2010 Tiered-Full Monitoring at the Port Gardner Non-Dispersive Unconfined Open-Water Dredged Material Disposal Site

Data Report
Final

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LIST OF ACRONYMS AND ABBREVIATIONS

µg	microgram
°	degree
Φ	phi
AFDW	ash-free dry weight
ARI	Analytical Resources, Inc.
BCOC	bioaccumulative contaminant of concern
BT	bioaccumulation trigger
cm	centimeter(s)
COC	chemical of concern
CTS	Chemical Tracking System
DMMP	Dredged Material Management Program
DNR	Department of Natural Resources
DW	dry weight
Ecology	Washington State Department of Ecology
g	gram
Hg	mercury
HPAH	high molecular polycyclic aromatic hydrocarbons
kg	kilogram(s)
LCL	lower confidence limit
LPAH	low molecular polycyclic aromatic hydrocarbons
MDL	method detection limit
mg	milligram(s)
MIG	mean individual growth rate
ML	maximum level (DMMP chemical criteria)
mm	millimeter(s)
MRL	method reporting limit
NA	not applicable
NCMA	normalized combined mortality/abnormality
ND	not detected
ng	nanogram
OSI	organism-sediment index
PCB	polychlorinated biphenyl
pg	picogram

PSDDA	Puget Sound Dredged Disposal Analysis
PSEP	Puget Sound Estuary Program
QA/QC	Quality Assurance/Quality Control
QA1	Quality Assurance Level 1
QASAP	Quality Assurance, Sampling and Analysis Plan
QL	quantitation level
R/V	research vessel
RPD	redox potential discontinuity
RSD	relative standard deviation
SAD	Strong Acid Digestion
SAIC	Science Applications International Corporation
SL	screening level (DMMP chemical criteria)
SMARM	Sediment Management Annual Review Meeting
SMS	Washington State Sediment Management Standards
SQS	Washington State Sediment Quality Standards
SVOA	semi-volatile organic compound
SVPS	sediment vertical profiling system
TAD	Total Acid Digestion
TBT	tributyltin
TEF	toxic equivalent factor
TEQ	toxic equivalent quotient
TOC	total organic carbon
TS	total solids
TVS	total volatile solids
U.S. EPA	U.S. Environmental Protection Agency, Region 10
UCL	upper confidence limit
UEMP	Updated Environmental Monitoring Plan
USACE	U.S. Army Corps of Engineers
VOA	volatile organic analysis
WHO	World Health Organization

1.0 INTRODUCTION

This report presents the results of the 2010 tiered-full monitoring program conducted at the Port Gardner non-dispersive unconfined open-water dredged material disposal site in Puget Sound, Washington. The Washington State Department of Natural Resources (DNR) conducted this study through a contract with Science Applications International Corporation (SAIC).

The Port Gardner dredged material disposal site is located near Everett, WA, and was established in 1988 by the Dredged Material Management Program (DMMP[1]), formerly known as the Puget Sound Dredged Disposal Analysis (PSDDA) program, during the Phase I studies for central Puget Sound (PSDDA 1988a-d). Since the baseline surveys at the Port Gardner disposal site (PTI 1988), environmental monitoring has been conducted in 1990 (full monitoring), 1994 (tiered-full monitoring), and 2006 (full monitoring). The following objectives are identified for the 2010 full monitoring program at the Port Gardner site:

- Ensure that disposal activities comply with federal Clean Water Act Section 404(b)(1) guidelines.
- Verify DMMP predictions concerning site conditions following disposal events.
- Provide the State of Washington, federal agencies, and the public with disposal site monitoring information.
- Conduct increased monitoring of disposal sites for dioxin/furan concentrations to track the impact of updated dioxin/furan guidelines for dredged material disposal in Puget Sound (DMMP 2010a).
- Determine the low level concentrations of polybrominated diphenyl ethers (PBDEs) and polychlorinated biphenyl (PCB) congeners in sediments at the Port Gardner site.
- Contribute data for the annual review of the DMMP dredging and disposal site evaluation process.

The DMMP is responsible for the environmental management of dredged material in western Washington. The DMMP is an interagency partnership consisting of the DNR, the U.S. Army Corps of Engineers, Seattle District (USACE), the Washington State Department of Ecology (Ecology), and the U.S. Environmental Protection Agency, Region 10 (U.S. EPA). The DMMP provides guidance for evaluating proposed dredged material to determine its suitability for unconfined, open-water disposal, obtaining disposal site use permits, and monitoring disposal sites following dredged material disposal. In Puget Sound, this guidance is outlined in the PSDDA program. The PSDDA dredged material management plan was first implemented in June of 1988 for central Puget Sound sites (Phase I) and in September of 1989 for north and south Puget Sound sites (Phase II) (PSDDA 1988a-d, 1989a,b).

[1] The Puget Sound Dredged Disposal Analysis Program was renamed the Dredged Material Management Program (DMMP) following the expansion of the geographic focus beyond Puget Sound to Grays Harbor and Willapa Bay in 1995, and the Lower Columbia River in 1998.

2.0 REVIEW OF THE DMMP MONITORING PLAN

This section briefly describes the DMMP monitoring program design and presents modifications to the sampling and testing program as implemented in 2010. A comprehensive review can be found in the Updated Environmental Monitoring Plan (UEMP) (SAIC 2007).

2.1 DMMP Monitoring Framework

The full DMMP monitoring plan (PSDDA 1988a-d) assesses the physical, chemical, and biological effects of dredged material disposal at approved Puget Sound confined aquatic disposal sites and their surrounding environments. Under the monitoring framework, specific hypotheses were formulated to answer three questions:

1. Does the dredged material stay on site?

2. Has dredged material disposal caused the biological effects conditions for site management to be exceeded at the site?

3. Are unacceptable adverse effects due to dredged material disposal occurring to biological resources off site?

A summary of the monitoring framework and the specific hypotheses and interpretive guidelines are presented in Table 2–1. Under a tiered-full monitoring program, samples are collected to address all three questions in the DMMP monitoring framework, but only samples to address the first two questions are initially analyzed. Analysis of archived samples to address the third monitoring question is contingent on answers to the first two questions. The sampling is designed around monitoring seven station types at and in the vicinity of the disposal site. In addition, offsite reference stations are included to provide a control for sediment toxicity testing. The station types and their purpose are described in Table 2–2. Port Gardner stations are identified with a “PG” prefix followed by a “station type” designation and a unique number.

Five monitoring parameters have been identified to assess the environmental effects of dredged material disposal: sediment vertical profiling system (SVPS) photography, sediment chemistry, sediment toxicity, tissue chemistry, and benthic infaunal community structure (Table 2–3). Specific interpretive guidelines and trigger values have been established for each monitored parameter (see Table 2–1). If guideline values for a given parameter are exceeded during a monitoring event, a potential disposal impact is indicated and the benchmark station monitoring and baseline data are compared and evaluated.

Table 2–1. The DMMP Monitoring Framework

Question	Hypothesis	Monitored Variable	Interpretive Guideline	Action Item (When exceedances noted)[1]
No. 1 **Does the deposited dredged material stay on site?**	1. Dredged material remains within the site boundary.	Sediment Vertical Profiling System (SVPS) Onsite and Offsite	Dredged material layer is greater than 3 cm at the perimeter stations.	Further assessment is required to determine full extent of dredged material deposit.
	2. Chemical concentrations do not measurably increase over time due to dredged material disposal at offsite stations.	Sediment Chemistry Offsite	Washington State Sediment Quality Standards and Temporal analysis	Post-disposal benchmark station chemistry is analyzed and compared with appropriate baseline benchmark station data.
No. 2 **Are the biological effects conditions for site management [PSDDA-defined Site Condition II] exceeded at the site due to dredged material disposal? (PSDDA 1988b)**	3. Sediment chemical concentrations at the onsite monitoring stations do not exceed the chemical concentrations associated with PSDDA Site Condition II guidelines due to dredged material disposal.	Sediment Chemistry Onsite	Onsite chemical concentrations are compared to DMMP maximum levels.	DMMP agencies may seek adjustments of disposal guidelines <u>and</u> compare post-disposal benchmark chemistry with appropriate baseline benchmark station data.
	4. Sediment toxicity at the onsite stations does not exceed the PSDDA Site Condition II biological response guidelines due to dredged material disposal.	Sediment Bioassays Onsite	DMMP Bioassay Guidelines (Section 401 Water Quality Certification)	Benchmark station bioassays are performed (if archived after monitoring) and compared with baseline benchmark bioassay data.
No. 3 **Are unacceptable adverse effects due to dredged material disposal occurring to biological resources off site?**	5. No significant increase due to dredged material disposal has occurred in the chemical body burden of benthic infauna species collected downcurrent of the disposal site.	Tissue Chemistry Transect	Guideline values Metals: 3x the baseline concentrations Organics: 5x the baseline concentrations	Compare post-disposal benchmark tissue chemistry with baseline benchmark tissue chemistry data.
	6. No significant decrease due to dredged material disposal has occurred in the abundance of dominant benthic infaunal species collected downcurrent of the disposal site.	Infaunal Community Structure Transect	Guideline values Abundance of major taxa < ½ baseline macrobenthic infauna abundances	Compare post-disposal benchmark benthic data with baseline benchmark data.

1. To determine if observed changes in chemical conditions or infaunal benthos are due to dredged material disposal, data from the benchmark stations are considered. All decisions are subject to DMMP agency review and best professional judgment.

Table 2–2. Station Types and Purpose for the DMMP Sampling Design

Station	Designation Letter	Location	Purpose
Zone	Z	Within disposal target zone.	Assess sediment chemistry and toxicity of dredged material deposited in the target area (Question 2).
Site	S	Within the site boundary but outside of the target zone.	In conjunction with zone data, site station sediment chemistry and toxicity are used to evaluate Question 1.
Perimeter	P	Located 0.125 nautical mile from the site boundary.	Physical and chemical data are obtained to determine if dredged material is present beyond the site boundary and document the chemical character of sediments outside the site boundary (Question 1).
Transect	T	Situated along a radial transect that extends outward from the perimeter line. Located in the direction of dredged material transport.	Sampled for benthic infauna abundance and infauna tissue contaminant body burden to evaluate biological resource impacts off site (Question 3).
Benchmark	B	Located in the vicinity of the disposal site, but beyond the region affected by disposal activity.	Used to identify potential changes in sediment quality that may be unrelated to dredged material disposal. Data are evaluated only if site, perimeter, or transect data indicate that conditions at or adjacent to the site have changed relative to baseline conditions and to test hypotheses that observed changes are due to dredged material disposal.[1] Data may be used to evaluate Hypotheses 2 through 6.
Central Transect	C	Situated along two perpendicular lines that bisect the disposal site and may extend beyond its boundaries.	Used for physical measurements to map the post-disposal distribution of dredged material (Question 1).
Reference	R	Located in areas documented to be free of potential sources of contamination (e.g., Carr Inlet). Location is selected on the basis of grain size comparability with the bioassay test sediments.	Sediments used as a control for physical effects in toxicity testing.

1. All data types (physical, sediment chemistry, tissue chemistry, sediment toxicity, and benthic infauna) may be collected. Benchmark sediments are generally archived until disposal site analyses indicate benchmark data are needed for full evaluation. However, benchmark chemical analyses for volatile organics, mercury, sulfides, and ammonia are conducted in conjunction with disposal site sediments due to holding time constraints. In addition, because the freezing of bulk sediment samples may result in structural changes in the sediment, which will alter the availability of tributyltin (TBT), samples to be held for future TBT analysis should have interstitial water extracted prior to freezing (Hoffman 1998).

Table 2–3. DMMP Disposal Site Station Types and Monitoring Tools

Station	SVPS	Sediment Chemistry	Bioassays	Benthic Infauna	Tissue Chemistry
Zone (Z)	●	●	●		
Site (S)	●	○	○		
Perimeter (P)	●	●			
Transect (T)	●			○	○
Benchmark (B)		● (A)	● (A)	○ (A)	○ (A)
Central Transect (C)	●				
Floating (F)	●				
Reference (R)			●		

○ Monitoring tools used for an intensive full monitoring program
● Monitoring tools used for a partial monitoring or full monitoring program
(A) Archived

2.2 2010 Modifications to Sampling and Testing Procedures

2.2.1 Molpadia Sea Cucumber Collections

The *Molpadia intermedia* sea cucumber was the target organism for chemical analysis at the transect and benchmark stations; triplicate tissue chemistry samples were proposed at each station for a total of 15 samples. Similar to the 2006 Full Monitoring Survey (SAIC 2006), *Molpadia* densities were low in Port Gardner. Therefore, in consultation with DMMP agencies, enough tissue for only one replicate sample was targeted for collection at each station. The transect and benchmark *Molpadia* tissue samples were archived pending the results of the sediment chemistry analysis.

2.2.2 Dioxin/Furan Analysis of Sediments

Increased monitoring at the non-dispersive open-water disposal sites in Puget Sound is being conducted to track the impact of the existing interim and proposed updated dioxin/furan interim guidelines on sediment quality (DMMP 2010b). The existing disposal site management objective for dioxin/furan congeners is 4.1 pg/g TEQ for surface sediments within the boundary of the disposal site (i.e., the proposed updated interim guideline is 4.0 pg/g TEQ). The number of onsite sediment monitoring samples collected at the non-dispersive disposal sites was increased from three to 10 to allow for a more robust statistical comparison with the Puget Sound main basin/reference area dioxin/furan concentrations and verify compliance with the proposed disposal site management objective (DMMP 2010b).

Following completion of the SVPS survey, seven additional onsite stations were selected at the Port Gardner site for dioxin/furan congener testing in consultation with the DMMP agencies. Surface sediments (top 10 cm) were collected from zone stations PGZ01 and PGZ06, and site stations PGS01, PGS02, PGS04, PGS05, PGS06, PGS07, PGS08, and PGS09, and submitted for dioxin/furan congener analysis.

2.2.3 PCB Congeners and PBDE Analysis of Sediments

The updated dioxin/furan interim guideline represents a background-based guideline for managing a toxic, persistent pollutant in Puget Sound dredged material. This is a departure from risk-based or effects-based guidelines which, in the case of dioxin/furan congeners, are so low that they are unachievable (DMMP 2010c). In the future, the DMMP agencies are considering the use of background levels to develop guidelines for other highly toxic persistent pollutants such as PCB congeners and PBDEs. To support this

effort, surface sediments (top 10 cm) from the Port Gardner onsite, perimeter, and benchmark stations were analyzed for PCB congener and PBDEs using U.S. EPA Methods 1668A and 1614, respectively to achieve low-level detection limits.

2.3 Summary of 1988 Baseline Conditions

Baseline conditions at the Port Gardner disposal site are reported in PTI (1988). Clean, fine-grained sediments were reported at and surrounding the Port Gardner disposal site. SVPS results and sediment grain size data indicated the entire region, except well beyond the northern boundary of the site, was dominated by silt-clay sediments. Sand fractions were typically less than 5% at the onsite stations, and at stations beyond the northern and western site perimeter. Sand content increased gradually up to 47% away from the site in the southeast direction. SVPS infaunal successional stage data indicated that deep-dwelling, head-down, deposit-feeding organisms were present throughout the disposal site region.

All DMMP chemicals of concern (COCs) were below maximum levels (MLs), and only nickel and diethyl phthalate exceeded screening levels (SLs). Under current DMMP guidelines, nickel concentrations would be below the SL and the diethyl phthalate concentration at PGS04 would be at the current SL (200 µg/kg).

Benthic infaunal abundances and species composition were relatively uniform throughout the disposal site and immediate vicinity, except for station PGB02. This station is located west of the disposal site, and was characterized by low abundance and a different species composition. Bioassay results exceeded Site Condition II at PGB02 because of high amphipod (*Rhepoxynius abronius*) mortality. Concentrations of COCs in *Molpadia intermedia* tissues were low or undetected at the Port Gardner transect stations.

2.4 Summary of 1990 Full Monitoring Conditions

Full monitoring was conducted in the spring of 1990 (SAIC 1991) following placement of approximately 990,000 cubic yards of dredged material. Dredged material footprint mapping indicated the presence of dredged material beyond the site boundary with layers greater than 5 cm along the northern, western, and southwestern perimeter line. Sediment grain size distribution also suggested possible offsite deposition to the southeast.

Onsite sediment testing showed that all COCs were below DMMP SLs, and toxicity testing passed DMMP criteria. Seven perimeter chemistry values exceeded guideline values, but the elevated concentrations did not appear to be due to dredged material disposal. These perimeter chemistry values were qualified as estimated ("J" qualifier), and the associated guideline values were based on qualified or undetected baseline values.[2]

Station PGB02 was determined unsuitable as a benchmark station based on its atypical infaunal community, unusually high clay content relative to other Port Gardner stations, and the failure of toxicity testing during the 1988 baseline surveys. Abundance of dominant benthic infauna significantly decreased at both the transect stations (PGT11, PGT13, and PGT15) and benchmark station (PGB01) between the 1988 baseline and 1990 monitoring study. The difference was greater than 50% of the difference between the transect

[2] The guideline value approach (PTI 1988) for perimeter chemistry (1.25X for metals and 1.47X for organics) was found to be statistically flawed (Lester 1995) and replaced with comparisons to the Washington State Sediment Quality Standards (SQS) and temporal analysis using the Chemical Tracking System (CTS) (SAIC and MWLS 1996).

stations, indicating an area-wide change in Port Gardner due to environmental factors other than dredged material disposal.

Tissue COCs in *Molpadia intermedia* at transect stations increased relative to baseline concentrations, and exceeded the guideline values for arsenic and nickel. This finding may have been an artifact of specimen size differences between the baseline and 1990 surveys, and the results were deemed inconclusive.[3] Based on the 1990 monitoring results, the DMMP agencies initiated a number of site management and monitoring changes, including the following:

- All dredged material disposal will occur at the site center to minimize the possibility of offsite dumping.
- A study was conducted to establish a new benchmark station (PGB09) to replace PGB02.
- A study of the bioaccumulation organism was conducted to determine the appropriate size to collect during future monitoring studies.

2.5 Summary of 1994 Tiered-Full Monitoring Conditions

A tiered-full monitoring study was conducted in June 1994. Under a tiered-full monitoring approach, all samples for a full monitoring program are collected but only partial monitoring samples are initially analyzed (SAIC 1995, 2005). SVPS imagery confirmed that all recently deposited dredged material was confined within the disposal site boundaries.

Onsite sediment testing showed that all COCs were below DMMP MLs, and toxicity testing passed DMMP criteria. A total of eight metals and twelve organic compounds exceeded guideline values derived from the 1988 baseline data. The guideline values were extremely low because the baseline values were either undetected or detected at extremely low levels. Mercury and phenol exceeded the PSDDA SLs, but would be below the SLs under current DMMP guidelines. Overall, the perimeter chemistry results suggested that dredged material was not deposited off site. Under the tiered-full monitoring approach, it was not necessary to evaluate transect tissue chemistry and benthic infaunal community structure.

2.6 Summary of 2006 Full Monitoring Conditions

A full monitoring study was conducted in June 2006. Physical and chemical monitoring results suggested that the dredged material remains within the boundaries of the disposal site. The SVPS survey did not identify dredged material accumulations outside of the site perimeter. Perimeter chemistry concentrations were below the Washington State SQS criteria and CTS time-trends analysis did not identify statistically significant increases in chemical concentrations that were of concern in offsite areas of Port Gardner.

Chemistry results from three onsite stations were below the DMMP MLs and bioassay testing passed the DMMP bioassay interpretive criteria. Therefore, PSDDA Site Condition II chemical criteria were not exceeded.

[3] All *Molpadia* sea cucumbers greater than 0.5 inch were retained during the baseline survey. Current PSDDA protocols recommend collection of *Molpadia* greater than 2 inches (SAIC 1991).

Molpadia intermedia sea cucumber tissue samples were collected at transect and benchmark stations and analyzed for the DMMP BCOCs, Lists 1 and 2. All chemical contaminants were below the 1988 guideline values. Arsenic concentrations at the transect stations exceeded the target tissue levels, but were comparable to the 1988 baseline concentrations. Benthic infauna community analysis in 2006 found that the abundances of arthropods and mollusca at the transect stations were significantly less than the 1988 baseline, but generally similar to 1990 monitoring conditions. The numerically dominant species in 2006 were different than previous surveys, suggesting that a region-wide shift in benthic community structure may have occurred.

Benthic infauna community analysis of the 2006 benchmark stations showed that arthropod abundance was similar to the 1988 baseline, but the mollusca abundance had significantly increased relative to the 1988 baseline. Although the benchmark hypothesis testing suggested potential offsite impacts due to dredged material disposal, the other findings from the 2006 monitoring survey did not support this hypothesis. Dredged material was not identified outside of the disposal site boundary and sediment chemistry at the site perimeter was below SQS criteria and not increasing over time based on the CTS analysis. The SVPS survey indicated healthy benthic habitat conditions within and outside of the disposal site.

3.0 METHODS

This section provides a summary of the sampling design, data collection, and field sampling method for the 2010 full monitoring program at Port Gardner. All sampling activities in Port Gardner were conducted aboard the research vessel (R/V) *Kittiwake*. Detailed procedures of sampling and analysis methodologies are provided in the Quality Assurance, Sampling and Analysis Plan (QASAP) (Appendix A). A complete description of schedule, site conditions, field procedures, and coordinates for occupied stations is found in the Cruise Report (Appendix B). A summary of samples collected and types of analyses is provided in Table 3–1.

3.1 SVPS Survey

The Port Gardner SVPS survey was conducted as the first phase of the tiered-full monitoring program. The survey was conducted approximately three weeks prior to other sampling activities in order to evaluate the dredged material footprint as soon as possible after completion of dredged material disposal operations. The SVPS survey was conducted using a Benthos® Model 3731 Sediment Profile Imaging System equipped with an Ocean Imaging Systems digital camera. A total of 183 images were collected from 61 stations including 14 onsite, 16 perimeter, 18 transect, 11 central cross, and 2 benchmark stations (Figure 3–1). During the first day of the survey, 102 images were collected from 34 stations. The images were downloaded to a laptop computer periodically throughout the day to verify successful data acquisition. A "quick-look" assessment of the digital images was conducted following the first day of the survey to prepare a preliminary dredged material map.

Following completion of the field survey, a computer image analysis system was used to analyze the SVPS images for the presence of dredged material and other physical and biological parameters. These parameters include sediment grain size major mode, prism penetration depth, surface boundary roughness, presence or absence of mud clasts, apparent redox potential discontinuity (RPD) depth, infaunal successional stage, and calculation of the organism-sediment index (OSI) (Rhoads and Germano 1982). Results were reviewed by an SAIC senior scientist following completion of the image analysis.

3.2 Benthic Infauna Sample Collections

Benthic infauna samples were collected using a 0.06 m^2 stainless Gray O'Hara box core. Five replicate samples were collected at three transect (PGT11, PGT13, PGT15) and two benchmark (PGB01, PGB09) stations for a total of 25 box core samples. Benthic infaunal collections and preservation were accomplished following the procedures detailed in the QASAP (Appendix A). Each box core sample was divided into two sections: the top 10 cm (0 to 10 cm) and the remaining section of the core (>10 cm to bottom of core). The top 10 cm was sieved through 1.0 mm and 0.50 mm nested sieves. The >10 cm section was sieved through the 1.0 mm screen only.

All benthic samples were preserved for long-term storage and archived in accordance with the tiered-full monitoring program. The benthic samples are currently archived at the SAIC warehouse in Bothell, WA, and will be transferred to DNR following completion of the 2010 monitoring program.

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Table 3–1. Analyses or Archiving Conducted for Individual Replicate Samples Collected from Port Gardner

Sample ID	Depth Interval	Total Sulfides	Grain Size	TOC	Ammonia	TS	TVS	Metals (incl. Hg)	Hg (only)	TBT (bulk)	TBT (pore)	VOAs	SVOA/ PEST/ PCBs	PBDEs/ PCB Congeners	Dioxin/ Furan Congeners	Benthos	Bioassays
Onsite																	
PGZ06	0-10 cm	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓
PGS04	0-10 cm	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓
PGS08	0-10 cm	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓
PGZ01	0-10 cm			✓		✓									✓		
PGS01	0-10 cm			✓		✓									✓		
PGS02	0-10 cm			✓		✓									✓		
PGS05	0-10 cm			✓		✓									✓		
PGS06	0-10 cm			✓		✓									✓		
PGS07	0-10 cm			✓		✓									✓		
PGS09	0-10 cm			✓		✓									✓		
Perimeter																	
PGP01_10cm	0-10 cm			✓		✓								✓	✓		
PGP01-A	0-2 cm	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓				
PGP01-B	0-2 cm	✓	✓	✓	✓	✓	✓	✓				✓	✓				
PGP01-C	0-2 cm	✓	✓	✓	✓	✓	✓	✓				✓	✓				
PGP07_10cm	0-10 cm			✓		✓								✓	✓		
PGP07-A	0-2 cm	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓				
PGP07-B	0-2 cm	✓	✓	✓	✓	✓	✓	✓				✓	✓				
PGP07-C	0-2 cm	✓	✓	✓	✓	✓	✓	✓				✓	✓				
PGP08_10cm	0-10 cm			✓		✓								✓	✓		
PGP08-A	0-2 cm	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓				
PGP08-B	0-2 cm	✓	✓	✓	✓	✓	✓	✓				✓	✓				
PGP08-C	0-2 cm	✓	✓	✓	✓	✓	✓	✓				✓	✓				
PGP09_10cm	0-10 cm			✓		✓								✓	✓		
PGP09-A	0-2 cm	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓				
PGP09-B	0-2 cm	✓	✓	✓	✓	✓	✓	✓				✓	✓				
PGP09-C	0-2 cm	✓	✓	✓	✓	✓	✓	✓				✓	✓				
Transect																	
PGT11_10cm	0-10 cm		✓	✓		✓									(A)	(A)[1]	
PGT13_10cm	0-10 cm		✓	✓		✓									(A)	(A)[1]	
PGT15_10cm	0-10 cm		✓	✓		✓									(A)	(A)[1]	
Benchmark																	
PGB01_10cm	0-10 cm			✓		✓								✓	(A)		
PGB01-A	0-2 cm	✓	(A)	(A)	✓	✓	(A)	(A)	✓	(A)	✓	✓	(A)			(A)[1]	(A)
PGB01-B	0-2 cm	✓	(A)	(A)	✓	✓	(A)	(A)	✓			✓	(A)			(A)[1]	
PGB01-C	0-2 cm	✓	(A)	(A)	✓	✓	(A)	(A)	✓			✓	(A)			(A)[1]	
PGB09_10cm	0-10 cm			✓		✓								✓	(A)		
PGB09-A	0-2 cm	✓	(A)	(A)	✓	✓	(A)	(A)	✓	(A)	✓	✓	(A)			(A)[1]	(A)

Sample ID	Depth Interval	Total Sulfides	Grain Size	TOC	Ammonia	TS	TVS	Metals (incl. Hg)	Hg (only)	TBT (bulk)	TBT (pore)	VOAs	SVOA/ PEST/ PCBs	PBDEs/ PCB Congeners	Dioxin/ Furan Congeners	Benthos	Bioassays
PGB09-B	0-2 cm	✓	(A)	(A)	✓	✓	(A)	(A)	✓			✓	(A)			(A)[1]	
PGB09-C	0-2 cm	✓	(A)	(A)	✓	✓	(A)	(A)	✓			✓	(A)			(A)[1]	
Reference																	
CR-23W	0-10 cm	✓	✓	✓	✓	✓	✓										✓
CR-24	0-10 cm	✓	✓	✓	✓	✓	✓										✓

1. Five replicates benthic infauna samples were collected from each transect and benchmark station.

✓ = Analysis conducted
(A) = Archive
TOC = Total Organic Carbon
TS = Total Solids
TVS = Total Volatile Solids
Hg = Mercury
TBT = Tributyltin
VOA = Volatile Organics Analysis
SVOA = Semi-Volatile Organic Analysis
PEST/PCB = Pesticides and PCBs
PBDEs = Polybrominated Diphenyl Ethers
PCB = Polychlorinated Biphenyls

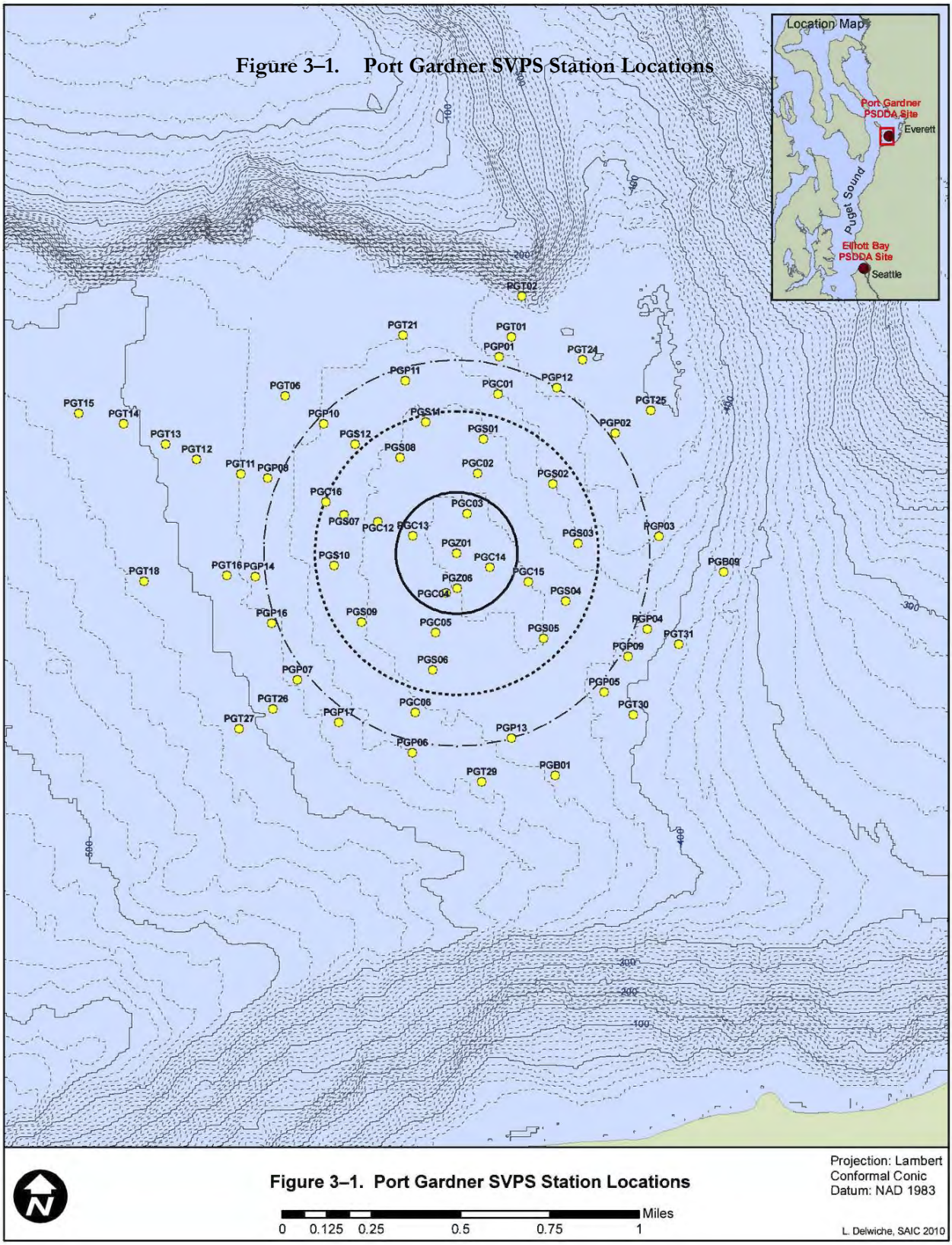


Figure 3–1. Port Gardner SVPS Station Locations

3.3 Sediment Chemistry

Port Gardner stations were sampled to acquire sediments for chemical testing (Figure 3–2). Collection methods were consistent with the QASAP. Stations sampled included three onsite (PGZ06, PGS04, and PGS08), four perimeter (PGP01, PGP07, PGP08, PGP09), two benchmark (PGB01 and PGB09), and three transect stations (PGT11, PGT13, and PGT15). Seven additional onsite stations were sampled for dioxin/furan congener analysis (PGZ01, PGS01, PGS02, PGS05, PGS06, PGS07, and PGS09). Two Carr Inlet reference stations (CR-23W and CR-24) were sampled for sediment conventional parameters and bioassays. A full summary of sediment chemistry collections and station locations for all samples collected are tabulated in the cruise report (Appendix B).

The three onsite, four perimeter, and two benchmark samples were analyzed for all DMMP parameters and chemicals of concern, including butyltins. Benchmark samples were archived, with the exception of compounds with short holding times (ammonia, total sulfides, mercury, porewater butyltins, and volatile organic analyses [VOAs]). Transect stations were sampled for grain size and total organic carbon (TOC). The Carr Inlet reference samples were analyzed for conventional parameters. In addition, surface sediment samples (top 10 cm) were collected from ten onsite, four perimeter, three transect, and two benchmark stations and analyzed for dioxin/furan congeners, PCB congeners, or PBDEs as outlined in Table 3–1.

Analyses of conventionals and DMMP parameters were conducted by Analytical Resources, Inc. (ARI), of Tukwila, Washington. Analyses of dioxin/furan, PCB, and PBDE congeners were conducted by Axys Analytical Services of Sidney, B.C.

3.4 Tissue Chemistry Sample Collection

Single replicate tissue samples of the sea cucumber *Molpadia intermedia* were collected at each transect and benchmark station and archived under the tiered-full monitoring approach. Extra *Molpadia* tissue was recovered from station PGT15 to run Quality Assurance/Quality Control (QA/QC) analyses for chemistry (matrix spike and matrix spike duplicate), if required. A total of five tissue samples were archived -18°C at the SAIC warehouse in Bothell, WA.

3.5 Toxicity Testing

Surface sediment was collected from five locations (one zone, two site, and two benchmark locations) and two reference locations (Carr Inlet) for confirmatory biological testing. Sediment collected from the zone, site, and reference locations was submitted to NewFields Northwest for confirmatory biological testing. Sediment collected from the benchmark locations was archived, with bioassays to be conducted if triggered by onsite bioassay results. Three bioassays were conducted on each sample: amphipod mortality (*Eohaustorius estuarius*), larval development (*Mytilus galloprovincialis*), and juvenile polychaete growth (*Neanthes arenaceodentata)*. All biological testing was in strict compliance with Recommended Guidelines for Conducting Laboratory Bioassays on Puget Sound Sediments (PSEP 1995), and subsequent Sediment Management Annual Review Meeting (SMARM) updates. Further details on the toxicity testing methodology are provided in the QASAP (SAIC 2010). The results of the toxicity testing are provided in Section 4.6.

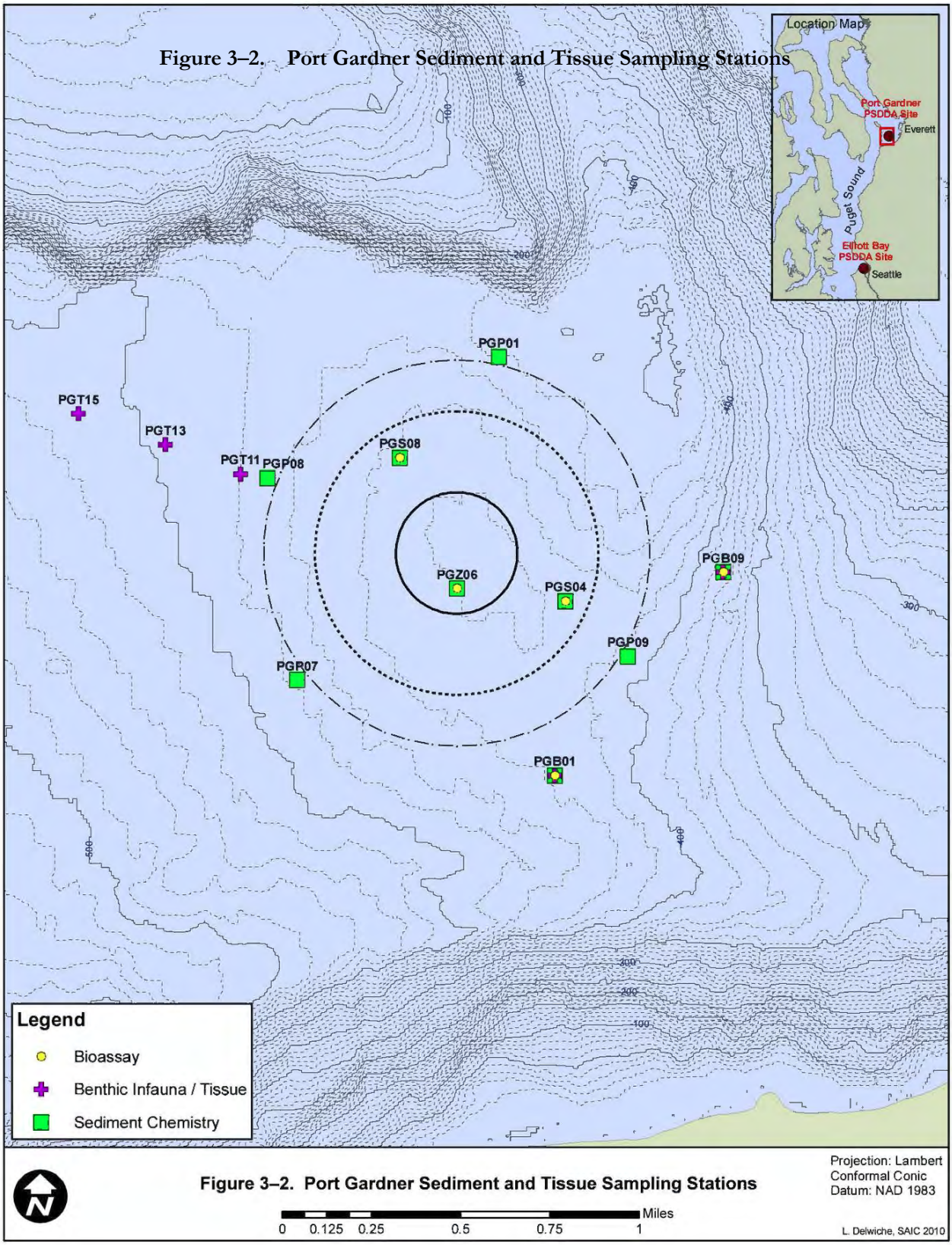


Figure 3–2. Port Gardner Sediment and Tissue Sampling Stations
Location Map
Port Gardner PSDDA Site
Everett
Puget Sound
Elliott Bay PSDDA Site
Seattle
PGP01
PGT15
PGT13
PGT11
PGP08
PGS08
PGZ06
PGS04
PGB09
PGP09
PGR07
PGB01
Legend
Bioassay
Benthic Infauna / Tissue
Sediment Chemistry
Figure 3–2. Port Gardner Sediment and Tissue Sampling Stations
Miles
0 0.125 0.25 0.5 0.75 1
Projection: Lambert Conformal Conic
Datum: NAD 1983
L. Delwiche, SAIC 2010

4.0 RESULTS

This section presents the results of the SVPS survey, sediment chemistry analysis, and bioassay testing conducted during the 2010 Port Gardner tiered-full monitoring survey. An evaluation of the data in accordance with the DMMP monitoring framework is provided in Section 5.0.

4.1 Sediment Vertical Profiling System Survey

The primary objective of the 2010 SVPS survey was to map the distribution of recent dredged material at the Port Gardner disposal site. SVPS images were collected at 61 stations at Port Gardner to map the dredged material footprint. In addition, other physical (grain size major mode, prism penetration depth, boundary roughness), chemical (apparent RPD), and biological (successional stage and OSI) characteristics of site sediments were determined from the SVPS images. Triplicate images were analyzed at each station, with the exception of eight stations (PGC03, PGC04, PGC06, PGP02, PGP04, PGP06, PGS06, and PGT15) where only two acceptable images were obtained. A full summary of the image analysis results is provided in Appendix C.

4.1.1 Ambient Sediment Characteristics

Ambient sediment characteristics at the Port Gardner DMMP site generally consist of tan to gray, homogeneous, unconsolidated (water-rich) sandy silts and clays, with deep apparent RPD depths. Numerous feeding voids are visible and indicate the presence of head-down deposit feeding organisms, which is a characteristic of well established benthic communities (Figure 4–1). Previous monitoring events in Port Gardner (1988 baseline, 1990 full monitoring, 1994 tiered-full monitoring, and 2006 full monitoring) have reported similar ambient sediment characteristics (PTI 1988; SAIC 1991, 1995, 2006). Ambient sediments were observed at all Port Gardner offsite stations and many stations along the site perimeter in 2010 (Figure 4–2). The offsite surface sediments show extensive biological mixing, evidenced by numerous burrow openings, feeding voids, biogenic surface mounds, and homogeneous sediment textures.

Sediments along the slope to the north and east of the Port Gardner site show ambient sediment characteristics, but surface sediments also show enrichment in fine sand and fine wood and shell particles (Figure 4–3). Station PGT02 is located at the base of the southeastern slope to Gedney Island, and the hydrodynamics in this area may differ from other areas of Port Gardner. Fine sand and particles observed at station PGT02 may have been transported down naturally from the upper slope of Gedney Island. Similarly, fine sand and wood particles observed near the base of the eastern slope (stations PGB09 and PBT31) may have been transported down naturally from the upper slope. These findings are consistent with SVPS measurements collected during the 1988 baseline survey and are consistent with ambient sediment conditions in these areas (PTI 1988; SAIC 2006).

PGT24-A **PGT26-C**

Figure 4–1. SVPS Images from Port Gardner Stations PGT24-A and PGT26-C

These images show fine-grained ambient sediments. The ambient sediments consist of tan to gray, soft, unconsolidated, slightly sandy silt-clays. Both stations show deep apparent RPD depths and feeding voids created by head-down deposit-feeding organisms (Stage III successional stage). The sea cucumber (*Molpadia intermedia*), a classic Stage III organism, is visible at depth at station PGT24 (arrow). A stick amphipod (*Podoceridae*; Stage II successional organism) is visible at the surface at station PGT26 (arrow) and a polychaete is also visible at depth (arrow).

PGP08-B **PGP11-C**

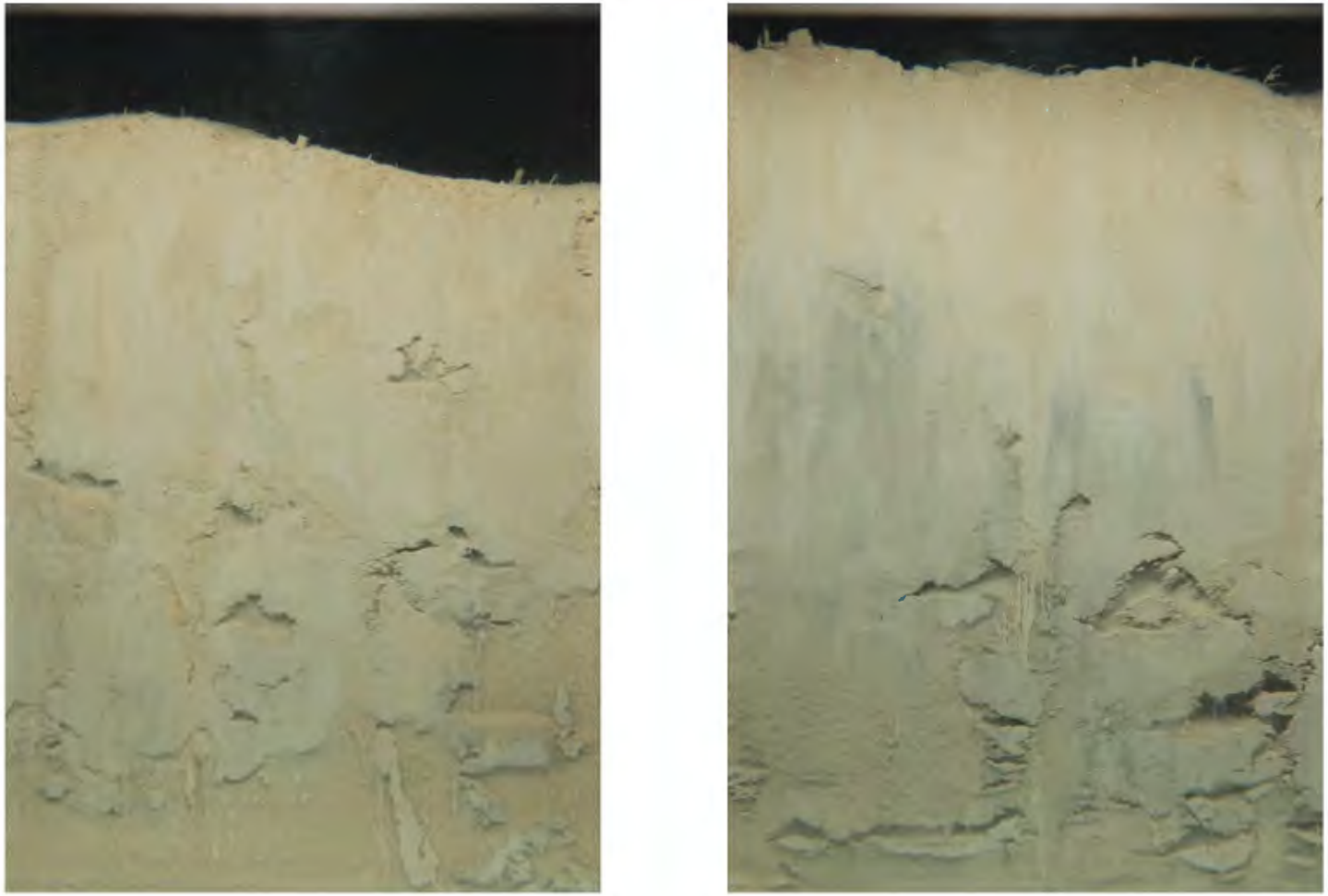


Figure 4–2. SVPS Images from Perimeter Stations PGP08-B and PGP11-C

Both perimeter stations show ambient sediment characteristics consisting of soft, tan to gray silts and clays, with a slight enrichment of fine sand near the surface. Both images show numerous feeding voids, deep apparent RPDs, and abundant Stage I surface tubes. Stage I communities are often observed in conjunction with Stage III infaunal communities and are classified as Stage I on III.

PGT02-A **PGT31-A**

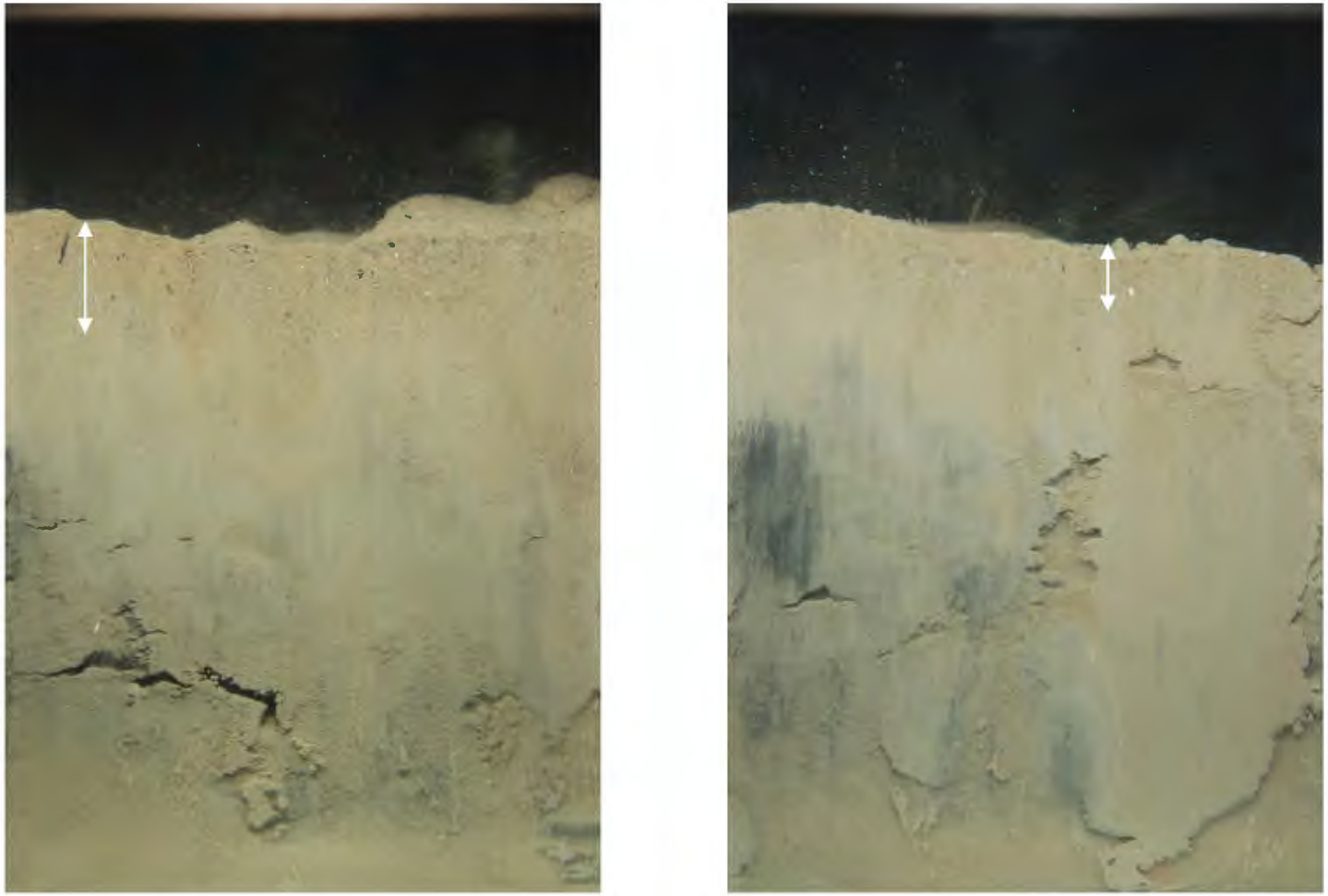


Figure 4–3. SVPS Images from Stations PGT02-A and PGT31-A

These images show fine-grained ambient sediments enriched with fine sand and wood and shell particles (arrows) in the upper sediment column. Station PGT02 is located near a rocky outcrop associated with Gedney Island and Station PGT31 is located at the base of the eastern slope. The fine sand and particles visible in the upper sediment column may be transported down naturally from the upper slope.

4.1.2 Dredged Material Distribution

Recent dredged material was detected in SVPS images collected from 24 stations, and the dredged material was confined within the perimeter of the Port Gardner disposal site (Figure 4–4). Dredged material is normally identified in SVPS images by its contrasting optical appearance relative to the ambient seafloor. Diagnostic characteristics can include grain size, color and reflectivity, high boundary roughness, and a mixed or chaotic sedimentary fabric. Near the site center of the Port Gardner site, dredged material consisted of gray, coarse to medium sands with scattered woody debris and shell particles (Figure 4–5). In addition, stations in the disposal zone showed a surface layer of tan to brown silt with pockets of fine sand, which may be related to recent deposition of ambient sediment from normal depositional processes in Port Gardner. Sedimentary layering with varying colors and textures can also occur following multiple dredged material disposal events at a site.

Prism penetration at stations within the disposal zone is low due to the presence of coarse-grained, consolidated dredged material. Recent dredged material along the outer flanks of the deposit consisted of layers of tan gray to dark gray silty fine sand greater than prism penetration, or overlying ambient sediments (Figure 4–6). Dredged material identified as historic was detected in images from 11 stations, primarily along the disposal site perimeter line (Figure 4–7). The dredged material was identified as historic when enough time has passed for a deep apparent RPD to be developed, feeding voids are present, and sedimentary layering due to dredged material disposal (if present) is not completely obscured through bioturbation. Dredged material was observed beyond the site perimeter during the 1990 SVPS survey (SAIC 1991), but visual characteristics of recent or historical dredged material were not observed beyond the perimeter stations during the 2010 survey.

4.1.3 Physical and Sedimentary Features

Physical and sedimentary features determined from SVPS images include grain size major mode, camera prism penetration, and boundary roughness. During the 2010 SVPS survey, the grain size major mode in phi (Φ) size for sediments at the Port Gardner site ranged from 4 to 3 Φ (fine sand) to >4 Φ (silt and clay). Sediments within the disposal zone and surrounding site stations were classified as 4 to 3 Φ due to the presence of recently deposited sandy dredged material (Figure 4–8). A similar pattern of grain size major mode was observed during previous monitoring surveys (1990 and 1994) due to the distribution of the sandy dredged material deposit.

SVPS camera prism penetration measurements for the 2010 SVPS survey are presented in Figure 4–9 and follow a distribution pattern similar to the dredged material footprint in Port Gardner. Camera prism penetration depths provide a relative measure of sediment bearing capacity. Deep camera prism penetration was measured in areas outside of the disposal site, where unconsolidated, water-rich, fine-grained sediments with extensive bioturbation are present. The majority of prism penetration depths less than 10 cm was observed at the disposal zone, due to the presence of coarse-grained, compact, dredged material sediments.

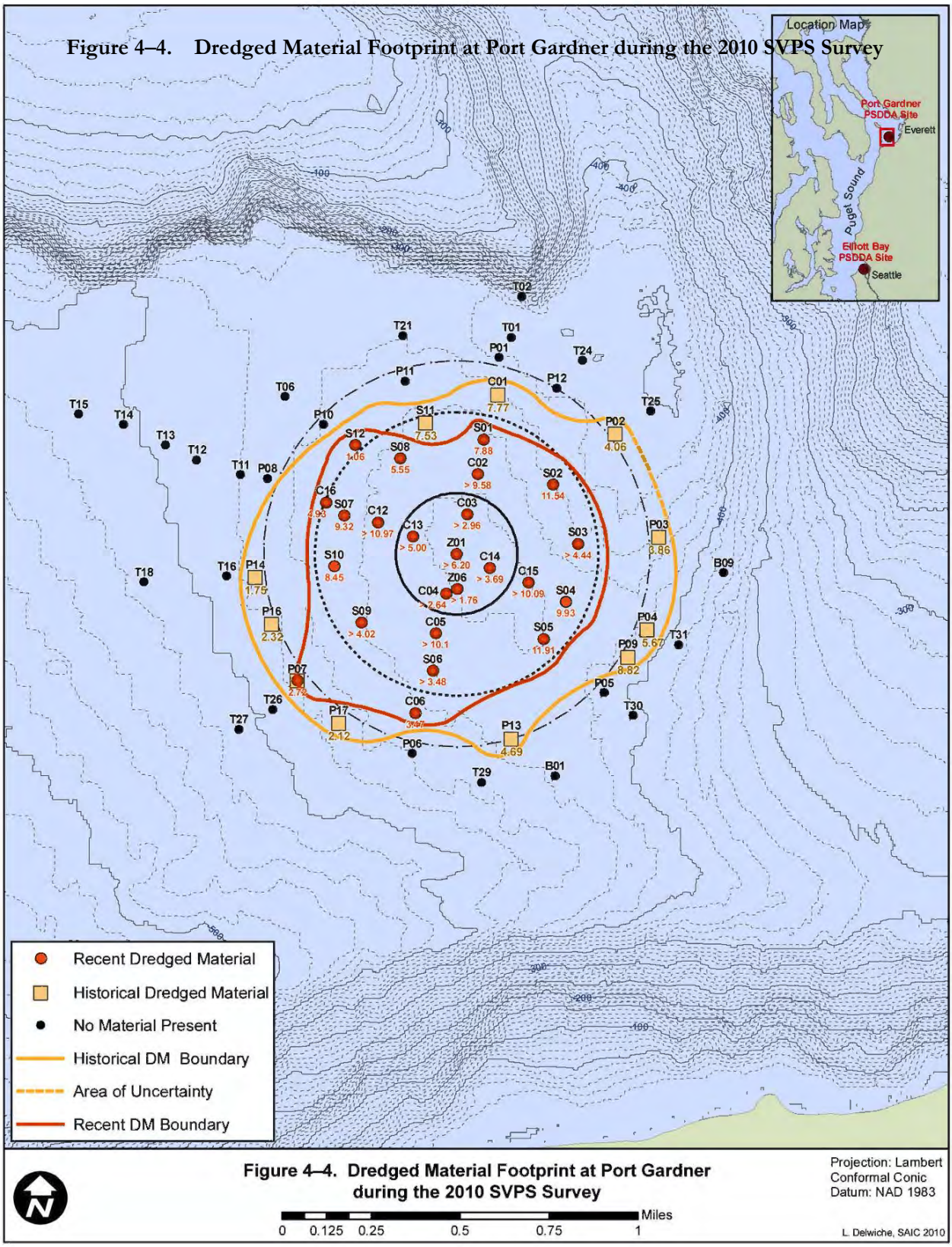


Figure 4–4. Dredged Material Footprint at Port Gardner during the 2010 SVPS Survey
Location Map
Port Gardner PSDDA Site
Everett
Puget Sound
Elliott Bay PSDDA Site
Seattle
Recent Dredged Material
Historical Dredged Material
No Material Present
Historical DM Boundary
Area of Uncertainty
Recent DM Boundary
Figure 4–4. Dredged Material Footprint at Port Gardner during the 2010 SVPS Survey
Miles
0 0.125 0.25 0.5 0.75 1
Projection: Lambert Conformal Conic
Datum: NAD 1983
L. Delwiche, SAIC 2010

PGZ01-B **PGC14-C**

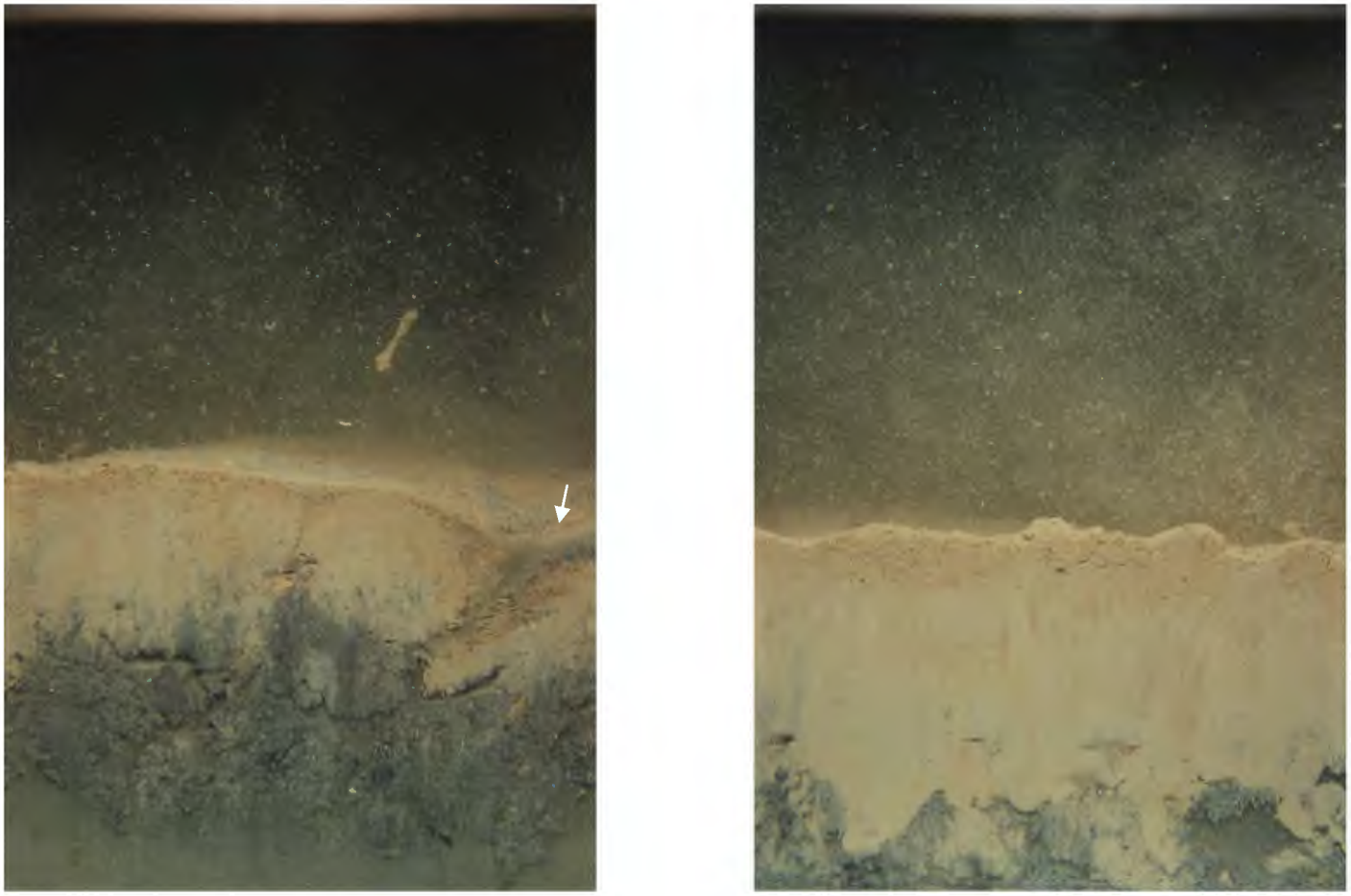


Figure 4–5. SVPS Images from Stations PGZ01-B and PGC14-C

These images show recent dredged material within the disposal zone. The dredged material consists of dark gray, silty sand with scattered fine wood and organic particles. The coarse-grained sediment minimizes the camera prism penetration. Both stations show a surface layer of tan to brown sandy silt. The fine-grained surface sediment may be due to natural sedimentation in Port Gardner or a dredged material layer of different sediment characteristics. Feeding voids are visible at the interface between the two layers. A possible burrow structure is visible at the surface at PGZ01 (arrow).

PGS09-A **PGS10-A**

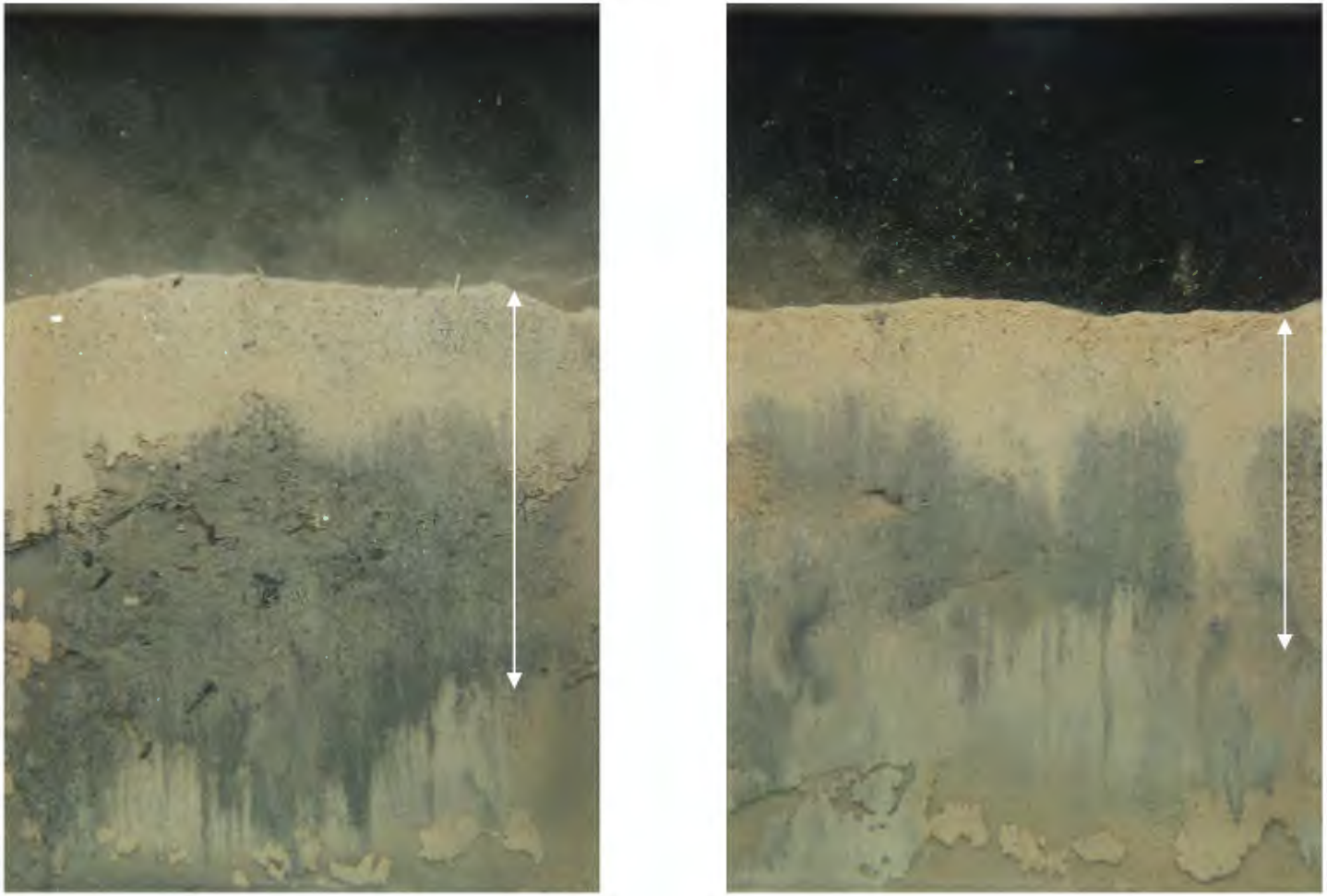


Figure 4–6. SVPS Images from Stations PGS09-A and PGS10-A

These images show layers of dredged material over ambient sediments along the flanks of the deposit. The recent dredged material layers consist of tan and gray fine sandy silt and dark gray fine sand with wood and shell debris (arrows). Subsurface sediments consist of tan to gray silt, which is consistent with ambient sediment characteristics. The interface between the recent dredged material layers and ambient sediments is visible and distinct.

PGP16-B **PGP17-A**

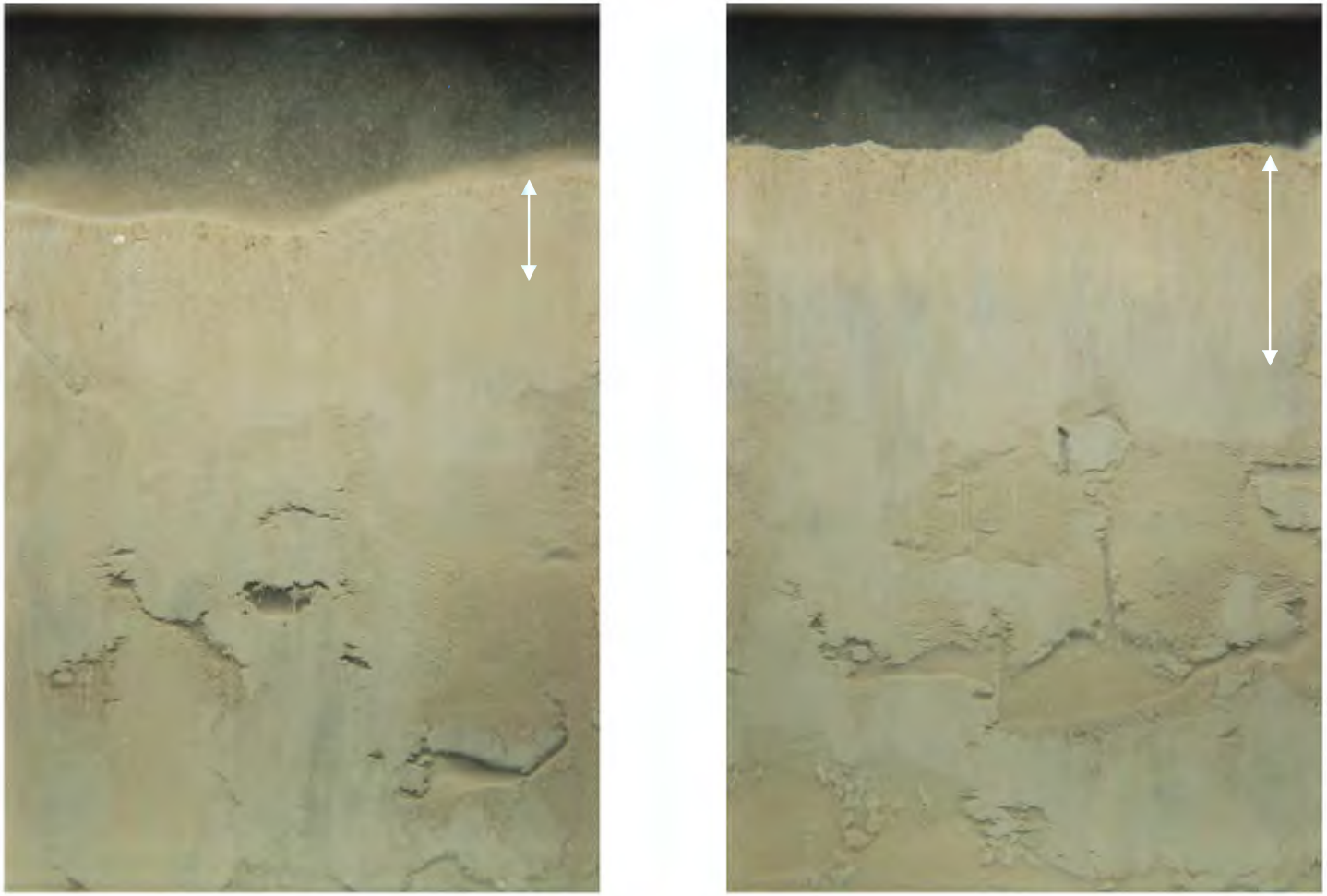


Figure 4–7. SVPS Images from Stations PGP16-B and PGP17-A

These images show thin layers of historic dredged material over ambient sediments. The dredged material in the upper 2 to 3 cm is indicated by an enrichment of fine sand (arrows) and has been designated as historic because it is well mixed and the interface with underlying ambient sediments has been obscured through bioturbation. Sediments at both stations consist of tan to gray, fine sandy silt and feeding voids are visible at depth indicating the presence Stage III infauna.

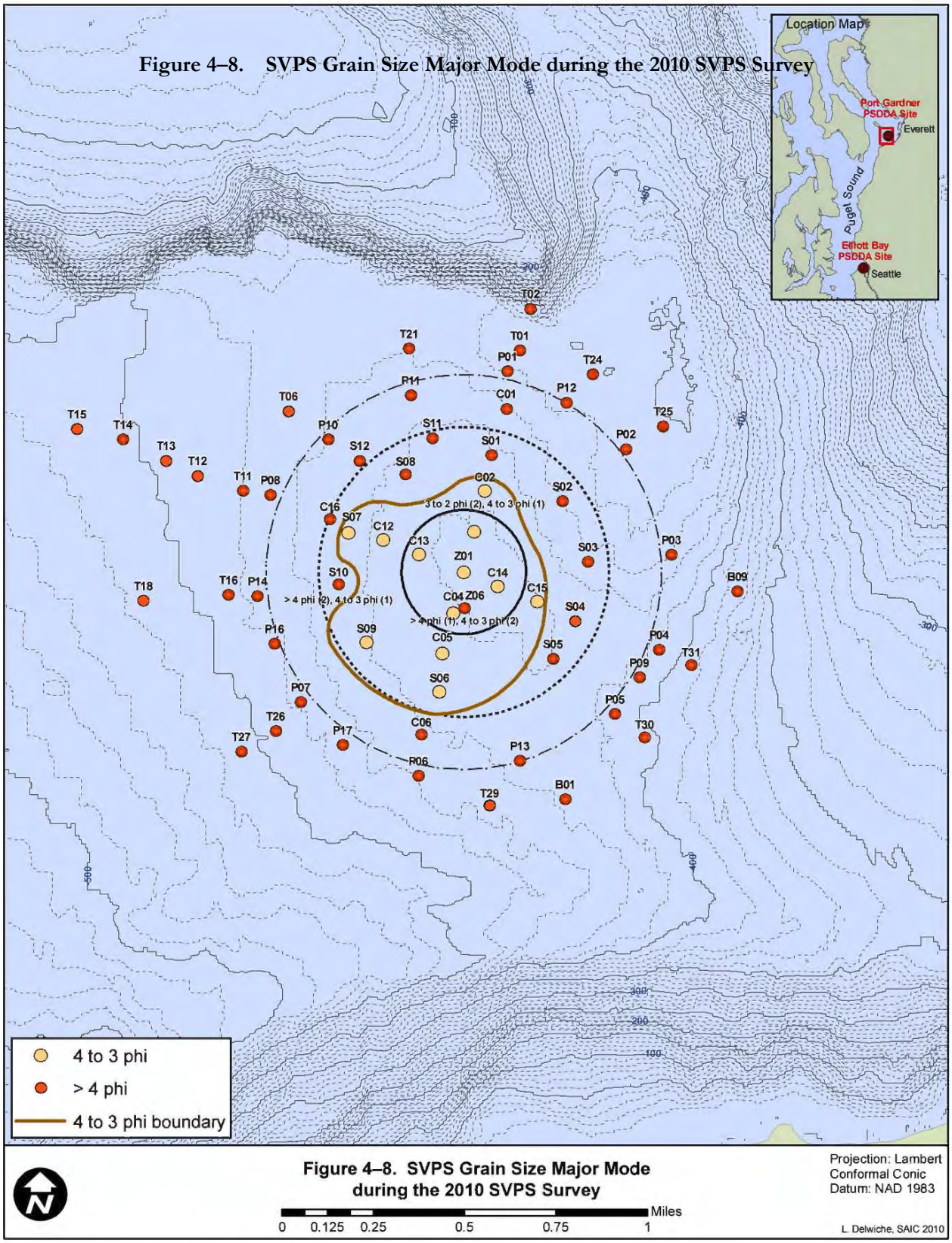
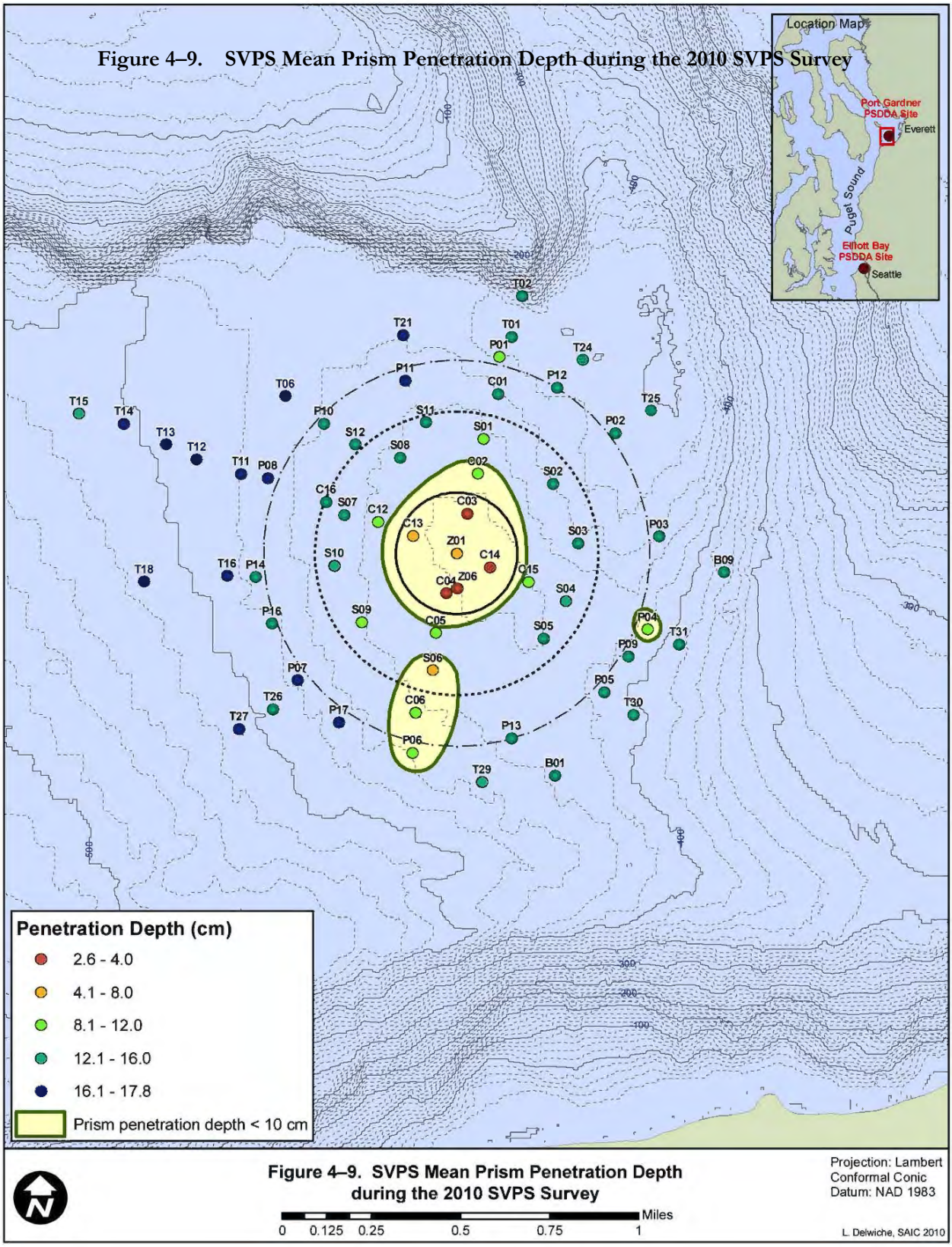


Figure 4–8. SVPS Grain Size Major Mode during the 2010 SVPS Survey

Figure 4–9. SVPS Mean Prism Penetration Depth during the 2010 SVPS Survey



Mean bottom boundary roughness measurements during the 2010 SVPS survey are shown in Figure 4–10. Mean small-scale boundary roughness (surface relief) can be physical or biological in nature, and is the difference between the highest and lowest penetration depth measured in an SVPS image. Physical boundary relief can include surface ripples, mud clasts, and irregular surface features due to dredged material disposal or bottom currents. Biogenic activity that creates boundary roughness includes fecal mounds, burrow excavations, and foraging and feeding pits. The 1988 baseline survey reported an average surface relief of 1.9 cm at Port Gardner, due to relatively large-scale biogenic features such as burrows, fecal mounds, and near-surface feeding pockets. The average surface relief during the 2010 survey was 1.39 cm, with a major mode of 1.00 to 1.25 cm. The vast majority of surface relief was identified as biogenic, with many images showing large surface burrow structures, fecal layers, and biogenic mounds (see Figures 4–1 and 4–5).

4.1.4 Chemical and Biological Features

Chemical and biological parameters include the apparent RPD depth, benthic infaunal successional stage, and calculation of the OSI. These parameters provide an assessment of the overall health of the benthic habitat at the Port Gardner disposal site.

Apparent Redox Potential Discontinuity

The apparent RPD depth estimates the depth of oxygenation in the upper sediment column and can be considered the biological mixing depth by infaunal organisms. Mean apparent RPD depths at the Port Gardner site range from 1.16 to 5.28 cm, with an average depth of 3.18 cm (Figure 4–11). Shallower apparent RPD depths (<2.0 cm) were measured at stations near the center of the disposal site, where recent dredged material is present. Deep apparent RPD depths were measured along the site perimeter and offsite areas suggesting a mature, well developed benthic community in these areas of Port Gardner. The major mode of mean apparent RPD depths during the 2010 SVPS survey (3.5 to 4.0 cm) was slightly lower than was measured during the 1988 baseline survey (4.0 to 4.5 cm) due to temporary impacts from recent dredged material disposal. It is expected that apparent RPD depths would rebound quickly at the disposal site if dredged material disposal operations were to cease.

Benthic Infaunal Successional Stage

Benthic infaunal communities generally follow a three-stage succession following a disturbance of the seafloor (Figure 4–12) (Pearson and Rosenberg 1978; Rhoads and Germano 1986). Stage I infauna typically colonize the sediment surface soon after disturbance (e.g., following dredged material disposal). These opportunistic organisms may consist of small, tubicolous, surface-dwelling polychaetes. Stage II organisms are typically shallow-dwelling bivalves or tube-dwelling amphipods. Stage II communities are considered a transitional community before reaching Stage III, the high-order successional stage consisting of long-lived, infaunal deposit-feeding organisms. Stage III invertebrates may feed at depth in a head-down orientation and create distinctive feeding voids visible in SVPS images.

Stage III benthic communities were observed at all stations at Port Gardner, with the exception of three stations near the disposal zone (PGC02, PGC03, and PGC05 where recent dredged material is present (Figure 4–13). The benthic community within the disposal site appears to be in the last stages of transition to the highest order of succession (full Stage III community) following recent dredged material disposal. Two transect stations (PGT24 and PGT26) showed Stage II on III succession where the indicator species for Stage II classification at Port Gardner was the stick amphipod (*Podoceridae*).

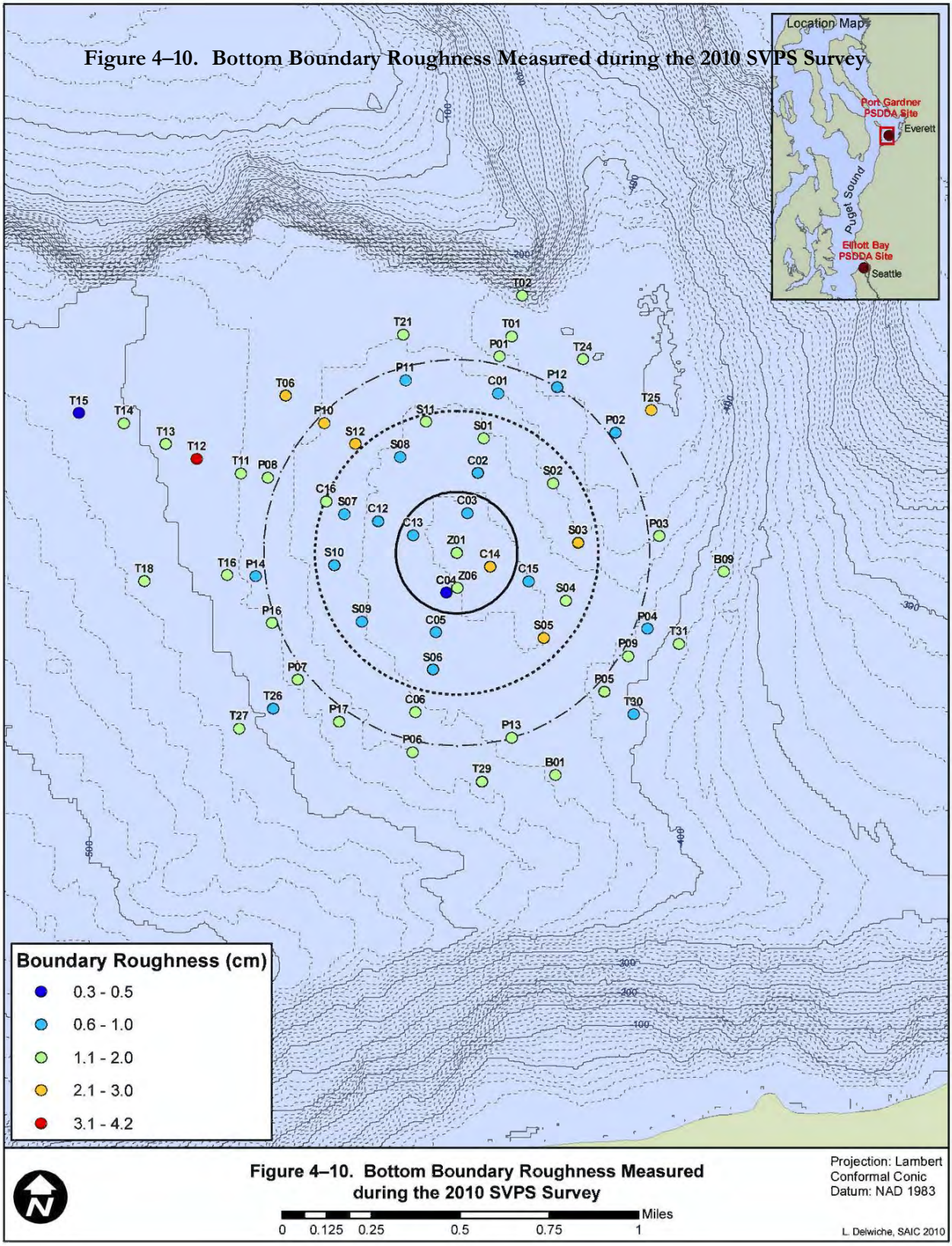


Figure 4–10. Bottom Boundary Roughness Measured during the 2010 SVPS Survey
Location Map
Port Gardner PSDDA Site
Everett
Puget Sound
Elliott Bay PSDDA Site
Seattle
Boundary Roughness (cm)
0.3 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.2
Figure 4–10. Bottom Boundary Roughness Measured during the 2010 SVPS Survey
Miles
0 0.125 0.25 0.5 0.75 1
Projection: Lambert Conformal Conic
Datum: NAD 1983
L. Delwiche, SAIC 2010

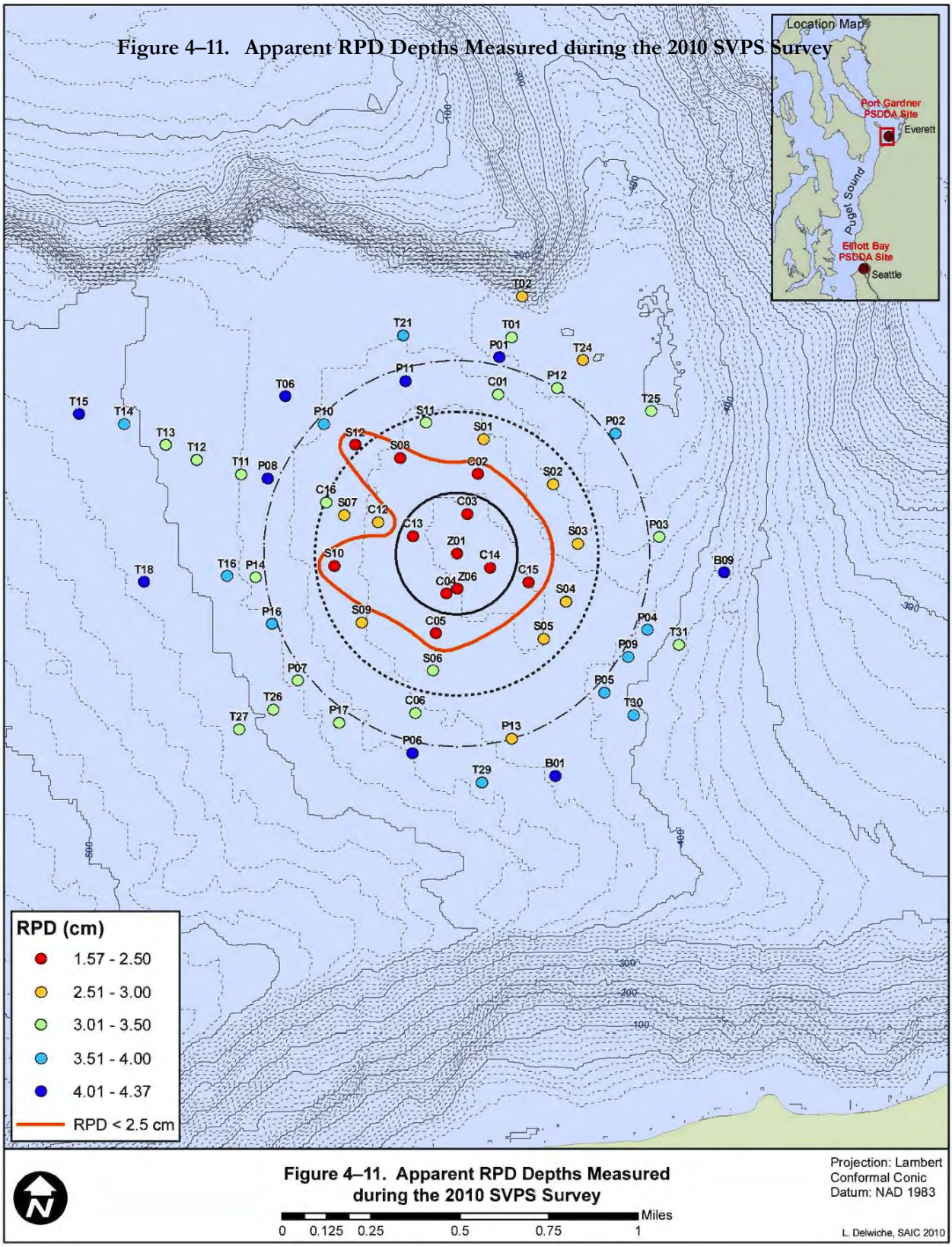


Figure 4–11. Apparent RPD Depths Measured during the 2010 SVPS Survey
Location Map
Port Gardner PSDDA Site
Everett
Puget Sound
Elliott Bay PSDDA Site
Seattle
RPD (cm)
1.57 - 2.50
2.51 - 3.00
3.01 - 3.50
3.51 - 4.00
4.01 - 4.37
RPD < 2.5 cm
Figure 4–11. Apparent RPD Depths Measured during the 2010 SVPS Survey
Miles
0 0.125 0.25 0.5 0.75 1
Projection: Lambert Conformal Conic
Datum: NAD 1983
L. Delwiche, SAIC 2010

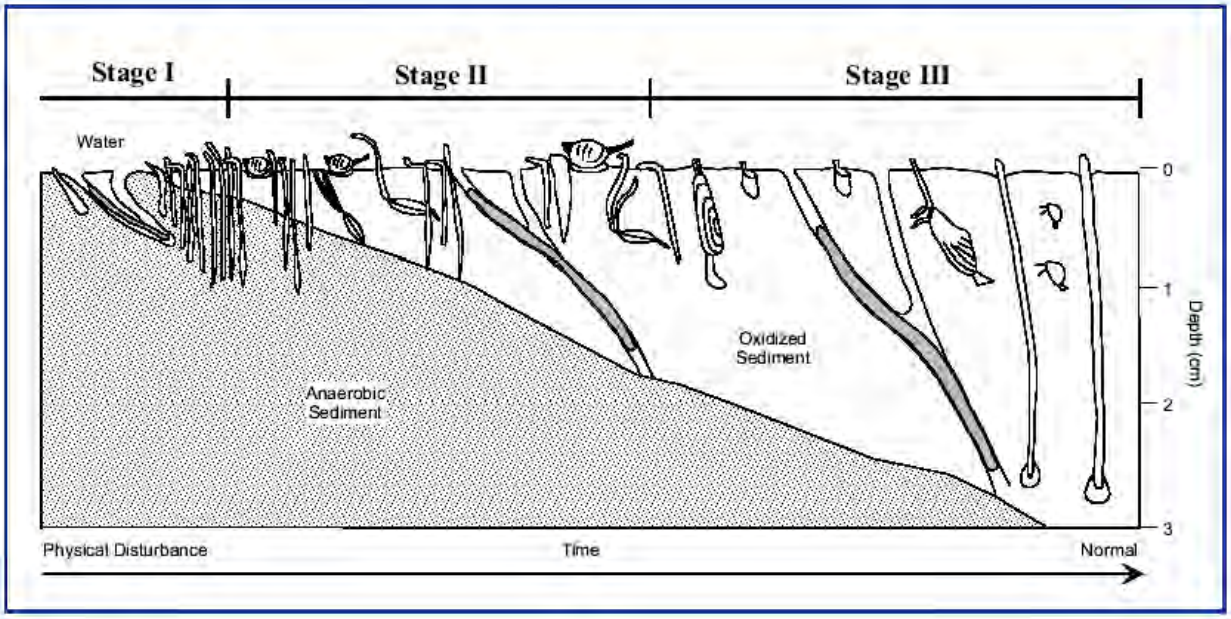


Figure 4–12. Idealized Development of Infaunal Succession Stages over Time Following a Physical Disturbance

Source: Rhodes and Germano (1986), modified from Pearson and Rosenberg (1978)

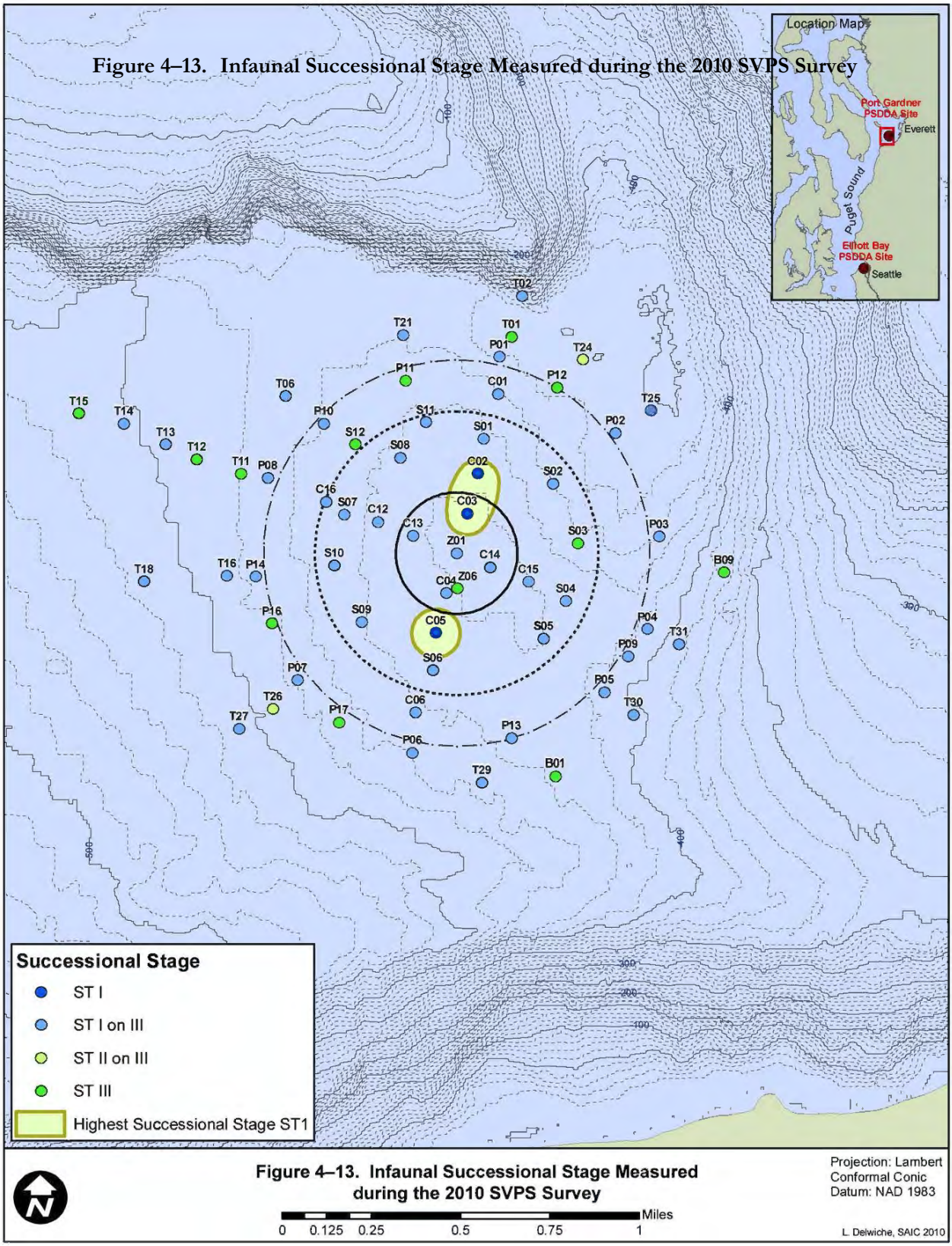


Figure 4–13. Infaunal Successional Stage Measured during the 2010 SVPS Survey
Location Map
Port Gardner PSDDA Site
Everett
Puget Sound
Elliott Bay PSDDA Site
Seattle
Successional Stage
ST I
ST I on III
ST II on III
ST III
Highest Successional Stage ST1
Figure 4–13. Infaunal Successional Stage Measured during the 2010 SVPS Survey
Miles
0 0.125 0.25 0.5 0.75 1
Projection: Lambert Conformal Conic
Datum: NAD 1983
L. Delwiche, SAIC 2010

Organism-Sediment Index

The OSI is a numerical index from -10 to +11 (Table 4–1), which provides a measure of general benthic habitat quality based on dissolved oxygen conditions, depth of the apparent RPD, infaunal successional stage, and presence or absence of sedimentary methane (Rhoads and Germano 1986). The lowest value is assigned to an area with low or no dissolved oxygen in the overlying bottom water, no apparent macrofaunal life, and the presence of methane gas in the sediment. The highest value is given to an aerobic bottom with a deep apparent RPD, evidence of a mature macrofaunal assemblage, and no methane gas bubbles. OSI values greater than or equal to +6 are generally considered to represent healthy or undisturbed benthic habitat quality.

Relatively high OSI values were measured in all areas of the Port Gardner site, given the deep apparent RPD depths and the prevalence of Stage III communities. Only the three onsite stations with Stage I communities (PGC02, PGC03, and PGC05) had OSI values that were slightly below +6. Mean OSI values at the Port Gardner disposal site ranged from +4 to +11, with a major mode of +10 (Figure 4–14). The distribution of high OSI values throughout Port Gardner suggests a healthy and robust benthic community that is resilient to disturbance from dredged material disposal.

Table 4–1. Calculation of the Organism-Sediment Index

Choose One Value:		
	Mean RPD Depth Classes	**Index Value**
	0.00 cm	0
	> 0 - 0.75 cm	1
	0.76 - 1.50 cm	2
	1.51 - 2.25 cm	3
	2.26 - 3.00 cm	4
	3.01 - 3.75 cm	5
	> 3.75 cm	6
Choose One Value:		
	Successional Stage	**Index Value**
	Azoic	- 4
	Stage I	1
	Stage I - II	2
	Stage II	3
	Stage II - III	4
	Stage III	5
	Stage I on III	5
	Stage II on III	5
Choose One or Both if Appropriate:		
	Chemical Parameters	**Index Value**
	Methane Present	- 2
	No/Low Dissolved Oxygen	- 4
Organism-Sediment Index =		**Range: - 10 + 11**

4.2 Sediment Chemistry

The Quality Assurance Level 1 (QA1) data review of sediment chemistry results for conventionals and DMMP parameters was conducted by SAIC, Bothell, WA. Independent Stage 4 data validation for the dioxin/furan, PCB, and PBDE congener results was conducted by EcoChem, Seattle, WA. The QA1 review and Stage 4 data validation demonstrated that the data are of generally high quality, and suitable for use (as qualified) in addressing the PSDDA monitoring questions and hypotheses. Summary tables of the sediment chemistry analytical results for each sampling location are provided in Appendix D. Results are compared to the DMMP sediment SL/ML list, Washington State Sediment Management Standards (SMS)/Sediment Quality Standards (SQS), and bioaccumulation triggers (BT), where appropriate. The data quality summary, QA1 checklists, EcoChem data validation report, and analytical laboratory data reports are found in Appendix E.

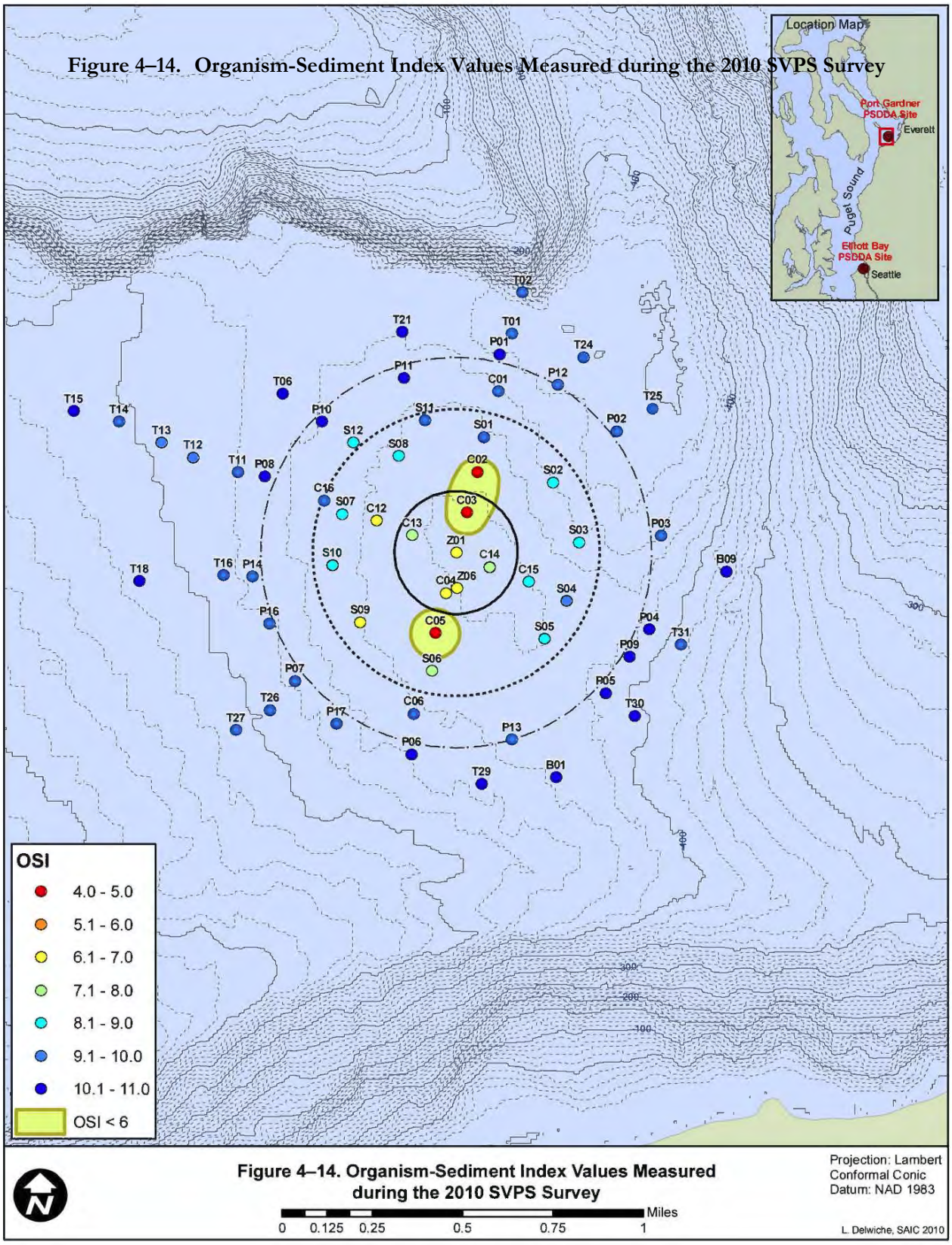


Figure 4–14. Organism-Sediment Index Values Measured during the 2010 SVPS Survey
Location Map
Port Gardner PSDDA Site
Everett
Puget Sound
Elliott Bay PSDDA Site
Seattle
OSI
4.0 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
OSI < 6
Figure 4–14. Organism-Sediment Index Values Measured during the 2010 SVPS Survey
Miles
0 0.125 0.25 0.5 0.75 1
Projection: Lambert Conformal Conic
Datum: NAD 1983
L. Delwiche, SAIC 2010

4.2.1 Conventional Parameters

Sediment conventional parameter summary statistics are presented in Table 4–2. Conventional parameters for onsite, perimeter, transect, and baseline stations were generally consistent among station types, with the exception of grain size. The site-wide average for percent fines was 82.2%, ranging from a low of 33.8% at station PGZ06 to a high of 97.8% at station PGT15. The site-wide average for percent clay was 29.6%, ranging from a low of 7.2% at station PGZ06 to a high of 47.7% at station PGT15. The transect stations had the highest percent fines and percent clay over all ranging from 96.4 to 97.8% for percent fines and 40.8 to 47.7% for percent clay. Percent silt was fairly consistent across the stations, averaging 52.5% site-wide and 48.5% at reference stations. Percent sand was the highest at onsite and reference stations averaging 43.4% and 45.2%, respectively. Gravel constitutes the lowest percentage of sediment for all stations and when detected, values ranged from 0.1 to 1.2%.

Table 4–2. Conventional Parameters Summarized by Station Type

Station		% Gravel	% Sand	% Silt	% Clay	% Fines	TOC (% DW)	Total Sulfides (mg/kg DW)	Ammonia (mg N/kg DW)	TVS (%)	Total Solids (%)
Onsite	Min	0.1	27.9	26.5	7.2	33.8	1.20	5.80	4.06	5.72	49.50
	Max	1.2	65.1	48.3	23.7	72.0	3.11	70.2	6.74	6.06	58.70
	Avg	0.7	43.4	39.6	16.5	56.2	1.79	34.0	5.19	5.91	54.25
Perimeter	Min	0.1	6.2	43.4	19.1	62.6	1.63	2.87	4.63	6.08	37.10
	Max	0.3	37.1	59.8	36.3	93.8	2.53	39.1	7.73	7.89	45.90
	Avg	0.2	15.1	55.6	29.3	84.9	2.18	15.0	6.31	7.17	41.15
Transect	Min	--	2.3	50.0	40.8	96.4	2.32	--	--	--	37.90
	Max	--	3.7	55.6	47.7	97.8	5.01	--	--	--	41.20
	Avg	--	2.8	53.1	44.1	97.3	3.25	--	--	--	39.43
Benchmark	Min	--	--	--	--	--	1.52	2.59	6.14	--	42.20
	Max	--	--	--	--	--	1.79	50.0	7.13	--	51.30
	Avg	--	--	--	--	--	1.66	19.8	6.75	--	46.06
Site-Wide	Min	0.1	2.3	26.5	7.2	33.8	1.20	2.59	4.06	5.72	37.10
	Max	1.2	65.1	59.8	47.7	97.8	5.01	70.2	7.73	7.89	58.70
	Avg	0.3	17.7	52.5	29.6	82.2	2.12	19.8	6.28	6.92	45.62
Reference	Min	0.1	35.4	39.4	5.6	45.0	0.469	85.0	4.24	2.54	61.90
	Max	0.1	54.9	57.6	6.9	64.5	0.653	255	5.50	3.06	64.80
	Avg	0.1	45.2	48.5	6.3	54.8	0.561	170	4.87	2.80	63.35

Site-Wide Includes onsite (incl. zone), perimeter, transect, and benchmark stations
TOC Total Organic Carbon
TVS Total Volatile Solids
DW Dry Weight
-- Not Analyzed

Total sulfides ranged from 2.59 mg/kg (PGB01-A) to 70.2 mg/kg (PGZ06) with a site-wide average of 19.8 mg/kg. Reference sediments collected from Carr Inlet were significantly higher in total sulfides, averaging 170 mg/kg. Ammonia concentrations ranged from 4.06 mg-N/kg (PGS08) to 7.73 mg-N/kg (PGP01-A) with a site-wide average of 6.28 mg/kg. Reference sediments collected from Carr Inlet had similar concentrations of ammonia, averaging 4.87 mg-N/kg. TOC values ranged from 1.20 to 5.01 %, while lower TOC values were reported for the reference sediments (0.469% to 0.653% TOC). The site-wide average of total solids was 45.62%, ranging from 37.10% to 58.70%. Reference stations had the highest percent total solids, averaging 63.35%, and a lower average of total volatile solids (2.80%, compared to the site-wide average of 6.92% total volatile solids).

4.2.2 Metals

All DMMP metals of concern except antimony, selenium, and silver were detected at low levels in the Port Gardner sediment samples submitted for analysis. All antimony results were UJ-qualified as estimated during data review to indicate a potential low bias because matrix spike recoveries were below established control limits. In general, perimeter stations had higher metal concentrations than onsite stations (Table 4–3). All reported concentrations fell well below their respective DMMP and SMS chemical criteria. The 2010 and 2006 metals concentrations at Port Gardner were generally lower than levels recorded in the 1988 baseline study, the 1990 monitoring event, and 1994 monitoring event (Table 4–4). However, it should be noted that metals analysis in 2010 and 2006 used the Strong Acid Digestion (SAD) method in accordance with current DMMP methodology. Previous monitoring events at Port Gardner had used the Total Acid Digestion (TAD) method, which generally reports higher metals concentrations. Chromium and selenium were not analyzed in previous studies.

Table 4–3. Metals Analysis Summary by Station Type

Metal (mg/kg DW)	DMMP	Onsite			Perimeter			Benchmark		
	SL	Min	Max	Average	Min	Max	Average	Min	Max	Average
Antimony	150	nd	nd	nd	nd	nd	nd	--	--	--
Arsenic	57	8.4	9.7	9.1	10.1	12.5	11.3	--	--	--
Cadmium	5.1	0.4	0.6	0.5	0.5	0.6	0.5	--	--	--
Chromium	--	34.4	50	40	43	53	48	--	--	--
Copper	390	36.4	48	41	46	53	48	--	--	--
Lead	450	9	14	11	13	18	16	--	--	--
Mercury	0.41	0.06	0.10	0.08	0.09	0.14	0.11	0.09	0.10	0.10
Nickel	140	38.7	52	44	48	58	53	--	--	--
Selenium	--	nd	nd	nd	nd	nd	nd	--	--	--
Silver	6.1	nd	nd	nd	nd	nd	nd	--	--	--
Zinc	410	62	84	70	76	100	88	--	--	--

B Estimated concentration that is less than the method reporting limit (MRL) but greater than or equal to the method detection limit (MDL)

nd Not detected

-- Not analyzed or not determined

Table 4–4. Average Metal Concentrations Summarized by Station Type and Survey Year

Metal (mg/kg DW)	DMMP	Onsite					Perimeter					Benchmark			
	SL	1988	1990	1994*	2006	2010	1988	1990*	1994*	2006	2010	1988	1994*	2006	2010
Antimony	150	nd	nd	1.43	0.13	nd	nd	1.04	1.38	0.18	nd	nd	--	--	--
Arsenic	57	9.87	5.96	9	7.12	9.1	10.0	10.8	8.67	8.32	11.3	9.2	--	--	--
Cadmium	5.1	0.22	0.20	0.36	0.19	0.5	0.20	0.22	0.31	0.23	0.5	0.20	--	--	--
Chromium	-	--	--	--	29.33	40	--	--	--	41.4	48		--	--	--
Copper	390	50	22.4	41.2	27.6	41	49	50.8	46.9	35	48	39.5	--	--	--
Lead	450	23	15.8	36	8.02	11	24.4	8.68	40.3	15.2	16	19	--	--	--
Mercury	0.41	0.16	0.09	0.08	0.07	0.08	0.17	0.14	0.12	0.12	0.11	0.13	0.13	0.11	0.10
Nickel	140	58.3	25.4	48.7	30.7	44	54.8	56.8	55.7	37	53	46.4	--	--	--
Selenium	-	--	--	--	0.40	nd	--	--	--	0.64	nd	--	--	--	--
Silver	6.1	0.35	0.07	0.26	0.14	nd	0.35	0.36	0.39	0.28	nd	0.30	--	--	--
Zinc	410	97.3	48.8	81.2	49.3	70	95.2	108	93.8	64.5	88	81.8	--	--	--

Note: The mean of detected concentrations are reported. If only one replicate sample had a detected concentration, that value is reported in this table. Undetected concentrations (detection limits) were not included.

nd Not detected

-- Not analyzed or not determined

* Total Acid Digestion (TAD) method used. Strong Acid Digestion (SAD) is current methodology.

4.2.3 Butyltins

Three onsite, four perimeter, and two benchmark samples were analyzed for butyltins in bulk sediment and porewater. Benchmark samples were analyzed for butyltins in porewater because of the short holding time and archived for bulk butyltins. The results are summarized in Table 4–5. No butyltins were detected in the bulk sediment samples. Monobutyltin was detected in all porewater samples with the exception of station PGS08. Dibutyltin and tributyltin were not detected in any porewater sample.

Table 4–5. Butyltins Results by Station Type

Butyltin	DMMP	Onsite			Perimeter			Benchmark		
	SL	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
Butyltins in Sediment (µg/kg DW)										
Monobutyltin ion	--	nd	nd	nd	nd	nd	nd	nd	nd	nd
Dibutyltin ion	--	nd	nd	nd	nd	nd	nd	nd	nd	nd
Tributyltin ion	--	nd	nd	nd	nd	nd	nd	nd	nd	nd
Butyltins in Porewater (µg/L)										
Monobutyltin ion	--	0.013	0.018	0.016	0.010	0.027	0.017	0.015	0.030	0.023
Dibutyltin ion	--	nd	nd	nd	nd	nd	nd	nd	nd	nd
Tributyltin ion	0.15	nd	nd	nd	nd	nd	nd	nd	nd	nd

nd Not detected
-- Not determined

4.2.4 Organic Compounds

A summary of detected organic compounds in Port Gardner sediments is provided in Table 4–6. DMMP volatile organic compounds, chlorinated aromatic hydrocarbons, miscellaneous extractables and PCBs (as Aroclors) were not detected in any of the sediment samples. Phthalates, phenols, high molecular polycyclic aromatic hydrocarbons (HPAH), low molecular polycyclic aromatic hydrocarbons (LPAH), and pesticide compounds were detected at low or trace levels in perimeter and onsite sediment samples. Fluoroanthene, pyrene, and bis(2-ethylhexyl)phthalate were detected at all perimeter stations. Phenol was detected at all perimeter stations except PGP08-B. Onsite stations had detected levels of benzo(a)anthracene, total benzofluoranthenes, fluoranthene, pyrene, 4-methylphenol, pentachlorophenol, phenol, heptachlor, and bis(2-ethylhexyl)phthalate. 4-methylphenol was detected at PGZ06, PGP01-C, and PGP08-B. Pentachlorophenol was detected at PGZ06. Heptachlor was detected in six perimeter stations and one onsite station.

The only detected LPAH compound was phenanthrene in samples collected from perimeter stations. HPAH compounds were detected at all perimeter and two onsite stations. All detected LPAH and HPAH concentration levels were well below the DMMP SLs. Detection limits for all organic compounds were below DMMP screening levels and all detected compounds were well below their respective DMMP and SMS chemical criteria.

For comparison purposes, Table 4–7 summarizes the mean detected concentrations of organic compounds at perimeter stations since the 1988 baseline survey at Port Gardner.[4] Nearly all of the organic compounds

[4] Temporal analysis of perimeter chemistry results was conducted using CTS and is reported in Section 5.1.2.

detected at the perimeter stations have remained at low or trace level concentrations since the baseline survey. Benzoic acid, detected in 2006, was below detectable levels in all previous and subsequent studies. Benzoic acid occurs naturally in food, particularly berries, is a common food preservative, and degrades quickly when released in the environment. In 1994, elevated levels of phenol were detected at PGP01 and PGP08. 2006 phenol levels were below detectable levels, with the exception of one low estimated concentration at PGP09. In 2010, phenol was detected at all perimeter stations except for one replicate sample at PGP08. Temporal variability of phenol concentrations in the marine environment has been observed in other Puget Sound studies and was recently evaluated by DNR at the Commencement Bay PSDDA site (SAIC 2005).

Table 4–6. Summary of Detected Organic Compounds by Station Type during the 2010 Survey

Detected Compounds	DMMP		Onsite				Perimeter			
	SL	ML	Min	Max	Frequency	Maximum Sample	Min	Max	Frequency	Maximum Sample
LPAH in µg/kg DW										
Phenanthrene	1500	21000	nd	nd	na	na	11 J	15 J	6/12	PGP07-A
HPAH in µg/kg DW										
Benzo(a)anthracene	1300	5100	10 J	10 J	1/3	PGS08	10 J	14 J	7/12	PGP07-B, PGP08-C, and PGP09-B
Benzo(a)pyrene	1600	3600	nd	nd	na	na	9.7 J	17 J	9/12	PGP09-B
Benzo(g,h,i)perylene	670	3200	nd	nd	na	na	12 J	12 J	2/12	PGP08-B and PGP09-B
Total benzofluoranthenes	3200	9900	16.4	16.4	1/3	PGS08	19.8 J	30 J	9/12	PGP08-C and PGP09-B
Chrysene	1400	21000	nd	nd	na	na	12 J	23	9/12	PGP07-B
Fluoranthene	1700	30000	10 J	12 J	2/3	PGS08	13 J	31	12/12	PGP07-A
Indeno(1,2,3-cd)pyrene	600	4400	nd	nd	na	na	10 J	10 J	1/12	PGP09-B
Pyrene	2600	16000	10 J	10 J	2/3	PGS08 and PGZ06	11 J	25	12/12	PGP08-B
Phenols in µg/kg DW										
4-Methylphenol	670	3600	11 J	11 J	1/3	PGZ06	10 J	27	2/12	PGP01-C
Pentachlorophenol	400	690	40	40	1/3	PGZ06	nd	nd	na	na
Phenol	420	1200	13 J	13 J	1/3	PGZ06	10 J	45	11/12	PGP08-C
Phthalate Esters in µg/kg DW										
Bis(2-ethylhexyl)phthalate	1300	8300	1500	1500	1/3	PGZ06	21	39	12/12	PGP09-B
Pesticides in µg/kg DW										
Heptachlor	10	-	1.6	1.6	1/3	PGZ06	1.2	9.2	6/12	PGP07-A

Note: Benchmark samples were archived with the exception of VOAs, which were undetected.
Frequency = number of detects / number of replicates
J Estimated concentration

Table 4–7. Mean of Detected Concentrations of Organic Compounds at Port Gardner Perimeter Stations by Monitoring Year

Parameter	DMMP SLs	1988	1990	1994	2006	2010
LPAH in µg/kg DW						
Naphthalene	2100	6.3			13	
Acenaphthylene	560	4			15	
Fluorene	540	4				
Phenanthrene	1500		38	27.6	20.2	12
Anthracene	960				18.5	
2-Methylnaphthalene	670	5				
HPAH in µg/kg DW						
Benzo(a)anthracene	1300	18.6		23.6	24.4	13
Benzo(a)pyrene	1600	35.3		28	23.7	13
Benzo(g,h,i)perylene	670	45.7		25	20.3	12
Benzofluoranthenes (b+k)	3200	68.3		47	26.25	25
Chrysene	1400	35.3	38	39.2	38.1	18
Dibenz(a,h)anthracene	230	14.3				
Fluoranthene	1700	33	42	40.2	54.2	20
Indeno(1,2,3-cd)pyrene	600	38.3		23.5	21.3	10
Pyrene	2600	38.3	52	46.2	42.7	18
Phthalate Esters in µg/kg DW						
Bis(2-ethylhexyl)phthalate	8300	10.1	53	31	16.8	29
Butylbenzylphthalate	970	8				
Di-n-butylphthalate	5100				31.8	
Di-n-octylphthalate	6200	6				
Phenols in µg/kg DW						
Pentachlorophenol	400	14				
Phenol	420			192.5	19.5	24
4-Methylphenol	670				38	19
Miscellaneous Extractables in µg/kg DW						
Benzoic Acid	650				220	
Dibenzofuran	540	5				
Pesticides and PCBs in µg/kg DW						
4,4'-DDE	6.9*		2			
Aroclor-1260	130*	40				
Dieldrin	10		1.65			
Lindane	10		3.9			
Heptachlor						3.0

Note: The mean of detected concentrations are reported. If only one replicate sample had a detected concentration, that value is reported in this table. Undetected concentrations (detection limits) were not included.

Blank not detected

* SL is for the total of that compound class (i.e., total DDT and total PCBs).

4.2.5 Bioaccumulative Contaminants of Concern (BCOCs)

The 2010 tiered-full monitoring program included analysis of onsite and perimeter station sediments for List 1 chemicals (primary list of BCOCs; required for analysis); sediments were not analyzed for List 2 chemicals (candidate list of BCOCs; strong concern and priority for study). Benchmark samples were analyzed only for BCOC compounds with short holding times (mercury and tributyltin [TBT] porewater). A summary of detected BCOCs in Port Gardner sediments is provided in Table 4–8. The complete sediment chemistry results of the BCOC analysis and a comparison to the DMMP BTs for List 1 contaminants are presented in Appendix D.

BCOCs detected in sediment samples included metals, HPAHs, and pentachlorophenol. All List 1 metals were detected in samples below the BT concentrations. List 1 HPAH compounds fluoranthene and pyrene were detected at low concentrations in all perimeter and onsite samples except PGS04, which was undetected for both of these HPAH compounds. List 1 chlorinated aromatics, pesticides, PCB Aroclors, and phenol were not detected in any samples. Detected concentrations and detection limits of all List 1 BCOCs were below their respective BT values.

Table 4–8. Summary of List 1 Detected BCOCs in Port Gardner Sediments

Detected Compounds	PSDDA BT	Benchmark				Onsite				Perimeter			
		Min	Max	Freq	Maximum Location	Min	Max	Freq	Maximum Location	Min	Max	Freq	Maximum Location
Metals in mg/kg DW													
Arsenic	507.1	-	-	-	-	8.4	9.7	3/3	PGS04	10.1	12.5	12/12	PGP08-C
Cadmium	11.3	-	-	-	-	0.4	0.6	3/3	PGS04	0.5	0.6	11/12	PGP01-A, B; PGP08-C, and PGP09-A
Chromium	267	-	-	-	-	34.4	50	3/3	PGS04	43	53	12/12	PGP01-A
Copper	1027	-	-	-	-	36.4	48	3/3	PGS04	46	53	12/12	PGP08-C
Lead	975	-	-	-	-	9	14	3/3	PGS04	13	18	12/12	PGP01-A, B; and PGP08-B, C
Mercury	1.5	0.09	0.10	6/6	PGB01-A, B, C; and PGB09-A	0.06	0.10	3/3	PGS04	0.09	0.14	12/12	PGP08-C
Nickel	370	-	-	-	-	38.7	52	3/3	PGS04	48	58	12/12	PGP01-A, and PGP08-C
Zinc	2783	-	-	-	-	62	84	3/3	PGS04	76	100	12/12	PGP01-A, and PGP08-C
HPAH in µg/kg DW													
Fluoranthene	4600	-	-	-	-	10 J	12 J	2/3	PGS08	13 J	31	12/12	PGP07-A
Pyrene	11980	-	-	-	-	10 J	10 J	2/3	PGS08 and PGZ06	11 J	25	12/12	PGP08-B
Phenols in µg/kg DW													
Pentachlorophenol	504	-	-	-	-	40	40	1/3	PGZ06	nd	nd	0/12	na

J Estimated concentration that is less than the laboratory reporting limit
na Not applicable
nd Not detected

4.2.6 Field Variability

An acceptability criterion of 50% relative standard deviations (RSD) between replicates collected at the sampling locations was used for each parameter. The majority of field variability results were acceptable, with exceptions summarized in Table 4–9. The most frequent and highest RSD values above 50% occurred at station PGP07, related to concentrations of total sulfides, grain size parameters, phenol, and heptachlor. Total sulfides had consistently high RSD values; all stations with detected concentrations of total sulfides exceeded the acceptability criterion.

Table 4–9. Field Variability Results Exceeding 50% RSD

Parameter	PGB01	PGB09	PGP01	PGP07	PGP09
Conventionals and Grain Size					
Total Sulfides	94.4	103.0	81.9	51.1	87.0
Grain Size, Phi Scale -1 to 0				97.6	
Grain Size, Phi Scale 0 to 1				90.1	
Grain Size, Phi Scale 1 to 2				126.0	
Phenols					
Phenol				73.3	79.3
Pesticides					
Heptachlor				87.9	

Note: no results exceeded 50% RSD for station PGP08

4.3 Dioxin/Furan Analyses

The 2010 Port Gardner tiered full monitoring study included the analysis of dioxin/furan congeners in sediments to address recent concerns related to dioxin/furan congeners at Puget Sound dredging projects and proposed disposal of the dredged material at the DMMP disposal sites. Sediment samples for dioxin/furan analysis consisted of single replicate samples (top 10 cm) at each onsite and perimeter station. The results reported as toxic equivalent quotients (TEQs) are provided in Table 4–10. The concentration of dioxin/furan congeners are normalized to the toxicity of 2,3,7,8-TCDD using toxic equivalent factors (TEFs) updated by the World Health Organization (WHO) in 2005 (Van den berg et al. 2006). The TEQ of a mixture is equal to the sum of the concentrations of individual congeners multiplied by their TEF (potency relative to 2,3,7,8-TCDD). Table 4–10 reports TEQs calculated using the full value of the detection limit for undetected congeners (TEQ^{full}), using one-half the detection limit for undetected congeners ($TEQ^{1/2}$), and not including undetected congeners (TEQ^{0}). For sediments, dioxin/furan congeners were relatively low and varied by location. The lowest concentrations were measured at PGS09 (1.40 pg/g TEQ), PGZ0109 (1.68 pg/g TEQ) and PGS06 (1.69 pg/g TEQ). Total organic carbon is also reported for the sediment samples in Table 4–10. The concentrations of individual dioxin/furan congeners can be found in Appendix D.

Table 4–10. Dioxin/Furan Results for Port Gardner Sediments Reported as TEQs

Sample ID	Date Sampled	Adjusted TEQ, pg/g DW (full value for ND)	Adjusted TEQ, pg/g DW (0.5 x QL for ND)	Adjusted TEQ, pg/g DW (0 for ND)	TOC (%)
PGS01	06/28/2010	2.38	2.27	2.15	1.20 J
PGS02	06/25/2010	2.60	2.48	2.36	1.77 J
PGS04	06/28/2010	2.40	2.26	2.12	1.75 J
PGS05	06/25/2010	2.49	2.36	2.22	3.11 J
PGS06	06/28/2010	1.69	1.51	1.33	1.60 J
PGS07	06/28/2010	2.27	2.15	2.04	1.47 J
PGS08	06/28/2010	2.26	2.13	1.99	1.71 J
PGS09	06/28/2010	1.40	1.25	1.10	1.32 J
PGZ01	06/28/2010	1.68	1.53	1.37	2.56 J
PGZ06	06/28/2010	2.18	2.03	1.89	1.44 J
PGP01_10cm	06/23/2010	4.11	4.11	4.11	2.28 J
PGP07_10cm	06/23/2010	2.99	2.83	2.68	2.01 J
PGP08_10cm	06/24/2010	3.11	2.97	2.83	2.03 J
PGP09_10cm	06/24/2010	3.61	3.61	3.61	2.18 J

DW dry weight
J estimated concentration
ND Not detected
TEQ Toxic equivalent quotient calculated using 2005 World Health Organization TEFs (Van den berg et al. 2006)
TOC Total organic carbon
QL Quantitation level

4.4 PCB Congener Analyses

Single replicate samples (top 10 cm) at four perimeter stations, two benchmark staions, and three onsite stations were also analyzed for PCB congeners. The results of the PCB congener analyses are reported as TEQs and are provided in Table 4–11. The concentration of PCB congeners are normalized to the toxicity of 2,3,7,8-TCDD using TEFs updated by the WHO in 2005 (Van den berg et al. 2006). The TEQ of a mixture is equal to the sum of the concentrations of individual congeners multiplied by their TEF (potency relative to 2,3,7,8-TCDD). Table 4–11 reports TEQ values using 0.5 of the quantitation limits of undetected compounds ($TEQ^{1/2}$), and TEQ values omitting undetected concentrations(TEQ^{0}). PCB congener TEQ concentrations were relatively low and varied by location. The lowest concentrations were measured at PGS04 (0.0283 pg/g DW TEQ). The highest concentration was measured at PGB01_10cm (0.165 pg/g DW TEQ). Total organic carbon is also reported in Table 4–11. The concentrations of the individual 209 PCB congeners can be found in Appendix D.

Table 4–11. PCB Congener Results for Port Gardner Sediments Reported as TEQs

Sample ID	Date Sampled	Adjusted TEQ, pg/g DW (0.5 x QL for ND)	Adjusted TEQ, pg/g DW (0 for ND)	TOC (%)
PGS04	06/28/2010	0.0283	0.0073	1.75 J
PGS08	06/28/2010	0.0456	0.0144	1.71 J
PGZ06	06/28/2010	0.0939	0.0907	1.44 J
PGB01_10cm	06/25/2010	0.165	0.148	1.79 J
PGB09_10cm	06/25/2010	0.0663	0.0161	1.52 J
PGP01_10cm	06/23/2010	0.113	0.108	2.28 J
PGP07_10cm	06/23/2010	0.0504	0.0119	2.01 J
PGP08_10cm	06/24/2010	0.121	0.106	2.03 J
PGP09_10cm	06/24/2010	0.121	0.115	2.18 J

DW dry weight
J estimated concentration
ND Not detected
TEQ Toxic equivalent quotient calculated using 2005 World Health Organization TEFs (Van den berg et al. 2006)
TOC Total organic carbon
QL Quantitation level

4.5 PBDE Analyses

Single replicate samples (top 10 cm) at three perimeter stations, two benchmark stations, and three onsite stations were also analyzed for 46 individual PBDE congeners. A summary of the results of the PBDE congener analyses is provided in Table 4–12. PBDE congener concentrations varied by location and congener. The lowest detected concentration of any congener was measured at PGB01_10cm (0.105 pg/g DW). The highest concentrations were measured for BDE-209 at values ranging from 615 to 1,440 pg/g DW. Eleven PBDE congeners were detected in all samples: BDE-007, BDE-008, BDE-015, BDE-017, BDE-028, BDE-047, BDE-049, BDE-051, BDE-099, BDE-100, and BDE-153. Seven PBDE congeners were not detected in any of the Port Gardner sediment samples: BDE-030, BDE-077, BDE-105, BDE-116, BDE-128, BDE-181, and BDE-190. Numerical results are not available for six PBDE congeners because they are reported as coeluting with other PBDE congeners. When coelutions occur, a single value is reported for the first listed congener. Coeluting PDBE congener pairs are: BDE-008/011, BDE-012/013, BDE-017/025, BDE-028/033, BDE-119/120, and BDE-138/166. The results for all 46 PBDE congeners can be found in Appendix D.

Table 4–12. Detected PBDE Congener Results for Port Gardner Sediments

PBDE Congener pg/g DW)	Benchmark					Onsite					Perimeter				
	Min	Max	Avg	Freq	Maximum Location	Min	Max	Avg	Freq	Maximum Location	Min	Max	Avg	Freq	Maximum Location
BDE-007	5.59	5.65	5.62	2/2	PGB01_10cm	5.43	12.9	8.33	3/3	PGZ06	5.03	5.98	5.66	5/5	PGP09_10cm
BDE-008	7.09	8.33	7.71	2/2	PGB01_10cm	5.97	6.21	6.110	3/3	PGS08	7.54	8.36	7.99	5/5	PGP08_10cm
BDE-010	nd	nd	nd	0/2	na	0.437	0.437	0.437	1/3	PGZ06	nd	nd	nd	0/5	na
BDE-012	0.665	0.846	0.756	2/2	PGB01_10cm	0.804	0.963	0.884	2/3	PGZ06	0.696	0.986	0.852	5/5	PGP07_10cm
BDE-015	3.06	3.98	3.52	2/2	PGB01_10cm	1.76	2.73	2.36	3/3	PGS08	3.62	4.51	3.96	5/5	PGP08_10cm
BDE-017	32.6	32.8	32.7	2/2	PGB09_10cm	25.6	32.2	29.6	3/3	PGS08	29.9	33.8	31.6	5/5	PGP08_10cm
BDE-028	10.7	11	10.9	2/2	PGB01_10cm	6.1	9.05	7.66	3/3	PGS08	10.2	11.7	10.8	5/5	PGP08_10cm
BDE-032	nd	nd	nd	0/2	na	0.289	0.289	0.289	1/3	PGS08	0.29	0.343	0.308	3/5	PGP07_10cm
BDE-035	nd	nd	nd	0/2	na	nd	nd	nd	0/3	na	0.205	0.205	0.205	1/5	PGP07_10cm
BDE-037	nd	nd	nd	0/2	na	0.692	0.692	0.692	1/3	PGS08	0.688	1.11	0.844	4/5	PGP08_10cm
BDE-047	120	121	121	2/2	PGB01_10cm	85.8	107	96.9	3/3	PGS08	115	136	125	5/5	PGP01_10cm
BDE-049	46.9	50.2	48.6	2/2	PGB09_10cm	33.9	44.4	38.3	3/3	PGS08	47.9	50	48.8	5/5	PGP08_10cm
BDE-051	6.76	7.29	7.03	2/2	PGB01_10cm	4.78	6.35	5.39	3/3	PGS08	6.8	7.9	7.33	5/5	PGP01_10cm
BDE-066	4.99	4.99	4.99	1/2	PGB01_10cm	1.61	5.03	3.58	3/3	PGS08	4.66	6.06	5.35	4/5	PGP07_10cm
BDE-071	2.27	3.48	2.88	2/2	PGB09_10cm	2.92	3.31	3.12	2/3	PGZ06	3.00	3.44	3.20	4/5	PGP07_10cm
BDE-075	nd	nd	nd	0/2	na	0.19	0.19	0.190	1/3	PGS04	0.393	0.393	0.393	1/5	PGP01_10cm
BDE-079	0.105	0.105	0.105	1/2	PGB01_10cm	nd	nd	nd	0/3	na	0.309	0.309	0.309	1/5	PGP09_10cm
BDE-085	nd	nd	nd	0/2	na	2.25	2.62	2.44	2/3	PGS08	3.24	3.28	3.26	2/5	PGP08_10cm
BDE-099	77.6	87.4	82.5	2/2	PGB01_10cm	53	63.9	58.6	3/3	PGS08	71.1	95.2	80.5	5/5	PGP08_10cm
BDE-100	25.8	26.7	26.3	2/2	PGB01_10cm	16.3	23.5	20.1	3/3	PGS08	25.4	32.3	27.8	5/5	PGP08_10cm
BDE-119	0.582	0.85	0.716	2/2	PGB01_10cm	0.6	0.6	0.600	1/3	PGS08	0.41	1.08	0.745	2/5	PGP08_10cm
BDE-126	nd	nd	nd	0/2	na	0.327	0.327	0.327	1/3	PGS08	nd	nd	nd	0/5	na
BDE-138	nd	nd	nd	0/2	na	1.6	1.6	1.60	1/3	PGS08	3.15	3.15	3.15	1/5	PGP07_10cm
BDE-140	nd	nd	nd	0/2	na	0.51	0.51	0.510	1/3	PGS04	nd	nd	nd	0/5	na
BDE-153	9.53	10.4	9.97	2/2	PGB01_10cm	7.12	10	8.27	3/3	PGS08	9.85	13.7	11.7	5/5	PGP08_10cm
BDE-154	10.9	12.6	11.8	2/2	PGB01_10cm	6.44	10.3	8.37	2/3	PGS08	11.7	16.1	13.7	4/5	PGP08_10cm
BDE-155	2.48	3.47	2.98	2/2	PGB01_10cm	1.01	2.01	1.66	3/3	PGS04	2.62	4	3.25	4/5	PGP01_10cm

PBDE Congener pg/g DW)	Benchmark					Onsite					Perimeter				
	Min	Max	Avg	Freq	Maximum Location	Min	Max	Avg	Freq	Maximum Location	Min	Max	Avg	Freq	Maximum Location
BDE-183	nd	nd	nd	0/2	na	6.36	10.2	8.28	2/3	PGS08	4.07	6.88	5.97	4/5	PGP07_10cm
BDE-203	23.7	23.7	23.7	1/2	PGB01_10cm	22.7	51.1	36.9	2/3	PGS08	15.8	30.8	26.0	5/5	PGP07_10cm
BDE-206	nd	nd	nd	0/2	na	38.2	151	82.5	3/3	PGS08	35.9	72	56.7	5/5	PGP08_10cm
BDE-207	157	157	157	1/2	PGB01_10cm	88.3	315	175	3/3	PGS08	86.8	236	165	5/5	PGP08_10cm
BDE-208	101	101	101	1/2	PGB01_10cm	49.7	191	100	3/3	PGS08	68.5	118	93.3	2/5	PGP01_10cm
BDE-209	1140	1310	1225	2/2	PGB09_10cm	615	1330	893	3/3	PGS08	794	1440	1224	4/5	PGP01_10cm

AVG average detected concentration
DW dry weight
Freq detection frequency
MIN minimum detected concentration
MAX maximum detected concentration
na not applicable
nd not detected

4.6 Bioassays

DMMP bioassay testing was conducted on the three onsite station sediments from Port Gardner (PGZ06, PGS04, and PGS08). The DMMP sediment bioassays included the 10-day acute amphipod test using *Eohaustorius estuarius*, the sediment larval test using *Mytilus galloprovincialis*, and the 20-day *Neanthes arenaceodentata* mean growth test. DMMP bioassay Site Condition II evaluation guidelines were not exceeded for any of the three bioassays at PGZ06, PGS04, and PGS08.

Results of the bioassay tests are summarized in Table 4–13. The full bioassay laboratory reports and quality assurance review are provided in Appendix F. Sample PGZ06 was tested with Carr Inlet reference sample CR-23W. Samples PGS04 and PGS08 were tested with Carr Inlet reference sample CR-24. The performance results of the negative control and reference sediments for each bioassay are presented in Table 4–14. The negative control performance standards were met for all three bioassays. The reference sediment CR-24 did not meet the performance criteria for the larval development bioassays. Therefore, the interpretation of the larval development test requires an alternate evaluation of results using comparisons to negative controls and additional lines of evidence, such as comparison of the re-suspension data results to interpretive guidelines.

4.6.1 Amphipod Mortality Test

The amphipod mortality tests were initiated on July 27, 2010, using test organisms (*E. estuarius*) obtained from Northwest Aquatic Sciences, Newport, OR. Mean mortality for the onsite test sediments ranged from 4.0 to 11.0%. All samples passed the DMMP nondispersive guidelines for the amphipod test (Table 4–13).

4.6.2 Larval Development Test

The larval development tests were initiated on July 7, 2010, using test organisms (*Mytilus galloprovincialis*) provided by Taylor Shellfish, Shelton, WA. The results of the larval development bioassay are summarized in Table 4–13. Two sets of data results were provided for the single batch of larval development bioassays: standard (PSEP) protocol results and resuspension results. The resuspension results were produced as part of a modified test protocol that included resuspending the sediment in the test chamber by pouring decanted water back into the chamber and allowing settlement overnight. An additional subsample of overlying seawater was then sampled and counted to produce a second set of results for the larval development test.

The reference sediment results for CR-24, following the standard protocol larval count did not meet the performance criteria. Therefore, it was necessary to use negative control results for comparative purposes to interpret the results of the larval tests for PGS04 and PGS08. The negative control for larval tests consists of seawater only (for performance criteria and normalization of test results); however, the results exceeded the performance criteria for reference sediment and therefore were deemed suitable for test interpretation purposes. The seawater control provides a more conservative comparison since the larvae are easier to identify and count in solution. The reference sediments both met the performance criteria for the re-suspension modified protocol data results.

The test sediment results for the larval development bioassay ranged from 73.5 to 90.1 mean percent normal survival following the standard test protocol and 77.7 to 84.9 mean percent normal survival for the re-suspension modified protocol. All three test sediments passed the DMMP nondispersive guidelines for both sets of larval data results.

4.6.3 Juvenile Polychaete Growth Test

The juvenile polychaete growth tests were initiated on July 7, 2010, using the test organism (*N. arenaceodentata*) obtained from Dr. Donald Reish, California State University, Long Beach, CA. The results of the juvenile polychaete growth bioassay are presented in Table 4–13. Two sets of data results were provided for the single batch of juvenile polychaete growth bioassays: standard (PSEP) protocol results and ash-free dry weight (AFDW) results. The AFDW results were produced as part of a modified test protocol that ashed the weight boats and test organisms to determine the influence of sediment particle ingestion to the growth rate calculations. The ashed weight (i.e., sediment particles) is subtracted from the dry weight to determine the AFDW.

The test sediment results of the juvenile polychaete growth bioassay ranged from 0.659 to 0.710 mean individual growth (mg/individual/day) for the dry weight results and from 0.501 to 0.515 mg/individual/day for the AFDW. All three test sediments passed the DMMP nondispersive guidelines for both sets of data results.

Table 4–13. Bioassay Results for Control, Reference, and Onsite Sediments

Sample	Grain Size (% fines)	Amphipod Test Mortality (%)	Larval Test Mean Normal Survival (%)	Larval Test Mean Normal Survival (%) *Resuspension Counts*	20 Day *Neanthes* Mean Growth Rate (mg/indiv/day)	20 Day *Neanthes* Mean Growth Rate (mg/indiv/day) *AFDW*
Control	NA	1 ± 2.2	89.2 ± 7.8	92.8 ± 5.8	0.732 ± 0.10	0.459 ± 0.056
CR23-W	45.0	2 ± 2.7	78.2 ± 10.9	78.8 ± 6.4	0.729 ± 0.07	0.511 ± 0.047
CR-24	64.5	1 ± 2.2	**62.7 ± 8.1**	87.6 ± 5.0	0.783 ± 0.21	0.542 ± 0.117
PGZ06	33.8	6 ± 4.2	73.5 ± 3.9	77.7 ± 9.9	0.659 ± 0.06	0.501 ± 0.046
PGS04	72.0	4 ± 4.2	90.1 ± 6.9	84.9 ± 8.9	0.670 ± 0.11	0.511 ± 0.059
PGS08	62.7	11 ± 8.9	87.5 ± 8.9	84.7 ± 10.3	0.710 ± 0.06	0.515 ± 0.049

NMCA Normalized combined mortality/abnormality
NA Not applicable (seawater control, or data not available)
AFDW Ash-free dry weight
CR-23W Reference for PGZ06
CR-24 Reference for PGS04 and PGS08
Bold Font Performance criteria not met
Note: Reported results included standard deviation (e.g., ± 2.2).

Table 4–14. Negative Control and Reference Performance Standards and Test Results

Test (Test Species)	Negative Control Performance Standard		Reference Sediment Performance Standard	
Amphipod Mortality (*E. estuarius)*	$M_C \leq 10\%$	1%	$M_R \leq 25\%$	CR-23W: 2%; CR-24: 1%
Larval Development (*M. galloprovincialis.*)	$N_C \div I \geq 0.70$	0.897	$N_R \div N_C \geq 65\%$	CR-23W: 78.2%; **CR-24: 62.7%**
Larval Development (*M. galloprovincialis.*) *Re-suspension results*	$N_C \div I \geq 0.70$	0.931	$N_R \div N_C \geq 65\%$	CR-23W: 78.8%; CR-24: 87.6%
Juvenile Polychaete Growth (*N. arenaceodentata*)	$M_C \leq 10\%$ and $MIG_C \geq 0.38$[1]	0.0%; 0.73	$MIG_R \div MIG_C \geq 0.80$	CR-23W: 0.96; CR-24: 0.96
Juvenile Polychaete Growth (*N. arenaceodentata*) *Ash free dry weight results*	$M_C \leq 10\%$ and $MIG_C \geq 0.38$[1,2]	0.0%; 0.459[2]	$MIG_R \div MIG_C \geq 0.80$	CR-23W: 1.11; CR-24: 1.18

Bold Font: Performance criteria not met
M = mean mortality
N = mean normal development survival in seawater control
I = initial count= 382.2
MIG = mean individual growth rate (mg/individual/day)
Subscripts: R = reference; C = negative control

1. Target MIGc is 0.72 mg/individual/day; the test is considered to be failed if the Control MIG is less than 0.38 mg/individual/day.
2. A mean individual growth rate for the control has not been established for AFDW measurements.

5.0 EVALUATION OF THE MONITORING DATA

This section evaluates the 2010 environmental monitoring data collected at the Port Gardner site using the DMMP interpretive guidelines described in Section 2.0. The evaluation is organized according to the questions and hypotheses of the PSDDA monitoring framework. A comparison of onsite dioxin/furan congener concentrations to the Puget Sound main basin/reference area concentrations is also included.

5.1 Question 1: Does the Dredged Material Stay On Site?

5.1.1 SVPS Results

Hypothesis No. 1: Dredged material remains within the disposal site boundary.

The 2010 SVPS survey at Port Gardner did not identify the presence of recent dredged material beyond the disposal site perimeter that exceeded the 3 cm DMMP interpretive criteria. Under the monitoring framework for non-dispersive dredged material disposal sites, ***PSDDA Hypothesis No. 1 is accepted*** (i.e., dredged material remains within the disposal site boundary).

5.1.2 Perimeter Chemistry

Hypothesis No. 2: Chemical concentrations at offsite stations do not measurably increase over time due to dredged material disposal.

A review of the 2010 perimeter station chemistry found that all detected chemicals were well below the Washington State SQS criteria.

A statistical time-trends analysis was conducted to determine if changes observed in perimeter site chemistry are significant over time. The time-trends analysis was conducted using the Chemical Tracking System (CTS) as described in detail in SAIC and MWLS (1996). Table 5–1 presents the maximum likelihood estimations for each chemical group at each perimeter station. The maximum likelihood estimations are expressed as a slope (mean percent change per year), indicating the trend in concentrations of chemicals or chemical groups over time. For statistical significance determinations (P-value), more than three individual chemical results are necessary within a chemical group to determine the slope for that chemical group. Chemical groups determined for the 2010 CTS analysis include conventionals, metals, LPAHs, and HPAHs. The detailed CTS output is provided in Appendix G.

The "global" maximum likelihood estimation for each perimeter station, which represents the estimate for all chemicals of concern and conventional parameters, is also reported in Table 5–1. The global estimation is no longer used for evaluating offsite chemical trends because it assumes that a common trend is present among all chemical concentrations, including conventional parameters (SAIC 2003). Some chemicals show increasing trends and many others show decreasing trends at the disposal sites. In addition, some conventional parameters do not follow the same trend as the COCs (e.g., an increase in percent fines). Therefore, trends for individual chemicals and groups of chemicals (e.g., metals or HPAHs) are used to assess time trends in perimeter chemistry.

The maximum likelihood results showed both increases and decreases in chemical groups at the perimeter stations since 1988 (Table 5–1). At station PGP01, all of the chemical groups show decreases in COCs over time with the exception of the phthalates group (+5.42% per year) and phenols (+0.94% per year). At station PGP07, all of the chemical groups show decreases with the exception of slight increases in the HPAHs and phthalates, both of which were statistically insignificant or had inadequate data to evaluate

statistically. The phenols group (driven only by phenol) showed an increase of 140% per year, but this is driven by a single observation in 2010 and will need additional data to confirm. At station PGP08, the conventionals, the phthalates group, and the LPAHs (phenanthrene only) all showed decreases; the metals, HPAHs, and phenols (phenol only) groups showed small increases. At station PGP09, all of the chemical groups show decreases with the exception of the phthalates group and a statistically significant increase in the LPAHs group (+2.72% per year).

Conventionals

The conventionals group shows a decrease at all stations with statistically significant decreases at stations PGP07 and PGP09. For individual conventional parameters, statistically significant decreasing trends were observed for ammonia (PGP07, PGP08), TVS (PGP01, PGP09), percent gravel and sand (PGP09), and percent silt (PGP07). Statistical significant increasing trends were observed for TOC (PGP01, PGP07, PGP09), ammonia (PGP01), percent silt (PGP08), and percent fines and clay (PGP09).

Metals

The metals group shows decreasing trends in concentrations at all stations except PGP08. For individual metals, statistically significant decreasing trends were observed for mercury (PGP01, PGP09), silver (PGP07), and zinc (PGP09). Cadmium showed a statistically significant increase at station PGP09.

At station PGP08 increasing trends were observed for all but mercury, with statistically significant increases for arsenic, cadmium, copper, nickel, and zinc. For these metals, the percent change per year ranged from 0.3% to 0.5%.

Antimony was excluded from the metals group trend for PGP07. The trend estimate was unstable because of concentrations ranging from undetected at 1.1 µg/kg in 1990, detected at 1.1 µg/kg in 1994, average concentrations of 0.15N µg/kg in 2006, and undetected at less than 0.5 µg/kg in 2010. It appears that the concentrations are decreasing, but additional detected data with low detection limits are needed to confirm.

Table 5–1. Maximum Likelihood Results for Port Gardner Perimeter Stations

Parameter	Slope and Significance (Log 10)								Percent Change Per Year		
	Mean	Max	Min	Median	S.E.	95% LCL	95% UCL	P-Value	Mean	95% LCL	95% UCL
PGP01											
Global	-0.008	0.045	-0.136	-0.004	0.004	-0.015	9.26E-05	0.053	-1.72	-3.43	0.02
Conventionals	-0.012	0.045	-0.136	2.95E-05	0.007	-0.027	0.004	0.138	-2.64	-6.02	0.87
Metals	-0.003	0.011	-0.015	-0.004	0.004	-0.012	0.006	0.440	-0.73	-2.71	1.29
LPAHs	-0.018	-0.018	-0.018	-0.018	0.009	-0.129	0.093	inad. data	-4.11	-25.77	23.88
HPAHs	-0.016	0.000	-0.034	-0.015	0.007	-0.032	0.001	0.088	-3.52	-7.20	0.32
Chl. Aromatics	inad. data	inad. data	Inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Phthalates	0.023	0.031	0.015	0.023	0.022	-0.070	0.116	inad. data	5.42	-14.83	30.48
Phenols	0.004	0.004	0.004	0.004	0.046	-0.579	0.587	inad. data	0.94	-73.64	286.51
Misc. Ext.	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Volatiles	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Pest./PCBs	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
PGP07											
Global	0.021	0.520	-0.158	-0.002	1.478	-3.017	3.060	0.989	5.01	-99.90	114,605
Conventionals	-0.028	0.006	-0.158	-0.003	0.008	-0.046	-0.011	0.009	-6.30	-10.05	-2.40
Metals	-0.001	0.009	-0.007	-0.003	0.003	-0.009	0.006	0.691	-0.31	-1.97	1.38
LPAHs	-0.007	-0.007	-0.007	-0.007	0.009	-0.117	0.103	inad. data	-1.67	-23.65	26.63
HPAHs	0.000	0.008	-0.010	0.001	0.012	-0.030	0.030	0.996	0.01	-6.65	7.15
Chl. Aromatics	inad. data	inad. data	Inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Phthalates	0.007	0.013	0.002	0.007	0.010	-0.034	0.048	inad. data	1.71	-7.47	11.81
Phenols	0.381	0.381	0.381	0.381	33.754	-428.500	429.261	inad. data	140.30	-inf	+inf
Misc. Ext.	inad. data	inad. data	Inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Volatiles	inad. data	inad. data	Inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Pest./PCBs	0.519929	0.519929	0.519929	0.519929	26.42339	-335.221	336.261	inad. data	231.08	-inf	+inf

Table 5–1. Maximum Likelihood Results for Port Gardner Perimeter Stations (continued)

Parameter	Slope and Significance (Log 10)								Percent Change Per Year		
	Mean	Max	Min	Median	S.E.	95% LCL	95% UCL	P-Value	Mean	95% LCL	95% UCL
PGP08											
Global	-0.002	0.021	-0.057	0.000	0.006	-0.015	0.011	0.767	-0.44	-3.40	2.62
Conventionals	-0.008	0.003	-0.057	-0.001	0.005	-0.018	0.002	0.129	-1.80	-4.07	0.53
Metals	0.002	0.005	0.000	0.001	0.003	-0.006	0.009	0.651	0.36	-1.33	2.08
LPAHs	-0.001	-0.001	-0.001	-0.001	0.001	-0.015	0.013	inad. data	-0.25	-3.47	3.08
HPAHs	0.000	0.009	-0.003	-0.001	0.006	-0.013	0.014	0.988	0.02	-3.06	3.20
Chl. Aromatics	inad. data	inad. data	Inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Phthalates	-0.007	0.004	-0.017	-0.007	0.089	-0.391	0.378	inad. data	-1.49	-59.37	138.86
Phenols	0.021	0.021	0.021	0.021	0.017	-0.196	0.238	inad. data	4.91	-36.39	73.03
Misc. Ext.	inad. data	inad. data	Inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Volatiles	inad. data	inad. data	Inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Pest./PCBs	inad. data	inad. data	Inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
PGP09											
Global	-0.005	0.078	-0.130	-0.003	0.003	-0.011	0.000	0.059	-1.23	-2.49	0.05
Conventionals	-0.017	0.009	-0.130	-0.002	0.005	-0.029	-0.005	0.016	-3.82	-6.43	-1.14
Metals	-0.004	0.020	-0.028	-0.003	0.004	-0.013	0.004	0.281	-1.00	-2.89	0.92
LPAHs	0.012	0.026	-0.002	0.012	0.007	-0.018	0.041	inad. data	2.72	-4.03	9.94
HPAHs	-0.009	0.003	-0.022	-0.007	0.006	-0.023	0.006	0.221	-1.98	-5.16	1.30
Chl. Aromatics	inad. data	inad. data	Inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Phthalates	0.011	0.011	0.011	0.011	0.005	-0.058	0.079	inad. data	2.49	-12.42	19.95
Phenols	inad. data	inad. data	Inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Misc. Ext.	inad. data	inad. data	Inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Volatiles	inad. data	inad. data	Inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Pest./PCBs	inad. data	inad. data	Inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data

LCL = lower conficence limit
UCL = upper conficence limit

PAHs

For the LPAHs group, phenanthrene was the only chemical that had sufficient data to evaluate a trend at all four stations. The trend was negative at all four stations, and statistically significant at PGP01. Acenaphthylene was sufficient to evaluate at PGP09, and resulted in a statistically significant positive trend.

The HPAHs group shows either decreasing trends overall, or a mean of zero. The average percent change ranged from -3.5% (PGP01) to + 0.02% (PGP08). Statistically significant decreasing trends were observed for benzo(a)pyrene (PGP01), and benzo(g,h,i)perylene (PGP01). Statistically significant increasing trends were observed for fluoranthene (PGP08).

Benzo(g,h,i)perylene was excluded for station PGP08 because of instability in the slope estimate. The concentrations ranged from 62E µg/kg in 1988 to a single detect (12 µg/kg) and two undetected values (less than 20 µg/kg) in 2010. It appears that the trend is decreasing but the higher detection limits in 2010 resulted in an undefined likelihood estimate. Additional data will be needed to confirm this negative trend.

Chlorinated Aromatics

There were inadequate detected data to determine trends for this group of compounds.

Phthalate Esthers

There were inadequate data to determine time trends for the phthalates group, with the exceptions of di-n-butyl phthalate and bis(2-ethylhexyl)phthalate. This group showed an increase in concentrations at stations PGP01, PGP07, and PGP09 and a decrease at station PGP08. The increase in bis(2-ethylhexyl)phthalate at station PGP08 was statistically significant with an annual estimated change of +0.8% per year.

Phenols

There were inadequate data to determine time trends for the phenols group, with the exception of phenol. At station PGP07, the phenol results indicated a fairly large positive trend (+140% per year). However, detected concentrations only occurred in 2010 (12J, 15J, and 43J µg/kg). Earlier lab results at this station ranged from 28U in 1990 to 12U µg/kg in 2006. The positive trend is primarily driven by a single replicate in 2010 (with the detected concentration of 43J µg/kg). Additional data are needed to confirm this trend.

Volatile Organics

There were inadequate detected data to determine trends for this group of compounds.

Miscellaneous Extractables

There were inadequate detected data to determine trends for this group of compounds.

Pesticides

There were inadequate data to determine time trends for all pesticides with the exception of heptachlor. At station PGP07, the heptachlor trend was flagged as an outlier. Concentrations at this perimeter station went from undetected at 1.3 µg/kg or less since 1990, to detection in all three replicates in 2010 with an average detected concentration of 4.6 µg/kg and a maximum concentration of 9.2 µg/kg. This resulted in a very large positive trend estimate (+231% per year).

The trend solution for heptachlor at station PGP08 was excluded due to instability in the slope estimate. Concentrations ranged from undetected (detection limits ranging from 0.98 to 3.0 µg/kg) to an average detected concentration of 1.55 µg/kg and maximum concentration of 1.9 µg/kg in 2010. There were only two detected values, both of which occurred in 2010. The trend for this compound cannot be adequately measured at this time due to the earlier data reporting detection limits at or above the 2010 detected values.

Heptachlor was never detected at station PGP01, and only detected in one replicate of PGP09 in 2010 (1.3 µg/kg).

Therefore, based on the comparison of perimeter chemistry results to the SQS criteria and CTS time-trends analysis, ***PSDDA Hypothesis No. 2 is accepted*** (i.e., chemical concentrations do not increase over time at offsite stations).

Table 5–2. Chemical Tracking System Output for Port Gardner Station PGP01

Per Chemical Results	Slope			Intercept				Slope as % change/year
	beta	SE(beta)	P-Value	alpha	SE(alpha)	sigma	SE(sigma)	
Conventionals								
Total Organic Carbon (% DW)	0.0058	0.0022	0.0339	0.1067	0.0750	0.0566	0.0133	1.354
Total Sulfides (mg/kg DW)	-0.0202	0.0171	0.2820	1.6583	0.5945	0.4094	0.1023	-4.549
Ammonia (mg-N/kg DW)	0.0447	0.0102	0.0120	-0.9358	0.3940	0.0500	0.0144	10.830
TVS (mg/kg DW)	-0.1363	0.0566	0.0470	7.9533	1.9125	1.4430	0.3401	-26.937
Total Solids (%)	0.0000	0.0011	0.9799	1.5798	0.0382	0.0288	0.0068	0.007
Percent Gravel (≥2.0 mm)	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Percent Sand (<2.0 mm - 0.06 mm)	-0.0020	0.0092	0.8317	0.8292	0.3113	0.2348	0.0554	-0.467
Percent Silt (0.06 mm - 0.004 mm)	-0.0035	0.0029	0.2620	1.8213	0.0971	0.0733	0.0173	-0.805
Percent Fines (<0.06 mm)	0.0006	0.0007	0.4449	1.9499	0.0246	0.0186	0.0044	0.136
Percent Clay (<0.004 mm)	0.0065	0.0049	0.2253	1.3857	0.1650	0.1245	0.0293	1.508
Metals in mg/kg DW								
Antimony	-0.0148	0.0189	0.4578	-0.1672	0.6258	0.3541	0.1188	-3.360
Arsenic	0.0008	0.0021	0.7240	0.9804	0.0719	0.0543	0.0128	0.180
Cadmium	0.0114	0.0063	0.1137	-0.9049	0.2088	0.1550	0.0381	2.651
Copper	-0.0043	0.0027	0.1517	1.8022	0.0899	0.0678	0.0160	-0.981
Lead	-0.0036	0.0063	0.5855	1.3888	0.2131	0.1608	0.0379	-0.827
Mercury	-0.0080	0.0030	0.0252	-0.6290	0.0960	0.0820	0.0175	-1.820
Nickel	-0.0047	0.0031	0.1752	1.8642	0.1063	0.0802	0.0189	-1.088
Silver	-0.0005	0.0040	0.8989	-0.4927	0.1191	0.0779	0.0219	-0.120
Zinc	-0.0049	0.0028	0.1175	2.0969	0.0930	0.0702	0.0165	-1.126
LPAHs in µg/kg DW								
Naphthalene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Acenaphthylene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Acenaphthene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Fluorene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Phenanthrene	-0.0182	0.0029	0.0015	1.9007	0.0904	0.0377	0.0163	-4.109
Anthracene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
2-Methylnaphthalene								
HPAHs in µg/kg DW								

Per Chemical Results	Slope			Intercept				Slope as % change/year
	beta	SE(beta)	P-Value	alpha	SE(alpha)	sigma	SE(sigma)	
Fluoranthene	-0.0054	0.0093	0.5812	1.5758	0.3180	0.2224	0.0557	-1.226
Pyrene	-0.0150	0.0072	0.0761	1.8544	0.2467	0.1753	0.0444	-3.394
Benzo(a)anthracene	0.0000	0.0063	0.9997	1.2002	0.2067	0.1216	0.0373	0.000
Chrysene	-0.0109	0.0074	0.1836	1.6707	0.2408	0.1610	0.0515	-2.474
Total fluoranthenes	-0.0152	0.0092	0.1414	1.9417	0.3012	0.2116	0.0757	-3.450
Benzo(a)pyrene	-0.0141	0.0034	0.0041	1.7553	0.1059	0.0658	0.0191	-3.188
Indeno(1,2,3-cd)pyrene	-0.0297	0.0135	0.0638	1.8424	0.4134	0.2206	0.1158	-6.610
Dibenz(a,h)anthracene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Benzo(g,h,i)perylene	-0.0341	0.0101	0.0118	2.1117	0.3019	0.1680	0.0983	-7.557
Chlorinated Aromatics in µg/kg DW								
1,3-Dichlorobenzene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
1,4-Dichlorobenzene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
1,2-Dichlorobenzene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
1,2,4-Trichlorobenzene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Hexachlorobenzene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Phthalate Esters in µg/kg DW								
Dimethylphthalate	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Diethylphthalate	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Di-n-Butylphthalate	0.0312	0.0368	0.4282	-0.1819	1.4077	0.4713	0.2502	7.4578
Butylbenzylphthalate	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
bis(2-Ethylhexyl)phthalate	0.0146	0.0101	0.1990	0.7435	0.3509	0.2233	0.0587	3.4146
Di-n-Octylphthalate	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Phenols in µg/kg DW								
Phenol	0.0041	0.0329	0.9059	0.9015	1.1800	0.6773	0.2666	0.939
2-Methylphenol	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
4-Methylphenol	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
2,4-Dimethylphenol	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Pentachlorophenol	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Miscellaneous Extractables in µg/kg DW								
Benzyl Alcohol	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Benzoic Acid	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Dibenzofuran	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data

Per Chemical Results	Slope			Intercept				Slope as % change/year
	beta	SE(beta)	P-Value	alpha	SE(alpha)	sigma	SE(sigma)	
Hexachloroethane	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Hexachlorobutadiene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
N-Nitrosodiphenylamine	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Volatile Organics in µg/kg DW								
Trichloroethene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Tetrachloroethene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Ethylbenzene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Total Xylene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Pesticides and PCBs in µg/kg DW								
4,4'-DDE	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
4,4'-DDD	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
4,4'-DDT	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Lindane	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Heptachlor	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Aldrin	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Dieldrin	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
alpha Chlordane	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Aroclor-1016	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Aroclor-1242	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Aroclor-1248	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Aroclor-1254	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Aroclor-1260	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Aroclor-1221	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Aroclor-1232	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data

Table 5–3. Chemical Tracking System Output for Port Gardner Station PGP07

Per Chemical Results	Slope			Intercept				Slope as % change/year
	beta	SE(beta)	P-Value	alpha	SE(alpha)	sigma	SE(sigma)	
Conventionals								
Total Organic Carbon (% DW)	0.0063	0.0022	0.0304	0.0270	0.0790	0.0459	0.0115	1.467
Total Sulfides (mg/kg DW)	-0.0164	0.0145	0.3105	1.2364	0.5301	0.2535	0.0677	-3.703
Ammonia (mg-N/kg DW)	-0.0692	0.0049	0.0001	3.4858	0.1883	0.0239	0.0069	-14.721
TVS (mg/kg DW)	-0.1583	0.0739	0.0758	8.6995	2.6013	1.5130	0.3782	-30.550
Total Solids (%)	-0.0017	0.0010	0.1350	1.7093	0.0356	0.0207	0.0052	-0.401
Percent Gravel (≥2.0 mm)	-0.0439	0.0222	0.1863	0.7391	0.7582	0.3499	0.2012	-9.606
Percent Sand (<2.0 mm - 0.06 mm)	0.0010	0.0093	0.9165	1.2242	0.3284	0.1910	0.0478	0.235
Percent Silt (0.06 mm - 0.004 mm)	-0.0038	0.0014	0.0336	1.8263	0.0483	0.0281	0.0070	-0.863
Percent Fines (<0.06 mm)	-0.0010	0.0024	0.6771	1.9357	0.0837	0.0487	0.0122	-0.239
Percent Clay (<0.004 mm)	0.0042	0.0068	0.5551	1.3066	0.2390	0.1390	0.0348	0.981
Metals in mg/kg DW								
Antimony	excluded	excluded	excluded	excluded	excluded	excluded	excluded	excluded
Arsenic	0.0005	0.0032	0.8788	0.9472	0.1112	0.0647	0.0162	0.116
Cadmium	0.0093	0.0066	0.2059	-0.8075	0.2313	0.1345	0.0336	2.168
Copper	-0.0029	0.0032	0.3997	1.7187	0.1123	0.0653	0.0163	-0.664
Lead	0.0027	0.0105	0.8031	1.0505	0.3683	0.2142	0.0536	0.630
Mercury	-0.0023	0.0016	0.1913	-0.9161	0.0535	0.0387	0.0086	-0.526
Nickel	-0.0043	0.0034	0.2448	1.7979	0.1186	0.0690	0.0172	-0.995
Silver	-0.0073	0.0013	0.0014	-0.3083	0.0415	0.0206	0.0065	-1.675
Zinc	-0.0063	0.0030	0.0770	2.0968	0.1048	0.0609	0.0152	-1.450
LPAHs in µg/kg DW								
Naphthalene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Acenaphthylene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Acenaphthene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Fluorene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Phenanthrene	-0.0073	0.0086	0.4303	1.4632	0.3131	0.1453	0.0386	-1.669
Anthracene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
2-Methylnaphthalene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
HPAHs in µg/kg DW								

Per Chemical Results	Slope			Intercept				Slope as % change/year
	beta	SE(beta)	P-Value	alpha	SE(alpha)	sigma	SE(sigma)	
Fluoranthene	0.0040	0.0145	0.7916	1.4242	0.5111	0.2973	0.0743	0.927
Pyrene	-0.0101	0.0141	0.5027	1.8720	0.4972	0.2892	0.0723	-2.291
Benzo(a)anthracene	-0.0024	0.0159	0.8828	1.3206	0.5721	0.2742	0.0733	-0.560
Chrysene	0.0044	0.0186	0.8203	1.2866	0.6663	0.3337	0.0903	1.019
Total fluoranthenes	0.0078	0.0187	0.6912	1.2787	0.6696	0.3407	0.0926	1.809
Benzo(a)pyrene	-0.0033	0.0150	0.8320	1.3438	0.5428	0.2597	0.0694	-0.764
Indeno(1,2,3-cd)pyrene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Dibenz(a,h)anthracene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Benzo(g,h,i)perylene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Chlorinated Aromatics in µg/kg DW								
1,3-Dichlorobenzene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
1,4-Dichlorobenzene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
1,2-Dichlorobenzene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
1,2,4-Trichlorobenzene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Hexachlorobenzene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Phthalate Esters in µg/kg DW								
Dimethylphthalate	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Diethylphthalate	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Di-n-Butylphthalate	0.0020	0.0158	0.9023	1.0681	0.5821	0.1346	0.0490	0.468
Butylbenzylphthalate	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
bis(2-Ethylhexyl)phthalate	0.0127	0.0107	0.2798	0.8584	0.3926	0.1572	0.0469	2.967
Di-n-Octylphthalate	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Phenols in µg/kg DW								
Phenol	0.3808	33.7536	0.9914	-14.1148	1366.1318	0.2419	0.0989	140.30
2-Methylphenol	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
4-Methylphenol	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
2,4-Dimethylphenol	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Pentachlorophenol	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Miscellaneous Extractables in µg/kg DW								
Benzyl Alcohol	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Benzoic Acid	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Dibenzofuran	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data

Per Chemical Results	Slope			Intercept				Slope as % change/year
	beta	SE(beta)	P-Value	alpha	SE(alpha)	sigma	SE(sigma)	
Hexachloroethane	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Hexachlorobutadiene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
N-Nitrosodiphenylamine	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Volatile Organics in µg/kg DW								
Trichloroethene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Tetrachloroethene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Ethylbenzene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Total Xylene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Pesticides and PCBs in µg/kg DW								
4,4'-DDE	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
4,4'-DDD	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
4,4'-DDT	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Lindane	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Heptachlor	0.5199	26.4234	0.9849	-20.4881	1069.4508	0.2898	0.1183	231.08
Aldrin	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Dieldrin	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
alpha Chlordane	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Aroclor-1016	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Aroclor-1242	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Aroclor-1248	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Aroclor-1254	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Aroclor-1260	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Aroclor-1221	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Aroclor-1232	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data

Table 5–4. Chemical Tracking System Output for Port Gardner Station PGP08

Per Chemical Results	Slope			Intercept				Slope as % change/year
	beta	SE(beta)	P-Value	alpha	SE(alpha)	sigma	SE(sigma)	
Conventionals								
Total Organic Carbon (% DW)	0.0001	0.0005	0.8005	0.2620	0.0209	0.0750	0.0147	0.030
Total Sulfides (mg/kg DW)	-0.0012	0.0040	0.7653	0.5692	0.1965	0.5293	0.1675	-0.285
Ammonia (mg-N/kg DW)	-0.0024	0.0006	0.0131	0.8785	0.0324	0.0767	0.0221	-0.553
TVS (mg/kg DW)	-0.0199	0.0092	0.0521	3.9077	0.3851	1.3790	0.2704	-4.487
Total Solids (%)	0.0001	0.0003	0.8378	1.6048	0.0113	0.0403	0.0079	0.013
Percent Gravel (≥2.0 mm)	-0.0571	0.0445	0.2692	0.4236	0.9705	0.4250	0.1783	-12.312
Percent Sand (<2.0 mm - 0.06 mm)	0.0032	0.0017	0.0800	0.8390	0.0699	0.2503	0.0491	0.741
Percent Silt (0.06 mm - 0.004 mm)	0.0014	0.0003	0.0004	1.7580	0.0121	0.0433	0.0085	0.332
Percent Fines (<0.06 mm)	-0.0007	0.0013	0.5986	1.9032	0.0557	0.1995	0.0391	-0.165
Percent Clay (<0.004 mm)	-0.0022	0.0011	0.0746	1.5506	0.0470	0.1684	0.0330	-0.506
Metals in mg/kg DW								
Antimony	0.0048	0.0026	0.0965	-0.3911	0.1166	0.3749	0.1030	1.112
Arsenic	0.0011	0.0004	0.0326	0.9865	0.0184	0.0657	0.0129	0.246
Cadmium	0.0022	0.0007	0.0121	-0.5209	0.0308	0.1102	0.0216	0.506
Copper	0.0015	0.0001	0.0000	1.6600	0.0060	0.0215	0.0042	0.341
Lead	0.0008	0.0017	0.6695	1.2341	0.0728	0.2607	0.0511	0.175
Mercury	-0.0001	0.0007	0.8380	-0.9363	0.0293	0.1049	0.0206	-0.034
Nickel	0.0018	0.0001	0.0000	1.7040	0.0059	0.0211	0.0041	0.413
Silver	0.0004	0.0006	0.5656	-0.5301	0.0258	0.0815	0.0179	0.083
Zinc	0.0017	0.0003	0.0000	1.9466	0.0110	0.0393	0.0077	0.393
LPAHs in µg/kg DW								
Naphthalene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Acenaphthylene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Acenaphthene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Fluorene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Phenanthrene	-0.001	0.001	0.361	1.328	0.052	0.164	0.038	-0.247
Anthracene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
2-Methylnaphthalene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
HPAHs in µg/kg DW								

Per Chemical Results	Slope			Intercept				Slope as % change/year
	beta	SE(beta)	P-Value	alpha	SE(alpha)	sigma	SE(sigma)	
Fluoranthene	-0.0027	0.0009	0.0137	1.5584	0.0392	0.1366	0.0294	-0.613
Pyrene	-0.0013	0.0012	0.3130	1.5286	0.0526	0.1829	0.0393	-0.297
Benzo(a)anthracene	-0.0008	0.0007	0.2931	1.2897	0.0341	0.1063	0.0240	-0.186
Chrysene	-0.0011	0.0010	0.3079	1.3983	0.0458	0.1525	0.0332	-0.252
Total fluoranthenes	-0.0019	0.0014	0.1968	1.5549	0.0592	0.2021	0.0462	-0.427
Benzo(a)pyrene	-0.0005	0.0012	0.7171	1.3182	0.0558	0.1844	0.0398	-0.106
Indeno(1,2,3-cd)pyrene	0.0088	0.0048	0.0957	0.8652	0.2447	0.3661	0.1683	2.053
Dibenz(a,h)anthracene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Benzo(g,h,i)perylene	excluded	excluded	excluded	excluded	excluded	excluded	excluded	excluded
Chlorinated Aromatics in µg/kg DW								
1,3-Dichlorobenzene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
1,4-Dichlorobenzene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
1,2-Dichlorobenzene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
1,2,4-Trichlorobenzene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Hexachlorobenzene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Phthalate Esters in µg/kg DW								
Dimethylphthalate	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Diethylphthalate	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Di-n-Butylphthalate	-0.0165	0.1788	0.9280	0.3854	12.5159	0.2029	0.0828	-3.734
Butylbenzylphthalate	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
bis(2-Ethylhexyl)phthalate	0.0035	0.0011	0.0092	1.3622	0.0483	0.1667	0.0354	0.812
Di-n-Octylphthalate	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Phenols in µg/kg DW								
Phenol	0.0208	0.0171	0.2486	0.7527	0.5881	0.7571	0.2703	4.914
2-Methylphenol	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
4-Methylphenol	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
2,4-Dimethylphenol	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Pentachlorophenol	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Miscellaneous Extractables in µg/kg DW								
Benzyl Alcohol	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Benzoic Acid	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Dibenzofuran	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data

Per Chemical Results	Slope			Intercept				Slope as % change/year
	beta	SE(beta)	P-Value	alpha	SE(alpha)	sigma	SE(sigma)	
Hexachloroethane	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Hexachlorobutadiene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
N-Nitrosodiphenylamine	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Volatile Organics in µg/kg DW								
Trichloroethene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Tetrachloroethene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Ethylbenzene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Total Xylene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Pesticides and PCBs in µg/kg DW								
4,4'-DDE	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
4,4'-DDD	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
4,4'-DDT	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Lindane	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Heptachlor	excluded	excluded	excluded	excluded	excluded	excluded	excluded	excluded
Aldrin	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Dieldrin	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
alpha Chlordane	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Aroclor-1016	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Aroclor-1242	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Aroclor-1248	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Aroclor-1254	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Aroclor-1260	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Aroclor-1221	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Aroclor-1232	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data

Table 5–5. Chemical Tracking System Output for Port Gardner Station PGP09

Per Chemical Results	Slope			Intercept				Slope as % change/year
	beta	SE(beta)	P-Value	alpha	SE(alpha)	sigma	SE(sigma)	
Conventionals								
Total Organic Carbon (% DW)	0.0038	0.0015	0.0356	0.1628	0.0488	0.0460	0.0098	0.878
Total Sulfides (mg/kg DW)	-0.0012	0.0127	0.9268	0.9341	0.4176	0.3606	0.0850	-0.277
Ammonia (mg-N/kg DW)	-0.0122	0.0274	0.6797	1.3323	1.0577	0.1342	0.0387	-2.770
TVS (mg/kg DW)	-0.1298	0.0436	0.0155	7.6524	1.3842	1.3053	0.2783	-25.839
Total Solids (%)	0.0005	0.0004	0.1858	1.6076	0.0112	0.0105	0.0022	0.116
Percent Gravel (≥2.0 mm)	-0.0318	0.0059	0.0016	0.3414	0.1832	0.1638	0.0410	-7.068
Percent Sand (<2.0 mm - 0.06 mm)	-0.0071	0.0027	0.0291	1.4456	0.0864	0.0815	0.0174	-1.611
Percent Silt (0.06 mm - 0.004 mm)	-0.0019	0.0013	0.1832	1.7929	0.0421	0.0397	0.0085	-0.440
Percent Fines (<0.06 mm)	0.0017	0.0006	0.0138	1.8626	0.0176	0.0166	0.0035	0.391
Percent Clay (<0.004 mm)	0.0088	0.0031	0.0198	1.1565	0.0991	0.0934	0.0199	2.054
Metals in mg/kg DW								
Antimony	-0.0276	0.0136	0.0722	0.3138	0.4007	0.3148	0.0881	-6.163
Arsenic	-0.0007	0.0019	0.7037	1.0037	0.0589	0.0555	0.0118	-0.168
Cadmium	0.0196	0.0050	0.0037	-1.1948	0.1600	0.1509	0.0322	4.608
Copper	-0.0023	0.0023	0.3603	1.6927	0.0745	0.0702	0.0150	-0.519
Lead	-0.0002	0.0054	0.9749	1.1899	0.1701	0.1604	0.0342	-0.040
Mercury	-0.0073	0.0024	0.0109	-0.6878	0.0734	0.0739	0.0145	-1.667
Nickel	-0.0034	0.0026	0.2292	1.7754	0.0826	0.0778	0.0166	-0.769
Silver	-0.0114	0.0064	0.1083	-0.1327	0.1819	0.1488	0.0357	-2.599
Zinc	-0.0061	0.0025	0.0399	2.1059	0.0803	0.0758	0.0162	-1.388
LPAHs in µg/kg DW								
Naphthalene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Acenaphthylene	0.0255	0.0089	0.0189	0.0120	0.2744	0.1270	0.0689	6.055
Acenaphthene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Fluorene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Phenanthrene	-0.0022	0.0104	0.8341	1.2688	0.3865	0.0986	0.0324	-0.517
Anthracene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
2-Methylnaphthalene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
HPAHs in µg/kg DW								

Per Chemical Results	Slope			Intercept				Slope as % change/year
	beta	SE(beta)	P-Value	alpha	SE(alpha)	sigma	SE(sigma)	
Fluoranthene	-0.0035	0.0065	0.5968	1.5435	0.2135	0.1783	0.0467	-0.813
Pyrene	-0.0073	0.0070	0.3264	1.6324	0.2321	0.1945	0.0511	-1.668
Benzo(a)anthracene	-0.0043	0.0086	0.6305	1.3252	0.2976	0.1935	0.0534	-0.979
Chrysene	-0.0106	0.0064	0.1313	1.6904	0.2115	0.1765	0.0461	-2.419
Total fluoranthenes	0.0026	0.0081	0.7500	1.3604	0.2745	0.2018	0.0577	0.611
Benzo(a)pyrene	-0.0066	0.0076	0.4073	1.4445	0.2629	0.1785	0.0477	-1.504
Indeno(1,2,3-cd)pyrene	-0.0222	0.0121	0.0997	1.6756	0.4111	0.2577	0.1110	-4.987
Dibenz(a,h)anthracene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Benzo(g,h,i)perylene	-0.0176	0.0097	0.1039	1.6250	0.3303	0.2080	0.0890	-3.967
Chlorinated Aromatics in µg/kg DW								
1,3-Dichlorobenzene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
1,4-Dichlorobenzene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
1,2-Dichlorobenzene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
1,2,4-Trichlorobenzene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Hexachlorobenzene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Phthalate Esters in µg/kg DW								
Dimethylphthalate	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Diethylphthalate	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Di-n-Butylphthalate	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Butylbenzylphthalate	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
bis(2-Ethylhexyl)phthalate	0.0107	0.0054	0.0777	0.9711	0.1881	0.1192	0.0293	2.495
Di-n-Octylphthalate	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Phenols in µg/kg DW								
Phenol	excluded	excluded	excluded	excluded	excluded	excluded	excluded	excluded
2-Methylphenol	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
4-Methylphenol	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
2,4-Dimethylphenol	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Pentachlorophenol	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Miscellaneous Extractables in µg/kg DW								
Benzyl Alcohol	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Benzoic Acid	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Dibenzofuran	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data

Per Chemical Results	Slope			Intercept				Slope as % change/year
	beta	SE(beta)	P-Value	alpha	SE(alpha)	sigma	SE(sigma)	
Hexachloroethane	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Hexachlorobutadiene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
N-Nitrosodiphenylamine	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Volatile Organics in µg/kg DW								
Trichloroethene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Tetrachloroethene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Ethylbenzene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Total Xylene	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Pesticides and PCBs in µg/kg DW								
4,4'-DDE	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
4,4'-DDD	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
4,4'-DDT	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Lindane	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Heptachlor	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Aldrin	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Dieldrin	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
alpha Chlordane	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Aroclor-1016	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Aroclor-1242	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Aroclor-1248	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Aroclor-1254	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Aroclor-1260	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Aroclor-1221	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data
Aroclor-1232	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data	inad. data

5.2 Question 2: Has dredged material disposal caused the biological effects condition for site management to be exceeded at the site [Site Condition II (PSDDA 1988)]?

5.2.1 Onsite Chemistry

Hypothesis No. 3: Sediment chemical concentrations at the onsite monitoring stations do not exceed chemical concentrations associated with PSDDA Site Condition II guidelines due to dredged material disposal.

PSDDA Site Condition II is evaluated by comparing onsite chemical concentrations to the DMMP MLs. DMMP MLs are chemical concentrations above which adverse biological effects are expected to occur. Onsite chemistry results did not exceed the DMMP ML values. Therefore, ***PSDDA Hypothesis No. 3 is accepted.***

5.2.2 Bioassays

Hypothesis No. 4: Sediment toxicity at the onsite stations does not exceed the PSDDA Site Condition II biological response guidelines due to dredged material disposal.

The Port Gardner bioassays were evaluated according to the DMMP evaluation guidelines for non-dispersive disposal sites (PSDDA 1989b; DMMP 2008). The three onsite stations passed the DMMP bioassay interpretive criteria for all toxicity tests. Therefore, ***PSDDA Hypothesis No. 4 is accepted.***

5.3 Question 3: Are unacceptable adverse effects due to dredged material disposal occurring to biological resources offsite?

Under a tiered-full monitoring program, samples are collected to address all three questions in the DMMP monitoring framework, but only samples to address the first two questions are initially analyzed. Analysis of archived samples to address the third monitoring questions was not necessary based on answers to the first two questions.

5.4 Dioxin/Furan Congener Concentrations at Onsite Stations

The number of onsite sediment monitoring samples collected at the Port Gardner site was increased from three to 10 to allow for a more robust statistical comparison with the Puget Sound main basin/reference area dioxin/furan concentrations and verify compliance with the proposed disposal site management objectives (DMMP 2010b).

Port Gardner onsite dioxin/furan concentrations were statistically compared to the Puget Sound dioxin/furan concentrations for all of Puget Sound (total EPA Vessel Bold data set of 70 samples), the main basin dataset (50 samples), and the reference dataset (20 samples). The Bold data are approximately log normal, so the Port Gardner onsite data was normalized and a statistical comparison was made using a 2-tailed, unpaired t-test with unequal variances. For all three comparisons, the Port Gardner onsite dioxin/furan data was significantly higher than the Puget Sound data sets (Table 5-6). However, the Port Gardner onsite dioxin/furan concentrations ranged from a low of 1.25 pg/g TEQ at station PGS09 to a high of 2.40 pg/g TEQ at PGS02, and concentrations comply with the proposed updated interim guideline of 4.0 pg/g TEQ.

Table 5–6. Statistical Comparison of Port Gardner Onsite Dioxin/Furan Concentrations to Puget Sound Values

Puget Sound Values	P-value
All of Puget Sound (70 samples)	6.94015E-07
Main Basin (50 samples)	5.1259E-06
Reference (20 samples)	0.002096019

6.0 CONCLUSIONS

The conclusions to the 2010 tiered-full monitoring program at Port Gardner are presented below. Table 6–1 summarizes the data within the context of the PSDDA monitoring framework.

6.1 Does the Dredged Material Remain On Site?

Physical and chemical monitoring results from the 2010 Port Gardner survey suggest that the dredged material remains within the boundaries of the disposal site. The 2010 SVPS survey did not identify dredged material accumulations outside of the site perimeter. Perimeter chemistry concentrations were below the Washington State SQS criteria, and CTS time-trends analysis did not identify statistically significant increases in chemical concentrations that were of concern in offsite areas of Port Gardner.

6.2 Is Site Condition II Exceeded?

Chemistry results from three onsite stations were compared to the DMMP MLs. No onsite ML values were exceeded. Bioassay testing of the same onsite stations passed the DMMP bioassay interpretive criteria. Therefore, PSDDA Site Condition II chemical criteria are not exceeded.

Table 6–1. Results of the 2010 Port Gardner DMMP Monitoring Framework

Question	Hypothesis	Monitored Variable	Interpretive Guideline	Action Taken
No. 1 **Does the deposited dredged material stay on site?**	1. Dredged material remains within the site boundary.	Sediment Vertical Profiling System (SVPS) Onsite and Offsite	Dredged material layer is greater than 3 cm at the perimeter stations? **NO**	
	2. Chemical concentrations do not measurably increase over time due to dredged material disposal at offsite stations.	Sediment Chemistry Offsite	SQS exceeded? **NO** Temporal increases? **NO**	
No. 2 **Are the biological effects conditions for site management [PSDDA-defined Site Condition II] exceeded at the site due to dredged material disposal? (PSDDA 1988b)**	3. Sediment chemical concentrations at the onsite monitoring stations do not exceed the chemical concentrations associated with PSDDA Site Condition II guidelines due to dredged material disposal.	Sediment Chemistry Onsite	Onsite chemical concentrations exceed DMMP maximum levels? **NO**	
	4. Sediment toxicity at the onsite stations does not exceed the PSDDA Site Condition II biological response guidelines due to dredged material disposal.	Sediment Bioassays Onsite	DMMP bioassays exceed guidelines? **NO**	
No. 3 **Are unacceptable adverse effects due to dredged material disposal occurring to biological resources off site?**	5. No significant increase due to dredged material disposal has occurred in the chemical body burden of benthic infauna species collected down current of the disposal site.	Tissue Chemistry Transect	Guideline tissue chemistry values exceeded? **N/A**	
	6. No significant decrease due to dredged material disposal has occurred in the abundance of dominant benthic infaunal species collected down current of the disposal site.	Infaunal Community Structure Transect	Abundance of major taxa < ½ baseline macrobenthic infauna abundances? **N/A**	

7.0 RECOMMENDATIONS

7.1 *Molpadia* Sea Cucumber Abundance

The abundance of *Molpadia* sea cucumbers appears to have decreased significantly at stations PGT11, PGB01, and PGB09, based on the sample collection rates during the 2010 full monitoring program (Figure 7–1). No *Molpadia* were collected at station PGT11 after attempting 22 dual van Veen grab samples. At station PGB01, a total of 360 g of tissue was collected after 40 grabs, and at station PGB09, a total of 62 g of tissue was collected after 20 grabs. Conversely, the abundance of *Molpadia* at station PGT15 has increased relative to the 2006 monitoring survey. The reason for the change in *Molpadia* abundances in Port Gardner is unclear.

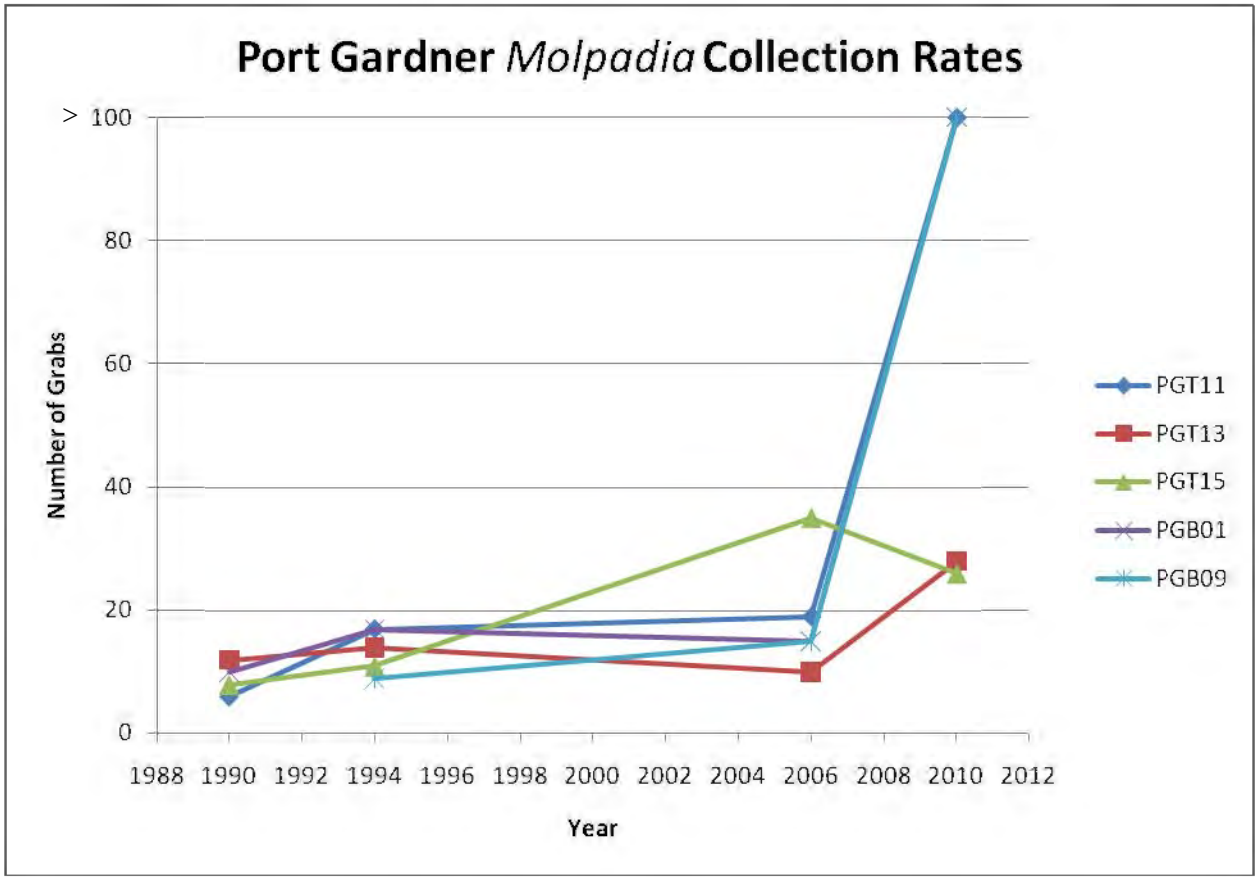
A review of the Port Gardner monitoring results does not indicate any particular physical or chemical reason for the population changes at the transect and benchmark locations. Benthic infauna studies during recent disposal site monitoring programs (Port Gardner, Commencement Bay, and Anderson/Ketron) have identified significant reduction in major taxa abundance (molluscs and arthropods) relative to baseline conditions that appear related to site-wide changes, and not due to dredged material disposal (Striplin 2002; SAIC and Caenum 2006). Other Puget Sound studies have identified temporal variability in benthic community structure that appear related to natural population cycles, and the dynamics are complex and difficult to relate to physical and chemical sediment parameters (Nichols 2003; Partridge et al. 2005).

However, the significant decrease in *Molpadia* abundance in some areas of Port Gardner is of concern, and particular attention should be paid to biological resources in Port Gardner during future monitoring surveys. Benthic infauna samples for transect and benchmark stations were collected and archived during the 2010 tiered-full monitoring program in Port Gardner and could be analyzed as part of a future evaluation of biological resources, if necessary.

7.2 SVPS Survey Scheduling

The 2010 SVPS survey at Port Gardner was conducted as soon as possible following the completion of dredged material disposal operations. The SVPS survey was conducted approximately three weeks prior to other sampling operations at Port Gardner. This approach is consistent with historical practices during previous monitoring surveys and reiterates the DMMP program refinement adopted during the 1990 monitoring of Elliott Bay and Port Gardner (SAIC 1991). Immediately following cessation of disposal activities, dredged material layers begin to be reworked by bioturbating infauna, which can soon mask the optical signature of the dredged material. Thin (i.e., less than a few centimeters) layers can be optically "erased" within weeks to months of disposal in extensively bioturbated systems (SAIC 1991).

It is recommended that the SVPS surveys continue to be scheduled soon after completion of dredged material disposal activities at the site. Conducting SVPS surveys soon after completion of the dredging season will ensure that the footprint of recently disposed dredged material is clearly delineated, and that the guideline trigger level for a management response (3 cm accumulation at perimeter stations) is accurately assessed.



Note: Number of grabs needed per tissue sample normalized to collect 900 grams whole tissue weight.

Figure 7–1. *Molpadia* Collection Rates at the Port Gardner DMMP Site

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