05I	1	04/18/89	0844	1	I,G
BBT05	BBT05I	2	04/18/89	0858	1	I
BBT05	BBT05I	3	04/18/89	0908	1	I
BBT05	BBT05I	4	04/18/89	0921	1	I
BBT05	BBT05I	5	04/18/89	0932	1	I
BBT06	BBT06I	1	04/18/89	0947	1	I,G
BBT06	BBT06I	2	04/18/89	0957	1	I
BBT06	BBT06I	3	04/18/89	1032	1	I
BBT06	BBT06I	4	04/18/89	1042	1	I
BBT06	BBT06I	5	04/18/89	1053	1	I
BBB01	BBB01I	1	04/18/89	1125	1	I,G
BBB01	BBB01I	2	04/18/89	1135	1	I
BBB01	BBB01I	3	04/18/89	1144	1	I
BBB01	BBB01I	4	04/18/89	1154	1	I
BBB01	BBB01I	5	04/18/89	1209	1	I
BBT10	BBT10A		04/18/89	1430	24	P,M
BBT02	BBT02A		04/18/89	1600	24	P,M
BBT01	BBT01A		04/18/89	1730	24	P,M
BBB03	BBB03A		04/19/89	0950	24	P,M
BBT03	BBT03A		04/19/89	1050	24	P,M
BBT12	BBT12A		04/19/89	1400	24	P,M
BBB01	BBB01A <sup>b</sup>		04/19/89	1550	24	P,M
BBB04	TESTB04A <sup>c</sup>		04/19/89	1700	6	P,M
BBT11	BBT11A		04/20/89	0840	24	P,M
BBB01	BBB01A-R <sup>b</sup>		04/20/89	1105	34	P,M
BBT04	BBT04A		04/20/89	1525	24	P,M
BBT05	BBT05A		04/20/89	1630	24	P,M
BBT06	BBT06A		04/20/89	1730	24	P,M
BBB04	BBB04A <sup>c</sup>		04/21/89	0830	32	P,M
BBT07	BBT07A		04/21/89	0935	24	P,M
BBT08	BBT08A		04/21/89	1030	24	P,M
BBT09	BBT09A		04/21/89	1145	24	P,M
BBZ01	BBZ01A		04/21/89	1350	4	P,M
BBB04	BBB04C		04/24/89	0926	14	G,V,Q,P,Z,M,S,I,B
BBP01	BBP01C		04/24/89	1118	14	G,V,Q,P,Z,M,S,I,B
BBP04	BBP04C		04/24/89	1333	10	G,V,Q,P,Z,M,S,I,B
BBB02	BBB02C		04/25/89	0634	16	G,V,Q,P,Z,M,S,I,B
BBP02	BBP02C		04/25/89	0820	10	G,V,Q,P,Z,M,S,I
BBZ01	BBZ01C		04/25/89	0915	6	G,V,Q,P,Z,M,S,I,B
BBP03	BBP03C		04/25/89	1015	6	G,V,Q,P,Z,M,S,I
BBB01	BBB01C		04/25/89	1123	14	G,V,Q,P,Z,M,S,I,B
BBB04	BBB04I	1	04/25/89	1544	1	I,G

TABLE 5. (Continued)

Station	Sample	Field Replicates	Date	Time	No. of Grabs	Analysis Codes <sup>a</sup>
BBB04	BBB04I	2	04/25/89	1552	1	I
BBB04	BBB04I	3	04/25/89	1617	1	I
BBB04	BBB04I	4	04/25/89	1628	1	I
BBB04	BBB04I	5	04/25/89	1638	1	I

<sup>a</sup> Analysis codes are listed in Table 6.

<sup>b</sup> Samples BBB01A and BBB01A-R were composited for analysis.

<sup>c</sup> Samples TESTB04A and BBB04A were composited for analysis.

TABLE 6. ANALYSIS CODES AND LABORATORIES

Analysis	Code	Laboratory
Infauna	I	E.V.S. <sup>a</sup>
Grain size and total organic carbon	G	CAS <sup>b</sup>
Bioaccumulation	A	CAS and ARI <sup>c</sup>
Volatile organic analysis	V	ARI
Acid, base, neutral	Q	ARI
PCB	P	ARI
Pesticides	Z	ARI
Metals	M	CAS
Sulfides, total volatile solids, total solids	S	CAS
Tributyltin	T	Battelle <sup>d</sup>
Bioassays	B	E.V.S.

<sup>a</sup> E.V.S. - E.V.S. Consultants Ltd.

<sup>b</sup> CAS - Columbia Analytical Services.

<sup>c</sup> ARI - Analytical Resources, Incorporated.

<sup>d</sup> Battelle - Battelle Northwest Laboratories.

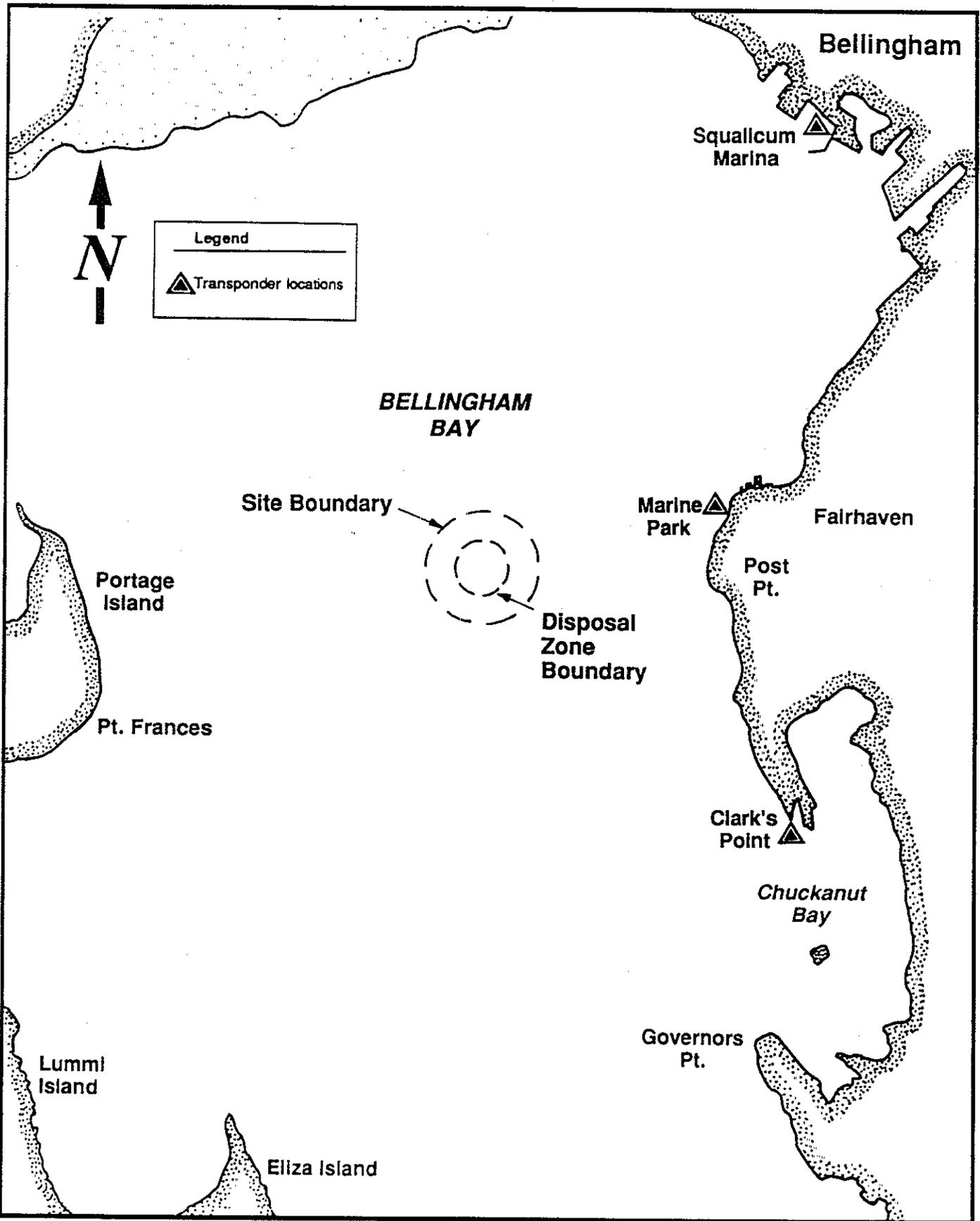


Figure 2. Transponder locations in Bellingham Bay

TABLE 7. CLARK'S POINT TRANSPONDER LOCATION

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STATION NAME:	GNARL
GENERAL LOCATION:	Bellingham Bay, Bellingham, WA
SPECIFIC LOCATION:	Jillpoke Lane, Clark's Point, Bellingham, WA
COORDINATES:	GEODETIC LATITUDE: 48 41' 24.38" GEODETIC LONGITUDE: 122 30' 21.70"
WASHINGTON STATE PLANE COORDINATES (NORTH ZONE)	X: 1,595,981.710 Y: 620,909.345

STATION IS A BENCHMARK

CONTACT: Mr. Doug Clark  
4700 Fieldstone Road  
Bellingham, WA 98225  
206/734-5554

From downtown Bellingham, travel south on South State Street. South State Street eventually becomes Route 11 (Chuckanut Drive). From Chuckanut Drive, turn left on Viewcrest Road (Viewcrest Road is about 3/4 mile south of Fairhaven). Follow Viewcrest Road until it terminates into Fieldston Road. Turn left on Fieldston Road. Follow Fieldston Road to the end, where there is a private drive. Follow the private drive to the first paved right. Turn right and immediately park. Follow the unpaved, unfinished driveway south. At the end of the driveway take the narrow path to the southernmost tip of the point, where the benchmark is set in exposed sandstone.

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**TABLE 8. THE MARINE PARK TRANSPONDER LOCATION**

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<b>STATION NAME:</b>	Marine Park
<b>GENERAL LOCATION:</b>	Bellingham Bay, Bellingham, WA
<b>SPECIFIC LOCATION:</b>	Port of Bellingham Marine Park, Bellingham, WA
<b>COORDINATES:</b>	<b>GEODETTIC LATITUDE:</b> 48 43' 10.14"N <b>GEODETTIC LONGITUDE:</b> 122 30' 53.70"W
<b>WASHINGTON STATE PLANE COORDINATES (NORTH ZONE)</b>	<b>X:</b> 1,594,068.56 <b>Y:</b> 631,675.06
<b>STATION SURVEYED BY:</b>	Mr. Dale Underhill Construction Surveyors 1500 I Street Bellingham, WA 98225 206/733-3383
<b>CONTACT:</b>	Mr. Ron Ellis, P.E. Port of Bellingham P.O. Box 1737 Bellingham, WA 98225

From downtown Bellingham, travel south on South State Street. From South State Street, turn left (west) on Harris Street, in the Fairhaven section of town. Follow Harris Street over the railroad tracks near the termination of the street. Bear left after the railroad tracks toward the parking area of the Port of Bellingham Marine Park. The station is located about 4 feet shoreward of the rock riprap surrounding the park and is due west of the lavatory pavilion. The station is marked by a brass tack and nail.

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**TABLE 9. THE SQUALICUM MARINA TRANSPONDER LOCATION**

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<b>STATION NAME:</b>	Squalicum Marina Esplanade
<b>GENERAL LOCATION:</b>	Bellingham Bay, Bellingham, WA
<b>SPECIFIC LOCATION:</b>	Observation tower, esplanade, Port of Bellingham, Squalicum Marina
<b>COORDINATES:</b>	<b>GEODETIC LATITUDE:</b> 48 45' 27.00"N <b>GEODETIC LONGITUDE:</b> 122 30' 12.42"W
<b>WASHINGTON STATE PLANE COORDINATES (NORTH ZONE)</b>	<b>X:</b> 1,597,136.59 <b>Y:</b> 645,478.53

**STATION SURVEYED BY:**

Mr. Dale Underhill  
Construction Surveyors  
1500 I Street  
Bellingham, WA 98225  
206/733-3383

**CONTACT:** Mr. Ron Ellis, P.E.  
Port of Bellingham  
P.O. Box 1737  
Bellingham, WA 98225

or

Mr. Art Choat, Harbormaster  
Squalicum Marina  
Port of Bellingham  
P.O. Box 1737  
Bellingham, WA 98225

From downtown Bellingham, travel west on East Holly Street. Turn left on F Street. Go to the end of F Street and turn right on Roeder Avenue. Follow Roeder Avenue to Coho Way, which is the entrance street to the Squalicum marina mall. Turn left on Coho Way. Follow Coho Way to the corner between the large building and the Squalicum Yacht Club (white building). The observation tower is at the western end of the esplanade (large building). The station is marked by a brass tack and nail on the top floor of the observation tower.

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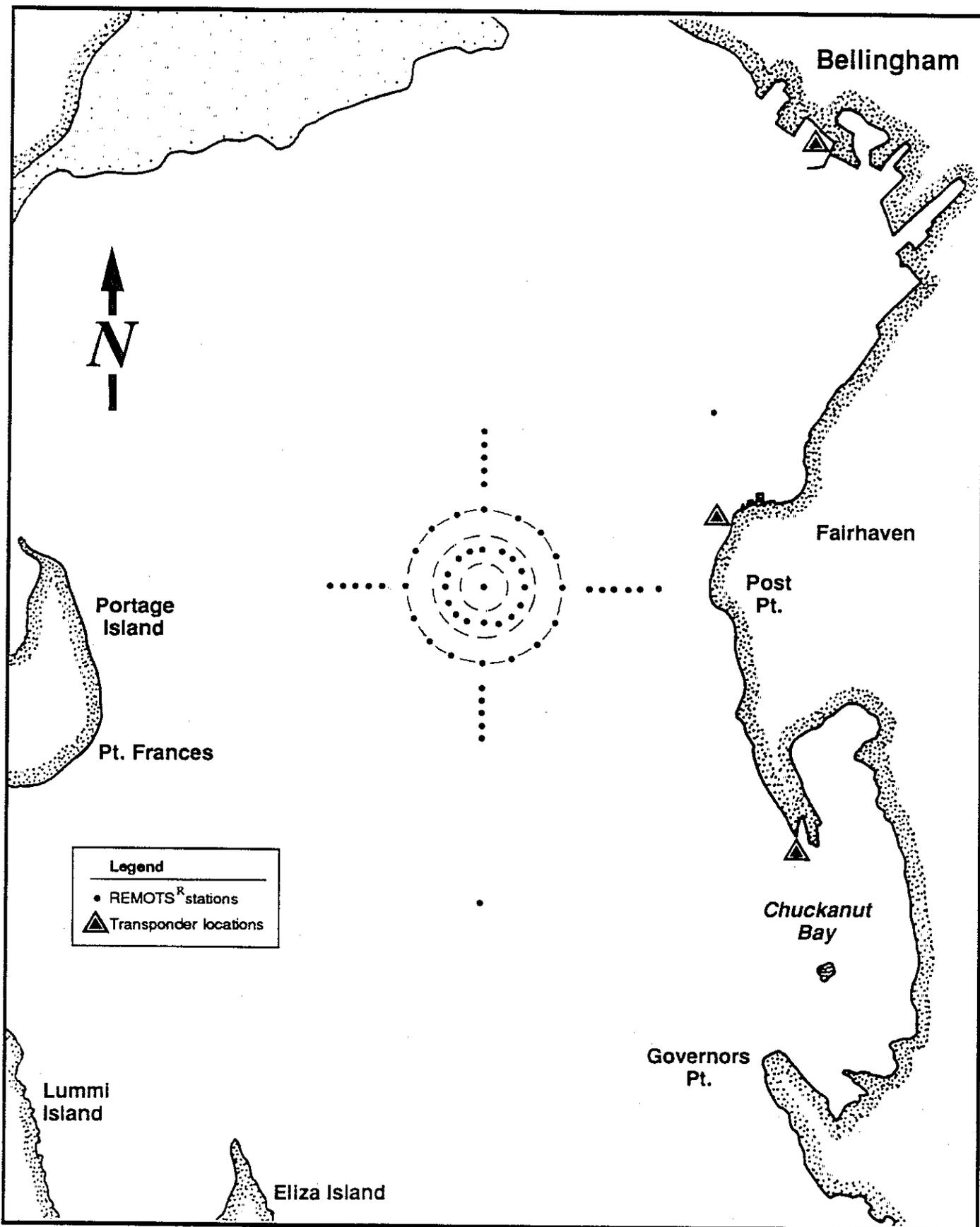


Figure 3. Location of REMOTS<sup>®</sup> stations in Bellingham Bay

Extremely low-reflectance (i.e., reduced) sediment layers are evident at several stations (Supplement, Plate 3). These layers range in thickness from 4 to 9 cm and occur predominantly along the eastern and southern transects. Possible sources or causes for this layer are construction activity in the Post Point area, relict dredged material, or bottom-trawler activity. During post-disposal REMOTS® surveys that will be conducted at the Bellingham Bay site, newly deposited dredged material should be readily discernible in these areas, because it will overlie the well established, high reflectance surface layers now covering the reduced apparent relict layers.

The apparent RPD depths range from 0.7 to 4.4 cm across the Bellingham Bay site. The southern transect, southeast perimeter stations, and southern benchmark station (BBB03), exhibit deeper apparent redox boundaries than the rest of the area. These deeper RPD values are associated with some of the stations exhibiting the reduced sediment layers described above, further suggesting that this material was not deposited recently.

The oxygenated surface layers throughout the Bellingham Bay site contrast sharply with the underlying reduced material (Supplement, Plate 3). This high contrast boundary suggests that a significant discharge of labile, organic-rich material has occurred in the region.

### **Biological Characteristics**

Analysis of the REMOTS® images indicate that Stage III benthic infauna communities are present at most stations on the site. The presence of head-down, deposit-feeding Stage III taxa is evidenced by both burrows and feeding voids visible in the REMOTS® images (Supplement, Plate 4). Near-surface, tubicolous polychaetes (Stage I species) are also evident in most images (Supplement, Plate 5). Small patches of the area surveyed lack evidence of Stage III taxa. This apparent lack of significant deep-dwelling fauna is most evident along the northern transect. The apparent distribution of benthic communities is consistent with the distribution of RPD depths at the site and may also reflect the regional pattern of benthic conditions in Bellingham Bay.

### **SEDIMENT CHEMISTRY**

One zone station, four perimeter stations, and three benchmark stations were sampled for chemistry analyses in Bellingham Bay. One reference station in Carr Inlet was also sampled. Sampling station locations are described in Table 4 and illustrated in Figure 4. All of the sediment samples collected were analyzed for PSDDA chemicals of concern and tributyltin.

Concentrations of conventional sediment variables are summarized in Table 10. Concentrations of chemicals of concern that were detected are listed in Table 11. Chemical data are presented in Appendix B. The concentrations of these chemicals are grouped by zone/perimeter and by benchmark stations in Tables 12 and 13, respectively.

A summary of chemicals with concentrations exceeding the PSDDA screening level (SL) and maximum level (ML) values and the frequency of exceedance are presented in Table 14. Appendix B (Table B-28) contains the PSDDA Phase II SL and ML values used to screen the data. Stations at which chemicals exceeded the SL or ML values are shown in Table 15. Phenol (4,800 µg/kg dry weight at Station BBP04), 4-methyl phenol (280 µg/kg dry weight at Station BBP01), and benzoic acid (410 µg/kg dry weight at Station BBP04) were the only organic compounds found to exceed the SL. Each of these compounds exceeded the SL at only one station. Phenol also exceeded the ML at Station BBP04, located west of the site.

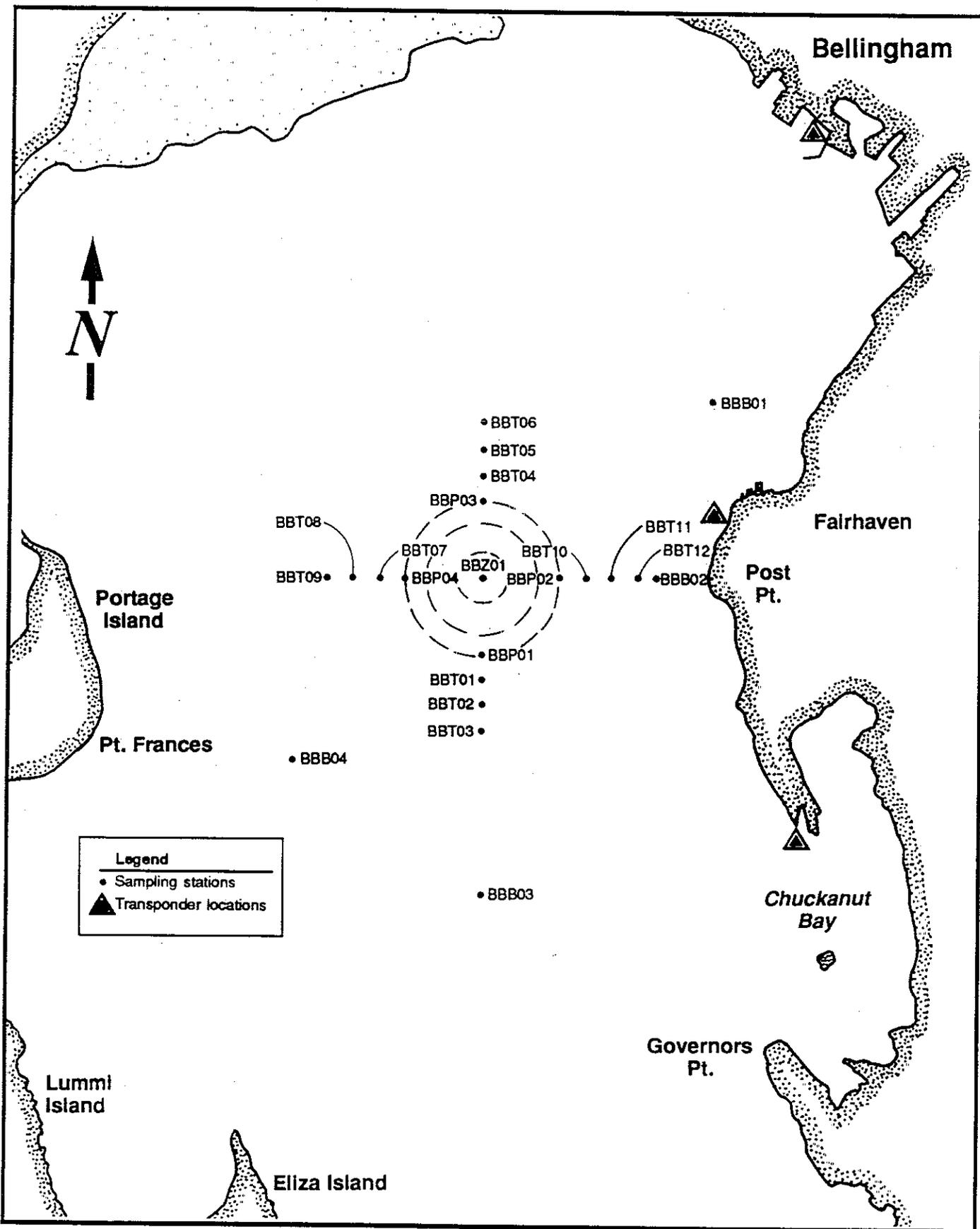


Figure 4. Location of chemistry, bioassay, infauna, and bioaccumulation stations in Bellingham Bay

**TABLE 10. CONCENTRATIONS OF CONVENTIONAL VARIABLES  
IN SURFACE SEDIMENTS FROM BELLINGHAM BAY<sup>a</sup>**

Variable	Range	Location of Maximum
Total organic carbon	1.3-2.8%	BBB01
Ammonia-nitrogen	69.1-232 mg/kg	BBB01
Sulfides	1.0-2.6 mg/kg	BBP01
Total solids	22.2-29.3%	BBZ01
Total volatile solids	7.5-9.8%	BBB02
Percent fines	91.9-99.82%	BBP02

<sup>a</sup> Concentrations on dry weight basis except total solids

TABLE 11. CONCENTRATIONS OF PSSDA CHEMICALS OF CONCERN  
DETECTED IN SURFACE SEDIMENTS FROM BELLINGHAM BAY<sup>a</sup>

Chemical	Range <sup>b</sup>	Median <sup>b</sup>	Detection Frequency <sup>c</sup>	Location of Maximum
<b>LPAH</b>				
naphthalene	U14-190	E50	0.88	BBB01
2-methylnaphthalene	E11-E27	E23	0.88	BBP02
acenaphthylene	E6-E49	U15	0.5	BBB01
fluorene	E6-U16	U14	0.38	BBP01
				BBP02
phenanthrene	16-250	120	1.0	BBB02
anthracene	E4-45	E17	1.0	BBB02
<b>HPAH</b>				
fluoranthene	41-200	140	1.0	BBB01
pyrene	34-180	86	1.0	BBB01
benzo(a)anthracene	16-92	45	1.0	BBB01
chrysene	0-110	61	1.0	BBB01
				BBB02
total benzofluoranthenes	50-170	E100	1.0	BBB02
benzo(a)pyrene	17-93	51	1.0	BBB01
indeno(1,2,3-c,d)pyrene	10-E47	E18	0.75	BBB02
benzo(g,h,i)perylene	U14-76	E30	0.75	BBB02
<b>Phenols</b>				
phenol	U28-E4,800	U33	0.38	BBP04
4-methylphenol	U12-280	U15	0.25	BBB01
<b>Phthalates</b>				
diethyl phthalate	U12-E26	U16	0.38	BBB01
di-n-butyl phthalate	U12-T43	U15	0.25	BBP03
bis(2-ethylhexyl)phthalate	U12-Z220	Z75	0.88	BBB01
				BBB02
<b>Miscellaneous extractables</b>				
benzoic acid	E55-410	U140	0.38	BBP04
dibenzofuran	E12-E37	U15	0.5	BBB01
<b>Organometallic compounds</b>				
tributyltin <sup>d</sup>	E2 6-12	E3 6	0.88	BBB02
<b>Metals<sup>e</sup></b>				
antimony	G0.14-G0.30	G0.23	1.0	BBB02
arsenic	G0.9-8.6	7.7	1.0	BBB02
cadmium	0.31-0.78	0.45	1.0	BBB01
copper	38-51	44	1.0	BBB01
lead	17.2-19.6	18.6	1.0	BBB02
mercury	0.20-0.56	0.36	1.0	BBB01
nickel	62-106	75	1.0	BBB01
silver	0.28-0.43	0.32	1.0	BBB02
zinc	104-120	110	1.0	BBB01

TABLE 11. (Continued)

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<sup>a</sup> Qualifier codes:

- G - estimate is greater than value shown
- U - undetected at detection limit shown
- E - estimate
- Z - blank-corrected, still above detection limit
- T - detected below quantification limit shown.

<sup>b</sup> Concentrations of organic compounds are measured in  $\mu\text{g}/\text{kg}$  dry weight. Metals concentrations are measured in  $\text{mg}/\text{kg}$  dry weight.

<sup>c</sup> Based on all samples collected in Bellingham Bay.

<sup>d</sup> Tributyltin is not defined as a PSDDA chemical of concern; concentrations expressed as the equivalent concentration of tin.

<sup>e</sup> All results reported for the strong acid digestion technique.

TABLE 12. CONCENTRATIONS OF PSDDA CHEMICALS OF CONCERN  
DETECTED IN SURFACE SEDIMENTS FROM BELLINGHAM BAY  
SITE AND PERIMETER STATIONS<sup>a</sup>

Chemical	Zone Station <sup>b</sup>	Perimeter Stations			
		Range <sup>b</sup>	Median <sup>b</sup>	Detection Frequency <sup>c</sup>	Location of Maximum
<b>LPAH</b>					
naphthalene	E33	16-E67	E50	1.0	BBP03
2-methylnaphthalene	E23	E11-E27	E19	1.0	BBP02
acenaphthylene	U14	E6.0-U16	U14	0.5	BBP01
fluorene	U14	E6.0-U16	U15	0.25	BBP02
phenanthrene	U5.1	16-190	120	1.0	BBP01
anthracene	E6.4	E4.0-E19	E15	1.0	BBP02
<b>HPAH</b>					
fluoranthene	140	41-160	100	1.0	BBP02
pyrene	72	34-130	84	1.0	BBP02
benzo(a)anthracene	47	16-65	E38	1.0	BBP02
chrysene	64	20-76	50	1.0	BBP02
total benzofluoranthenes	E100	50-E130	E92	1.0	BBP02
benzo(a)pyrene	53	17-71	40	1.0	BBP02
indeno(1,2,3-c,d)pyrene	E22	10-E33	E19	1.0	BBP02
benzo(g,h,i)perylene	E38	E16-E61	E32	1.0	BBP02
<b>Phenols</b>					
phenol	U28	U30-E4,800	E48	0.5	BBP04
<b>Phthalates</b>					
diethylphthalate		U12-E20	U16	0.25	BBP03
di-n-butyl phthalate	E15	U12-T43	U16	0.25	BBP03
bis(2-ethylhexyl)phthalate	Z37	U12-Z88	Z55	0.75	BBP03
<b>Miscellaneous extractables</b>					
benzoic acid		E55-410	0.50	0.5	BBP04
dibenzofuran	U14	E12-E17	U14	0.5	BBP02
<b>Organometallic compounds</b>					
tributyltin <sup>d</sup>		U3-E6.0	E4.2	0.75	BBP01
<b>Metals<sup>e</sup></b>					
antimony	G0.25	G.14-G.28	G.24	1.0	BBP02
arsenic	6.9	6.9-7.9	7.7	1.0	BBP02
cadmium	0.46	0.36-0.45	0.44	1.0	BBP02
copper	44.5	41.5-45.1	44.5	1.0	BBP04
lead	19.4	18.3-19.3	18.5	1.0	BBP03
mercury	0.34	0.22-0.38	0.34	1.0	BBP04
nickel	77	65.2-84.2	76.0	1.0	BBP02
silver	0.31	0.30-0.33	0.32	1.0	BBP03
zinc	112	104-114	108	1.0	BBP04

TABLE 12. (Continued)

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<sup>a</sup> Qualifier codes:

- G - estimate is greater than value shown
- U - undetected at detection limit shown
- E - estimate
- Z - blank-corrected, still above detection limit
- T - detected below quantification limit shown.

<sup>b</sup> Concentrations of organic compounds are measured in  $\mu\text{g}/\text{kg}$  dry weight. Metals concentrations are measured in  $\text{mg}/\text{kg}$  dry weight.

<sup>c</sup> Based on samples collected from the four perimeter stations.

<sup>d</sup> Tributyltin is not defined as a PSDDA chemical of concern; concentrations expressed as the equivalent concentration of tin.

<sup>e</sup> All results reported for the strong acid digestion technique.

**TABLE 13. CONCENTRATIONS OF PSSDA CHEMICALS OF CONCERN  
DETECTED IN SURFACE SEDIMENTS FROM BELLINGHAM BAY  
AT BENCHMARK STATIONS<sup>a</sup>**

Chemical	Range <sup>b</sup>	Median <sup>b</sup>	Detection Frequency <sup>c</sup>	Location of Maximum
<b>LPAH</b>				
naphthalene	U14-190	120	0.67	BBB01
2-methylnaphthalene	U14-27	27	0.67	BBB01
				BBB02
acenaphthylene	U14-E49	E25	0.67	BBB01
fluorene	11-14	12	0.67	BBB04
phenanthrene	96-250	140	1.0	BBB02
anthracene	E8.3-45	23	1.0	BBB02
<b>HPAH</b>				
fluoranthene	72-200	190	1.0	BBB01
pyrene	46-180	120	1.0	BBB01
benzo(a)anthracene	31-92	87	1.0	BBB01
chrysene	40-110	110	1.0	BBB01
				BBB02
total benzofluoranthenes	67-170	160	1.0	BBB02
benzo(a)pyrene	28-93	U92	1.0	BBB01
indeno(1,2,3-c,d)pyrene	U14-E47	U14	0.33	BBB02
benzo(g,h,i)perylene	U14-76	U14	0.33	BBB02
<b>Phenols</b>				
4-methylphenol	U14-280	100	0.67	BBB01
phenol	U29-E93	U34	0.33	BBB01
<b>Phthalates</b>				
diethyl phthalate	U14-E26	U17	0.33	BBB01
bis(2-ethylhexyl)phthalate	Z100-Z220	Z220	1.0	BBB01
				BBB02
<b>Miscellaneous extractables</b>				
benzoic acid	E56-U170	U146	0.33	BBB02
dibenzofuran	U14-E37	E27	0.67	BBB01
<b>Organometallic compounds</b>				
tributyltin <sup>d</sup>	E2.6-12	E3.0	1.0	BBB02
<b>Metals<sup>e</sup></b>				
antimony	G0.15-G0.30	G0.16	1.0	BBB02
arsenic	7.6-8.6	8.5	1.0	BBB02
cadmium	0.31-0.78	0.52	1.0	BBB01
copper	38.6-51.0	45.1	1.0	BBB01
lead	17.2-19.6	18.0	1.0	BBB02
mercury	0.20-0.56	0.39	1.0	BBB01
nickel	62-106	74	1.0	BBB01
silver	0.28-0.43	0.33	1.0	BBB02
zinc	106-120	111	1.0	BBB01

TABLE 13. (Continued)

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<sup>a</sup> Qualifier codes:

- U - undetected at detection limit shown
- E - estimate
- Z - blank-corrected, still above detection limit
- G - estimate is greater than value shown

<sup>b</sup> Concentrations of organic compounds are measured in  $\mu\text{g}/\text{kg}$  dry weight. Metals concentrations are measured in  $\text{mg}/\text{kg}$  dry weight.

<sup>c</sup> Based on samples from the three benchmark stations.

<sup>d</sup> Tributyltin is not defined as a PSDDA chemical of concern; concentrations expressed as the equivalent concentration of tin.

<sup>e</sup> All results reported for the strong acid digestion technique unless otherwise noted.

**TABLE 14. CHEMICALS EXCEEDING PSDDA SCREENING LEVEL  
AND MAXIMUM LEVEL VALUES IN BELLINGHAM BAY  
AND FREQUENCY OF EXCEEDANCE<sup>a</sup>**

Chemical	Screening Level	No. of Times SL Exceeded <sup>b</sup>	Maximum Level	No. of Times ML Exceeded <sup>c</sup>
<b>Phenols</b>				
phenol	120	1	E4,800 <sup>d</sup>	1
4-methylphenol	120	1	280	0
<b>Miscellaneous extractables</b>				
benzoic acid	216	1	410	0
<b>Metals</b>				
mercury	0.21	7	0.56	0

<sup>a</sup> Concentrations of organic compounds are measured in  $\mu\text{g}/\text{kg}$  dry weight. Metals concentrations are measured in  $\text{mg}/\text{kg}$  dry weight.

<sup>b</sup> SL - screening level.

<sup>c</sup> ML - maximum level.

<sup>d</sup> Qualifier code:

E - estimate.

**TABLE 15. EXCEEDANCES OF PSDDA SCREENING LEVEL  
AND MAXIMUM LEVEL VALUES IN BELLINGHAM BAY  
SEDIMENT CHEMISTRY DATA**

Station	Chemical	Concentration <sup>a,b</sup>	Exceedance Factor <sup>c</sup>
BBB01	4-methylphenol	280	2.33 (SL)
	mercury	0.56	2.67 (SL)
BBB02	mercury	0.39	1.86 (SL)
BBP01	mercury	0.22	1.05 (SL)
BBP02	mercury	0.38	1.81 (SL)
BBP03	mercury	0.38	1.81 (SL)
BBP04	phenol	E4,800	4.0 (ML)
	phenol	E4,800	40.0 (SL)
	benzoic acid	410	1.86 (SL)
	mercury	0.31	1.48 (SL)
BBZ01	mercury	0.34	1.62 (SL)

<sup>a</sup> Concentrations of metals and organic compounds are in mg/kg dry weight and µg/kg dry weight, respectively.

<sup>b</sup> Qualifier code:

E - estimate.

<sup>c</sup> SL - screening level; ML - maximum level.

Only one metal, mercury, exceeded the SL. Mercury concentrations exceeded the SL at all stations at which it was measured except one, BBB04. Mercury never exceeded the ML. The maximum mercury concentration in Bellingham Bay (0.56 µg/kg dry weight), occurring at Station BBB01, exceeded the SL by a factor of 2.7.

## BIOASSAYS

Bioassays were conducted on sediments from four Bellingham Bay stations including the disposal zone station and three benchmark stations (Figure 4). Responses for each bioassay are presented in Table 16. In addition, ranges for each of the bioassays performed on reference sediment collected from Carr Inlet are presented in Table 16. Data were analyzed in accordance with PSDDA Phase II test interpretation procedures. All data met dredged material disposal guidelines.

The amphipod bioassay met PSDDA control and reference performance standards, and all test sediments were <20 percent over control (Table 16). The Carr Inlet reference data for amphipod bioassays also met Element P2 performance standards (Pastorok et al. 1989).

Data for the oyster larvae bioassay listed in Table 16 are expressed as combined mortality and abnormality. All reference and test sediment values were standardized relative to the final seawater control responses as per PSDDA Phase II guidelines (i.e., the final number of healthy larvae in the seawater control was used as the initial value of larvae for the reference and test sediment analyses). PSDDA agencies are currently considering control and reference performance standards for the test. Combined mortality and abnormality in the seawater control and Carr Inlet reference sediment were 51 percent and 61 percent, respectively. All test sediments were within 20 percent of the Carr Inlet reference response.

All Microtox tests showed no dose response to Bellingham Bay sediments. Sediments from all stations tested were therefore not toxic, and subsequent comparisons with Microtox reference were not performed.

## BENTHIC INFAUNA

Macrobenthic infauna samples were collected at 16 stations in Bellingham Bay (Table 4; Figure 4). Samples from four benchmark stations and the anticipated downcurrent transect as specified by the Corps were analyzed. These data are presented in Appendix B and summarized in Table 17. Abundances are expressed as the average number of individuals per box core (0.06 m<sup>2</sup>) for all benchmark stations and transect stations BBT01, BBT02, and BBT03. Benthic infauna samples collected at all other stations were archived and may be analyzed by Ecology following the first post-disposal monitoring effort. Total abundance and number of taxa per station were relatively constant among the four locations. Total abundance ranged from an average of 138 to 1,475 individuals (2,300 to 24,583 individuals per square meter).

Molluscs were the most abundant major taxon at all but one of the stations (BBB01), ranging in abundance from 51 to 208 individuals per box core. At Station BBB01 polychaetes were more than an order of magnitude more abundant than any major taxon at any other station (1,229 individuals per box core). Cirratulid polychaetes, a taxonomic family frequently associated with areas of organic enrichment, were responsible for the high density of organisms at this station. The Georgia Pacific deep-water discharge is approximately 300 meters from Station BBB01. The TOC at Station BBB01 (2.8 percent) was higher than at any other Bellingham Bay station, which suggests that the elevated polychaete abundance may be a response to elevated levels of organic

TABLE 16. BIOASSAY SUMMARY FOR BELLINGHAM BAY

Station	Amphipod Mortality			Oyster Larvae Abnormality and Mortality		
	Mean	Range	Standard Deviation	Mean	Range	Standard Deviation
<b>Bellingham Bay</b>						
BBB01	0.09	0.05-0.10	0.04	0.65	0.47-0.72	0.91
BBB02	0.16	0.10-0.20	0.04	0.42	0.0-0.70	0.75
BBB04	0.10	0.05-0.15	0.05	0.52	0.35-0.67	0.90
BBZ01	0.19	0.10-0.35	0.10	0.60	0.39-0.71	0.88
Control	0.04 <sup>a</sup>	0.0-0.10 <sup>a</sup>	0.04 <sup>a</sup>	0.51 <sup>b</sup>		
<b>Reference</b>						
CRR01	0.04	0.0-0.10	0.04	0.61	0.47-0.75	0.89

Note: Microtox - all stations nontoxic,  $EC_{50} > 1,000 \mu\text{L}/\text{mL}$ . No light decrease observed

<sup>a</sup> Sediment control.

<sup>b</sup> Seawater control.

TABLE 17. BENTHIC INFAUNA SUMMARY FOR BELLINGHAM BAY

	Station						
	BBB01	BBB02	BBB03	BBB04	BBT01	BBT02	BBT03
<b>Total macrofauna</b>							
Average abundance <sup>a</sup>	1,475	150	138	154	150	153	166
Standard deviation	443	24	36	53	27	29	60
Range <sup>a</sup>	930-1,999	126-189	98-174	106-235	131-197	113-187	116-265
<b>Major taxa</b>							
<b>Polychaete</b>							
Average abundance <sup>a</sup>	1,229	64	37	58	34	45	32
Standard deviation	448	11	14	35	10	16	8
Percent of total	83	43	27	38	23	29	19
<b>Mollusc</b>							
Average abundance <sup>a</sup>	208	71	51	67	106	94	108
Standard deviation	66	19	13	28	33	10	47
Percent of total	14	47	37	44	71	61	65
<b>Crustacean</b>							
Average abundance <sup>a</sup>	33	12	43	23	6	11	20
Standard deviation	16	5	21	11	2	5	5
Percent of total	3	8	31	15	4	7	12

<sup>a</sup> Individuals per box core (0.06 m<sup>2</sup>).

materials. Crustacean ranked third in major taxa abundance at all but one of the seven stations listed in Table 17. With the exception of Station BBB01, the relative abundance of major taxa generally remained consistent among stations. The sediment grain-size and IOC content also varied little among stations.

The relatively low variability in total benthic infauna abundance and major taxa among the five replicate samples collected at each station will lower the minimal detectable differences achievable during post-disposal monitoring. Excluding the data for Station BBB02, which were an exception to this generalization, a minimal detectable difference of 54 percent of the grand mean can be expected for tests of total benthic infauna abundance ( $s^2 = 1,641$ ;  $\bar{x} = 152$ ;  $\alpha = 0.05$ ;  $1-\beta = 0.80$ ).

## BIOACCUMULATION

*C. subdiaphana* were collected at 16 stations in Bellingham Bay for bioaccumulation analyses (12 transect, 3 benchmark, and 1 site station). Tissue samples were analyzed for PSDDA chemicals of concern (except volatile organic compounds) at all stations except BBT12A, which was only analyzed for metals due to insufficient sample size. No *C. subdiaphana* were collected at Station BBB02 after 12 casts with the van Veen sampler.

Tissue concentrations for all chemicals detected in sediments are summarized in Table 18. All of the metals of concern were detected in all of the Bellingham Bay stations except for antimony. Of the metals detected, tissue concentrations varied by a factor of 2 or less (for cadmium and nickel) to a factor of 15 (for arsenic) among samples collected from Bellingham Bay. Metal concentration ranges (in mg/kg wet weight) were from 0.16 to 2.3 for arsenic, 0.29 to 0.60 for cadmium, 0.73 to 4.6 for copper, 0.02 to 1.6 for lead, 0.02 to 0.05 for mercury, 0.40 to 0.78 for nickel, 0.11 to 0.89 for silver, and 6.1 to 12.8 for zinc. No geographical gradients in tissue metals concentrations were noted, and all values were less than PSDDA guidelines (Table 18).

The only organic compounds detected in tissue samples from Bellingham Bay were benzoic acid (15/15 samples), bis(2-ethylhexyl)phthalate (2/15 samples), and 2-methylphenol (1/15 samples). Concentrations of benzoic acid ranged from 2,800 to 25,000 ng/g wet weight. Bis(2-ethylhexyl)-phthalate was less than the PSDDA guideline value (Table 18).

Possible sources of benzoic acid are atmospheric (from auto exhaust and refuse combustion) and wastewater discharge. Benzoic acid also occurs naturally in berries and resins. Bioconcentration factors (BCF) have been shown to be high in a gastropod (i.e., 2,800), though the investigators measured total radioactivity from labeled compound, not benzoic acid, so metabolites may have also accumulated in the snails. Bis(2-ethylhexyl)phthalate is a very common plasticizer often found in the environment and as a laboratory contaminant. 2-Methylphenol is commonly found in solvents and disinfectants, and as a degradation product of wood and pulp processing.

## SUMMARY

The most notable feature of the Bellingham Bay disposal site was the presence of disturbed sediment at the southeast portion of the site (i.e., Stations BBP01, BBP02, BBT01, BBT02, and BBT03). The REMOIS® photograph revealed a layer of low-reflectance material located several centimeters below the sediment/water interface. No other variables were correlated with the presence of this layer.

TABLE 18. CONCENTRATIONS OF DETECTED PSDDA CHEMICALS OF CONCERN AND DETECTION FREQUENCY IN *COMPSOMYAX SUBDLAPHANA* TISSUE FROM BELLINGHAM BAY

Chemical	Range <sup>a</sup>	Detection Frequency	PSDDA Tissue Guideline
Organic Compounds			
benzoic acid	2,750-25,000	1.0	--
bis(2-ethylhexyl)phthalate	U82-3,000	0.1	15,000
2-methylphenol	U58-E180	0.1	--
Metals			
arsenic	0.16-E2.3	1.0	10.1
cadmium	0.34-0.6	1.0	--
copper	0.73-4.6	1.0	--
lead	Z0.02-1.6	1.0	--
mercury	0.02-0.05	1.0	300
nickel	0.40-0.78	1.0	20,000
silver	E0.11-E0.89	1.0	200
zinc	6.1-12.8	1.0	--

<sup>a</sup> Concentrations of organic compounds are measured in  $\mu\text{g}/\text{kg}$  dry weight. Metals concentrations are measured in  $\text{mg}/\text{kg}$  dry weight.

Sediment concentrations of several PSDDA chemicals of concern exceeded the SL in Bellingham Bay. The ML values were exceeded for phenol at one station, BBP04. Organic chemicals with sediment concentrations that exceeded the SL include phenol, 4-methyl phenol, and benzoic acid. Mercury was the only metal to exceed the SL.

Seven stations had sediment concentrations exceeding the SL for mercury (i.e., Stations BBB01, BBB02, BBP01, BBP02, BBP03, BBP04, and BBZ01). The highest concentration of mercury (0.56 mg/kg dry weight) was found in sediments collected from Station BBB01.

Macrobenthic abundance in Bellingham Bay was typical of shallow-water coastal areas. Molluscs were the most abundant major taxon at all stations sampled except Station BBB01. At Station BBB01, polychaetes were the most abundant taxon, averaging 1,229 individuals per box core. Cirratulid polychaetes, a taxonomic family frequently associated with areas of organic enrichment, were responsible for the high density of organisms at this station.

All sediments tested in Bellingham Bay met PSDDA Phase II disposal guidelines. The sediment chemistry and bioassay data from Bellingham Bay will not change any existing Puget Sound apparent effects threshold values.

#### 4. DATA SUMMARY FOR ANDERSON/KETRON ISLANDS DISPOSAL SITE AND CARR INLET REFERENCE STATION

##### OVERVIEW OF SAMPLING

One zone station, four perimeter stations, six transect stations, and one benchmark station were sampled at the Anderson/Ketron islands disposal site. REMOTS® photographs were collected at additional site and perimeter stations. One reference station in Carr Inlet was also sampled. Coordinates of these stations and the types of data collected at each station are listed in Tables 19 and 20. A summary of the data collected from each sample is shown in Tables 21 and 22. The analysis codes used in Tables 21 and 22 are listed in Table 6.

Station positioning was achieved using shore-based transponders located at the Dupont Powderworks, Riviera Country Club pier, and the yard of Bill and Joy Johnston on Anderson Island. These locations are shown in Figure 5. Detailed descriptions are provided in Tables 23, 24, and 25. The navigation system is described in Appendix A.

Sediment texture throughout the site was a mixture of silt, clay, and sand. Sediments at the center of the site were generally finer, and increasing proportions of sand found at greater distances. Sand constituted such a high fraction of the bottom sediment at Station AKT06 (the northernmost transect station) that adequate penetration of the mini-Soutar sampler could not be achieved even with all extra weight added. Sand also made up a significant fraction of the sediment at Station AKB02, the only benchmark station sampled. *C. subdiaphana* was the only benthic organism of sufficient size and abundance to be used for bioaccumulation studies. During sampling, its abundance seemed to be positively correlated with finer sediment size fractions. No *C. subdiaphana* were found at Station AKB02. Several individuals of *M. intermedia* were observed during bioaccumulation sampling but none were collected at Station AKB02.

Sediment at the Carr Inlet reference station was silt and clay, soft enough that the van Veen grab sampler was used with all extra weights removed.

##### REMOTS® DATA

A total of 42 REMOTS® stations were sampled at the Anderson/Ketron islands disposal site, including 12 stations within the site (S), 16 at the perimeter of the site (P), 10 along transects (T), and 4 from benchmark (B) stations (Figure 6). Three replicate images were obtained at each station. At least one image was analyzed for each station, and two images were analyzed at Stations AKP01, AKT01, AKT02, AKT03, AKT07, AKT08, AKB01, and AKB04.

##### Physical Characteristics

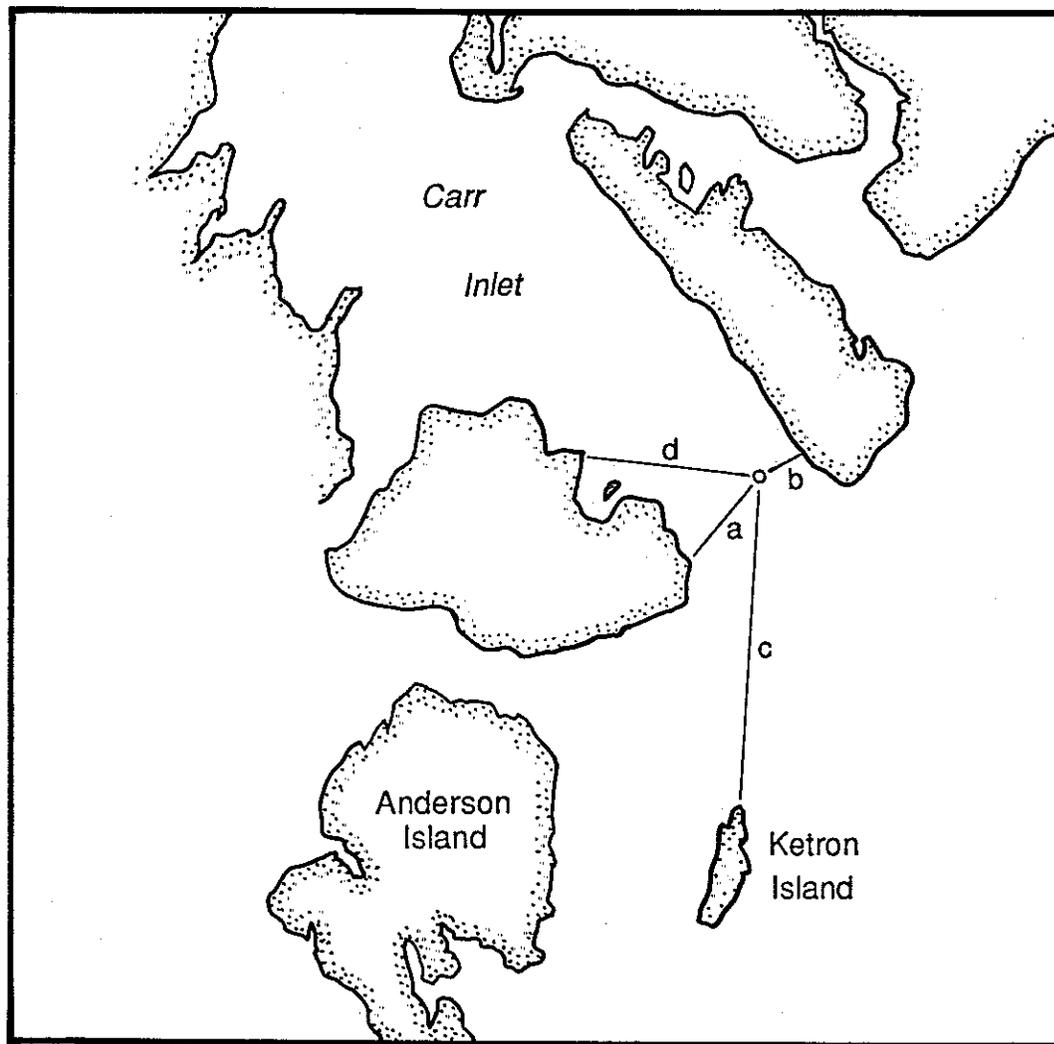
Most of the Anderson/Ketron islands disposal site stations are characterized by a mixture of fine-grained sediments and very fine to fine sands. Comparison of the REMOTS® images using the grain-size comparator indicated that the grain-size of the fine-grained material was >4 phi and the fine sands ranged from 4-3 and 3-2 phi (Supplement, Plate 4). Typically, relatively coarse material was observed at the sediment/water interface (0-4 cm depth) overlying finer material at depth (Supplement, Plate 5). Several peripheral stations along the eastern, western, and northern

TABLE 19. SAMPLING STATION LOCATIONS AND TYPES  
OF DATA COLLECTED AT ANDERSON/KETRON ISLANDS DISPOSAL SITE

Station	Latitude	Longitude	REMOTS*	Sediment Chemistry	Bioassay	Infauna Abundance	Bioaccumu- lation
AKZ01	47 09 25.80	122 39 24.00		C	B		
AKS01	47 09 12.60	122 39 30.00	R				
AKS03	47 09 12.90	122 39 16.38	R				
AKS04	47 09 16.44	122 39 09.96	R				
AKS05	47 09 27.18	122 39 03.12	R				
AKS06	47 09 32.58	122 39 04.80	R				
AKS07	47 09 36.60	122 39 08.82	R				
AKS08	47 09 40.56	122 39 17.46	R				
AKS09	47 09 40.92	122 39 26.04	R				
AKS10	47 09 39.90	122 39 32.04	R				
AKS11	47 09 35.76	122 39 39.00	R				
AKS12	47 09 24.84	122 39 43.50	R				
AKS13	47 09 19.32	122 39 43.02	R				
AKP01	47 08 58.20	122 39 36.42	R	C			
AKP02	47 09 16.50	122 38 49.80	R	C			
AKP03	47 09 53.88	122 39 11.40	R	C			
AKP04	47 09 35.40	122 39 58.80	R	C			
AKP05	47 08 57.72	122 39 20.16	R				
AKP06	47 09 00.12	122 39 08.70	R				
AKP07	47 09 07.62	122 38 55.92	R				
AKP08	47 09 28.68	122 38 45.24	R				
AKP09	47 09 38.76	122 38 47.76	R				
AKP10	47 09 46.68	122 38 55.32	R				
AKP11	47 09 54.78	122 39 27.96	R				
AKP12	47 09 52.50	122 39 39.78	R				
AKP13	47 09 44.88	122 39 52.62	R				
AKP14	47 09 23.40	122 40 02.64	R				
AKP15	47 09 13.14	122 40 00.60	R				
AKP16	47 09 05.58	122 39 52.68	R				
AKT01	47 08 49.80	122 39 40.08	R			I	A
AKT02	47 08 41.40	122 39 43.98	R			I	A
AKT03	47 08 33.00	122 39 47.40	R			I	A
AKT04	47 10 02.40	122 39 07.80	R			I	A
AKT05	47 10 10.80	122 39 03.90	R			I	A
AKT06	47 10 19.92	122 39 00.00	R			I	A
AKT07	47 08 45.54	122 39 42.18	R				
AKT08	47 08 37.32	122 39 45.90	R				
AKT09	47 10 06.72	122 39 05.70	R				
AKT10	47 10 15.54	122 39 01.68	R				
AKB01	47 10 36.00	122 39 46.50	R				
AKB02	47 09 48.60	122 38 30.48	R	C	B	I	
AKB03	47 08 22.80	122 39 00.00	R				
AKB04	47 08 00.00	122 40 00.00	R				

TABLE 20. REFERENCE STATION LOCATIONS AND TYPES OF DATA COLLECTED IN CARR INLET

Station	Latitude	Longitude	Sediment Chemistry	Bioassay
CRR01 <sup>a</sup>	47 13 11.40	122 37 27.00	C	B



<sup>a</sup> Radar range for CRR01: Northeast point of McNeil Island - 1.00 mile  
 Fox Island shore - 0.47 mile  
 North end of Ketron Island - 3.13 miles  
 Point west of Gertrude Island - 1.74 miles.

TABLE 21. SAMPLING INFORMATION FOR ANDERSON/KETRON ISLANDS DISPOSAL SITE

Station	Sample	Field Replicates	Date	Time	No. of Grabs	Analysis Codes <sup>a</sup>
AKZ01	AKZ01C		04/28/89	1059	8	G,V,Q,P,Z,M,S,I,B
AKB02	AKB02C		04/28/89	1217	12	G,V,Q,P,Z,M,S,I,B
AKP01	AKP01C		04/28/89	1420	6	G,V,Q,P,Z,M,S,I
AKP04	AKP04C		04/28/89	1515	6	G,V,Q,P,Z,M,S,I
AKP02	AKP02C		05/01/89	0843	6	G,V,Q,P,Z,M,S,I
AKP03	AKP03C		05/01/89	0947	8	G,V,Q,P,Z,M,S,I
AKT03	AKT03I	1	05/01/89	1143	1	I,G
AKT03	AKT03I	2	05/01/89	1202	1	I
AKT03	AKT03I	3	05/01/89	1219	1	I
AKT03	AKT03I	4	05/01/89	1232	1	I
AKT04	AKT03I	5	05/01/89	1243	1	I
AKT02	AKT02I	1	05/01/89	1321	1	I,G
AKT02	AKT02I	2	05/01/89	1335	1	I
AKT02	AKT02I	3	05/01/89	1404	1	I
AKT02	AKT02I	4	05/01/89	1417	1	I
AKT02	AKT02I	5	05/01/89	1434	1	I
AKT01	AKT01I	1	05/01/89	1450	1	I,G
AKT01	AKT01I	2	05/01/89	1507	1	I
AKT01	AKT01I	3	05/01/89	1521	1	I
AKT01	AKT01I	4	05/01/89	1532	1	I
AKT01	AKT01I	5	05/01/89	1545	1	I
AKT04	AKT04I	1	05/02/89	0855	1	I,G
AKT04	AKT04I	2	05/02/89	0920	1	I
AKT04	AKT04I	3	05/02/89	0933	1	I
AKT04	AKT04I	4	05/02/89	1001	1	I
AKT04	AKT04I	5	05/02/89	1014	1	I
AKT05	AKT05I	1	05/02/89	1039	1	I,G
AKT05	AKT05I	2	05/02/89	1057	1	I
AKT05	AKT05I	3	05/02/89	1111	1	I
AKT05	AKT05I	4	05/02/89	1127	1	I
AKT05	AKT05I	5	05/02/89	1142	1	I
AKB02	AKB02I	1	05/02/89	1343	1	I,G
AKB02	AKB02I	2	05/02/89	1401	1	I
AKB02	AKB02I	3	05/02/89	1414	1	I
AKB02	AKB02I	4	05/02/89	1428	1	I
AKB02	AKB02I	5	05/02/89	1444	1	I
AKT06	AKT06I	1	05/02/89	1542	1 <sup>b</sup>	I,G
AKT06	AKT06I	2	05/02/89	1542	1 <sup>b</sup>	I
AKT06	AKT06I	3	05/02/89	1613	1 <sup>b</sup>	I
AKT06	AKT06I	4	05/02/89	1613	1 <sup>b</sup>	I
AKT06	AKT06I	5	05/02/89	1639	1 <sup>b</sup>	I
AKT03	AKT03A		05/03/89	1000	24	P,M
AKT02	AKT02A		05/03/89	1150	24	P,M
AKT01	AKT01A		05/03/89	1430	24	P,M
AKT04	AKT04A <sup>c</sup>		05/03/89	1640	26	P,M
AKT05	AKT05A		05/04/89	1200	24	P,M
AKT06	AKT06A		05/04/89	1420	24	P,M
AKT04	AKT04A-R <sup>c</sup>		05/04/89	1600	24	P,M

<sup>a</sup> Analysis codes defined in Table 6

<sup>b</sup> Sample collected from one side of the dual 0.1 m<sup>2</sup> van Veen grab sampler rather than the 0.6 m<sup>2</sup> mini-Soutar box corer.

<sup>c</sup> Samples AKT04A and AKT04A-R were composited for analysis.

TABLE 22. SAMPLING INFORMATION FOR  
CARR INLET REFERENCE STATION

Station	Sample	Field Replicate	Date	Time	No. of Grabs	Analysis Codes <sup>a</sup>
CRR01	CRR01C	0	04/28/89	0745	18	G,V,Q,P,Z,M,S,I,B

<sup>a</sup> Analysis codes are defined in Table 6.

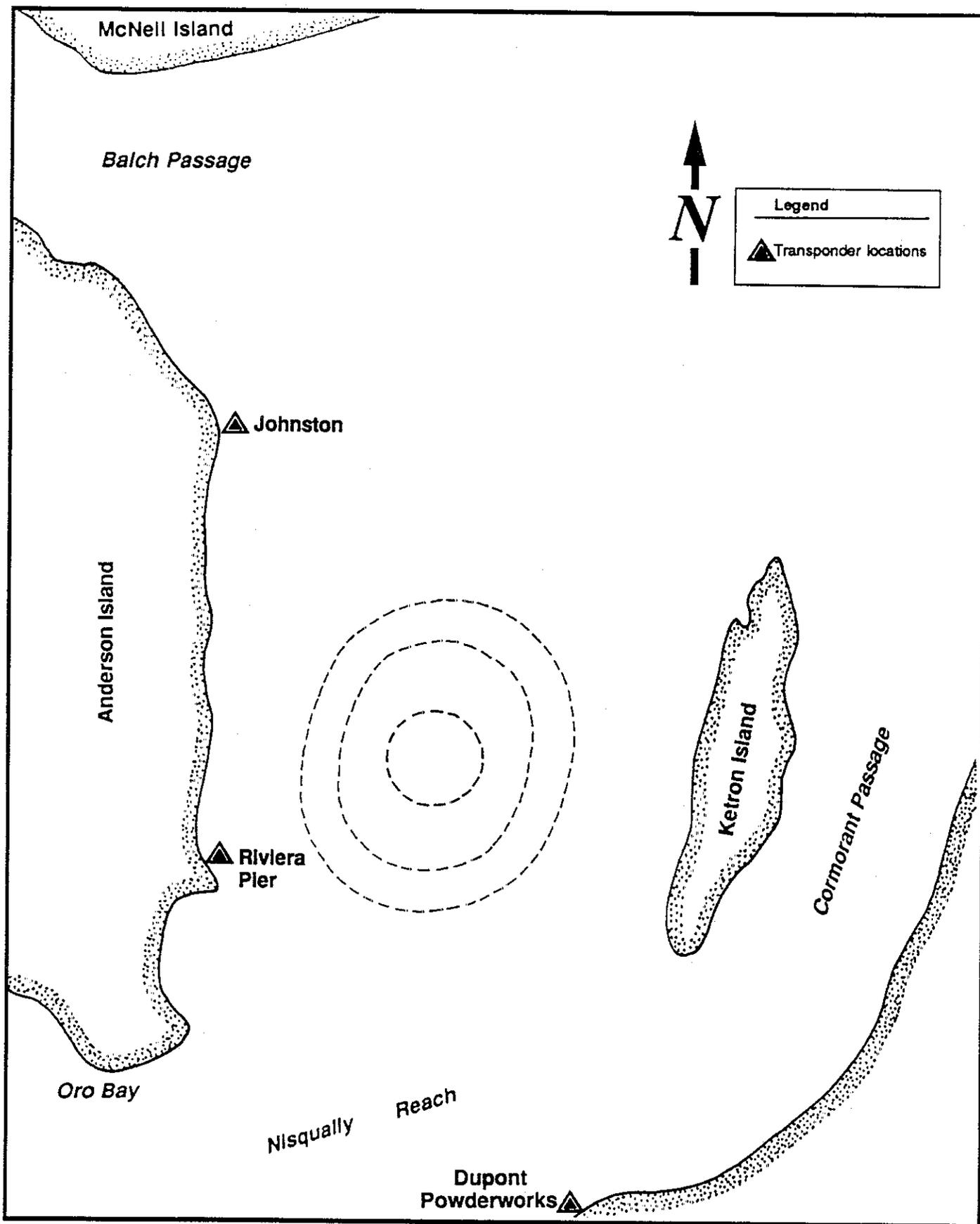


Figure 5. Transponder locations at Anderson/Ketron islands disposal site

**TABLE 23. DUPONT POWDERWORKS TRANSPONDER LOCATION**

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<b>STATION NAME:</b>	DUP
<b>GENERAL LOCATION:</b>	Nisqually Reach, Dupont, WA
<b>SPECIFIC LOCATION:</b>	Old Dupont Powderworks, Dupont, WA
<b>COORDINATES:</b>	<b>GEODETIC LATITUDE:</b> 47 07' 08.48"N <b>GEODETIC LONGITUDE:</b> 122 39' 47.93"W
<b>WASHINGTON STATE PLANE COORDINATES (SOUTH ZONE)</b>	<b>X:</b> 1,461,467.87 <b>Y:</b> 658,567.58

**STATION IS A BENCHMARK**

**CONTACT:** Mr. Bob Shedd  
Weyerhaeuser Corporation  
(for use of access road through Weyerhaeuser property)

From Interstate-5 traveling south, take exit 218 (the Dupont-Steilacoom exit) and head west. Turn right at the traffic light on the Dupont-Steilacoom highway. Follow this road a few miles, watching for a large landfill on the left side of the road. Turn left on the gravel road immediately preceding the landfill. Follow this gravel road to its termination in a small parking area. Follow the trail from the parking area down the hill to the railroad tracks. Turn right at the railroad tracks and head north approximately 300 feet. The benchmark is 40 feet west of the railroad tracks.

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**TABLE 25. JOHNSTON TRANSPONDER LOCATION**

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**STATION NAME:** JOHNSTON

**GENERAL LOCATION:** Nisqually Reach, Anderson Island, WA

**SPECIFIC LOCATION:** 9513 Villa Beach Road, Anderson Island, WA

**COORDINATES:** GEODETIC LATITUDE: 47 10' 13.32"N  
GEODETIC LONGITUDE: 122 40' 26.76"W

**WASHINGTON STATE PLANE COORDINATES (SOUTH ZONE)** X: 1,459,301.24  
Y: 677,370.44

**STATION SURVEYED BY:**

Mr. Vic McLind  
Sprout Engineers  
100 - 116th Avenue, S.E.  
Bellevue, WA 98004  
206/455-8454

**CONTACT:** Mr. Bill Johnston and Mrs. Joy Johnston  
9513 Villa Beach Road  
Anderson Island, WA 98303

Take the Anderson Island ferry from Steilacoom. Disembarking on Anderson Island, take the first left turn after leaving the ferry ramp, on Villa Beach Road. Follow Villa Beach Road south to the first house on the left, the Johnston residence at 9513 Villa Beach Road. The station is marked by a brass tack and nail about 3 feet from the bluff in the yard of the Johnston's residence.

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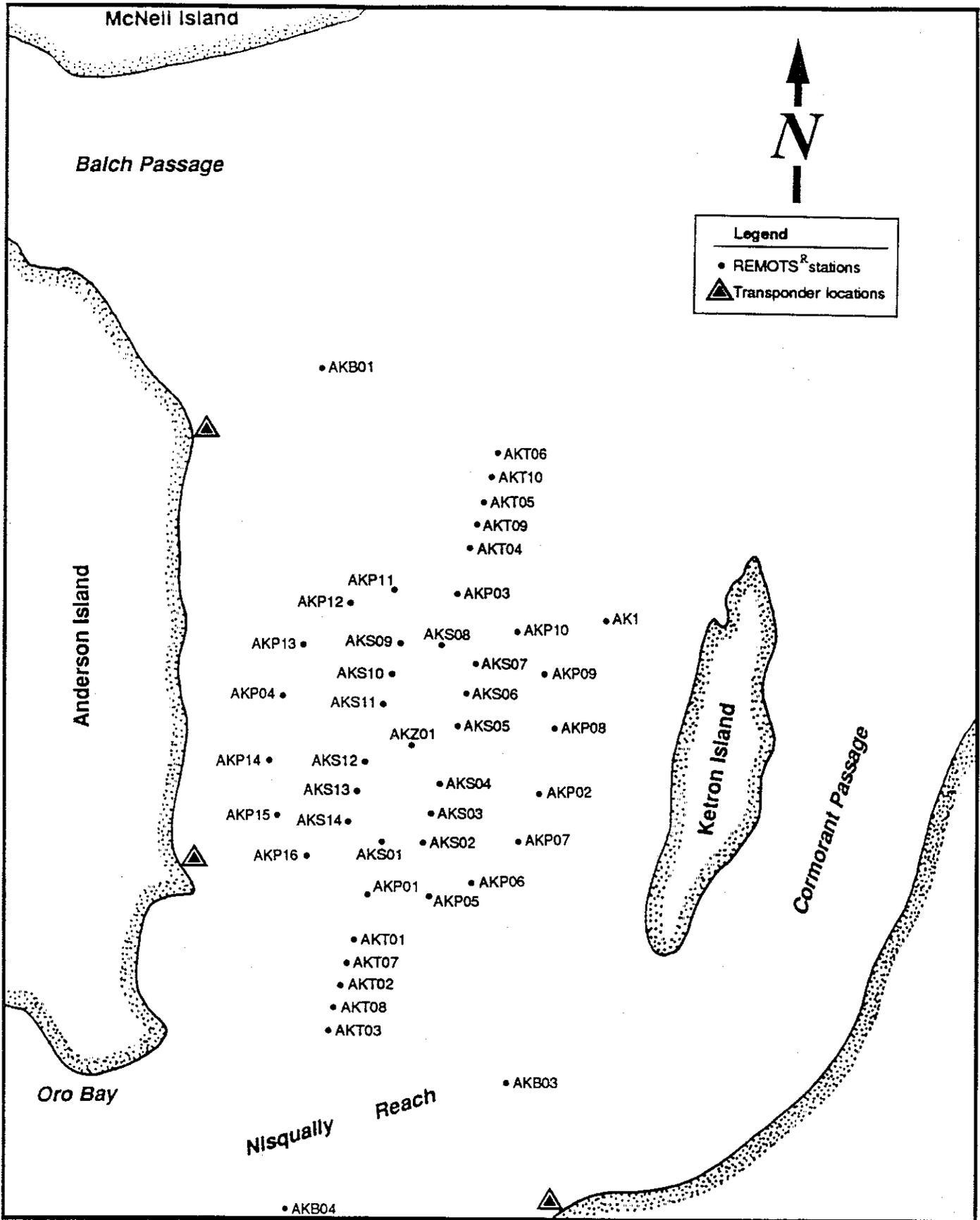


Figure 6. REMOTS<sup>®</sup> stations at the Anderson/Ketron islands disposal site

borders of the area surveyed are both shallower than the disposal site and are dominated by very fine sands, suggesting increasing kinetic gradients away from the disposal site. This suggestion is further supported by the distribution of prism penetration depths, which show relatively deep penetration throughout the center of the disposal site, while outlying areas show reduced prism penetration and apparently represent more hydrodynamically active environments. These areas include the northernmost stations (AKB01, AKT06, AKT10, and AKT05), the southwestern flank (AKP14, AKP15, and AKP16), and the southernmost stations (AKT03 and AKB04). This pattern is consistent with previous studies around the Anderson/Ketron islands disposal site.

The sediment surface at the disposal site reflects extensive reworking by benthic organisms at some stations and physically controlled fractures at other stations located in shallower depths outside of the disposal site. Analysis of REMOTS® images and measurements of boundary roughness indicate that one-third of the stations, scattered throughout the area, show predominately biogenic roughness features, such as fecal mounds (Supplement, Plate 6) and feeding depressions, while the remaining stations exhibit physically induced surface features, such as bedforms (Supplement, Plate 7).

The apparent RPD ranges from 1.3 to 4.5 cm. Relatively deep apparent oxidized layers occur in the southern two-thirds of the site. The peripheral and outlying areas generally show shallower RPD values (e.g., the northernmost stations exhibit values <2.0 cm). However, excluding the far northern stations, there are no steep gradients in biogenic mixing depths across the site.

### **Biological Characteristics**

Analysis of the REMOTS® images indicates that Stage III benthic communities are present at most stations. In general, the presence of head-down, deposit-feeding Stage III taxa is evidenced by the presence of feeding voids. In several images, however, large polychaetes are directly observed at depth in the sediment column (Supplement, Plate 8). Stage III infauna are widespread throughout the central portion of the disposal area and along both the north and south transects. The eastern and western borders of the site and both Stations AKB01 and AKB04 appear to lack Stage III taxa. While the apparent lack of these taxa at Stations AKB01 and AKB04 may be an artifact of relatively poor camera prism penetration, the RPD depths and physical characteristics associated with these areas support the inference that these sites are physically disturbed relative to the remainder of the region.

### **SEDIMENT CHEMISTRY**

One zone station, four perimeter stations, and one benchmark station were sampled for chemistry analyses at the Anderson/Ketron islands disposal site. Sampling station locations are described in Table 21 and illustrated in Figure 7.

Concentrations of conventional variables are summarized in Table 26. Concentrations of chemicals of concern that were detected are presented in Table 27. Chemical data are presented in Appendix C. The concentrations of these chemicals are grouped by location (i.e., zone, perimeter, and benchmark stations) in Table 28.

No organic chemical exceeded the PSDDA SL. Only one metal, zinc (266 mg/kg dry weight), exceeded the SL by a factor of 1.69. Zinc exceeded the SL at only Station AKP02 and never exceeded the ML. Appendix B (Table B-28) contains the PSDDA Phase II SL and ML values used to screen the data.

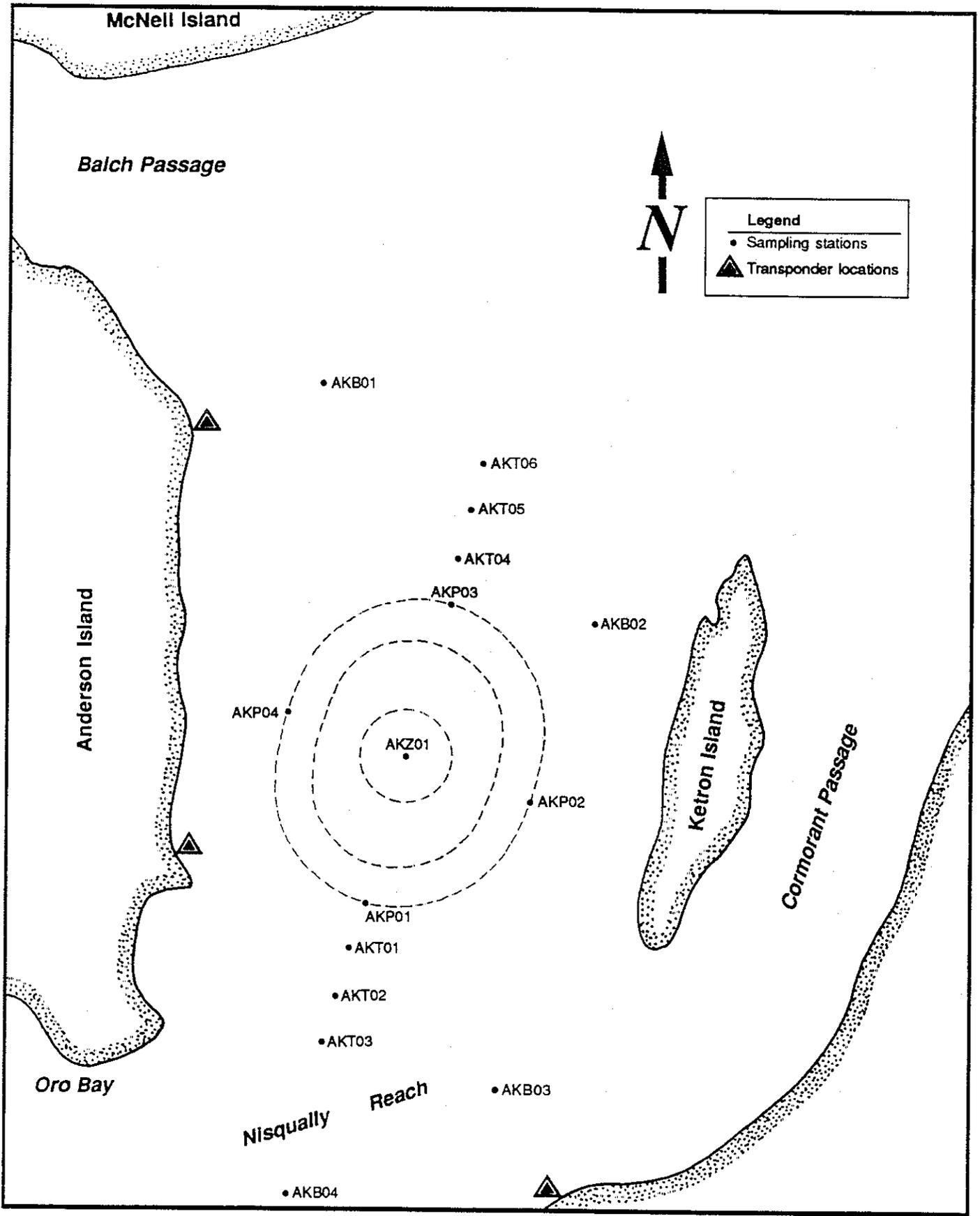


Figure 7. Location of chemistry, bioassay, infauna, and bioaccumulation stations at the Anderson/Ketron islands disposal site

**TABLE 26. CONCENTRATIONS OF CONVENTIONAL VARIABLES IN SURFACE SEDIMENTS FROM ANDERSON/KETRON ISLANDS DISPOSAL SITE<sup>a</sup>**

Variable	Range	Location of Maximum
Total organic carbon	0.4-1.0%	AKZ01
Ammonia-nitrogen	32.6-59.3 mg/kg	AKP01
Sulfides	U <sup>b</sup> 1.0 mg/kg	N/A <sup>c</sup>
Total solids	45.7-56.8%	AKB02
Total volatile solids	2.1-4.0%	AKZ01
Percent fines	13.1-41.6%	AKZ01

<sup>a</sup> Concentrations on dry weight basis except total solids.

<sup>b</sup> U - undetected at 1.0 mg/kg.

<sup>c</sup> N/A - not applicable, undetected in all samples.

TABLE 27. CONCENTRATIONS OF PSDDA CHEMICALS OF CONCERN  
 DETECTED IN SURFACE SEDIMENTS FROM  
 ANDERSON/KETRON ISLANDS DISPOSAL SITE<sup>a</sup>

Chemical	Range <sup>b</sup>	Median <sup>b</sup>	Detection Frequency <sup>c</sup>	Location of Maximum
<b>LPAH</b>				
phenanthrene	E5.1-Z31	E17	0.67	AKP03
anthracene	E5.1-Z10	E7	0.50	AKP03
<b>HPAH</b>				
fluoranthene	Z15-Z53	Z25	1.0	AKP03
pyrene	Z15-Z55	Z27	1.0	AKP03
benzo(a)anthracene	8.0-Z21	Z10	0.83	AKP03
chrysene	Z9.0-Z32	Z19	1.0	AKP03
total benzofluoranthenes	E22-E72	E39	1.0	AKP03
benzo(a)pyrene	U5.1-E29	E15	0.83	AKP03
indeno(1,2,3-c,d)pyrene	U5.1-E7.9	U6.8	0.17	AKP04
benzo(g,h,i)perylene	U5.1-E8.9	U6.8	0.17	AKP04
<b>Phenols</b>				
pentachlorophenol	U8.0-E54	U11	0.17	AKP04
<b>Phthalates</b>				
bis(2-ethylhexyl)phthalate	Z26-Z52	Z32	1.0	AKP02
di-n-octyl phthalate	U5.1-E17	U6.8	0.17	AKP04
<b>Miscellaneous extractables</b>				
benzoic acid	E28-U76	U61	0.17	AKP02
<b>Organometallic compounds</b>				
tributyltin <sup>d</sup>	0.95-3.0	2.0	0.67	AKP01
<b>Metals<sup>e</sup></b>				
antimony	G.96-G2.5	G1.6	1.0	AKZ01
arsenic	6.6-15	11	1.0	AKZ01
cadmium	0.28-0.54	0.41	1.0	AKP01
copper	25.3-45.0	33.4	1.0	AKZ01
lead	13.8-26.1	19.7	1.0	AKZ01
mercury	0.07-0.16	0.11	1.0	AKZ01
nickel	16.6-27.8	26.9	1.0	AKP01
silver	0.16-0.35	0.27	1.0	AKZ01
zinc	58.5-266	82.7	1.0	AKP02

TABLE 27. (Continued)

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<sup>a</sup> Qualifier codes:

- G - estimate is greater than value shown
- U - undetected at detection limit shown
- E - estimate
- Z - blank-corrected, still above detection limit.

<sup>b</sup> Concentrations of organic compounds are measured in  $\mu\text{g}/\text{kg}$  dry weight. Metals concentrations are measured in  $\text{mg}/\text{kg}$  dry weight.

<sup>c</sup> Based on six sediment samples collected from the Anderson/Ketron islands.

<sup>d</sup> Tributyltin is not defined as a PSDDA chemical of concern; concentrations expressed as the equivalent concentration of tin.

<sup>e</sup> All results reported for the strong acid digestion technique.

**TABLE 28. CONCENTRATIONS OF PSDDA CHEMICALS OF CONCERN  
DETECTED IN SURFACE SEDIMENTS FROM ANDERSON/KETRON ISLANDS  
BENCHMARK, SITE, AND PERIMETER STATIONS<sup>a</sup>**

Chemical	Benchmark Station <sup>b</sup>	Zone Station <sup>b</sup>	Perimeter Stations			
			Range <sup>b</sup>	Median <sup>b</sup>	Detection Frequency <sup>c</sup>	Location of Maximum
<b>LPAH</b>						
phenanthrene			E13-Z31	E17	0.75	AKP03
anthracene	B6.4	B6.4	E6.0-Z10	28.4	0.75	AKP03
<b>HPAH</b>						
fluoranthene	Z15	Z25	Z24-Z53	Z29	1.0	AKP03
pyrene	Z15	Z27	23-Z55	Z28	1.0	AKP03
benzo(a)anthracene	B8	Z11	Z9.0-Z21	Z12	1.0	AKP03
chrysene	Z9	Z20	Z14-Z32	Z21	1.0	AKP03
total benzofluoranthenes	E22	41	E37-E72	E39	1.0	AKP03
benzo(a)pyrene		E15	E14-E29	E15	1.0	AKP03
indeno(1,2,3-c,d)pyrene			U6.0-E7.9	U7.6	0.25	AKP04
benzo(g,h,i)perylene			U6.0-E8.9	U7.6	0.25	AKP04
<b>Phenols</b>						
pentachlorophenol			U10-E54	U12	0.25	AKP04
<b>Phthalates</b>						
bis(2-ethylhexyl)phthalate	Z26	Z27	Z32-Z52	Z34	1.0	AKP02
di-n-octyl phthalate			U6.0-E17	U7.6	0.25	AKP04
<b>Miscellaneous extractables</b>						
benzoic acid			E28-U78	U67	0.25	AKP02
<b>Organometallic compounds</b>						
tributyltin <sup>d</sup>			0.95-3.0	2.1	0.75	AKP01
<b>Metals<sup>e</sup></b>						
antimony	G1.2	G2.5	G0.96-G1.9	G1.6	1.0	AKP03
arsenic	6.6	15.2	6.7-12.7	11.0	1.0	AKP03
cadmium	0.31	0.44	0.28-0.54	0.43	1.0	AKP01
copper	25.3	45	27.0-39.3	33.4	1.0	AKP03
lead	14.2	26.1	13.8-22.1	19.6	1.0	AKP01
mercury	0.07	1.6	0.08-0.13	0.11	1.0	AKP01
nickel	17.6	27	16.6-27.8	27.1	1.0	AKP01
silver	0.18	0.35	0.16-0.34	0.27	1.0	AKP03
zinc	58.5	89.8	67.9-266	82.7	1.0	AKP02

TABLE 28. (Continued)

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<sup>a</sup> Qualifier codes:

- B - blank-corrected down to detection limit
- U - undetected at detection limit shown
- E - estimate
- Z - blank-corrected, still above detection limit

<sup>b</sup> Concentrations of organic compounds are measured in  $\mu\text{g}/\text{kg}$  dry weight. Metals concentrations are measured in  $\text{mg}/\text{kg}$  dry weight.

<sup>c</sup> Based on samples collected from the four perimeter stations.

<sup>d</sup> Tributyltin is not defined as a PSDDA chemical of concern; concentrations expressed as the equivalent concentration of tin.

<sup>e</sup> All results are reported for the strong acid digestion technique.

The sediment sample collected from the reference station located in Carr Inlet (CRR01) did not exceed any SL or ML values. Sediment chemistry data from Carr Inlet met all P2 interim performance standards (Pastorok et al. 1989), although PCB were undetected and the detection limit exceeded the interim standard.

## BIOASSAYS

Bioassays were conducted on sediments from two Anderson/Ketron islands disposal site stations: the disposal zone station (AKZ01) and the benchmark station (AKB02) (Table 19; Figure 7). Responses for each bioassay are presented in Table 29. In addition, ranges for each of the bioassays performed on reference sediment collected from Carr Inlet are presented in Table 29. Data were analyzed in accordance with PSDDA Phase II test interpretation procedures. All data met dredged material disposal guidelines.

The amphipod bioassay met PSDDA control and reference performance standards, and all test sediments were <20 percent over control (Table 16). The Carr Inlet reference data for amphipod bioassays also met Element P2 performance standards (Pastorok et al. 1989).

Data for the oyster larvae bioassay listed in Table 16 are expressed as combined mortality and abnormality. All reference and test sediment values were standardized relative to the final seawater control responses as per PSDDA Phase II guidelines (i.e., the final number of healthy larvae in the seawater control was used as the initial value of larvae for the reference and test sediment analyses). PSDDA agencies are currently considering control and reference performance standards for the test. Combined mortality and abnormality in the seawater control and Carr Inlet reference sediment were 51 percent and 61 percent, respectively. All test sediments were within 20 percent of the Carr Inlet reference response.

All Microtox tests showed no dose response to Anderson/Ketron islands disposal site sediments. Sediments from all stations tested were therefore not toxic, and subsequent comparisons with Microtox reference were not performed. Bioassay results can be found in Appendix C.

## BENTHIC INFAUNA

Macrobenthic infauna samples were collected at seven stations at the Anderson/Ketron islands disposal site (Table 19; Figure 7). Only samples from the benchmark station AKB02 and the anticipated downcurrent or transect as specified by the Corps were analyzed; the remainder were archived. These data are presented in Appendix C and summarized in Table 30. Abundances are expressed as the average number of individuals per box core (0.06 m<sup>2</sup>). Benthic samples collected at all other stations were archived and may be analyzed by Ecology following the first post-disposal monitoring effort. Total abundance and number of taxa per station were relatively constant among the four locations. Total abundance ranged from an average of 146 to 237 individuals (2,433 to 3,950 individuals per square meter).

Crustaceans were the most abundant major taxon at the Anderson/Ketron islands disposal site, with station averages ranging from 91 to 165 individuals per box core. Polychaetes were the second most abundant group (25 to 57 individuals per box core), and molluscs ranked third (7 to 15 individuals per box core). The relative abundance of the major taxa was generally constant among all four stations. Densities of organisms at the transect stations were generally higher than at the benchmark station. Sediments at Station AKB02 were coarser (80 percent sand) and had less TOC content (0.5 percent) than at the transect stations. Infaunal differences between the center of the disposal site (including Stations AKT01, AKT02, and AKT03) and the peripheral areas (e.g.,

TABLE 29. BIOASSAY SUMMARY FOR ANDERSON/KETRON ISLANDS DISPOSAL SITE

Station	Amphipod Mortality			Oyster Larvae Abnormality and Mortality		
	Mean	Range	Standard Deviation	Mean	Range	Standard Deviation
<b>Anderson/Ketron</b>						
AKB02	0.13	0-0.25	0.12	0.36	0.11-0.76	0.75
AKZ01	0.17	0.05-0.3	0.10	0.53	0.44-0.72	0.91
<b>Control</b>	0.04 <sup>a</sup>	0-0.10 <sup>a</sup>	0.04 <sup>a</sup>	0.51 <sup>b</sup>		
<b>Reference</b>						
CRR01	0.04	0-0.10	0.04	0.61	0.47-0.75	0.89

Note: Microtox - all stations nontoxic,  $EC_{50} > 1,000 \mu\text{L}/\text{mL}$ . No light decrease observed.

<sup>a</sup> Sediment control

<sup>b</sup> Seawater control

TABLE 30. BENTHIC INFAUNA SUMMARY FOR  
ANDERSON/KETRON ISLANDS DISPOSAL SITE

	Station			
	AKB02	AKT01	AKT02	AKT03
<b>Total macrofauna</b>				
Average abundance <sup>a</sup>	146	237	205	172
Standard deviation	17	68	46	31
Range <sup>a</sup>	134-174	170-343	131-256	160-199
<b>Major taxa</b>				
Polychaete				
Average abundance <sup>a</sup>	43	57	25	27
Standard deviation	7	62	4	5
Percent of total	29	24	12	16
Mollusc				
Average abundance <sup>a</sup>	7	11	15	11
Standard deviation	4	5	4	6
Percent of total	5	5	7	6
Crustacean				
Average abundance <sup>a</sup>	91	165	165	133
Standard deviation	11	36	45	33
Percent of total	62	70	80	77

<sup>a</sup> Individuals per box core (0.06 m<sup>2</sup>).

Station AKB02) suggested by the REMOTS® images cannot be confirmed with either the major taxa data or total benthic abundance.

The relatively low variability in total benthic infauna abundance and major taxa among the five replicate samples collected at each station will decrease the minimal detectable differences achievable during post-disposal monitoring. A minimal detectable difference of 48 percent of the grand mean can be expected for tests of total benthic infauna abundance ( $s^2 = 1,966$ ;  $\bar{x} = 190$ ;  $\alpha = 0.05$ ;  $1-\beta = 0.80$ ).

## BIOACCUMULATION

*C. subdiaphana* were collected at six transect stations at the Anderson/Ketron islands disposal site for bioaccumulation analyses. No *C. subdiaphana* were collected at the benchmark station (AKB02) after 12 casts with the van Veen sampler. Tissue samples were analyzed for PSDDA chemicals of concern (except volatile organic compounds) at five Anderson/Ketron islands stations (AKT01A, AKT02A, AKT03A, AKT04A, and AKT05A) and just for metals (due to insufficient sample) at Station AKT06A.

Tissue concentrations for all chemicals detected in sediments are summarized in Table 31. All of the metals of concern were detected in all of the Anderson/Ketron islands samples except for antimony. Of the metals detected, tissue concentrations varied by a factor of 2 or less (for nickel, silver, and zinc) to a factor of 3 (for copper and mercury). Metal concentrations ranges (in mg/kg wet weight) were from 1.4 to 3.4 for arsenic, 0.40 to 0.80 for cadmium, 2.0 to 6.2 for copper, 1.8 to 4.7 for lead, 0.01 to 0.03 for mercury, 0.56 to 0.86 for nickel, 1.5 to 2.8 for silver, and 16.2 to 21.3 for zinc. All values were less than PSDDA tissue guidelines (Table 31).

The only organic chemical detected in tissue samples from the Anderson/Ketron islands disposal site was benzoic acid (in 4/5 samples). The detected concentrations of benzoic acid ranged from 8,800 to 26,000 ng/g wet weight.

Possible sources of benzoic acid are atmospheric (from auto exhaust and refuse combustion) and wastewater discharge. Benzoic acid also occurs naturally in berries and resins. BCF have been shown to be high in a gastropod (i.e., 2,800), though the investigators measured total radioactivity from labeled compound, not benzoic acid, so metabolites may have also accumulated in the snails.

## SUMMARY

The sediments in and near the Anderson/Ketron islands disposal site consist of a mixture of silt, clay, and very fine to fine sand. Stations along the eastern, western, and northern borders of the area are dominated by very fine sands, while stations along the southern border and in the central portion of the site are characterized by sediments having a high silt-clay fraction. One chemical, zinc, exceeded the SL by a factor of 1.69.

Crustaceans were the most abundant major taxon at the Anderson/Ketron islands disposal site. Densities of organisms among the transect stations were generally higher than at the benchmark station. All stations met PSDDA Phase II disposal guidelines based on the amphipod, oyster larvae, and Microtox bioassays. Amphipod mortality for bioassays conducted with sediments collected from Station AKZ01 were found to be significantly different from the Carr Inlet reference station, but the difference in mortality was less than 30 percent.

TABLE 31. CONCENTRATIONS OF DETECTED PSDDA CHEMICALS OF CONCERN AND DETECTION FREQUENCY IN *COMPSOMYAX SUBDIAPHANA* TISSUE FROM THE ANDERSON/KETRON ISLANDS DISPOSAL SITE

Chemical	Range <sup>a</sup>	Detection Frequency	PSDDA Tissue Guideline
Organic Compounds			
benzoic acid	U1,700-26,000	0.8	--
Metals			
arsenic	1.4-E3.4	1.0	10.1
cadmium	0.4-0.85	1.0	--
copper	2.0-6.2	1.0	--
lead	1.8-4.7	1.0	--
mercury	0.01-0.03	1.0	300
nickel	0.56-8.6	1.0	20,000
silver	E1.5-E2.8	1.0	200
zinc	16.2-21.3	1.0	--

<sup>a</sup> Concentrations of organic compounds are measured in  $\mu\text{g}/\text{kg}$  dry weight. Metals concentrations are measured in  $\text{mg}/\text{kg}$  dry weight.

## 5. CONCLUSIONS

Results of the PSDDA Phase II baseline survey are summarized in terms of accomplishments and changes to the sampling plan, which are discussed separately below.

### ACCOMPLISHMENTS

The PSDDA baseline cruise collected a total of 445 samples, categorized by data type and site as shown in Table 32. Of these samples, all sediment chemistry, bioassay, and bioaccumulation samples were analyzed. Only portions of the infauna abundance samples and REMOTS® images were analyzed in accordance with the Phase II monitoring plan. The resulting data will provide PSDDA agencies with the necessary information to monitor and detect changes in environmental conditions in and near the Bellingham Bay and Anderson/Ketron islands disposal sites as specified in the PSDDA monitoring plan.

### CHANGES TO SAMPLING PLAN

During field sampling, situations were encountered that required changes to the original sampling plan. These changes are summarized below:

- Bioaccumulation sampling at Station BBB02 resulted in an insufficient number of the selected organism (*C. subdiaphana*). A brief survey of alternative benchmark sites resulted in the establishment of a new station, BBB04. Bioaccumulation, sediment chemistry, and infauna data were collected at Station BBB04.
- Field observations of the abundance of *C. subdiaphana* in Bellingham Bay suggested that this clam occurred at the center of the site as well as the peripheral transect stations. Two casts were therefore made at Station BBBZ01 after all other bioaccumulation samples had been collected. Over 200 grams (wet weight in shell) were collected in these two casts. This tissue was analyzed.
- The bottom at Station AKT06 was too sandy to permit adequate penetration with the mini-Soutar box corer. Infauna samples were therefore taken using the dual van Veen grab sampler.

### RECOMMENDATIONS

The following summarizes recommendations for conducting post-disposal monitoring at the PSDDA disposal sites:

- Ensure that all future monitoring efforts at the PSDDA disposal sites incorporate the monitoring plan modifications instituted during the Phase I (PTI 1988) and Phase II baseline surveys
- Bioaccumulation trigger values for metals should be 2 times the tissue values reported in the baseline studies and organic compounds should be 5 times the tissue values

TABLE 32. NUMBERS OF SAMPLES COLLECTED DURING  
PSDDA PHASE II BASELINE SURVEY

Variable	Bellingham Bay	Anderson/Ketron Islands	Carr Inlet
Sediment chemistry	8	6	1
Bioassay	4	2	1
Infauna abundance	75 (40) <sup>a</sup>	35 (15) <sup>a</sup>	0
Bioaccumulation	15	7	0
REMOTS®	165 (98) <sup>b</sup>	126 (76) <sup>b</sup>	0

<sup>a</sup> Number in parentheses is the number of samples archived.

<sup>b</sup> Number in parentheses is the number of REMOTS® images archived.

- Post-disposal monitoring efforts for the Phase II disposal sites should be conducted in early April and monitoring efforts for the Phase I sites should be conducted in early May to maintain seasonal compatibility with the data collected during the baseline studies
- All future benthic infauna sampling at Station AKT06 should be conducted with a van Veen sampler to maintain sample equipment compatibility.

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