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Sediment Quality Verification Study and Baseline for Process Improvement at Puget Sound Naval Shipyard & Intermediate Maintenance Facility, Bremerton, Washington

Draft Final Report
December 2019

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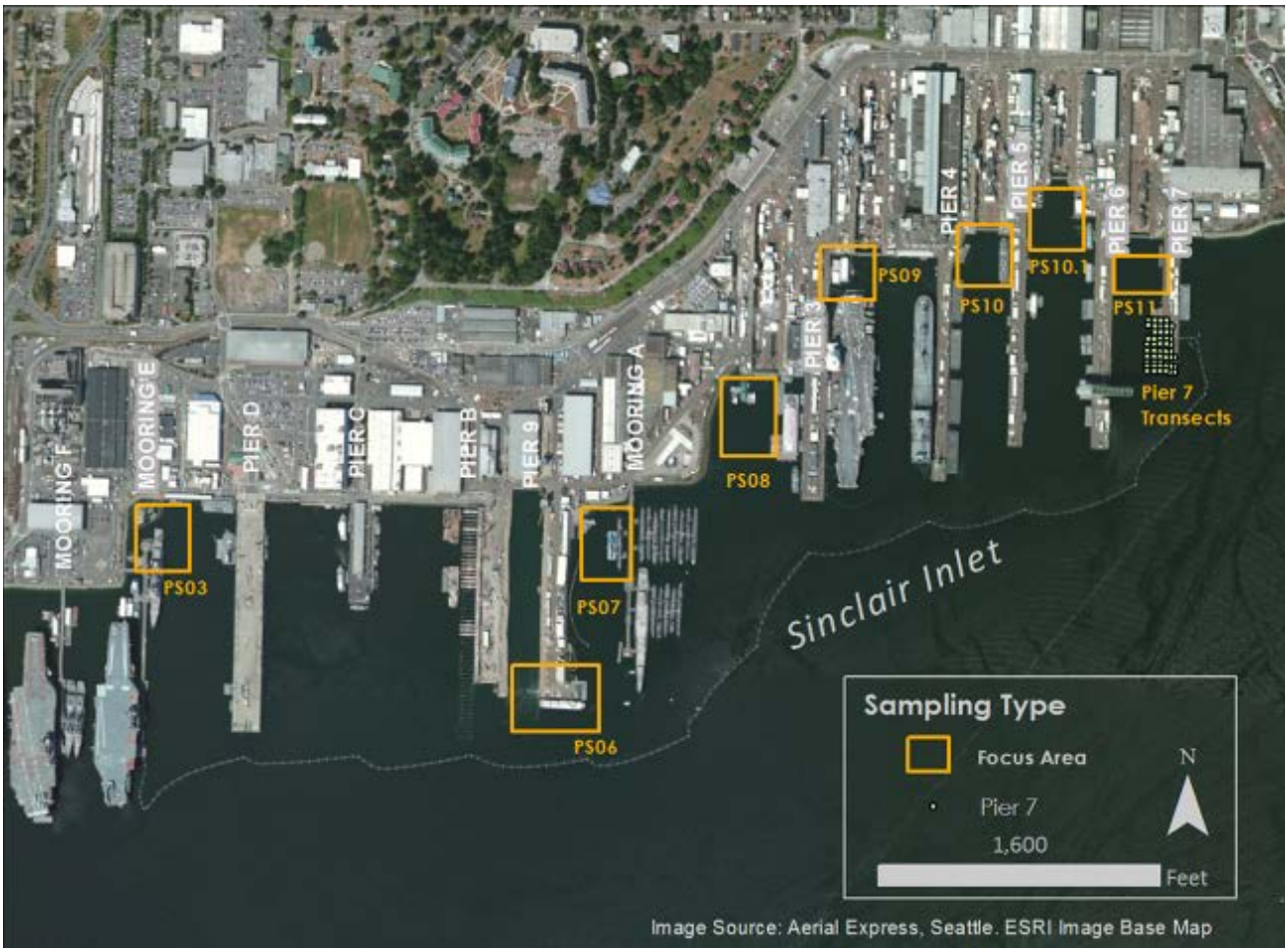

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Abstract

The Sediment Quality Verification (SQV) study, conducted for Puget Sound Naval Shipyard & Intermediate Maintenance Facility (PSNSIMF) Bremerton, WA, established a baseline for continuous process improvement by characterizing contaminant concentrations, bioavailability, and texture of sediment and silt in the vicinity of outfalls and dry docks. The data addresses specific data gaps identified for applying mixing zones for NPDES discharges, assessing sediment impact zones, and evaluating anti-degradation requirements for water quality certifications needed for pier and dry dock infrastructure improvements. Data from the study were also used to support research and development studies of sediment treatability and bioavailability and identify strategies for recovering sediment quality in Sinclair Inlet. The sampling was divided into four components: (1) split sampling with Sinclair Inlet Long Term Monitoring (LTM) conducted to assess remedy effectiveness for contaminated sediments in Operable Unit B Marine (OUBM), (2) focus areas around dry docks, quays, and nearshore areas collocated with industrial outfalls, storm drains, and other potential sources within the shipyard, (3) sampling conducted in support of an activated carbon remedial action demonstration project at a site on the south end of Pier 7, and (4) sampling silts and other sedimentary materials associated with docking operations that accumulated on caissons and in dry docks. Parameters measured included metals (Al, Cr, Cu, Fe, Pb, Ni, Zn, Hg), polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), grain size, and total organic carbon (TOC). Sample results were compared to Sediment Quality Guidelines (SQG), estimates of bioavailability, and sediment toxicity to evaluate sediment quality and assess potential bioavailability and toxicity. Sampling conducted throughout Sinclair from the OUBM LTM showed that there were only minor changes in concentrations of Cu, Pb, and Zn between 2003 and 2010, however, the maximum concentrations and number of SQG exceedances tended to decrease over time. The focus area sampling showed that Hg, Cu, Zn, and total PCB were highly variable. On average, concentrations of Hg, Cu, As, and total PCB/TOC exceeded the SQG at one or more of the focus areas. However, assessment of metal bioavailability and sediment toxicity (bioassays performed for 2 of the most contaminated sites) showed that the sediments were likely not toxic to benthic organisms. The results from the dry dock silt study were used to evaluate contaminant loading from coarse and fine particles sampled on the dry dock floor after dewatering. The geochemical distributions from Hg, PCB, Cu, Pb, and Zn were evaluated for the complete data set which included samples from the OUBM LTM grids, focus area core sections and grabs, storm drain catch basins, and caisson and dry dock silt samples to provide insight on how contaminants are distributed within Sinclair Inlet and identify possible recovery strategies. An example from dry dock cleaning operations conducted in 2012 was used to evaluate the efficacy of management actions to reduce contaminant cycling within the nearshore sediments of the Shipyard.

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Executive Summary

The Puget Sound Naval Shipyard & Intermediate Maintenance Facility (PSNS&IMF) and Naval Base Kitsap-Bremerton (NBK-Bremerton, herein after referred to as Shipyard) located in Bremerton, WA are committed to a culture of continuous process improvement for all aspects of Shipyard operations, including reducing the releases of hazardous materials and waste in discharges from the Shipyard. The Shipyard is located within the Sinclair and Dyes Inlet watershed of Puget Sound, near Bremerton, WA. Operable Units (OUs) within the Shipyard were defined to focus Installation Restoration (IR) activities on achieving remediation goals. For Operable Unit B Marine (OUBM), which encompassed the contaminated sediments within the Shipyard and surrounding Sinclair Inlet, a remedial investigation and feasibility study was completed, the Record of Decision (ROD) to remediate contaminated sediments was signed in 2000 and a long-term monitoring program to track the attainment of cleanup goals for OUBM was developed and implemented in 2003.

Historically, Sinclair Inlet received pollution from industrial activities. Pollution from past practices is being addressed under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) program. Historical practices have changed significantly and led to an overall decrease in contaminants entering Sinclair Inlet from Shipyard activities. However, sediment quality may still be impacted by pollution from a variety of active sources including current Shipyard operations, marina and vessel traffic, storm event runoff, discharges from waste water treatment plants, industrial outfalls, surface streams, and legacy contaminated sediments. Sediment quality verification studies were needed to establish the baseline of current sediment quality conditions in selected areas, assess the effectiveness of cleanup and pollution control measures, identify areas of potential re-contamination, provide data to assess sediment impact zones from industrial outfalls and stormwater drains, and determine if discharges from all sources were protective of beneficial uses including aquatic life.

The industrial discharges from the Shipyard are regulated by the National Pollutant Discharge Elimination System (NPDES) permit program as authorized by the Clean Water Act. The improvement and recovery of sediment quality in Sinclair Inlet is actively being addressed by the Navy under the CERCLA and NPDES programs, Washington Department of Ecology (Ecology) under the Urban Waters Initiative, and the Shipyard's ENVironmental inVESTment (ENVVEST) Project. Under the ENVVEST Project, a cooperative agreement among PSNS, U.S. Environmental Protection Agency (EPA), Washington State Department of Ecology (Ecology), and local stakeholders was implemented to improve the environmental quality of the Sinclair and Dyes Inlet watershed and develop total maximum daily loads for priority pollutants.

The objective of this sediment quality verification (SQV) study was to leverage the cooperation between the various programs addressing sediment and water quality in Sinclair Inlet to characterize the sediment quality at priority areas within the Shipyard for a suite of heavy metals, polychlorinated biphenyls (PCBs), and polycyclic aromatic hydrocarbons (PAHs) both at the sediment surface and at depths representative of sediment that could be redistributed to the surface. The study was designed to fill data located near outfalls and storm drains, by characterizing contaminant concentrations in surface (0-10 cm depth) and deeper (0-25 cm) sediments. Additional work included evaluating bioavailability and supporting research and development studies of treatability and bioavailability of sediments from selected sites within the Shipyard. Specific objectives of this study were to:

- Establish a baseline for continuous process improvement
- Characterize contaminant concentrations, bioavailabilty, and texture of silt and sediment in the vicinity of outfalls and dry docks (e.g., operational areas not included in OUBM sediment monitoring)

- Provide data to assess sediment impact zones for NPDES discharges
- Provide data to assess anti-degradation requirements for water quality certifications needed for pier and dry dock infrastructure improvements
- Support research and development studies of sediment treatability and bioavailability.

Methods

The sampling was divided into four components: (1) split sampling with Sinclair Inlet Long Term Monitoring (LTM) conducted to assess remedy effectiveness of CERCLA remedial actions (RA) for contaminated sediments in Operable Unit B Marine (OUBM), (2) focus areas around dry docks, quays, and nearshore areas collocated with industrial outfalls, storm drains, and other potential sources within the shipyard (Figure ES-1), (3) sampling conducted in support of an activated carbon remedial action RDTE demonstration project at site on the south end of Pier 7, and (4) sampling silts and other sedimentary materials associated with docking operations that accumulated on caissons and in dry docks.

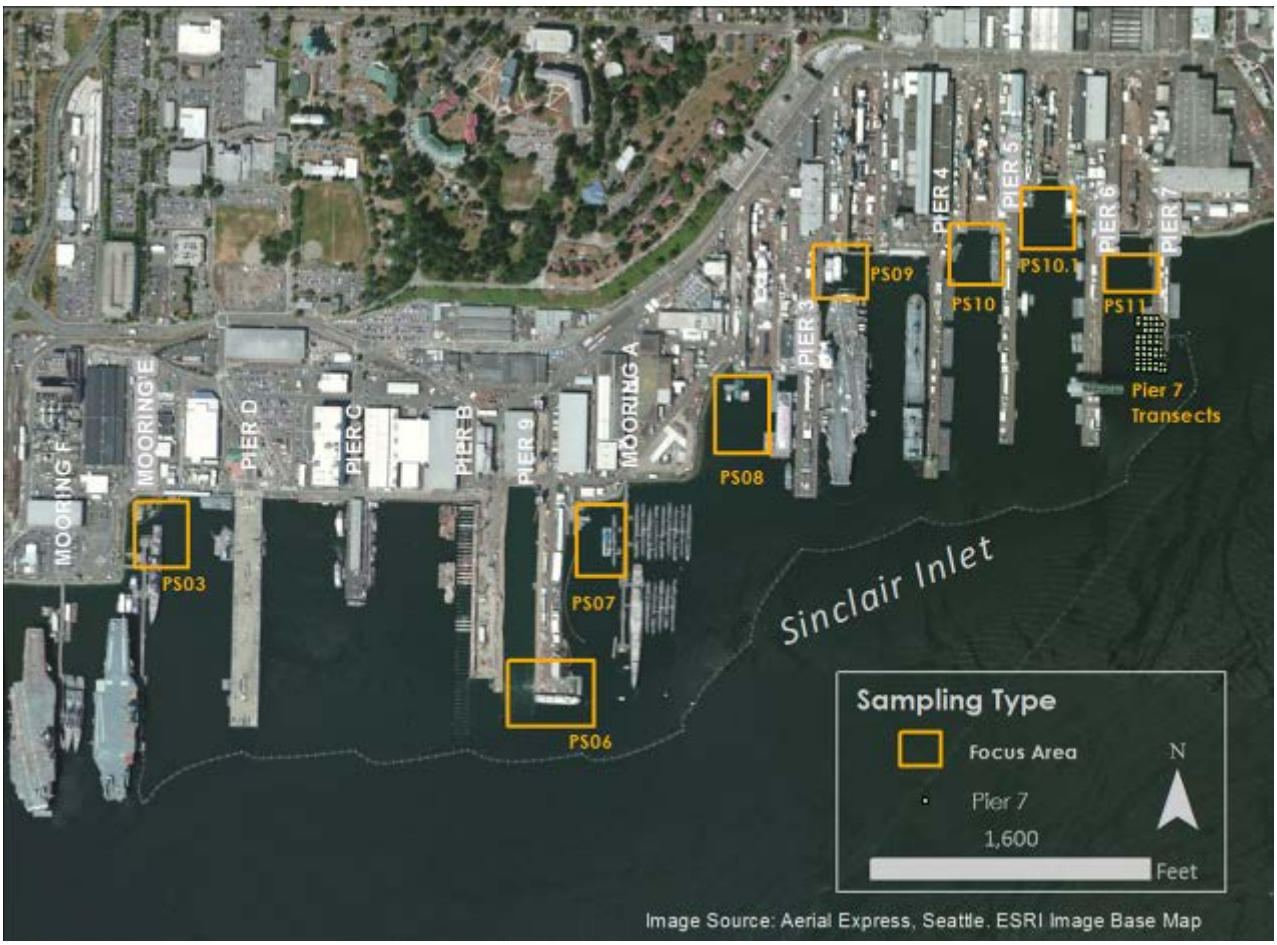

Figure ES1-1. Focus areas selected for sampling within the Shipyard.

Briefly, the sampling consisted of obtaining splits from the surface sediment composite samples collected by the 2010 OUBM LTM, the splits were screened using Rapid Sediment Characterization (RSC) procedures. All samples from OUBM were screened for metals (Fe_{XRF}, Cu_{XRF}, Pb_{XRF}, and Zn_{XRF},) and PAHs, (PAH_{RSC}) and a sub-set of samples were selected for confirmatory analysis using ICP for metals

and GC/MS for PAHs. The focus area sites were selected based on the ranking for sediment areas of concern (Table **11**) and targeted sampling included surface grabs and sediment cores analyzed for heavy metals, PCBs, and PAHs to evaluate sediment quality and assess bioavailability and toxicity. The RDTE Pier 7 Demo Project sampling consisted of collecting high-resolution transects of surface grabs (0-10 cm) adjacent to and under the south end of Pier 7 to characterize PCBs, PAHs, and metals at the site prior to placement of the AC sediment amendment. The Pier 7 transect samples were analyzed for Fe_{XRF}, Cu_{XRF}, Pb_{XRF}, Zn_{XRF}, PAH_{RSC}, PCB_{RSC}, total Hg, and grain size. A subset of about 20% of the samples were confirmed for metals, and PAHs using standard laboratory methods. The caisson and dry dock silt sampling characterized silt and sedimentary material that accumulated in front of the caissons between docking operations, material that accumulated on the dry dock floor after dewatering, and material entrained within the dry dock drainage system. The dry dock silt samples were size-fractionated for metals analyses by passing first through a 2 mm and then a 63 µm sieve. The fractions were analyzed for Al, Cr, Cu, Fe, Pb, Ni, Zn, Hg, TOC, and grain size.

Sample results were compared to Sediment Quality Guidelines (SQG) which included the Sediment Quality Standards (SQS) and Maximum Chemical Concentrations (MCC) defined by Washington State Sediment Management Standards (SMS) and Equilibrium Partitioning Sediment Benchmarks (ESB) for the protection of benthic organisms for exposure to metal mixtures recommended by EPA. The exceedance of SQG, estimates of bioavailability, and sediment toxicity were used to evaluate sediment quality and assess potential bioavailability and toxicity.

Results and Discussion

The analytical chemistry data reports for the study are provided in Appendix A Data Reports and the data in EIM format is provided in Appendix B Raw Data .The results of the 2010 OUBM confirmation and verification analysis are presented including the determination of definitive results for the screening using RSC methods, comparison to previous years' sampling in 2003 and 2007, and status for 303(d) sediment listings in Sinclair Inlet. The results from sediment surface and core sampling in the focus areas within the Shipyard are presented and discussed for each focus area and the Pier 7 transect sampling. For each focus area, the analytical chemistry results are plotted for the surface grabs and core profiles followed by a presentation of the mSQGq calculated from the chemicals analyzed, normalized by their respective SQS thresholds resulting in the ∑SQGq for Hg, TPCB, Zn, Cr, Cu, Cd, Ag, As, Pb, and TPAH for each surface grab and core profile section. For PS03 and PS09, the results from the squeeze core for pore water and AVS and the results of the sediment toxicity study were also evaluated.

Split samples from the 2010 LTM were obtained and analyzed for Fe, Cu, Pb, Zn, total PAH using RSC methods for all samples. Confirmation analysis using ICP for metals and GC-MS for PAHs were conducted on a subset of samples to establish definitive concentrations for the sample results. The confirmation results showed that the definitive results met acceptability requirements and provided a cost-effective means of expanding the data set. Sampling was conducted throughout Sinclair Inlet for 32 samples from the Sinclair Inlet 1500 ft^2 grid (SIN) and 71 samples from the 500 ft^2 grids within OUBM. There were only minor changes in concentrations of Cu, Pb, and Zn between 2003 and 2010 (Figure 34), however, the maximum concentrations and number of SQG exceedances tended to decrease over time.

The focus area sampling showed that Hg, Cu, Zn, and total PCB were highly variable. On average, concentrations of Hg, Cu, As, and total PCB/TOC exceeded the SQG at one or more of the focus areas. The relative variability in contaminants measured in the surface samples from the focus areas showed that Hg, Cu, Zn, and total PCB/TOC were highly variable (Figure 53). On average, the highest concentrations of Hg were measured at PS10, PS09 had the highest average concentrations of As, Cd, Cr, Cu, Ni, Pb, Zn, and total PAHs, PS11 had the highest average concentration of Pb, and PIER 7 had the highest average

for total PCB (Appendix D2.4 Surface Grab Summary). For Hg, the average surface concentrations exceeded the MCC in all the focus areas except for PS07 and PIER7 which both exceeded the Hg SQS.

However, assessment of metal bioavailability and sediment toxicity (bioassays performed for 2 of the most contaminated sites) showed that the sediments were likely not toxic to benthic organisms. Metal bioavailability assessed by $(\sum SEM\text{-}AVS)/f_{oc}$ showed that all the samples from the focus areas were below the SQG, indicating that there was low risk of adverse benthic effects (Table 29). This result was also collaborated by pore water analysis at PS03 and PS09 as pore water concentrations were well below water quality standards for the metals evaluated (Cd, Cr, Cu, Hg, Ni, Pb, and Zn, Appendix D2.3 Porewater Results).

Sediment toxicity was only performed on samples from PS03 and PS09 (Table 29), but these were two of the most contaminated sites with respect to bulk chemistry results. In general, the toxicity tests for 48-hr sediment-water-interface (SWI) exposure to mussel larvae, 10-day whole sediment exposure to two species of amphipods, and 28-day whole sediment exposure to worms, showed that the sediments from PS03 and PS09 were nontoxic, however slight toxicity to one of the amphipod species was observed for PS09 (Table 26).

The sedimentary environment of the focus areas consisted primarily of sandy muds and muds while the Pier 7 site had coarser deposits (Figure 52A, Appendix A.3 Grain Size Analysis Data Report). On average, the percent of fines (<63 um) in the 0-10 cm surface was 70% or higher for most of the sites, however coarser material was present at PS09, PS11, and PIER9, and about 10% of the material at PS09, PS11, and PS01 was > 2 mm, which consisted of mostly shell hash and other biogenic debris (Figure 52B). The presence of coarser material could be an indication of more disturbance. Overall, the surficial sediments of the Sinclair Inlet have followed a clear and significant trend in which they have become progressively coarser, more poorly sorted, and more negatively skewed in the years from 1998 to 2011 (Figure 54). The coarsening trend line (Figure 54) suggests that throughout the last two decades there has been an increase in the availability of coarser sediment for the transport regime. This could occur, for example, by dredging deeper into underlying glacial deposits in which a greater range of sediment sizes become available for transport and deposition than was available prior to their disturbance and exposure. At the same time, larger vessels, an increase in ship activities (propeller wash), and in-water construction projects could also increase the movement and deposition of coarser sediment (Wang et al. 2016).

The results from the dry dock silt study were used to evaluate contaminant loading from the Coarse and Fine particles sampled on the dry dock floor after dewatering. The data showed that the dry docks may be selectively accumulating sedimentary materials that are enriched in total PCB, Cu, Pb, Zn, and Hg. A linear relationship between contaminant and Fe concentrations calculated for the Sinclair Inlet (1500 ft grid) sediment samples represents the “background” concentrations of the contaminant. The trendline shows that as Fe or TOC increases the contaminant concentration increases in a predictable manner, however many of the other samples fall far above the trendline showing that the particles in those samples were enriched in the contaminants beyond what would be expected based on the Sinclair Inlet samples (Figure 64).

The samples from the caisson and dry dock silt, OUBM, and FA 0-3 cm samples were enriched well above the trendline for total PCB, Cu, Pb, Zn, and Hg (Figure 64). The FA 0-3 cm samples are the materials most likely resuspended during docking/undock, in-water construction, ship movements, or other operations that may disturb the bottom sediments. By capturing and removing the enriched particles, the cleaning BMPs have a means of “skimming off the cream” of the most contaminated particles that are currently mobile within the nearshore areas of the Shipyard. These results suggest a testable hypothesis that dry dock cleaning operations are selectively capturing particles that are enriched with contaminants that are a priority for recovering sediment quality within Sinclair Inlet

An example from dry dock cleaning operations conducted in 2012 was used to evaluate the efficacy of management actions to reduce contaminant cycling within the nearshore sediments of the Shipyard. In 2012, DD1 was open to the Inlet for six months; after dewatering about 7-10 cm (3-4 in) of silt material covered the dry dock floor. Cleaning procedures used at that time, which were newly implemented and not as efficient as current operations, resulted in collecting 115 55-gallon drums full of bay silt which amounted to about 25 tons (22,750 kg) of material removed. Using the average and maximum concentrations obtained from the dry dock silt samples collected from the dry docks after dewatering, the estimated average and maximum mass of contaminants permanently removed from Sinclair Inlet were calculated to be 8-11 kg of Cu, 13-364 kg of Zn, and 18-22 g of Hg (Figure 65).

If managed properly, the dry dock cleaning BMPs would not only prevent further release of COCs, but could also collect and remove contaminants already present in the nearshore sediments. Ultimately, this means that with effective cleaning BMPs in place, every time a docking/undocking evolution takes place a net improvement in the quality of nearshore sediments within the shipyard would occur.

Since the 1970's major programs have been implemented by the Navy, City of Bremerton, Kitsap County and other jurisdictions to control and eliminate sources of pollution discharged into the receiving waters of Sinclair and Dyes Inlets (Table 1). While the projects could disturb and resuspend sediment-bound contaminants, the projects also significantly enhanced the commercial and transportation infrastructure of the region and helped improve environmental conditions within the nearshore areas of the Shipyard.

The results from this study showed that the total Hg concentrations of surface sediments within Sinclair and Dyes Inlets were some of the highest in the Puget Sound (Figure 66). That Sinclair Inlet sediments are elevated in Hg compared to other areas of the Puget Sound has been well established (U.S. Navy 2017b). On average, total Hg concentrations measured in the sediments of Sinclair Inlet were about 4.5-7 times higher than reference areas, while total Hg concentrations in biota were only about two times higher in Sinclair Inlet compared to reference areas of the Puget Sound. This may be because methyl Hg in Sinclair Inlet is not being produced in proportion to total Hg concentrations present in the sediment and water exchange with the Puget Sound likely moderates increases in methyl Hg within Sinclair and Dyes Inlets (U.S. Navy 2017b). Furthermore, it is recognized that legacy Hg contamination in the nearshore sediments of the Shipyard could be redistributed by resuspension by vessel movement, dry dock operations, in-water construction projects, and flux from bottom sediment to the water column where it could be exported to other ares of Sinclair and Dyes Inlets and the larger Puget Sound (U.S. Navy 2017b). Therefore, any process that can selectively capture and remove particles enriched with Hg and other contaminants, as the dry dock cleaning BMPs appear to be able to do, would greatly contribute to meeting sediment quality goals for Sinclair Inlet and recovery of the Puget Sound.

Conclusion

The SQV study established a baseline for continuous process improvement by characterizing contaminant concentrations, bioavailability, and texture of sediment and silt in the vicinity of outfalls and dry docks. The data addresses specific data gaps identified for applying mixing zones for NPDES discharges, assessing sediment impact zones, and evaluating anti-degradation requirements for water quality certifications needed for pier and dry dock infrastructure improvements. Data from the study were also used to support research and development studies of sediment treatability and bioavailability and identify strategies for recovering sediment quality in Sinclair Inlet.

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Acronyms and Abbreviations

AAS	Atomic Absorption Spectrometry
AC	Activated Carbon
Ag	Silver
AKART	All Known Available and Reasonable Methods of Treatment
ANOVA	Analysis of variance
As	Arsenic
AVS-SEM	Acid Volatile Sulfide Simultaneously Extracted Metals
AWA	Area-weighted average
BG	Blasting Grit
BMP	Best Management Practice
BNC	Bremerton Naval Complex
CAB	Cellulose acetate butyrate
CAD	Confined Aquatic Disposal Pit
CAS	Columbia Analytical Services
Cd	Cadmium
CDD	Caisson in front of dry dock
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CH3D	Curvilinear Hydrodynamics in 3-Dimensions, Numerical Modeling System
CL	Confidence level
COC	Chain of Custody
Cr	Chromium
CSO	Combined Sewer Overflow
Cu	Copper
Cu_{XRF}	Copper determined using field portable x-ray fluorescence detector
CVAF	Cold Vapor Atomic Fluorescence
CWA	Clean Water Act
DD	Dry Dock
DGT	Diffusive Gradients in Thin films passive sampler
DMA	Direct Mercury Analyzer
DOC	Dissolved organic carbon
DQA	Data Quality Assessments
ECD	Electron Capture Detector
Ecology	Washington State Department of Ecology
EDD	Electronic Data Deliverable
EIM	Environmental Information Management System maintained by Washington State Department of Ecology

ELISA	Enzyme-linked immunosorbent assay
ENVVEST	Environmental Reinvestment
EPA	U.S. Environmental Protection Agency
ESB	Equilibrium Partitioning Sediment Benchmarks
ESTCP	Environmental Security Technology Certification Program
FFCA	Federal Facility Compliance Agreement
FAS	Focus Area Study
FC	Fecal Coliform
Fe	Iron
Fe_{XRF}	Fe determined using field portable x-ray fluorescence detector
f_{oc}	Fraction of organic carbon
FPXRF	Field portable x-ray fluorescence detector
GC-MS	Gas Chromatography Mass Spectrometry
GFF	Glass fiber filter
GPS	Global Positioning System
H_2S	Hydrogen Sulfide
Hg	Mercury
HPAH	High Molecular Weight PAHs
HSPF	Hydrological Simulation Program Fortran
HTL	Holding Time Limits
ICP-MS	Inductively coupled Plasma-Mass Spectrometry
ICP-OS	Inductively coupled Plasma-Optical Spectroscopy
ID	Identification
IR	Installation Restoration
LCS	Laboratory Control Sample
LPAH	Low Molecular Weight PAHs
LTM	Long-term monitoring
MB	Method Blank
MCC	Maximum Chemical Concentration
MCUL	Minimum Cleanup Level
MDL	Method Detection Limit
MDR	Mixed Diamine Reagent
MILCON	Military Construction
Mn	Manganese
MS/MSD	Matrix Spike/Matrix Spike Duplicate
MSL	Marine Sciences Laboratory, formerly Battelle Marine Sciences Laboratory
mSQGq	Mean Sediment Quality Guideline Quotient
NAD	North American Datum

NaOH	Sodium Hydroxide
NAVFAC	Naval Facilities Engineering Command
NBK	Naval Base Kitsap
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
Ni	Nickel
NIWC	Naval Information Warfare Center (formerly Space and Naval Warfare Center)
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollution Discharge Elimination System
NSB	Naval Station Bremerton
OUBM	Operable Unit B Marine (Bremerton Naval Complex IR Site)
OWTS	Oily Waste Treatment System
PAH	Polycyclic aromatic hydrocarbons (total PAH is TPAH)
PAH_{RSC}	Rapid Sediment Characterization of PAHs using immunoassay
Pb	Lead
Pb_{XRF}	Lead determined using field portable x-ray fluorescence detector
PCB	Polychlorinated biphenyls (total PCB is TPAH)
PBC_{RSC}	Rapid Sediment Characterization of PCBs using immunoassay
PDA	Personal digital assistant
PMI	Preventative Maintenance Instruction
PNNL	Pacific Northwest National Laboratory
PSEMP	Puget Sound Ecosystem Monitoring Program
PSEP	Puget Sound Estuary Project
PSNS&IMF	Puget Sound Naval Shipyard and Intermediate Maintenance Facility
PVDF	Polyvinylidene difluoride
PWCS	Process Water Control System
QA/QC	Quality Assurance and Quality Control
RI/FS	Remedial Investigation/Feasibility Study
RIS	Recovery Internal Standard
RL	Reporting Limit
RMTS	Recycled Metal Transfer Station
ROD	Record of Decision
RPD	Relative Percent Difference
QAPP	Quality Assurance Project Plan
SAP	Sampling and Analysis Plan
SBI	Sediment Benthic Index
SEA Ring	Sediment Ecotoxicity Assessment Ring
SCI	Sediment Chemistry Index
SIS	Surrogate Internal Standard

SIZ	Sediment Impact Zone
SKWRF	South Kitsap Water Reclamation Facility
SL1	Sediment Screening Level 1
SMS	Sediment Management Standards
SOP	Standard Operating Procedure
SPME	Solid phase microextraction
SQG	Sediment Quality Guideline
SQGq	Sediment Quality Guideline Quotient
SQS	Sediment Quality Standard
SQTi	Sediment Quality Triad Index
SQV	Sediment Quality Verification
SRM	Standard Reference Material
SSC	Space and Naval Warfare Systems Center (now Naval Information Warfare Center)
STI	Sediment Toxicity Index
SWAC	Surface Weighted Average Concentration
SWI	Sediment-Water Interface
TAC	Test Acceptability Criteria
TMDL	Total Maximum Daily Load
TOC	Total Organic Carbon
TPAH	Total polycyclic aromatic hydrocarbons
TPCB	Total polychlorinated biphenyls
TU	Toxic Unit
UTM	Universal Transverse Mercator
USGS	U.S. Geologic Survey
WAC	Washington Administrative Code
WDFW	Washington State Department of Fish and Wildlife
WDNR	Washington State Department of Natural Resources
WDOH	Washington State Department of Health
WRIA	Water Resource Inventory Area
WWTP	Waste Water Treatment Plant
XRF	X-Ray Fluorescence
Zn	Zinc
Zn_{XRF}	Zn determined using field portable x-ray fluorescence detector

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1.0 Introduction

1.1 Study Objectives

The Puget Sound Naval Shipyard and Intermediate Maintenance Facility (PSNS&IMF) and Naval Base Kitsap-Bremerton (NBK-Bremerton, herein after referred to as Shipyard for brevity) located in Bremerton, Washington, are committed to a culture of continuous process improvement for all aspects of Shipyard operations, including reducing releases of hazardous materials and waste in discharges from the Shipyard. The Shipyard is located within the Sinclair and Dyes Inlet watershed of Puget Sound, Washington (Figure 1). Historically, Sinclair Inlet received pollution from industrial activities and other sources. Pollution from past practices is being addressed under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) program. Historical practices have changed significantly and led to an overall decrease in contaminants entering Sinclair Inlet from Shipyard activities. However, sediment quality may still be impacted by pollution from a variety of active sources including current Shipyard operations; marina and vessel traffic; storm event runoff; discharges from wastewater treatment plants, industrial outfalls, and surface streams; and legacy sources such as historically contaminated sediments. SQV studies were needed to establish a baseline of sediment quality conditions in selected areas, assess the effectiveness of cleanup and pollution control measures, identify areas of potential re-contamination, provide data to assess sediment impact zones from industrial outfalls and stormwater drains, and determine if discharges from all sources are protective of beneficial uses including aquatic life. Industrial discharges from the Shipyard are regulated by the National Pollutant Discharge Elimination System (NPDES) permit program as authorized by the Clean Water Act.

The improvement and recovery of sediment quality in Sinclair Inlet is actively being addressed by the U.S. Navy under the CERCLA and NPDES programs, Washington Department of Ecology (Ecology) under the Urban Waters Initiative (Dutch et al. 2009), and the Shipyard's ENVironmental inENVestment (ENVVEST) Project. Under Project ENVVEST, a cooperative agreement among PSNS, U.S. Environmental Protection Agency (EPA), Ecology, and local stakeholders (U.S. Navy, EPA and Ecology 2000) has been helping to improve the environmental quality of the Sinclair and Dyes Inlet watershed (ENVVEST 2006) and develop total maximum daily loads (TMDLs) for priority pollutants (Johnston et al. 2009, Lawrence et al. 2011).

Operable Units (OUs) within the Shipyard were defined to focus Installation Restoration (IR) activities on achieving remediation goals. For Operable Unit B Marine (OUBM), which encompassed the contaminated sediments within the Shipyard and surrounding Sinclair Inlet, a remedial investigation and feasibility study was completed (URS 2002a), the Record of Decision (ROD) to remediate contaminated sediments was signed in 2000 (U.S. Navy 2000), and a long-term monitoring program to track the attainment of cleanup goals for OUBM was developed and implemented in 2003 (URS 2000b).The objectives of this sediment quality verification (SQV) study were to leverage cooperation among the various programs that are addressing sediment and water quality in Sinclair Inlet. The SQV study characterized sediment quality at priority areas within the Shipyard for a suite of heavy metals, PCBs, and PAHs both at the sediment surface and at depths representative of sediment that could be redistributed to the surface. This potential redistribution of historically contaminated sediment may be a pathway for contaminants currently bound to sediment (a pollution sink) to become a renewed source of pollution if contaminants are transported back to the water column.

Figure 1. The Puget Sound Naval Shipyard and Intermediate Maintenance Facility and Naval Base Kitsap-Bremerton (Naval Shipyard) is located in Bremerton, Washington, within the Sinclair and Dyes Inlet watershed. These Inlets are a sub-basin of Puget Sound, Washington.

The SQV study was designed to address data gaps by characterizing surface (0-10 cm depth) and deeper (0-20 cm) sediment contamination concentrations and evaluating bioavailability and toxicity at selected focus areas within the Shipyard. In addition, work was conducted to support research and development studies of treatability (Kirtay et al. 2016) and bioavailability (Bridges et al. 2017) of sediments from OUBM that had elevated concentrations of PCBs and other contaminants. The various tasks were designed to help address key monitoring questions for assessing environmental quality and protecting beneficial uses in Sinclair and Dyes Inlets:

Key monitoring questions to be addressed were?

- Are discharges from Shipyard industrial outfalls and storm drains protective of beneficial uses of Sinclair Inlet?
- Are discharges from all sources of contamination into Sinclair and Dyes Inlets impacting the quality of water, sediment, and biota in the inlets?
- What is the status and trend of water, stormwater, sediment, and biota residue quality in Sinclair and Dyes Inlets?

Specific data quality objectives of the SQV study were to:

- Establish a baseline for continuous process improvement considering both contemporary and historical sediment quality
- Characterize contaminant concentrations, bioavailabilty, and texture of silt and sediment in the vicinity of outfalls and dry docks (e.g., operational areas not included in OUBM sediment monitoring)
- Provide data to assess sediment impact zones for NPDES discharges
- Provide data to assess anti-degradation requirements for water quality certifications needed for pier and dry dock infrastructure improvements
- Support research and development studies of sediment treatability and bioavailability.

According to the State of Washington guidance for implementing the cleanup provisions of the Sediment Management Standards, Chapter 173-204 WAC (Washington State Dept. of Ecology 2013), sediment impact zones may be authorized for NPDES discharges if certain conditions are met, which include monitoring the biologically active zone of sediments directly adjacent to NPDES permitted outfalls and storm drains. This report assesses the impact of sedimentary bound contaminants within identified areas of concern to characterize the status and trend of ecological resources, assess the effectiveness of cleanup and pollution control measures, and determine if discharges from local sources are protective of beneficial uses including aquatic life in the receiving waters of Sinclair Inlet. The Sampling and Analysis Plans developed for the study provide the sampling procedures and quality assurance/quality control (QA/QC) requirements for the SQV study (Brandenberger et al. 2011; CardnoTEC and Pacific Northwest National Laboratory 2014).

1.2 Report Structure

This report provides the Sediment Quality Verification (SQV) study objectives, rationale, study design, field-sampling and analytical methods used, raw results and findings, and conclusions determined from the study. In Section 2 the historical background of environmental conditions in Sinclair and Dyes Inlets are described and the relevant sediment studies and considerable data that have been developed for the inlets over the last couple decades are reviewed. Section 3 presents the study design and describes how

the data gaps were identified, sampling sites were selected, and the sampling design was implemented. Field-sampling methods and analytical methods including QA/QC procedures are detailed in Sections 4 and 5, respectively. Results and discussion of the results are provided in Section 6 for each of the focus areas sampled. Section 7 reviews the significant findings and summarizes the conclusions of the study. The reference list is provided in Section 8.

Data and supporting information developed for the study are provided in the Appendices and are included on the distribution compact disk (CD).

- Appendix A provides the data reports for analytical chemistry, the rapid sediment characterization (RSC), grain-size analysis results, and sediment toxicity assessment. (Available on distribution CD)
- Appendix B contains all the raw data generated by the SQV study in the electronic data format compatible with Ecology's Environmental Information Management (EIM) system (Washington State Dept. of Ecology 2013). (Available on distribution CD)
- Appendix C provides the analysis for comparing pre- and post-construction monitoring data collected for Military Construction (MILCON) projects within the waterfront areas of the Shipyard.
- Appendix D presents the summary data tables by focus area.
- Appendix E provides an evaluation of the spatial distribution of mercury (Hg) in Puget Sound sediments conducted in collaboration with University of Washington Tacoma researchers.

2.0 Historical and Current Environmental Conditions of Sediment in Sinclair Inlet

2.1 Background

The historic contamination of the marine sediments in Sinclair Inlet has been documented since the 1970s (Malins et al. 1980; Malins et al. 1984; Long et al. 2003). Contaminants of concern included heavy metals, polychlorinated biphenyls (PCBs), and polycyclic aromatic hydrocarbons (PAHs) (URS Group, Inc. 2002a). Sediment reconstructions spanning back to pre-industrialization sediment quality (Figure 2) suggest the maximum contaminant loading occurred around the middle of the 20th Century (noted as the subsurface peak in sediment cores) followed by marked declines in sediment concentrations as Navy processes changed, environmental regulations were enacted, and pollution abatement, control, and cleanup programs were implemented (Crecelius et al. 2003; Brandenberger, Crecelius, and Johnston 2008) (Figure 2). For Sinclair Inlet in 2002, the subsurface peak was located at a depth of ~12-13 cm for heavy metals and 20-25 cm for PCBs (Figure 2). Legacy PCB and mercury (Hg) contaminated sediments are being addressed by the Navy's IR program (URS Group, Inc. 2002b; Paulson et al. 2010) pursuant to Section 121(c) of the CERCLA and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). Operable Units (OU) A, B, C, D, and Naval Supply Center (NSC) within the Shipyard were defined to focus IR activities on achieving remediation goals. For OUB two components were identified OUBT which included the terrestrial portion of the Shipyard, and OUBM, which encompassed the marine contaminated sediments within the Shipyard and surrounding Sinclair Inlet. For OUBM, a remedial investigation and feasibility study (RI/FS) was completed (URS Group, Inc. 2002a) and a Record of Decision (ROD) to remediate contaminated sediments was signed in 2000 (U.S. Navy 2000). The remediation consisted of navigational and cleanup dredging and where the most contaminated sediments were disposed in a confined aquatic disposal (CAD) pit created in inner Sinclair Inlet and covered with material from the navigation dredging and a clean six foot sand cap (U.S. Navy 2017a). Following completion of the cleanup, a long-term monitoring program to track the attainment of cleanup goals for OUBM was implemented in 2003 (URS Group, Inc. 2002b).

Discharges from the Shipyard are regulated by the U.S. Environmental Protection Agency (EPA) under the Clean Water Act (CWA) NPDES Industrial Permit (Permit No.: WA-000206-2, issued April 1, 1994 and administratively extended since 1999) that covers all of NBK-Bremerton and authorizes the discharge of dry dock drainage, non-contact cooling water, treated steam plant wastewater, stormwater runoff, demineralized water, steam condensate, salt water from the supply system, and potable water from the facility. On March 23, 2013, PSNS&IMF entered into a Federal Facilities Compliance Agreement (FFCA, EPA Docket No. CWA-10-2013-0045) to complete MILCON projects to upgrade the dry-dock process water control system (PWCS), increase the capacity of the oily waste treatment systems (OWTS), and make other improvements to best management practices (BMPs) to meet All Known, Available, and Reasonable Methods of Treatment (AKART) for preventing, controlling, or abating the pollutants discharged from the Shipyard (U.S. Navy and Puget Sound Naval Shipyard & IMF 2012).

Since the 1970's major programs have been implemented by the Navy, City of Bremerton, Kitsap County and other jurisdictions to control and eliminate sources of pollution discharged into the receiving waters of the Inlets (Table 1). These projects represent significant investment of public funds to correct, repair, and improve the environmental quality of the Inlets and surrounding watershed. Actions conducted to meet NPDES requirements included treating point source discharges from industrial and waste water treatment plant outfalls, eliminating combined sewer overflows (CSOs), and implementing industrial stormwater BMPs to control the release of contaminants.

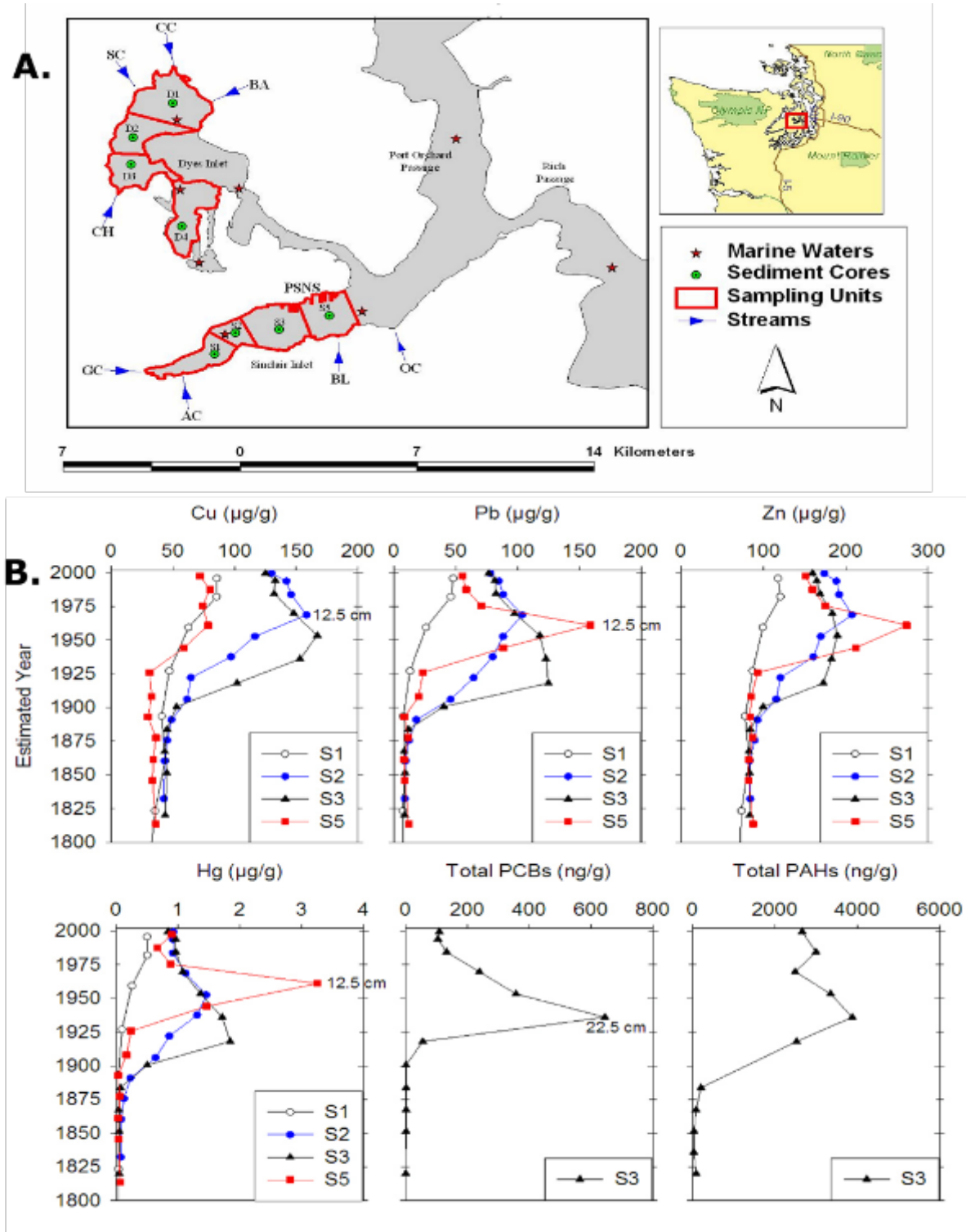

Figure 2. (A) The location of depositional areas in Sinclair and Dyes Inlets where sediment cores were collected and age-dated using radionuclide tracers and (B) the resulting sediment core profiles for Cu, Pb, Zn, Hg, PCBs, and PAHs in sediment cores collected from Sinclair Inlet (Brandenberger, Crecelius, and Johnston 2008).

Table 1. Time line of major actions and programs that have been implemented by the Navy and other jurisdictions to reduce discharges of pollutants and clean up contaminated areas within Sinclair and Dyes Inlets. Actions are shown for NPDES/AKART in purple, CERCLA in red, watershed in green, and in-water construction projects in blue.

1978 Executive Order 12088--Federal compliance with pollution control standards
1980 CERCLA enacted
1986 Superfund Amendments and Reauthorization Act; Defense Environmental Restoration Account created to fund cleanup at military sites
1989 Model Toxics Control Act (MTCA); Washington State Waste Discharge Permit Manual
1980s-1990s Standup of Pollution Abatement, Hazardous Materials, and Hazardous Waste Programs at PSNS
1990 Remedial Investigations for OUBT and OUBM and Removal Actions for OUBT [1]
1993 Feasibility Studies for OUBT, OUBM, OUA, OUD [1]
1994 NPDES permit process for industrial discharges [2]
1995 Environmental Safety and Health managers assigned to projects [3]
1998 Recycled Metals Transfer Station (RMTS) stormwater treatment system installed [3]
1999 Record of Decision for OUBM [1]; Bremerton Ferry and Transit Center Completed [4]
2000 ENVVEST Final Project Agreement [5]; Remedial Action for OUA [1]
2000-2003 Pier D reconstruction at PSNS [6,7]
2000-2009 City of Bremerton CSO elimination program [8]
2000-2001 Navigational and Cleanup Dredging and CAD for OUBM [1]
2001 Oily waste treatment system online for Pier D [3]; ENVVEST FC TMDL Study [9]
2003 Dry Dock and stormwater inspections implemented [3]; Bremerton Eastside Treatment Plant online [8]
2003-2008 Pollution identification and control (PIC) program [10] for Dyes Inlet Watershed [11]
2004 Effective cleaning, inspections, reporting process and revised industrial process instructions implemented at PSNS [3]; Repair of major storm and sanitary sewer line on “R” street at PSNS [1]
2005 Stormwater system repairs, increased environmental management oversight, and catch basin PMI implemented at PSNS [3]; ENVVEST Technical Study for FC TMDL completed [12]
2006 Sanitary sewer and storm drain repair at PSNS [3]; Remedy for OUBT implemented [1]; Expanded capacity for South Kitsap Water Reclamation Facility (SKWRF) completed [13]
2006-2013 KPH/SSWM PIC program for Sinclair Inlet [10]
2007 BMP briefs prior to docking implemented at PSNS [3]
2008 Containment BMPs for blasting and painting implemented [3]; Bremerton Marina redevelopment [14]
2009 Upgraded reverse osmosis system for OF21 completed for PSNS [3]; ENVVEST modeling study for Sinclair and Dyes Inlet FC TMDL completed [15]; Disconnect CSO16 from PSNS126 and CSO Elimination Project Completed [8]; Demolition of Pier 8 at PSNS [1]
2009-2012 Demolition and Replacement of Pier B at PSNS [1]
2010 Implemented new BMPs for AKART [16]; Piling replacement for Pier 7 [1]; Beach replenishment for OUA [1]
2010-2011 Repairs of quay walls and entrances for dry docks 1-5 at PSNS [1]; Manette Bridge Replacement [17]
2010-2012 Repairs for Piers 5 & 6 at PSNS [1]
2010-2018 Clean Water Kitsap Watershed Improvement Projects [10]
2011 Additional BMPs for AKART implemented at PSNS [16]
2012 Implementation Plan for Sinclair and Dyes FC TMDL [18];
2013 Dry Dock MILCON improvements completed [16]; Activated carbon demo project for Pier 7 at PSNS [19]
2015 Beach replenishment for OUA [1]
2016 Beach replenishment for OUA [1]
2014 Non-Dry Dock AKART improvements completed at PSNS [16]
2017-2019 Seawater main replacement at PSNS [20]
2017 Ex-INDEPENDENCE Biofouling Removal [21–23]
2018 Membrane bioreactor upgrades online for SKWRF [13]

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Legacy contamination is being addressed by CERCLA response actions to remediate past contamination sources identified during the RI/FS which included removal actions, interim actions, remedial actions, and institutional controls. Watershed initiatives have also been conducted though projects performed by Kitsap County Surface and Stormwater Management (SSWM), Kitsap Public Health District (KPHD), Clean Water Kitsap, and others to meet Total Maximum Daily Load (TMDL) targets and achieve water quality improvement goals for the inlets. In-water construction projects were also implemented to improve harbor and industrial operations within the Shipyard and complete significant upgrades for the dry dock PWCS and OWTS, substantially increasing the capacity and efficiency for treating industrial wastes (U.S. Navy and Puget Sound Naval Shipyard & IMF 2012). While the construction projects could disturb and resuspend sediment-bound contaminants, the projects also significantly enhanced the commercial and transportation infrastructure of the region and improved environmental conditions within the nearshore areas of the Shipyard.

The sediments of Sinclair and Dyes Inlets accumulate contaminants from a variety of point and non-point sources within the watershed including: Shipyard operations, marina and vessel traffic, non-point source runoff, combined sewer overflows (CSO), discharges from waste water treatment plants (WWTP), industrial effluents, surface streams (Brandenberger, May, Cullinan, and Johnston 2007; Cullinan et al. 2007), atmospheric deposition (Brandenberger et al. 2010), and groundwater (Paulson et al. 2013; Conn et al. 2018). Any metal and organic contaminants released within the inlets, as well as those transported into the inlets from the Puget Sound will tend to partition to the particulate phase and subsequently accumulate in depositional areas located within Shipyard and the surrounding Sinclair Inlet (Figure 3) (McLaren 1998; McLaren 2004). The dry dock outfalls, stormwater drains, stormwater outfalls of special concern identified in the NPDES permit, and the remediation dredging, navigational dredging, and confined aquatic disposal (CAD) pit implemented as part of the CERCLA ROD for OUBM in 2001 are shown in Figure 4.

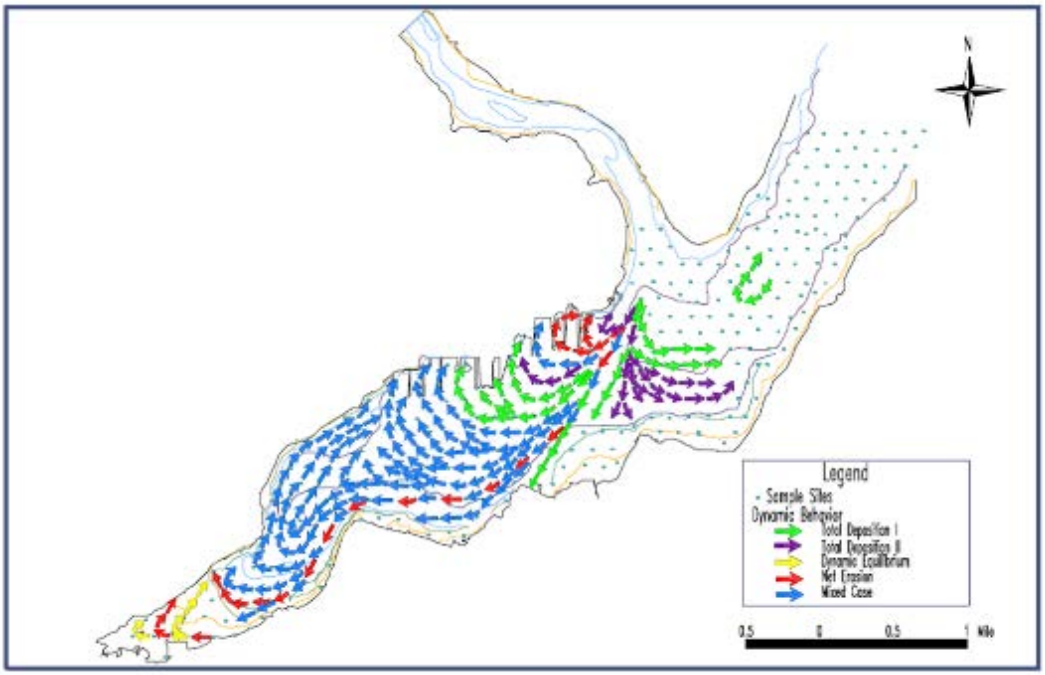


Figure 3. Net transport for muddy sediment obtained from Sediment Trend Analysis performed on samples collected from Sinclair Inlet between May 20, 1998 and July 21, 1998 (McLaren 1998).

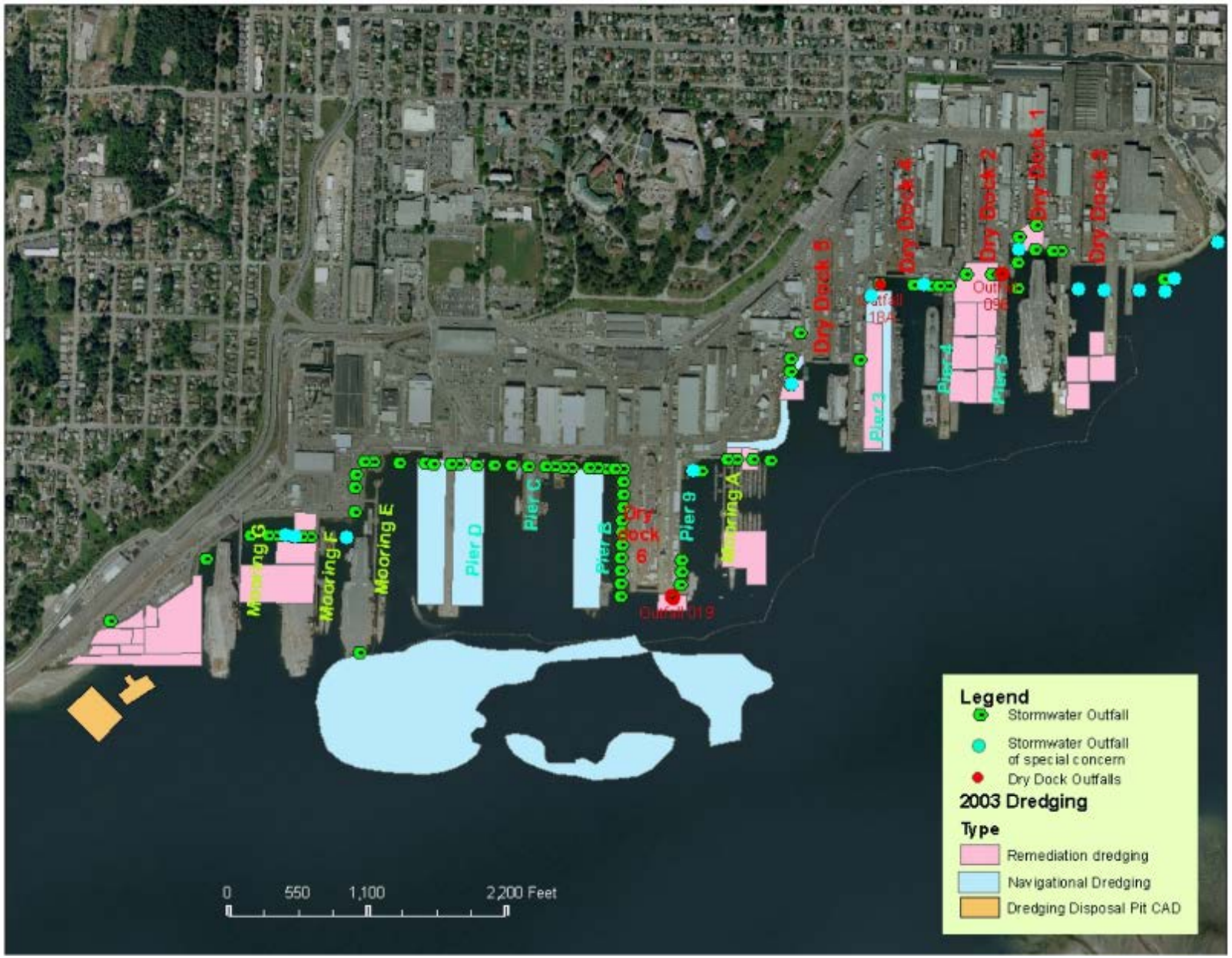


Figure 4. Locations within the Shipyard of dry dock outfalls, stormwater drains, stormwater outfalls of special concern identified in the NPDES permit review, and the remediation dredging, navigational dredging, and CAD pit implemented as part of the CERCLA ROD for OUBM in 2001.

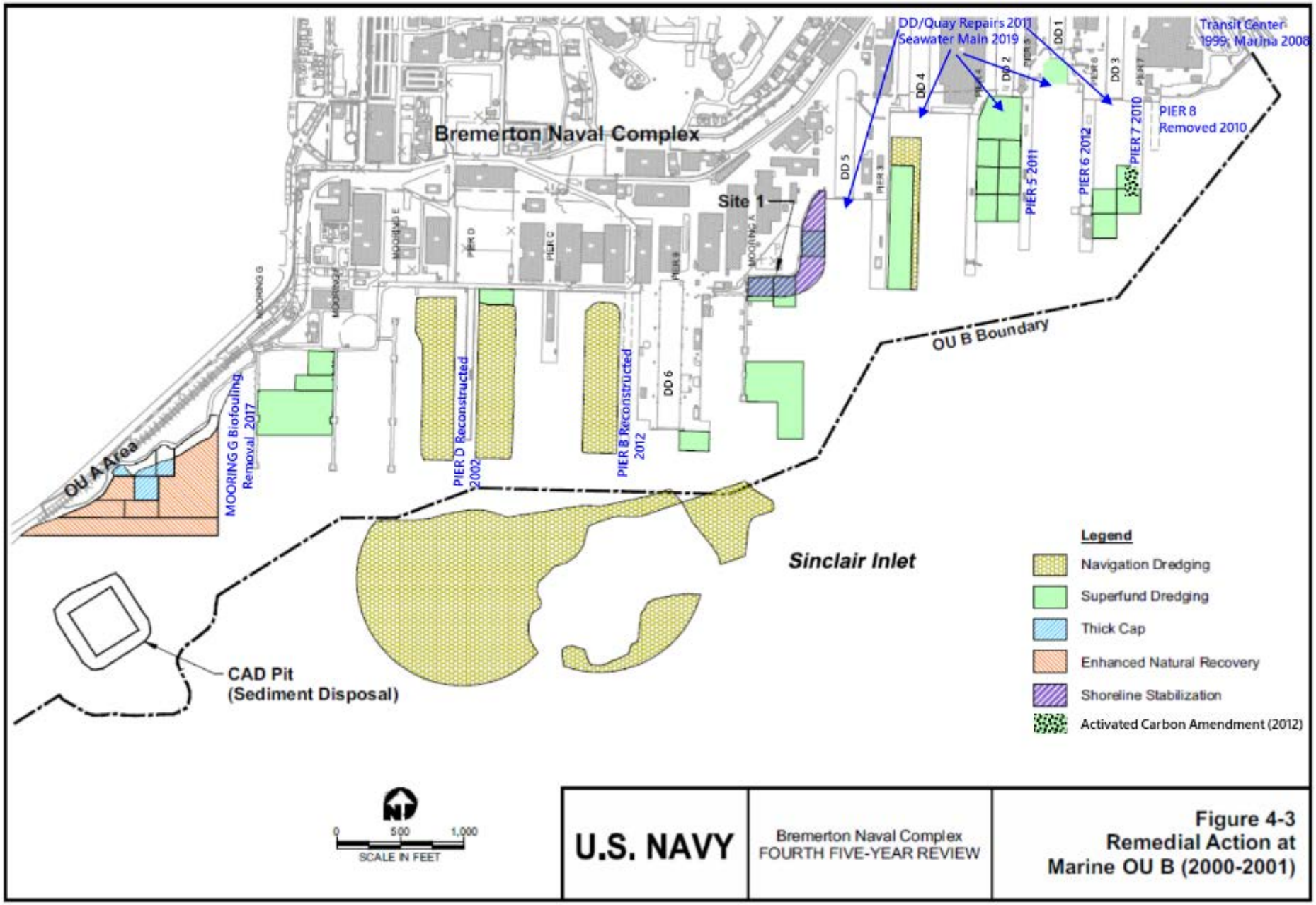


Figure 5. Footprint of remedial actions conducted for OUBM in 2000-2001, 2012, and major waterfront projects (blue text). Figure modified from (U.S. Navy 2017a).

2.2 Relevant Studies

Previous studies have developed a wealth of environmental quality information from both a watershed-scale (e.g., regional water and sediment quality within Kitsap County) and the localized Shipyard area. The two scales are necessary to provide information for the development of TMDLs and provide resource managers with a relative scale considering all sources, to determine what is achievable in this region. However, improving cooperation between the various programs poses some challenges, as each program has different objectives and generally require different study designs (e.g., compositing grab samples versus individual grabs, sediment collection of 0-10 cm surface grabs versus core profiles to a depth of 25 cm with 2.5 cm resolution, etc.).

The improvement and recovery of sediment quality in Sinclair Inlet is actively being addressed by the Navy under the CERCLA and NPDES programs; by the Washington Department of Ecology (Ecology) under the Urban Waters Initiative (Dutch et al. 2009), and by the Shipyard's ENVvironmental reinENVment (ENVVEST) Project. Under ENVVEST, a cooperative agreement among PSNS&IMF, USEPA Region X, Ecology, and local stakeholders (Puget Sound Naval Shipyard et al. 2000; ENVVEST 2006) has been helping to improve the environmental quality of the Sinclair and Dyes Inlet watershed and develop TMDLs for priority pollutants (May et al. 2005; Johnston et al. 2009; Lawrence et al. 2012).The following is a short description of each of these programs and synopsis of data available to date that was used to inform the SQV study.

2.2.1 Installation Restoration OUBM Program

A CERCLA Early Action ROD for Puget Sound Naval Shipyard OUBM project area was signed on June 13, 2000. The selected remedy included dredging of contaminated sediments with onsite disposal in a CAD pit, thick and thin-layer capping, enhanced natural recovery, monitored natural recovery, and implementation of institutional controls (U.S. Navy 2000). Sinclair Inlet is naturally depositional in nature, and modeling in support of remedy selection predicted that the ultimate cleanup goal would be met within 10 years from the completion of active remedial measures through the processes of natural sediment recovery (U.S. Navy 2000). Clean up and navigational dredging was conducted for OUBM in 2000-2001 under the Navy's IR program (Figure 5, URS Group Inc. 2002a) and a long-term monitoring (LTM) plan was approved (URS Group Inc. 2002b) and initiated in 2003 (U.S. Navy 2017a).

The primary objective of the marine sediment cleanup was to reduce the potential risk from PCBs in the tissues of bottom-dwelling fish that could be consumed by humans engaged in a subsistence lifestyle (U.S. Navy 2000). The PCBs found in fish tissues are believed to have resulted from consumption of prey species impacted by contamination in marine sediments. A secondary consideration in the cleanup was the presence of elevated levels of Hg measured in species collected in Sinclair Inlet and marine sediments which were above the state sediment quality standards throughout much of the inlet.

A summary of the sediment investigations occurring under the CERCLA investigations included the following activities:

1. LTM events for OUBM were conducted in 2003, 2005, 2007, 2010, 2012, and 2014 (URS Group, Inc. 2009; U.S. Navy 2012; U.S. Navy 2017a). The LTM program consists of sampling seventy-one 500 ft^2 grids within OUBM and thirty-two 1,500 ft^2 grids encompassing the remainder of Sinclair Inlet. For each grid, three randomized 0-10 cm surface grabs were composited and analyzed for PCBs (as total Aroclors), total Hg, total organic carbon (TOC), grain size, and percent moisture to obtain an unbiased estimate of the surface area-weighted average (AWA) of contaminant concentrations within

the entire Inlet. Additionally, English sole (*Parophrys vetulus*) were periodically sampled by the Navy and Washington Department of Fish and Wildlife (WDFW) and analyzed for PCBs, Hg, and lipid content (U.S. Navy 2012; U.S. Navy 2017a).

2. Sediment sampling within OUBM conducted in support of in-water MILCON projects along the waterfront of the Shipyard (U.S. Navy 2017a). Conducted between FY2009 and FY2017, in-water construction work included demolition and removal of Pier 8, piling replacement for Pier 7, quay wall and dry dock improvements, demolition and replacement of Pier B, and piling replacements for Piers 5 and 6 (Table 1). Pre- and post-construction marine sediment sampling and analysis of metals (arsenic, cadmium, chromium, copper, lead, nickel, silver, and zinc), PCBs, grain size, TOC, and percent moisture was required for construction permits for projects that included in-water work within OUMB. When the construction included removal of piers, under-pier samples were also collected (U.S. Navy 2012; U.S. Navy 2017a).
3. Directed studies were conducted by the United States Geological Survey (USGS) Washington Water Science Center to identify mercury sources and sinks and the distribution of mercury in the sediment, water, and biota of Sinclair Inlet (Paulson et al. 2010; Huffman et al. 2012; Paulson et al. 2012; Paulson et al. 2013; Paulson et al. 2018).
4. An activated carbon demonstration project conducted to remediate elevated PCB concentrations at the southwestern end of Pier 7. The field demonstration was initiated in August 2012 as a remedial action under the CERCLA ROD for OUBM. The demonstration project was conducted to demonstrate and validate placement, stability, and performance of reactive amendments for the treatment of contaminated sediments in an area with elevated PCB and mercury contamination (Johnston et al. 2013; Kirtay et al. 2016; Kirtay et al. 2017; Kirtay et al. 2018).

2.2.1.1 LTM for OUBM

The LTM sampling grids of 500-ft^2 for OUBM (Figure 6A) and 1500-ft^2 for Sinclair Inlet (Figure 6B) were sampled during seven LTM events conducted between 2003 and 2014 (URS Group, Inc. 2009; U.S. Navy 2012; U.S. Navy 2017a). The goals of the ROD were to:

(1) reduce the area-weighted concentration of PCBs to the minimum cleanup level (MCUL) of 3 mg of PCB per 1 Kilogram of organic carbon (3 mg/KgOC) and obtain a Clean Up Goal for the Inlet of 1.2 mg/KgOC within 10 years;

(2) selectively remove high concentrations of Hg collocated with PCBs; and

(3) control shoreline erosion of contaminated fill.

Although cleanup goals for total Hg were not specified in the ROD, the Washington State Sediment Management Standards (SMS) defines the Maximum Chemical Criterion (MCC) and Sediment Quality Standard (SQS) for total Hg as 0.59 mg/Kg and 0.41 mg/Kg, respectively (Washington State Dept. of Ecology Toxics Cleanup Program 2013). The sediment sampling was used to determine the AWA based on the geometric mean for PCBs and the arithmetic mean for total Hg.

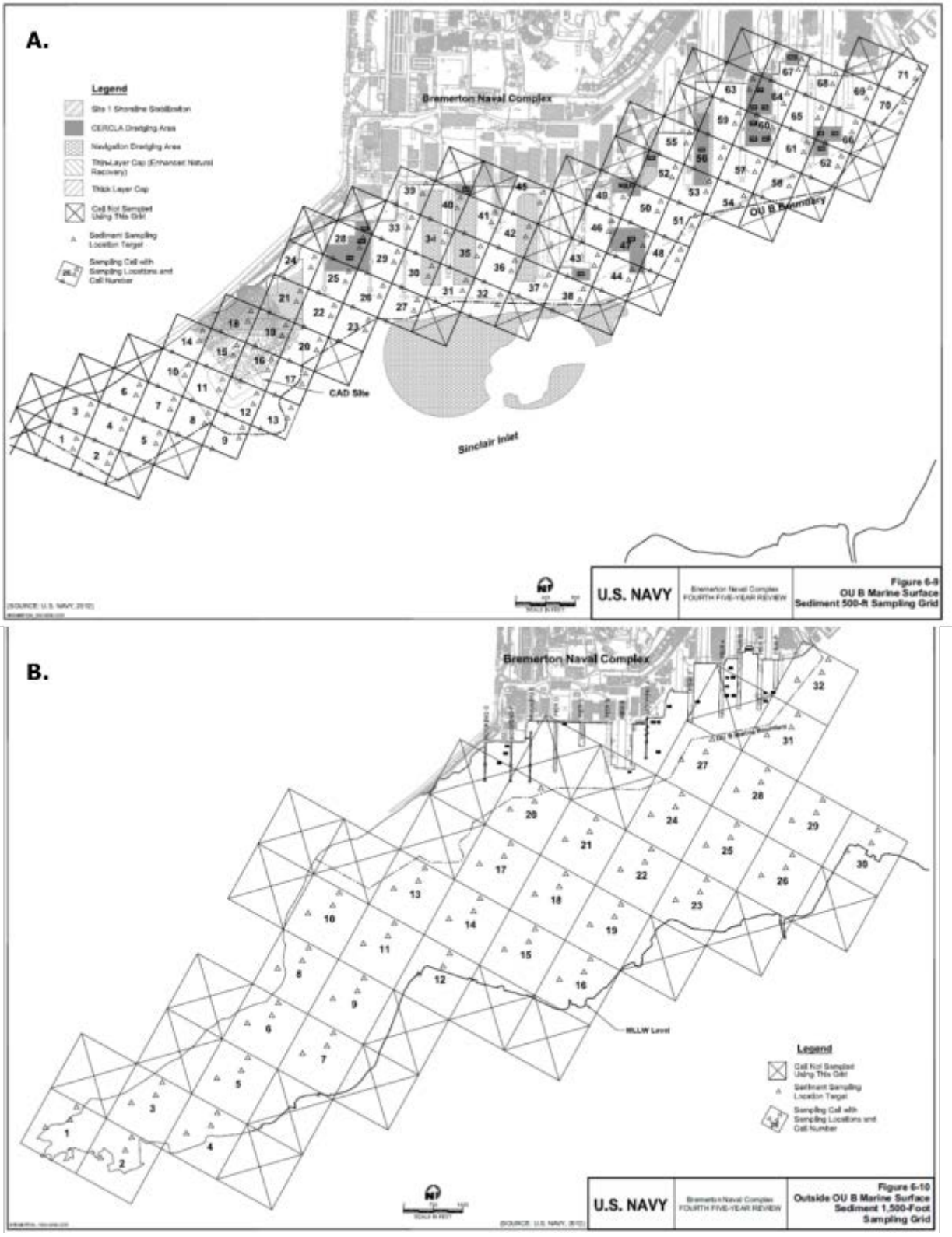


Figure 6. The LTM sediment sampling grids of 500-ft^2 for OUBM (A) and 1500-ft^2 for Sinclair Inlet (B) (U.S. Navy 2017a).

The results showed a generally decreasing trend of PCBs and total Hg over the sampling events except for an increase in AWA concentrations during the 2012 sampling interval (Table **2**, Figure **7**). The increase in PCB and Hg concentrations found during the 2012 LTM event may be due to the increase of in-water MILCON work conducted at the Shipyard from 2009-2013 (U.S. Navy 2017a: 201). Data from the 2014 LTM monitoring showed that the AWA of PCBs had decreased below the MCUL within the 500-ft grids and decreased below the Clean Up Goal for the 1500-ft grids (Table **2**, Figure **7**A). The total Hg data from the 2014 LTM monitoring event showed that the AWA concentrations for Hg were approaching the SMSs (Table **2**, Figure **7**B).

English sole samples were collected in the center of Sinclair Inlet by WDFW using a trawl net, with samples made up from composites of skin-off fillets of 20 fish, each fish a minimum of 22 cm long. The average concentration of PCBs decreased from 0.106 mg/Kg in 2003 to 0.033 ug/Kg in 2007 and 2010, but increased to 0.068 mg/Kg in 2012 and fell to 0.030 mg/Kg in 2015. The AWA for 2015 was close to the cleanup goal defined in the ROD of 0.023 mg Total PCB/Kg (Table **3**, Figure **8**A). The average concentrations of total Hg in English sole were less variable than PCBs – Hg concentrations ranged from 0.056 mg/Kg in 2010 to 0.025 mg/Kg in 2007 (Table **3**, Figure **8**A). A cleanup goal for total Hg was not specified in the ROD.

Overall, there has been more than a 2-fold reduction of PCBs in the surface sediments of Sinclair Inlet as a result of cleanup and remediation efforts (Figure **9**). The long-term trend of PCB concentrations in English sole sampled from Sinclair Inlet and reference locations in South Puget Sound, shows that PCB concentrations in English sole in Sinclair Inlet appear to spike following major dredging and in-water construction projects (Figure **10**), probably due to the disturbance and resuspension of sediment-bound contamination within Sinclair Inlet.

Table 2. The AWA of PCBs and total Hg determined for the 500-ft and 1500-ft grids for each LTM monitoring event between 2003 and 2014 **(U.S. Navy 2012; U.S. Navy 2017a)**.

	PCB		Total Hg	
	mg/KgOC		mg/Kg	
	500-ft	1500-ft	500-ft	1500-ft
2003	6.70	2.60	1.00	0.52
2005	6.10	2.40	1.10	0.50
2007	4.60	1.60	0.86	0.49
2010	3.20	1.70	0.73	0.46
2012	5.10	2.40	0.88	0.55
2014	1.60	0.73	0.66	0.42

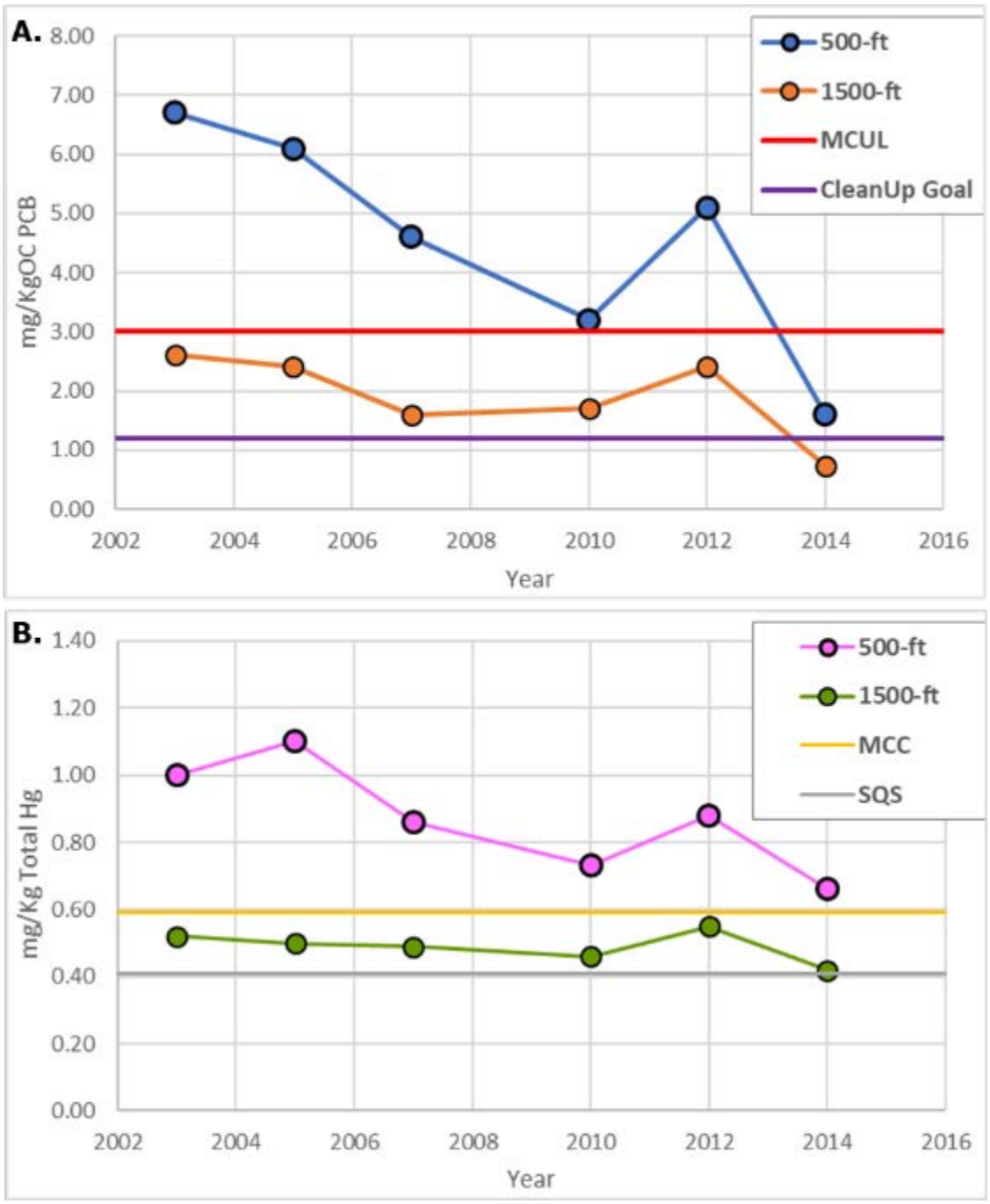


Figure 7. The AWA of Total PCB based on geometric mean (A) and Total Hg based on arithmetic mean (B) for 500-ft^2 grids within OUBM and 1500-ft^2 grids within Sinclair Inlet from LTM monitoring events between 2003 and 2014 **(U.S. Navy 2012; U.S. Navy 2017a)**. The MCUL and Cleanup Goal for PCBs and the MCC and SQS for Total Hg are also shown. 2014 **(U.S. Navy 2012; U.S. Navy 2017a)**

Table 3. The average of PCBs and total Hg (mg/kg wet wt.) determined from English sole tissue samples collected during LTM monitoring events between 2003 and 2014 **(U.S. Navy 2012; U.S. Navy 2017a)**.

	PCB	Total Hg
	mg/Kg	mg/Kg
2003	0.106	0.044
2007	0.033	0.025
2010	0.033	0.056
2012	0.068	0.048
2015	0.030	0.037

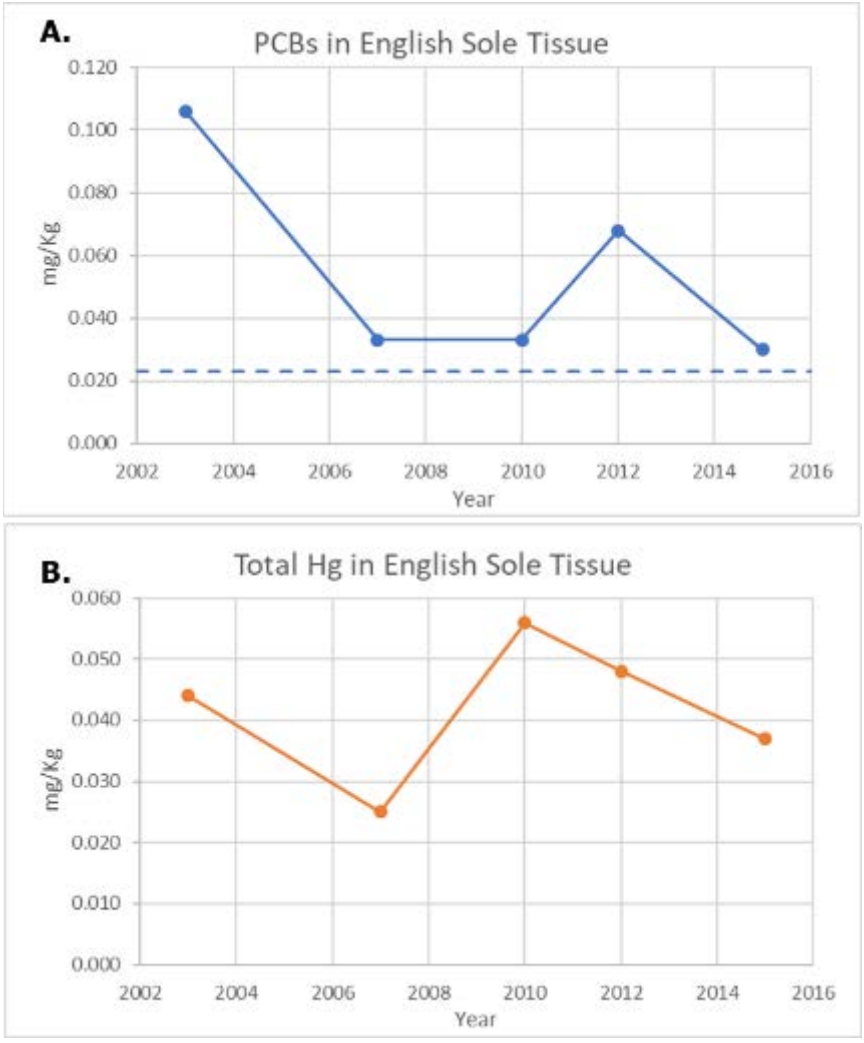


Figure 8. The average concentrations of PCBs (A) and total Hg (B) in English sole tissue samples collected during LTM sampling events. The PCB cleanup goal of 0.023 mg/Kg for English sole tissue defined in the ROD is shown as a dashed line (A).

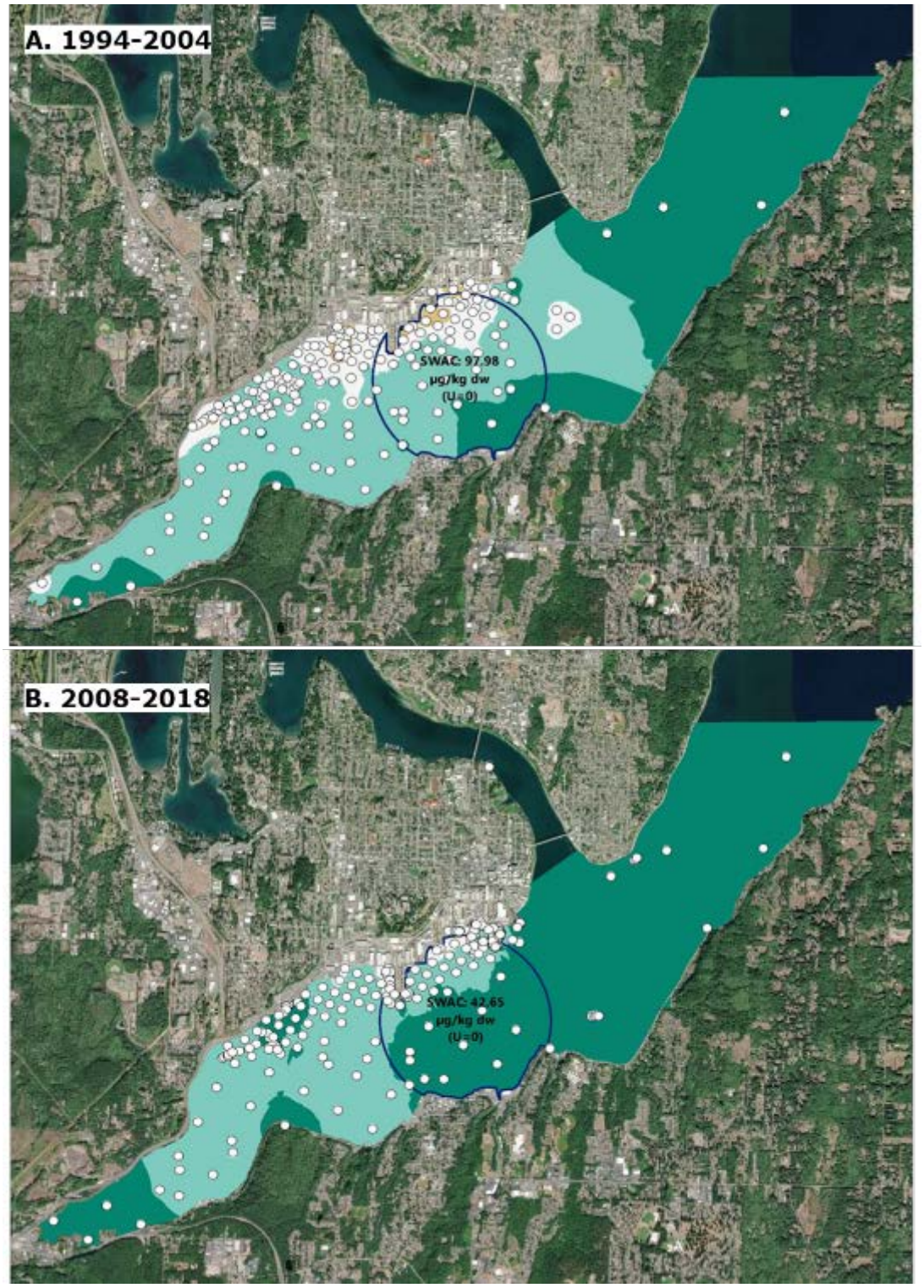


Figure 9. The Surface Weighted Average Concentration (SWAC) of PCBs determined for the bottom fish trawl area (black circle) sampled for English sole by WDFW using data from 1994 to 2004 (A) and 2008 to 2018 (B). Data from EIM, map prepared by Anchor QEA (Johnston 2019).

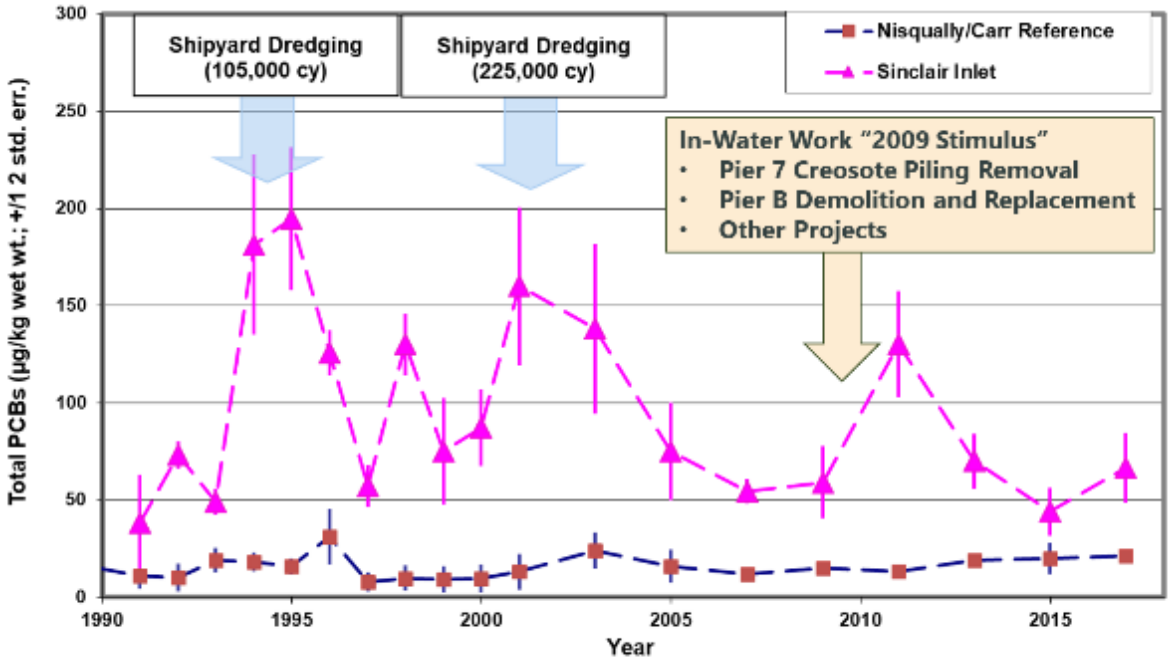


Figure 10. The average PCB concentrations in English sole sampled by WDFW in Sinclair Inlet and Nisqually Reach/Carr Inlet reference sites. Periods of major dredging and in-water construction projects in Sinclair Inlet are also shown. Data from EIM, chart prepared by Anchor QEA (Johnston 2019).

2.2.1.2 Supplemental Sampling for MILCON Projects

Pre- and post-construction sediment sampling was conducted for MILCON projects for the replacement of Pier B and demolition of Pier 8 (2009-2012), replacement of fender piles at Pier 7 (2009 -2010), repair of quay walls and drydock entrances at Dry Docks 1, 3, 4, 5, and 6 (2010-2011), and repair of fender systems at Piers 5 and 6 (2010-2012). While the construction projects could disturb and resuspend sediment-bound contaminants, the projects also significantly improved environmental conditions within the nearshore areas of the Shipyard by removing hundreds of deteriorating creosote pilings – which can themselves be a major source of contamination to the environment (Chadwick et al. 1999). The MILCON projects also resulted in the removal of debris and other scrap materials found underwater near piers and quay walls, improved industrial waste water treatment and reduced discharges from industrial outfalls, retrofitted stormwater discharges along piers and dry docks, improved material handling, and facilitated the implementation of improved water pollution prevention BMPs along the waterfront (U.S. Navy and Puget Sound Naval Shipyard & IMF 2012). The pre- and post-construction data were evaluated to determine if the in-water work resulted in higher sediment concentrations of metals, PAHs, and PCBs after construction was completed and whether sediment quality exceeded SMSs.

The data were grouped by sampling locations for Pier 5 (P5), Pier 6 (P6), Pier 7 (P7), Dry Docks 3, 4, 5, and 6 (DD), and all sites (ALL). The data from before and after construction for TOC, PCB/organic carbon (OC), total Hg, Cd, Cr, Cu, Pb, Ag, and Zn were tested for differences in contamination levels before and after construction using analysis of variance (ANOVA) assuming a lognormal distribution and nonparametric Kruskal-Wallis statistic with no assumption about the underlying distribution (Statistix 4.0, Analytical Software, St. Paul, MN). The null hypothesis was:

There are no differences in contamination levels before and after construction, where the null hypothesis was rejected if p≤0.05.

For most of the parameters measured, the results showed that there were no statistical differences between the pre- and post-construction results. However, the following exceptions were noted: TOC was significantly lower for ALL and P7 sites; total Hg was significantly lower for P7 and DD sites; Cr was significantly lower for P5 sites; Ag was significantly lower for ALL and P5 sites; and Cu was significantly higher for P6 sites (Table **4**, Figure **11**). Very high variance for all parameters was encountered at all sites for both pre- and post-construction sampling. The data also had a high probability of exceeding sediment quality standards at all sites for PCB/OC (Figure **11**A), total Hg (Figure **11**B), Cu, and Zn; P6 sites for As and Pb, and DD sites for As (see Appendix C Pre- and Post-Construction Comparison for details of statistical analysis).

Based on these results, it is most likely that the contaminant distributions were unrelated to in-water construction projects and were a result of pre-existing conditions. The sampling did identify pockets of elevated sediment contamination within the nearshore areas of the Shipyard which can be used to help address anti-degradation requirements, assess the site conditions and possible contaminant sources, characterize areas not previously sampled, and inform management decisions for the Shipyard (U.S. Navy 2012; U.S. Navy 2017a).

Table 4. Statistical results for differences between Pre- and Post-MILCON sediment sampling where ↓ indicates Post- samples were significantly lower and ↑ indicates Post- samples were significantly higher (p≤0.05).

	ALL	P5	P6	P7	DD
TOC	↓			↓	
PCB/OC					
Hg				↓	↓
As					
Cd					
Cr		↓			
Cu			↑		
Pb					
Ag	↓	↓			
Zn					

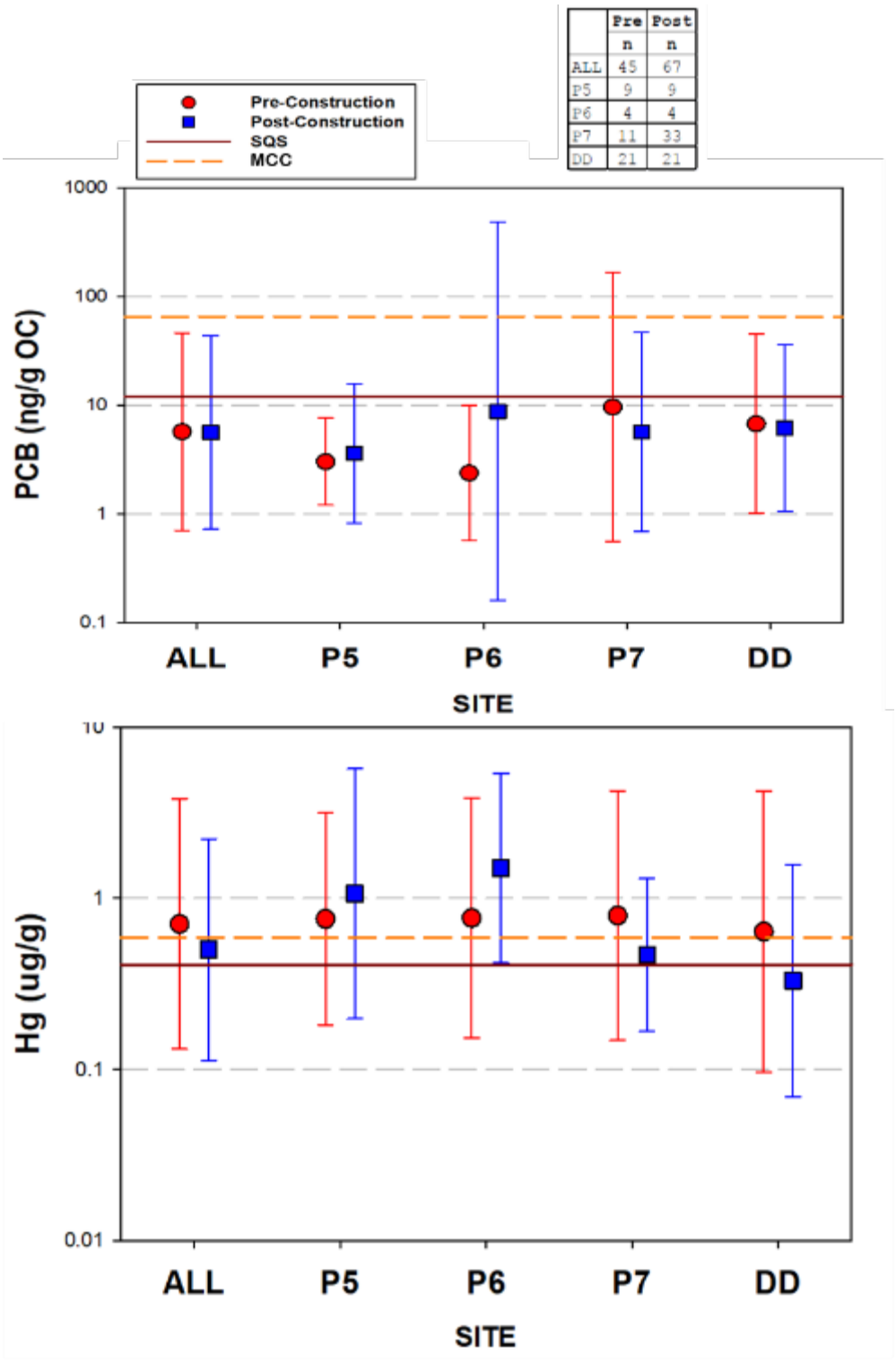


Figure 11. Results from Pre- and Post-construction projects for PCB/OC and total Hg for all sites (ALL), Pier 5 (P5), Pier 6 (P6), Pier 7 (P7), and Dry Dock (DD) repair projects. Data are shown as mean and 5^{th} – 95^{th} percentile of the mean (error bars), SQS (brown solid line), and MCC (orange dashed line).

2.2.1.3 USGS Hg Studies

The identification of Hg sources, sinks, and the distribution of Hg in the sediment, water, and biota of Sinclair Inlet has been a focus of directed studies performed by the US Geological Service (USGS) Washington Water Science Center (Paulson et al. 2010; Huffman et al. 2012; Paulson et al. 2012; Paulson et al. 2012; Paulson et al. 2013; Paulson et al. 2018). The objectives of these studies were to:

(1) estimate the magnitudes of the different predominant sources of total Hg to Sinclair Inlet, including those from the Shipyard,

(2) evaluate the transformation of mercury to a bioavailable form in Sinclair Inlet, and

(3) assess the effect of the sources and transformation processes on the mercury burden in marine organisms and sediment.

The evaluation of total Hg in surface sediments of Sinclair Inlet found that the 2000-2001 remediation resulted in a significant reduction of total Hg for Sinclair Inlet as a whole, nevertheless the total Hg concentrations in the surface sediments have decreased slowly due to the relatively low rate of sediment burial and possible terrestrial sources of Hg from the Shipyard (Paulson et al. 2010).

A quantitative mass balance of filtered total Hg (filtered through a 0.45 um filter, FTHg) in Sinclair Inlet was developed using historical data and data collected by the USGS (Paulson et al. 2012; Paulson et al. 2013). Most of the FTHg in Sinclair Inlet originates from salt water flowing from Puget Sound. Sources of Hg within Sinclair Inlet include atmospheric, terrestrial, and sedimentary inputs which contribute approximately 420 grams of FTHg per year and results in FTHg concentrations in Sinclair Inlet of 0.33 ng/L compared to 0.2 ng/L in Puget Sound seawater entering Sinclair Inlet. The two major sources of FTHg within the Sinclair Inlet watershed were identified as diffusion from marine sediment and fresh water and tidal flushing discharged from the largest stormwater drain system (PSNS015) located on the west side of the Shipyard that apparently passes through a zone of contaminated soil (Site 2 in Figure **12**). Secondary potential sources included rain falling directly on Sinclair Inlet, discharge from creeks draining into the inlet, and discharges from stormwater basins within the watershed. Additional lesser sources of FTHg included discharges from the municipal wastewater treatment plant and discharges from the dry dock drainage systems which captures groundwater from eastern part of the Shipyard (capture zone of sumps in Figure **12**). Finally, relatively minor sources of FTHg from stormwater and groundwater discharged from the rest of the Shipyard were also identified (Figure **12**).

An evaluation of Hg methylation rates and uptake by phytoplankton and zooplankton in Sinclair Inlet showed that methylation varied over the year – the highest methyl Hg concentrations were correlated with high biological activity in the spring and summer months. In comparison to the rest of Puget Sound, the methyl Hg concentrations of surface water, phytoplankton, and zooplankton (Figure **13**) observed in Sinclair Inlet were within the range of concentrations observed at Holmes Harbor (HH), Liberty Bay (LB), and Budd Inlet (BI) which were representative of embayments located in Whidbey Basin, Bainbridge Basin, and South Puget Sound, respectively (Paulson et al. 2018).

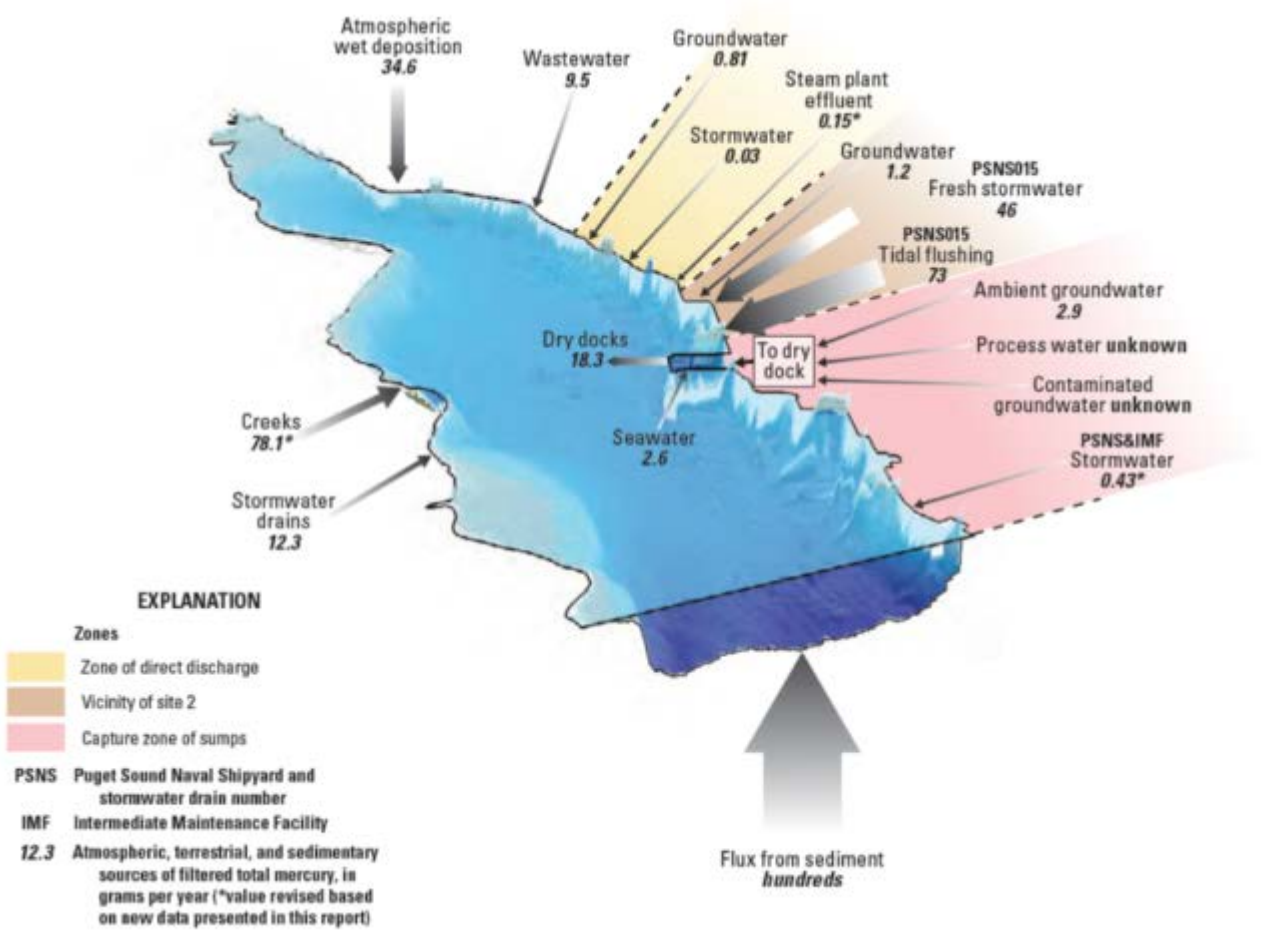


Figure 12. Loadings of filtered total Hg (FTHg) in g/yr from freshwater sources, from seawater recycled in and out of the Shipyard, and from net advective transfers between Sinclair Inlet and Puget Sound (Paulson et al. 2013).

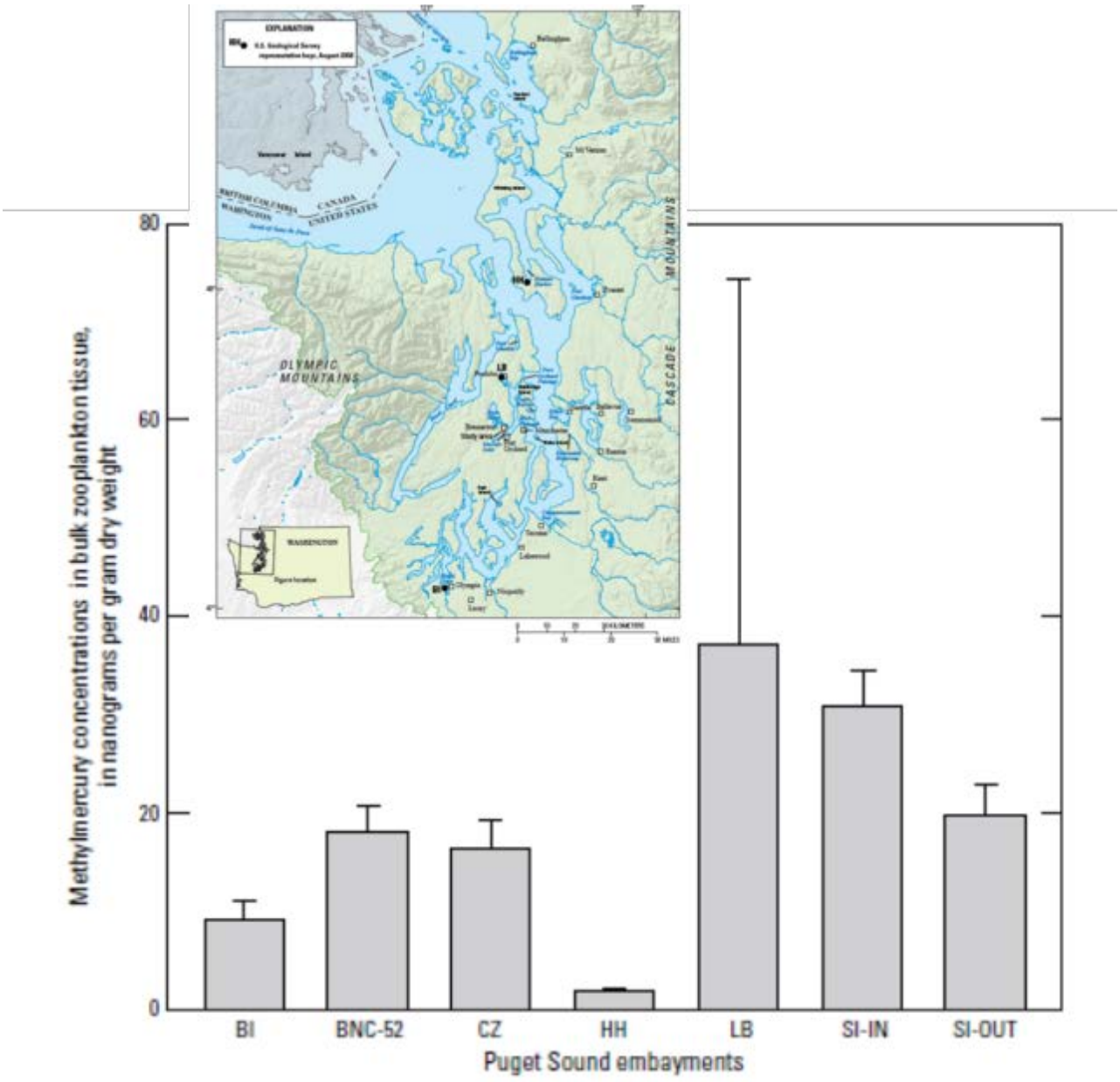


Figure 13. Concentrations of methylmercury in bulk zooplankton tissue measured in August 2008. Stations include three representative bays (Budd Inlet [BI], Holmes Harbor [HH], and Liberty Bay [LB]); greater Sinclair Inlet (SI) stations (OU B- Marine station (Bremerton naval complex [BNC-52], CZ, convergence zone Inner [SI-IN], and Outer [SI-OUT]) (Paulson et al. 2018).

2.2.1.4 Pier 7 Activated Carbon Demonstration Project

During a fender pile replacement project for Pier 7 in 2010, elevated PCBs, Hg, and other contaminants were found adjacent to Pier 7. Based on these findings, the Navy submitted a proposal to the Environmental Security Technology Certification Program (ESTCP) to conduct a full-scale sediment amendment demonstration project at the site using activated carbon (AC). The proposal was selected for funding in Fiscal Year 2011, and following a successful laboratory go/no-go evaluation the field

demonstration was initiated in August 2012 as a remedial action under the CERCLA ROD for OUBM (Johnston et al. 2013; Kirtay et al. 2017; Kirtay et al. 2018). The amendment resulted in a reduction in contaminant bioavailability at the site which was evaluated with in situ bioaccumulation testing to obtain tissue concentrations and passive sampling to obtain concentrations in sediment porewater. The bioaccumulation testing utilized Sediment Ecotoxicity Assessment Ring (SEA Ring) technology with the polychaete worm *Nephtys caecoides* and bent-nose clam *Macoma nasuta*, as well as in situ passive sampling conducted with solid phase microextraction (SPME) samplers to provide a chemical measure of PCBs in sediment porewater. The results showed that concentrations of total PCBs were reduced in clam tissues by 68%, 82%, and 88%, reduced in worm tissues by 87%, 89%, and 97%, and reduced in porewater by 75%, 86%, and 81% on average for the 10-, 21-, and 33-month monitoring events compared to the baseline, respectively (Figure **14**).

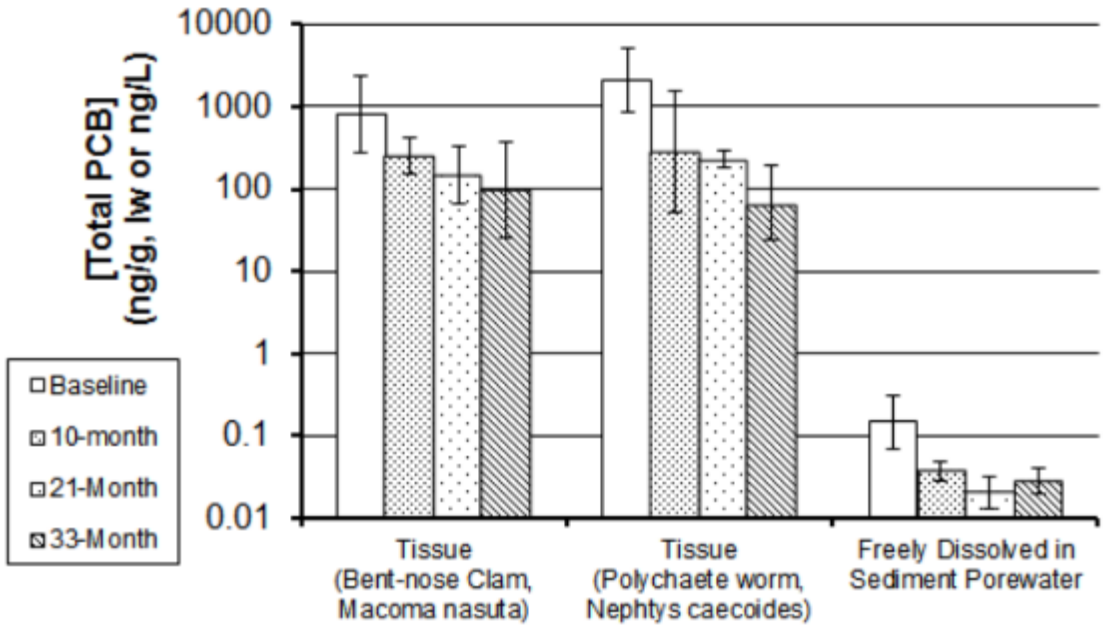


Figure 14. Summary of reduction in concentrations of Total PCBs in tissue (Lipid Normalized) and sediment porewater from Baseline following application of sediment amendment with AC for 10-, 21-, and 33-month post application monitoring. Results are shown as mean ± 95% Confidence Level (CL) (Kirtay et al. 2017).

Total Hg and methyl Hg were also measured during the study, but results were unclear regarding the efficacy of the amendment to reduce Hg or methyl Hg bioavailability. Concentrations of total Hg and methyl Hg in clams and worms were below risk-based thresholds and were consistent with ambient/natural levels. Overall, there was a general lack of consistent differences in total Hg and methyl Hg concentrations among the monitoring events, indicating the amendment did not have a detectable effect on bioavailability. However, this does not necessarily indicate AC would be ineffectual in reducing total Hg and methyl Hg bioavailability in sediments, because it is possible reductions in Hg bioavailability would be more discernable if baseline levels were greatly elevated (Kirtay et al. 2017).

Sediment amendment with AC may be suitable for a variety of environmental conditions – from shallow, quiescent, flat bottom settings to deep water, variable or sloping water depths, as well as tidal environments with active vessel traffic and infrastructure. This technology would be of great interest as a remedy for hydrophobic organic (e.g., PCBs, PAHs, and pesticides) contaminated surface sediments. Benthic invertebrate census and sediment profile imagery surveys did not indicate significant differences in benthic community ecological metrics among the pre-amendment and post-amendment monitoring

events, confirming that adverse effects on benthic invertebrates were not expected as a result of the AC amendment (Kirtay et al. 2017; Kirtay et al. 2018).

2.2.2 Project ENVVEST Studies

In 2000, a collaborative partnership formed through an ENVironment inVESTment (ENVVEST) partnership among PSNS&IMF, Ecology, U.S. EPA, and local stakeholders began conducting a comprehensive water quality improvement project for the watersheds of Sinclair and Dyes Inlets (Puget Sound Naval Shipyard et al. 2000; U.S. Environmental Protection Agency 2000a). By addressing environmental issues at the proper ecological scale, Project ENVVEST has made major contributions in addressing environmental concerns in the inlets by providing data to support TMDLs and developing a more efficient and effective means of protecting the environment. Project ENVVEST is part of EPA's eXcellence and Leadership Program which was developed to give communities, states and local agencies, federal facilities, and industry the opportunity to propose cleaner, cheaper, and smarter ways of protecting the environment (U.S. Environmental Protection Agency 2000b). The goal of PSNS Project ENVVEST is to create an alternative model for the development and implementation of environmental regulations, provide the technical data and information needed to implement TMDLs for the Sinclair and Dyes Inlet watershed, and achieve real improvements in environmental quality with less cost.

Through this collaboration and cooperation the ENVVEST working groups have made major contributions to improving the environmental quality of the Sinclair and Dyes Inlet watershed (ENVVEST 2006; Dunagan 2006 Feb 15; Dunagan 2008 Feb 15). In November 2003, 1500 acres of shellfishing beds in Dyes Inlet were reopened for the first time in decades based on the elimination of CSO events by the City of Bremerton and results of the ENVVEST modeling studies using a Curvilinear Hydrodynamics 3-dimensional (CH3D) model of Sinclair and Dyes Inlets (Washington State Dept. of Health 2003; Dunagan 2003 Nov 1; Wang et al. 2005). The ENVVEST working group completed a watershed monitoring and modeling effort that involved all the stakeholders in conducting a comprehensive sampling program throughout the watershed. The data were used to support the FC TMDL for Sinclair and Dyes Inlets (May et al. 2005) and resulted in an integrated watershed (Hydraulic Simulation Program Fortran - HSFP) and receiving water model (CH3D) that was used to simulate FC discharge scenarios needed for the TMDL (Johnston et al. 2009). The implementation plan (Lawrence et al. 2012), approved by USEPA in July 2012, established the capacity of the two inlets to accept discharges of FC bacteria from streams, stormwater outfalls, sewage treatment plants, and surface runoff, and still meet water quality standards. The study found numerous sources of bacterial pollution in the watershed that could impact water quality and shellfish harvesting areas. In general, microbial pollution was higher in sub-watersheds with greater population densities, in areas with a greater percentage of impervious area, and in areas served by older sewer infrastructures or onsite wastewater treatment (septic) systems.

The value of an integrated watershed approach to water quality management was demonstrated during this project. The number and variety of sources for bacterial pollution throughout the study area does not support a conventional “end-of-pipe” approach to pollution control. Elevated bacteria concentrations may indicate the presence of viruses and human pathogens as well as other pollutants that can be filtered from marine waters and concentrated by shellfish. The Washington Department of Health (WDOH) monitoring program for shellfish growing areas (Detterman 2009) relies on water quality measurements of bacteria to determine whether shellfish can be safely harvested. The safety of marine and freshwater beaches for swimming also is determined by measurements of indicator bacteria. Therefore, the detection, quantification, and correction of existing sources of bacterial pollution should be a high priority for watershed and water-resource managers, as should the development and implementation of an effective prevention program. Since September 2010, PSNS&IMF and NBK-Bremerton have been conducting

monthly FC bacteria monitoring as part of a bacterial pollution assessment and control program for the Shipyard (Johnston, Young, et al. 2010; Johnston, Aylward, Caswell, et al. 2018). This work is being coordinated with the Kitsap Public Health District and Naval Facilities Engineering Command Northwest to assess continuous process improvement for the release of bacterial contamination into Sinclair Inlet.

Achieving real improvements in environmental quality requires relevant and appropriate data to better inform management actions. From 2003-2006, the ENVVEST team completed a major effort to monitor stream and stormwater discharges during storm events for heavy metals, toxic organic contaminants, nutrients, and suspended particulates from the watershed to determine contaminant loads as a function of upstream land use, land cover, and storm intensity (TEC 2003; Brandenberger, May, Cullinan, and Johnston 2007; Brandenberger, May, Cullinan, Johnston, et al. 2007; Cullinan et al. 2007). The ENVVEST team also evaluated ambient water and sediment quality (ENVVEST 2006), measured contaminant bioaccumulation and effects on marine organisms within the inlets (Johnston et al. 2007; Applied Biomonitoring 2009), and assessed the toxicity of Cu in marine waters of the Inlets (Rosen et al. 2009).

Since August 2009, seasonal ENVVEST Ambient Monitoring has been conducted within nearshore areas of the Shipyard and surrounding Sinclair and Dyes Inlets to assess water quality and toxicity of effluents from NPDES discharges from the Shipyard and assess the status and trends of contaminant levels and toxicity within the receiving waters of the Inlets. The data are being used to assess the effectiveness of cleanup and pollution control measures and determine if discharges from all sources are protective of beneficial uses including aquatic life and human health in the receiving waters of the inlets (Johnston, Rosen, et al. 2010; Johnston, Rosen, et al. 2018). A network of water, sediment, and biota monitoring locations were selected that were co-located near suspected sources (industrial, waste water, and stormwater outfalls; marinas, stream mouths, and other sources) and locations that were representative of ambient marine and nearshore conditions for periodic sampling (Figure **15**).

For the ENVVEST Ambient Monitoring, water column stations and effluents from industrial outfalls were sampled seasonally for trace metals, conventional parameters, and toxicity. Additionally, indigenous mussels have been sampled biennially for contaminant residues of metals and toxic organic compounds. Key management questions include: (1) Are discharges from the Shipyard protective of beneficial uses? (2) Are discharges from all sources of contamination impacting the quality of water, sediment, and biota in the Inlets? (3) What is the status and trend of water, sediment, and biota residue quality in the Inlets? (Johnston, Aylward, Rosen, et al. 2018; Strivens et al. 2018; Robert K. Johnston et al. 2019).

The protection of beneficial uses for aquatic life and human health consumption are defined by Water Quality Standards (WQS) promulgated in WAC 173-201A-240 and 40 CFR 131.36. By definition, contaminate concentrations below WQS are protective of beneficial uses. The ENVVEST Ambient Monitoring results to date show a gradient of dissolved metals (filtered through 0.45 µm filter) that were higher in the Navy Nearshore areas of the Shipyard but concentrations of dissolved metals at the Navy Barrier were similar to other nearshore areas of Sinclair Inlet and slightly higher than dissolved metals found within marine areas of Dyes Inlet and Passages connecting to the main basin of Puget Sound (Figure **16**, for station locations see Figure **15**).

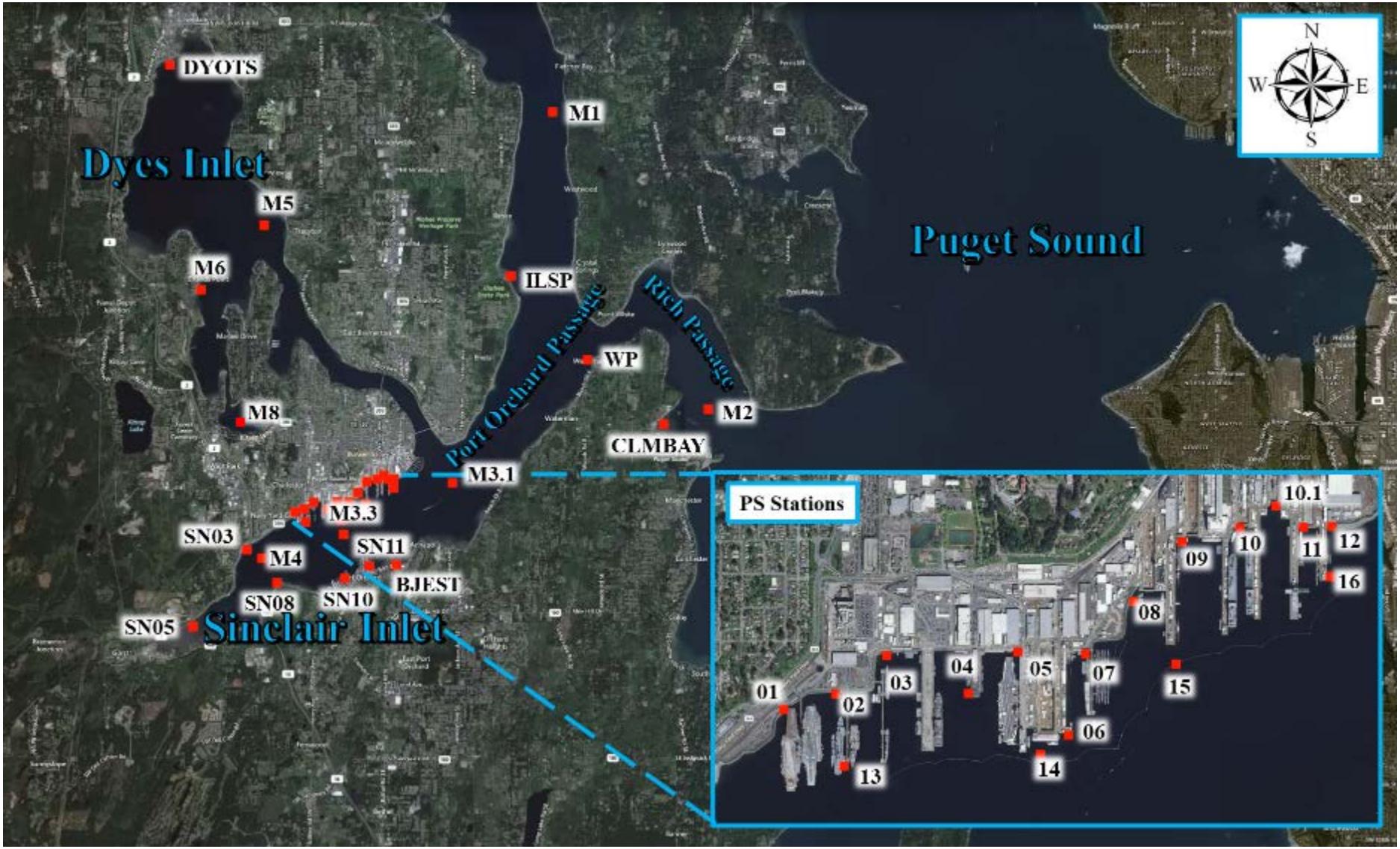


Figure 15. The network of ENVVEST Ambient Monitoring Stations established to track water quality and toxicity of nearshore and marine locations in Sinclair and Dyes Inlets **(Johnston, Rosen, et al. 2010; Johnston, Rosen, et al. 2018: 201; Strivens et al. 2018)**.

The monitoring data showed that dissolved metals nearly always met WQS and that water quality in Navy Nearshore areas appeared to improve after BMPs for industrial process improvements (U.S. Navy and Puget Sound Naval Shipyard & IMF 2012) were completed in Sept. 2013 (Figure **17**). In general, toxicity from exposure to whole effluent samples was not observed and ambient water samples were not toxic to test organisms, except that ambient toxicity was only observed during the presence of algal blooms which showed that toxicity was highly correlated with the abundance of the toxic algae *Gymnodinium splendens* (Rosen et al. 2009).

The ENNVEST Mussel Watch monitoring was conducted following the protocols recommended by the NOAA Status and Trends program (Kimbrough et al. 2008). Biennial sampling was initiated in winter of 2010 and has continued through 2018. Indigenous mussels (*Mytilus* spp.) were collected at stations located near suspected sources (industrial, waste water, and storm water outfalls; marinas, stream mouths, and other sources) as well as stations that were representative of ambient conditions (Johnston, Rosen, et al. 2010; Johnston, Rosen, et al. 2018). The mussel samples were kept on ice or held frozen until they were transferred to the laboratory for processing which consisted of shucking the soft tissue from the shell and homogenizing about 30-50 individuals (whole body) tissues from each station for residue analysis of metals, PCBs, PAHs, lipid content, and stable isotopes of C and N. The contaminant concentrations were compared to Critical Body Residue (CBR) thresholds of ecological effects. The CBR is the concentration of a chemical in mussel tissues below which effects to mussel growth, reproduction, and survival are not expected (Johnston et al. 2007; Applied Biomonitoring 2009). The sum of the CBR Hazard Quotient (HQ) was defined as:

$$\Sigma HQ = \sum C_i/CBR_i, \qquad \text{Equation 1}$$

where

C_i is the mussel tissue concentration of chemical i,

CBR_i is the low effect dose for chemical i, and

i = 10 (Ni, Hg, Pb, Cr, Cu, Cd, Zn, As, total PCBs, and the sum of 46 parent and alkylated PAHs)

Overall, mussel tissue residues were below benchmarks based on CBR at most locations, however there were locations that had elevated levels of PAHs, PCBs, Hg, and Cu (Figure **18**) (R. K. Johnston et al. 2019; Robert K. Johnston et al. 2019).

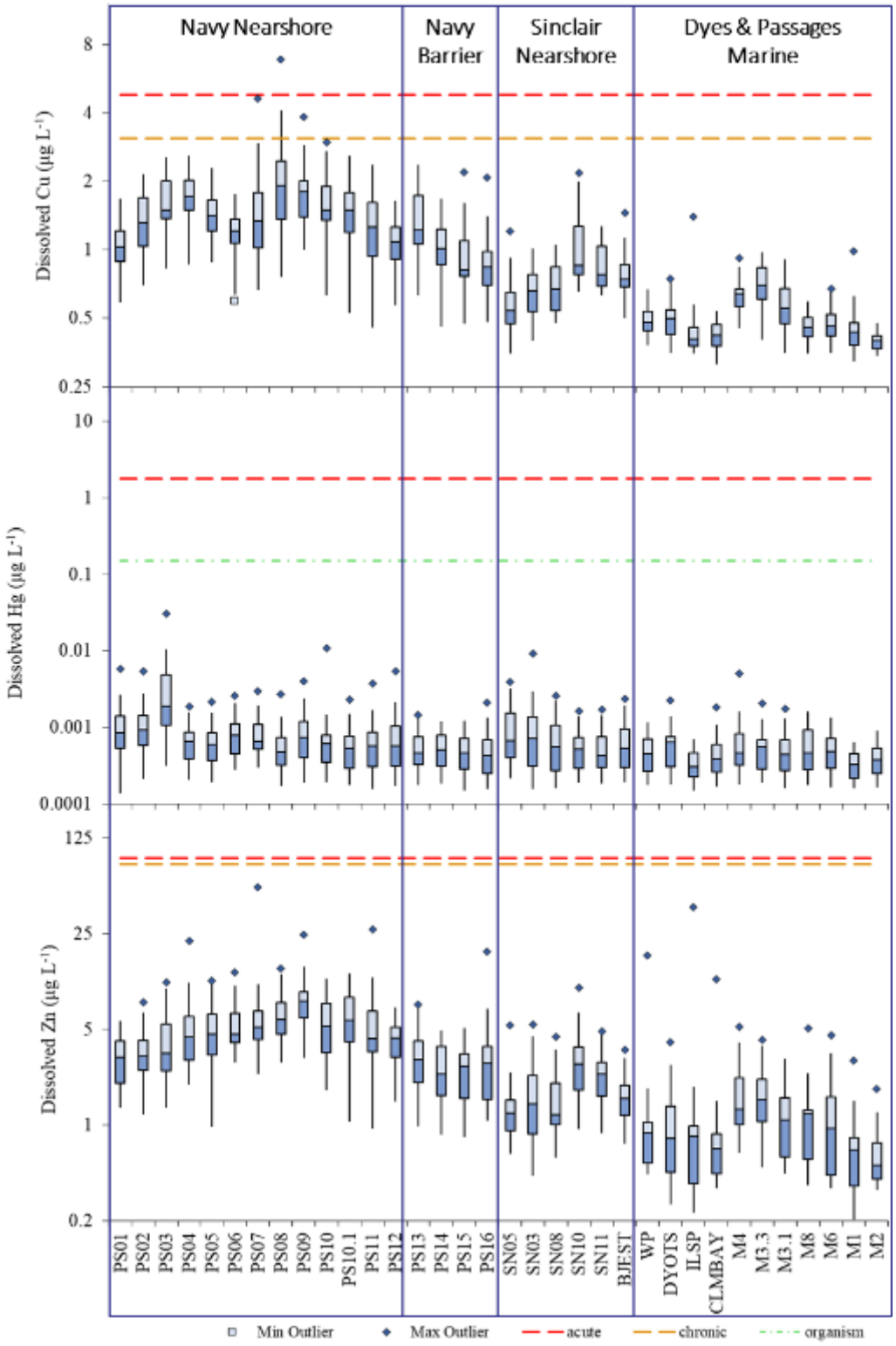


Figure 16. Concentrations of dissolved Cu, Hg, and Zn based on the average of 24 sampling events over 8 years measured at sampling areas within Sinclair and Dyes Inlets compared to WQS (Strivens et al. 2018).

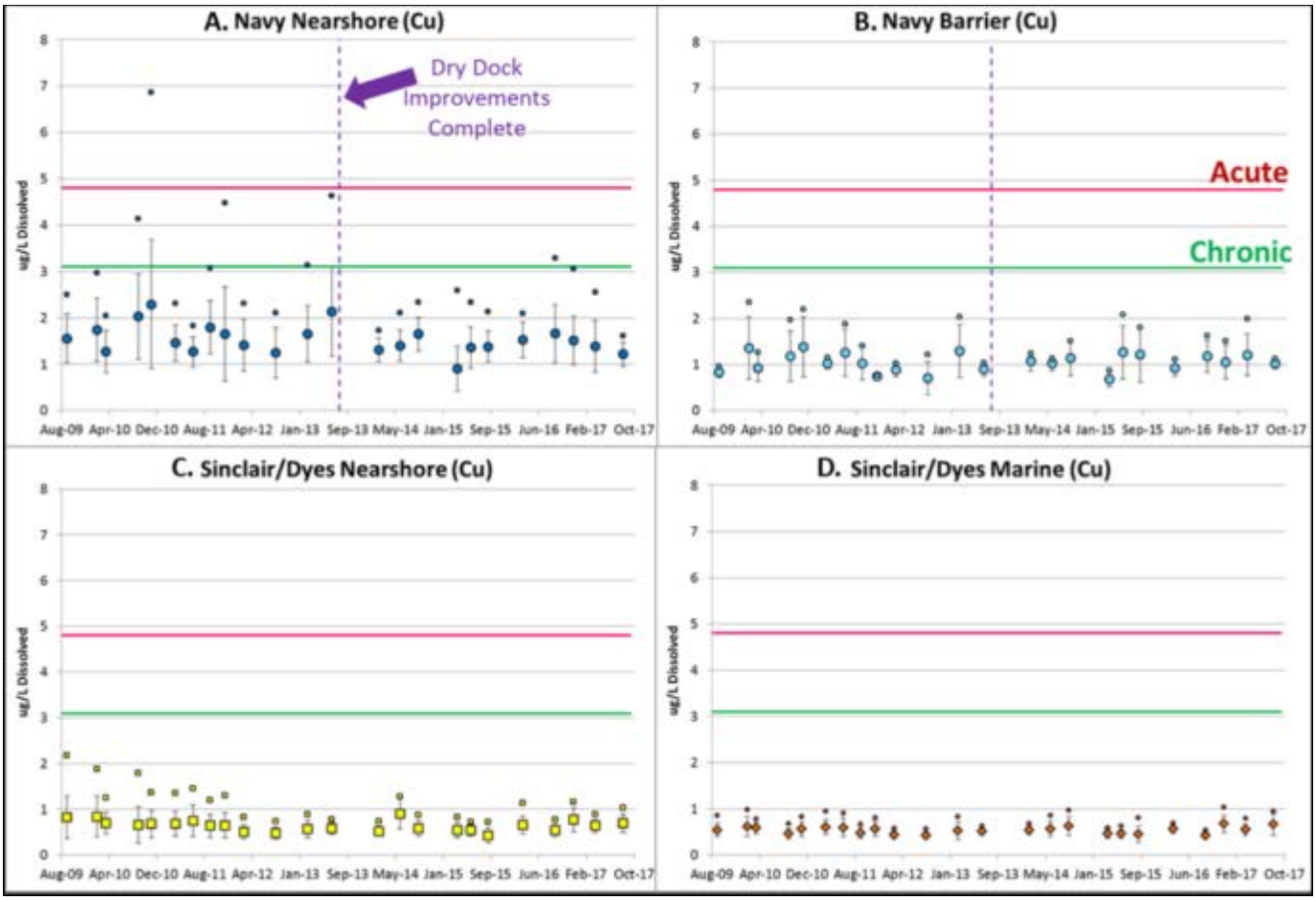


Figure 17. Concentrations of dissolved Cu measured for seasonal sampling events within nearshore areas of the naval base (A. Navy Nearshore, n=13 stations), at the edge of the Navy security barrier (B. Navy Barrier, n=4), nearshore stations within Sinclair and Dyes Inlets (C. Sinclair/Dyes Nearshore, n=10-12), and marine stations located in the main channels of the Inlets (D. Sinclair/Dyes Marine, n=6-8). The data points show the mean (large symbol), standard deviation (error bars), and maximum concentration (small dot) of Cu measured for each sampling event. The WQS for acute (red line) and chronic (green line) exposure to Cu and the date dry dock BMPs were completed (purple dashed line) are also shown **(R. K. Johnston et al. 2019)**.

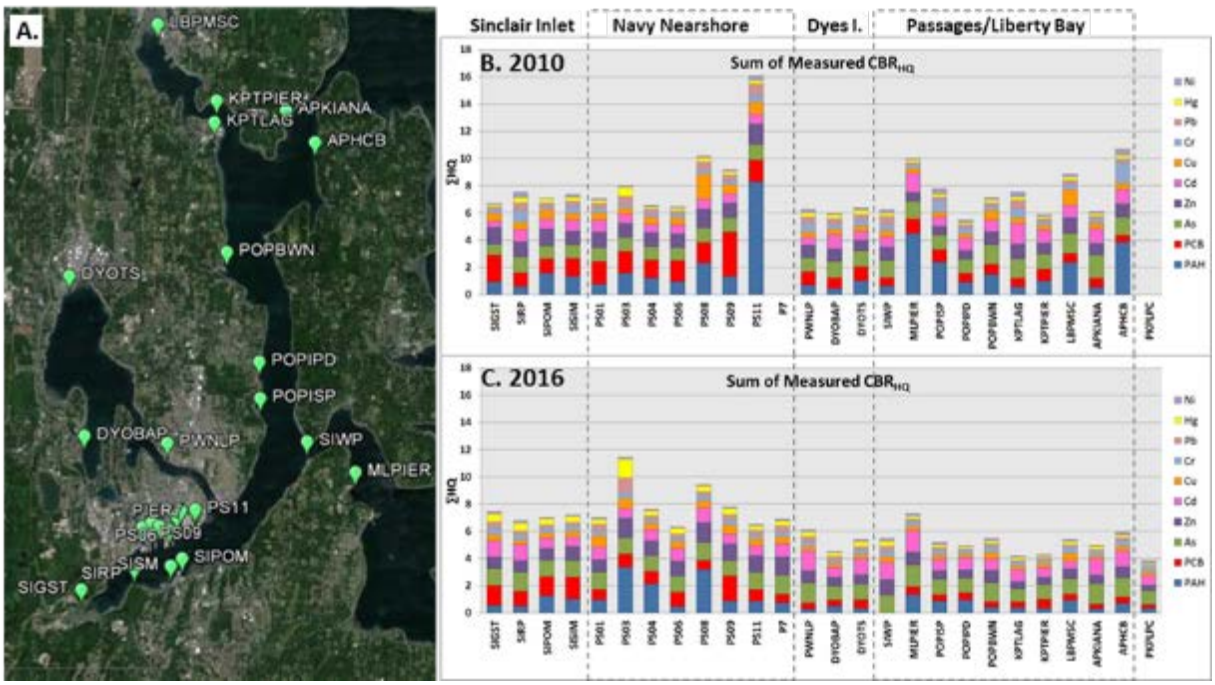


Figure 18. ENVVEST mussel watch sampling stations within Sinclair/Dyes Inlets and passages (A) and the sum of the CBR HQ determined from mussel (*Mytilus* spp.) tissue residue concentrations sampled in 2010 (B) and 2016 (C) (Robert K. Johnston et al. 2019).

Integrating contaminated sediment cleanup and restoration issues within the larger perspective of watershed management are especially critical in populated coastal and estuarine areas with multiple sources of stress from urbanization and development as well as sediment contaminated from past sources. Historical trends of contamination in the inlets obtained from age-dated sediment cores collected from areas of sediment accumulation in Sinclair and Dyes Inlets (Crecelius et al. 2003; Brandenberger et al. 2008a) showed that maximum contamination levels occurred between the 1940s and 1960s followed by a decreasing trend of contamination for more recent deposits (Figure 2). Sediment cores collected by other studies from the main basin of the Puget Sound also showed that maximum pollution levels occurred between 1945 and 1965 followed by a trend of decreasing contamination in more recent deposits (Bloom and Crecelius 1987; Brandenberger et al. 2008b). Sedimentation rates for the inlets, estimated from the age-dated cores, ranged from 0.06 g/cm^2/yr to 0.20 g/cm^2/yr (dry sediment, Table **5**) and the thickness of the contaminated layer of sediment ranged from 0-15 cm to 0-45 cm (Brandenberger et al. 2008a).

To further address contaminated sediments in the Inlets, a study plan was developed and executed in conjunction with OUB monitoring in 2003 (Kohn et al. 2004; Kohn et al. 2006) and 2007 (Kohn et al. 2008) to address sediment concentrations of metals and PAHs in addition to PCBs and Hg. The studies were conducted to provide data to inform the 303(d) listing process and determine whether there has been a decrease in sediment contamination since cleanup and source reduction activities at PSNS&IMF have been implemented. The evaluation showed improvement in the number of chemicals meeting sediment quality standards in Sinclair and Dyes Inlets (Figure **19**).

Table 5. Summary of Sedimentation and Sediment Accumulation Rates Determined for sediment cores from Sinclair (S1-S4) and Dyes (D1-D4) using two independent methods and reported accumulation rates (Brandenberger et al. 2008). See Figure 2 for core locations.

Core ID	Mixing Depth (cm)	Sed. Rate (cm/yr)[a]	Sediment Accum. Rate from ^{210}Pb (g/cm^2/yr)[a]	Depth of First Excess Pb, Hg 1895 (cm)	Total Dry Accum. Post 1895 (g/cm^2)	Sediment Accum. Rates from Pb and Hg (g/cm^2/yr)[b]	Sediment Accum. Rates Applied to Data (g/cm^2/yr)
D1	2.5	0.50 ± 0.1	0.21 ± 0.01	45	22.5	0.21	0.21 ± 0.01
D2	2.5	0.20 ± 0.05	0.14 ± 0.01	25	15.5	0.15	0.14 ± 0.01
D3	5.0	0.37 ± 0.06	0.17 ± 0.01	40	19.7	0.18	0.17 ± 0.01
D4	2.5	0.18 ± 0.1	0.10 ± 0.01	35	18.2	0.17	0.10 ± 0.01
S1	2.5	0.16 ± 0.1	0.072 ± 0.01	25	10.2	0.095	0.072 ± 0.01
S2	2.5	0.35 ± 0.05	0.15 ± 0.01	45	20.1	0.19	0.15 ± 0.01
S3	5.0	0.34 ± 0.06	0.14 ± 0.02	40	17.7	0.17	0.14 ± 0.02
S4 [c]	5.0	0.31 ± 0.04	0.17 ± 0.03	52.5	29.4	0.27	0.17 ± 0.03
S5	5.0	0.20 ± 0.03	0.11 ± 0.01	40	26.8	0.25	0.18 ± 0.04

Footnotes:

a. Sedimentation and sediment accumulation rates determined using the ^{210}Pb data and ^{137}Cs confirmation.

b. Sediment accumulation rates derived from contaminant peaks (Pb and Hg) = total dry accumulation post 1895 (g/cm^2) divided by elapsed time (107 years). Sediment cores were collected in 2002 and shipyard activities began in 1895 for an elapsed time of 107 years.

c. Upper portion of this core was disturbed by dredging activities in 2001.

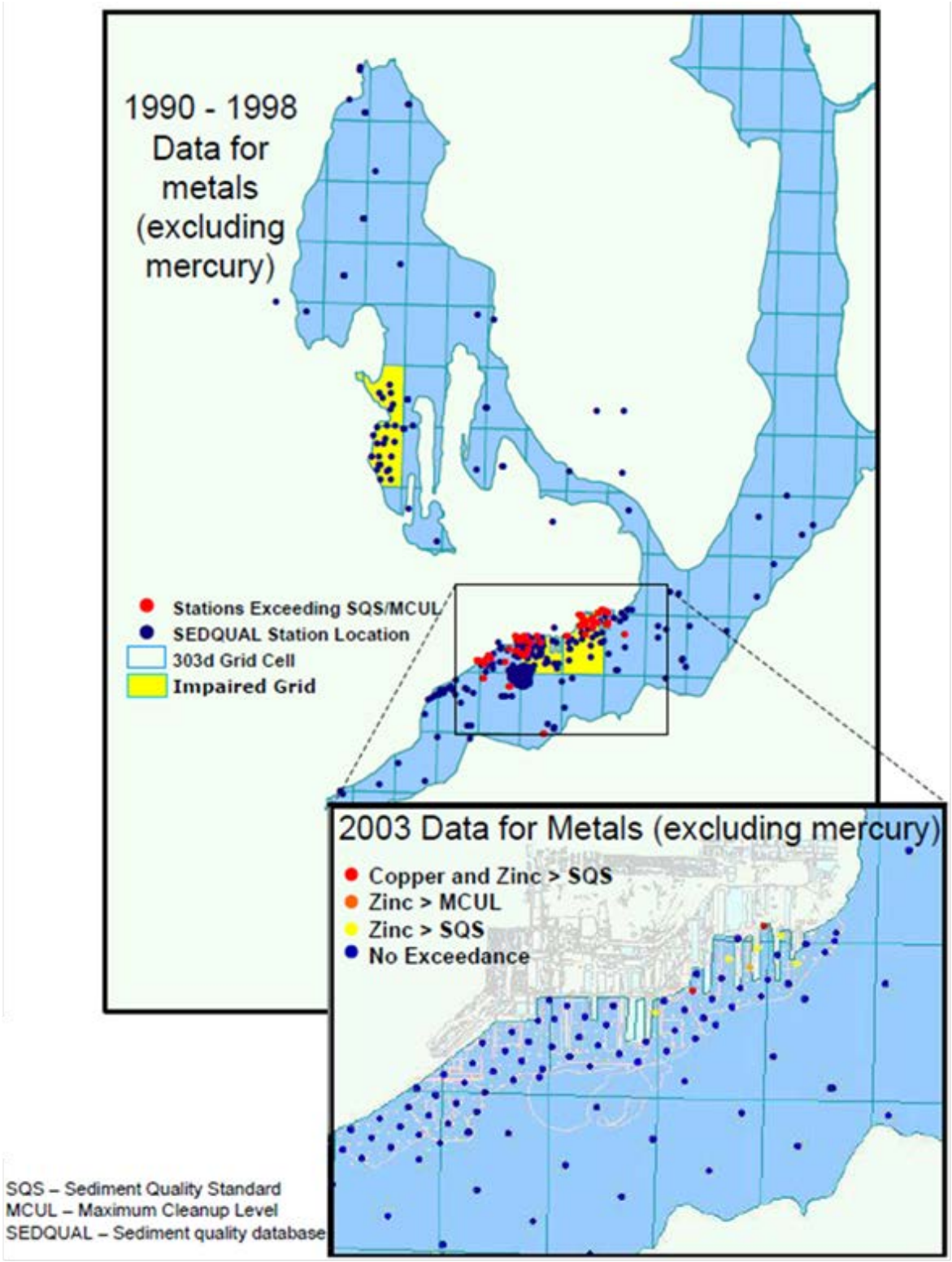


Figure 19. Map of sediment monitoring data in Sinclair and Dyes Inlets for metals – excluding Hg – with data from 1990-1998 and 2003 (inset). Sediment monitoring has shown an improvement in sediment quality within the Inlets (Kohn et al. 2004; Kohn et al. 2006).

2.2.3 Puget Sound Sediment Monitoring – Puget Sound Ecosystem Monitoring (PSEMP) for Bainbridge Basin

Since the late 1990s, Ecology has been monitoring sediment quality conditions within areas of the Puget Sound including the Bainbridge Basin consisting of Sinclair and Dyes Inlets, Port Orchard Passage, Rich Passage, Port Madison, and Liberty Bay as part of the Puget Sound Ecosystem Monitoring Program (PSEMP) (Long et al. 2003; Partridge et al. 2013; Weakland et al. 2017). Sediment quality was evaluated based on the concentrations of potentially toxic chemicals (Sediment Chemistry Index – SCI), the toxicity of sediment and pore water to test organisms (Sediment Toxicity Index – STI), and the composition and abundance of sediment dwelling organisms (Sediment Benthos Index – SBI). Based on these factors an overall Sediment Quality Triad Index (SQTI) was calculated for each station sampled to obtain an integrated assessment of spatial status and temporal trends of sediment quality using a sampling design that weighs the sample results by area (Long et al. 2003; Partridge et al. 2013; Weakland et al. 2017). The Bainbridge Basin stations were sampled in 1998, 2009, and 2015 and the results of almost two decades of monitoring were summarized in (Weakland et al. 2017).

The SCI is based on the apparent effects thresholds defined by the Washington State SMS (Washington State Dept. of Ecology Toxics Cleanup Program 2013) developed for toxic metals, PCBs, PAHs, and other toxic organic compounds (Table **6**). The SCI for Puget Sound (Long, Dutch, et al. 2013) is based on the mean Sediment Quality Guideline quotient (mSQGq) determined by the average of the Sediment Quality Guideline quotients (SQGq) which are the chemical concentrations divided by their respective SQS:

$$mSQGq = (\sum C_i/SQS_i)/n \qquad \text{Equation 2}$$

where C_i is the concentration of the chemical in sediment (mg/Kg) or sediment per unit organic carbon (mg/Kg OC)

SQS_i is the toxicity threshold for the chemical (Table **6**), and

n is the number of chemicals evaluated.

The mSQGq represents potential effects from individual as well as mixtures of toxic chemical exposure to benthic organisms in the sediment (Long, Dutch, et al. 2013; Long, Carr, et al. 2013). Thresholds of potentially toxic exposure of 39 chemicals or chemical classes were defined for minimum, low, moderate, and maximum exposure for mSQGq when $mSQGq < 0.1$, $0.1 \leq mSQGq < 0.3$, $0.3 \leq mSQGq < 0.5$, and $mSQGq \geq 0.5$, respectively, (Long, Dutch, et al. 2013). The mSQGq obtained for the stations sampled in Sinclair Inlet are summarized by Station-Year in Table **7** and Figure **20**.

For the analysis in Table **7** and Figure **20**, the mSQGq was calculated from the SQGq determined for concentrations of (n = 10 chemicals or chemical classes) Hg, Zn, Cr, Cu, Cd, As, Ag, Pb, total PCB/f_{OC}, and total PAH/f_{OC}, where total PCB/f_{OC} was calculated using the sum of the measured Aroclors and total PAH/f_{OC} was calculated as the sum of the individual PAHs belonging to LPAH and HPAH compounds, and both were normalized to the fraction of organic carbon (f_{OC}) in the sample (Table **6**). The data showed a decreasing trend over time in the ∑SQGq calculated for each of the stations in Sinclair Inlet, with the highest SQGq calculated for Hg (1.1 – 2.3) and TPCB (0.2 – 0.6) (Figure **20**). Because the PSEMP monitoring assesses the most recently deposited sediment (0-3 cm), these data indicate that contaminant loading into Sinclair Inlet had decreased during the monitoring period (Weakland et al. 2017).

The overall SQTI calculated for the stations in Sinclair Inlet for 2009 – 2015 showed little change in the Chemistry Index and Benthic Index and a slight worsening in the Toxicity Index that resulted in likely unimpacted to likely impacted Triad Index for the stations in Sinclair Inlet (Figure **21**). The Benthic Index for stations in Sinclair Inlet has continued be adversely affected over time based on the reduced

abundance and richness of benthic infauna and the presence of stress-tolerant species (Weakland et al. 2017) and loss of benthic foraminifera in the samples from Sinclair Inlet (Martin and Nesbitt 2015).

Table 6. Sediment Quality Standards (SQS) and Maximum Chemical Concentration (MCC) for toxic chemicals in marine and estuarine sediments based on dry weight of sediment **(Washington State Dept. of Ecology Toxics Cleanup Program 2013)**.

Chemical	SQS	MCC	units	Group
As	57	93	mg/Kg	metal
Cd	5.1	6.7	mg/Kg	metal
Cr	260	270	mg/Kg	metal
Cu	390	390	mg/Kg	metal
Pb	450	530	mg/Kg	metal
Hg	0.41	0.59	mg/Kg	metal
Ag	6.1	6.1	mg/Kg	metal
Zn	410	960	mg/Kg	metal
1,2,4-Trichlorobenzene	0.81	1.8	mg/Kg OC	
1,2-Dichlorobenzene	2.3	2.3	mg/Kg OC	
1,4-Dichlorobenzene	3.1	9	mg/Kg OC	
2,4-Dimethylphenol[a]	29	29	ug/Kg	
2-Methylnaphthalene	38	64	mg/Kg OC	
2-Methylphenol[a]	63	63	ug/Kg	
4-Methylphenol[a]	670	670	ug/Kg	
Acenaphthene	16	57	mg/Kg OC	LPAH
Acenaphthylene	66	66	mg/Kg OC	LPAH
Anthracene	220	1200	mg/Kg OC	LPAH
Benz(a)anthracene	110	270	mg/Kg OC	HPAH
Benzo[a]pyrene	99	210	mg/Kg OC	HPAH
Benzo[g,h,i]perylene	31	78	mg/Kg OC	HPAH
Benzoic acid(a)	650	650	ug/Kg	
Benzyl alcohol[a]	57	73	ug/Kg	
Bis(2-ethyl hexyl) phthalate	47	78	mg/Kg OC	
Butyl benzyl phthalate	4.9	64	mg/Kg OC	
Chrysene	110	460	mg/Kg OC	HPAH
Dibenzo[a,h]anthracene	12	33	mg/Kg OC	HPAH
Dibenzofuran	15	58	mg/Kg OC	
Diethyl phthalate	61	110	mg/Kg OC	
Dimethyl phthalate	53	53	mg/Kg OC	
Di-n-butyl phthalate	220	1700	mg/Kg OC	
Di-n-octyl phthalate	58	4500	mg/Kg OC	
Fluoranthene	160	1200	mg/Kg OC	HPAH
Fluorene	23	79	mg/Kg OC	LPAH
Hexachlorobenzene	0.38	2.3	mg/Kg OC	
Hexachlorobutadiene	3.9	6.2	mg/Kg OC	
Indeno[1,2,3-cd]pyrene	34	88	mg/Kg OC	HPAH

Chemical	SQS	MCC	units	Group
Naphthalene	99	170	mg/Kg OC	LPAH
n-Nitrosodiphenylamine	11	11	mg/Kg OC	
Pentachlorophenol	360	690	ug/Kg	
Phenanthrene	100	480	mg/Kg OC	LPAH
Phenol[a]	420	1200	ug/Kg	
Pyrene	1000	1400	mg/Kg OC	HPAH
Total benzofluoranthenes	230	450	mg/Kg OC	HPAH
Total PCBs	12	65	mg/Kg OC	
LPAH	370	780	mg/Kg OC	
HPAH	960	5300	mg/Kg OC	

[a]Excluded from mSQSq calculation by Long et al. 2013

Table 7. Sediment Quality Guideline quotients (SQGq) determined for metals, TPCB, and TPAH and the mSQCq for Sinclair Inlet stations from Bainbridge Basin studies sampled in 1998, 2009, and 2015 (Long et al. 2005; Partridge et al. 2013; Weakland et al. 2017)

Station-Year	Hg	TPCB	Zn	Cr	Cu	Cd	As	Ag	Pb	TPAH	mSQCq
160-1998	2.0598	0.4372	0.4171	0.3673	0.3256	0.2922	0.2368	0.2295	0.1733	0.0295	**0.4568**
160-2009	2.0878	0.5197	0.4098	0.2765	0.3077	0.3608	0.2439	0.2672	0.1182	0.0326	**0.4624**
160-2015	1.3683	0.3351	0.3756	0.2473	0.3128	0.4549	0.2456	0.2262	0.1484	0.0238	**0.3738**
161-1998	1.4768	0.3506	0.3707	0.3304	0.2528	0.1686	0.2035	0.1639	0.1498	0.0538	**0.3521**
161-2009	1.5902	0.2684	0.3512	0.2115	0.2303	0.2353	0.1930	0.1082	0.0969	0.0471	**0.3332**
161-2015	1.0707	0.2745	0.3488	0.2027	0.2449	0.3510	0.2123	0.1205	0.1287	0.0430	**0.2997**
162-1998	1.8341	0.3160	0.4488	0.3338	0.2667	0.1020	0.2053	0.1639	0.1762	0.0614	**0.3908**
162-2009	1.4610	0.2883	0.3415	0.2254	0.2315	0.1725	0.1965	0.1049	0.1096	0.0576	**0.3189**
162-2015	1.3317	0.2113	0.3122	0.1750	0.2105	0.2216	0.1947	0.0993	0.1118	0.0494	**0.2917**
163-1998	2.2732	0.4156	0.4305	0.3400	0.3154	0.1637	0.2421	0.1639	0.2026	0.0495	**0.4596**
163-2009	1.7878	0.5955	0.3780	0.2173	0.2692	0.2176	0.2298	0.1246	0.1120	0.0491	**0.3981**
163-2015	1.3695	0.3959	0.3549	0.2029	0.2731	0.2912	0.2211	0.1281	0.1410	0.0558	**0.3433**
164-1998	2.0073	0.4786	0.4488	0.3602	0.3385	0.1980	0.1904	0.2705	0.1897	0.0716	**0.4553**
164-2009	1.7756	0.4740	0.2976	0.1738	0.2208	0.2000	0.1593	0.1361	0.1038	0.0569	**0.3598**
164-2015	1.6549	0.3777	0.3537	0.1931	0.2492	0.2824	0.1842	0.1530	0.1319	0.0556	**0.3636**
165-1998	2.1927	0.3918	0.3854	0.3742	0.3231	0.1412	0.1860	0.1967	0.1791	0.0796	**0.4450**
165-2009	1.7415	0.4071	0.3268	0.2050	0.2441	0.2059	0.1965	0.1443	0.1122	0.0474	**0.3631**
165-2015	1.8524	0.2914	0.3171	0.1904	0.2497	0.2480	0.1904	0.1385	0.1272	0.0446	**0.3650**

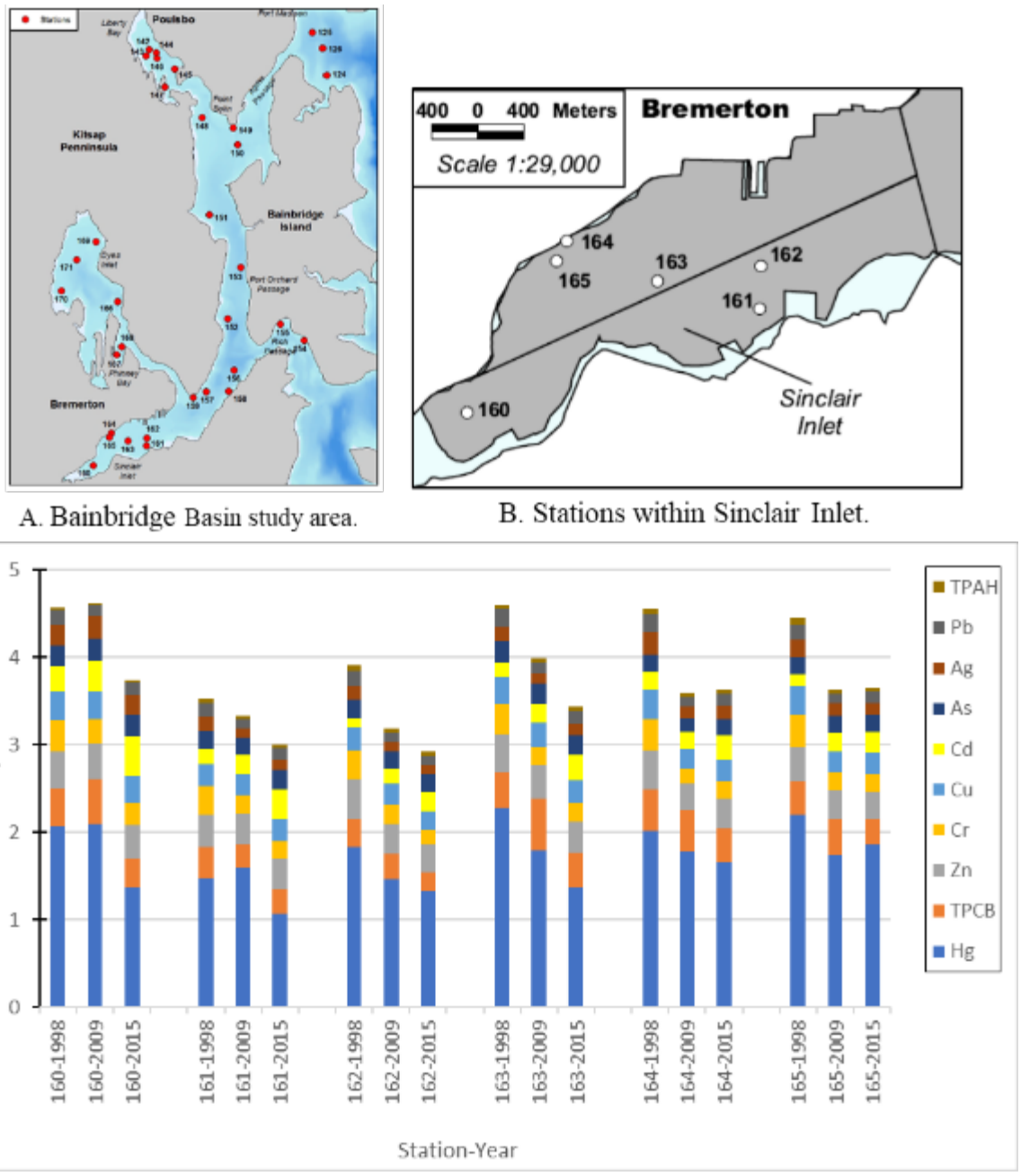


Figure 20. Sediment Quality Guideline quotients (SQGq) determined for metals, TPCB, and TPAH for data from Bainbridge Basin studies (A) in 1998, 2009, and 2015 for stations sampled in Sinclair Inlet (B) by Station-Year (C). Data from (Long et al. 2005; Partridge et al. 2013; Weakland et al. 2017).

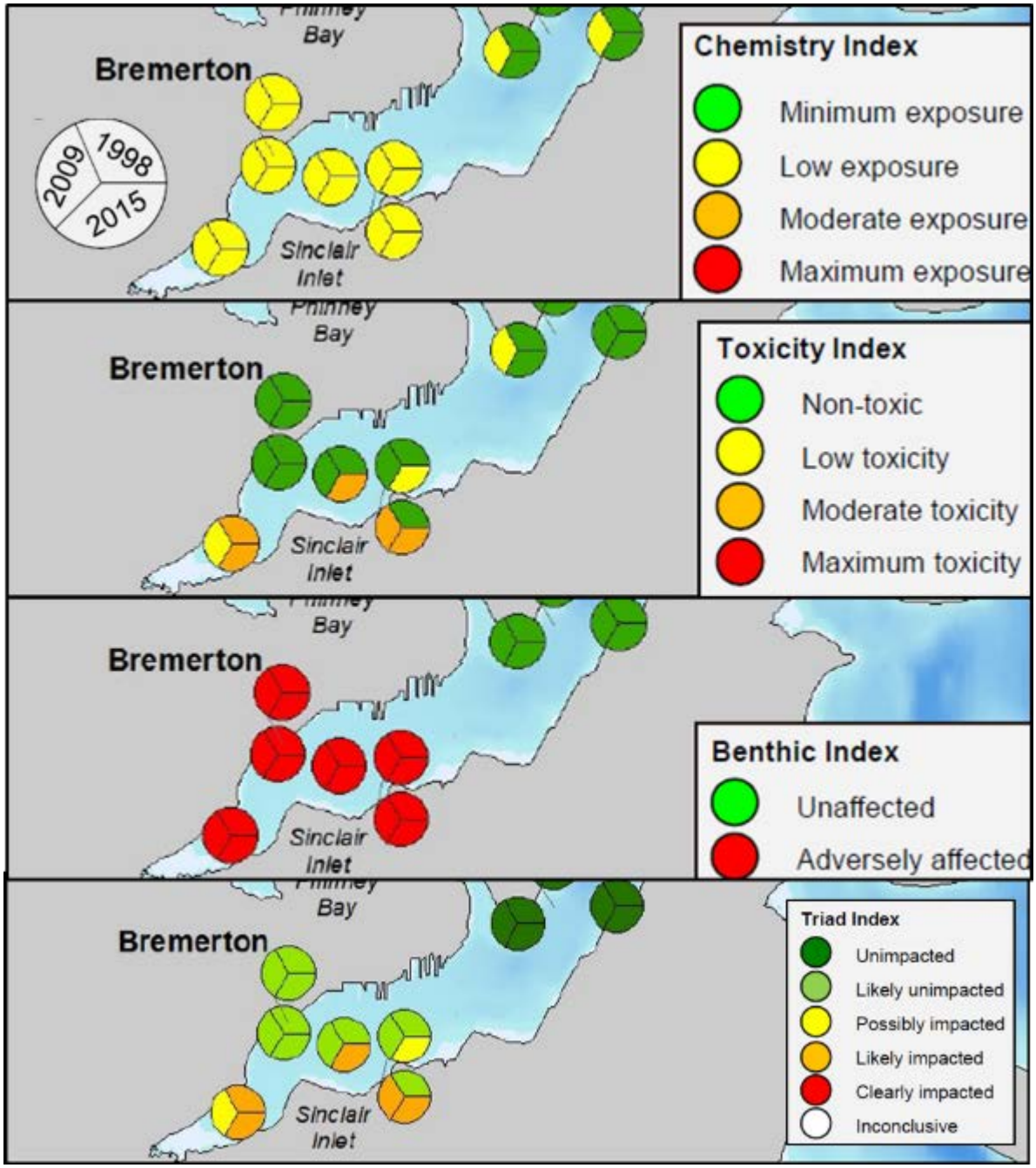


Figure 21. Sediment quality indices measured at Urban Waters Initiative (UWI) monitoring stations in Sinclair Inlet from Bainbridge Basin studies in 1998, 2009, and 2015 (Long et al. 2005; Partridge et al. 2013; Weakland et al. 2017).

3.0 Sampling Methods for Sediment Quality Verification

The SQV study plan was developed to support enhanced collaboration between the IR program and ENVVEST monitoring activities for the Shipyard. The study focused on the sediment quality within the Shipyard boundaries which includes the 500-ft grid cells in the OUBM monitoring program (Figure 6). This report assesses the impact of sediment-bound contaminants within identified focus areas to establish a baseline of sediment conditions to assess the status and trend of ecological resources, evaluate the effectiveness of cleanup and pollution control measures, and determine if discharges from local sources are protective of beneficial uses including aquatic life in Sinclair Inlet.

This study was divided into the following primary tasks to achieve the overall objectives:

1. Extend OUBM LTM data yield by analyzing split samples from the 2010 OUBM LTM sampling of Sinclair Inlet for a suite of metals and PAHs that were not included the OUBM LTM program. This work provides another iteration of split samples with the OUBM LTM monitoring that was previously conducted in 2003 and 2007 (Kohn et al. 2004; Kohn et al. 2006; Kohn et al. 2008).
2. Characterize sediment quality adjacent to dry dock outfalls and stormwater drains for focus areas located within the Shipyard.
3. Support research, development, test and evaluation (RDTE) projects by conducting additional pore water measurements and toxicity evaluations at selected high priority sites and provide supporting data for the Pier 7 AC Demo Project (Johnston et al. 2013; Kirtay et al. 2018).
4. Evaluate contaminant concentrations associated with silts collected from caissons and dry docks that accumulated as part of docking operations.

These sediment studies were guided by state sediment management sampling and analysis requirements to assure collection of appropriate data needed to meet the state Water Quality Program Policy. The IR Program for OUBM maintains a technical review and management team which includes representatives from the Navy, EPA, Ecology, Washington Department of Natural Resources (WDNR), and the Suquamish Tribe. The data quality objectives (DQO) defined for the study are provided in Table **8**.

3.1 Identified Data Gaps

The 1998 303(d) list included As, Cd, Cu, Pb, Zn, and Hg in sediments of Sinclair Inlet and Cd, Hg, and Ag in the sediments of Dyes Inlet due to exceedances of the SQS or MCC (formerly referred to as the Minimum Clean Up Level - MCUL) (ENVVEST 2002). Sediment verification studies conducted on splits of the 2003 and 2007 OUBM LTM samples were included in the data set used for the 2008 Water Quality Assessment and 303(d) list (Kohn et al. 2004; Kohn et al. 2006; Kohn et al. 2008). The current Water Quality Assessment[1] for Sinclair Inlet sediments includes:

(1) four segments for Category 5 -Polluted waters that require a water improvement project;

(2) ten segments for Category 4b -has a pollution control program, similar to a TMDL plan, that is expected to solve the pollution problems; and

(3) five segments for Category 2 - Waters of concern (Figure **22**).

In addition, the 2008 Water Quality Assessment identified nine 500-ft and one 1500-ft grids that exceeded SQS or MCC sediment quality standards for metals and PAHs (excluding Hg, Figure **23**).

[1] Available from https://appstest.ecology.wa.gov/approvedwqa/ApprovedSearch.aspx (accessed 7/29/2019).

Table 8. Data Quality Objectives defined for the SQV study (Brandenberger et al. 2011).

Sediment Sampling Data Quality Objectives
STEP 1: State the Problem Sinclair Inlet, Bremerton, WA, historically received pollution from industrial activities, which is being addressed under the CERCLA program. Historical practices have changed significantly and led to an overall decrease in contaminants entering Sinclair Inlet from Shipyard activities. However, sediment quality may still be impacted by pollution from a variety of active sources including current Shipyard operations, marina and vessel traffic, storm event runoff, discharges from WWTP, industrial outfalls, and surface streams and legacy sources, such as historically contaminated sediments, that are being addressed by cleanup and restoration activities. Sediment verification studies are needed to assess the effectiveness of cleanup and pollution control measures, identify areas of potential re-contamination, and determine if discharges from all sources are protective of beneficial uses including aquatic life.
STEP 2: Identify the Decision 1. Are discharges from Shipyard industrial outfalls and storm drains protective of beneficial uses of Sinclair Inlet? 2. Could remediation, construction, and/or navigational dredging activities expose and mobilize or release historically deposited sediment-associated contaminants within the Shipyard? 3. What is the status and trend of sediment quality in the Shipyard?
STEP 3: Identify Inputs to the Decision 1. Verify surface sediment quality in Sinclair Inlet to inform Ecology's Water Quality Assessment for Water Resource Inventory Area 15 (WRIA). 2. Select sediment sampling areas that are co-located near suspected sources within the Shipyard (outfalls and storm drains) or located in nearshore areas with low flushing. 3. Identify focus areas where historically contaminated sediments are either potentially redistributed into surface sediment (e.g., construction areas) or historically deposited sediment-bound contaminants are released into overlying waters (e.g., porewater gradient). 4. Coordinate with CERCLA, Ecology, and NPDES sampling programs to optimize resources. 5. Provide logistical and data support for RDTE studies on sediment treatability and bioavailability.
STEP 4: Define the Study Boundaries Spatial boundaries are Sinclair Inlet marine sediment with a focus on the nearshore sediments in the Shipyard located within 200 ft. of industrial outfalls, storm drains, and other potential sources.
STEP 5: Develop a Decision Rule The data collected will be used to: (1) assess the impact of pollution sources on the quality of water, sediment, and biota in Sinclair Inlet, (2) determine the effectiveness of cleanup and pollution control measures, and (3) determine if discharges from all sources are protective of beneficial uses including aquatic life. The results of this study will be used to inform adaptive management by identifying the need for pollution control measures and evaluate the effectiveness of BMPs and other corrective actions.

Sediment Sampling Data Quality Objectives (Cont.)

STEP 6: Evaluate Decision Errors

The data will be evaluated to assure accuracy, precision, completeness, comparability, and representativeness (see Section 5 Quality Assurance and Quality Control Requirements).

STEP 7: Optimize the Design for Obtaining Data

Optimize sampling locations with following considerations:

- Obtain split samples from 2010 OUBM LTM sampling event
- Proximity to current contaminant sources (e.g., industrial outfalls and storm drains)
- Sediment locations not included in the OUBM sampling grids
- Sediment locations where historically deposited contaminated sediment may be remobilized or contaminants released into overlying waters (e.g., dredge walls, construction, etc.)
- Sediments located in nearshore areas with low flushing
- Obtain samples of silt from caissons and dry docks that accumulated as part of docking operations

Optimize sample types:

- Sediment cores in focus study areas to provide information on contaminants at depth that could be remobilized and porewater profiles to evaluate bioavailability
- Sediment grabs to evaluate surface sediment quality and variability near current discharges
- Composites of sediment grabs split from OUBM to optimize spatial coverage to all of Sinclair Inlet

Optimize analytes and analytical methods:

- Couple rapid sediment characterization analysis for metals (Cu, Pb, and Zn) and PAHs with laboratory confirmatory analyses to supplement OUBM analytes list and obtain better coverage and estimates of variance from non-composited samples
- Achieve detection limits that support comparison to sediment quality standards and other ecologically relevant benchmarks (i.e., ecological effects thresholds) and regional monitoring data
- Obtain data on ancillary parameters important in controlling contaminant mobility, reactivity, bioavailability (TOC, grain size, oxidation-reduction potential, porewater salinity and other oxidants), and pore water profiles

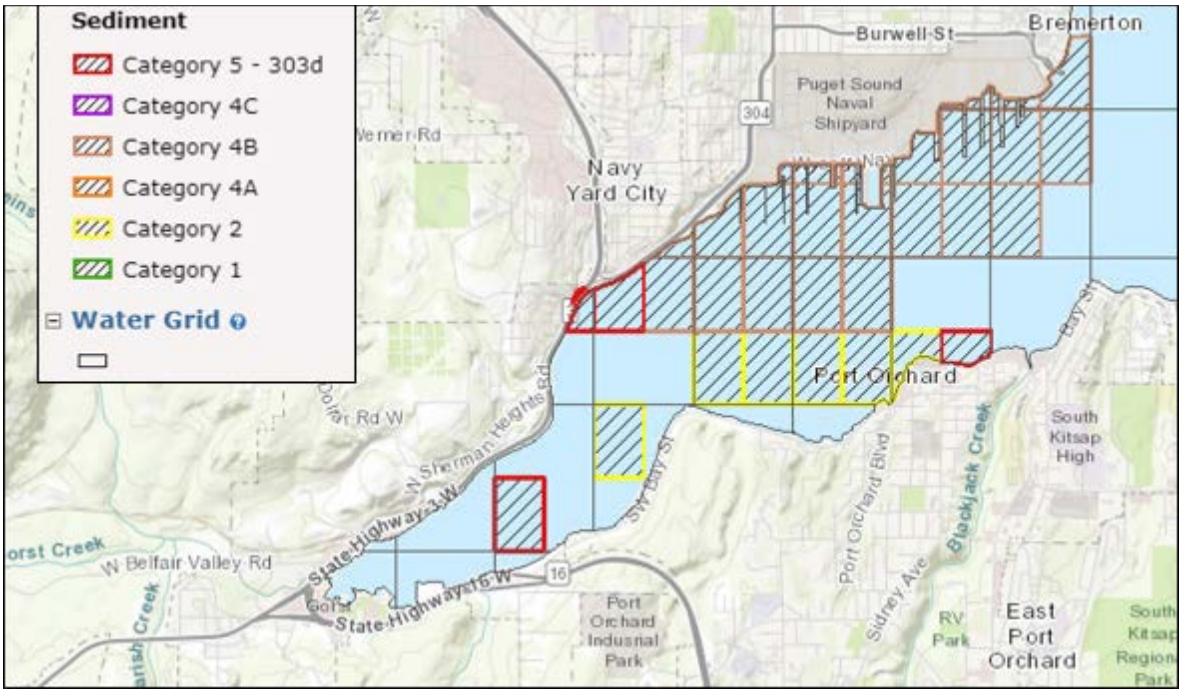


Figure 22. The current Water Quality Assessment Categories defined for sediment segments in Sinclair Inlet, image generated from Washington State Water Quality Atlas available at https://fortress.wa.gov/ecy/waterqualityatlas/StartPage.aspx (accessed 7/29/2019).

In addition to the 303(d) sediment listings, Ecology identified nine priority focus areas for sediment quality that should be considered under the NPDES permit review and request for mixing zone submitted by the Navy (Podger 2010). These areas were selected based on existing sediment data in Ecology's database and the locations within the Shipyard of industrial outfalls, storm drains, and areas of remedial and navigational dredging (Figure **24**, Table **9**, see Figure 4 for dredging footprint). These included areas around specific piers, moorings, and locations near outfalls and storm drains of concern. Ecology (Podger 2010) concluded there was not enough information to determine if outfall discharges are in compliance with the SMS. Sediment data available prior to sampling (1998-2011) for Hg, Zn, Cu and PCB show there are areas with elevated concentrations and exceedances of the SQS. Ecology provided the following recommendations:

(1) Sediment monitoring at dry docks and 14 major outfalls listed in Table **9**;

(2) "Diagnostic" monitoring for Cu, Zn, Hg, and PCB in areas of concern;

(3) Sediment sampling near outfalls to support a mixing zone for Cu and Zn; and

(4) Discrete sediment monitoring (not composites) for source control evaluations.

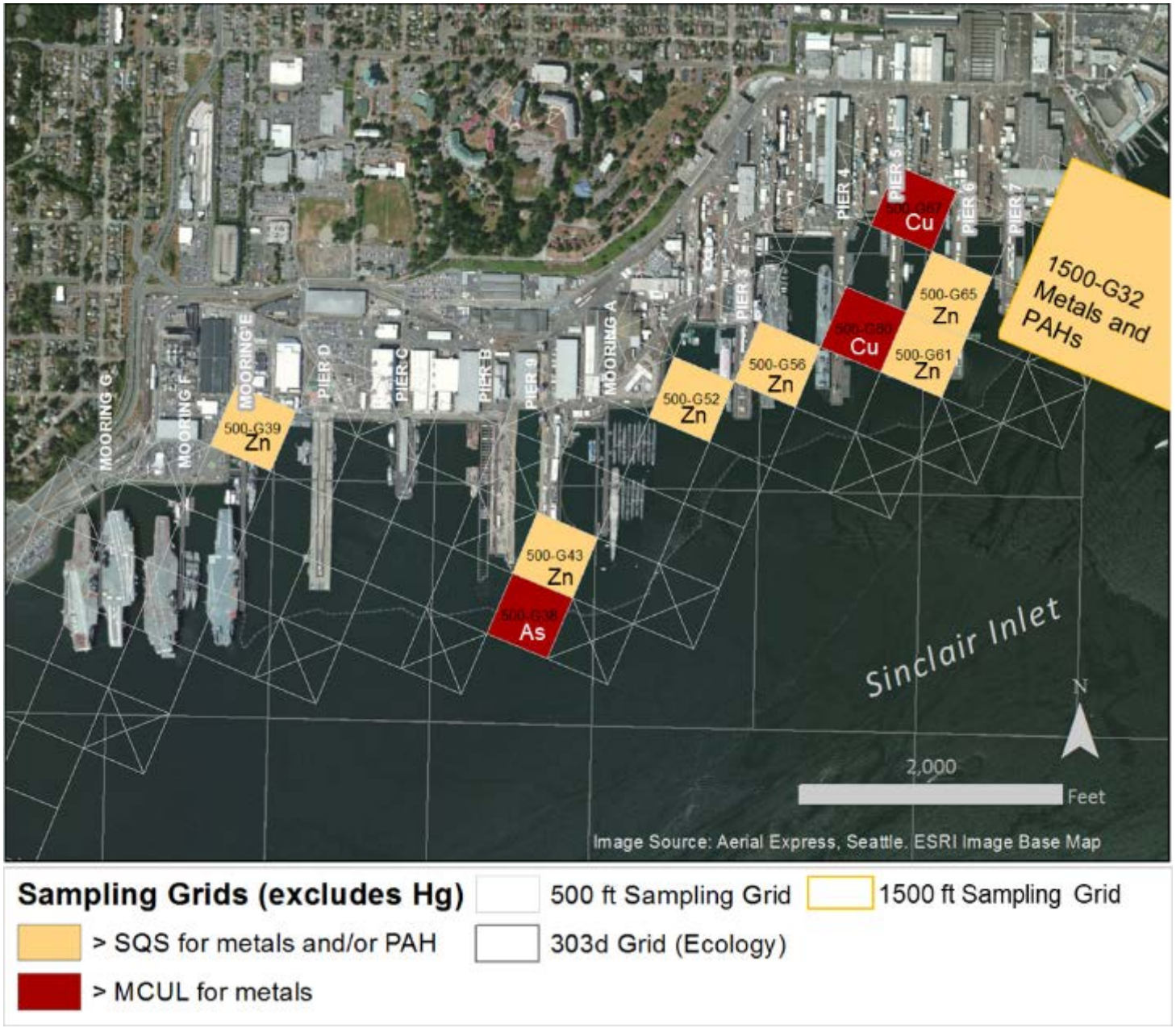


Figure 23. The OUBM LTM grids highlighted in yellow if sediment concentrations exceeded the SQS or red if they exceeded MCC for Cu, Pb, Zn, Cr, Ag, Cd, As, and/or PAHs. The 303(d) segments are overlaid in dark gray.

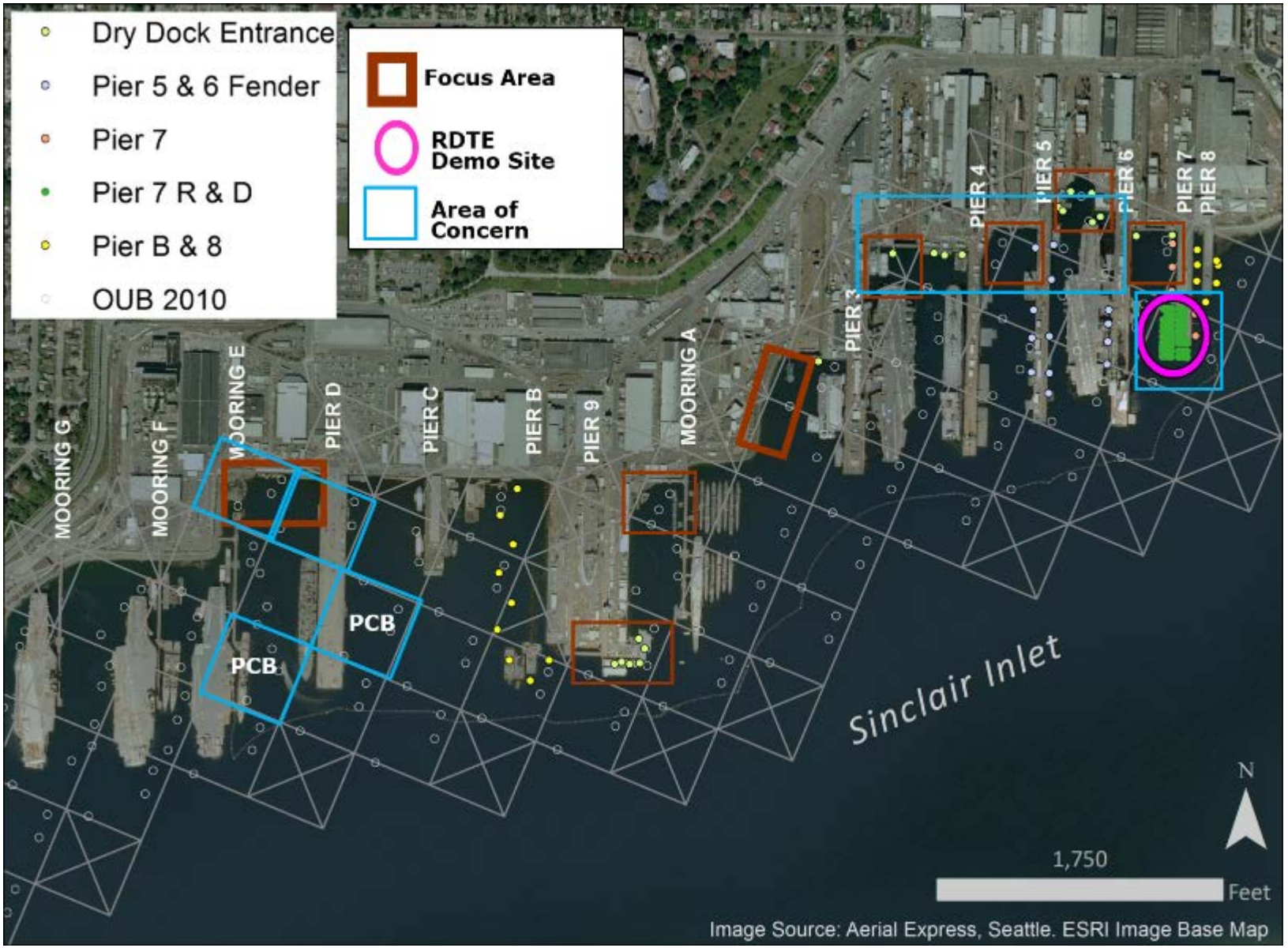


Figure 24. Locations of the sediment focus areas, RDTE Demo site, and areas of concern identified by Ecology (Podger 2010). Other sediment sampling locations shown include pre- and post-construction sampling for Dry Dock entrance areas, Pier 5 and Pier 6 fender repair, Pier 7, Pier 8 removal, Pier B removal and reconstruction, and Pier 7 RDTE sampling; and the 2010 OUBM LTM 500 ft grid sample locations (gray circles).

Table 9. Areas of sediment quality concern for PCBs, Hg, Cu, and Zn around specific piers, moorings, and outfalls (numbers are EPA outfall numbers) in the Shipyard.

Focus Areas of Concern	PCB	Hg	Cu	Zn
Pier D	X	X		
Mooring E	X	X		
Pier 7, 8 (removed)	X			
Pier 4, 5, 6		X	X	X
Outfalls 15, 95	X			
Outfalls 3, 4, 5, 6, 7, 26, 27, 28, 35, 37, 42, 43, 44, 46, 48, 49, 50, 51, 52, 53, 97		X		
Outfalls 13, 14, 25, 38, 39, 40, 41, 82, 83, 84, 85	X	X		
Outfall 1 – East of Pier 8 (removed)		X		
Dry Dock Outfall 096 (Pier 3, 4)		X	X	

In addition to Ecology's recommendations, data from previous IR and ENVVEST studies discussed above were compiled and prioritized to further support the identification and prioritization of the areas of concern for this study. Based on this review, 303d grids F6C9, F6E3, F6F4, F6F5, F6F3, F6F2, F6G3, and F6G2 were targeted for further sediment quality evaluations and served as a line of evidence in the selection of the 2010 OUBM composite samples for confirmatory analyses in this study.

The coarseness of the 303(d) grids does not allow for the detail necessary to target the areas of concern within the Shipyard. Therefore, Table **10** lists the ENVVEST ambient monitoring station code and a description of the target areas along with the available data for the focus areas of concern, repair projects, and ENVVEST sediment and stormwater investigations. Data that exceeds the SQS, the discharges within those areas identified using the PSNS outfall number that corresponds to the EPA outfall number, and the potential sources or processes of concern within each area are also listed. This resulted in 11 areas of concern with significant overlap with the areas of concern identified by Ecology (Table **9**). The potential sources identified include stormwater or drydock discharges where dissolved and/or particulate contaminants may partition to the sediment and accumulate in sediment near the outfalls; areas where maintenance or remedial dredging that may have exposed historically contaminated sediment (e.g., dredge walls); sediment areas not included in the OUBM sediment monitoring grids and therefore were not previously monitored; and/or areas where specific processes have changed or will change due to waterfront construction and infrastructure improvements. Legacy contamination could be remobilized by physical redistribution of contaminated sediment or chemical release of the contaminants from the sediment as the areal extent of sediment/water boundary post disturbance can increase and the exposed surfaces providing an oxidation pathway to release metals from reduced sediment complexes (e.g., metal sulfides).

The ENVVEST ambient marine monitoring program provides seasonal surface water samplings for metals from 2009 to present and bi-annual indigenous mussel sampling for metals, PAHs, and PCBs (Johnston, Rosen, et al. 2010). Seasonal surface water sampling conducted prior to the SQV study identified potential water quality concerns for Cu around PS07, PS08, PS09, and PS10 ambient monitoring stations (Strivens et al. 2018). Dissolved concentrations of Cu were evaluated against the Washington Toxic Substance chronic (3.1 µg/L) and acute (4.8 µg/L) criteria for the protection of aquatic life (WAC-173-201A-240). The Cu chronic criterion was exceeded in September and November 2010 at PS07 (average 3.4 µg/L) and PS08 (average 3.8 µg/L) and in November 2013 at PS09 (3.9 µg/L).

Prior to the SQV study, indigenous mussels were sampled by 2010. The data were evaluated against tissue residue benchmarks, which were developed to assess the potential for ecological and human health effects (Johnston et al. 2007). Ecological benchmarks consisted of water quality criteria-based tissue screening values (TSV) and threshold concentrations above which adverse effects could occur in an organism expressed as the Critical Body Residue (CBR). The benchmark values for Cu were expressed as parts per million (ppm) dry weight and TSV =21.3 and CBR = 20. Only PS08 exceeded these benchmarks. The benchmarks for Zn were TSV=142 and CBR= 200. The CBR for Zn was exceeded at PS01, PS03, PS08, PS09, and PS11. At PS11 the Pb concentration exceeded the TSV=2.8 for Pb, but not the CBR=3.5. For the PAHs the CBR of 317 parts per billion (ppb) was exceeded at PS08 and PS11 and the PCB TSV = 437 ppb was not exceeded. However, the PCB CBR=28.2 ppb was exceeded at all Shipyard stations. Each of these lines of evidence was used in the site prioritization process.

Table 10. The ENVVEST ambient monitoring station name and description, available data, outfalls and potential sources for areas considered in site selection for the SQV study.

ENVVEST Station ID Target Area	**Available Data**	**Exceed SQS[5] or Marine Water Quality Criteria[7]**	**Outfall (OF) or Storm Drain (PSNS#)**	**Potential Source**
PS03 Mooring E to Pier D	1. Stormwater drain monitoring PSNS015[1] 2. Sediment OUBM[2] 3. Ambient Monitoring[6] 4. ENVVEST Mussel Watch Station[8]	• OUBM Grid 30 and 39 increasing for PCB • OUBM Hg • Mussel watch tissue screening values for Zn, PCB[9]	012, 011.2, 011.3, 014, 015, 017.1, 017;	Dredging; stormwater drains; 303(d) segments F6F5 and F6F4 for PCB and Zn; active ships moored at Pier D; nearshore area with low flushing
PS08 Mooring A to Pier 3; in front of DD5	1. Stormwater drain monitoring PSNS082.5[1] 2. Sediment OUBM[2] 3. Ambient Monitoring[6] 4. ENVVEST Mussel Watch Station[8]	• OUBM Hg • 2007 OUBM Zn; 2010 screen passes • PS08 AMB marine Cu • Mussel watch tissue screening values for Cu, Zn, PAHs, PCB[9]	082.5	Stormwater drains; dredging; shoreline stabilization; outside LTM grid; 303(d) segment F6F3 for Cu, Pb, Zn; DD5 operations; Recycled Metal Transfer Station (RMTS) operations; Inactive ships at Mooring A; nearshore area with low flushing

ENVVEST Station ID Target Area	Available Data	Exceed SQS[5] or Marine Water Quality Criteria[7]	Outfall (OF) or Storm Drain (PSNS#)	Potential Source
PS06, PS07 DD6 Entrance to Pier 9	1. Outfall NPDES019 2. Stormwater drain monitoring PSNS081.1[1] 3. Sediment OUBM[2] 4. ENVVEST silt grabs DD6 5. Ambient Monitoring[6] 6. ENVVEST Mussel Watch Station (PS06)[8]	• OUBM Hg and Zn • Caisson silt Hg • 2010 grabs • PS07 AMB marine Cu • Mussel watch tissue screening values for PCB[9]	OF19 081.1	Industrial outfall OF19; dredging; Pier B reconstruction; DD6 operations; Active ship mooring at Pier B during non-construction; Active barge mooring at Pier 9
PS09 Pier 3 to Pier 4; in front of DD4	1. Storm drain monitoring PSNS096[1] 2. OF18 monitoring 3. Sediment OUBM[2] 4. Ambient Monitoring[6] 5. ENVVEST Mussel Watch Station[8]	• OUBM Hg, Pb, Zn • PS09 AMB marine Cu • Mussel watch tissue screening values for Zn, PCB[9]	OF18A, OF18B 096, 099, 101 to 104, 106	Industrial outfall OF18; dredging; storm drains; DD2 operations; outside LTM grids; active ships moored at piers; 303(d) segments F6F3 and F6G3; nearshore area with low flushing
PS10 Pier 4 to 5; in front of DD2	1. Ambient Monitoring[6] 2. Sediment OUBM[2]	• OUBM Hg, Cu, Pb, Zn	107, 108	Storm drains; DD2 operations; dredging; active ships moored at piers; 303(d) segment F6F3
PS 10.1 Pier 5 to Pier 6; in front of DD1	1. Ambient Monitoring[6] 2. Sediment OUBM[2]	• OUBM Hg, Cu, Zn, Pb	OF96; 122, 123, 117, 115.1, 113, 118.2, 116, 110, 121	Industrial OF96; DD1 operations; Dredging; Outside LTM grids; 303(d) segments F6F3 and F6G3
PS11 Pier 6 to Pier 7	1. Storm drain monitoring PSNS124 and PSNS126[1] 2. Sediment OUBM[2] 3. Pier 7 RDTE Demo Project 4. Pre/Post Const. Pier 7[3] 5. Ambient Monitoring[6] 6. ENVVEST Mussel Watch Station[8]	• OUBM Hg, Zn, Pb • Post Pier 7 Zn, Hg • Mussel watch tissue screening values for Zn, Pb, PAHs, PCB[9]	124, 124.1, 126	Process change for outfall PSNS126; DD3 operations; Inactive ships and active barges moored at piers; Pier 8 removal;

ENVVEST Station ID Target Area	Available Data	Exceed SQS[5] or Marine Water Quality Criteria[7]	Outfall (OF) or Storm Drain (PSNS#)	Potential Source
PS04 Pier D to Pier C	1. Storm drain monitoring PSNS008[1] 2. Sediment OUBM[2] 3. Ambient Monitoring[6]	• OUBM grid 35 increasing for PCB • OUBM Hg	020.1, 031, 024	Dredging; storm drains; tug boat operations; Active ships moored at piers
PS05 Pier C to Pier B	1. Storm drain monitoring PSNS032[1] 2. Sediment OUBM[2] 3. Pier B Pre-Construction[4] 4. Ambient Monitoring[6]	• Pre-Const. Hg	NA – construction will alter outfalls	Storm drains; reconstruction of Pier B; Tugboat operations; Active ships moored at piers during non-construction; Nearshore area with low flushing
PS 12 Pier 8	1. Storm drain monitoring PSNS126[1] 2. Sediment OUBM[2] 3. Pier 8 Pre-Construction[4] 4. Ambient Monitoring[6]	• OUBM Hg • Pre-Pier Ag, Zn, Hg	126, 126.4 City of Bremerton Storm Drains ST29, ST14	Process change for outfall PSNS126[10]; Pier 8 removal
PS01 Mooring E to Mooring F	1. Sediment OUBM[2] 2. Ambient Monitoring[6] 3. ENVVEST Mussel Watch Station[8]	Mussel watch tissue screening values for Zn, PCB[9]	011, 011.1 City of Bremerton Storm Drain ST28	Storm drains; Inactive ships moored at moorings; Nearshore area with low flushing

[1] Non-Dry Dock Stormwater Sampling Plan (Taylor Associates, Inc. and Pacific Northwest National Laboratory 2011)

[2] Sediment composites from OUBM monitoring 2003, 2005, 2007, 2010

[3] Pier 7 Pre-construction sampling for fender pile replacement (URS Group, Inc. 2008a) and Pier 7 Post-construction sampling in 2009 (report in progress as of May 2010)

[4] Pier B and Pier 8 Pre-construction sampling for Pier B upgrade and Pier 8 removal (URS Group, Inc. 2008b) and Pier B Under Pier sampling in 2009 (report in progress as of May 2010).

[5] SQS evaluations were done on post-construction data unless unavailable, then pre-construction data was used. The number of sediment samples exceeding SQS for the metal of interest is noted in parentheses.

[6] Five Ambient marine water quality surveys conducted from 2009 to 2010 (Johnston et al. 2011; Strivens et al. 2018).

[7] Washington Toxic Substance dissolved copper concentration chronic (3.1 µg/L) and acute (4.8 µg/L) criteria for the protection of aquatic life (WAC-173-201A-240).

[8] ENVVEST Mussel Watch program (Johnston et al. 2011)

[9] Mussel data evaluated against ecological benchmarks of TSV and CBR (Johnston et al. 2007; Johnston et al. 2011).

[10] City of Bremerton CSO disconnected after Burwell Street Tunnel was completed in 2009.

3.2 Site Selection

Eleven areas of concern were identified based on existing sediment data or information on potential sources. Since sampling at all areas of concern was not feasible, the locations were prioritized and ranked based on all the lines of evidence discussed above. Eight Focus Areas and the Pier 7 RDTE Demo Project were selected for sampling (Table **11**, Figure **25**).

Ranking factors included evaluating the available data for SMS exceedances, determining if there was a specific process change occurring within an area (e.g., construction), and prioritizing those areas in discussion with ENVVEST, NPDES, and CERCLA program managers. Table **11** lists each of the eleven sites, the relative ranking score, and the justification for selection. The nine areas of concern identified by EPA and Ecology were included in the selected areas except Pier 8, Pier B, and Mooring E to Pier D. Pier 8 was not included as it was waiting for post-construction monitoring at that time of the 2011 sampling and it was included in the stormwater monitoring study at outfall PSNS126. Pier B was still under construction and Mooring E to Pier D was part of the OUBM program that was addressing the increasing PCBs in OUBM grids 30 and 39 (U.S. Navy 2017a). A summary of the samples collected by site is provided in Table **12**.

Table 11. Ranking and justification of sediment sampling areas.

Sediment Area	Rank	Justification
PS09 OF18 DD4	Highest	OF18, No Data for outside OUBM grids Dredge Wall/shoreline stabilization Elevated Monitoring Data – Water (Cu), Mussels (Zn, PCBs), Sediment (Hg, Pb, Zn)
PS08 DD5 RMTS	Highest	No Data for outside OUBM grids Dredge Wall/shoreline stabilization Elevated Monitoring Data – Water (Cu), Mussels (Cu, Zn, PAH, PCB), Sediment (Hg, Zn)
PS03 Mooring E – Pier D	High	Ecology/EPA concern area No Data for outside OUBM grids Elevated Monitoring Data – Water (Hg), Mussels (Hg, Pb, Zn, PCB), Sediment (Hg, PCB)
PS11 DD3	High	Ecology/EPA concern area Elevated Monitoring Data – Mussels (Pb, Zn, PCB, PAH), Sediment (Hg, Pb, Zn)
PS06 OF19 DD6	High	OF19, Ecology/EPA concern area No Data for outside OUBM Dredging, Pier Improvement Elevated Monitoring Data – Mussels (PCB), Sediment (Hg, Zn)
PS07 Finger Pier	High	No Data for outside OUBM grids Elevated Monitoring Data – Water (Cu), Sediment (Hg, Zn)
PS10 DD2	High	Ecology/EPA concern area Elevated Monitoring Data – Sediment (Hg, Cu, Pb, Zn)
PS10.1 DD1	High	Ecology/EPA concern area, No Data for outside OUBM grids Elevated Monitoring Data – Sediment (Hg, Cu, Pb, Zn)

Sediment Area	Rank	Justification
PS12 Pier 8	Med	Ecology/EPA concern area Waiting for Post Demolition Data Elevated Monitoring Data – Sediment (Hg, Ag, Zn)
PS04 Pier D to C	Low	On target to meet PCB cleanup goal Waiting for Pier B construction to finish Elevated Monitoring Data – Sediment (PCB, Hg)
PS05 Pier C to B	Low	Waiting for Pier B construction to finish
PS01, PS02 Mooring E to F	Lowest	Stormwater, mussel, and ambient monitoring continues

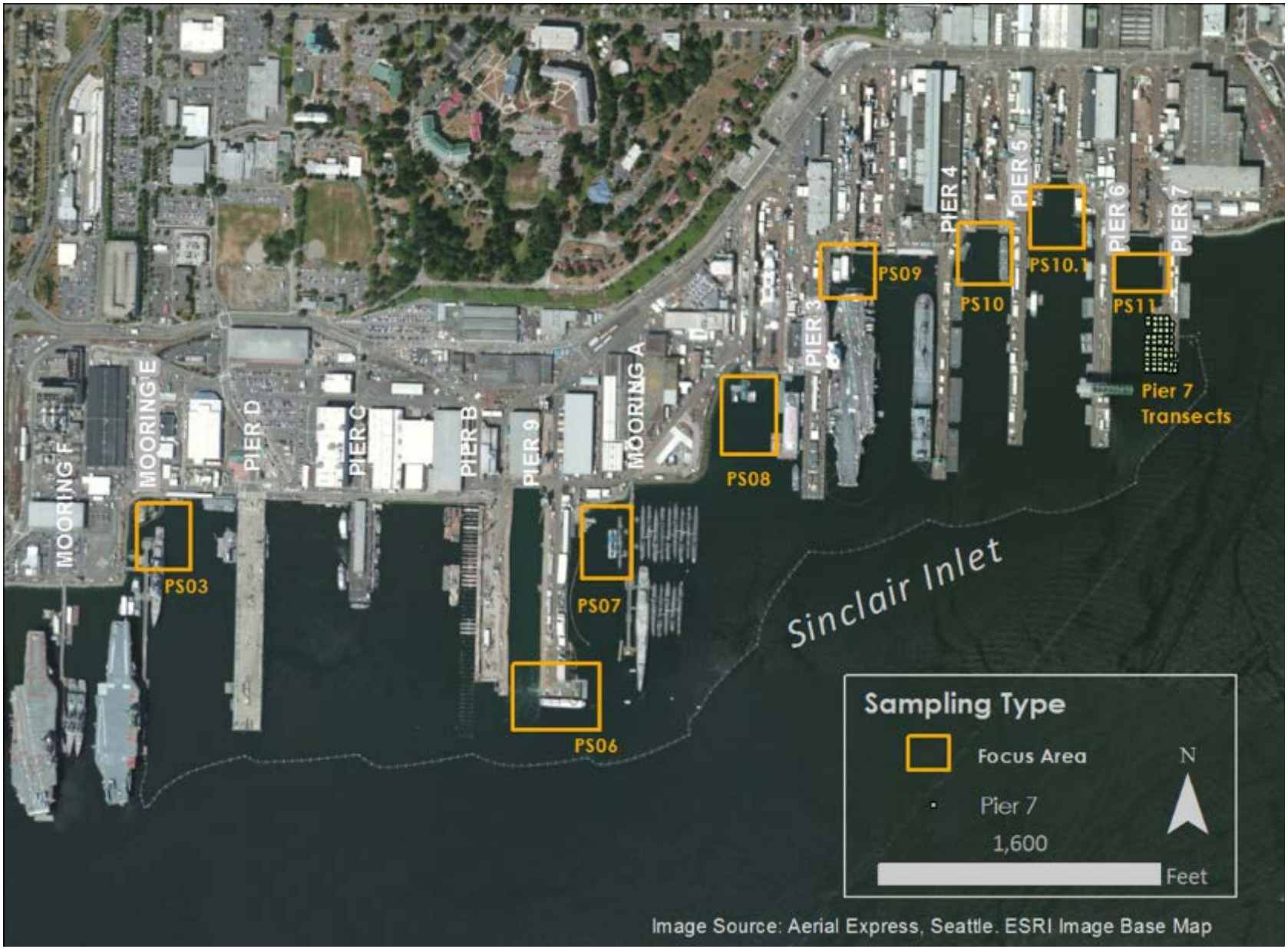


Figure 25. Focus Areas and Pier 7 RDTE Demo Project transects selected for sampling for the SQV study.

Table 12. Summary of samples collected and analyzed for the SQV study.

		Performing Lab	SSC-Pacific				GeoSea	PNNL									
			Analysis														
Project				Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Pore Water	Pore Water	Sediment
Site	Location	Sample Type	Samples	metalsXRF	PAH-aa	PCB-aa	Toxicity	GrainSize	HgDMA	TOC	metal-ICPMS	PAH-GCMS	PCB-GCMS	Met/PAH/PC	metal-ICPMS	DOC etc	AVS/SEM
OUB Marine Monitoring																	
	OUB 500ft grid	0-10cm grab COMP	71	71	71			71		22	19	22					
	OOUB 1500 ft grid	0-10cm grab COMP	32	32	32			32		11	11	8					
Pier 7 RDTE Demo																	
PS16	Surface Cores	0-10cm	50	50		50		50	50	50							
	Bulk Samples	0-10cm (top 6in)	2														
	Drum Samples	0-10cm (top 6in)	6														
	Post Drum Samples	0-10cm (top 6in)	5	5	5	5		5	5	5							
Focus Area Sampling																	
PS03	Mooring E - Pier D	0-10cm grab	6	6	6	6		6	6	6							6
		0-25cm core(1)	1	5	5	5			5	5							4
PS06	DD6 Entrace and Pier 9	0-10cm grab	6	6	6	6		6	6	6							6
		0-25cm core(1)	1	5	5	5			5	5							4
PS07	W. Side DD6 and Finger Pier	0-10cm grab	6	6	6	6		6	6	6							6
		0-25cm core(1)	1	5	5	5			5	5							4
PS08	RMTS and DD5	0-10cm grab	6	6	6	6		6	6	6							6
		0-25cm core(1)	1	5	5	5			5	5							4
		0-25cm Squeeze Core(2)	1	6	6	6			6	6				6	6	6	
		0-5cm Tox Eval(3)	1				4										
PS09	DD4 and Btwn Piers 3 & 4	0-10cm grab	6	6	6	6		6	6	6							6
		0-25cm core(1)	1	5	5	5			5	5							4
		0-25cm Squeeze Core(2)	1	6	6	6			6	6				6	6	6	
		0-5cm Tox Eval(3)	1				4										
PS10	DD2 and Btwn Piers 4 & 5	0-10cm grab	6	6	6	6		6	6	6							6
		0-25cm core(1)	1	5	5	5			5	5							4
PS10.1	DD3 and Btwn Piers 5 & 6	0-10cm grab	6	6	6	6		6	6	6							6
		0-25cm core(1)	1	5	5	5			5	5							4
PS11	DD1 and Btwn Piers 6 & 7	0-10cm grab	6	6	6	6		6	6	6							6
		0-25cm core(1)	1	5	5	5			5	5							4
	Confirmaton Analysis (20%)										31	21	31				
		Total Analysis	249	258	208	155	8	206	160	188	61	51	31		12	12	80

20% of XRF screening samples

20% of PAHaa screening samples

20% of PCBaa screening samples

NOTES

(1) Core sectioned at intervals of 0-2.5, 2.5-5, 5-10, 10-15, 15-20 cm

(2) PW extracted at intervals of 0-2.5, 2.5-5, 5-7.5, 7.5-10, 10-15, 15-20 cm

(3) Toxicity endpoints: a) polychaete (*Neanthes arenaceodentata*) survival and growth, b) amphipod (*Leptocheirus plumulosus)* survival, c) amphipod (*Ampelisca abdita*) survival, and d) bivalve (Mytilus galloprovincialis) embryo-larval development

3.3 Sampling Design

The sampling design was optimized for each of the subtasks and is described in detail in (Brandenberger et al. 2011; CardnoTEC and Pacific Northwest National Laboratory 2014). The sampling was divided into four components:

(1) split sampling with OUBM LTM,

(2) Focus Area sampling,

(3) sampling conducted in support of the RDTE Pier 7 Demo Project, and

(4) caisson and dry dock silt sampling.

In addition, contaminant bioavailability was analyzed in selected samples from the focus area by analyzing sediment metal binding capacity, analyzing pore water concentrations of metals, dissolved sulfide, and dissolved organic carbon (DOC) and other binding species, and conducting toxicity assessments of sediment and overlying water at two sites.

The overall sampling design for the OUBM screening and confirmatory sediment sampling is detailed by (Kohn et al. 2004; Kohn et al. 2006; Kohn et al. 2008). Briefly, the sampling consisted of obtaining splits from the surface sediment composite samples collected by the 2010 OUBM LTM, the splits were screened using the RSC procedures. All samples from OUBM were screened for metals (Fe_{XRF}, Cu_{XRF}, Pb_{XRF}, and Zn_{XRF},) and PAHs, (PAH_{RSC}) and a sub-set of samples were selected for confirmatory analysis using ICP for metals and GC/MS for PAHs. The focus area sites were selected based on the ranking for sediment areas of concern (Table **11**) and targeted sampling included surface grabs and sediment cores analyzed for heavy metals, PCBs, and PAHs to evaluate sediment quality and assess bioavailability and toxicity. The RDTE Pier 7 Demo Project sampling consisted of collecting high-resolution transects of surface grabs (0-10 cm) adjacent to and under the south end of Pier 7 to characterize PCBs, PAHs, and metals at the site prior to placement of the AC sediment amendment. The Pier 7 transect samples were analyzed for Fe_{XRF}, Cu_{XRF}, Pb_{XRF}, Zn_{XRF}, PAH_{RSC}, PCB_{RSC}, total Hg, and grain size. A subset of about 20% of the samples were confirmed for metals, and PAHs using standard laboratory methods. The caisson and dry dock silt sampling characterized silt and sedimentary material that accumulated in front the caissons between docking operations, material that accumulated on the dry dock floor after dewatering, and material entrained within the dry dock drainage system. The dry dock silt samples were was fractionated for metals analyses by passing first through a 2 mm and then a 63 µm sieve. The fractions were analyzed for Al, Cr, Cu, Fe, Pb, Ni, Zn, Hg, TOC, and grain size. The details of the sampling design are described below.

3.3.1 OUBM LTM Split Sampling

Sediments throughout Sinclair Inlet were routinely sampled as part of the OUBM LTM. The primary objectives of the OUBM LTM split sampling were to 1) provide updated sediment concentrations for metals and organics in Sinclair Inlet segments that were considered impaired for sediment quality, 2) provide sediment data at a spatial distribution throughout Sinclair Inlet that supports the determination of sediment recovery trends, modeling of contaminant loading and transport, and 3) provide a baseline to measure continuous process improvement. Under the LTM program, samples are analyzed for PCBs, Hg, TOC, and grain size. Therefore, the ENVVEST program collected split samples from the 2010 OUBM LTM and analyzed them for Cu, Pb, Zn, Fe, and PAHs.

There is a strong rationale for coordinating the ENVVEST activities with those of the OUBM sediment monitoring. Nearly all the sediment stations historically exceeding SQS were located within the 500-ft OUBM grid, which is the focus of ENVVEST sampling. Selected OUBM grids represent the locations where present activities (dry dock pumping, stormwater discharge) are most likely to exhibit impacts to sediment. The 1500-ft grid cells provide additional coverage in the 303(d)-listed segments and a wider spatial coverage to evaluate overall sediment trends in Sinclair Inlet. Additionally, coordinating with the monitoring program is a very cost-effective means of obtaining a larger number of samples in the areas of interest.

The primary outcome of the study is a non-statistical comparison of target metal concentrations with Washington State SQS and MCC, but the sampling and analytical design was intended to reduce uncertainty associated with the target measurements. The chance of false negatives (samples in which true metal concentration exceeds MCC but measured concentration was less than MCC) was limited by 1) increased sampling density where concentrations are likely to exceed SQS, 2) selecting methods and setting quality control limits to minimize analytical error, and 3) comparing screening values to 90% SQS. The chance of false positives (samples in which true metal concentration is below MCC but measured exceeds MCC) was also limited by these measures.

The split sampling with OUBM LTM is summarized in Table **13**. To the degree possible, the study incorporated the requirements of SMS regulation (WAC 173-204) and the 303(d)-listing policy[1]. The following information and guidance were also considered:

- The OUBM LTM Program, for Bremerton Naval Complex (BNC);
- Design for adequate spatial coverage for short-term (CH3D) (Johnston et al. 2009; Wang et al. 2011) and long-term (Box Model) (Pelletier and Mohamedali 2009; Osterberg and Pelletier 2015) contaminant transport modeling efforts;
- Include segments that were already sampled since 2002. This includes the sediment mass balance study (Brandenberger, Crecelius, and Johnston 2008), where sediment data are available from cores and depositional areas associated with the major streams and storm water outfalls;
- Ecology's Water Quality categories (i.e., no impairment, waters of concern, or TMDL required) and
- Ecology's Sampling and Analysis Plan guidance (Washington State Dept. of Ecology 2003).

[1] See https://ecology.wa.gov/Water-Shorelines/Water-quality/Water-improvement/Assessment-of-state-waters-303d/Assessment-policy-1-11 , accessed 7/29/2019)

Table 13. ENVVEST OUBM Sediment Monitoring Study Design Summary for Sinclair Inlet

Location	Objective(s)	Approach	Number of Stations
Sinclair Inlet, Shipyard 500-foot grid for OUB Marine	1. Sediment quality in segments listed as Category 5 or 4B and focus areas within the Shipyard. 2. Spatially representative data to support contaminant transport modeling in Sinclair Inlet	Directed sampling: screen all 2010 OUBM sediment samples for Cu, Pb, Zn and total PAHs, select 25% for quantitative confirmatory analyses, and conduct quantitative analyses on ~30 samples.	71
Sinclair Inlet, 1500-foot OUB Marine	1. Sediment quality throughout Sinclair Inlet and two grids previously exceeding SQS. 2. Spatially representative data to support contaminant transport modeling in Sinclair Inlet		32
		Sinclair Inlet Total Samples for Screening	103
		20-25% for Laboratory Confirmation	30 Metal 27 PAH

As previously described (Kohn et al. 2004; Kohn et al. 2006; Kohn et al. 2008), the OUBM LTM split sampling design maximizes sample distribution (high density) and data utility while reducing field-sampling costs by leveraging the two programs. All samples were screened for metals and PAHs and 20-25% of the samples were selected for confirmatory analyses. A weight of evidence approach used to rank the OUBM samples for the selection of confirmatory analyses is detailed in (Brandenberger et al. 2011), below is a brief summary of the lines of evidence.

1. The following tiered approach was employed:
   - Tier 1 - Rapid screening analysis on all samples. Sediment were screened for metals by X-ray fluorescence (Cu_{XRF}, Pb_{XRF}, Zn_{XRF}) and PAHs by using enzyme-linked immunosorbent assay (ELISA) methods (PAH_{RSC}) (Kirtay and Apitz 2000; Kirtay and Apitz 2001).
   - Tier 2 - Confirmatory analysis of at least 20-25%. Confirmatory analysis for metals by ICP-MS or ICP-OES. Confirmatory analyses for PAHs by GC-MS.
   - Tier 3 – Based on the correlation between screening and quantitative confirmatory results, a regression equation between the screening result and the confirmation result was used to determine definitive concentrations for all other samples that were not confirmed by the quantitative analyses (Kohn et al. 2004; Kohn et al. 2006; Kohn et al. 2008).

2. Considerations for selection of metals confirmatory samples included:
   - Samples in which XRF result exceeded 90% of the SQS for one or more target metals (Cu, Pb, and Zn)
   - Predicted concentrations based on (Kohn et al. 2008) relational equations that were ≥90% SQS
   - Variability between 2003, 2007, and 2010 screening concentrations ≥50%
   - Corresponding 303(d) Segment listed as Category 4B for metals
   - Samples that were representative of the screening concentration range.

3. Considerations for selection of PAH confirmatory samples were altered because screening results only provide estimates of the total concentration rather than compound specific data. The considerations included:

- Immunoassay result ≥90% SQS
- Immunoassay result <90% SQS but >10 mg/kg dry weight
- Select samples to represent areas where there appears to be potential for PAH to exceed SQS
- Select at least one sample in segments on the 2008 Category 2 listed segments
- Screening results with high variability
- Locations with anomalous confirmatory results from previous verification studies
- Samples that were representative of the concentration range.

One hundred and three sediment grab samples (0-10 cm) were collected in 2010 in accordance with procedures detailed in the OUBM LTM (URS Group, Inc. 2002b). Three locations within each 500-ft and 1500-ft grid were sampled and composited to represent the entire grid, as described above. A split from each sample was provided to ENVVEST in a 16 oz. pre-cleaned glass jar with Teflon liners for the screening and confirmatory analyses of metals and organics not already analyzed by the OUBM program. Each sample was further homogenized using a pre-cleaned plastic spatula and split into a 2 oz. pre-cleaned polycarbonate jar for metals, 8 oz. pre-cleaned glass jar for organics, and an 8 oz. pre-cleaned glass jar for the screening analyses. All samples for confirmatory chemical analyses were archived frozen (<-20˚C) until analyses.

3.3.2 Focus Area Sampling

The sedimentary environment offshore of the Shipyard is very heterogeneous consisting of different bathymetries and varying sediment facieses and substrates as a result of shoreline modifications and developments, industrial activities, Shipyard operations, and historical dredging operations (Figure **26**). The bathymetry of the bottom shows a very complex geochemical environment that affects the accumulation, distribution, and bioavailability of contaminants that may be present. Based on sediment core profiles (Figure 2) and OUBM sediment monitoring results (U.S. Navy 2017a) the sediments deposited over the last l50 years represent the top 20-30 cm of undisturbed sediment. Dredging, pier construction, and channel deepening projects have removed or displaced these deposits and exposed materials deposited during past glaciations including recessional outwash and till deposits (Figure **27**) (Whitney and Wright 2003). The most recent deposits, comprising the surface (0-2 cm) sediment, consists of a mixture of geological material from the bottom, biogenic organic matter, resuspended silts and clays, particulates from runoff, anthropogenic debris, and other sedimentary materials present in Sinclair Inlet. The biologically active layer usually consists of the top 5-10 cm and the amount of biological activity is highly dependent on the geochemical conditions of the sediment, the substrate characteristics, the level of contamination, and other ecological conditions present at the site.

The primary objectives of the focus area sampling were to:

1. provide a snap shot of the 2011 sediment concentrations for metals and organics in the Shipyard areas of concern for Ag, Cu, Pb, Zn, Hg, PAHs, and PCBs not currently addressed by OUBM monitoring;
2. characterize silt and sediment in the vicinity of outfalls, storm drains, and dry docks;
3. provide data to assess sediment impact zones for NPDES discharges;
4. provide data to assess anti-degradation requirements for water quality certifications needed for pier and dry dock infrastructure improvements;

The data from this study provides an assessment of sediment recovery trends, supports contaminant loading and transport modeling in Sinclair Inlet, and helps establish a baseline to measure continuous

process improvement. The existing stormwater monitoring data and the spatial resolution of the sediment data were not sufficient to determine or rule out sediment degradation from active processes (e.g., stormwater runoff, ship maintenance, repair, and decommissioning) or redistribution of historically contaminated sediment.

A summary of the samples collected for each sampling site is provided in Table **12**. The sampling and analysis procedures were as follows:

1. For each of the eight focus areas six grab (0-10 cm) samples were obtained to provide a measure of site variability and a (0-25 cm) core profile was collected to evaluate contaminant levels and geochemical processes with depth. At two sites (PS03 and PS09) additional sampling consisted of a collecting a 0-25 cm squeeze core for pore water analysis and surface grabs (0-5 cm) for toxicity evaluations.
2. All samples were analyzed for total Hg using cold vapor atomic absorption (CVAA).
3. For metals all Focus Area samples were analyzed using ICP-MS for Ag, As, Cd, and Pb, and ICP-OES for Al, Cu, Cr, Fe, Mn, Ni, and Zn. RSC methods were used for PAHs and PCBs and Cu, Pb, and Zn for the Pier 7 sampling using the same tiered approach discussed above for OUBM.

3.3.2.1 Surface Sediment Grabs

Forty-eight surface sediment grab samples were collected in April 2011. Divers collected grabs by penetrating approximately 10 cm into the sediment using a 16 oz. pre-cleaned amber glass jar as a sediment coring device. At the lab, each grab sample was homogenized using a pre-cleaned plastic spatula and split into a 2 oz. pre-cleaned polycarbonate jar for metals, 2 oz. pre-cleaned glass jar for TOC, 8 oz. pre-cleaned glass jar for organics, and a 4 oz. glass jar for grain size. All samples except grain size were stored frozen (<-20˚C).

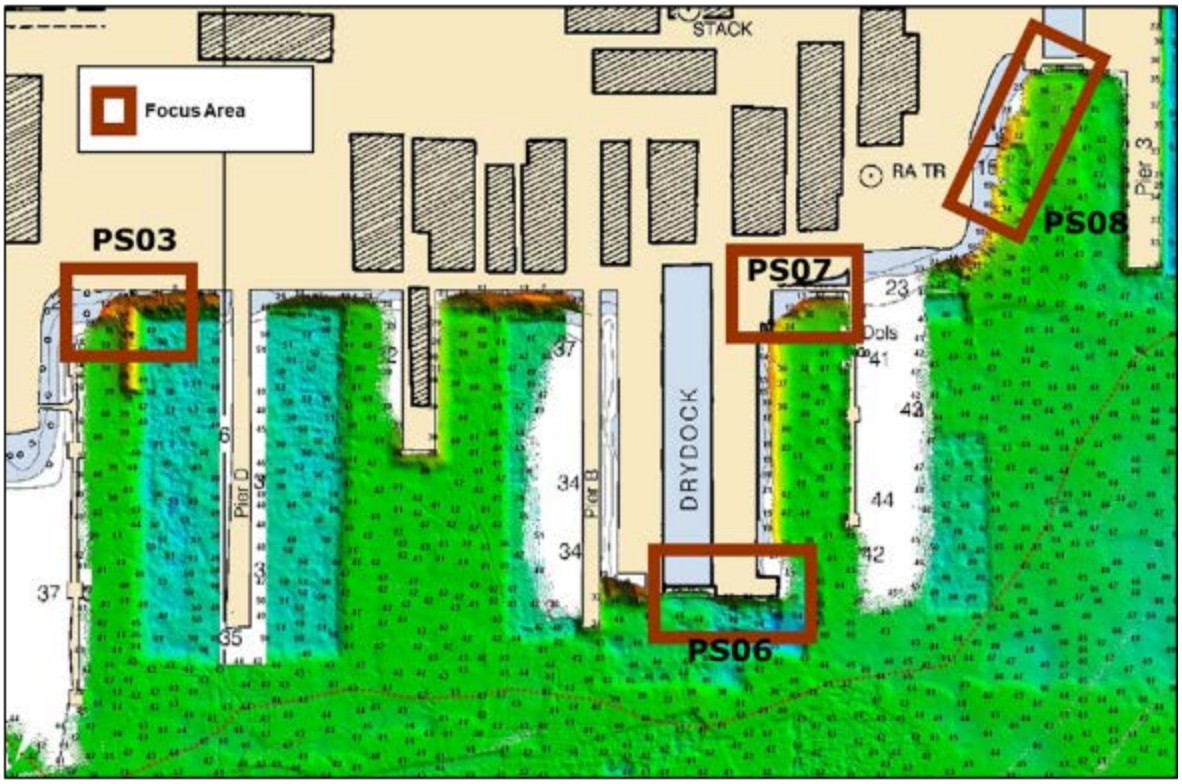
3.3.2.2 Short Cores

The short cores consisted of a 40 cm cellulose acetate butyrate (CAB) plastic core tube with a 5.5 cm inner diameter (ID). One short core was collected at each of the eight sampling locations. The cores were transported upright to the MSL where they were extruded and sub-sectioned at the following intervals: 0-3 cm, 3-6 cm, 6-9 cm, 9-13 cm, 13-19 cm, and 19-25 cm. A duplicate core was collected at PS06, but due to an artifact in the core, only the upper two segments were collected. Each core segment was homogenized and split using a pre-cleaned plastic spatula into a 2 oz. pre-cleaned polycarbonate jar for metals, 2 oz. pre-cleaned glass jar for TOC, 8 oz. pre-cleaned glass jar for organics, and a 4 oz. glass jar for grain size. All samples except grain size were stored frozen (<-20˚C).

3.3.2.3 Squeeze Cores and Porewater

At PS03 and PS09, a squeeze core was collected by divers using a specialized polycarbonate core liner (9 cm ID) fitted with sampling ports at 1-cm intervals (Figure **28**). The cores were transported upright to the Navy lab at the Shipyard where porewater was extracted from the intact sediment cores using a modification of the whole core squeezing technique originally described by (Jahnke 1988) with modifications described by (Warnken et al. 2000). In summary, the core barrels were constructed of polycarbonate with threaded ports drilled at 1 cm intervals. The nylon end caps contained a valve to allow pressurization from the top of the core. Nitrogen gas was used to pressurize the cores to 10 to 12 psi to

A. Sediment sampling areas for western portion of Shipyard



B. Sediment sampling areas for eastern portion of Shipyard

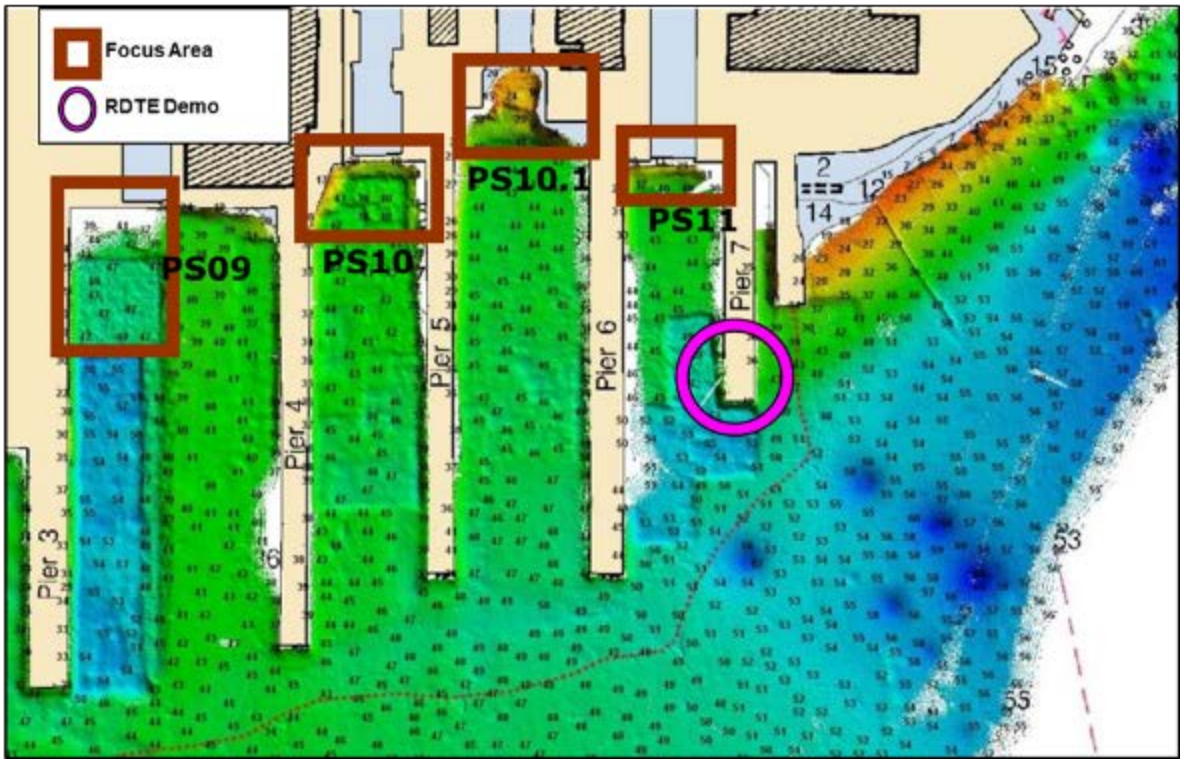


Figure 26. Image of high-resolution bathymetry and sediment sampling areas for the western (A) and eastern (B) portions of the Shipyard **(U.S. Navy 2007)**.

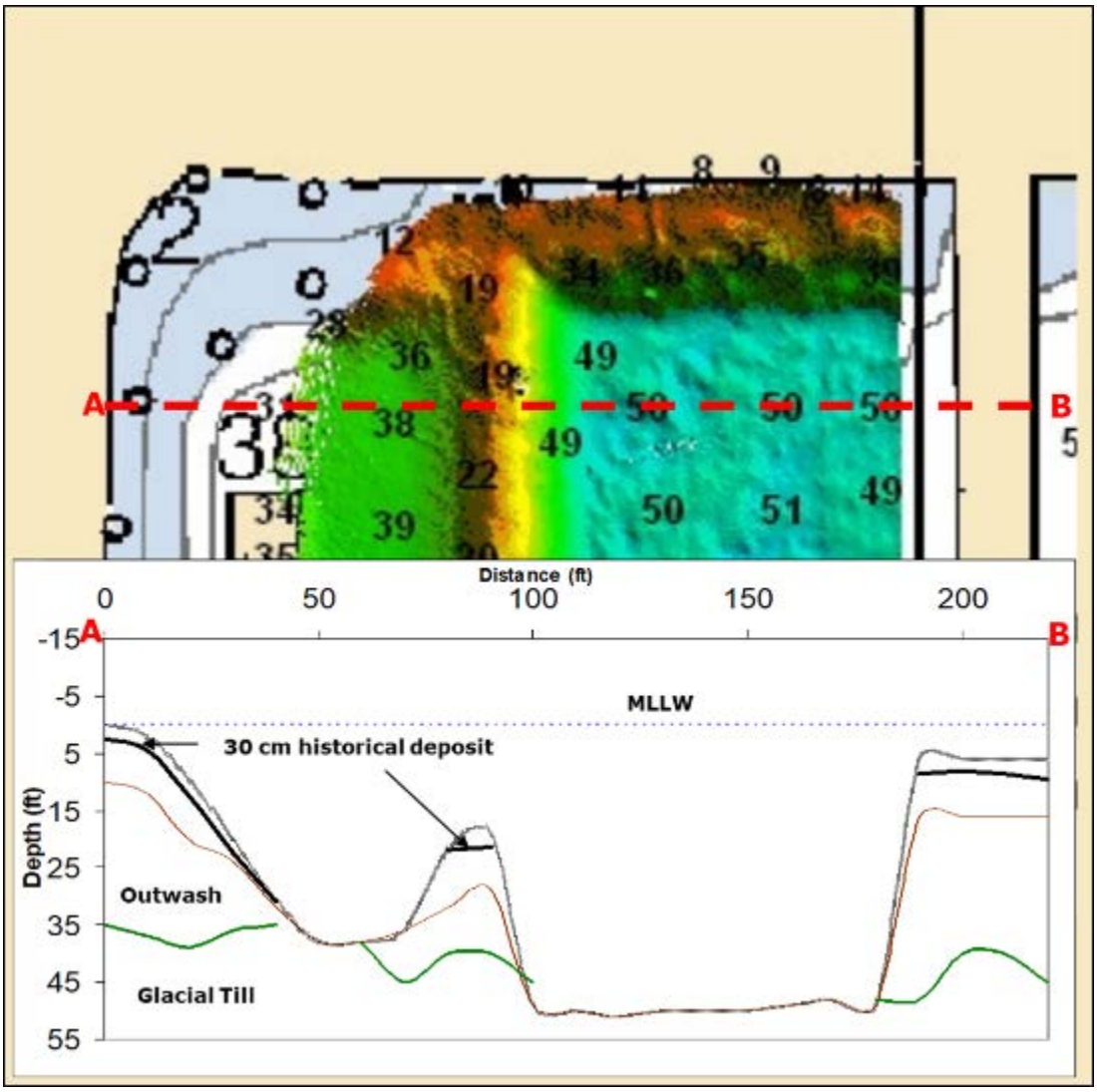


Figure 27. Conceptual model of bottom profile along transect A–B near focus area PS03 showing dredge cuts, pier location, and the thickness of sedimentary deposits.

limit sampling artifacts (i.e., drawdown of overlying water, channeling within the core, vertical replenishment, and cell lysis).

The porewater was extracted at the following intervals: 0-3 cm, 3-6 cm, 6-9 cm, 9-13 cm, 13-19 cm, and 19-25 cm to allow enough volume without vertical displacement of the interface and dilution of the top-most sample. A syringe fitted with a Porex rod, Teflon tubing, and a leur fitting was threaded into each port. The Porex rod was cut so that upon insertion it extended half way into the core, approximately 5 cm, and was attached to the leur by a small piece of Teflon tubing, preventing the sampling of pore water close to the core wall. Porewater was extruded through the Porex rod directly into a 10-mL pre-cleaned syringe attached to the ports to prevent exposure to oxygen. The porewater was then filtered through a 0.45 µm PVDF filter for metals and dissolved sulfide and an ashed glass fiber filter (GFF) for DOC. The metals were filtered into a Teflon bottle and preserved to 0.2% double distilled nitric acid, dissolved sulfide was placed in a separate 60 mL Teflon bottle pre-charged with zinc acetate preservative, and the DOC aliquot was stored in an ashed amber glass vial.

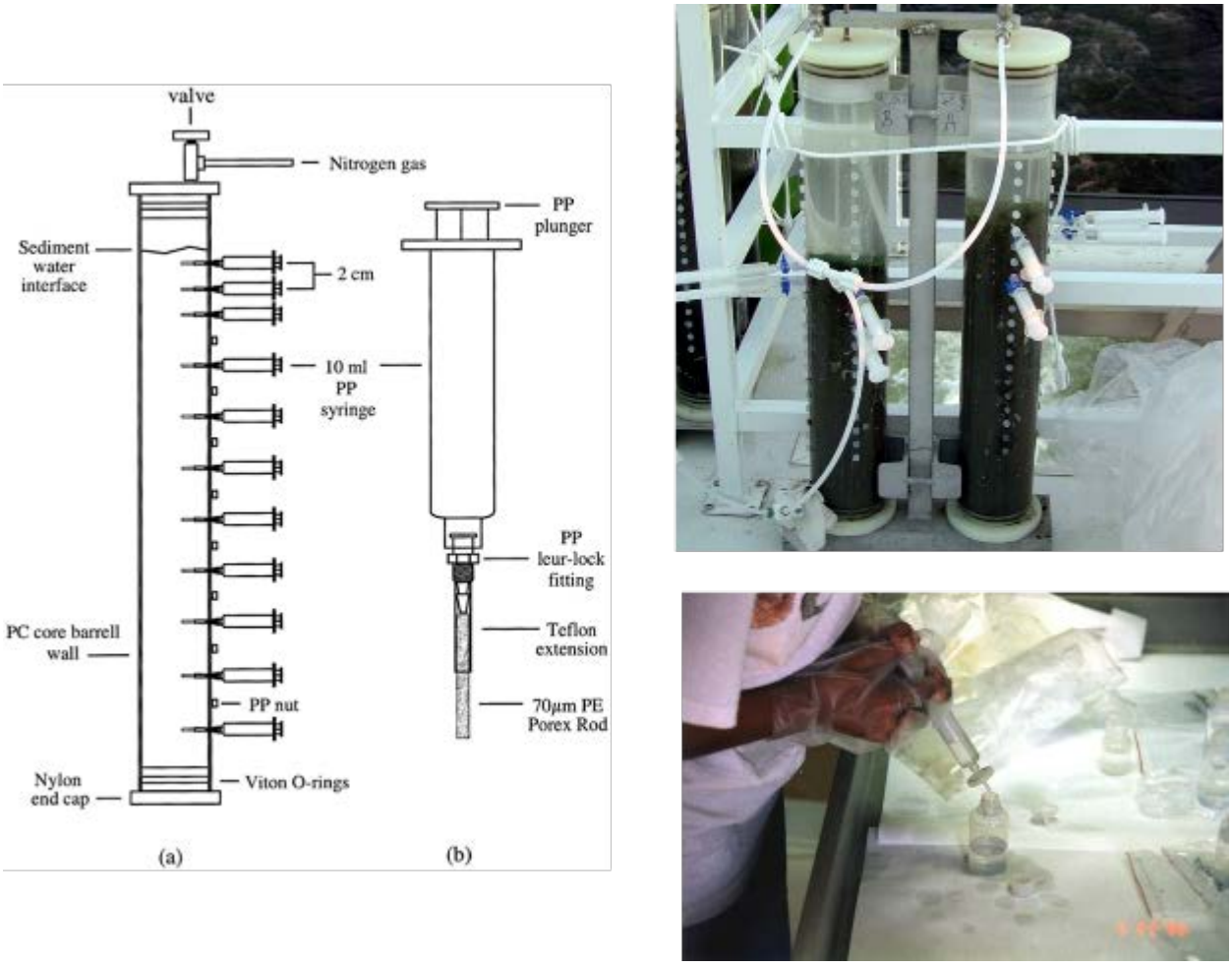


Figure 28. The (a) core squeezer used to extract pore water from a sediment cores with a (b) blow-up of the syringe set-up, consisting of a 10 mL polypropylene syringe, leur lock fitting, Teflon extension, and Porex rod and photos of the sampling device (Warnken et al. 2000).

After porewater extraction, sediment cores were extruded and sectioned using the same intervals as the porewater. Each segment was homogenized and split into containers for metals and TOC as described above for the short cores. The limited volume of porewater required microscale analyses and prioritization of the parameters of interest and the use of modeled partitioning for organics (International Atomic Energy Agency 2004). The porewater samples were analyzed in priority order for dissolved Hg, Ag, As, Cd, Cu, Cr, Ni, Pb, Zn, DOC, and sulfide. The DOC and dissolved sulfide measures provide ancillary information to support the calculation of partitioning between the sediment and porewater using established coefficients (K_d and C_w). The bulk sediment from each core segment from which the porewater was extracted was also analyzed for the same list of metals, TOC, PAHs, and PCBs.

3.3.2.4 Metal Bioavailability

The focus area sediment grab and core samples were extracted and analyzed for acid volatile sulfide (AVS) and simultaneously extracted metal (SEM) using methods recommended by EPA Method EPA-821-R-100 (Allen et al. 1991; Allen et al. 1993). When the molar concentration of AVS is greater that the

molar concentration of the sum of the SEM metals, bioavailability and toxicity of the metals are not expected because the metals are likely bound as non-soluble sulfides (U.S. Environmental Protection Agency 2005). If sum of SEM metals are greater than AVS, then the metals would be released in order of their sulfide solubility product (K_{sp}) that expresses the ratio of dissolved : solid species, where the lower the K_{sp} the more tightly bound is the metal-sulfide compound (Morse et al. 1987). The divalent metals form metal-sulfide complexes at the expense of iron and manganese sulfide (FeS ≅ MnS << NiS < ZnS < CdS < PbS < CuS < HgS). The SEM metals analyzed were metals of interest because they have lower sulfide ratios than FeS, therefore if the sum of the SEM metals were greater than AVS, then the metals with the largest sulfide solubility product would be present as potentially toxic free metal (U.S. Environmental Protection Agency 2005).

Equilibrium Partitioning Sediment Benchmarks (ESB) for the protection of benthic organisms from metal exposure have been developed based on the knowledge of AVS, the sum of the simultaneously extracted metals (ΣSEM), and the fraction of OC (f_{OC}) in the sediment (U.S. Environmental Protection Agency 2005):

Low risk of adverse biological effects

$$(\Sigma SEM - AVS)/f_{OC} \leq 130 \text{ umol/g OC} \qquad \text{Equation 3}$$

May have adverse biological effect

$$130 \text{ umol/g OC} < (\Sigma SEM - AVS)f_{oc} \leq 3000 \text{ umol/g OC} \qquad \text{Equation 4}$$

Adverse biological effects expected

$$(\Sigma SEM - AVS)f_{oc} > 3000 \text{ umol/g OC} \qquad \text{Equation 5}$$

Previous studies of Sinclair Inlet sediments showed that AVS production was high and that most of the divalent metals were bound as nonreactive and nonmobile sulfides (Johnston 1993). In situ benthic flux rates of metals measured at the same time (Chadwick et al. 1992) reported higher flux rates of Ni and Zn when AVS was lower, probably due to the low sulfide solubility of Ni and Zn which would be the first metals to be released as AVS decreases. The results from the AVS and SEM analysis were used to evaluate metal bioavailability in the Focus Areas of the Shipyard.

3.3.2.5 Toxicity Evaluation

Marine sediments at many coastal U.S. Navy facilities are frequently elevated with Cu and Zn. Although these metals are naturally occurring, and essential for life, there are numerous anthropogenic sources of Cu and Zn that frequently result in elevated, potentially harmful, sediment concentrations. For the Navy, one of the largest sources of Cu and Zn in coastal embayments is from antifouling paint systems on ship hulls. Assessment and regulation of adverse effects in these sediments is typically based on SQG using total metal concentration (Long et al. 2005; Washington State Dept. of Ecology 2013). However, the bioavailability and potential toxicity of Cu and Zn, is not necessarily related to total concentrations measured in bulk sediments, complicating appropriate application of SQGs for environmental regulation.

A research project “Compliance Tools Development for Metals in Antifouling Paints Program” was funded by the Navy to address short-term requirements and data gaps identified by the Navy and the program’s technical work group (composed of scientific experts in government, industry, and academia). Funding was provided to support development of improved tools for assessing Cu and Zn bioavailability and toxicity in sediments located at selected Navy facilities, which included two sites at the Shipyard. The primary focus of the study was to build on the recent results published by others (Simpson and Batley

2007; Strom et al. 2011), which suggest that expressing sediment Cu concentrations in terms of the metal concentration measured in the fraction of sediment equal or smaller to 63 µm (silt-size fraction of the sediment), normalized to the TOC content in the silt-size fraction, provides a vast improvement in the predictability of metal toxicity over current methods based on bulk sediment concentration, or TOC normalization of the bulk concentration.

Successful demonstration and validation of this methodology could vastly simplify and improve the assessment of contaminant bioavailability and toxicity in sediments U.S. Department of Defense (DoD) installations, potentially reducing costs associated with their future assessment and remediation. Samples at selected sites were evaluated for toxicity using the protocols developed in support of the Navy's research program to assess bioavailability and toxicity of sediments contaminated with Cu, Zn, and other contaminants. As part of toxicity evaluations being conducted at selected Navy sites, the surface sediments were collected from the top 0-5 cm and tested for toxicity with a maximum holding time of two weeks (see 9.0A.4Appendix A.4 Sediment Toxicity Data Report).

For the sediment toxicity study, divers collected grabs and intact cores for toxicity testing from the PS03 and PS09 Focus Areas. The samples were collected by inserting core tubes into the top 5-10 cm of sediment, capping the top of the core with at least 2 cm of overlying water, removing the core tube from the sediment and capping the bottom of the core tube to bring the core to the surface without disturbing the sediment. Replicate cores were taken within a 20 x 20 cm location on the bottom. Following core removal, the top 5cm remaining of the 20 x 20cm location was also sampled to obtain about 4L (1 gallon grab) of sediment for homogenization. Only the top 5 cm of the core tubes were used in the bioassays. The replicate cores tubes were processed in the same manner. Toxicity testing included testing exposure to bedded sediments obtained from the top 5 cm and overlying water from an intact core. The toxicity tests that were conducted included:

- *Ampelisca abdita*: whole sediment 10-day amphipod survival (U.S. Environmental Protection Agency 1994)
- *Leptocheirus plumulosus*: whole sediment 10-day amphipod survival (U.S. Environmental Protection Agency 1994)
- *Neanthes arenaceodentata*: whole sediment 28-day polychaete survival & growth (D. Farrar and Bridges 2011)
- *Mytilus galloprovincialis*: sediment-water interface 48-hour survival and embryo-larval development (U.S. Environmental Protection Agency 1995; Anderson et al. 2001).

Sediment toxicity testing using the marine amphipods, polychaetes, and bivalve embryos were performed to evaluate the environmental quality of sediments collected from two locations at the Shipyard. The amphipods and polychaete worms were tested in homogenized sediment samples, whereas bivalve embryos were exposed in sediment-water interface (SWI) toxicity tests described by (Anderson et al. 2001). Samples were collected April 27, 2011 and testing was conducted at the SPAWAR Systems Center Pacific (SSC Pac) Bioassay Laboratory in San Diego, California, from May 3 through 31, 2011. Sediment chemistry evaluating the metal content as well as grain size and organic content was performed on the samples and diffusive gradients in thin films (DGTs) were also concurrently deployed to assess the bioavailability of metals associated with the sediment porewater as an additional line of evidence to assess the environmental quality of the sediments tested. The details of the toxicity testing and QA/QC procedures are provided in Appendix A.4 Sediment Toxicity Data Report.

3.3.2.6 Assess Sediment Deposition

Data on sediment grain-size analysis were collected to provide information about the texture and potential source of materials deposited around the dry docks, piers, and pilings. Sediments collected during this study were analyzed for their complete grain-size distribution using a laser particle sizer, which employs lenses of different focal lengths to quantify the portions of the total range of grain sizes that may be present. The distributions, combined with sieve data for sizes >1500 microns, were "merged" to obtain the complete grain-size distribution (McLaren 1998; McLaren 2004).

Aliquots of surface grabs, cores, Pier 7 transects, and dry dock silt samples were obtained and processed for grain-size analysis using the same methods described in (McLaren 1998; McLaren 2004). In addition, systematic sediment samples taken in the vicinity of Pier 7 were evaluated for sediment trend analysis (STA). The STA is a technique used identify patterns of net sediment transport and their dynamic behavior in all environments (SedTrend 2011).

3.3.3 Pier 7 RDTE Demo Project

Sediment samples were collected to support treatability (Kirtay et al. 2018) and bioavailability (Bridges et al. 2017) assessment for the RDTE Demo Project conducted at Pier 7. Based on high PCB concentrations measured in samples collected as part of repair projects conducted at Pier 7, additional sampling was conducted to determine the nature and extent of contamination around Pier 7. Divers collected 0-10 cm surface cores along a grid of 10 transects perpendicular to the pier, for a total of 51 samples (Figure **29**). Each sample was screened for metals with XRF and PCBs and PAHs using the immunoassay analysis kits. Bulk samples were subsequently obtained from the area of elevated contamination for laboratory testing (Chadwick et al. 2017; Kirtay et al. 2017). Additionally, 55-gal drum samples were obtained from the location of elevated contamination, by using divers to fill 5 gal buckets with sediment from the top 6 inches of bottom, hauling the buckets to the surface, and placing the material into 55 gal drums. Enough material was obtained to half-fill six 55-gal drums which were shipped to ERDC-ERL to be used in laboratory studies (Bridges et al. 2017). Following the drum sample, five grab samples of the top 2 inches (0-5 cm) were collected for chemical analysis of PCBs, PAHs, and metals using the RSC methods.

3.3.4 Caisson and Dry Dock Silt Sampling

Between docking operations, silt and other sedimentary materials accumulate on aprons in front of the caissons that seal the entrances to the dry docks. During the many months that a dry dock is closed 15-24 cm (6-10 in) of silt may accumulate in front of the caisson which is dispersed during docking and undocking operations. Docking operations also stir up silts and sediments adjacent to the dry dock and the material can become entrained inside the dry dock drainage system. Contaminated silts have been implicated as a source of elevated concentrations causing exceedances of NPDES discharge limits for the dry dock outfalls. The purpose of the caisson and dry dock silt sampling was to sample and characterize silt and sedimentary material that accumulated in front of the caissons between docking operations, material that accumulated on the dry dock floor after dewatering, and material entrained within the dry dock drainage system.

Caisson samples were collected in July 2012. Divers collected nepheloid sediments accumulated at the base of the dry dock caissons with a “slurp” gun at two to four locations in front of each dry dock (except for DD1, Figure **30**). The “slurp gun” consisted of a 2-inch core liner fitted with a plunger. Two sizes of cores were used at DD4, 3 ft and 1ft (samples 1-6). Samples 7-12 were taken with 3 ft cores, samples 13-14 were taken with 1 ft cores.

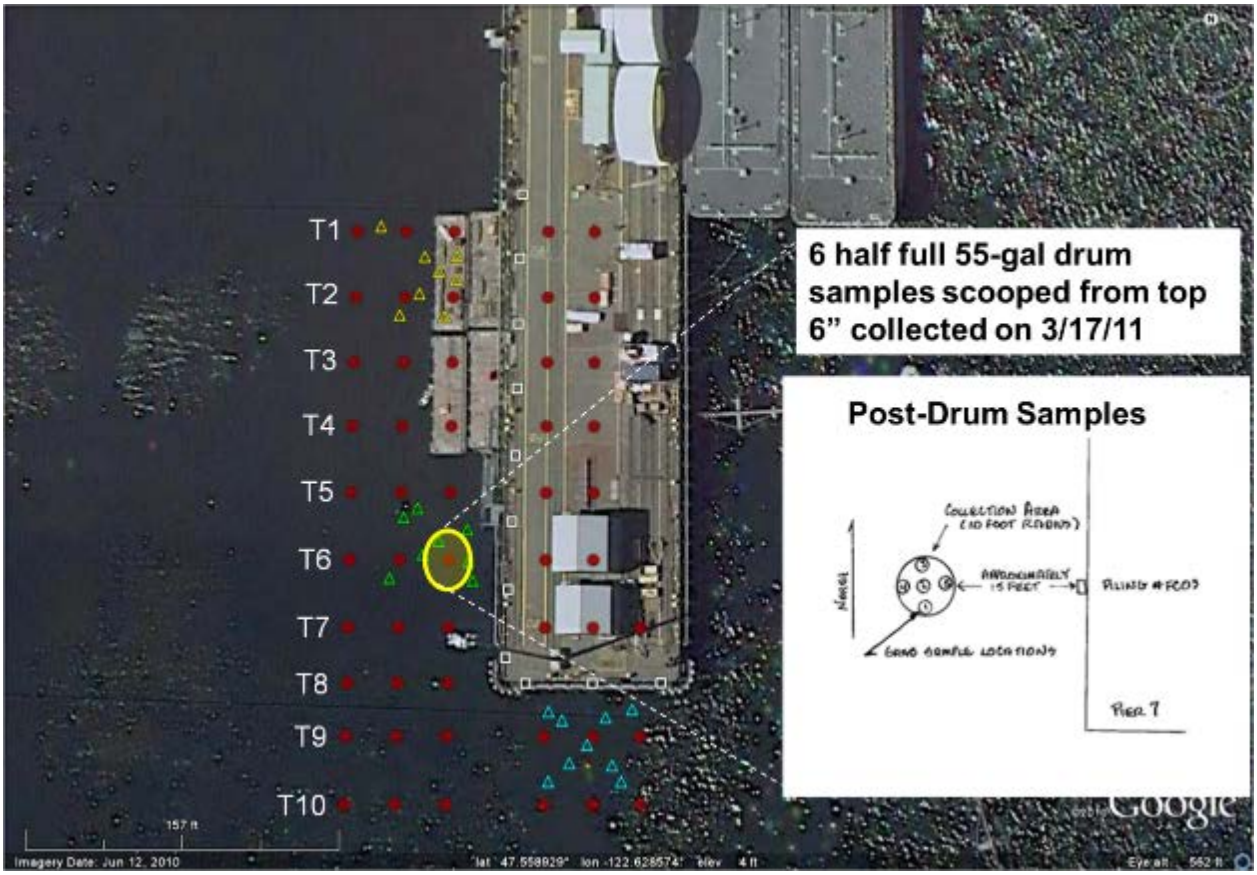


Figure 29. Sampling transects collected adjacent to and under the south end of Pier 7 for the RDTE Demo Project. Colored triangles show the locations of the pre- and post-construction monitoring.

During the repair of Pier B, DD6 was open to the Inlet for almost 6 months from March to July 2010. During that time about 5-8 cm (2-3 in) of silt accumulated on the dry dock floor. Prior to dewatering, divers collected six silt samples using core tubes along the sides at the front, middle, and rear of the dry dock (Figure **31**).

Immediately following dewatering, two silt samples of material accumulated on the dry dock floor were also sampled. Additionally, sediment grabs were collected from a barge located near the entrance of DD4 prior to undocking. In 2013, DD1 was open to the Inlet for about six months from June to December 2013. After dewatering, silt samples were collected from the dry dock floor. In December 2013, Dry Dock Cleaning BMPs were implemented to capture and remove silts rather than simply washing the material back into bay through the drainage system. Samples of material removed from DD1 were also obtained. From 2014 – 2015, dry dock silt samples were opportunistically sampled following dewatering of various dry docks. The dry dock silt samples were collected from the dry dock surface (floor) with a clean plastic spoon and placed into a pre-cleaned polycarbonate or glass jar and held on ice until transported to the lab. At the lab, each sample was homogenized using a pre-cleaned plastic spatula and split into a 2 oz. pre-cleaned polycarbonate jar for metals, 2 oz. pre-cleaned glass jar for TOC, 8 oz. pre-cleaned glass jar for organics, and a 4 oz. glass jar for grain size. All samples except grain size were stored frozen (<-20˚C). The silt samples were analyzed for metals, PCBs, PAHs, Hg, TOC, and grain size.

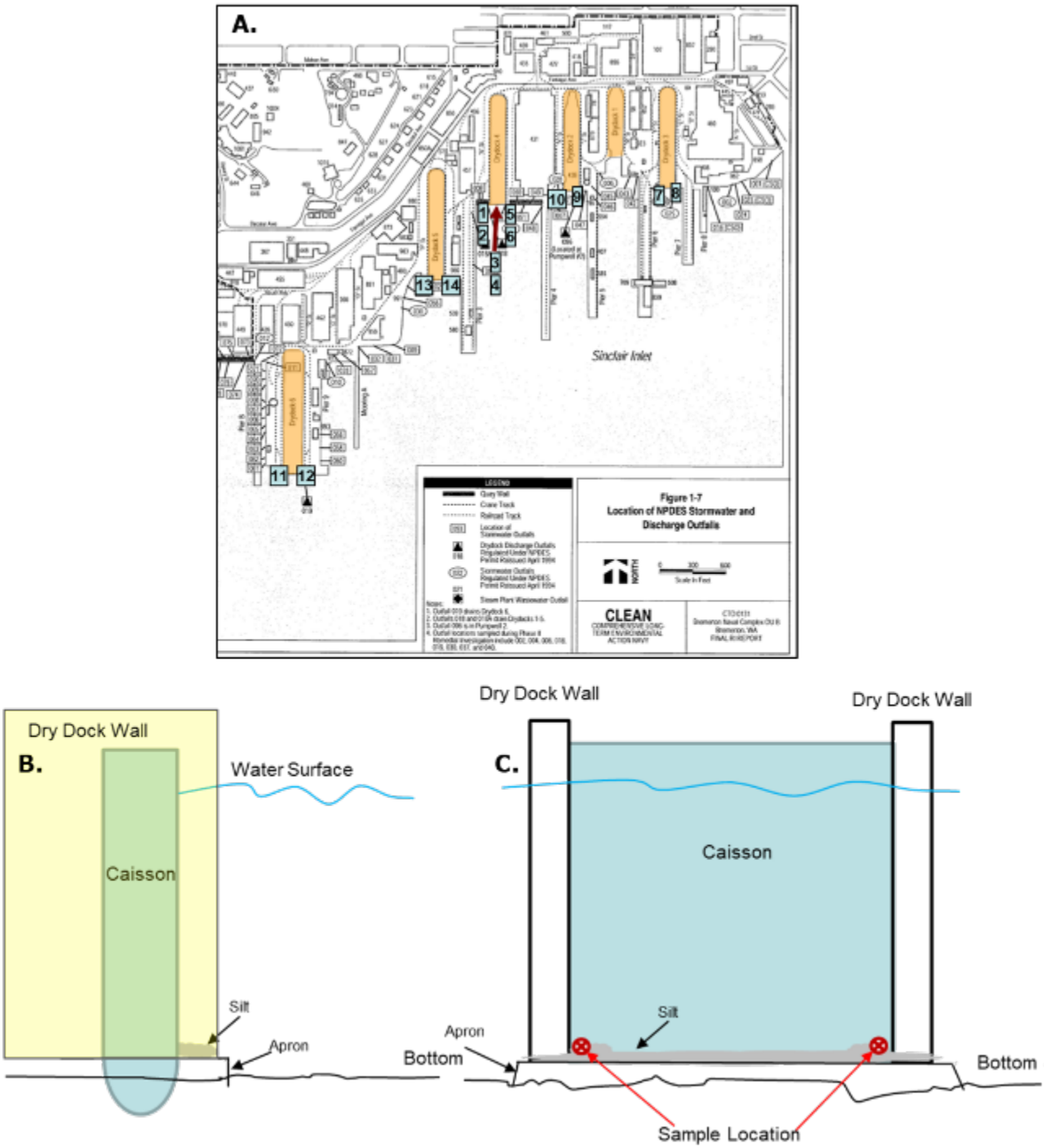


Figure 30. Location of caisson silt samples (A) and schematic of dry dock caisson side view (B) and front view (C) showing silt sampling locations (not to scale).

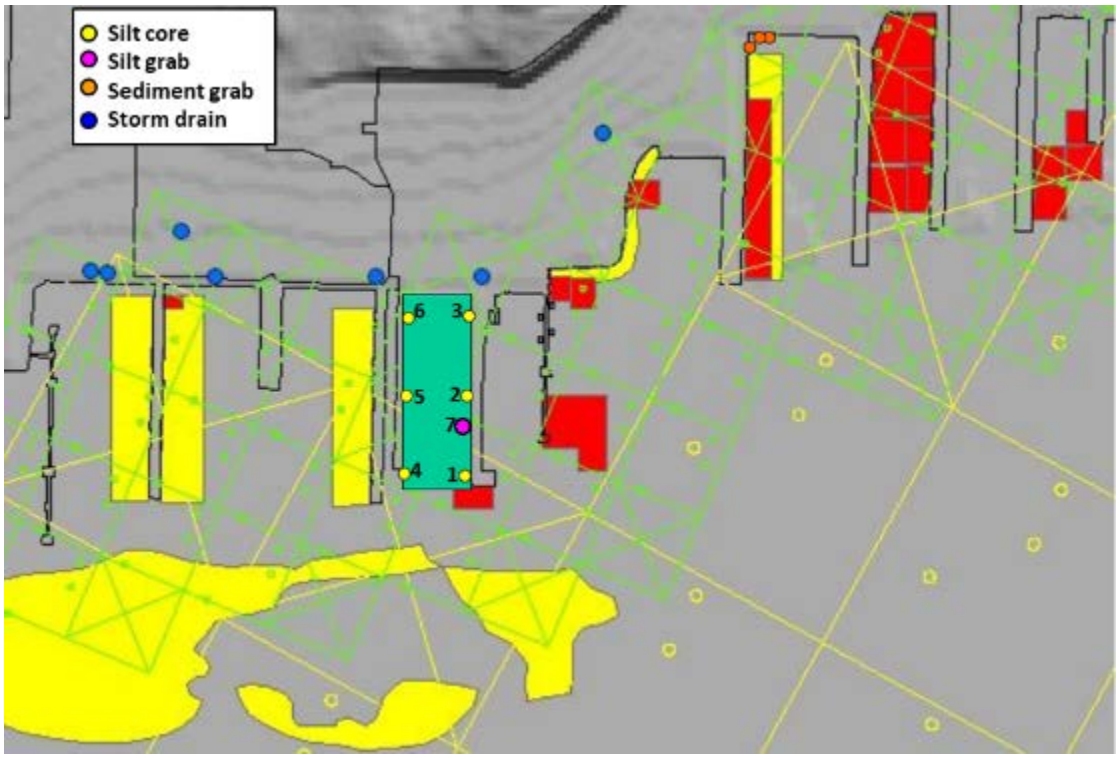


Figure 31. Location of silt cores and grabs collected inside DD6 before dewatering in 2010 after being opened to the Inlet for six months (samples 1-6) and after dewatering (sample 7) and sediment grabs collected near entrance to DD4 (orange points). Storm drain monitoring is reported in **(Brandenberger et al. 2018)**, yellow and green circles are OUBM LTM sampling locations.

Sediment/silt samples were collected opportunistically from the floors and caissons of the dry dock during docking and undocking operations. Silt samples were collected as described in the sampling and analysis plan (PNNL and CardnoTEC 2014). Typical dry dock silt sampling is shown in Figure 33. A brief description of the sample preparation and fractionation is provided below.

The bulk sample was fractionated into two fractions Coarse and Fine for metals analyses by passing first through a 2 mm (to remove pebbles, shell hash, and other debris) and then a 63 µm sieve. The sieves were pre-cleaned plastic material to prevent metal contamination. Due to the limited material, the priority order for analyses was metal>TOC>grain size. The fractionation steps are listed below.

1. Divide the bulk sample into aliquots for fractionation, TOC, moisture, and grain size. With approximate masses of 10g, 3g, and 20 g, respectively.

2. Weigh out approximately 10 g wet aliquot for fractionation.

3. Pass the entire sample through a pre-cleaned, plastic 2mm sieve using DI water to make sure smaller particles are not entrained with the larger particles left on the sieve.

4. Weight the sample and freeze at -80°C.

5. Lyophilize the sample to remove the excess water, ball mill to homogenize, and digest a representative aliquot for metals analyses as discussed below.

6. If the sample was primarily silt, the optional step was to skip steps 4 and 5. Collect an aliquot for metals analyses of the sample that passes 2 mm and pass the remaining sample through a 63µm pre-cleaned, plastic sieve. After the second sieving, follow step 4 and 5 to create a second sample for metals analyses.

7. Between each sample the plastic sieves were washed with hot dilute Micro solution, 5 % Nitric acid, and copious DI water rinse.

The particle size fractions represented two material classes (Figure 32):

Coarse: sands that were < 2 mm but ≥ 63 µm and

Fine: silts/clays < 63 µm.

The data were analyzed to characterize the texture and contaminant concentrations of the material collected from the dry docks after dewatering by analyzing the concentration of contaminants on the coarse (C_{Coarse}) and fine (C_{Fine}) fractions and calculating the apparent loading concentrations on the total material (C_{Total})

$$C_{Total} = (C_{Coarse} \times M_{Coarse} + C_{Fine} \times M_{Fine})/(M_{Coarse} + M_{Fine})$$

$$= (C_{Coarse} \times M_{Coarse})/(M_{Coarse} + M_{Fine}) + (C_{Fine} \times M_{Fine})/(M_{Coarse} + M_{Fine})$$

$$= C_{Coarse} \times (M_{Coarse})/(M_{Coarse} + M_{Fine}) + C_{Fine} \times (M_{Fine})/(M_{Coarse} + M_{Fine})$$

$$= C_{Coarse} \times f_{COARSE} + C_{Fine} \times f_{FINE}$$

Where $f_{COARSE} = (M_{Coarse})/(M_{Coarse} + M_{Fine})$

$f_{FINE} = (M_{Fine})/(M_{Coarse} + M_{Fine})$

and M_{Coarse} and M_{Fine} were the mass (g dry weight) of the coarse and fine fractions, respectively.

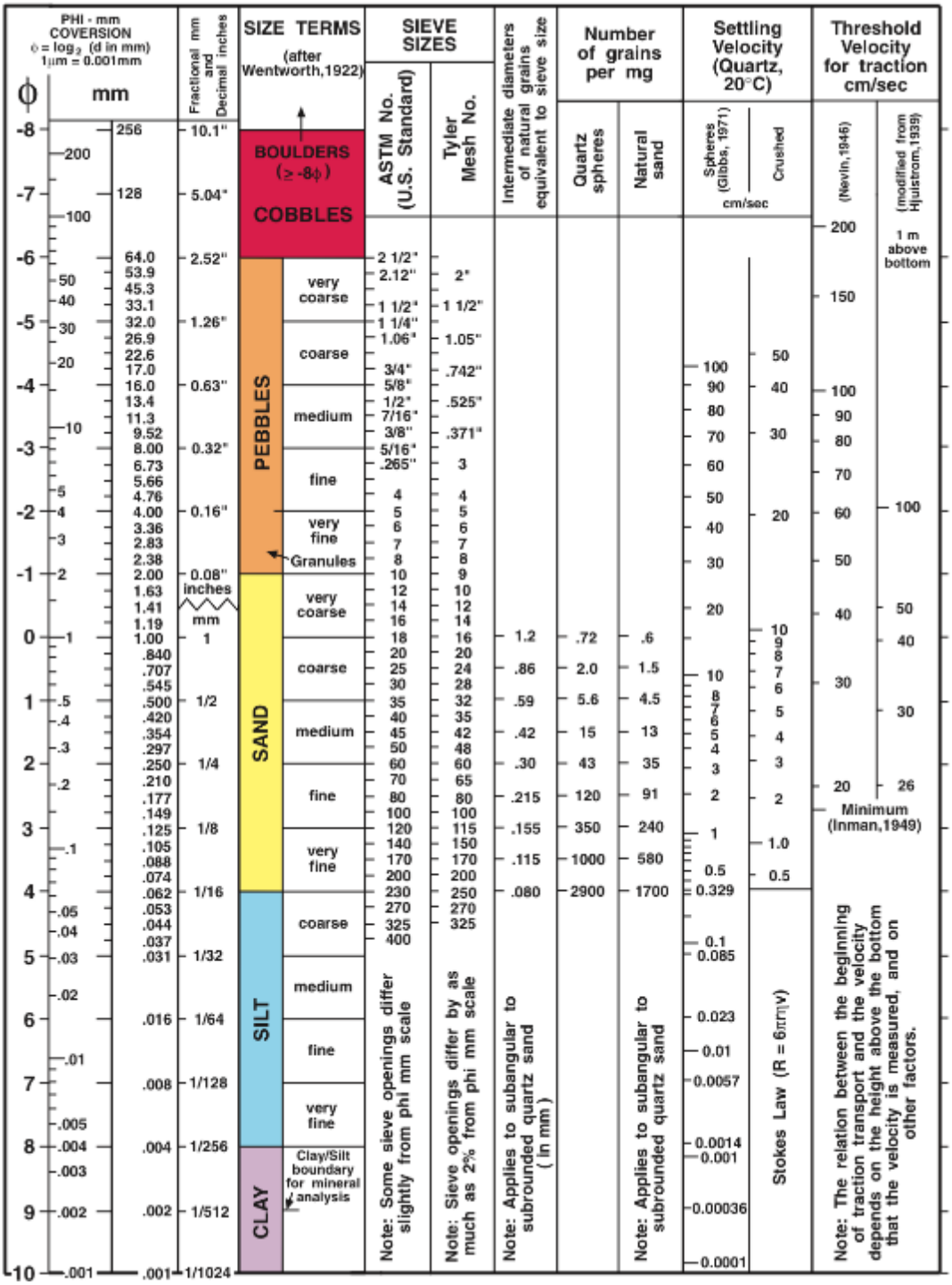


Figure 32. Wentworth scale showing scale for fractions collected during dry dock silt study which included a Coarse fraction (sands < 2.0 mm and ≥ 0.0625 mm (62.5 µm)) and a Fine fraction (silts and clays < 62.5 µm). Image from https://upload.wikimedia.org/wikipedia/commons/a/a0/Wentworth_scale.png

Figure 33. Example of collecting silt samples from dry dock floor after dewatering. DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.

4.0 Analytical Methods

4.1 Rapid Sediment Characterization

RSC analysis were conducted following procedures recommended by (Kirtay and Apitz 2000; Kirtay and Apitz 2001) and conducted for previous verification studies (Kohn et al. 2004; Kohn et al. 2006; Kohn et al. 2008). Two types of analyses were conducted for this study: 1) screening analysis using a field portable XRF for metals and immunoassays for PCBs and PAHs and 2) quantitative laboratory analytical analysis using ICP for metals, and GCMS for PAHs. The RSC methods were used to screen the OUBM for metals and PAHs and the other samples were screened for PAHs and PCBs. As discussed above, laboratory confirmation was conducted on a subset of the samples. The methods, reliable detection limits, SQS, and MCC are summarized in Table **14**.

Sample aliquots for XRF analysis were homogenized and analyzed directly using the modified EPA Method 6200 (U.S. Environmental Protection Agency 1998). XRF spectrometry is an analytical technique that provides rapid, multi-element analysis of metals in soils/sediments. Samples were exposed to X-ray energy, which liberates electrons in the inner shell of metal atoms. As the outer electrons cascade toward the inner shells to fill the vacancies, energy is released (fluorescence). The fluorescing energy spectrum identifies the metals and the intensity is proportional to concentration. Sediment samples were analyzed using a X-MET 3000TX Field Portable X-ray Fluorescence (FPXRF) Spectrometer (Oxford Instruments, Elk Grove Village, IL). The X-MET is a field portable elemental analyzer based on energy dispersive XRF technology. The instrument was specifically calibrated for soil/sediment (alloy class) applications and utilized an integrated personal digital assistance (PDA) computer for data storage. The probe contained a miniature, programmable X-ray tube for primary generation of x-rays (40 kV, 40 μamps) and a Peltier cooled, solid-state Silicone-P-type/intrinsic/N-type detector. The X-MET data output from each sample analysis included a broad elemental spectrum display from the K series X-ray lines at the 2.04–31.68 keV energy range and their associated dry-weight metal concentrations (in mg/Kg or ppm) with error estimates. XRF values were obtained for Fe_{XRF}, Cu_{XRF}, Pb_{XRF}, and Zn_{XRF}.

Immunoassay test kits for PAHs and PCBs (RaPID® Assay, Strategic Diagnostics Inc., Newark, DE) available at (Modernwater 2013a; Modernwater 2013b) were used to quantify the total PAHs (PAH_{RSC}) and PCBs (PCB_{RSC}) in the sediment samples. In general, the immunoassay method was performed on samples extracted with methanol. An enzyme conjugate and paramagnetic antibodies were added to the sample extract. The enzyme conjugate "competes" with the contaminant of interest (PCB/PAH) present in the sample for binding to the antibody. In relatively proportional concentrations, both the sample PCBs and the "labeled" PCB/PAH (conjugate) compete for the binding sites on the magnetic particles. After an incubation period, a magnetic field was applied to hold (in-place) the magnetic particles having the sample PCB/PAH and its "labeled" analog to bind with the antibodies. Any unbound reagents were decanted and washed repeatedly. The PCB/PAH concentration in the mixture was detected with the addition of an enzyme substrate (color solution) containing a chromagen, which specifically react to the "labeled" PCB/PAH. After another incubation, the reaction was stopped and stabilized by addition of acid (stopping solution). Since the labeled PCB/PAH and sample PCB/PAH were in competition (proportionally) with the binding sites, the color developed at the end of reaction was inversely proportional to the concentration of PCB/PAH in the sample. This color response was measured by a spectrophotometer (set at 450 nm) and compared the response produced by the sample test to the response produced by testing a range of kit-supplied standards simultaneously.

Table 14. Reliable detection limits of RSC methods and Lab methods compared with state SMSs for ENVVEST metals of concern.

Analyte	Units	Reliable Detection Limit for RSC	Lab Method	Laboratory Method Detection Limits	Washington State Sediment Management Standards	
					SQS	MCC
Al	mg/kg dry wt	N/A	ICP-OES	4	na	na
Ag	mg/kg dry wt	10.0	ICP-MS	0.002	6.1	6.1
As	mg/kg dry wt	20.0	ICP-MS	0.2	57	93
Cd	mg/kg dry wt	5.0	ICP-MS	0.003	5.1	6.7
Cr	mg/kg dry wt	100	ICP-OES	0.2	260	270
Cu	mg/kg dry wt	18.0	ICP-OES	0.1	390	390
Fe	mg/kg dry wt	1000	ICP-OES	1.0	na	na
Mn	mg/kg dry wt		ICP-OES	0.1	na	na
Ni	mg/kg dry wt	50.0	ICP-OES	0.3	na	na
Pb	mg/kg dry wt	8.0	ICP-MS	0.003	450	530
Zn	mg/kg dry wt	16.0	ICP-OES	0.2	410	960
Hg	mg/kg dry wt		CVAA	0.0057	0.41	0.59
PAHs	µg/kg dry wt	200			See Table 6	
Naphthalene	µg/kg dry wt		GC/MS	0.28		
2-Methyl naphthalene	µg/kg dry wt		GC/MS	0.54		
Acenaphthylene	µg/kg dry wt		GC/MS	0.45		
Acenaphthene	µg/kg dry wt		GC/MS	0.43		
Fluorene	µg/kg dry wt		GC/MS	0.54		
Phenanthrene	µg/kg dry wt		GC/MS	0.70		
Anthracene	µg/kg dry wt		GC/MS	0.76		
Fluoranthene	µg/kg dry wt		GC/MS	0.62		
Pyrene	µg/kg dry wt		GC/MS	0.60		
Benzo(a)anthracene	µg/kg dry wt		GC/MS	0.55		
Chrysene	µg/kg dry wt		GC/MS	0.66		
Benzo(a)pyrene	µg/kg dry wt		GC/MS	0.81		
Total Benzofluoranthenes	µg/kg dry wt		GC/MS	NA[a]		
Indeno(1,2,3-c,d)pyrene	µg/kg dry wt		GC/MS	1.05		
Dibenz(a,h)anthracene	µg/kg dry wt		GC/MS	0.80		
Benzo(g,h,i)perylene	µg/kg dry wt		GC/MS	0.89		
PCB**s**	µg/kg dry wt	500				
PCB Congeners (NOAA NS&T 20 congeners)	µg/kg dry wt		GC/ECD	0.075		

4.2 Sediment Confirmatory Analyses

4.2.1 Metals Analysis

Samples for metals analysis were freeze-dried and homogenized using a ball-mill prior to digestion according to Battelle SOP MSL-C-003, Percent Dry Weight and Homogenizing Dry Sediment, Soil and Tissue. Sediment samples were digested in accordance with Battelle SOP MSL-I-006, Mixed Acid Sediment Digestion. The sediment samples were digested using a total dissolution method followed by boric acid neutralization. Briefly, an approximately 400-mg (dry weight) aliquot of each sample was combined with nitric, hydrochloric, and hydrofluoric acids in a Teflon digestion vessel and heated in an oven at 130ºC (±10ºC) for a minimum of eight hours. After cooling, boric acid was added to the digestate and reheated to 130°C for an additional four hours in order to neutralize the hydrofluoric acid, finally deionized water was added to achieve analysis volume.

Digested samples were analyzed for Hg using cold-vapor atomic absorption spectroscopy (CVAA) according to Battelle SOP MSL-I-016, Total Mercury in Tissues and Sediments by Cold Vapor Atomic Absorption. This is a deviation from the proposed method (Direct Mercury Analysis) due to the higher concentrations of Hg. The achieved MDL is slightly higher, but all samples were detected more than an order of magnitude of the MDL. Therefore, there was no impact to the data quality due to this deviation. All results were reported in units of µg/g on a dry-weight basis.

For all other metals, digested samples were analyzed for Al, Cr, Ni, and Zn using inductively coupled plasma-optical emissions spectroscopy (ICP-OES) according to Battelle SOP MSL-I-033, Determination of Elements in Aqueous and Digestate Samples by ICP-OES. This procedure is based on two methods modified and adapted for analysis of low-level samples: EPA Method 6010B and 200.7.

Digested samples were analyzed for Ag, As, Cd, Cu, and Pb using inductively coupled plasma-mass spectrometry (ICP-MS) according to Battelle SOP MSL-I-022, Determination of Elements in Aqueous and Digestate Samples by ICP/MS. All results will be reported in units of µg/g on a dry-weight basis.

4.2.2 Organics Analysis

For the analysis of PAH compounds, cleanup procedures followed the low-level methods developed for the National Oceanic and Atmospheric Administration (NOAA) Status and Trends Program (Lauenstein and Cantillo 1993). PAH analysis used MSL SOPs MSL-O-015 (Identification and Quantification of Polynuclear Aromatic Hydrocarbons by Gas Chromatography/Mass Spectrometry Following EPA Method 8270B Quality Control Criteria). The MSL methods were modifications of SW-846 EPA Methods 8270B and 8080A. Specific analytes and their respective detection limits are provided in Table **14**.

4.2.3 Ancillary

For the verification study the TOC, PCB, Hg, and grain size data were obtained from the 2010 OUBM LTM monitoring. For the other sediment studies TOC was analyzed by Columbia Analytical Services (CAS, Kelso, Washington) following Method ASTM D4129-82 M. The following QC procedures were followed by the method:

1. Method Blank: analyze a method blank at a rate of 1:20 samples, do not blank correct data; level <20x lowest sample

2. Precision: Duplicate sample analyzed at a rate of 1:20 samples; RPD ≤ 20%
3. Reference Material: Reference sample analyzed at a rate of 1:20 samples; Recovery Range 85-115%
4. Matrix spike/matrix spike duplicate: MS/MSD analyzed at rate of 1:20 samples; Recovery range 75-125% and RPD ≤ 20%.

4.2.4 AVS-SEM

Sediment samples were extracted and analyzed for AVS in accordance with MSL SOP MSL-C-001. This procedure is based on a peer-reviewed, published procedure for the analysis of AVS in sediment and dissolved sulfide in aqueous samples, which was adopted from a draft EPA Method (Allen et al. 1991). In this method, sulfide in the sample is converted to hydrogen sulfide by the addition of hydrochloric acid at room temperature. The hydrogen sulfide (H_2S) is purged from the sample by an inert gas and trapped in a sodium hydroxide (NaOH) solution. With the addition of a mixed-diamine reagent (MDR), the sulfide is converted to methylene blue and measured on a spectrometer. The AVS results were reported in units of µmole/g on a dry-weight basis.

The SEM extracts were analyzed for Cd, Cu, Ni, Pb, and Zn by ICP-MS in accordance with SOP MSL-I-022.The analysis guidelines for this procedure are adapted from EPA Method 1638 Determination of Trace Elements in Ambient Waters by Inductively Coupled Plasma-Mass Spectrometry. The SEM extracts were analyzed for total Hg by Cold Vapor Atomic Fluorescence (CVAF) following EPA Method 1631 revision E. The SEM metal solution concentrations were determined in units of µg/L and then converted to µg SEM/g of sediment extracted for AVS. These data were further converted to µmole/g for each SEM metal to calculate the ∑SEM.

4.2.5 Porewater

Porewater samples were analyzed for the SEM metals plus iron (Fe), manganese (Mn), and dissolved sulfide. The porewater samples were analyzed at a dilution to provide sufficient volume for the analyses of metals by ICP-MS, Hg, dissolved sulfide, and DOC. The analysis of metals by ICP were conducted in the same manner as described above. The dissolved sulfide were analyzed following MSL SOP MSL-C-001 and the DOC samples were analyzed by high temperature combustion methods modified from (Spyres et al. 2000).

4.3 Sediment Toxicity Assessment

Contaminants like Cu and Zn are frequently elevated in marine sediments at coastal U.S. Navy facilities. Although these metals are naturally occurring, and essential for life, there are numerous anthropogenic sources of Cu and Zn that frequently result in elevated, potentially harmful, sediment concentrations. For the Navy, one of the largest sources of Cu and Zn in coastal embayments is from antifouling paint systems on ship hulls (Earley et al. 2018). Assessment and regulation of adverse effects in these sediments typically occurs via co-occurrence-based SQG using total metal concentration (e.g. Long et al. 1995; McDonald et al. 1996). The bioavailability and potential toxicity of Cu and Zn, however, is not necessarily related to total concentrations measured in bulk sediments, complicating appropriate application of SQGs for environmental regulation.

This study was designed to support the development of improved tools for assessment of Cu and Zn bioavailability and toxicity in sediments located at Navy facilities. The primary focus of the study was to build on the recent results published by others (e.g. Simpson et al. 2008; Strom et al., 2011), which

suggest that expressing sediment Cu concentrations in terms of the metal concentration measured in the fraction of sediment equal or smaller to 63 µm (silt-size fraction of the sediment), normalized to the total organic carbon (TOC) content in the silt-size fraction, provides a vast improvement in the predictability of metal toxicity over current methods based on bulk sediment concentration, or TOC normalization of the bulk concentration. Successful demonstration and validation of this tool could vastly simplify and improve the assessment of contaminant bioavailability and toxicity in DoD sediments, potentially reducing costs associated with their future assessment and remediation.

For this study, all toxicity testing was conducted in accordance with standard methods (USEPA 1994, 1995; ASTM 1996). The 10-day amphipod survival tests were conducted with whole sediment, the 28-day polychaete survival and growth tests, and the 2-day SWI bivalve embryo development tests were conducted on the samples listed in Table **15**. Negative controls consisting of sediment from the amphipod collection site were included in the 10-day whole sediment test. For the 2-day SWI test, a chamber control (screen tube) and a seawater negative control were also tested concurrently.

Table 15. Sediment Sample Location, Sample Type, Collection and Receipt Dates, and Temperature of the Samples upon Receipt at the Bioassay Laboratory.

Sample/ Station ID	Latitude	Longitude	Type	Sample Collection Date	Sample Receipt Date/Time	Sample Receipt Temperature (°C)
PS03 (NBK)	47.555783	-122.65192	Grab	4/27/2011 11:25	4/29/2011 09:00	6.1
			Intact Core	4/27/2011 10:50	4/29/2011 09:00	6.1
PS09 (PSNS)	47.560127	-122.63649	Grab	4/27/2011 12:35	4/29/2011 09:00	6.1
			Intact Core	4/27/2011 12:20	4/29/2011 09:00	6.1

For both the whole sediment and SWI toxicity tests, samples from the overlying water were collected at the beginning and end of the exposures, while porewater, DGT samplers and sediment samples were collected and analyzed at the test termination only. All test chambers were set up with sediment, water and aeration on the day prior to test initiation. Screen tubes for the SWI test were gently introduced to each core tube on the day of test initiation. Exposure concentrations of total and dissolved Cu and Zn were analyzed in the pore water (PW), overlying water (OW), bulk sediment, and tissue concentrations of polychaete worms following methodology recommended by USEPA, including use of trace metal clean sampling techniques in the collection, handling and analysis (see Appendix A.4 Sediment Toxicity Data Report). The Toxic Units (TU) were calculated by summing the exposure concentrations of dissolved Cu and Zn divided by their respective chronic water quality standards.

Water quality parameters including pH, dissolved oxygen (DO), salinity, temperature and ammonia were measured in the overlying water prior to organism addition to ensure that conditions were within those tolerated. Daily observations of water quality, aeration and sediment condition (e.g., anoxia, microbial growth, etc.) were made. All instruments used for water quality measurements were calibrated daily according to manufacturer specifications (see Appendix A.4 Sediment Toxicity Data Report). Test Acceptability Criteria (TAC) were evaluated for each bioassay (Table 16).

Table 16. Bioassay method, test media, and test acceptability criteria (TAC) used for the toxicity assessment.

Bioassay Method	Media	TAC
2-day Chronic Exposure Using Mussel Embryo-Larvae	Sediment-Water Interface	≥ 80% mean normal alive in control
10-day Acute Exposure Using Marine Amphipods	Whole Sediment	≥ 90% survival in control sediment
28-day Chronic Exposure Using the Marine Polychaete	Whole Sediment	≥ 80% mean survival in control sediment and positive growth in control organisms

5.0 Quality Assurance and Quality Control Requirements

5.1 Analytical Chemistry

This section defines the QA program that was followed for this study. Appropriate field and laboratory QC procedures were designed to assess data quality through the measures of accuracy and precision.

5.1.1 Measurement and Data Definitions

Accuracy is defined as the degree of agreement between an observed value and an accepted reference value. Accuracy includes a combination of random error (precision) and systematic error (bias) components that are due to sampling and analytical operations.

Precision is defined as the degree to which a set of observations or measurements of the same property, obtained under similar conditions, conform to themselves. Precision is usually expressed as standard deviation, variance, or range, in either absolute or relative terms.

Completeness is the amount of data collected as compared to the amount needed to ensure that the uncertainty or error is within acceptable limits. The goal for data completeness is 100%. However, the project will not be compromised if 90% of the samples collected are analyzed with acceptable quality.

Comparability is a measure of the confidence with which one data set can be compared to another. This is a qualitative assessment and is addressed primarily in sampling design through use of comparable sampling procedures or, for monitoring programs, through accurate re-sampling of stations over time. In the laboratory, comparability is assured through the use of comparable analytical procedures and ensuring that project staff is trained in the proper application of the procedures. Study comparability will be assessed through analytical performance (results from the analysis of QC samples), especially those that assess accuracy (standard reference materials, matrix spikes).

Representativeness is the degree to which data accurately and precisely represent a characteristic of a population. This is a qualitative assessment and is addressed primarily in the sample design, through the selection of sampling sites, and procedures that reflect the project goals and environment being sampled. It is ensured in the laboratory through (1) the proper handling, homogenizing, and storage of samples and (2) analysis within the specified holding times so that the material analyzed reflects the material collected as accurately as possible.

Sensitivity is the capability of a test method or instrument to discriminate between measurement responses representing different levels (*e.g.*, concentrations) of a variable of interest. Sensitivity is addressed primarily through the selection of appropriate analytical methods, equipment, and instrumentation. The methods selected for the Metals Verification Study were chosen to allow analysis of a large number of samples yet provide the sensitivity required for the end-use of the data. This is a quantitative assessment and is monitored through the instrument calibrations and calibration verification samples and the analysis of procedural blanks with every analytical batch.

Method Detection Limits (MDLs) were determined annually through an MDL Verification Study or full MDL study according to Battelle MDL SOP Q-007.

Reporting Limits (RLs) for trace metals are calculated by multiplying the target analyte MDL by 3.18. The value 3.18 is based on the Student's *t*-value for 7 to 10 replicates, the number of replicates usually

analyzed to generate the MDL. The standard practice for PAHs is to use the lowest standard as the RL. The data qualifier "J" was added to any reported values that were less than the RL.

5.1.2 QA/QC for Chemical Analyses

The study design and QC samples were used to assess the major components of total study error, which facilitated the final evaluation of whether environmental data are of sufficient quality to support the related decisions. The QC sample requirements were designed to provide measurement error information that was used to initiate corrective actions with the goal of limiting the total measurement error. The QC samples and frequency are detailed in Table **17**. Measurement quality objectives for the analyses were expressed in terms of accuracy, precision, completeness, and sensitivity goals. Accuracy and precision were monitored through the analysis of QC samples. Table **18** defines the required accuracy and precision for QC samples, along with corrective actions that must be implemented when QC criteria are not met. Table **19** provides formulas for the calculation of QC sample assessment statistics. All QC sample failures and associated corrective actions were documented in the accompanying analytical chemistry data reports (9.0Appendix A Appendix A Data Reports). If data were reported with failing QC results, then data qualifiers were assigned to the QC sample data. The project data qualifiers are listed in Table **20**.

Table 17. Definitions, Requirements, and Frequency for Laboratory Quality Control Samples

QC Sample	Definition	Frequency
Method or Procedural Blank (MB)	A combination of solvents, surrogates, and all reagents used during sample processing, processed concurrently with the field samples. Monitors purity of reagents and laboratory contamination.	1/sample batch[a] All analytes
Standard Reference Material (SRM) or Certified	An external reference sample which contain a certified level of target analytes; serves as a monitor of accuracy. Extracted and analyzed with samples of a like matrix.	1/ sample batch[a] Analyzed for metals.
Matrix Spike (MS) [b]	A field sample spiked with the analytes of interest is processed concurrently with the field samples; monitors effectiveness of method on sample matrix; performed in duplicate (MSD) for sediments. An MS must be processed for each distinct matrix.	1/sample batch[a] Analyzed for metals
Duplicate Sample	Second aliquot of a field sample processed and analyzed to monitor precision; each sample set should contain a duplicate.	1/sample batch[a] All analytes
Recovery Internal Standards (RIS)	All field and QC samples are spiked with recovery internal standards just prior to analysis; used to quantify surrogates to monitor extraction efficiency on a per sample basis.	Each sample analyzed for organic compounds
Surrogate Internal Standards (SIS)	All field and QC samples are spiked with a known amount of surrogates just prior to extraction; recoveries are calculated to quantify extraction efficiency.	Each sample analyzed for organic compounds

a. A batch was defined as 20 field samples or less processed simultaneously and sharing the same QC samples such that QC samples were about 5% of the total analyses conducted.
b. Non-Navy samples may not be substituted to meet this requirement.

Table 18. Measurement quality criteria parameters, acceptance criteria for data quality objectives, and corrective actions used for the SQV study.

QC Parameter	Acceptance Criteria	Corrective Action
Accuracy		
Method Blank (MB) *(For this table, MB or EB = B)*	B or B<MDL If B>MDL and <RL then perform corrective action	Review data and analysis for possible sources of contamination. Reanalyze and/or document corrective action.
	B or B<MDL If B>MDL and >RL; sample values > 10X B, then perform corrective action	Review data and analysis for possible sources of contamination. Reanalyze and/or document corrective action. Data must be flagged.
	B<MDL If B>MDL and >RL; sample values ≤10X B, then perform corrective action	Perform corrective action as above and re-process (extract, digest) sample batch. If batch cannot be re-processed, notify client and flag data.
	XRF Instrument Blank (quartz): Sample values >10X MB	Review data and analysis for possible sources of contamination. Reanalyze and/or document corrective action. Data must be flagged.
	Immunoassay Instrument Blank: Sample values >10X MB	Review data and analysis for possible sources of contamination. Reanalyze and/or document corrective action. Data must be flagged.
Standard Reference Material (SRM)	Organic compounds: Average percent difference (PD) ≤30%; ≤35% for each analyte. Metals: ≤20% PD. XRF (PACS-1 and/or PACS-2)[a]: ≤20% PD Determined vs. certified range. Analyte concentration must be 10xMDL to be used for DQO.	Review data to assess impact of matrix. Reanalyze sample and/or document corrective action. If other QC data are acceptable then flag associated data if sample is not reanalyzed.
MS/MS Duplicate (MSD)	Organic compounds: 40 - 120% recovery Metals: 70 - 130% recovery	Review data to assess impact of matrix. If other QC data are acceptable and no spiking error occurred, then flag associated data. If QC data are not affected by matrix failure or spiking errors occurred, then re-process MS. If not possible, then notify client and flag associated data.
Surrogate Spike (SIS)	Organic compounds: 40 - 120% recovery	Review data. Discuss with Project Manager. Reanalyze, re-extract, and/or document corrective action and deviations.
Laboratory Control Sample (LCS)	Organic compounds: 40 - 120% recovery Metals: 70 - 130% recovery Immunoassay (Aroclor 1254 and Phenanthrene): ±20% Recovery	Perform corrective action. Reanalyze and/or re-process sample batch. Batch data associated with failed LCS (LCS data outside control limits) cannot be reported. If batch cannot be re-processed: notify client, flag data, discuss impact in report narrative.
Instrument Check	Organic compounds: 85 - 115% recovery	Perform corrective action. Reanalyze and/or re-process sample batch. Data outside control limits cannot be reported. If batch cannot be re-processed, notify client, flag data, discuss impact in report narrative.
Precision: *Laboratory Duplicates*	Organic compounds (MSD): <30% RPD Metals: <30% RPD XRF: <20% RPD Immunoassay Extraction duplicate <30% RPD Immunoassay Assay duplicate <30% RPD	Review data to assess impact of matrix. If other QC data are acceptable, then flag associated data. If QC data are not affected by matrix failure, then re-process duplicate. If not possible, then notify client and flag associated data.

a. Marine sediment reference material for trace metals and other constituents (National Research Council Canada 2013 Oct 15)

Table 19. Calculation of Quality Control Assessment Statistics

Percent Recovery

The percent recovery is a measurement of accuracy, where one value is compared with a known/certified value. The formula for calculating this value is:

$$Percent\ Recovery = \frac{amount\ detected}{amount\ expected}\ x\ 100$$

Percent Difference

The PD is a measurement of precision as an indication of how a measured value is difference from a "real" value. It is used when one value is known or certified, and the other is measured. The formula for calculating PD is:

$$Percent\ Difference = \frac{X_2 - X_1}{X_1}\ x\ 100$$

where: X_1 = known value (*e.g.*, SRM certified value)
X_2 = determined value (*e.g.*, SRM concentration determined by analyst)

Relative Percent Difference

The relative percent difference (RPD) is a measurement of ***precision***; it is a comparison of two similar samples (MS/MSD pair, field sample duplicates). The formula for calculating RPD is:

$$RPD = \left| \frac{2\ x\ (X_1 - X_2)}{(X_1 + X_2)} \right|\ x\ 100$$

where: X_1 is concentration or percent recovery in sample 1
X_2 is concentration or percent recovery in sample 2

Note: Report the absolute value of the result -- the RPD is always positive.

Relative Standard Deviation

The relative standard deviation (RSD) is a measurement of ***precision***; it is a comparison of three or more similar samples (*e.g.*, field sample triplicates, initial calibration, MDLs). The formula for calculating RSD is:

%RSD = (Standard Deviation of All Samples)/(Average of All Samples) x 100

Table 20. ENVVEST Data Qualifiers.

#	Outside Project DQO guidelines for SIS recovery (40-120%)
*	Associated Surrogate recovery exceeded guidelines (40-120%)
&	Outside Project DQOs for Spike Recovery (40-120% recovery) or Replicate Analysis (≤30% RPD) or SRM (<30% difference)
E	Estimate; see narrative
ME	Estimate due to matrix effect; see narrative
D	Results determined from dilution
T	Hold time exceeded; see narrative
NC	Not able to calculate
NR	No result reported; see narrative
NS	Sample not spiked
NA	Not applicable/available
A	Result is most likely an outlier; see narrative
B	Analyte detected in the method blank above the RL, sample concentration <10 times detected blank value.
U	Analyte not detected at or above the laboratory achieved detection limit, MDL reported
J	Analyte concentration is less than the RL, but greater than the MDL
c	Exceeds Project DQO but meets contingency criteria
R	Data exceeds calibration range; see narrative for data use limits
N	Spiked sample recovery outside QC criteria of 70-130% recovery
&	Accuracy result outside QC criteria of ≤ 20% PD
*	Precision result outside QC criteria of < 30% RPD

5.1.3 Data Quality Review Procedures

Data quality review includes data verification, validation, and oversight, as well as reconciliation of the data quality with user requirements. The data verification process includes the initial review of the data packages to ensure that the analyses requested have been provided. Data validation is the process of reviewing data and accepting, qualifying, or rejecting data on the basis of sound criteria. Data were reviewed by the PNNL MSL Chemistry Task Leader to assure that it was complete. The data report for quantitative metals analysis was submitted by the Chemistry Task Leader to the PNNL QA Manager for QA review. All QA review comments and corrective actions were implemented before the final data report and narrative was provided to the client. The PNNL QA Manager conducted project reviews frequently enough to ensure that the work was being conducted according to the QAPP and SOPs, and that any corrective action plans were implemented to address any deficiencies identified.

5.1.4 Instrumentation/Equipment Testing, Inspection, and Maintenance

Field Equipment. The Navy provided field equipment, instruments, the boat(s), GPS, and other supplies for the field-sampling program. After inspection and testing prior to use in the field, the GPS was used to determine actual sampling station coordinates. Coordinates for each sampling were reported in Universal Transverse Mercator (UTM) grid coordinates to the USGS 1983 North American Datum (NAD 83).

Laboratory Equipment. All analytical instruments and equipment were maintained according to SOPs and the manufacturers' instructions. Equipment and instrument maintenance and frequency are defined in SOPs and are summarized in Tables 16 and 17. All routine maintenance and non-routine repairs are to be documented in a bound logbook. The information recorded should include analyst initials, date maintenance was performed, a description of the maintenance activity, and (if the maintenance was performed in response to a specific instrument performance problem) the result of re-testing to demonstrate that the instrument performance had been returned to acceptable standards prior to re-use. The return to analytical control is demonstrated by successful calibration.

Table 21. Maintenance Procedures for General Laboratory Equipment

Equipment	Activity	Frequency
Deionized water system	Replace seals Replace cartridges	As needed for leaks and to maintain resistivity > 18 megohm
MilliQ deionized water system	Replace seals Replace cartridges	Every 6 months or as needed for leaks and to maintain resistivity > 18 megohm
Electronic balances	Clean	As needed
Freezers/refrigerators	Clean Defrost	As needed
Ovens	Clean	As needed
Glass thermometers	Store in protective case	Always except when in use
Digital thermometer	Avoid bending thermocouples	Always

Table 22. Maintenance Procedures for Analytical Instruments

Equipment	Activity	Frequency
ICP-MS Maintenance		
Argon supply	Check and record; replace as needed	Daily
Vacuum	Check and record	Daily
Cooling chiller	Check and record temperature	Daily
Nebulizer flow	Check and adjust	Daily or as needed
Sensitivity and stability	Check and record	Daily
Auto sampler tubing	Change	As needed
Cones	Clean or change	As needed
ICP-OES Maintenance		
Pump tubing	Check and replace	Daily
Diluent bottle	Check and refill	Daily
Torch	Check and clean or replace	Weekly
GC/MS Maintenance		
Rough pumps Turbomolecular pump Diffusion pumps	Routine service (service contract) Check fluid levels	Six months Weekly

Equipment	Activity	Frequency
Foreline traps Helium gas traps	Inspect trap pellets for color change Replace adsorbent pellets	Routinely 6-12 months, as needed
Injection port septum	Replace	As needed to maintain EPC pressure
Injection port liners	Replace	Approximately every 30-40 samples
Precolumn	Replace	As needed to improve peak shape, resolution, or sensitivity
Calibration vial (PFTBA)	Refill	4 months or as needed
Back grills of the MS	Vacuum dust	6 months or as needed
Ion source	Clean	As indicated when usage-dependent surface deposits degrade ion source function
GC Maintenance		
Injection port	Replace	Weekly (~50 injections) or as needed
Injection port liner	Replace	Weekly or as needed
Injection port	Clean	Monthly or as needed
Column	Clip	As needed to maintain performance
Precolumn	Replace	As needed when chromatographic degradation is observed
Gas cylinders	Replace	When PSI is < 300
Autosampler rinse vial	Fill	Prior to analysis
Autosampler syringe	Replace/align	As needed
Ferrule	Replace	As needed for leaks
Gas drying/purification traps	Replace	Annually or as needed
Column, detector	Bakeout	As needed
SSC Instruments for Immunoassay Screen		
Lamp	Check linearity	Daily with standard series
SSC Instruments for XRF Screen		
Energy	Check calibration	Daily
Cu-stability	Check stability	Bi-monthly

5.2 Toxicity Testing QA/QC

The NIWC Pacific Environmental Sciences Bioassay Laboratory (formerly SPAWAR Pacific Environmental Sciences Bioassay Laboratory) maintains laboratory certifications for bioassays from the Washington State Department of Ecology and the State of California Laboratory Accreditation Programs, employs qualified toxicologists, conducts external and internal audits, and maintains up-to-date standard operating procedures (SOPs) and good laboratory practices. A thorough QA/QC review of the data and test procedures showed that all test acceptability criteria (TAC) were met and there were no data quality issues that could impact test results; therefore, all presented data were deemed acceptable (9.0A.4 Appendix A.4 Sediment Toxicity Data Report). All tests were conducted within the recommended 1-month holding time (initiated within three days of receipt). While the temperatures of the samples upon receipt were slightly outside the EPA recommended range of 0-6 °C, the samples were in a state of cooling and this exceedance was not deemed an issue.

Control TAC were met for the *Leptocheirus* amphipod and the *Neanthes* polychaete toxicity tests. Control TAC for the SWI exposure with embryos of *M. galloprovincialis* was just under the 80% mean normal-alive. However, the tests were deemed acceptable based on the responses of the site sediments all performing better than the control. For the *Ampelisca* amphipod toxicity tests, acceptability criteria of the controls were not met (mean survival of controls <90% survival). However, percent survival in the

samples were greater than the controls, so the results were compared against the control to evaluate performance. The total ammonia concentrations were below those that would be anticipated to be toxic to the test endpoints.

5.2.1 *Reference Toxicant Testing*

A 2-day copper sulfate ($CuSO_4$) reference toxicant test was conducted concurrently for the bivalve embryo-larval development test. The lab controls associated with this test did not meet TAC and therefore was not deemed official. However, since the dose response observed was typical, the reference toxicant test results were reported for comparative and informational purposes (Table **23**). The median effective concentration (EC_{50}) was 10.2 and 9.9 µg/L for the proportion normal and proportion normal-alive endpoints, respectively. Each of these endpoints fell within two standard deviations of the laboratory's historical means (Table **23**); indicating sensitivity to copper was consistent with that historically observed for this species.

Table 23. Results Summary for the Copper Reference Toxicant Tests Concurrently Conducted with Samples Collected from Naval Base Point Loma on May 11, 2016.

Species & Endpoint	NOEC (µg/L copper)	LC_{50} or EC_{50} (µg/L copper)	Historical mean ± 2 SD (µg/L copper)
Mediterranean Mussel Embryo-Larval Development:			
Proportion Normal	8.4	9.9	7.1 ± 3.7
Proportion Normal-Survival	8.4	10.2	7.0 ± 4.3

6.0 Results and Discussion

The analytical chemistry data reports for the study are provided in Appendix A Data Reports and the data in EIM format is provided in Appendix B Raw Data . In this Section, the results of the 2010 LTM for OUBM confirmation and verification analysis are presented including the determination of definitive results for the screening using RSC methods, comparison to previous years' sampling in 2003 and 2007, and status for 303(d) sediment listings in Sinclair Inlet. Next, the results from sediment surface and core sampling in the focus areas within the Shipyard are presented and discussed for each focus area and the Pier 7 transect sampling. For each focus area, the analytical chemistry results are plotted for the surface grabs and core profiles followed by a presentation of the mSQGq calculated from the chemicals analyzed, normalized by their respective SQS thresholds resulting in the ∑SQGq for Hg, TPCB, Zn, Cr, Cu, Cd, Ag, As, Pb, and TPAH for each surface grab and core profile section. For PS03 and PS09, the results from the squeeze core for pore water and AVS and the results of the sediment toxicity study conducted are also presented.

The results from the dry dock silt study were used to evaluate contaminant loading from the coarse and fine particles sampled from the dry dock floor after dewatering. The geochemical distributions from Hg, PCB, Cu, Pb, and Zn were evaluated for the complete data set, which included samples from the OUBM LTM 1500 ft and 500 ft grids, caisson silt samples, focus area core sections and grabs, storm drain catch basins, and dry dock silt samples, were analyzed to provide insight on how contaminants were distributed within Sinclair Inlet and identify possible recovery strategies. An example from dry dock cleaning operations conducted in 2012 was used to evaluate the efficacy of management actions to reduce contaminant cycling within the nearshore sediments of the Shipyard.

6.1 Confirmation and Verification Results

The ENVVEST 2010 OUBM split samples were screened for Cu, Pb, Zn, PAHs and PCBs using RSC methods as described in (Kohn et al. 2004; Kohn et al. 2006; Kohn et al. 2008). Thirty samples were selected for confirmatory analysis for metals by ICP-MS or ICP-OES and PAHs by GC-MS. Eleven samples were selected for confirmatory analysis from the 1500-ft grid and 19 from the 500-ft grid. The lines of evidence and corresponding data evaluation were developed to lessen the probability of obtaining false negatives (low concentrations when values are actually high) and false positives (high concentrations when values are actually low) from the screening analysis (Appendix D.1). The lines of evidence were:

1. **XRF Screening result ≥ 90% SQS for Cu, Pb, or Zn** - The screening concentrations of four samples were ≥ 90% of the SQS for Zn.
2. **Predicted concentration based on Kohn et al. (2008) ≥ 90% SQS** - Predicted concentrations were estimated using the results of least squares regression relationship between XRF and ICP/MS results for Cu, Pb, and Zn following procedures used in (Kohn et al. 2008) to determine the definitive concentrations. Of the predicted concentrations, one sample exceeded 90% of the Cu SQS and eight samples exceeded 90% of the SQS for Zn.
3. **Variability between 2003, 2007, and 2010 screening ≥50%** - The coefficient of variation (CV) between the three sampling events was calculated for Cu, Pb, and Zn. Samples with a CV ≥ 50% received a score of 1 for each metal. This provided a measure of change through time as typical laboratory variability was < 30% relative percent difference (RPD); therefore, greater than 50% variability was ascribed to field variability through time and not analytical. There were eight samples scored for Cu, nine for Pb, and seven for Zn.

4. **Corresponding 303(d) Segment listed for metals** - Sinclair Inlet contains no sediment segments listed as Category 5 for Cu, Pb, or Zn. The 2008 Water Quality Assessment listed segments F6E4, F6F2, F6F3, F6F4, F6F5, F6G2, F6G3 as Category 4b for Ag, Cr, Cu, Zn, As, Cd, and Pb based on 2003 data. Samples located within these grids received a score of 1. Sixty-three samples met this criterion.
5. **Representative of Screening Concentration Range** - The 2007 relationship between XRF and ICP-MS analyses was used to predict the 2010 concentrations for Cu, Pb, and Zn (Kohn et al. 2008). The predicted concentrations increased or decreased relative to the screening by 25% to 159% for Cu, -15% to 103% for Pb, and -4% to 20% for Zn. The smallest increases were noted in the highest screening concentrations suggesting the concentrations decreased the XRF detection capability and these data required the largest correction factor. Screening concentrations in the middle and lower range were scored to further support regressions with additional data in these ranges. Predicted concentrations that increased by 50-60% and >200% for Cu were given additional weight in the selection process.
6. **Other** - The additional criteria ensured two or three OUBM grids were selected for each Category 4b 303(d) grid, 2010 screening results that appeared anomalous would be confirmed, and OUBM grid samples where the RPD between 2007 and 2010 screening was >75% for at least two metals.

Immunoassay screening analyses for PAHs (PAH_{RSC}) was conducted on all the 2010 OUBM sediment splits (Appendix D.1). The screening data were examined against the following criteria to select samples for confirmatory analysis. The six lines of evidence used to select the confirmatory samples are listed below. Eight confirmatory samples were selected from the 1500-ft grid and 22 from the 500-ft grid.

1. **Immunoassay result ≥90% SQS** – Since there is no SQS value for total PAHs, but there are SQS values normalized to organic carbon (OC) for low molecular weight (LPAH) and high molecular weight (HPAH) PAHs (370 mg/kg OC and 960 mg/kg OC, respectively). Immunoassays screening results reported as TPAH were normalized to OC using the TOC values. These values were compared to 90% of the sum of LPAH and HPAH SQS values. In addition, the Northwest Sediment Evaluation Framework (Northwest Regional Sediment Evaluation Team 2018) provides sediment quality guidelines for PAHs on a dry-weight basis. The equivalent value to the SQS is called screening level 1 (SL1) of SQG and is 5.2 mg/kg dry weight for LPAH and 12 mg/kg dry weight for HPAH. No OUBM grids exceeded these criteria.
2. **Immunoassay result < 90% SQS but >10 mg/kg dry weight** - This criterion selects for moderate to high PAH concentrations to span the regression range and provide additional support for these areas of the calibration range. Only one grid exceeded this criterion.
3. **Confirmatory sample in 303(d) segments listed for PAHs or phthalates** - There were no segments listed for PAHs on the 2008 303(d) list, but one sediment segment in Sinclair Inlet is listed as Category 2 for LPAH and HPAH (F6E3). Individual PAHs, phthalates, and chlorobenzenes listed on the 2008 Water Quality Assessment are all on the Category 1 list thus they were not considered in this OUBM Sediment Monitoring.
4. **Screening results with high variability** - The CV of the immunoassay results from 2003, 2007, and 2010 were calculated for all samples. Samples with a CV >50% received additional weight. Nineteen grids exceeded this criterion.
5. **Locations with anomalous confirmatory results from previous analyses** - Two criteria were used to determine the anomaly in the previous confirmatory analysis: 1) tPAH confirmatory concentration

in 2007 were higher than the screening value and 2) tPAH confirmatory concentration in 2007 was higher than 20 mg/kg dry weight.

6. **Representative of concentration range** - In addition to the criteria above, selected OUBM grids should cover the concentration range in 2010 immunoassay results (e.g., lowest, median, and highest concentrations).

Adherence to the procedures described above assured that the screening results provided reliable data that were confirmed by more rigorous laboratory analysis and reduced the uncertainty and bias in the analytical results obtained. The application of RSC methods greatly increased the data yield for the study that could have been achieved using laboratory analysis alone.

The results of the confirmation and verification analysis are detailed in Appendix D.1. Previous verification studies were conducted by ENVVEST on the OUBM sediment samples collected in 2003 and 2007 and PCB, Hg, and TOC data were obtained from the OUBM LTM program[1] (URS Group, Inc. 2009). Table **24** summarizes confirmation results for the 2003, 2007, and 2010 OUBM sediment composites that were analyzed for Cu, Pb, and Zn. Highlighted cells identify concentrations > 90% SQS, > SQS, or > MCC. In 2010, only two grids (500-ft 60 and 67) exceeded the MCC for Cu, and seven grids exceeded the SQS for Zn (Table **24**). Based on the definitive concentrations (see below) obtained for all the OUBM grids in 2010 for Cu, Pb, Zn, and Total PAHs an additional two grids exceeded the SQS for Zn. No grids exceeded SQS for Pb or Total PAHs. One grid one grid exceeded SQS for indeno(1,2,3-cd) and benzo(g,h,i)perylene (SIN-G32), and one grid exceeded the MCC for As (OUBM-G38). The majority of grids (60 of 109) exceeded the MCC for Hg and 24 additional grids exceeded the SQS for Hg (Appendix D.1).

There were only minor changes in concentrations of Cu, Pb, and Zn between 2003 and 2010 (Figure 34), however, the maximum concentrations and number of SQG exceedances tended to decrease over time. In 2010, there were only 2 stations that exceeded the SQS for Cu and 9 stations that exceeded the SQS for Zn, while all stations meet the SQS for Pb and total PAH (Appendix D.1). It was a different story for Hg, where 59% (61/103) exceeded the MCC, another 23% (24/103) exceeded the SQS, while only 17% (24/103) of the samples were below the SQS.

[1] Data were downloaded from Ecology's EIM database for StudyID = USNSILTM*

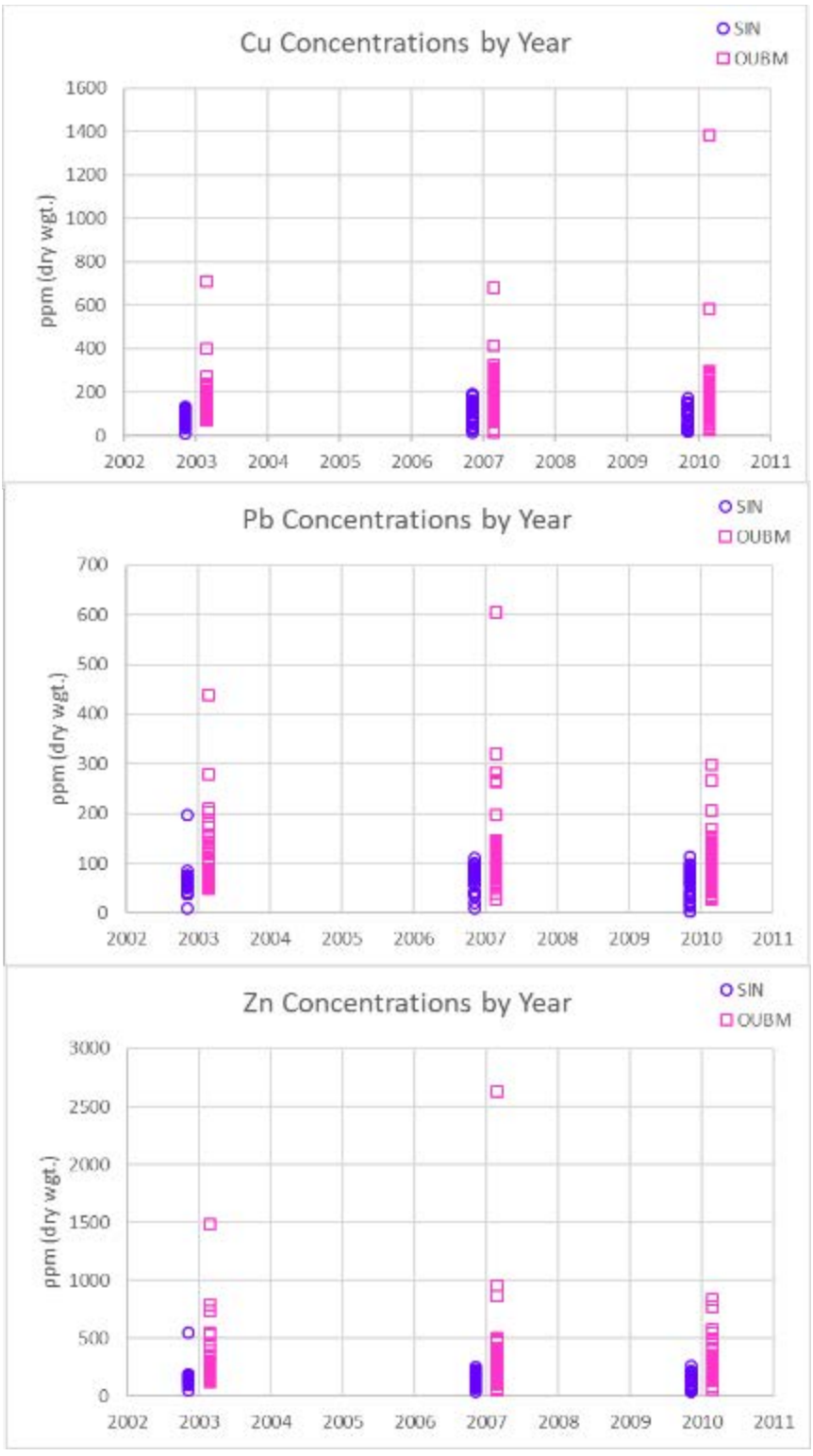


Figure 34. Concentrations of Cu, Pb, and Zn in ug/g dry weight measured in samples from the LTM conducted in 2003, 2007, and 2010 for 32 samples from the Sinclair Inlet 1500 ft^2 grid (SIN) and 71 samples from the 500 ft^2 grids within OUBM.

Table 24. Select grids from the 2003, 2007, and/or 2010 OUBM monitoring where Cu, Pb, and/or Zn exceeded 90% of the SQS (green), > SQS (orange), or > MCC (red).

OUB Grid ID	Grid Size	47122 303d Grid	Screening Cu (mg/Kg)			Cu Confirmation (mg/Kg dry wt)			Screening Pb (mg/Kg)			Pb Confirmation (mg/Kg dry wt)			Screening Zn (mg/Kg)			Zn Confirmation (mg/Kg dry wt)		
			2003	2007	2010	2003	2007	2010	2003	2007	2010	2003	2007	2010	2003	2007	2010	2003	2007	2010
30	500	F6F4, F6F5	108	186	119		159	146	49	167	82		74.6	83	120	522	178		250	182
34	500	F6F5, F6F4	138	191	187	171		266	104	92	115	132		112	250	252	206	391		273
38	500	F6F4	97	207	203			168	63	91	132			113	131	175	383			277
39	500	F6F5	181	195	111	173	205	203	94	169	168	128	142	205	425	316	385	288	304	447
43	500	F6F4	106	165	183	155	157	216	49	135	138	74.3	82.3	149	148	217	440	241	307	769
46	500	F6F4, F6F3	133	117	32	142		72	92	67	46	155		41	286	149	135	428		147
52	500	F6F3	247	219	180	**398**	261	231	171	159	186	279	265	168	417	339	360	785	483	494
59	500	F6F3	152	252	158	272	237	222	117	183	105	439	197	99	280	366	192	736	505	254
60	500	F6F3	126	351	211	200	**413**	**1380**	75	488	188	180	320	298	291	931	345	**1480**	863	450
61	500	F6F3, F6F2	75	233	178		170	253	167	153	140		266	168	191	375	337		463	832
63	500	F6F3	192	368	202		296	288	107	174	96		140	87	253	386	221		383	296
64	500	F6F3	149	248	167	230		236	113	126	127	209		127	279	292	286	425		391
65	500	F6F2, F6F3	118	175	133		124	207	70	73	129		131	153	197	315	348		381	485
66	500	F6F2	87	115	65	227		82	66	106	114	159		111	249	166	185	428		243
67	500	F6G3	211	**1618**	283	**710**	**683**	**584**	140	378	211	204	281	265	283	863	382	547	954	576
68	500	F6G2	129	280	171	217	230	210	67	146	125	144	**605**	112	558	347	292	526	**2632**	346
1	1500	F6C9	63	47	12	102	31.8	15	102	23	31	198	19.1	18	260	48	70	547	71.2	74
25	1500	F6E3	60	24	31		55.9	42	32	63	53		42.1	32	87	436	102		101	83

	Cu	Pb	Zn
90% SQS	351	405	369
WA SQS	390	450	410
WA MCC	390	530	960

6.1.1 Definitive Data for Fe, Cu, Pb, Zn, and Total PAH

The results from the confirmation analysis were used to determine the definitive data for the RSC results using the results from least squares regression between the RSC results and the laboratory confirmation results using ICP for metals and GC/MS for PAHs. Since no confirmation samples were analyzed for PCBs during this study, the regression results previously reported for Sinclair Inlet were used (Guerrero et al. 2011). The results of the least squares regression are provided below, the raw data and regression results are provided in Appendix D.1.

$Fe_{DEF} = 0.90939*Fe_{RSC} + 1796.1$, $R^2 = 0.669$

$Cu_{DEF} = 1.5074*Cu_{RSC} - 15.632$, $R^2 = 0.7902$

$Pb_{DEF} = 1.2686*Pb_{RSC} - 34.144$, $R^2 = 0.8069$

$Zn_{DEF} = 1.4699*Zn_{RSC} - 29.317$, $R^2 = 0.6642$

$PAH_{DEF} = 1.4757*PAH_{RSC} + 744.6$, $R^2 = 0.7810$

$PCB_{DEF} = 0.8344*PCB_{RSC}$, $R^2 = 0.811$ (Guerrero et al. 2011)

There was good agreement between Fe analyzed by XRF and ICP-OES, no non-detected values were determined by either method, no outliers were identified, and the regression accounted for about 67% of the variance in the data (Figure Appendix D.1.1 Because the Fe concentrations in the samples ranged from 20 – 45 mg/g (0.002 – 0.0045%), Fe concentrations were well above the detection limit of the XRF and were reliably quantified by the field instrument. The regression determined for Cu also showed good agreement, although the Cu concentrations determined by XRF were about 50% lower than the results from ICP-OES and outliers were identified that were excluded from the regression (Figure Appendix D.1.2 There were many samples that had Cu concentrations below the detection limit of the XRF, but they did not appreciably affect the regression results. For Pb, there were also many samples that were below the detection limit of the XRF and three outliers were identified that were not representative of the data set, nevertheless regression showed good agreement between the methods accounting for about 81% of the variance in the data (Figure Appendix D.1.3). The regression for Zn showed that the XRF values were consistently about 47% lower than the values determined by ICP-OES and no outliers were identified (Figure Appendix D.1.4).There is some uncertainty in comparing the Total PAHs determined by both methods because the amino assay measures total PAHs directly while GC-MS quantified total PAHs as the sum of all the parent and alkylated compounds measured during the analysis. However, a good regression was obtained over the range of concentrations measured, although two outliers were identified which were non-representative because the samples were from storm drains and not bedded sediment and could have possibly been inadvertently switched when sent to the separate labs for processing (Figure Appendix D.1.5

Overall, the confirmation analysis provided acceptable results for converting for the screening results to definitive values. In the final data set, the ICP and GC/MS values were used, for samples with only RSC results, the regressions above were used to convert the screening value to the definitive value.

6.2 Sediment Focus Areas

In this section the results from sediment surface and core sampling in the focus areas within the Shipyard are presented and discussed for each focus area and the Pier 7 transect sampling. For each focus area, the analytical chemistry results for Cu, Pb, Hg, and Zn are plotted for the surface grabs and core profiles. The core profiles for SEM and AVS are also presented. The relative concentration of contaminant levels was evaluated by calculating the SQGq for chemicals analyzed, normalized by their respective SQS thresholds resulting in the ∑SQGq and mSQGq for total Hg, total PCB, Zn, Cr, Cu, Cd, Ag, As, Pb, and total PAH (ten chemicals) for each surface grab and core profile section. For PS03 and PS09, the results from the squeeze core for pore water and AVS were compared to water quality standards. The results of the sediment toxicity study conducted for PS03 and PS09 are presented in Section 6.3 Sediment Toxicity Assessment.

6.2.1 PS03

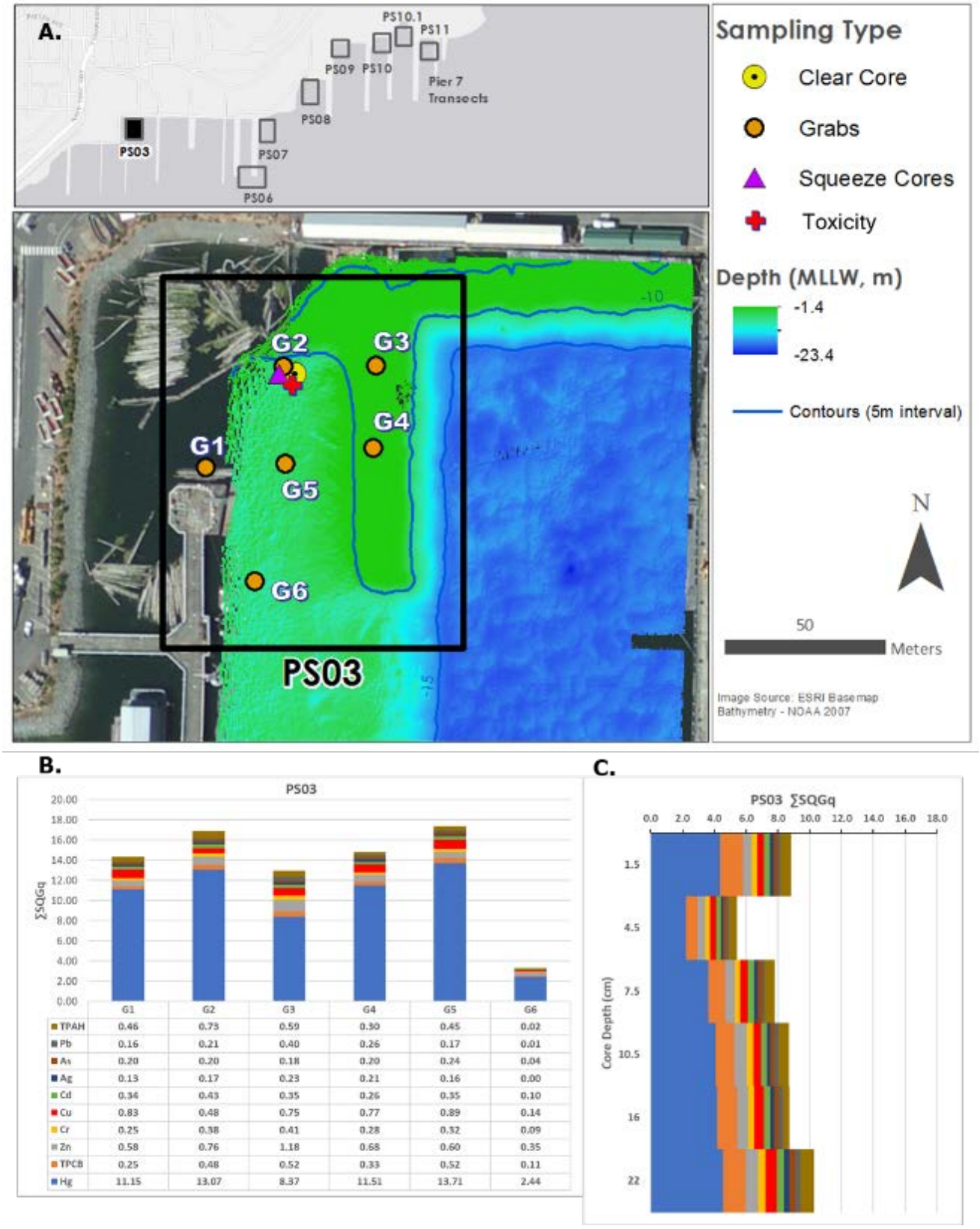
The PS03 focus area is located on the western side of the Shipyard in the nearshore area between Mooring E and Pier D within OUBM grid cell 39. The site is located in the vicinity of storm drains including PSNS015 which drains the largest basin within the Shipyard and has been identified as a possible pathway for contaminants from seawater exchange with contaminated soils within the tidally influenced drainage system (Paulson et al. 2013; Conn et al. 2018). The site has a long history of waterfront operations (Reh and Ross 1991), the shoreline has been extensively modified by dredging, construction and demolition of piers, wharfs, seawalls, and rip-rapped shoreline. The divers reported the presence of much debris, rocks, and boulders on the bottom which interfered with sampling. Formerly, a CSO (CSO15) discharged in the nearshore area of Pier D, it was abandoned in 1999 (City of Bremerton 2018). During 2000-2001 navigational dredging was conducted all along the western side of Pier D (Figure 5) which was dredged to a depth of about 50 ft (Figure **26**). Current uses include berthing of inactive ships at Mooring E, berthing of active ships at Pier D, storage of bumper logs, containment booms, and other mooring equipment, and small boat operations along the wharf on the northern shoreline. Potential sources include legacy contamination in the sediment which can be resuspended during ship movements, runoff from storm drains, active ships and barges moored at Pier D and inactive ships at Mooring E, and accumulation of contaminants within the nearshore area with low flushing due to restricted currents.

The sediment cores and grabs were collected at the site within 50 m of shore at varying depths outside of the most recently dredged area adjacent to Pier D. A squeeze core for pore water analysis and samples for toxicity evaluations were also collected from the site (Figure 35A). Plots of the concentrations of Hg, Cu, Pb, and Zn measured in the surface grabs and cores are shown in Figure 36, the SQGq calculated for the surface grabs and cores are shown in Figure 35, and the raw data and mSQGq calculated for each sample are tabulated in Appendix D2.1 Sediment Concentrations and SQG Quotients.

The results showed that total Hg was highly variable and elevated exceeding sediment quality guidelines in both 0-10 cm surface grabs and core sections (Figure 35). Cu and Pb were less variable and did not exceed the SQS and only one Zn surface grab exceeded the SQS. The core profiles showed an increasing trend of concentrations with depth and both the clear core and squeeze showed remarkably similar sediment profiles. The SQGq for Hg ranged from 2.4-13.7 for surface grabs (Figure 35B) and 2.2-4.6 in the core profile (Figure 35C). The SQGq calculated for all the other chemicals was < 1.0 and the mSQGq did not exceed 2 in any of the samples collected (Appendix D2.1 Sediment Concentrations and SQG Quotients). There was high spatial variability for the mSQGq (CV = 39%, Figure 35B) which was higher than the temporal variability (CV = 10%, Figure 35C) inferred by the core samples (Appendix D2.1 Sediment Concentrations and SQG Quotients).

The results for the AVS and SEM analysis are provided in Appendix D2.2 Results for SEM and AVS. The AVS concentrations in the core from focus area PS03 varied between 42.6 µmole/g at the surface to 62.6 µmole/g at the bottom. SEM concentrations of Cd, Ni, and Zn did not vary significantly (<25% variability-within allowable analytical error) within the core, while Cu, Pb, Ag and Hg varied significantly. The ∑SEM calculated for the samples were more than an order of magnitude lower than the AVS (ASV : SEM ≥ 10, Figure 35) indicating that the metals in the sediment were likely bound as insoluble sulfides and not biologically available.

The porewater results from the squeeze core (Figure 35, Appendix D2.3 Porewater Results) showed that all the metals analyzed were well below water quality standards. Ag was not analyzed in the pore water; Cd and Pb were analyzed but not detected. Cu, Zn and Hg varied significantly. Cu and Zn varied inversely with the AVS concentration while Hg co-varied with AVS. For Cd, Cu, Ni, Pb, Zn and Ag, SEM concentrations co-varied with bulk sediment concentration while pore water (where analyzed with detected concentrations) varied inversely with bulk sediment metal and total sulfide concentrations. Hg behaved in the opposite manner, with pore water co-varying with bulk sediment concentrations while SEMs varied inversely. The AVS measured in the porewater was more than 2 orders of magnitude greater than the metal concentrations measured in the pore waters (Appendix D2.3 Porewater Results).



	G1	G2	G3	G4	G5	G6
TPAH	0.46	0.73	0.59	0.50	0.45	0.02
Pb	0.16	0.21	0.40	0.26	0.17	0.01
As	0.20	0.20	0.18	0.20	0.24	0.04
Ag	0.13	0.17	0.23	0.21	0.16	0.00
Cd	0.34	0.43	0.35	0.26	0.35	0.10
Cu	0.83	0.48	0.75	0.77	0.89	0.14
Cr	0.25	0.38	0.41	0.28	0.32	0.09
Zn	0.58	0.76	1.18	0.68	0.60	0.35
TPCB	0.25	0.48	0.52	0.33	0.52	0.11
Hg	11.15	13.07	8.37	11.51	13.71	2.44

Figure 35. PS03 sampling locations (A) and ∑SQGq for surface grabs (B) and core sections (C).

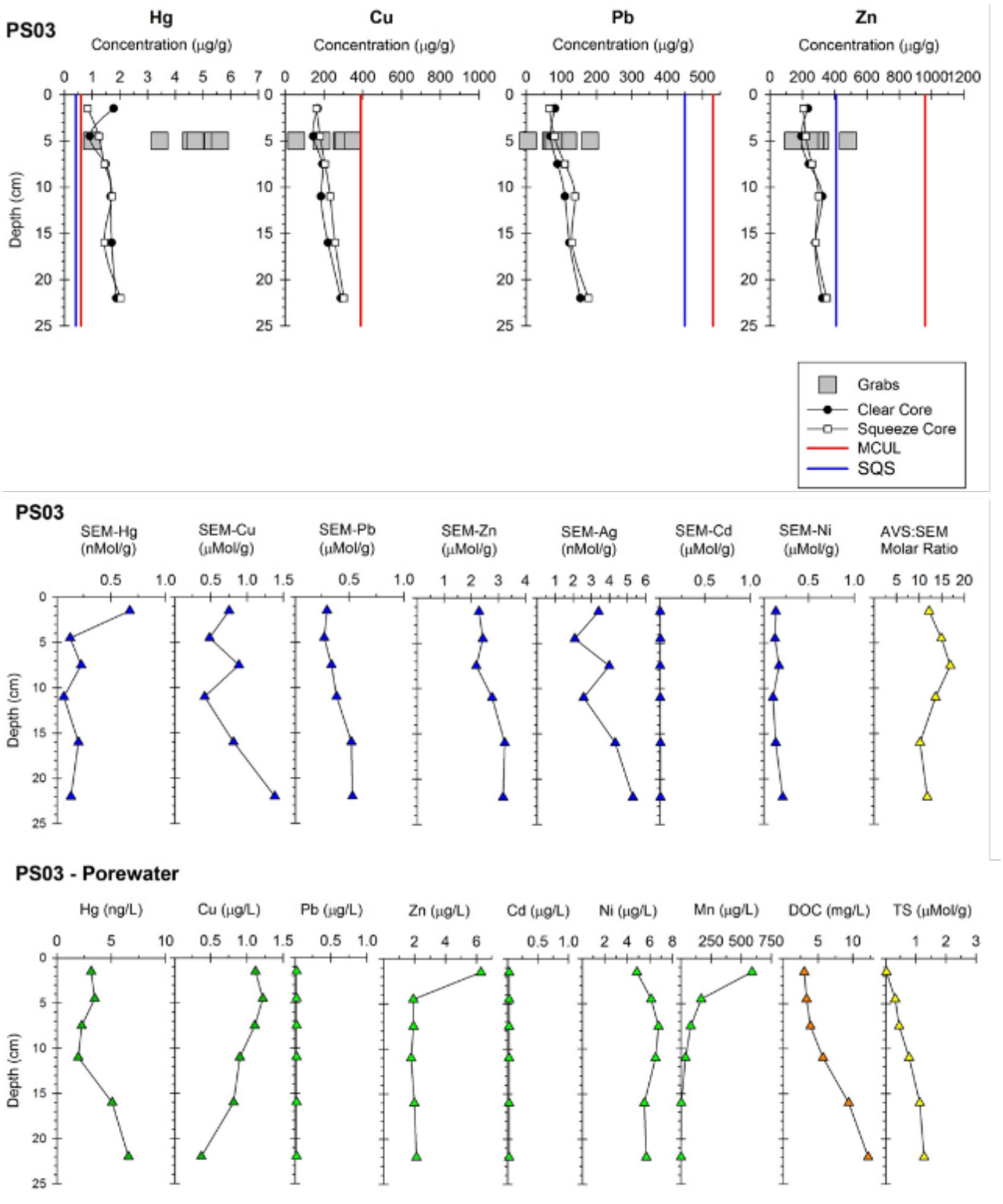


Figure 36. PS03 core profiles and surface grabs for bulk sediment (top panel), SEM and AVS (middle panel), and porewater metal, DOC, and total sulfide (TS) concentrations (bottom panel).

6.2.2 PS06

The PS06 focus area is located at the end of Dry Dock 6 adjacent to Pier 9 within OUBM grid cell 43. The site is located near the opening of Dry Dock 6, the industrial OF19, and is in the vicinity of the flooding and dewatering intake and outlets of Dry Dock 6. Construction of Dry Dock 6 was completed in 1962, it is 1,180 ft long, 180 ft wide, and 60 ft deep with a capacity of 88 million gallons (Reh and Ross 1991). Dry Dock 6 is the only dry dock on the west coast of the U.S. with the capability of docking NIMITZ class air craft carriers. During 2000-2001 remedial dredging was conducted all along the southern end of the wharf (Figure 5) which was dredged to a depth of 48-50 ft (Figure **26**). Potential sources include OF19, docking and undocking activities, legacy contamination in the sediment which can be resuspended during ship movements, and active ships and barges moored at Pier B and Pier 9. Because the dry dock extends well out into the inlet there is relatively high flushing in the area. During sampling in 2011, Pier B was undergoing reconstruction and an aircraft carrier was docked in Dry Dock 6.

The sediment grabs were collected near the mouth of the dry dock and along the south side of Pier 9 at varying depths and within areas that were previously dredged during the remedial action for OUBM (Figure 5). The core was collected near the SE end of Pier 9 within 50 m of OF19 and the eastern dewatering outlet (Figure 37A). Plots of the concentrations of Hg, Cu, Pb, and Zn measured in the surface grabs and cores are shown in Figure 38, the SQGq calculated for the surface grabs and cores are shown in Figure 37, and the raw data and mSQGq calculated for each sample are tabulated in Appendix D2.1 Sediment Concentrations and SQG Quotients.

The results showed that total Hg was elevated exceeding sediment quality guidelines in both 0-10 cm surface grabs and core sections (Figure 38). Cu and Pb did not exceed the SQS while two Zn surface grabs exceeded the SQS and the deepest core sample exceeded the MCC for Zn. The core profiles showed an increasing trend of concentrations with depth for Pb and Zn. The SQGq for Hg ranged from 0.7-1.8 for surface grabs (Figure 37B) and 1.8-3.0 in the core profile (Figure 37C). The SQGq calculated for Zn, PCBs, and As exceeded 1.0, however the mSQGq did not exceed 2 in any of the samples collected (Appendix D2.1 Sediment Concentrations and SQG Quotients).

The AVS concentrations in the core from focus area PS06 varied between 3.6 µmole/g at the surface increasing to 112 µmole/g at the bottom of the core (Figure 38, Appendix D2.2 Results for SEM and AVS). SEM concentrations of all metals was fairly constant in the upper potions of core and was more variable down the core. Only Cu and Ag SEM concentrations co-varied with bulk sediment concentration. The top core sample had low AVS, probably because the sediments at the surface were more oxidized, however the AVS still exceeded the ∑SEM measured in the surface samples. Except for the surface section of core, the ∑SEM calculated for the samples was much lower than the AVS (ASV : SEM ≥ 5, Figure 38) indicating that the metals in the sediment were likely bound as insoluble sulfides and not biologically available.

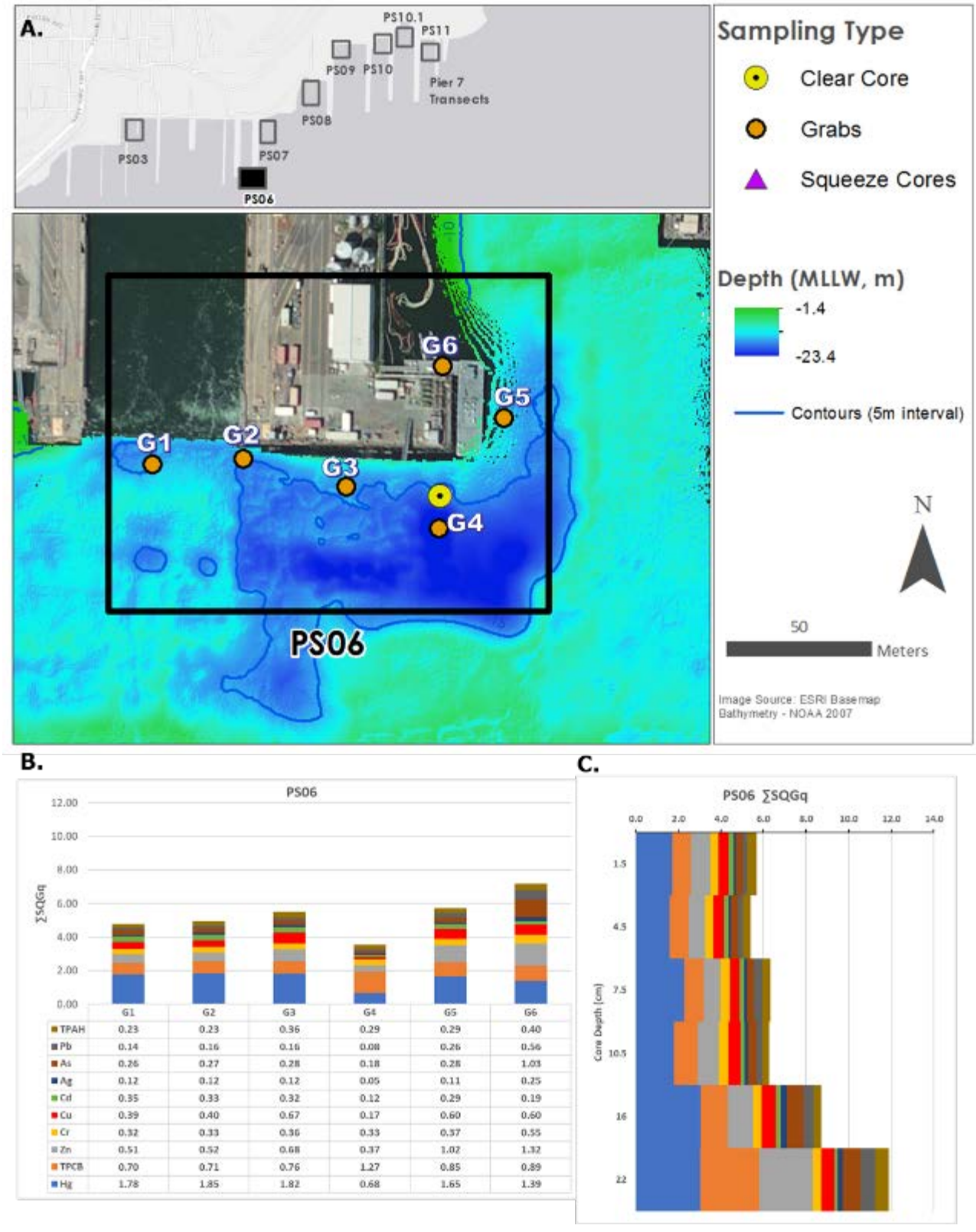


Figure 37. PS06 sampling locations (A) and ∑SQGq for surface grabs (B) and core sections (C).

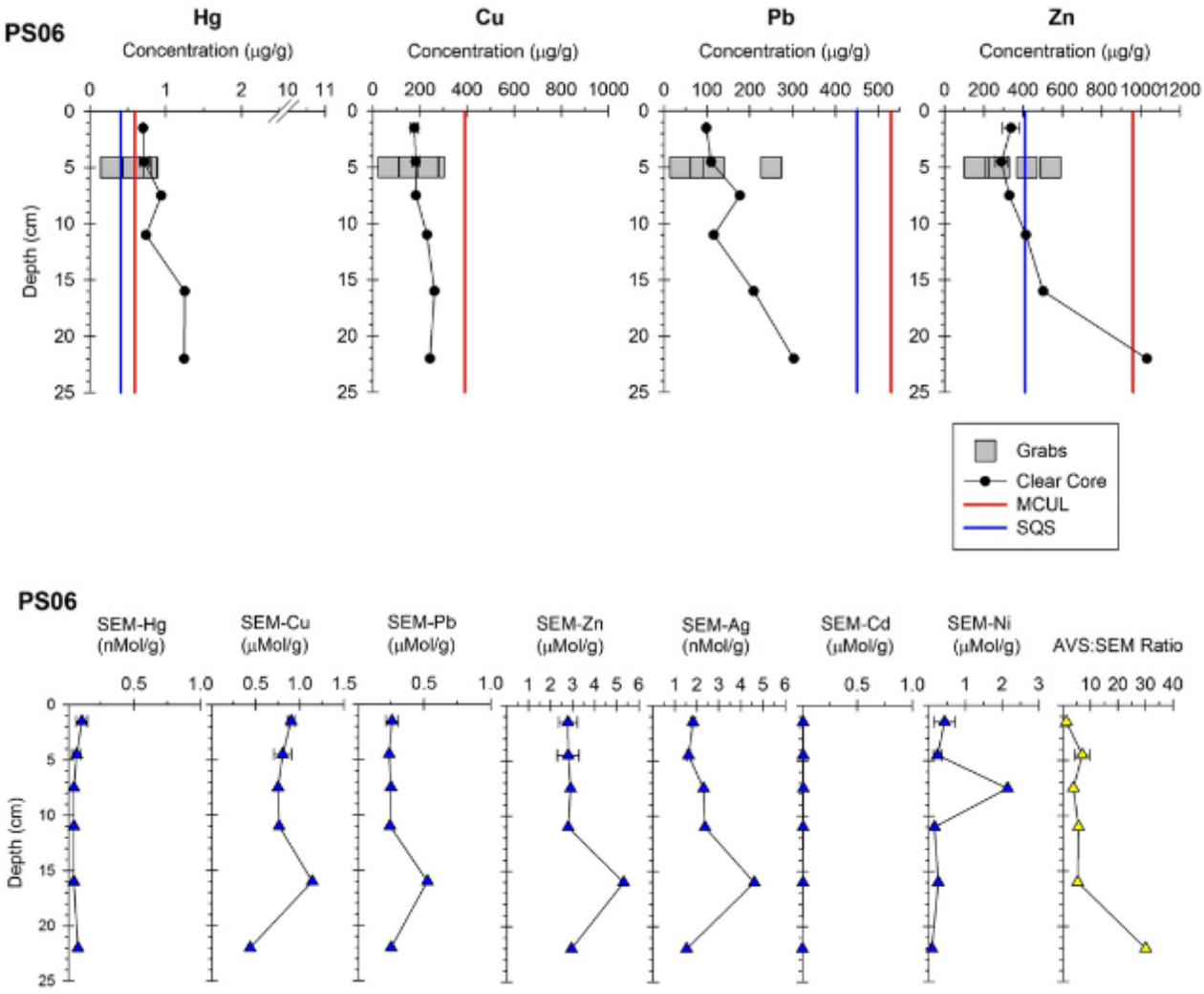


Figure 38. PS06 core profiles and surface grabs for bulk sediment (top panel) and SEM and AVS (bottom panel).

6.2.3 PS07

The PS07 focus area is located at the northeast end of Dry Dock 6 between the finger pier and Mooring A within OUBM grid cell 49. The site is located near a major storm drain (PSNS081.1), small boat operations, and inactive ship storage at Mooring A. During 2000-2001 no navigational or remedial dredging was conducted in the area (Figure 5). Because of extensive shoreline modification there is very limited flushing. The sediment grabs and core sample were collected between the finger pier and Mooring A (Figure 39A). Plots of the concentrations of Hg, Cu, Pb, and Zn measured in the surface grabs and cores are shown in Figure 40, the SQGq calculated for the surface grabs and cores are shown in Figure 39, and the raw data and mSQGq calculated for each sample are tabulated in Appendix D2.1 Sediment Concentrations and SQG Quotients.

The results showed that total Hg exceeded sediment quality guidelines in both 0-10 cm surface grabs and core sections; Cu, Pb, and Zn did not exceed the SQS; and the core profiles remained constant over depth (Figure 40). The SQGq for Hg ranged from 0.8-1.9 for surface grabs and core samples (Figure 39). The SQGq calculated for PCBs exceeded 1.0 in three samples, however the mSQGq did not exceed 1 in any of the samples collected (Appendix D2.1 Sediment Concentrations and SQG Quotients).

The AVS concentrations in the core from focus area PS07 ranged between 34.5 µmole/g and 85.2 µmole/g, with the maximum occurring in the 3-6 cm section (Figure 38, Appendix D2.2 Results for SEM and AVS). SEM concentrations of all metals except Pb varied significantly within the core but did not consistently vary with the AVS or bulk sediment concentrations for any metal. The SEM Hg concentrations were very low (< 0.02 nmol/g) and inversely varied with bulk sediment concentration. The ∑SEM concentrations calculated for the samples were much lower than the AVS (ASV : SEM ≥ 10, Figure 38) indicating that the metals in the sediment were likely bound as insoluble sulfides and not biologically available.

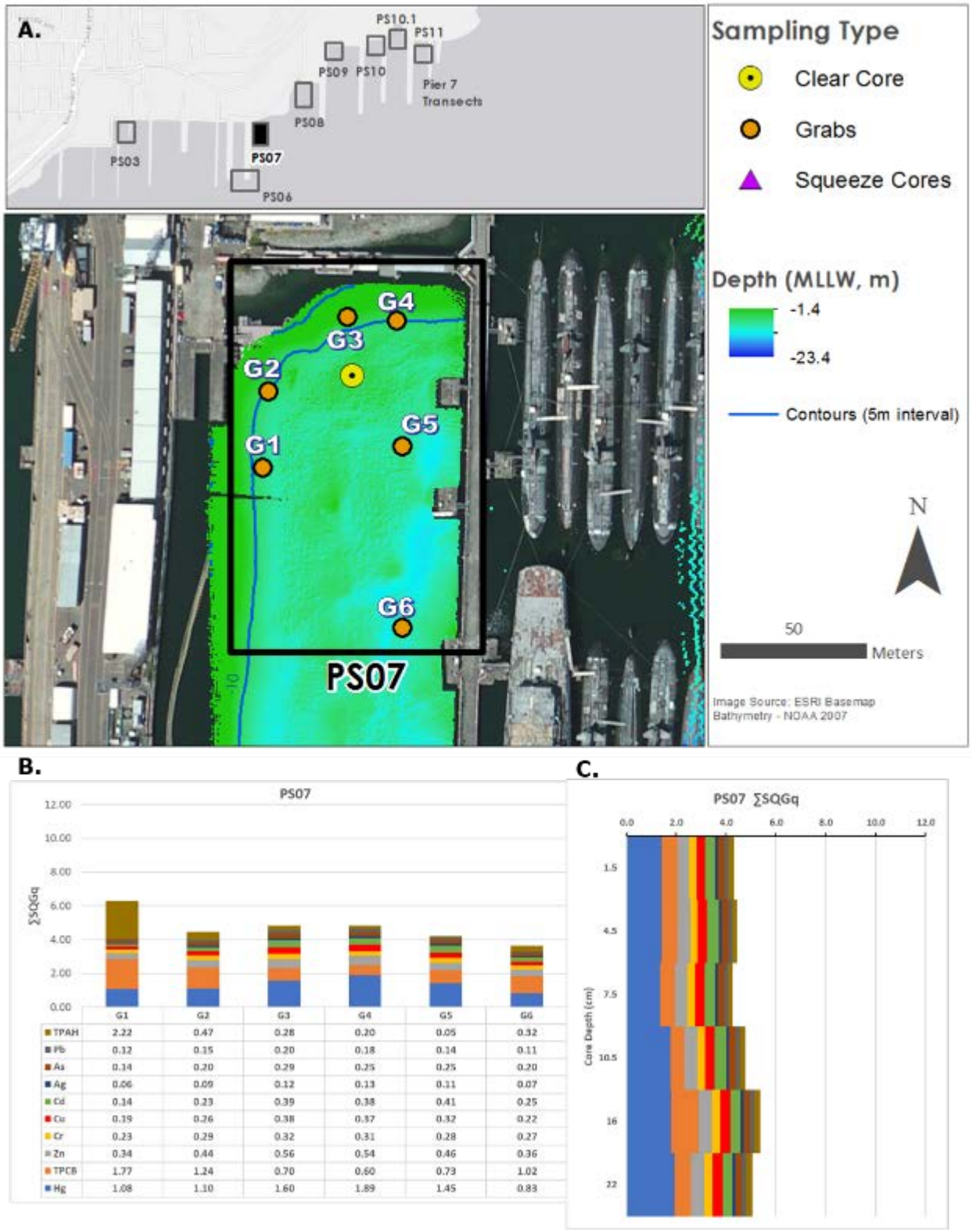


Figure 39. PS07 sampling locations (A) and ∑SQGq for surface grabs (B) and core sections (C).

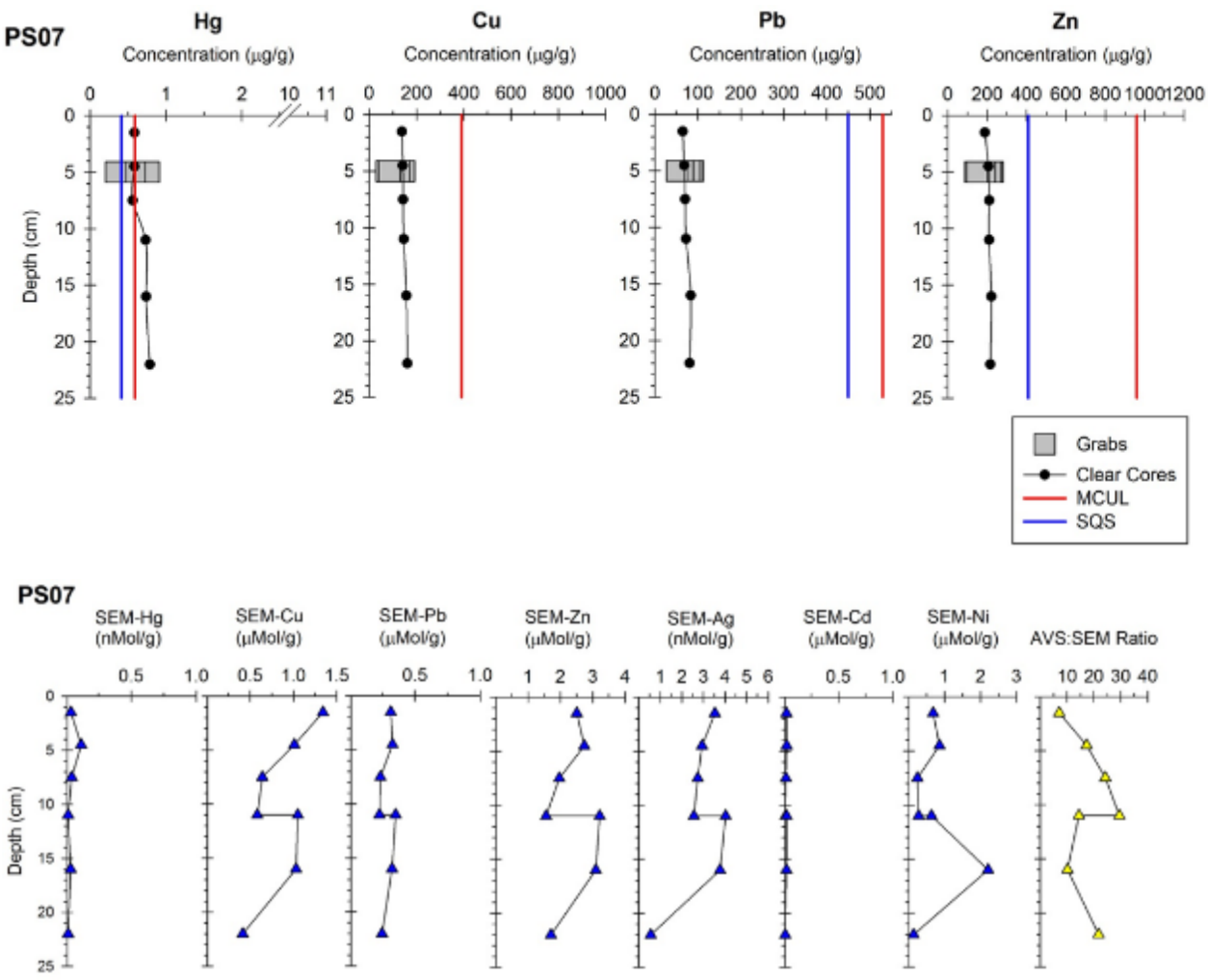


Figure 40. PS07 core profiles and surface grabs for bulk sediment (top panel) and SEM and AVS (bottom panel).

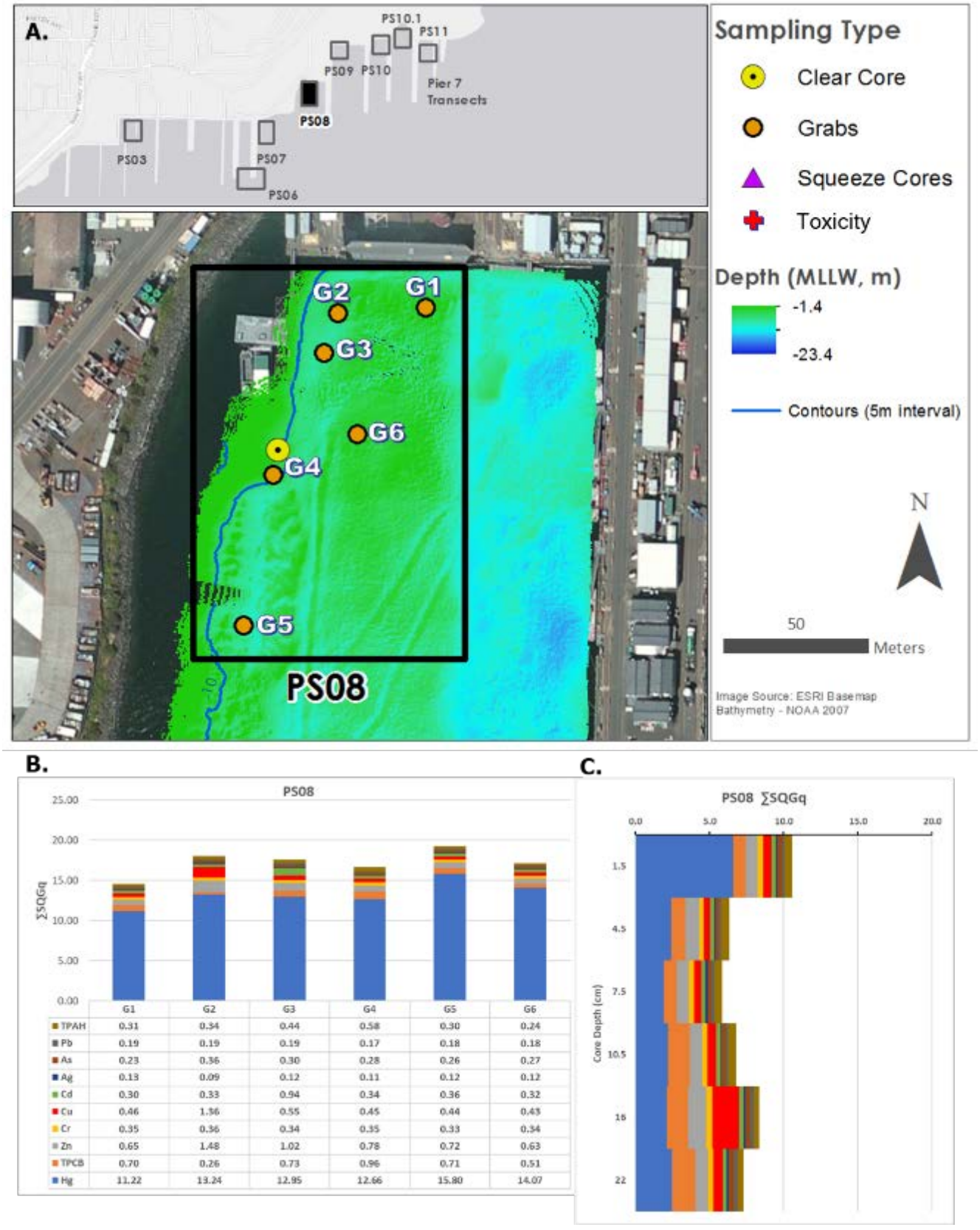
6.2.4 PS08

The PS08 focus area is located south of Dry Dock 5 between the RMTS and Pier 3 within OUBM grid cells 52 and 55. During 2000-2001 remedial dredging and shoreline stabilization was conducted all along the shore of Site 1 (Figure 5). Bottom depths in the area ranged from intertidal to about 38 ft (Figure **26**). The PS08 focus area is affected by docking operations at Dry Dock 5, legacy contamination in the sediment which can be resuspended during ship movements, active ships moored at Pier 3, small boat operations, stormwater runoff, and low flushing due to restricted currents within the nearshore area.

The surface grabs were collected in front of Dry Dock 5 and along the shoreline of the RMTS and the core sample was collected just offshore of Site 1 (Figure 41A). Plots of the concentrations of Hg, Cu, Pb, and Zn measured in the surface grabs and cores are shown in Figure 42, the SQGq calculated for the surface grabs and cores are shown in Figure 41, and the raw data and mSQGq calculated for each sample are tabulated in Appendix D2.1 Sediment Concentrations and SQG Quotients.

The results showed that total Hg exceeded sediment quality guidelines in both 0-10 cm surface grabs and core sections, Cu exceed the SQS in one surface grab, and Zn exceeded the SQS in two surface grab samples. The core profile for Hg showed that the highest concentration was in the surface section while the core profiles for the other metals were constant over depth except for the 15-20 cm section which exceeded the SQS for Cu and Zn (Figure 42). The SQGq for Hg ranged from 11.2-15.8 for surface grabs and 1.9-6.6 for core samples (Figure 41). The SQGq exceeded 1.0 in three samples for PCBs and Zn and two samples for Cu, however the mSQGq did not exceed 2 in any of the samples collected (Appendix D2.1 Sediment Concentrations and SQG Quotients).

The AVS concentrations in the core from focus area PS08 varied between 24.7 µmole/g and 79.9 µmole/g, with the maximum occurring in the 6-9 cm section (Appendix D2.2 Results for SEM and AVS). SEM Hg and SEM Cu concentrations were highest in the surface of the core, while the other metals were relatively constant (Figure 42) and did not consistently vary with the AVS concentration for any metals. None of the SEM concentrations co-varied with bulk sediment concentration. In all core sections for focus area PS08, the AVS : SEM molar ratio ranged from 5-15 (Figure 42) indicating that the metals in the sediment were likely bound as insoluble sulfides and not biologically available.



	G1	G2	G3	G4	G5	G6
TPAH	0.31	0.34	0.44	0.58	0.30	0.24
Pb	0.19	0.19	0.19	0.17	0.18	0.18
As	0.23	0.36	0.30	0.28	0.26	0.27
Ag	0.13	0.09	0.12	0.11	0.12	0.12
Cd	0.30	0.33	0.94	0.34	0.36	0.32
Cu	0.46	1.56	0.55	0.45	0.44	0.43
Cr	0.35	0.36	0.34	0.35	0.33	0.34
Zn	0.65	1.48	1.02	0.78	0.72	0.63
TPCB	0.70	0.26	0.73	0.96	0.71	0.51
Hg	11.22	13.24	12.95	12.66	15.80	14.07

Figure 41. PS08 sampling locations (A) and ∑SQGq for surface grabs (B) and core sections (C).

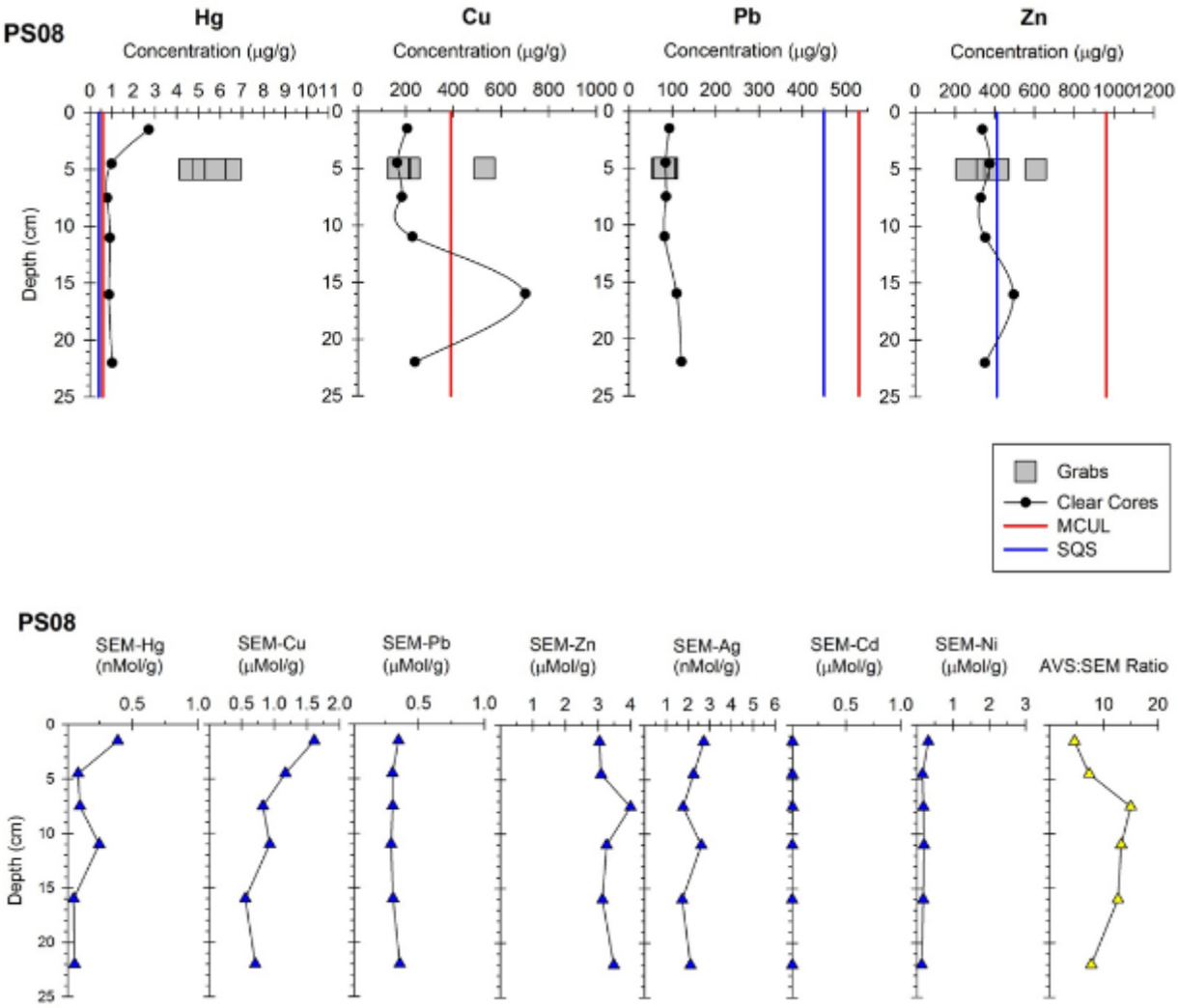


Figure 42. PS08 core profiles and surface grabs for bulk sediment (top panel), and SEM and AVS (bottom panel).

6.2.5 PS09

The PS09 focus area was located in the northwest corner of Pier 3 next to Dry Dock 4, OF18, and outside of the OUBM sampling grids in an area that was not dredged during the 2000-2001 remedial dredging (Figure 5). Located in the heart of the heavy industrial area of the Shipyard, PS09 is affected by discharges from OF18, stormwater runoff, docking operations at Dry Dock 4, legacy contamination in the sediment which can be resuspended during ship movements, active ships and barges moored at Piers 3 and 4, and the accumulation of contaminants due to restricted currents and low flushing in the area.

The PS09 samples were collected along the quay and adjacent to Pier 3 outside of the dredging footprint and within 100 ft of the industrial outfalls and storm drains discharging near the surface of the receiving

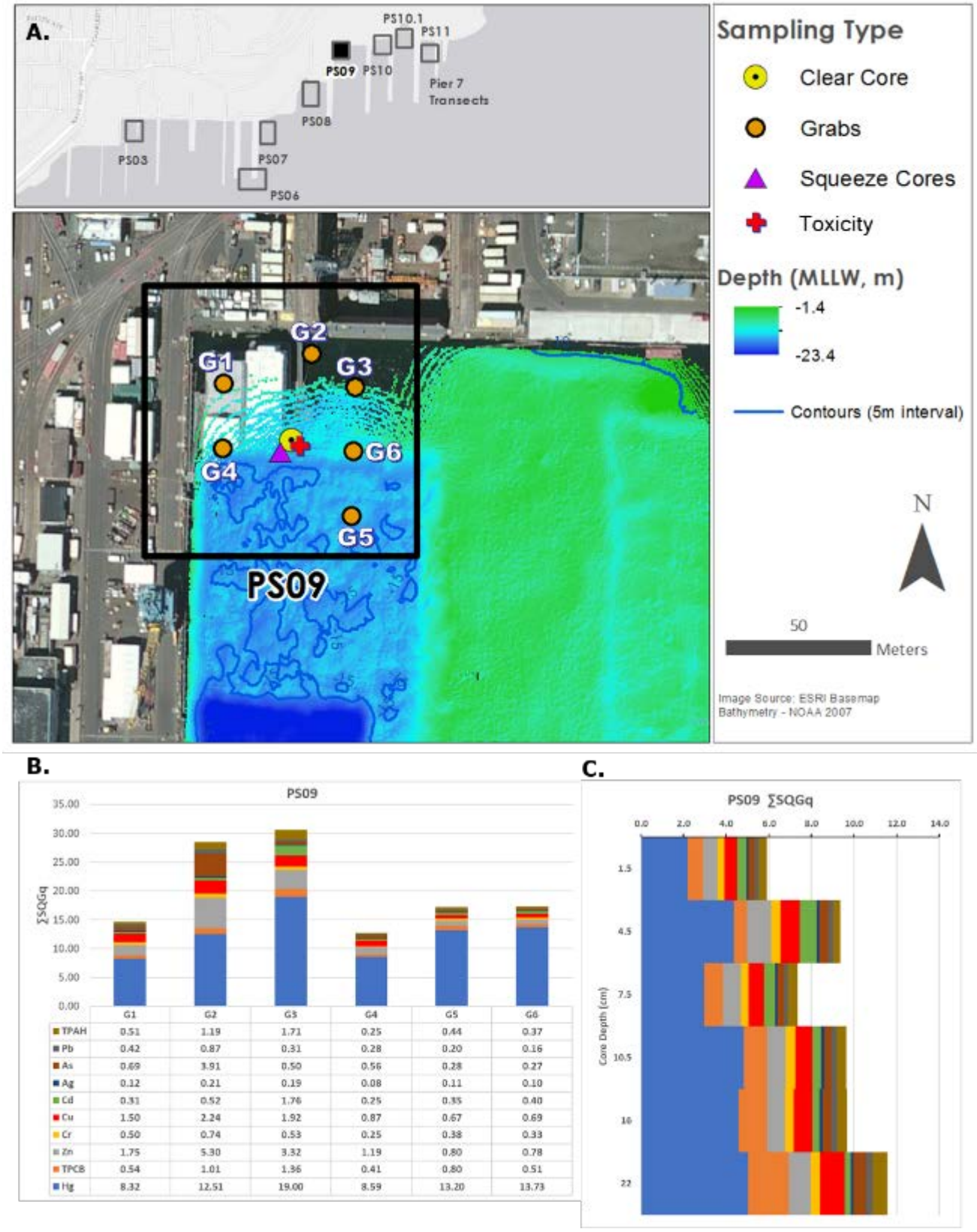
waters. Core samples and samples for toxicity were also collected from the site (Figure 43A) at a depth of about 39-48 ft. Plots of the concentrations of Hg, Cu, Pb, and Zn measured in the surface grabs and cores are shown in Figure 44, the SQGq calculated for the surface grabs and cores are shown in Figure 43, and the raw data and mSQGq calculated for each sample are tabulated in Appendix D2.1 Sediment Concentrations and SQG Quotients.

The surface grabs and cores samples all exceeded SQGs for Hg, three grab samples and one core sample exceeded the SQS for Cu, and two grab samples and three core samples exceeded the SQS for Zn (Figure 44). The core profiles obtained from the clear and squeeze cores were very similar, both showed a pattern of lower concentrations at the surface with relatively constant concentrations down the core (Figure 44). The SQGq calculated for Hg ranged from 8.2-19.0 for the surface grabs and 2.2-5.0 for the core profiles. Surface grabs with an SQGq > 2 included As (3.9), Cu (2.4), and Zn (3.3 and 5.3) (Figure 43B, Appendix D2.1 Sediment Concentrations and SQG Quotients). There was higher spatial variability for the mSQGq (CV = 37%, Figure 43B) which was higher than the temporal variability inferred by the core samples (CV = 22%, Figure 43C).

The AVS concentrations in the core from focus area PS09 varied between 48.0 µmole/g and 104 µmole/g, with the maximum occurring in the 3-13 cm range and then decreasing to the bottom of the core. The SEM concentrations of Ni and Pb were relatively constant, while Cd, Cu, Ag, Zn and Hg varied but did not consistently vary with the AVS concentrations. The SEM concentrations were quite low, except for the 3-6 cm section which had the maximum concentration of SEM Zn of 28.2 umole/g, however the AVS was much greater at 104.0 umole/g, so it is very unlikely that any of the metals were biologically available.

The dissolved metals concentrations in porewater samples extracted from the squeeze core were well-below water quality standards, although dissolved Cu concentrations ranged from 1.5-2.1 ug/L and the higher concentrations were measured in the deeper core segments. Cd and Pb were not detected, Cr and Ni were relatively constant, while Zn, Mn, and Hg were more variable, with the highest Zn and Mn concentrations in the surface segment and the highest Hg concentration was in the deepest segment (Figure 44) For Cd and Zn, SEM concentrations co-varied with bulk sediment concentration while pore water varied inversely with bulk sediment metal and total sulfide concentrations. Hg behaved in the opposite manner, with pore water co-varying with bulk sediment concentrations while the SEM varied inversely.

Dissolved Hg concentrations in the surfaces waters at PS09 were significantly lower than PS03 for dissolved Hg (0.4-17 ng/L) and range 0.24-1.1 ng/L . The porewater for PS09 suggests little mixing may occur at this site. Only Zn and Hg varied significantly in the pore water but did not consistently co-vary or inversely co-vary with the AVS concentration. For Cd and Zn, SEM concentrations co-varied with bulk sediment concentration while pore water varied inversely with bulk sediment metal and total sulfide concentrations. Hg behaved in the opposite manner, with pore water co-varying with bulk sediment concentrations while SEMs varied inversely.



	G1	G2	G3	G4	G5	G6
TPAH	0.51	1.19	1.71	0.25	0.44	0.37
Pb	0.42	0.87	0.31	0.28	0.20	0.16
As	0.69	3.91	0.50	0.56	0.28	0.27
Ag	0.12	0.21	0.19	0.08	0.11	0.10
Cd	0.31	0.52	1.76	0.25	0.35	0.40
Cu	1.50	2.24	1.92	0.87	0.67	0.69
Cr	0.50	0.74	0.53	0.25	0.38	0.33
Zn	1.75	5.30	3.32	1.19	0.80	0.78
TPCB	0.54	1.01	1.36	0.41	0.80	0.51
Hg	8.32	12.51	19.00	8.59	13.20	13.73

Figure 43. PS09 sampling locations (A) and ∑SQGq for surface grabs (B) and core sections (C).

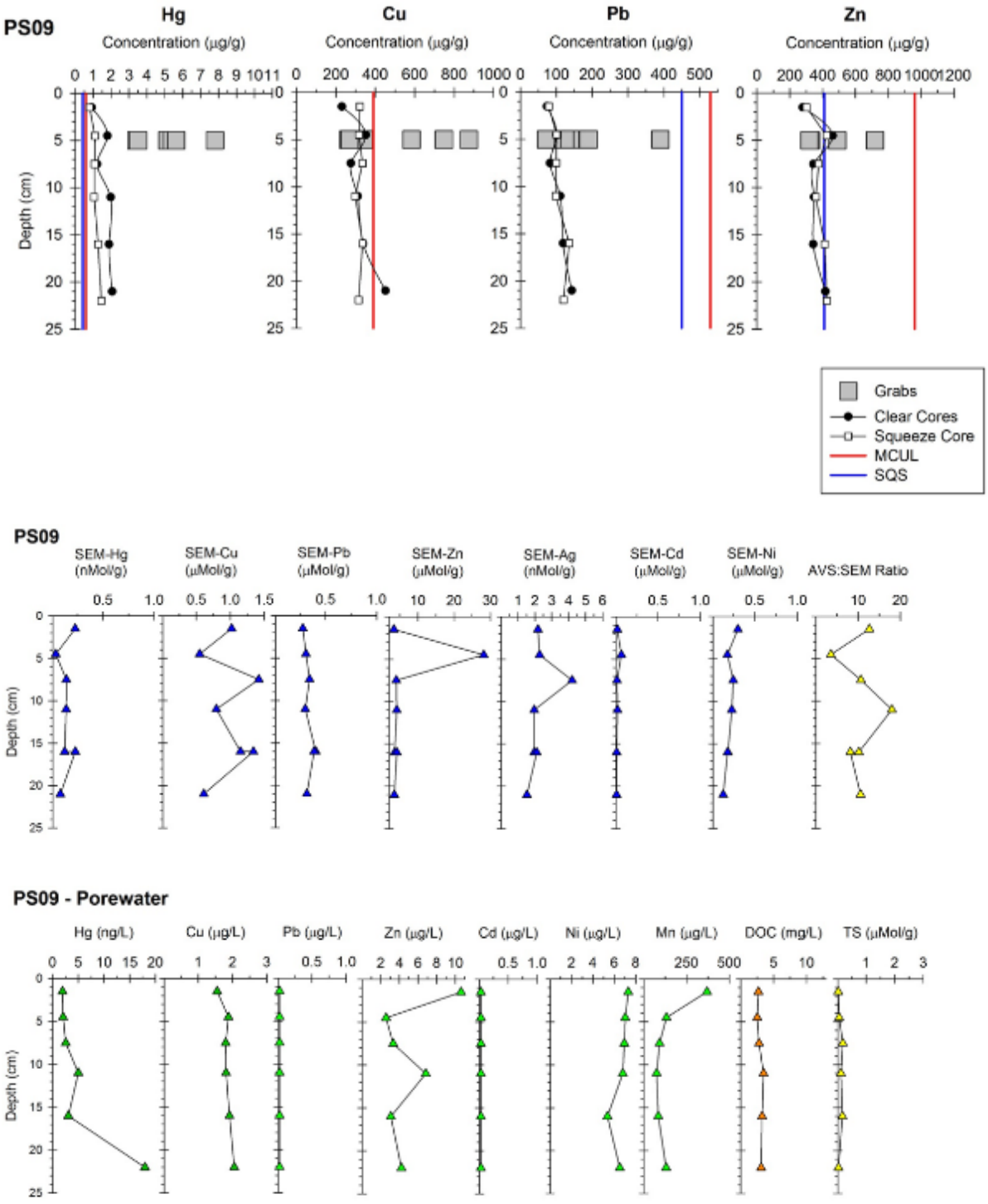


Figure 44. PS09 core profiles and surface grabs for bulk sediment (top panel), SEM and AVS (middle panel), and porewater metal, DOC, and total sulfide (TS) concentrations (bottom panel).

6.2.6 PS10

Located in front of Dry Dock 2, between Piers 4 and 5, and within OUBM grid cells 63, 64, and 67, focus area PS10 is affected by docking operations in Dry Dock 2, legacy contamination in the sediment which can be resuspended during ship movements, active ships and barges moored at the piers and quay, stormwater runoff, and industrial discharges from OF96. Remedial dredging was conducted for almost all of area between Piers 4 and 5 during the 2000-2001 remedial actions (Figure 5). Due to the fact that the site is surrounded by piers rather than quays or wharfs, currents are less restricted so there is relatively more flushing at PS10. However, when large vessels are docked at the piers their hulls will impede the current flow.

The PS10 samples were collected along the quay in front of Dry Dock 2, between Piers 4 and 5, at a depth of about 30-44 ft, and within 150 ft of OF96 and storm drains discharging at the surface of the receiving waters (Figure 45A). Plots of the concentrations of Hg, Cu, Pb, and Zn measured in the surface grabs and cores are shown in Figure 46, the ∑SQGq calculated for the surface grabs and cores are shown in Figure 45, and the raw data and mSQGq calculated for each sample are tabulated in Appendix D2.1 Sediment Concentrations and SQG Quotients.

The surface grab and core samples all exceeded the MCC for Hg, the SQS was exceeded in one surface grab for Cu, two surface grabs for Zn, and the deepest core sample also exceeded the SQS for Cu, Pb, and Zn (Figure 46). The deeper core samples were much higher for Hg, Cu, Pb, Zn, total PCB, and total PAH than the surface samples, possibly because the core profile extended below the remedial dredging horizon. The SQGq for total Hg ranged from 16.4-25.6 in the surface grab samples and 2.2-25.9 in the core profile. No other chemicals exceeded SQGq > 2.0, however the mSQGq was > 2.0 in all the grab samples except one surface grab (G5, Figure 45). The spatial variability for the mSQGq (CV = 20%, Figure 45B) was lower than the temporal variability inferred by the core samples (CV = 95%, Figure 45C).

The AVS concentrations in the core from focus area PS10 varied between 107 µmole/g at the top, decreasing steadily to 22.3 µmole/g at the bottom while the ∑SEM concentrations ranged from 3.0-6.7 umole/g, which was many factors below the AVS concentration suggesting that the metals were likely bound as insoluble sulfides and not biologically available. The Cu, Ni, Pb and Hg SEM concentrations varied within the core and SEM Cd, Cu, Pb and Zn co-varied with the bulk sediment concentrations.

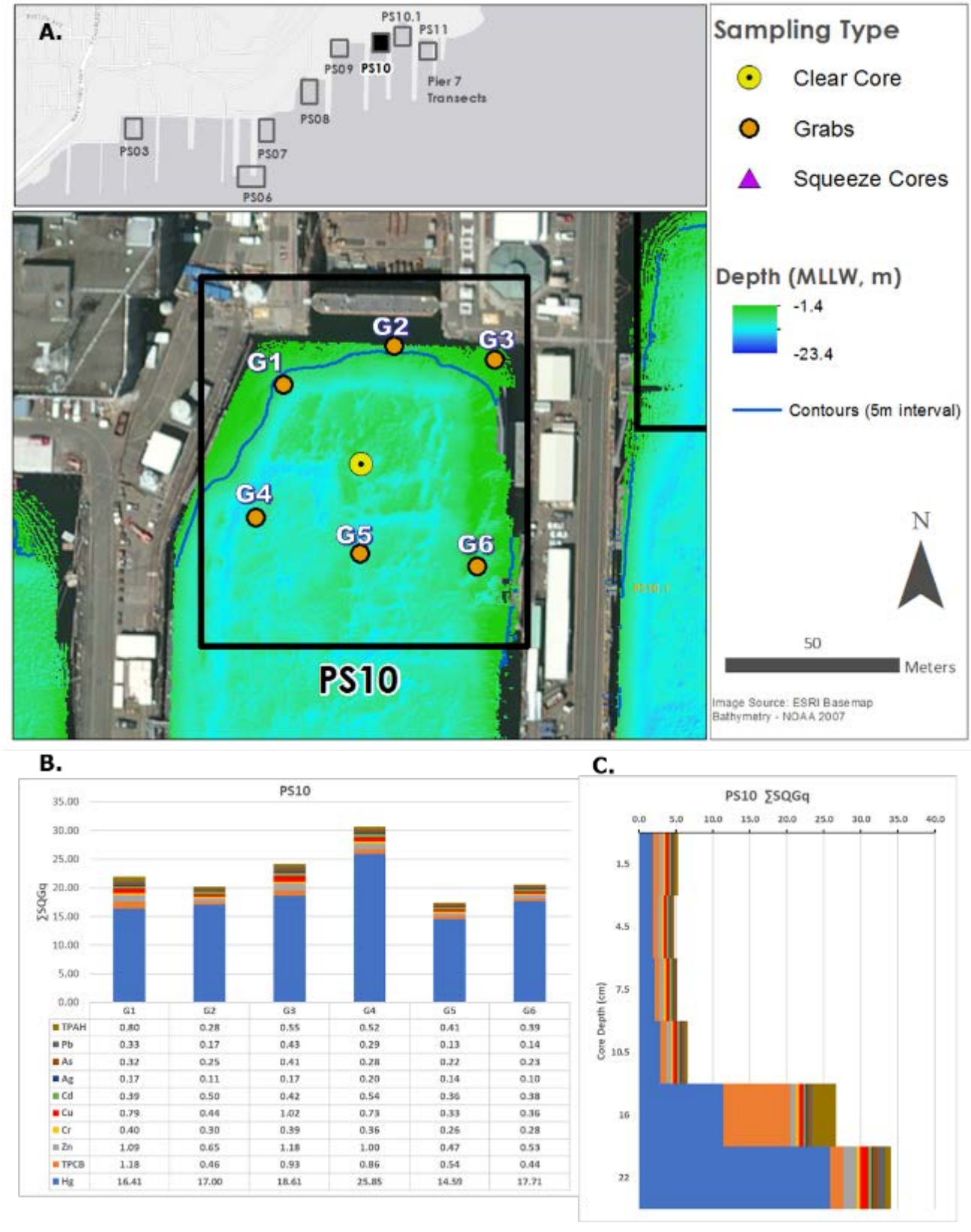


Figure 45. PS10 sampling locations (A) and ∑SQGq for surface grabs (B) and core sections (C).

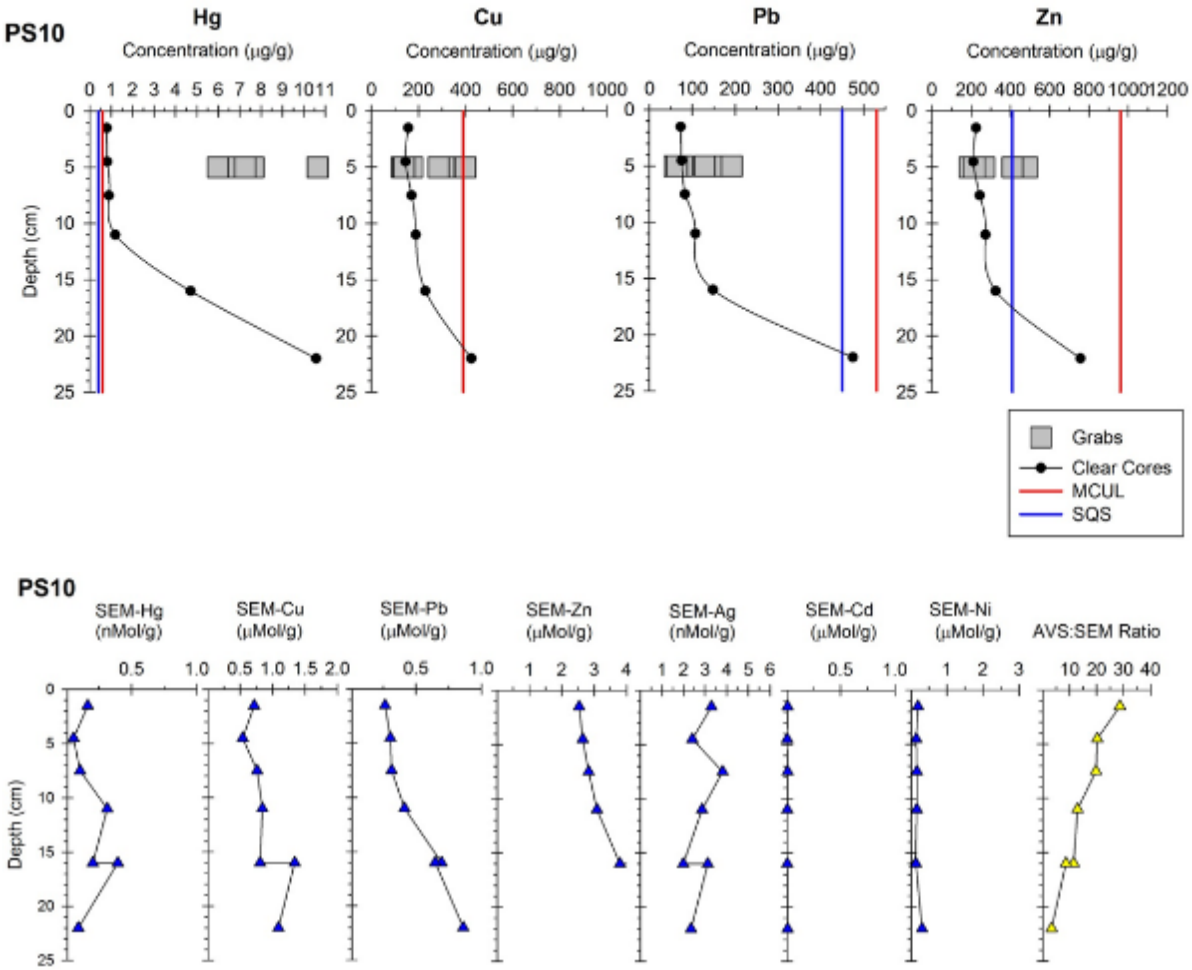


Figure 46 PS10 core profiles and surface grabs for bulk sediment (top panel) and SEM and AVS (bottom panel).

6.2.7 PS10.1

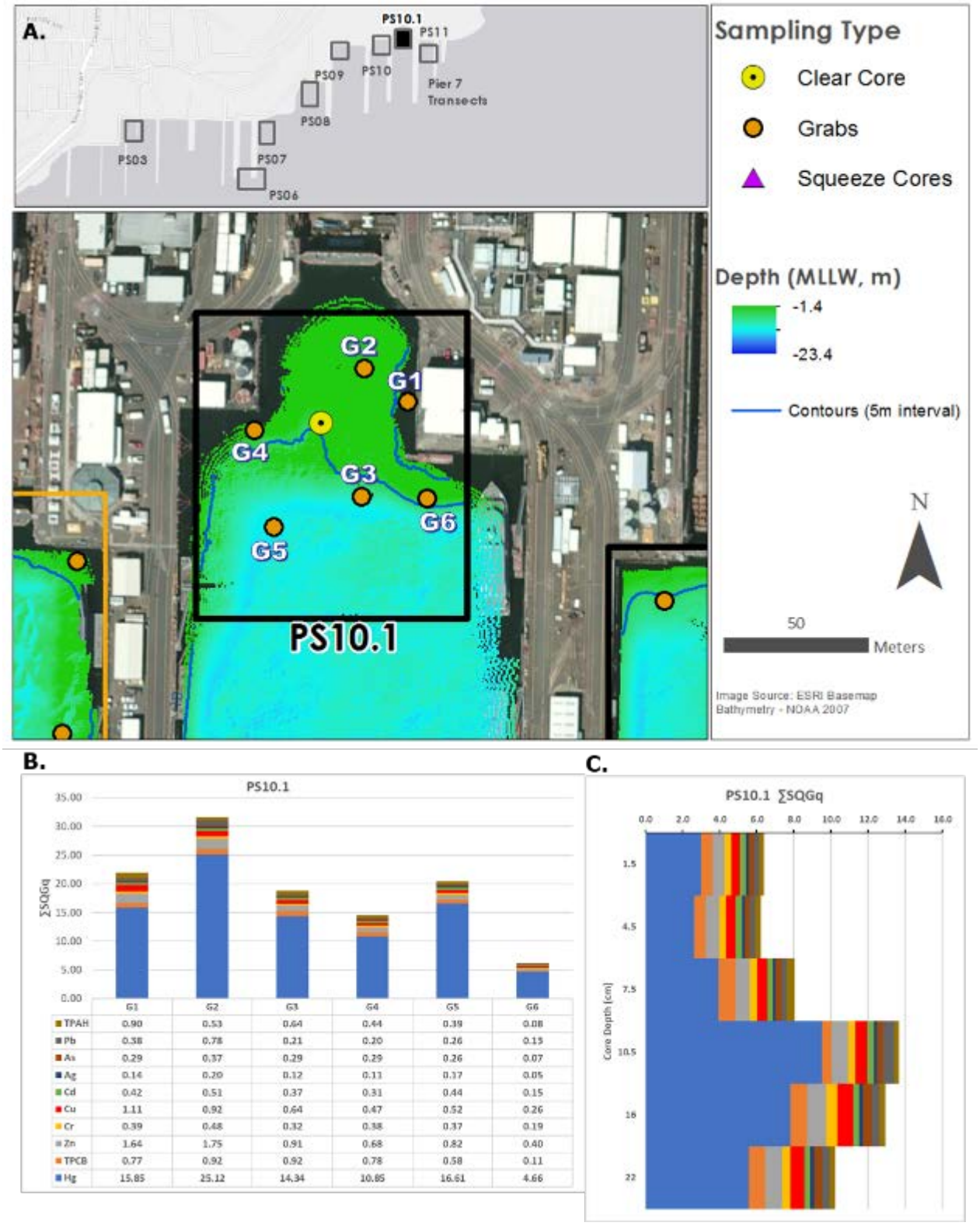
Focus area PS10 was located in front of Dry Dock 1, between Piers 5 and 6, within OUBM grid cell 67. The site is affected by docking operations in Dry Dock 1, legacy contamination in the sediment which can be resuspended during ship movements, mooring of active ships and barges, and stormwater runoff. Remedial dredging occurred at the site during the 2000-2001 remedial actions (Figure 5). Piers 5 and 6 are relatively open to currents, although when large vessels are docked at the piers their hulls impede the current flow. Additionally, the entrance to Dry Dock 1 is recessed from the main flow of the inlet creating a capture zone for silts, shell hash, and other sedimentary particles.

The samples were collected directly in front of Dry Dock 1 at a depth of about 24-40 ft (Figure 47A). Plots of the concentrations of Hg, Cu, Pb, and Zn measured in the surface grabs and cores are shown in Figure 48, the ∑SQGq calculated for the surface grabs and cores are shown in Figure 47, and the raw data

and mSQGq calculated for each sample are tabulated in Appendix D2.1 Sediment Concentrations and SQG Quotients.

All the surface grab and core profile samples collected from PS10.1 exceeded the MCC for Hg. The SQS was exceeded for Cu in one grab sample and the SQS was exceeded for Zn in two grab samples and the 13-19 cm core section (Figure 48). The grab samples were highly variable (mSQGq CV = 45%) mostly due to high variability of total Hg concentrations which had a SQGq range of 4.7-25.1 (Figure 47B). Due to the high concentrations of Hg, three of the surface grabs had a mSQGq > 2.0 (Appendix D2.1 Sediment Concentrations and SQG Quotients). The concentrations of Hg and Zn tended to be higher deeper in the core than near the surface, while the other chemicals were relatively constant in the core profile (Figure 47C). The spatial variability for the mSQGq (CV = 45%, Figure 47B) was higher than the temporal variability inferred by the core samples (CV = 34%, Figure 47C).

The AVS concentrations ranged from 39.1-76.2 umole/g which were well above the ∑SEM concentrations of 5.7-10.9 umole/g. The highest SEM concentrations were measured for Zn (3.1-4.3 umole/g) except for the 13-19 cm section which had a higher Ni concentration (4.4 umole/g) (Figure 48). The AVS : SEM ratio was above 5 for all the core segments, suggesting that the metals were bound as insoluble sulfides and were likely not biologically available to marine infauna.



	G1	G2	G3	G4	G5	G6
TPAH	0.90	0.53	0.64	0.44	0.39	0.08
Pb	0.38	0.78	0.21	0.20	0.26	0.13
As	0.29	0.37	0.29	0.29	0.26	0.07
Ag	0.14	0.20	0.12	0.11	0.17	0.05
Cd	0.42	0.51	0.37	0.31	0.44	0.15
Cu	1.11	0.92	0.64	0.47	0.52	0.26
Cr	0.39	0.48	0.32	0.38	0.37	0.19
Zn	1.64	1.75	0.91	0.68	0.82	0.40
TPCB	0.77	0.92	0.92	0.78	0.58	0.11
Hg	15.85	25.12	14.34	10.85	16.61	4.66

Figure 47. PS10.1 sampling locations (A) and ∑SQGq for surface grabs (B) and core sections (C).

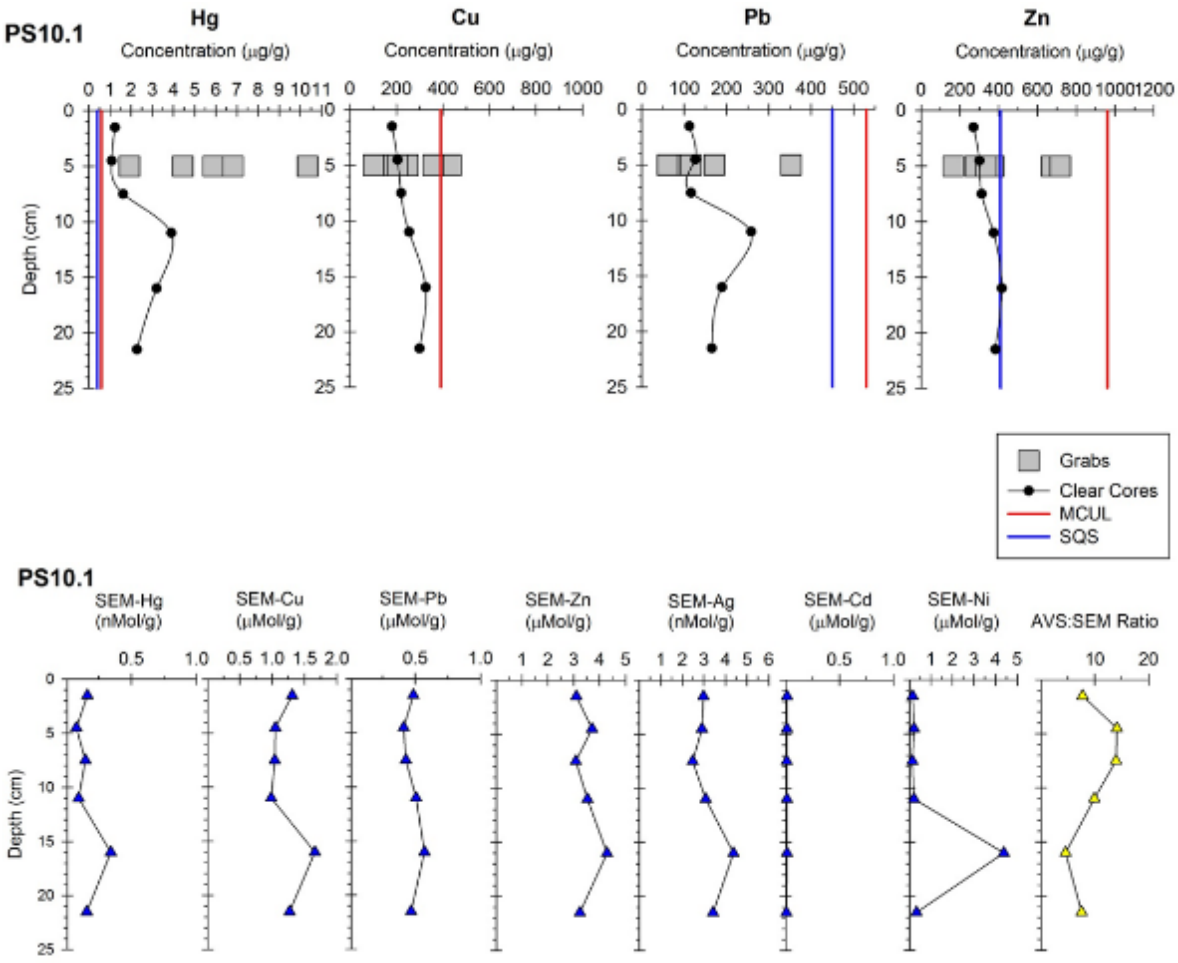


Figure 48. PS10.1 core profiles and surface grabs for bulk sediment (top panel) and SEM and AVS (bottom panel).

6.2.8 PS11

The PS11 focus area is located in front of Dry Dock 3 between Piers 6 and 7, and within OUBM grid cell 68. The area was not dredged during the 2000-2001 remedial actions (Figure 5). The site is affected by docking operations in Dry Dock 3, legacy contamination in the sediment which can be resuspended during ship movements, stormwater runoff, active ships and barges and inactive ships moored at the piers, and recycling operations at Pier 7 and Dry Dock 3. Formerly, a CSO (CSO16) discharged in the nearshore area of Pier 7. The CSO was diverted upon the completion of the Bremerton Tunnel and Pacific Ave. basin separation projects in 2009 (City of Bremerton 2018). Piers 6 and 7 are open to the currents so there is relatively more flushing, except for when large vessels are docked at the piers. Since the security barrier was put into place in 2004, Pier 7 has been generally free of vessels on its eastern side allowing more exchange of water across the area. Following removal of Pier 8 in 2010, the ecological habitat in the nearshore area east of Pier 7 has reestablished itself.

The samples were collected directly in front of Dry Dock 3 and between Piers 6 and at depths of about 37-40 ft (Figure 49A). Plots of the concentrations of Hg, Cu, Pb, and Zn measured in the surface grabs and cores are shown in Figure 50, the ∑SQGq calculated for the surface grabs and cores are shown in Figure 50, and the raw data and mSQGq calculated for each sample are tabulated in Appendix D2.1 Sediment Concentrations and SQG Quotients.

All of the samples from focus area PS11 exceeded the MCC for total Hg, one grab sample (G2) exceeded the SQS for total PCB and Zn and the MCC for Pb, and two other surface grab samples exceeded the SQS for Zn (Figure 50). The SQGq for Hg ranged from 8.7-19.7 in the surface grabs and 1.7-2.1 in the core samples (Figure 49), however only two grab samples had mSQGq > 2.0 (Appendix D2.1 Sediment Concentrations and SQG Quotients). The contaminant concentrations were relatively constant in the core profile, and the spatial variability for the mSQGq (CV = 20%, Figure 49B) was higher than the temporal variability inferred by the core samples (CV = 10%, Figure 49C).

The AVS concentrations in the core from focus area PS11 were highly variable, the lowest AVS concentration of 8.2 umole/g was measured in the 6-9 cm section and the highest AVS concentration of 120.0 umole/g was measured in the 13-19 cm section (Appendix D2.2 Results for SEM and AVS). The SEM concentrations were relatively constant down the core, the ∑SEM concentration ranged from 3.4-4.0 umole/g and the AVS:SEM molar ratio was ranged from 2.0-34.7 (Figure 50), suggesting that the metals were not biologically available.

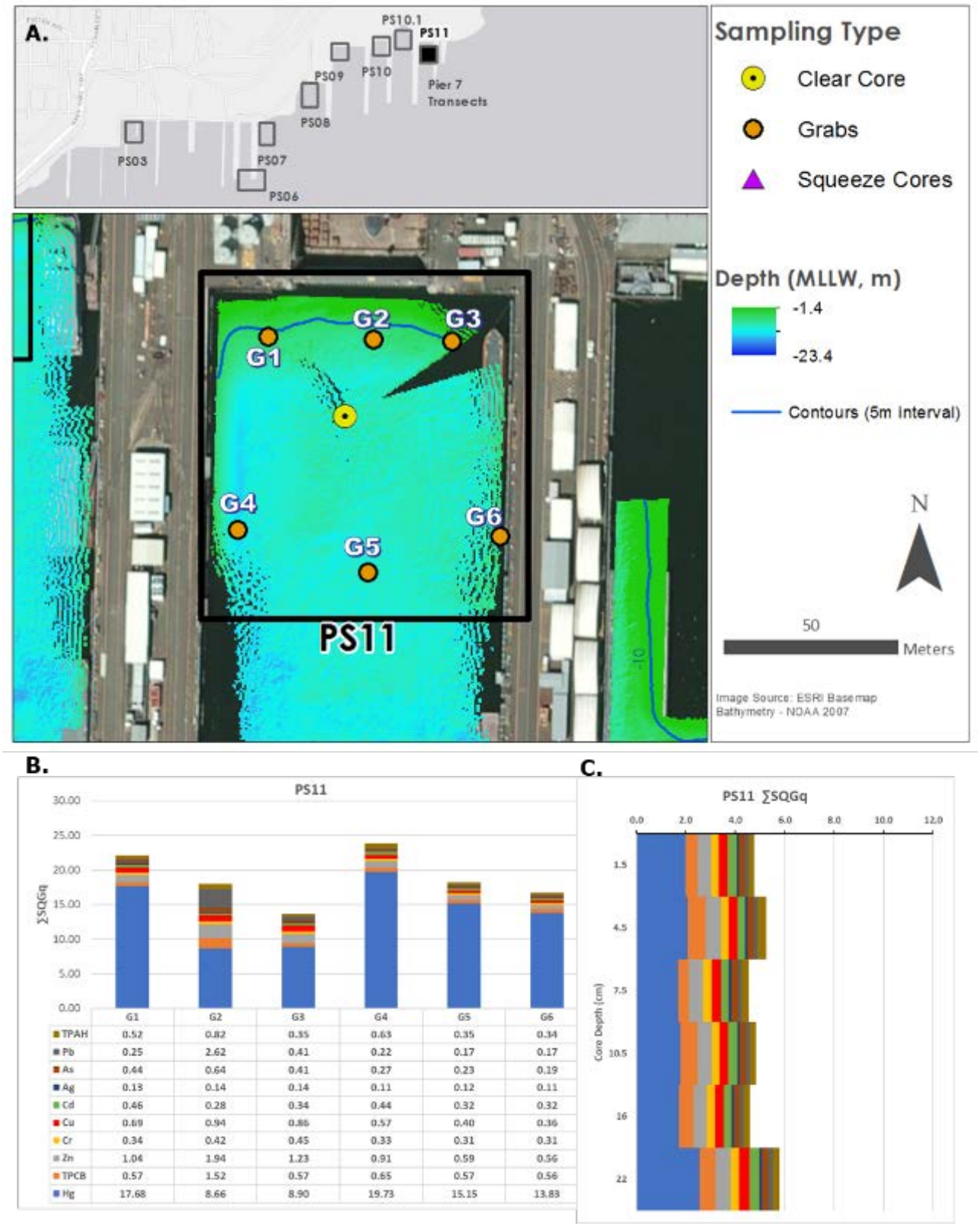


Figure 49. PS11 sampling locations (A) and ∑SQGq for surface grabs (B) and core sections (C).

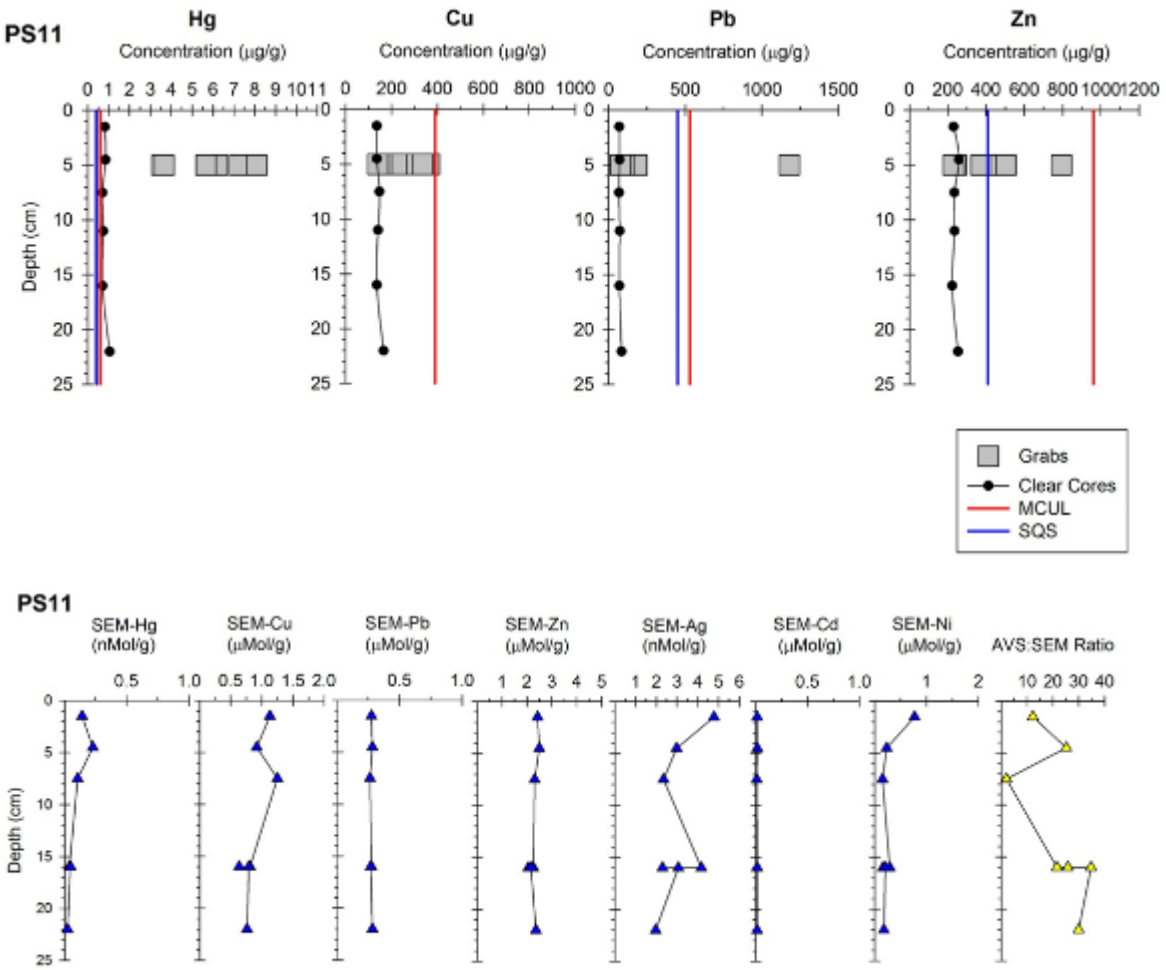


Figure 50. PS11 core profiles and surface grabs for bulk sediment (top panel) and SEM and AVS (bottom panel).

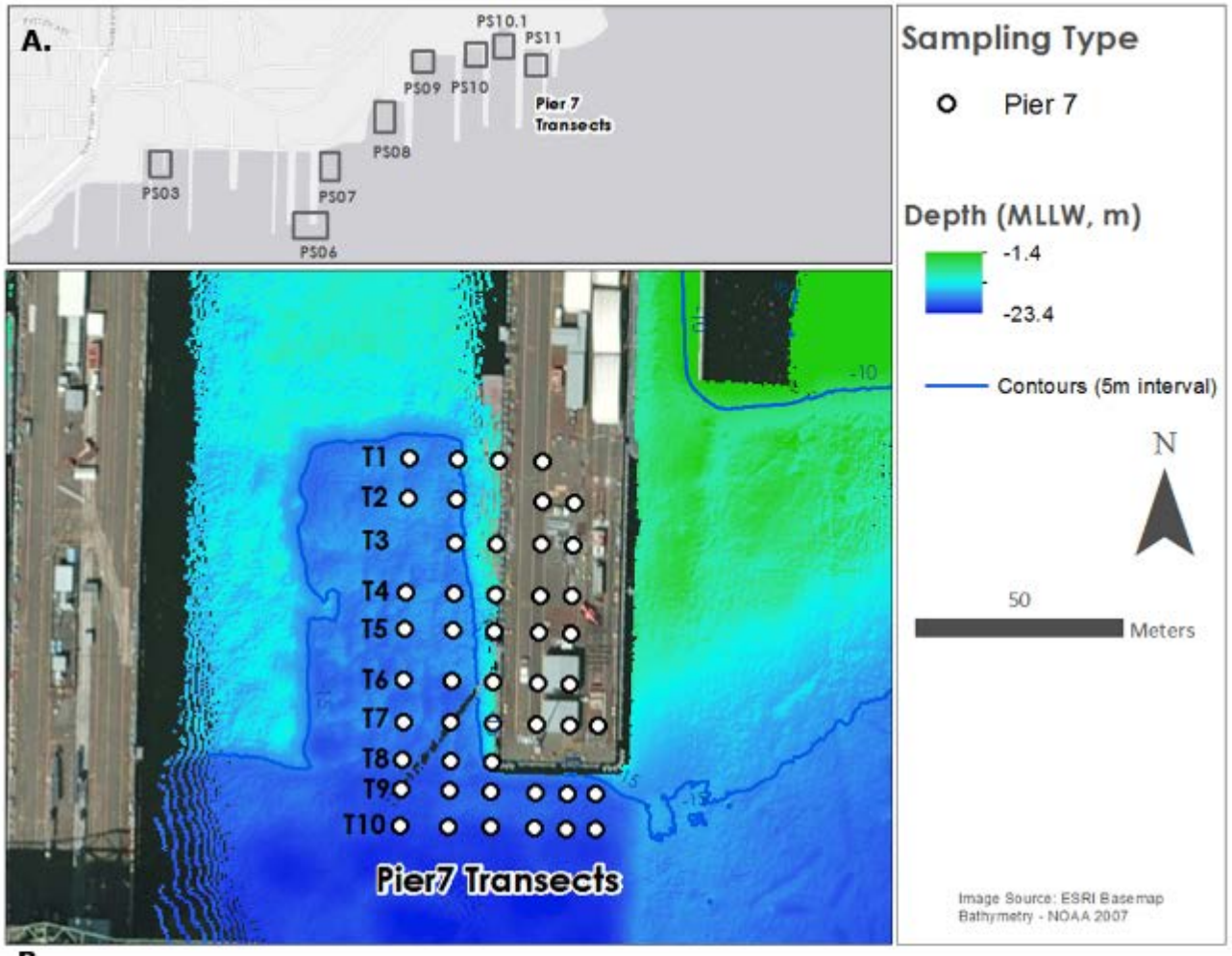
6.2.9 PIER 7

Located at the eastern edge of the Shipyard, the southwestern end of Pier 7 was selected as the site to conduct the in-situ sediment AC amendment demonstration study to remediate elevated concentrations of total PCB measured at the site during the fender pile replacement project in 2010. Previously, the berthing area at the end of Pier 7 was dredged during the remedial dredging conducted in 2000-2001 (Figure 5) and the successful field AC demonstration was initiated in August 2012 as a remedial action under the CERCLA ROD for OUBM (Johnston et al. 2013; Kirtay et al. 2017; Kirtay et al. 2018). The site is affected by docking operations in Dry Dock 3, legacy contamination in the sediment which can be resuspended during ship movements (Wang et al. 2016), active ships and barges and inactive ships moored at the pier, and recycling operations at Pier 7. Because Pier 7 extends out into the inlet, the site is exposed to currents and waves generated by wind and ferry traffic at the nearby Bremerton Ferry Terminal resulting in relatively high flushing at the site.

When the demo project was initiated in October 2011, the site was characterized by sampling transects of 0-10 cm surface grabs at 50 ft intervals adjacent to and extending under Pier 7 (Figure 51A). The diver-collected samples were analyzed using RSC methods for total PCB, total PAH, Cu, Pb, and Zn and confirmation analyses were conducted on a subset of samples as described in Section 6.1 Confirmation and Verification Results. In addition, each sample was analyzed for total Hg and grain size.

The high resolution sampling showed that the contaminant concentrations were highly variable and patchy; no clear gradient of contamination was identified, however high concentrations of total PCB, total PAH, total Hg, Cu, Pb, and Zn were found within the area remediated (Figure 51B-C). The maximum $mSQGq_6$ (where the mean SQG quotient was calculated from the six chemicals measured) of 9.7 was measured alongside the pier (Figure 51D) and was the focus of the remediation effort. The spatial variability calculated from the 51 transect samples at Pier 7 (CV of $mSQGq_6$ = 101%) was higher than the variability obtained for the surface grabs obtained from the other focus areas where the spatial variability (CV of mSQGq) ranged from 9% to 0 45%. This indicates that increasing the sample size within a focus area may not necessarily reduce the variability of the results. The inherent variability in the surface sediments within the Shipyard is probably caused by the inhomogeneous nature of the contaminant releases from multiple sources which were subjected to complex transport and sedimentation patterns resulting in patchy and highly variable surface contamination. High variability in the surface contamination, was one of the reasons that the OUBM LTM monitoring program was based on composite samples obtained from each grid cell (URS Group, Inc. 2002b).

While AVS was not measured in any of the Pier 7 transect samples, it is likely that AVS concentrations would have also been high enough to bind the metals present as the metal concentrations measured in the Pier 7 transect samples were within the range of metal concentrations measured at the other focus areas, except for the high concentrations of Cu and Zn measured two samples collected adjacent to the pier (T5-3 and T5-2, respectively, Figure 51C).



B.

PCB_T ug/g OC dry wt.

	C1	C2	C3	C4	C5	C6
T1	7.5	6.2	2.9	1.5	4.9	
T2	5.7	4.8	0.9	8.4	1.9	
T3	5.5	3.1	9.1	2.4	1.6	
T4	10.9	4.5	3.6	4.3	0.4	
T5	3.6	19.1	5.1	4.8	2.4	
T6	7.8	8.4	656.3	9.8	14.1	
T7	7.2	8.4	4.1	21.0	6.2	3.4
T8	7.3	4.1	5.2			
T9	2.9	2.4	2.4	2.4	2.7	2.6
T10	5.2	0.8	4.1	2.9	4.3	3.7

PAH_Total ug/g OC dry wt.

	C1	C2	C3	C4	C5	C6
T1	1466	717	528	132	304	
T2	818	501	84	487	186	
T3	740	536	463	214	180	
T4	634	582	406	500	225	
T5	415	636	550	586	175	
T6	481	681	889	299	509	
T7	566	680	462	542	251	192
T8	621	228	265			
T9	362	508	418	179	371	333
T10	510	136	362	219		

Hg ug/g dry wt.

	C1	C2	C3	C4	C5	C6
T1		0.64	0.40	0.24	0.62	
T2	0.53	0.20		0.70	0.17	
T3	0.43	0.11	0.73	0.19		
T4	1.19	0.29	0.45	0.57	0.21	
T5	0.21	0.83	0.69	0.44	0.49	
T6	0.56	0.50	0.79	0.36	0.60	
T7	0.33	0.85	0.14	0.69	0.34	0.26
T8	0.12	0.17	0.28			
T9	0.32	0.35	0.17	0.08	0.18	0.20
T10	0.67	0.06	0.44	0.81	0.92	1.00

Figure 51. Pier 7 transect sampling locations (A), distribution of TPCB, TPAH, Hg (B), Cu, Pb, and Zn (C) and the $mSQGq_6$ for surface transect samples (D).

C.

	Cu ug/g dry wt.					
	C1	C2	C3	C4	C5	C6
T1	94	155	100	284	128	
T2	128	100	57	185	57	
T3	64	66	141	57	57	
T4	183	66	61	102	57	
T5	84	486	3754	979	24	
T6	93	91	113	98	82	
T7	52	89	30	130	123	35
T8	41	30	46			
T9	30	71	33	15	34	57
T10	57	57	62	57	57	57

	Pb ug/g dry wt.					
	C1	C2	C3	C4	C5	C6
T1	75	119	29	250	71	
T2	64	29	29	140	29	
T3	81	39	98	44	29	
T4	212	65	100	77	40	
T5	42	492	73	45	16	
T6	80	55	90	628	55	
T7	31	70	23	94	39	26
T8	23	24	43			
T9	16	69	32	14	58	29
T10	47	29	31	29	29	29

	Zn ug/g dry wt.					
	C1	C2	C3	C4	C5	C6
T1	306	521	200	700	234	
T2	281	255	34	557	80	
T3	251	505	303	151	150	
T4	439	204	360	227	242	
T5	380	1212	578	378	81	
T6	239	239	278	391	182	
T7	111	181	147	225	168	136
T8	119	149	161			
T9	79	183	131	67	334	85
T10	239	90	174	126	299	86

D.

	mSQGq[6] dry wt.					
	C1	C2	C3	C4	C5	C6
T1	0.6	0.8	0.4	0.6	0.5	
T2	0.6	0.4	0.1	0.8	0.2	
T3	0.5	0.4	0.7	0.2	0.2	
T4	1.0	0.4	0.5	0.5	0.3	
T5	0.4	1.6	2.3	0.9	0.3	
T6	0.6	0.6	9.7	0.8	0.6	
T7	0.4	0.7	0.3	0.8	0.4	0.3
T8	0.3	0.2	0.3			
T9	0.3	0.4	0.2	0.1	0.3	0.2
T10	0.5	0.1	0.4	0.5	0.7	0.6

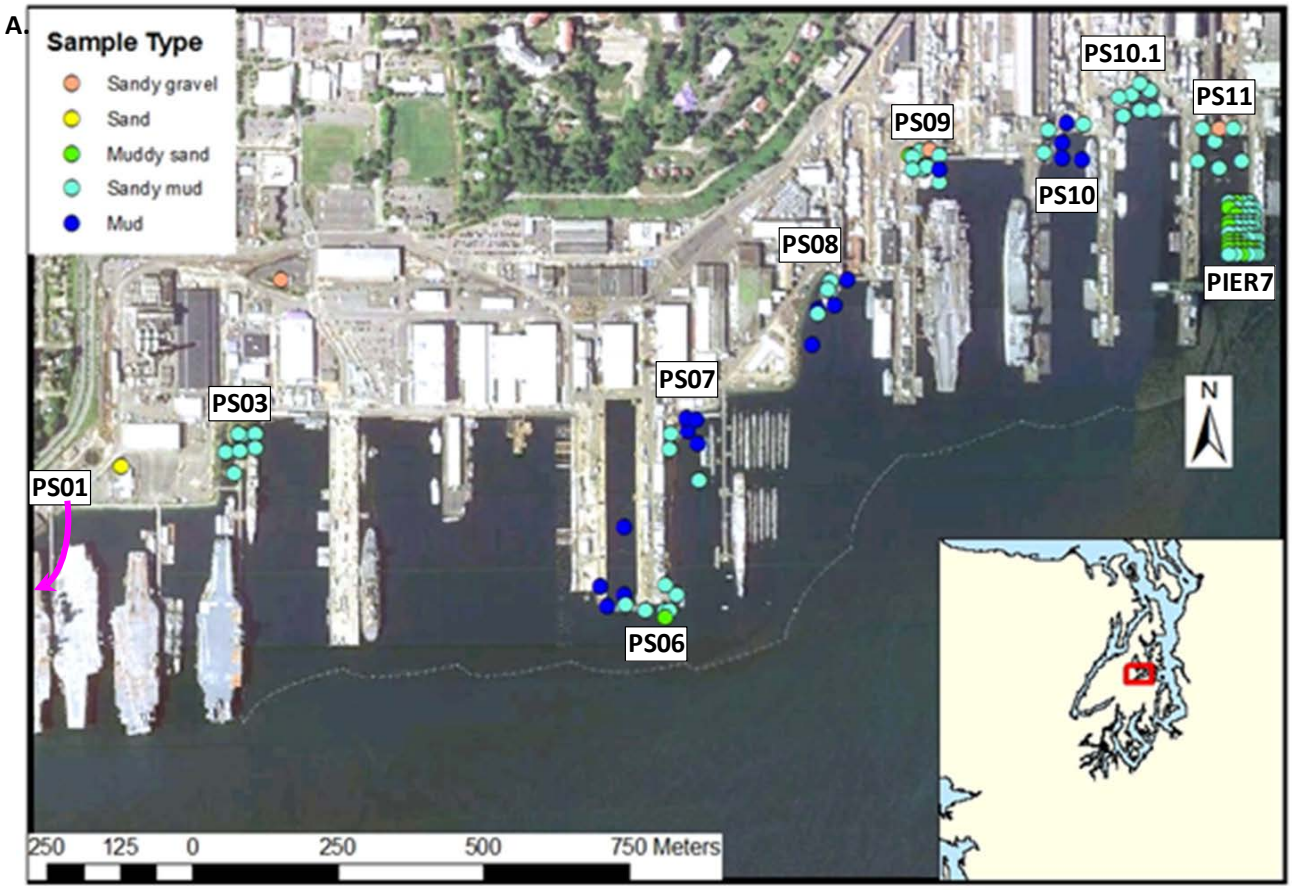
Fig 50. Cont.

6.2.10 Focus Area Summary

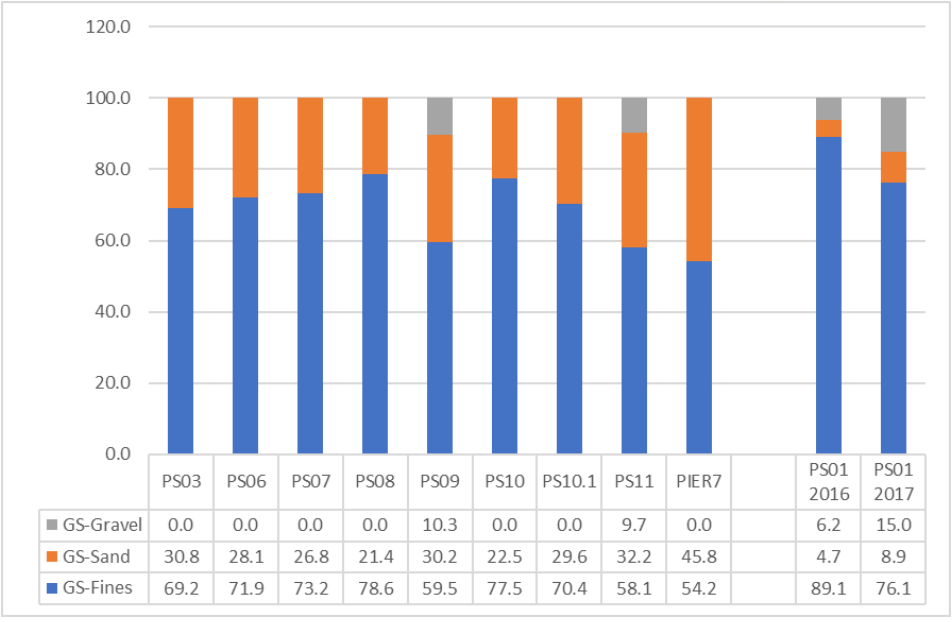
The sedimentary environment is shaped by the hydrodynamics of the site and the grain sizes of the particles available to be deposited (McLaren 1981). The sedimentary environment of the focus areas consisted primarily of sandy muds and muds while the Pier 7 site had coarser muddy sand and sandy mud deposits (Figure 52A, Appendix A.3 Grain Size Analysis Data Report). On average, the percent of fines (<63 um) in the 0-10 cm surface was 70% or higher for PS03, PS06, PS07, PS08, PS10, PS10.1 and PS01 (Figure 52B). Coarser material was present at PS09, PS11, and PIER9, and about 10% of the material at PS09, PS11, and PS01 was > 2 mm, which consisted of mostly shell hash and other debris (Figure 52B). The TOC content was significantly higher at PS03 than the other sites (Figure 53A), while the average grain size was about the same for all the sites (4.1-5.3 phi) but was highly variable at PS09, PS11, and PIER7 (Figure 53B).

The presence of coarser material could be an indication of more disturbance. Overall, the surficial sediments of the Sinclair Inlet have followed a clear and significant trend in which they have become progressively coarser, more poorly sorted, and more negatively skewed in the years from 1998 to 2011 (Figure 54). The change in mean grain size ranged from 6.01 phi to 4.45 phi. The trend is interrupted only in the 3 years from 2003 to 2007, during which there was a relatively minor but significant reversal in the coarsening sequence. Recognizing that the nearshore areas of the Bremerton waterfront have had a complex history of dredging and waterfront operations (Table 1), the discovery of such a significant trend might be regarded as surprising. Both the coarsening and fining trends can be explained by depositional processes only. Erosion, although resulting in a coarsening trend will also improve the sorting of the trend. In this case, sorting has become poorer which, as described in McLaren (2008) can only happen when coarse sediment is added to pre-existing finer sediment. The short period of reversal where the sediments became slightly finer again can also only happen under depositional conditions. (McLaren 2004; McLaren 2008).

The coarsening trend line (Figure 54) suggests that throughout the last two decades there has been an increase in the availability of coarser sediment for the transport regime. This could occur, for example, by dredging deeper into underlying glacial deposits in which a greater range of sediment sizes become available for transport and deposition than was available prior to their disturbance and exposure. At the same time, larger vessels, an increase in ship activities (propeller wash), and in-water construction projects could also increase the movement and deposition of coarser sediment (Wang et al. 2016). Only from 2003 to 2007 did the trend reverse, suggesting that there was a hiatus in the dredging or a decline in vessel maneuverings enabling a return to the deposition of finer sediments. For example, the sediments at PS01 at Mooring G were sampled in 2016 and 2017 (Johnston, Arias, et al. 2018). The PS01 samples collected in 2016 followed a period of more than 18 years that an inactive air craft carrier was moored at the site which precluded any physical disturbance of the seafloor. The PS01 2017 samples were collected following biofouling removal and towing of the air craft carrier from Sinclair Inlet, which resulted in more coarse material (Figure 52B) and higher variability in TOC, Cu and Zn (Figure 53A, C, and D), (Johnston, Arias, et al. 2018).



B.



	PS03	PS06	PS07	PS08	PS09	PS10	PS10.1	PS11	PIER7		PS01 2016	PS01 2017
GS-Gravel	0.0	0.0	0.0	0.0	10.3	0.0	0.0	9.7	0.0		6.2	15.0
GS-Sand	30.8	28.1	26.8	21.4	30.2	22.5	29.6	32.2	45.8		4.7	8.9
GS-Fines	69.2	71.9	73.2	78.6	59.5	77.5	70.4	58.1	54.2		89.1	76.1

Figure 52. (A) Sediment texture type for surface sediment samples collected from focus areas, dry docks, and selected storm drains, see Appendix A.3 Grain Size Analysis Data Report for details. (B) Percent fines, sands, and gravel for focus areas sampled in 2011 and PS01 sampled in 2016 and 2017.

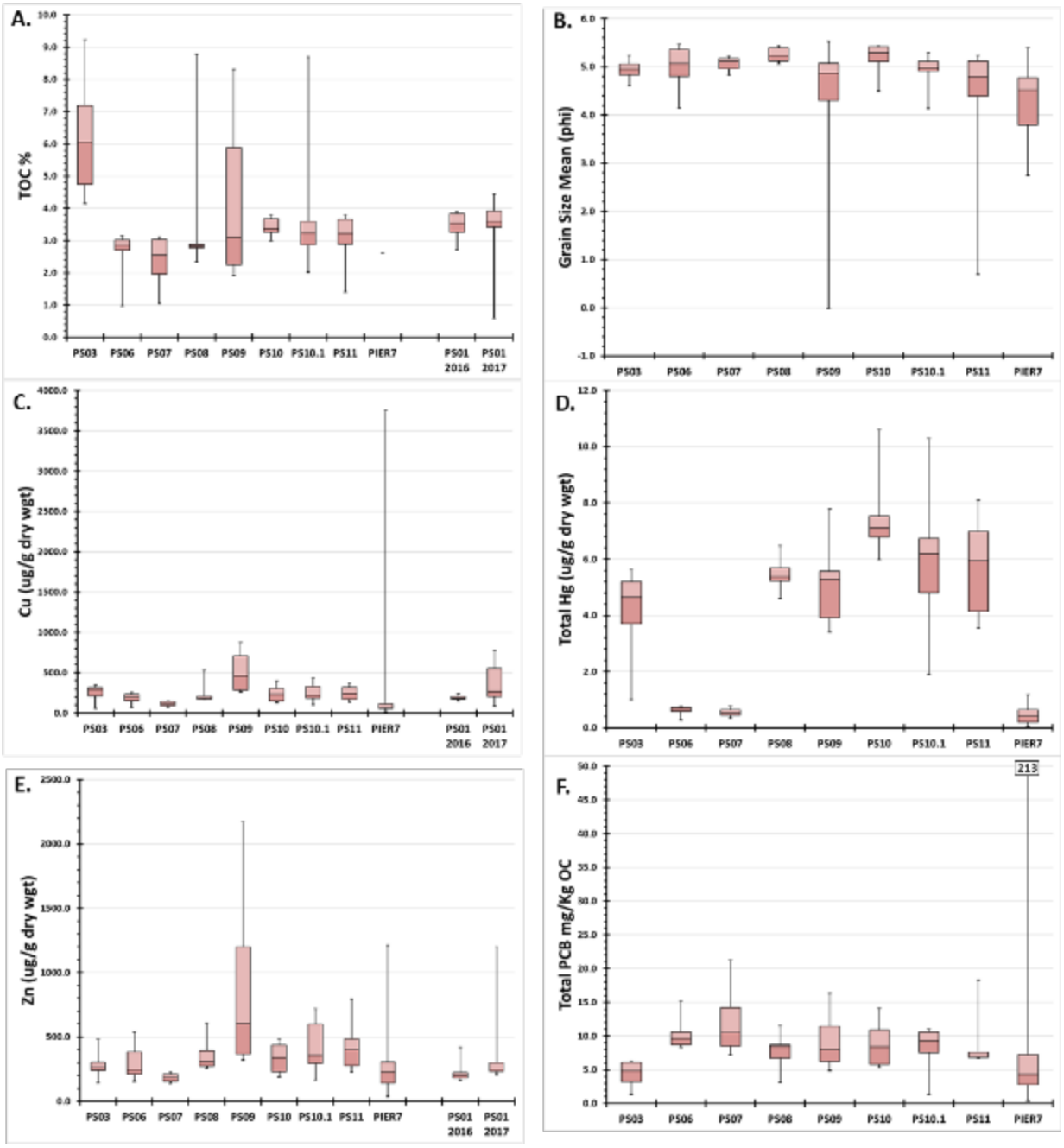


Figure 53. Summary of sediment characteristics for surface sediment samples collected from focus areas in 2011 and PS01 in 2016 and 2017.

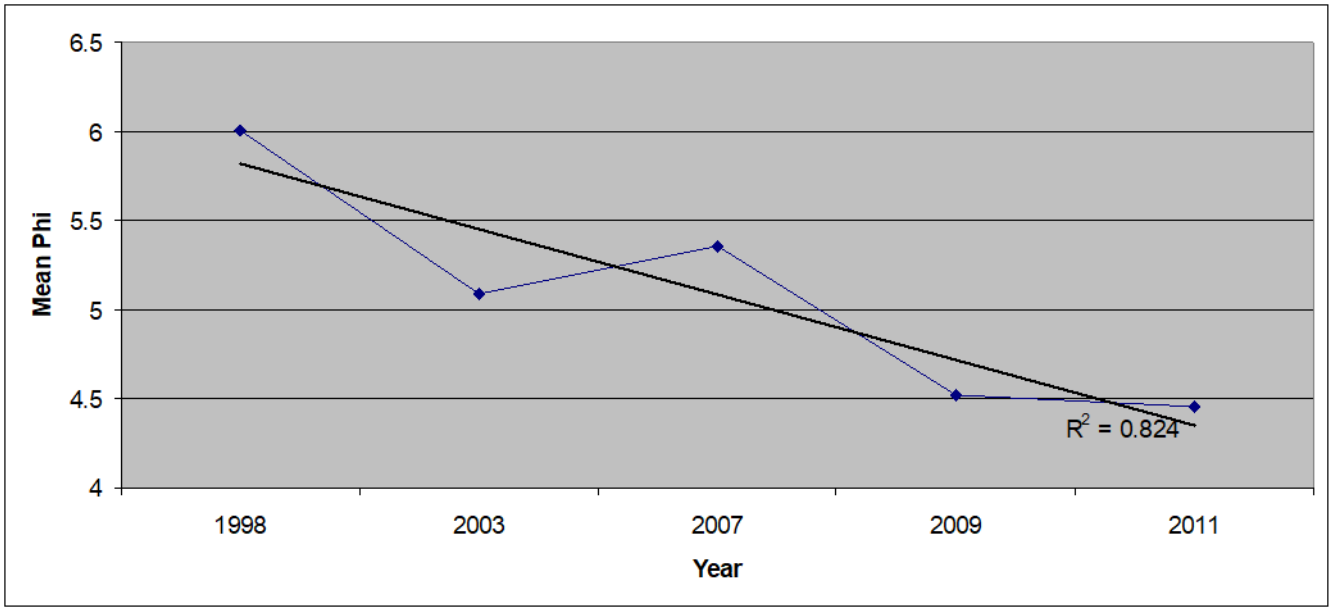


Figure 54. Change in mean grain size for Sinclair Inlet sediments from 1998 to 2011 (Appendix A.3 Grain Size Analysis Data Report).

To explore for the presence of systematic textural changes with depth, the entire grain-size distribution for each sub-sample was examined for each core, followed by a regression of the mean, sorting and skewness descriptors with depth down the core (Appendix A.3 Grain Size Analysis Data Report). The most striking feature of the grain-size distributions found in the core profiles was the lack of variability. An examination of the distributions with depth down each core revealed very similar distributions. It could be argued that, given the relatively consistent changes in the surficial sediments that were discussed above (namely that textures have become generally coarser since 1998) that the same observation of coarsening sediment should be seen from depth to the surface in the cores. However, the data do not show enough consistent trends to support such a supposition. One explanation is that dredging and propeller wash are processes that continually (and randomly) disturb the sediments (at least in the top 25 cm) thereby destroying any regularity to the stratigraphic sequence that may have otherwise formed.

The relative variability in contaminants measured in the surface samples from the focus areas showed that Hg, Cu, Zn, and total PCB/OC were highly variable (Figure 53). On average, the highest concentrations of Hg were measured at PS10, PS09 had the highest average concentrations of As, Cd, Cr, Cu, Ni, Pb, Zn, and total PAHs, PS11 had the highest average concentration of Pb, and PIER 7 had the highest average for total PCB (Appendix D2.4 Surface Grab Summary). For Hg, the average surface concentrations exceeded the MCC in all the focus areas except for PS07 and PIER7 which both exceeded the Hg SQS.

The relative differences in concentrations of contaminants in surface sediment samples and core profiles were evaluated by comparing the magnitude and variability of concentrations measured in both zones. Sites with higher surface concentration are likely indicative of recent sources associated with settling of new and resuspended particles, while higher concentrations at depth could indicate historical sources buried by more recent deposits or residual contamination left behind by remedial dredging. The comparison showed that most of the sites had similar concentrations in both zones (PS07, PS10.1, PS11, PS01-2017), however higher surface Hg concentrations were measured at PS03, PS08, and PS09; PS09 also had higher surface concentrations of Cu, Pb, and Zn; PS06 had higher profile concentrations for Hg, Zn, and PCBs; and PS10 had higher profile concentrations for Hg, Pb, Zn, and PCBs (Appendix D2.4 Surface Grab Summary).

The AVS concentrations measured in the core profiles collected from the focus areas were highly variable and no distinct pattern was evident (Figure 55). However, AVS concentrations were abundant and exceeded the $(\sum SEM\text{-}AVS)/f_{OC}$ was less than 130 umole/g OC in all the samples analyzed (Appendix D2.2 Results for SEM and AVS). The comparison to benchmarks for protection of benthic organisms from metal exposure showed that all the samples had low risk of adverse biological effects (Figure 56). These results show the importance of maintaining favorable geochemical conditions that will keep the metals (especially Hg) bound as insoluble sulfides. The AVS benchmarks are only applicable for assessing the potential for metal toxicity through pore water exposure to free metal, the AVS benchmarks do not address metal bioaccumulation or trophic transfer in the food web (U.S. Environmental Protection Agency 2005; Burgess et al. 2013).

In all focus areas, with the exception of the top section at PS06, the molar ratio of AVS:SEM greatly exceeded 1, usually by a factor of 5–10, indicating that there is sufficient sulfide present to sequester the divalent metals. In the two cores where pore water concentrations were measured (PS03 and PS09), the porewater concentrations of the divalent metals (Cu, Ni, and Zn) varied inversely with the bulk sediment concentrations and total sulfide concentrations, indicating that excess sulfide was able to sequesters those metals under anoxic conditions. Hg acted in the reverse manner, indicating that Hg does not necessarily behave as a true divalent metal-sulfide and that other Hg compounds may control the solubility of Hg in sediments.

Excluding Hg, food-web biomagnification of metals is not likely a major concern as marine invertebrates and fish are well adapted for mediating Cu and Zn since these metals are both micro-nutrients and essential to life at low levels and toxic at higher levels, thus limiting biomagnification in the food web (Paquin et al. 2011). For Hg, the key question is whether inorganic Hg will be methylated thus becoming more toxic and more bioavailable for transfer in the food web. Recent work has shown that Hg methylation level in Sinclair Inlet were relatively lower than other areas of the Puget Sound (see Figure **13**) and Hg methylation rates were dependent on temperature, sediment redox, sediment bulk density (organic content and grain size), and total Hg present in the sediment (U.S. Navy 2017b; Paulson et al. 2018). The USGS, results showed that total sediment Hg only had a minor effect on the net methyl Hg production potential rate (Paulson et al. 2018), thus it is important to maintain the geochemical conditions that are apparently limiting methyl Hg production.

Under the anoxic conditions, the metal contaminants present would most likely be inert, bound up in insoluble metal sulfides. Under natural recovery processes the surface sediment would be recolonized by benthic organisms which are capable of reworking the surface sediment and oxidizing the metal sulfides and releasing the metals. The rate this occurs would be dependent on many factors including benthic community development, inputs of organic matter to the sediment, recovery rates, and other mediating factors (Johnston 1993).

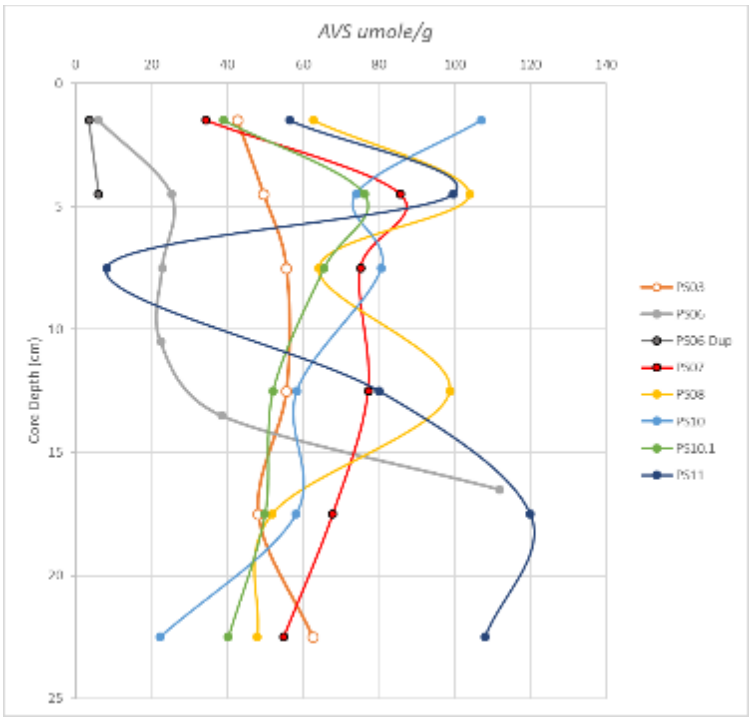


Figure 55. AVS core profiles measured for each of the focus areas.

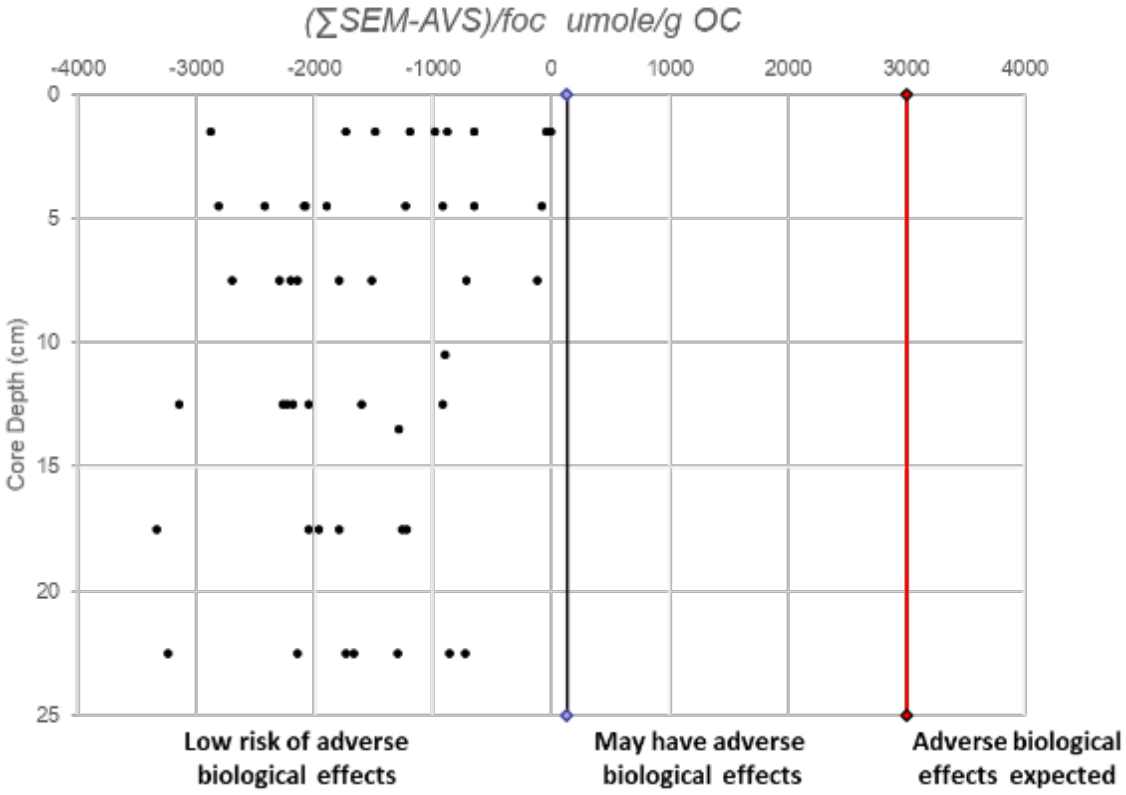


Figure 56. Plot of (∑SEM-AVS)/f_{OC} as a function of core depth for samples collected within the Focus Areas and the relationship to sediment quality benchmarks for the protection of benthic organisms from metal exposure (U.S. Environmental Protection Agency 2005; Burgess et al. 2013).

6.3 Sediment Toxicity Assessment

Sediment toxicity testing was conducted using standardized protocols with the marine amphipods, *Leptocheirus plumulosus* and *Ampelisca abdita*, the polychaete worm, *Neanthes arenaceodentata*, (US EPA 1994; J.D. Farrar and Bridges 2011) and Mediterranean mussel (*Mytilus galloprovincialis*) embryos (Anderson et al. 1996) to evaluate the environmental risk of sediment samples collected from PS03 and PS09. The results reported are from a single collection event (April 2011) and included a total of 6 test endpoints for two samples (Appendix A.4 Sediment Toxicity Data Report).

The controls associated with the exposure at the sediment-water interface using embryos from the bivalve, *Mytilus galloprovincialis*, did not meet test acceptability criteria because the chamber control associated with the SWI exposures with *M. galloprovincialis* was slightly outside of test acceptability criteria at 75.6% (acceptability criteria: ≥ 80% mean normal-alive). However, the tests were deemed acceptable based on the responses of the site sediments all performing better than the control and no evidence of toxicity for either sediment samples as found (Figure 57A).

No toxicity was observed for the whole sediment test with the marine amphipod, *Leptocheirus plumulosus* (Figure 57B). The whole sediment test with the marine amphipod, *Ampelisca abdita*, also did not meet test acceptability criteria because the mean control survival was below 90% survival, however, when the samples were compared against the control, PS09 was significantly decreased from the control sediment ($p = 0.0493$) and while PS03 did not show significance relative to the control, the trend for toxicity was similar to PS09 (Figure 57B).

For the marine polychaete, *Neanthes arenaceodentata*, survival was 100% for both samples and positive growth of 5.1 and 4.7 mg was observed for PS03 and PS09, respectively (Figure 57C-D). Each sample was compared statistically against the laboratory control sediment and no significant differences were observed for either survival or growth ($p>0.05$).

The exposure concentrations of total and dissolved Cu and Zn measured in the test media are summarized in Table 25. The dissolved concentrations of Cu were about the same for both stations ranging from 0.6-0.8 ug/L for OW and 0.4-0.8 ug/L for PW. The highest concentrations of dissolved Zn (7.2-20.8 ug/L) were measured in the OW from PS03. The exposure concentrations were well below the chronic WQS of 3.1 ug/L for Cu and 81.0 ug/L for Zn resulting in toxic units < 1 (0.19-0.39) for all the exposure concentrations tested (Table 25).

In general, the toxicity tests showed that the sediments from PS03 and PS09 were nontoxic, however slight toxicity to amphipod survival was observed for the sediment from PS09 (Table 26). Because the toxic units calculated for Cu and Zn were well below effects thresholds, it is unlikely that any toxicity was caused by exposure to Cu and Zn. Other factors such as sediment texture, other contaminants, and/or other sources of benthic stress could have contributed to the results observed. Sediment mSQGq calculated for PS09 ranged from 1.0-3.0 (see 9.0Appendix DAppendix D.2 Focus Area Results), however the mSQGq was driven by Hg concentrations which are probably bound as insoluble sulfides and not biologically available. No effects were observed for the same exposure to *L. plumulosus*, suggesting that species differences may have contributed to the observation of slight toxicity in the sample from PS09.

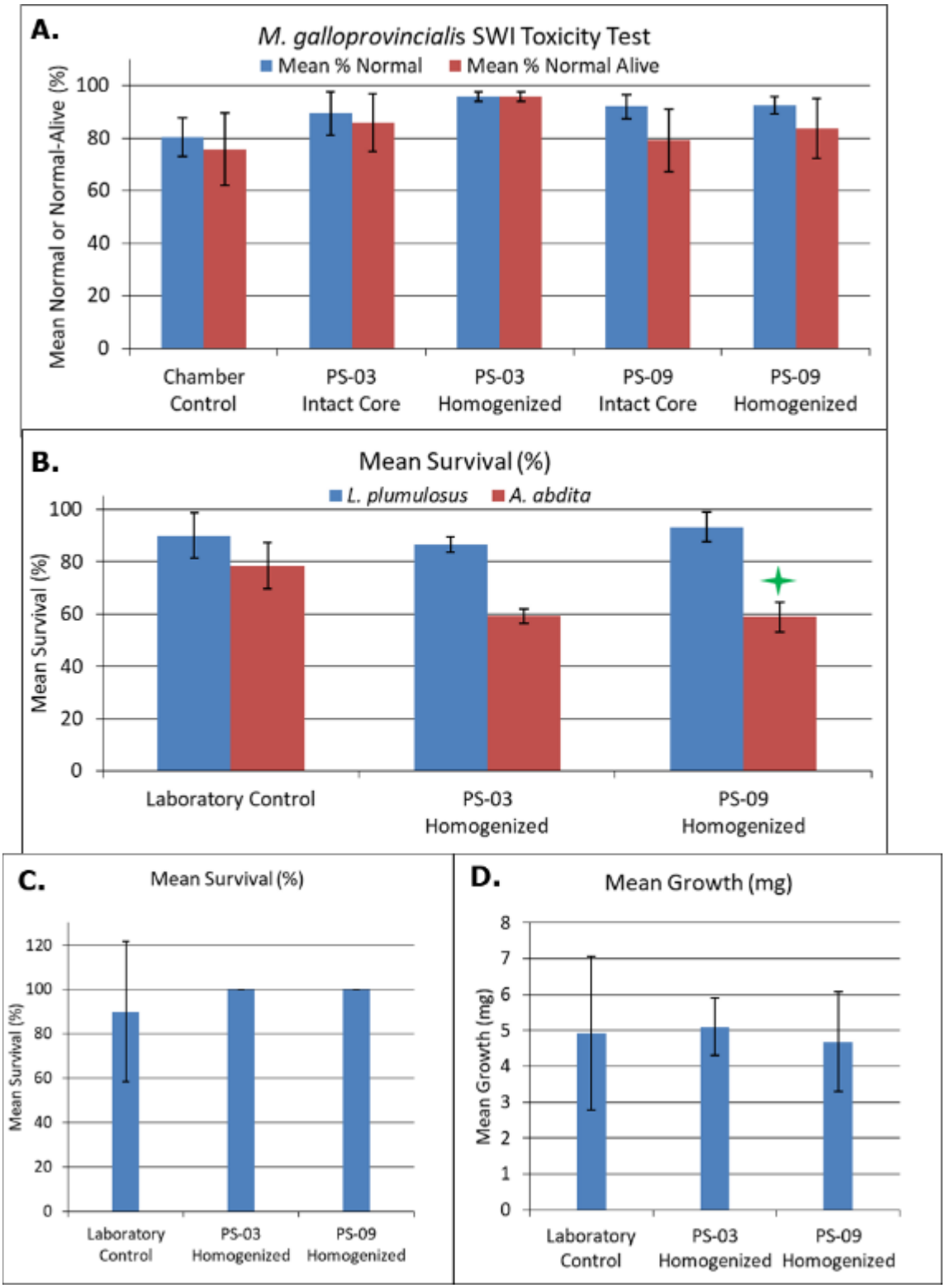


Figure 57. Results of SWI exposure to mussel embryos (A), whole sediment exposure to amphipods (B), and whole sediment exposure to polychaete worms (C and D) toxicity tests. Green star indicates significance at $p<0.05$.

Table 25. Summary of exposure concentrations measured for exposure to amphipods (A and B), polychaete worms (C), and mussel embryos (D).

A. Exposure to amphipods (*L. plumulosus*)

	Overlying Water – Time Final				Pore Water		Toxic Units	
Sample ID	Total Cu (µg/L)	Dissolved Cu (µg/L)	Total Zn (µg/L)	Dissolved Zn (µg/L)	Dissolved Cu (µg/L)	Dissolved Zn (µg/L)	Overlying Water	Pore Water
PS03	1.2	0.8	3.0	7.2	0.8	10.4	0.35	0.39
PS09	1.7	0.8	9.4	6.1	0.4	1	0.33	0.14

B. Exposure to amphipods (*A. abdita*)

	Overlying Water – Time Final				Pore Water		Toxic Units	
Sample ID	Total Cu (µg/L)	Dissolved Cu (µg/L)	Total Zn (µg/L)	Dissolved Zn (µg/L)	Dissolved Cu (µg/L)	Dissolved Zn (µg/L)	Overlying Water	Pore Water
PS03	1.1	0.8	17.2	20.8	0.8	10.4	0.51	0.39
PS09	1.6	1.0	17.6	13.4	0.4	1	0.49	0.14

C. Exposure to polychaete worms

	Overlying Water – Time Final				Pore Water			Toxic Units	
Sample ID	Total Cu (µg/L)	Dissolved Cu (µg/L)	Total Zn (µg/L)	Dissolved Zn (µg/L)	Dissolved Cu (µg/L)	Dissolved Zn (µg/L)	DOC (mg/L)	Overlying Water	Pore Water
PS03	1.2	0.8	1.8	0.5	0.4	ND	<5.0	0.26	0.13
PS09	0.8	0.8	3.1	3.1	0.4	16.5	<5.0	0.30	0.33

D. Exposure to mussel embryos (C indicates intact core, H indicates homogenized core)

	Overlying Water – Time 0					Overlying Water – Time Final						
Sample ID	Total Cu (µg/L)	Dissolved Cu (µg/L)	Total Zn (µg/L)	Dissolved Zn (µg/L)	Toxic Units	Total Cu (µg/L)	Dissolved Cu (µg/L)	Total Zn (µg/L)	Dissolved Zn (µg/L)	Toxic Unit	DOC (mg/L)	TOC (mg/L)
PS03 - C	1.4	0.7	4.5	4.3	0.28	1.7	0.6	2.4	0.4	0.20	<0.5	<0.5
PS03 - H	1.3	0.6	1.7	1.9	0.22	2.6	0.6	3.1	ND	0.19	<0.5	<0.5
PS09 - C	0.9	0.6	2.4	2.2	0.22	1.3	0.6	2.2	ND	0.19	<0.5	<0.5
PS09 - H	1.1	0.6	1.6	2.5	0.22	4.7	0.6	5.3	ND	0.19	<0.5	<0.5

Table 26 Summary of toxicity results conducted on samples from PS03 and PS09 for sediment water interface toxicity (A), whole sediment toxicity (B), water chemistry for overlying water (OW) and pore water (PW) (C), sediment chemistry (D), and tissue residue chemistry (E).

	A. Sediment Water Interface Toxicity (48 hrs)			
	M. galloprovincialis			
	Normal		Normal Alive	
Station	Core	Homogenized	Core	Homogenized
PS03	89%	96%	86%	97%
PS09	92%	93%	79%	83%
	B. Whole Sediment Toxicity			
	10 days		**28 days**	
	L. plumulosus	*A. adbita*	*N. arenaceodentata*	
Station	Survival	Survival	Survival	Growth (mg)
PS03	87%	59%	100%	5.10
PS09	93%	**59%**	100%	4.68

Key for Toxicity Results	
$p \geq 0.05$	**Non Toxic**
$0.05 > p < 0.01$	**Slightly Toxic**
$p \leq 0.01$	**Toxic**

		C. Water Chemistry			
		L. plumulosus	*A. adbita*	*N. arenaceodentata*	*M. galloprovincialis*
PS03	OW	Low	Low	Low	Low
	PW	Low	Low	Low	Low
PS09	OW	Low	Low	Low	Low
	PW	Low	Low	Low	Low

	D. Sediment Chemistry		
	Bulk Sed	<63 um	(SEM-AVS)/foc
PS03	Low	Low	Low
PS09	Low	Low	Low

	E. Tissue Residue Chemistry in *Neanthes arenaceodentata*	
	Cu	Zn
PS03	Low	Low
PS09	Low	Low

Key for Chemistry Results	
Low Risk of Effects	**Low**
Medium Risk of Effects	**Mediuim**
High Risk of Effects	**High**

6.4 Dry Dock Silt

The purpose of the caisson and dry dock silt sampling was to sample and characterize the texture and contaminant levels in the silt and sedimentary material that accumulated in front of the caissons between docking operations, material that accumulated on the dry dock floor after dewatering, and material entrained within the dry dock drainage system. The sampling was also conducted to provide information about dry dock cleaning BMPs implemented as part of the improvements to achieve AKART for industrial processes at the Shipyard (Figure 58).

Figure 58. Photos of dry dock cleaning after dry dock dewatering.

6.4.1 Texture and Chemical Analysis of Dry Dock Silt Samples

A summary of silt sampling events is included in Table 27, the raw data for the dry dock silt sampling conducted from 2012 – 2014 are provided in Appendix A.6 , and a summary of results are shown in Appendix D.3 Dry Dock Silt . During the sampling, a bag of blasting grit (copper slag) used in the 1970s-80s was discovered in DD5 underneath a keel block so a sample of unused historical blasting grit (BG) was also collected and submitted for analysis.

In 2010, the caisson samples were collected at the base of caissons in front of the dry docks (see Figure **30**) that had been closed for several months which had allowed material to accumulate in front of the caissons. The divers reported that about 20-25 cm (8-10 in) of material was present on the apron and in the corners along the dry dock wall. In 2010, DD6 was open to the inlet for about six months and divers collected silt samples from within DD6 prior to replacement of the caisson and dewatering (see Figure **31**). The divers reported that there was about 5-8 cm (2-3 in) of material present on the bottom of DD6. Subsequently, after dewatering, silt samples were collected from the floor of DD6; cleaning consisted of washing the material back into the inlet through the drainage system. During this period, surface grab samples were also obtained from along the quay wall and pier adjacent to DD4 (PS09) which had also been closed for many months (Table 27).

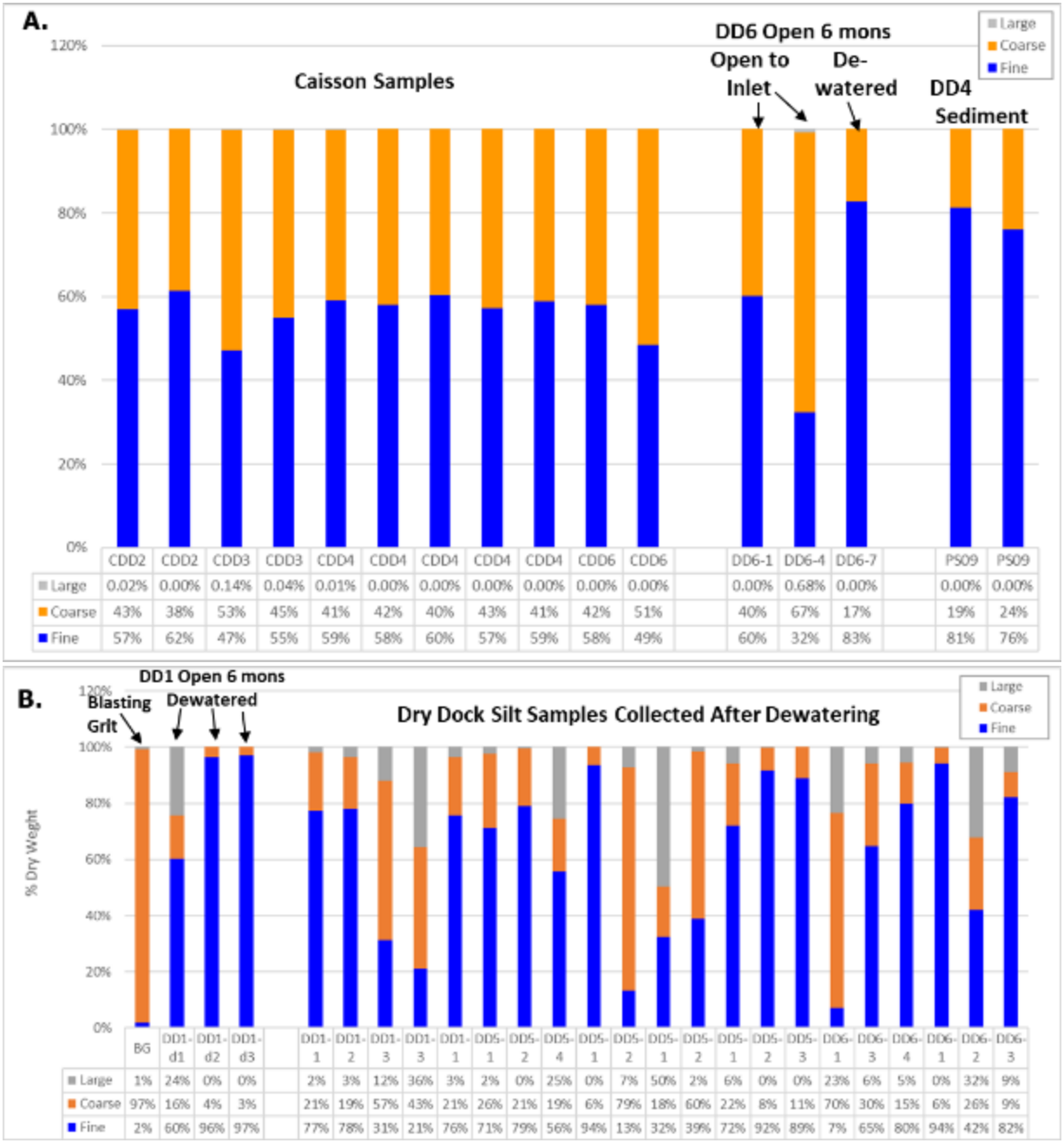
In 2012-2014, silt samples were collected after dewatering in various dry docks (Table 27). The sampling included a sample of unused historical blasting grit (BG) that was found under a keel block in DD5, samples collected in DD1 dewatered after DD1 had been open to the inlet for six months, and samples from DD1, DD5, and DD6 after normal undocking/docking procedures which were usually concluded within 2-3 days.

The texture characteristics of the silt samples for the caisson and dry dock sampling conducted in 2009-2010 and after dewatering samples collected in 2012-2014 are shown in Figure 59. The caisson samples had about 40-50% coarse material, the samples collected while DD6 was still open to the inlet had

Table 27. Summary of dry dock silt sampling events.

Date	Parameters	Sample Processing	Comment
7/10/2009	Fe, Cu, Pb, Zn, Total PCB, grain size	bulk sample	Caisson sampling
7/15/2010	Fe, Cu, Pb, Zn, Hg, Total PAH, grain size	bulk sample	DD6 open to Inlet for 6 months; DD6 sampling before and after dewatering; Grab samples also collected in front of DD4 (PS09)
12/10/2012	Al, Cr, Cu, Fe, Ni, Pb, Zn, Hg, grain size, TOC	bulk sample; coarse and fine fractions	DD1 open to Inlet for 6 months; sampling after dewatering
12/21/2012			DD5 after dewatering
1/9/2013			DD1 after dewatering
2/6/2013			DD1 after dewatering
2/7/2013			DD6 after dewatering
3/15/2013			Unused historical BG
5/15/2013			DD5 after dewatering
6/5/2013			DD1 after dewatering
6/7/2013			DD5 after dewatering
6/28/2013			DD6 after dewatering
10/1/2014			DD5 after dewatering

40-67% coarse material, while the samples collected after dewatering were more variable and tended to have higher percentages of fines (>80%), were more similar to the bedded surface sediment sampled near DD4 (Figure 59A), and appeared similar to the texture of surface grabs from the focus areas (see Figure 52). The BG was almost entirely (97%) coarse material, while the samples collected from DD1 after DD1 was open for six months, was predominantly fine material (60-97%), and the silts collected after normal dewatering operations were highly variable (Figure 59B).



	CDD2	CDD2	CDD3	CDD3	CDD4	CDD4	CDD4	CDD4	CDD4	CDD6	CDD6	DD6-1	DD6-4	DD6-7	PS09	PS09
Large	0.02%	0.00%	0.14%	0.04%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.68%	0.00%	0.00%	0.00%
Coarse	43%	38%	53%	45%	41%	42%	40%	43%	41%	42%	51%	40%	67%	17%	19%	24%
Fine	57%	62%	47%	55%	59%	58%	60%	57%	59%	58%	49%	60%	32%	83%	81%	76%

	BG	DD1-d1	DD1-d2	DD1-d3	DD1-1	DD1-2	DD1-3	DD1-3	DD5-1	DD5-2	DD5-4	DD5-1	DD5-2	DD5-1	DD5-2	DD5-1	DD5-2	DD5-3	DD6-1	DD6-3	DD6-4	DD6-1	DD6-2	DD6-3
Large	1%	24%	0%	0%	2%	3%	12%	36%	3%	2%	0%	25%	0%	7%	50%	2%	6%	0%	0%	23%	6%	5%	0%	32%	9%
Coarse	97%	16%	4%	3%	21%	19%	57%	43%	21%	26%	21%	19%	6%	79%	18%	60%	22%	8%	11%	70%	30%	15%	6%	26%	9%
Fine	2%	60%	96%	97%	77%	78%	31%	21%	76%	71%	79%	56%	94%	13%	32%	39%	72%	92%	89%	7%	65%	80%	94%	42%	82%

Figure 59. The texture characteristics of silt samples by sample location for the caisson and dry dock samples collected in 2009-2010 (A) and after dewatering samples collected in 2012-2014 (B).

There was no clear pattern in the silt samples collected after normal docking procedures (Figure 59B). Coarse material appeared frequently as did large particles >2 mm, which were composed of mainly shell hash and other biogenic debris. The variability may be due to the irregular structure of the dry docks themselves which could selectively entrain particles based on the presence of troughs, drains, and other surfaces that selectively accumulated particles during the dewatering process (Figure 33). Two of the samples (collected from DD5-3 and DD6-1) appeared to resemble BG as they contained 70-79% coarse material. Occasionally, relatively high percentages of large particles consisting of shell hash and other biogenic debris were encountered in the samples (Figure 59B).

There is uncertainty in comparing the texture results of the 2009-2010 and the 2012-2014 samples, as the former were analyzed using laser diffraction (McLaren 2008) and the later were analyzed using standard sieve analysis (CardnoTEC and Pacific Northwest National Laboratory 2014). The solid and TOC content of the silt samples collected in 2012-2014 (Figure 60) showed that some of the samples that had very high TOC (>10%) also had high amounts of large particles suggesting that the high TOC was due to the presence of biogenic material in the bulk sample. Based on the results obtained, it appeared that the active sedimentary materials collected from the caissons and open dry docks were much coarser than the materials that settled out after dewatering which were more similar to the bedded sediment sampled from the focus areas (see Figure 52).

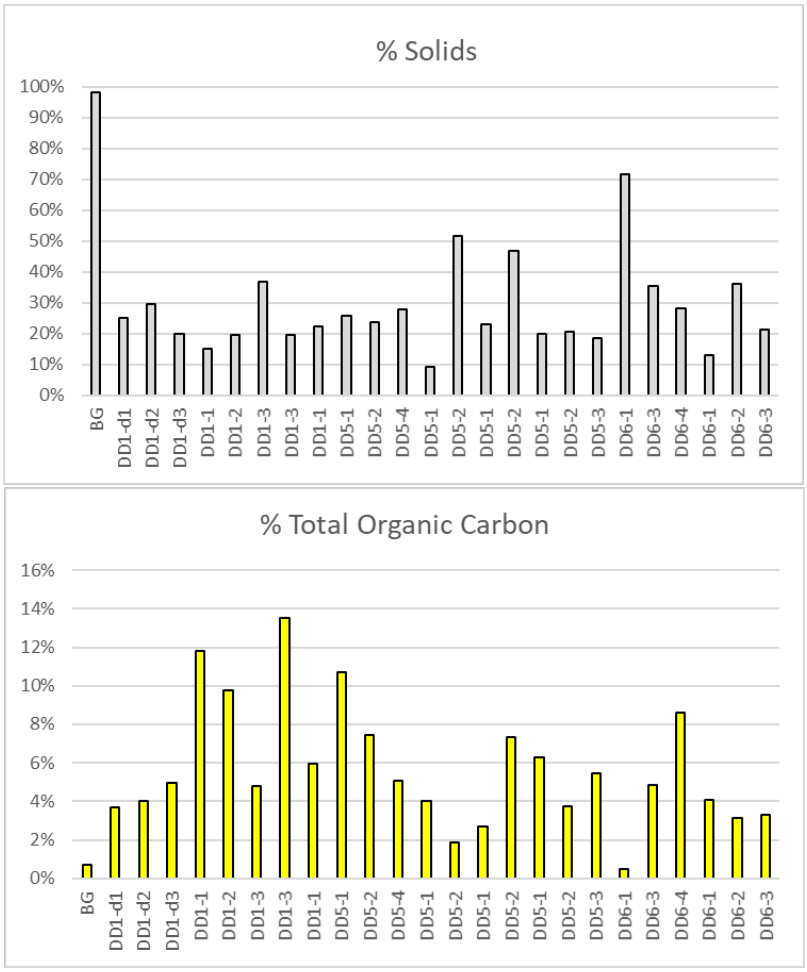


Figure 60. The percent solids and TOC in BG and silt samples collected from the dry dock floor after dewatering.

The concentrations of Cu, Pb, Zn, and total PCB measured in the caisson and dry dock samples collected in 2009-2010 (Figure 61, Appendix D.3.1 Caisson and Dry Dock Silts Sampled in 2009 and 2010) were similar to the range of concentrations found in the surface samples collected from the focus areas (see Figure 52). In general, the concentrations of Cu and Zn in the caisson samples were much higher than the dry dock samples, total PCB was elevated in the caisson samples, and Pb concentrations were higher in the dry dock samples.

The concentrations of metals measured in coarse and fine fractions of dry dock silt samples collected in 2012-2014 are shown in Figure 62 and summarized in Appendix D.3.2 Dry Dock Silts Sampled 2012-2014. The composition of BG was very interesting. The BG had very high concentrations of Fe, Cu, Ni, and Cr all contained within the coarse fraction. While some of the dry dock silt samples had similar concentrations of Cu and Ni, none of the silt samples matched the BG pattern. However, it is likely that a mixture that contained some portions of historical BG was present in many of the silt samples. The use of copper slag blasting grit was phased out in the 1990s. Currently, the primary paint removal practice used is reusable steel blasting grit, which is conducted within containments to prevent the release of dust and prevent water from contacting blast material or waste (U.S. Navy and Puget Sound Naval Shipyard & IMF 2012).

While the number of dry dock silt samples was admittedly small, the following results were obtained (Figure 62). The highest concentrations of Cu were measured in samples from DD5 and DD6, Pb was highest in samples from DD5, DD1, and DD6, and Zn was highest in samples from DD5 and DD6. High concentrations of Al and Ni in a sample from DD5 (DD5-2) indicated a separate source that was not present in the other samples. Overall, there were higher concentrations of metals in the coarse fraction than in the fine fraction and the concentrations appeared to be higher than the surface samples from the focus areas (see Figure 52), except for Hg which was much lower than the focus areas.

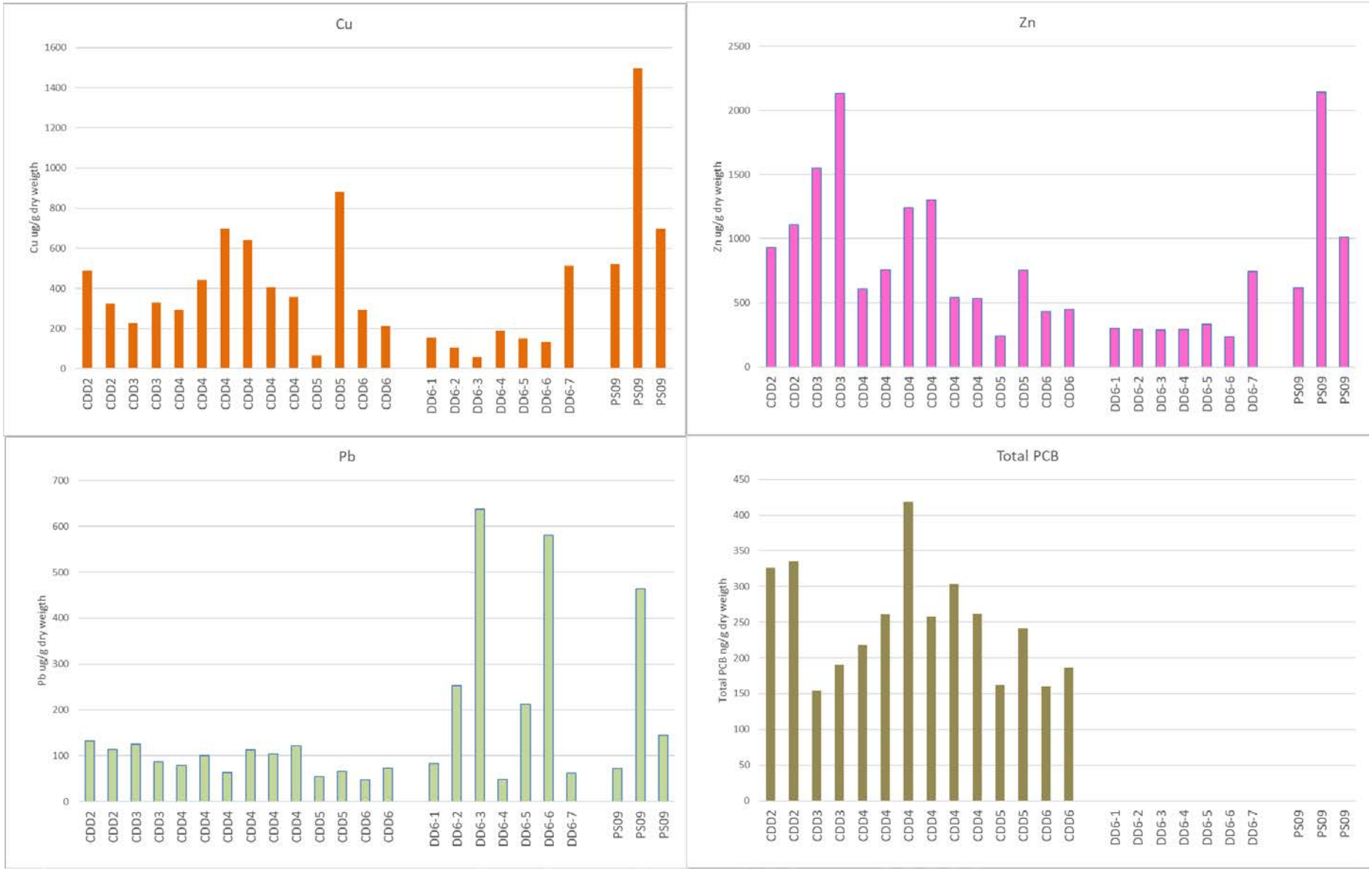


Figure 61. Concentrations of Cu, Pb, Zn, and Total PCB measured in caisson and dry dock silt samples collected in 2009-2010.

A.

Figure 62. The concentrations of metals measured in coarse and fine fractions of BG and dry dock silt samples collected in 2012-2014 for Al, Fe, Cu, and Pb (A), and Zn, Hg, Ni, and Cr (B).

B.

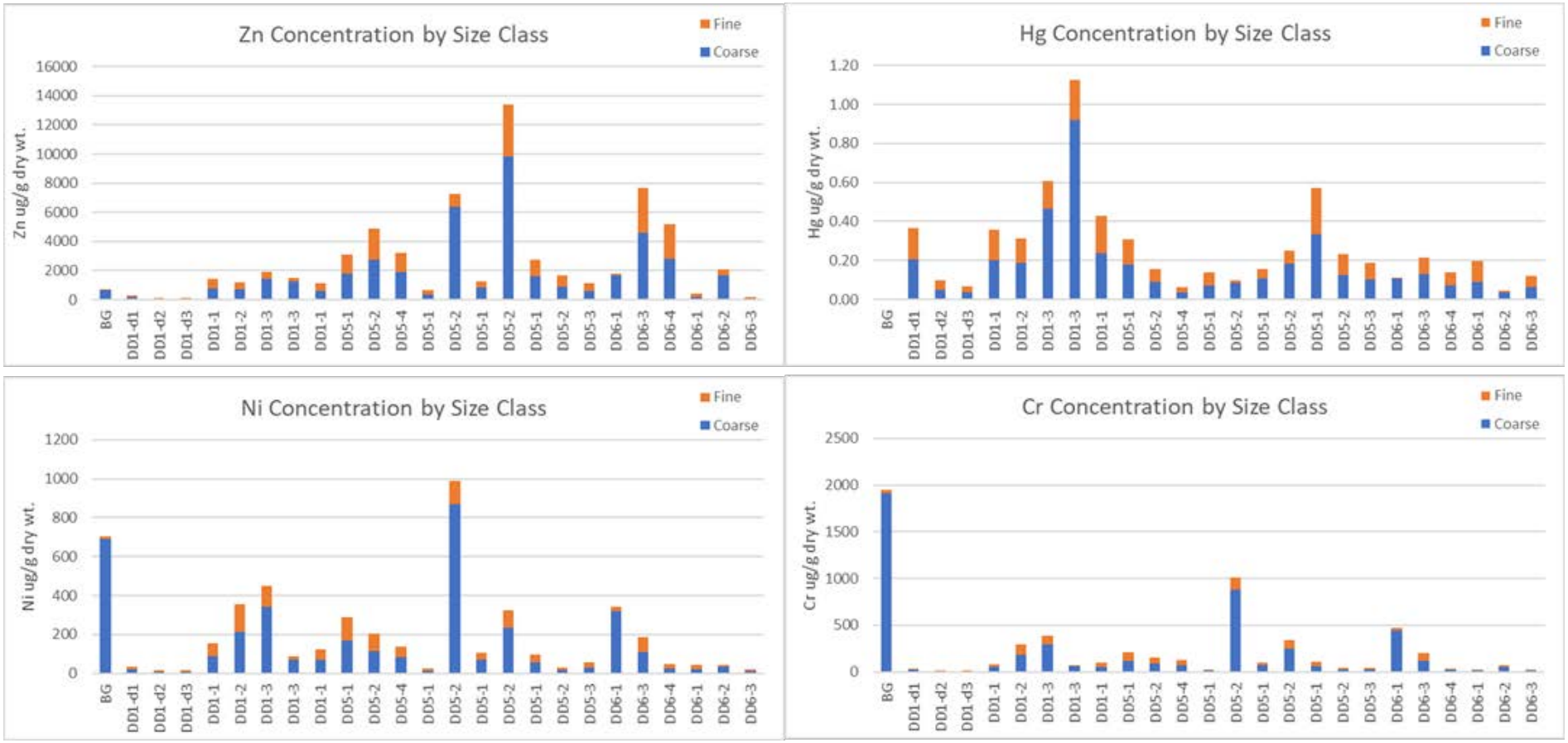


Fig 62 continued.

The Hg concentrations measured in the dry dock silt samples subjected to fractionation may have been compromised. Because of Hg's high vapor pressure, Hg can be volatized and lost during sample preparation and chemical analysis (Agency for Toxic Substances and Disease Registry 1999; Souza et al. 2018). Although the QA/QC procedures and percent recovery of SRMs indicated that the method performed admirably, the SRMs were not subjected to the fractionation procedure and thus are not a true measure of accuracy in this case. It is possible that the fractionation procedure, necessary for obtaining the size fractions for analysis, may have resulted in the loss of Hg from the sample handling. Evidence for this is that bulk samples (sample splits) analyzed by PSNS&IMF c/134 were higher than the combined concentrations of coarse + fine sediment fractions analyzed by PNNL (Fig D.3.2.4. Hg and the Hg concentration from the coarse + fine fraction fell far below the relationship expected between Hg and TOC for Sinclair Inlet sediments reported by previous studies (Paulson et al. 2010) (Figure 63). The recommended holding time for Hg analysis is 28 days (Northwest Regional Sediment Evaluation Team 2018) but in this case sediment samples were held for many months under refrigeration (4° C) in tight fitting glass jars before they were analyzed within 1 year of sample collection. This was necessary so that unfrozen samples would be available for grain size analysis. In retrospect it would be advantageous to homogenize and split the samples for the various geochemical analysis shortly after collection, however this was not possible in this case due to the requirements of the contracting procedures between the Government and the performing laboratories.

The dry dock silt sampling showed that silt particles were captured during dry dock operations and that the particles collected were loaded with COCs notably, Hg, Cu, Pb, Zn, and total PCBs.

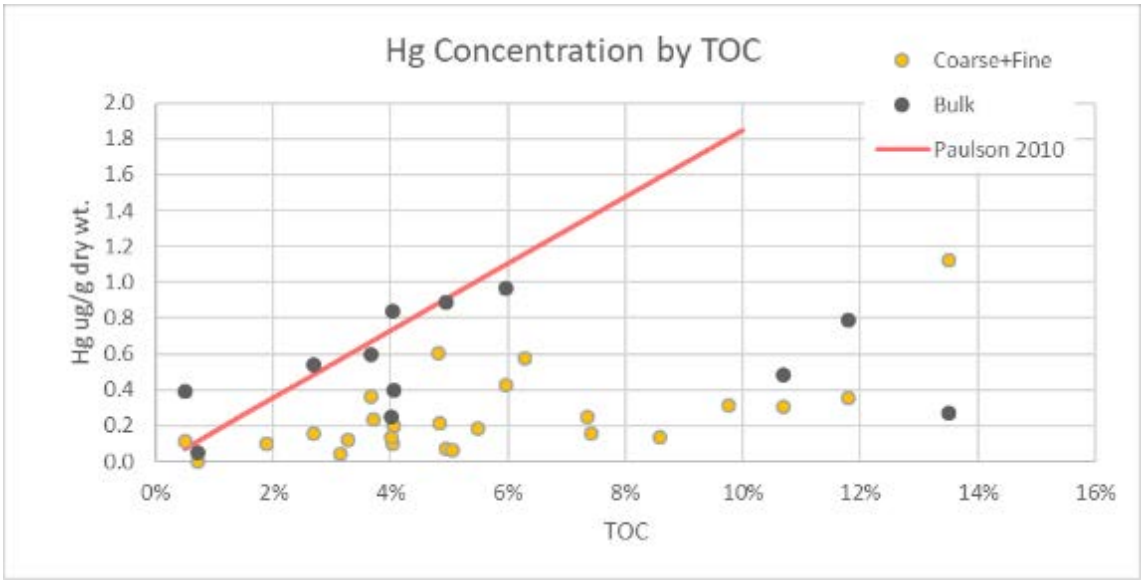


Figure 63. The Hg concentrations measured in bulk and coarse+fine dry dock silt samples and the regression between Hg and TOC for Sinclair Inlet sediments collected from stations outside of Bremerton Naval Complex in 2007 reported by (Paulson et al. 2010).

6.4.2 Geochemical Distributions

The geochemical distributions from Hg, PCB, Cu, Pb, and Zn were evaluated for the complete data set, which included samples from the OUBM LTM 1500 ft (Sinclair Inlet) and 500 ft (OUBM) grids, caisson silt samples (CDD Silt), dry dock silt samples (DD Silt), focus area samples from the 0-3 cm surface (FA 0-3 cm), core profile samples (FA Cores), and 0-10 cm surface grabs (FA 0-10 cm), storm drain catch basins (Storm Drain), and were analyzed to provide insight on how contaminants were distributed within Sinclair Inlet and identify possible recovery strategies. The results are shown in Appendix D.4 Geochemical Distributions and summarized in Figure 64.

The data shown in Figure 64 indicates that the dry docks may be selectively accumulating sedimentary materials that are enriched in total PCB, Cu, Pb, Zn, and Hg. A linear relationship between contaminant and Fe concentrations (or TOC) calculated for the Sinclair Inlet (1500 ft grid) sediment samples represents the “background” concentrations of the contaminant. The trendline shows that as Fe or TOC increases the contaminant concentration increases in a predictable manner, however many of the other samples fall far above the trendline showing that the particles in those samples were enriched in the contaminants beyond what would be expected based on the Sinclair Inlet samples.

The samples from the caisson and dry dock silt, OUBM, and FA 0-3 cm samples were enriched well above the trendline for total PCB, Cu, Pb, Zn, and Hg (Figure 64). The FA 0-3 cm samples are the materials most likely resuspended during docking/undock, in-water construction, ship movements, or other operations that may disturb the bottom sediments. By capturing and remove the enriched particles, the cleaning BMPs have a means of “skimming off the cream” of the most contaminated particles that are currently mobile within the nearshore areas of the Shipyard. These results suggest a testable hypothesis that dry dock cleaning operations are selectively capturing particles that are enriched with contaminants that are a priority for recovering sediment quality within Sinclair Inlet.

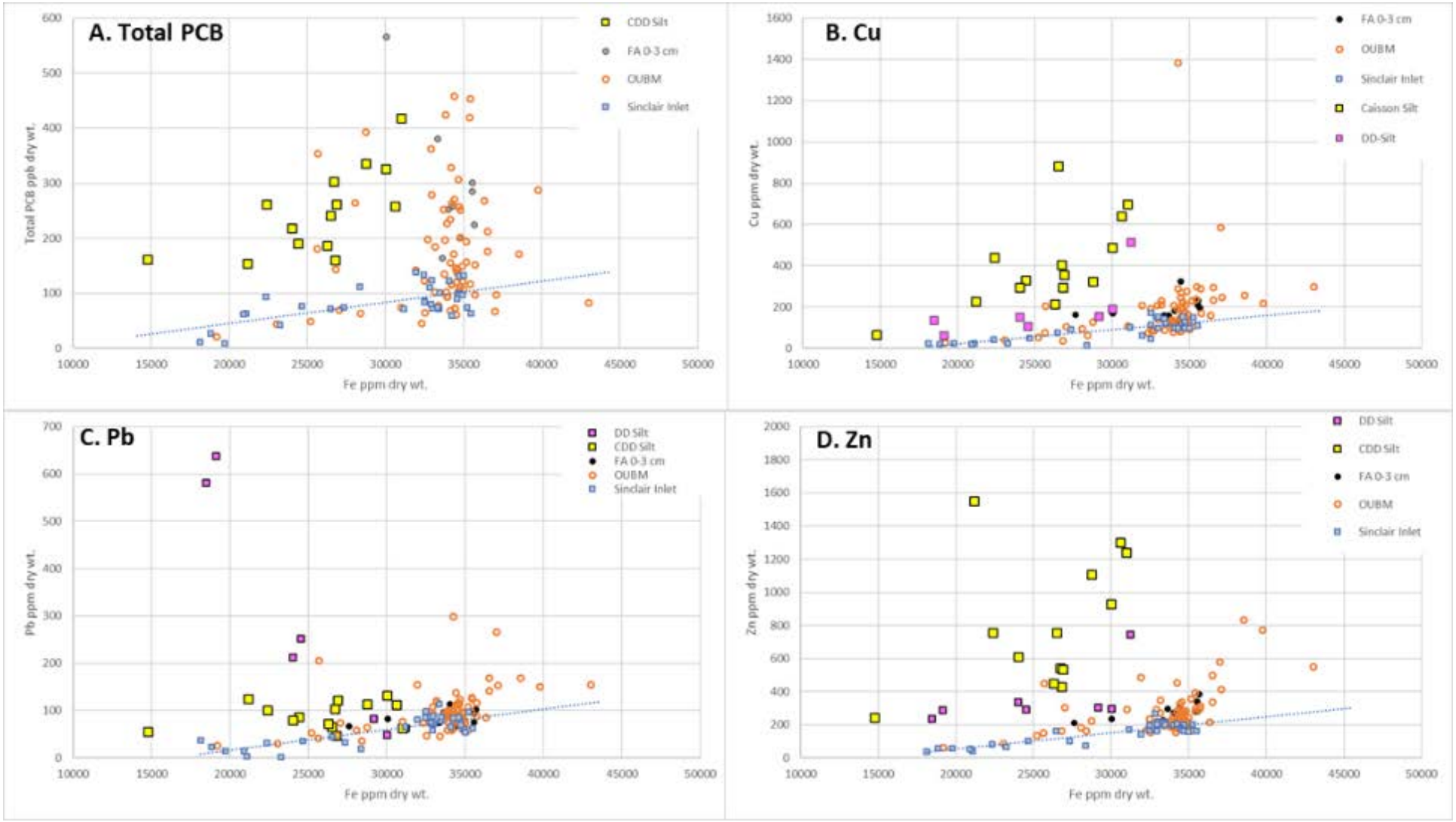


Figure 64. The relationship between metal concentrations and Fe content (A-E) and Hg and TOC (F) measured in samples from Sinclair Inlet 1500 ft grids (Sinclair Inlet), OUBM 500 ft grids (OUBM), focus area 0-3 cm surface samples (FA 0-3 cm), caisson silt samples (CDD Silt), and dry dock silt samples (DD-Silt).

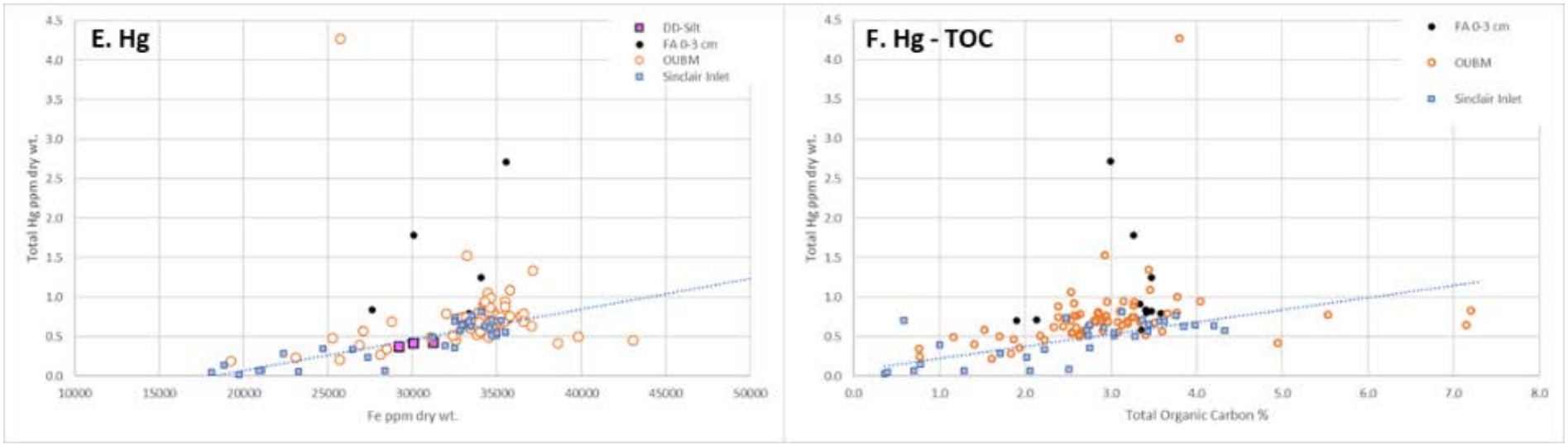
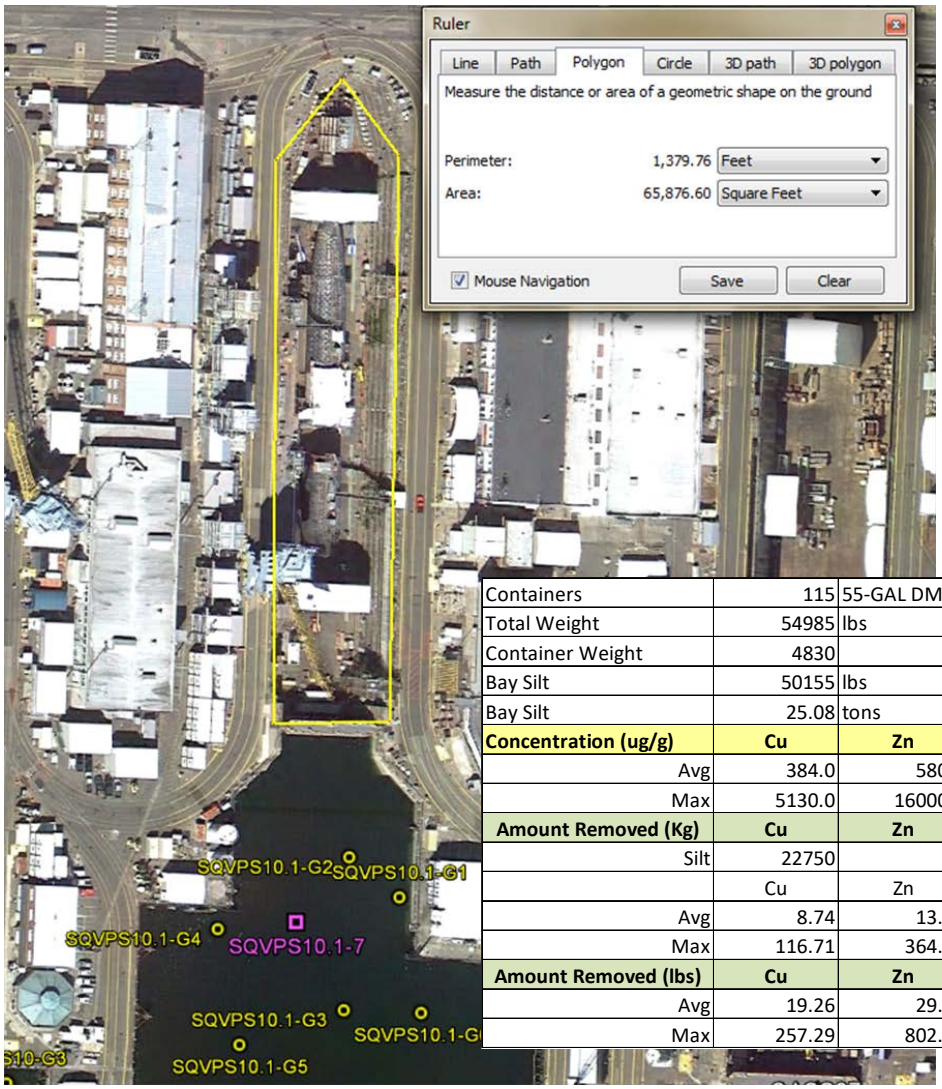


Fig 64 continued.

6.5 Results from Drydock Cleaning Operation

An example from dry dock cleaning operations conducted in 2012 was used to evaluate the efficacy of management actions to reduce contaminant cycling within the nearshore sediments of the Shipyard. In 2012, DD1 was open to the Inlet for six months; after dewatering about 7-10 cm (3-4 in) of silt material covered the dry dock floor. Cleaning procedures used at that time, which were newly implemented and not as efficient as current operations, resulted in collecting 115 55-gallon drums full of bay silt which amounted to about 25 tons (22,750 kg) of material removed. Using the average and maximum concentrations obtained from the dry dock silt samples collected from the dry docks after dewatering, the estimated average and maximum mass of contaminants permanently removed from Sinclair Inlet were calculated to be 8-11 kg of Cu, 13-364 kg of Zn, and 18-22 g of Hg (Figure 65).



Containers	115	55-GAL DM	
Total Weight	54985	lbs	
Container Weight	4830		
Bay Silt	50155	lbs	
Bay Silt	25.08	tons	
Concentration (ug/g)	**Cu**	**Zn**	**Hg**
Avg	384.0	580.0	0.78
Max	5130.0	16000.0	0.97
Amount Removed (Kg)	**Cu**	**Zn**	**Hg**
Silt	22750		
	Cu	Zn	Hg
Avg	8.74	13.19	0.018
Max	116.71	364.00	0.022
Amount Removed (lbs)	**Cu**	**Zn**	**Hg**
Avg	19.26	29.09	0.04
Max	257.29	802.48	0.05

Figure 65. Arial view of DD1, the estimated surface area of 65,876 ft^2, locations of focus area grabs and core samples, and calculation of amount of material removed based on average and maximum concentrations measured in DD silt samples collected after dewatering.

A back of the envelope calculation of how much material was entrained in DD1, assuming that the silt material had a uniform depth of 3.5 in, with the density of sand (1602 kg/m³), and a solid content of 30%, estimated that about 288 tons (dry) of material was in the dry dock after dewatering was completed (Table 28). This means that only a small fraction (9%) of the silt entrained in DD1 was collected for disposal. Much more efficient methods could greatly increase the efficiency of removal actions conducted in this manner. While removing 18 g of Hg may not seem like much, recall that 18 g/yr (Figure 12) was the total amount of filtered total Hg estimated to be discharged from the combined dry dock discharges on an annual basis (Paulson et al. 2013). While there is a great difference between aqueous Hg released by discharges and solid Hg captured in the dry dock silt cleaned and removed from DD1, the important result is that there is a sink or exit strategy for reducing contaminant levels in the surface sediment of the nearshore areas environments within the Shipyard.

Caissons are removed for maintenance periodically (about 5-10 yr intervals for each dry dock) necessitating leaving the dry dock open to the inlet for extended periods (months) and creating a giant sediment trap for the nearshore sediments around the open dry dock. Under normal operating conditions, docking/undocking operations are completed within 2-3 days, but even during these short duration openings there is still significant amounts of silts that must be cleaned before the dry dock can be put back into operation (U.S. Navy and Puget Sound Naval Shipyard & IMF 2012). If managed properly, the dry dock cleaning BMPs would not only prevent further release of COCs, but could also collect and remove contaminants already present in the nearshore sediments. Ultimately this means that with effective cleaning BMPs in place, every time a docking/undocking evolution takes place a net improvement in the quality of nearshore sediments within the shipyard would occur.

Table 28. Calculation of mass of material entrained within a dry dock assuming a uniform depth of 3.5 in of silt, with the density of sand (1602 kg/m³), and a solid content of 30%.

Dry Dock	Area		Silt Depth		Volume Wet		Density		Solid Content		Mass of Material					
DD1	65867	ft^2	0.29167	ft	19211.21	ft^3	100.0096	lb/ft^3	0.3	lb dry/lb wet	1921305	lbs wet	576392	lbs dry	288	tons dry
	6119	m^2	0.08890	m	544.00	m^3	1602	kg/m^3	0.3	kg dry/kg wet	871489	kg wet	261447	kg dry		
DD2	122563	ft^2	0.29167	ft	35747.54	ft^3	100.0096	lb/ft^3	0.3	lb dry/lb wet	3575097	lbs wet	1072529	lbs dry	536	tons dry
	11386	m^2	0.08890	m	1012.26	m^3	1602	kg/m^3	0.3	kg dry/kg wet	1621636	kg wet	486491	kg dry		
DD3	122460	ft^2	0.29167	ft	35717.5	ft^3	100.0096	lb/ft^3	0.3	lb dry/lb wet	3572093	lbs wet	1071628	lbs dry	536	tons dry
	11377	m^2	0.08890	m	1011.41	m^3	1602	kg/m^3	0.3	kg dry/kg wet	1620273	kg wet	486082	kg dry		
DD4	135857	ft^2	0.29167	ft	39624.96	ft^3	100.0096	lb/ft^3	0.3	lb dry/lb wet	3962876	lbs wet	1188863	lbs dry	594	tons dry
	12622	m^2	0.08890	m	1122.05	m^3	1602	kg/m^3	0.3	kg dry/kg wet	1797530	kg wet	539259	kg dry		
DD5	138785	ft^2	0.29167	ft	40478.96	ft^3	100.0096	lb/ft^3	0.3	lb dry/lb wet	4048284	lbs wet	1214485	lbs dry	607	tons dry
	12894	m^2	0.08890	m	1146.24	m^3	1602	kg/m^3	0.3	kg dry/kg wet	1836270	kg wet	550881	kg dry		
DD6	200788	ft^2	0.29167	ft	58563.17	ft^3	100.0096	lb/ft^3	0.3	lb dry/lb wet	5856878	lbs wet	1757064	lbs dry	879	tons dry
	18654	m^2	0.08890	m	1658.32	m^3	1602	kg/m^3	0.3	kg dry/kg wet	2656634	kg wet	796990	kg dry		

6.6 Mercury in Sinclair Inlet Sediment Compared to Puget Sound

In 2011, the University of Washington-Tacoma (UWT) collected 78 surface sediment samples from 45 different sites throughout Puget Sound. Splits of these samples were obtained by PNNL and analyzed for total Hg to provide a comparative assessment of total Hg concentrations in the surface sediments of Puget Sound (: Appendix E Spatial Distribution of Mercury in Puget Sound Sediments). Surface (0-5 cm) sediment samples were collected using either a Craib Corer or a Van Veen grab and analyzed for total mercury using the same methods and QA/QC procedures as the SQV Study (see Sections 4.0 and 5.0). In addition, total Hg concentrations from prior studies were obtained from the EIM database by performing a search was for total Hg reported for surficial sediments (0-5 cm) in Puget Sound waterbodies. The surficial sediment was selected because it represented the most recent deposits and were comparable to the UWT data set.

The results showed that the total Hg concentrations of surface sediments within Sinclair and Dyes Inlets were some of the highest in the Puget Sound (Figure 66). By assuming that the production of methyl Hg was inversely correlated to TOC, the study also identified areas in Puget Sound with elevated concentrations of total Hg and low TOC as areas most likely to have increased methylation rates (: Appendix E Spatial Distribution of Mercury in Puget Sound Sediments).

That Sinclair Inlet sediments are elevated in Hg compared to other areas of the Puget Sound has been well established (U.S. Navy 2017b). On average, total Hg concentrations measured in the sediments of Sinclair Inlet were about 4.5-7 times higher than reference areas, while total Hg concentrations in biota were only about two times higher in Sinclair Inlet compared to reference areas of the Puget Sound. This may be because methyl Hg in Sinclair Inlet is not being produced in proportion to total Hg concentrations present in the sediment and water exchange with the Puget Sound likely moderates increases in methyl Hg within Sinclair and Dyes Inlets (U.S. Navy 2017b). Furthermore, it is recognized that legacy Hg contamination in the nearshore sediments of the Shipyard could be redistributed by resuspension by vessel movement, dry dock operations, in-water construction projects, and flux from bottom sediment to the water column where it could be exported to other ares of Sinclair and Dyes Inlet and the larger Puget Sound (U.S. Navy 2017b). Therefore, any process that can selectively capture and remove particles enriched with Hg and other contaminants, as the dry dock cleaning BMPs appear to be able to do, would greatly contribute to meeting sediment quality goals for Sinclair Inlet and recovery goals for the Puget Sound.

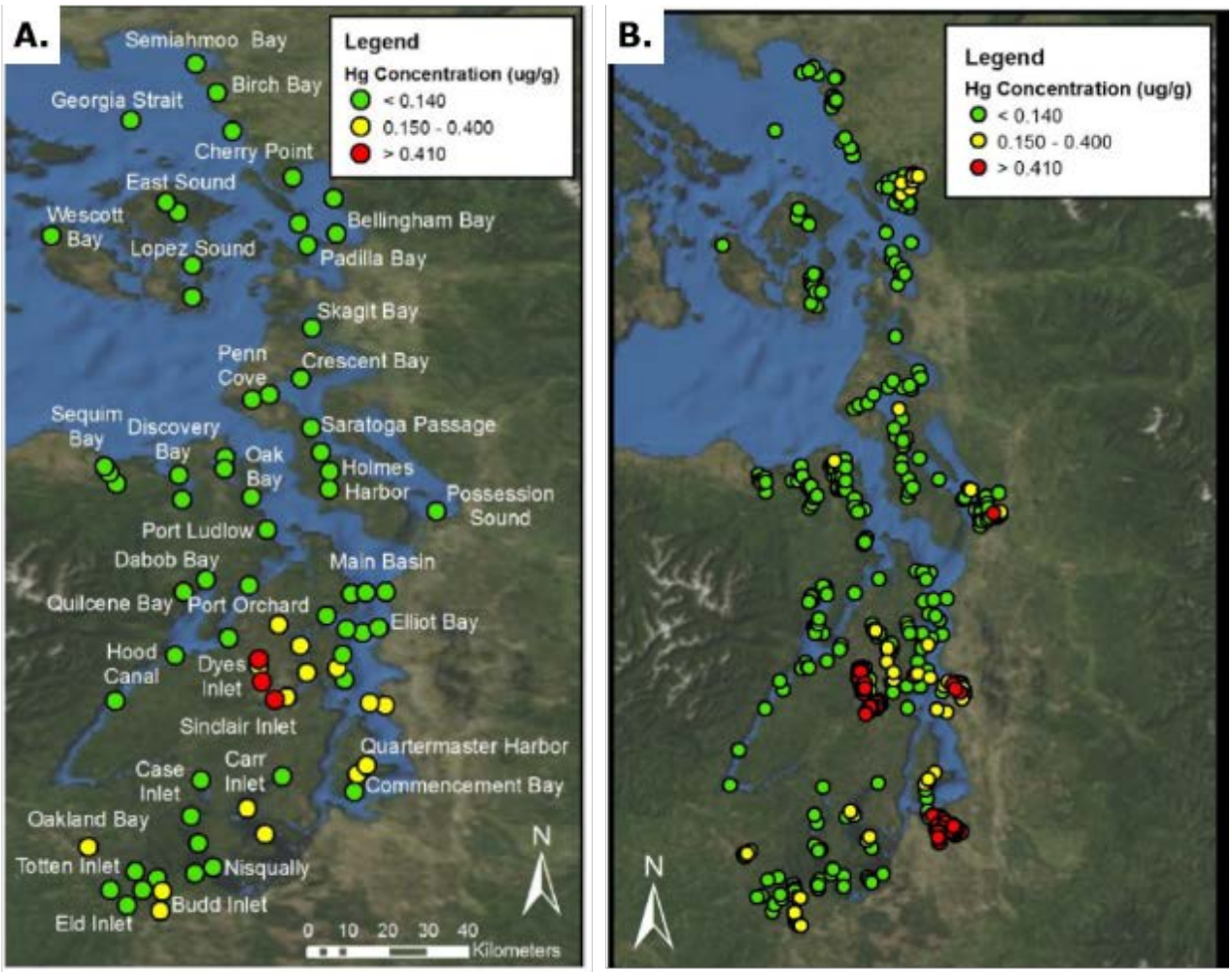


Figure 66. Spatial distribution of total Hg in surface sediments (0-5 cm) of the Puget Sound measured in samples collected by UWT in 2001 (A) and combined with data obtained from EIM and the SQV Study (B) (: Appendix E Spatial Distribution of Mercury in Puget Sound Sediments).

7.0 Summary and Conclusions

The SQV study established a baseline for continuous process improvement by characterizing contaminant concentrations, bioavailability, and texture of sediment and silt in the vicinity of outfalls and dry docks. The data addresses specific data gaps identified for applying mixing zones for NPDES discharges, assessing sediment impact zones, and evaluating anti-degradation requirements for water quality certifications needed for pier and dry dock infrastructure improvements. Data from the study were also used to support research and development studies of sediment treatability and bioavailability and identify strategies for recovering sediment quality in Sinclair Inlet.

7.1 Confirmation and Verification Results

Split samples from the 2010 LTM were obtained and analyzed for Fe, Cu, Pb, Zn, total PAH using RSC methods for all samples. Confirmation analysis using ICP for metals and GC-MS for PAHs were conducted on a subset of samples to establish definitive concentrations for the sample results. The confirmation results showed that the definitive results met acceptability requirements and provided a cost-effective means of expanding the data set.

Sampling was conducted throughout Sinclair Inlet for 32 samples from the Sinclair Inlet 1500 ft^2 grid (SIN) and 71 samples from the 500 ft^2 grids within OUBM. There were only minor changes in concentrations of Cu, Pb, and Zn between 2003 and 2010 (Figure 34), however, the maximum concentrations and number of SQG exceedances tended to decrease over time. In 2010, there were only 2 stations that exceeded the SQS for Cu and 9 stations that exceeded the SQS for Zn, and all stations meet the SQS for Pb and total PAH. However, the majority of stations (83%) did not meet SQG for Hg (Appendix D.1).

7.2 Focus Area Trends

Focus areas of concern were identified for sampling based on elevated concentrations reported from previous monitoring, proximity to industrial outfalls, storm drains, and other potential sources, the lack of sampling by the LTM program, and nearshore areas with low flushing – in short, the “worst-case” locations for accumulating sediment contamination within the Shipyard. The primary objectives of the focus area sampling were to:

1. provide a snap shot of the 2011 sediment concentrations for metals and organics in the Shipyard areas of concern for Cu, Pb, Zn, Hg, PAHs, and PCBs not currently addressed by OUBM LTM;
2. characterize silt and sediment in the vicinity of outfalls, storm drains, and dry docks;
3. provide data to assess sediment impact zones for NPDES discharges;
4. provide data to assess anti-degradation requirements for water quality certifications needed for pier and dry dock infrastructure improvements;

The relative variability in contaminants measured in the surface samples from the focus areas showed that Hg, Cu, Zn, and total PCB/OC were highly variable (Figure 53). On average, the highest concentrations of Hg were measured at PS10, PS09 had the highest average concentrations of As, Cd, Cr, Cu, Ni, Pb, Zn, and total PAHs, PS11 had the highest average concentration of Pb, and PIER 7 had the highest average for total PCB (Appendix D2.4 Surface Grab Summary). For Hg, the average surface concentrations exceeded the MCC in all the focus areas except for PS07 and PIER7 which both exceeded the Hg SQS.

Relative to the SQG, the data from the focus areas showed that Hg was elevated for all the sites evaluated. In addition, Zn at PS09, PS10.1 and PS11, total PCB at PIER7, and As and Cu at PS09 also exceeded SQG (Table 29). The mSQGq, which was used to assess the potential impact of the mixture of contaminants present was greater than two at PS09, PS10, PS10.1, PS11, and PIER7 (Table 29).

The relative differences in concentrations of contaminants in surface sediment samples and core profiles were evaluated by comparing the magnitude and variability of concentrations measured in both zones. Sites with higher surface concentration are likely indicative of recent sources associated with settling of new and resuspended particles, while higher concentrations at depth could indicate historical sources buried by more recent deposits or residual contamination left behind by remedial dredging. The comparison showed that most of the sites had similar concentrations in both zones (PS07, PS10.1, PS11, PS01-2017), however higher surface Hg concentrations were measured at PS03, PS08, and PS09; PS09 also had higher surface concentrations of Cu, Pb, and Zn; PS06 had higher profile concentrations for Hg, Zn, and PCBs; and PS10 had higher profile concentrations for Hg, Pb, Zn, and PCBs (Table 29).

Metal bioavailability assessed by $(\sum SEM\text{-}AVS)/f_{oc}$ showed that all the samples from the focus areas were below the SQG of 130 umole/g OC dry weight, indicating that there was low risk of adverse benthic effects (Table 29). This result was also collaborated by pore water analysis at PS03 and PS09 as pore water concentrations were well below water quality standards for the metals evaluated (Cd, Cr, Cu, Hg, Ni, Pb, and Zn, Appendix D2.3 Porewater Results).

Sediment toxicity was only performed on samples from PS03 and PS09 (Table 29), but these were two of the most contaminated sites with respect to bulk chemistry results. The toxicity tests for 48-hr SWI exposure to mussel larvae, 10-day whole sediment exposure to two species of amphipods, and 28-day whole sediment exposure to worms, showed that the sediments from PS03 and PS09 were nontoxic, however slight toxicity to one of the amphipod species was observed for PS09 (Table 26).

Table 29. Summary of results within the focus areas (na = not applicable).

Location	Surface 0-10 cm Chemicals with Average Conc. > SQS	Surface 0-10 cm mSQGq>2	Magnitude and Variability of Core Profile to Surface Grabs	Surface 0-10 cm Risk of Adverse Benthic Effects from Metal Exposure $(SEM\text{-}AVS)/f_{oc}$	Surface 0-5 cm Sediment Toxicity
PS03	Hg	No	Surface Hg↑	Low Risk	Not Toxic
PS06	Hg	No	Profile (Hg, Zn, PCB)↑	Low Risk	na
PS07	Hg	No	Similar	Low Risk	na
PS08	Hg	No	Surface Hg↑	Low Risk	na
PS09	Hg, As, Cu, Zn	Yes	Surface (Hg, Cu, Pb, Zn)↑	Low Risk	Not Toxic (Slightly Toxic)
PS10	Hg	Yes	Profile (Hg, Pb, Zn, PCB)↑	Low Risk	na
PS10.1	Hg, Zn	Yes	Similar	Low Risk	na
PS11	Hg, Zn	Yes	Similar	Low Risk	na
PIER7	Hg, TPCB/OC	Yes	na	Low Risk	na
PS01-2016*	none	na	na	na	na
PS01-2017#	none	na	Similar	Low Chance of Probable Impact, Medium Chance of Potential Impact, and High Chance of Negligible Impact	na
*Samples were only analyzed for Cu and Zn (Johnston et al. 2018)					
#Samples were only analyzed for Cu, Zn, and $(SEM\text{-}AVS)/f_{oc}$ (Johnston et al. 2018)					

7.3 Grain Size Analysis

The sedimentary environment of the focus areas consisted primarily of sandy muds and muds while the Pier 7 site had coarser muddy sand and sandy mud deposits (Figure 52A, Appendix A.3 Grain Size Analysis Data Report). On average, the percent of fines (<63 um) in the 0-10 cm surface was 70% or higher for most of the sites, however coarser material was present at PS09, PS11, and PIER9, and about 10% of the material at PS09, PS11, and PS01 was > 2 mm, which consisted of mostly shell hash and other biogenic debris (Figure 52B). The presence of coarser material could be an indication of more disturbance. Overall, the surficial sediments of the Sinclair Inlet have followed a clear and significant trend in which they have become progressively coarser, more poorly sorted, and more negatively skewed in the years from 1998 to 2011 (Figure 54). The coarsening trend line (Figure 54) suggests that throughout the last two decades there has been an increase in the availability of coarser sediment for the transport regime. This could occur, for example, by dredging deeper into underlying glacial deposits in which a greater range of sediment sizes become available for transport and deposition than was available prior to their disturbance and exposure. At the same time, larger vessels, an increase in ship activities (propeller wash), and in-water construction projects could also increase the movement and deposition of coarser sediment (Wang et al. 2016).

7.4 Acid Volatile Sulfides/Simultaneously Extracted Metals

AVS, defined as the metastable sulfides released by reaction with cold 1N HCl, serves a critical role in setting the limits of availability of divalent metals, including Cu, Cd, Ni, Pb, and Zn (Di Toro et al. 1992; U.S. Environmental Protection Agency 2005) and, therefore, the toxicity of those metals in sediments. Because divalent metal sulfides are very insoluble in the presence of excess sulfide, most of the reactive metals (SEM) will form insoluble metal sulfides. The five divalent metals and, to a lesser degree Ag, for which stoichiometric relationship differs slightly (one mole of SEM Ag reacts with two moles of AVS), will bind to sulfide. This means, in essence, that the metals will all exist in the form nontoxic solids if the $(\sum SEM\text{-}AVS)/f_{oc}$ is less than 130 umole/g OC, the reactive metals will be bound to sulfides as well as other binding sites in sediments associated with organic matter (U.S. Environmental Protection Agency 2005; Burgess et al. 2013).

7.5 Texture and Chemical Analysis of Dry Dock Silt

The texture characteristics of the silt samples for the caisson and dry dock sampling showed that he caisson samples had about 40-50% coarse material, the samples collected while DD6 was still open to the inlet had 40-67% coarse material, while the samples collected after dewatering were more variable and tended to have higher percentages of fines (>80%), were more similar to the bedded surface sediment sampled near DD4 (Figure 59A), and appeared similar to the texture of surface grabs from the focus areas. The BG was almost entirely (97%) coarse material, while the samples collected from DD1 after DD1 was open for six months, was predominantly fine material (60-97%), and the silts collected after normal dewatering operations were highly variable (Figure 59B). Based on the results obtained, it appeared that the active sedimentary materials collected from the caissons and open dry docks were much coarser than the materials that settled out after dewatering which were more similar to the bedded sediment sampled from the focus areas.

In general, the concentrations of Cu and Zn in the caisson samples were much higher than the dry dock samples, total PCB was elevated in the caisson samples, and Pb concentrations were higher in the dry dock samples. The composition of BG was very interesting. The BG had very high concentrations of Fe, Cu, Ni, and Cr all contained within the coarse fraction. While some of the dry dock silt samples had

similar concentrations of Cu and Ni, none of the silt samples matched the BG pattern. However, it is likely that a mixture that contained some portions of historical BG was present in many of the silt samples. For the dry dock silt samples collected after dewatering, there were higher concentrations of metals in the coarse fraction than in the fine fraction and the concentrations appeared to be higher than the surface samples from the focus areas, except for Hg which was much lower than the focus areas. It is possible that the fractionation procedure, necessary for obtaining the size fractions for analysis, may have resulted in the loss of Hg during the sample handling. The dry dock silt sampling showed that silt particles were captured during dry dock operations and that the particles collected were loaded with COCs notably, Hg, Cu, Pb, Zn, and total PCBs.

7.6 Geochemical Distributions

The geochemical distributions from Hg, PCB, Cu, Pb, and Zn were evaluated for the complete data set to provide insight on how contaminants were distributed within Sinclair Inlet and identify possible recovery strategies. The data showed that the dry docks may be selectively accumulating sedimentary materials that are enriched in total PCB, Cu, Pb, Zn, and Hg. A linear relationship between contaminant and Fe concentrations (and TOC) calculated for the Sinclair Inlet (1500 ft grid) sediment samples represents the "background" concentrations of the contaminant. The trendline shows that as Fe or TOC increases the contaminant concentration increases in a predictable manner, however many of the other samples fall far above the trendline showing that the particles in those samples were enriched in the contaminants beyond what would be expected based on the Sinclair Inlet samples (Figure 64).

The samples from the caisson and dry dock silt, OUBM, and FA 0-3 cm samples were enriched well above the trendline for total PCB, Cu, Pb, Zn, and Hg (Figure 64). The FA 0-3 cm samples are the materials most likely resuspended during docking/undocking, in-water construction, ship movements, or other operations that may disturb the bottom sediments. By capturing and removing the enriched particles, the cleaning BMPs have a means of "skimming off the cream" of the most contaminated particles that are currently mobile within the nearshore areas of the Shipyard. These results suggest a testable hypothesis that dry dock cleaning operations are selectively capturing particles that are enriched with contaminants that are a priority for recovering sediment quality within Sinclair Inlet.

7.7 Dry Dock Cleaning

An example from dry dock cleaning operations conducted in 2012 was used to evaluate the efficacy of management actions to reduce contaminant cycling within the nearshore sediments of the Shipyard. In 2012, DD1 was open to the Inlet for six months; after dewatering about 7-10 cm (3-4 in) of silt material covered the dry dock floor. Cleaning procedures used at that time, which were newly implemented and not as efficient as current operations, resulted in collecting 115 55-gallon drums full of bay silt which amounted to about 25 tons (22,750 kg) of material removed. Using the average and maximum concentrations obtained from the dry dock silt samples collected from the dry docks after dewatering, the estimated average and maximum mass of contaminants permanently removed from Sinclair Inlet were calculated to be 8-11 kg of Cu, 13-364 kg of Zn, and 18-22 g of Hg (Figure 65).

If managed properly, the dry dock cleaning BMPs would not only prevent further release of COCs, but could also collect and remove contaminants already present in the nearshore sediments. Ultimately this means that with effective cleaning BMPs in place, every time a docking/undocking evolution takes place a net improvement in the quality of nearshore sediments within the shipyard would occur.

7.8 Sinclair Inlet and Puget Sound Recovery

Since the 1970's major programs have been implemented by the Navy, City of Bremerton, Kitsap County and other jurisdictions to control and eliminate sources of pollution discharged into the receiving waters of Sinclair and Dyes Inlets (Table 1). While the projects could disturb and resuspend sediment-bound contaminants, the projects also significantly enhanced the commercial and transportation infrastructure of the region and helped improve environmental conditions within the nearshore areas of the Shipyard.

The results from this study showed that the total Hg concentrations of surface sediments within Sinclair and Dyes Inlets were some of the highest in the Puget Sound (Figure 66). That Sinclair Inlet sediments are elevated in Hg compared to other areas of the Puget Sound has been well established (U.S. Navy 2017b). On average, total Hg concentrations measured in the sediments of Sinclair Inlet were about 4.5-7 times higher than reference areas, while total Hg concentrations in biota were only about two times higher in Sinclair Inlet compared to reference areas of the Puget Sound. This may be because methyl Hg in Sinclair Inlet is not being produced in proportion to total Hg concentrations present in the sediment and water exchange with the Puget Sound likely moderates increases in methyl Hg within Sinclair and Dyes Inlets (U.S. Navy 2017b). Furthermore, it is recognized that legacy Hg contamination in the nearshore sediments of the Shipyard could be redistributed by resuspension by vessel movement, dry dock operations, in-water construction projects, and flux from bottom sediment to the water column where it could be exported to other ares of Sinclair and Dyes Inlets and the larger Puget Sound (U.S. Navy 2017b). Therefore, any process that can selectively capture and remove particles enriched with Hg and other contaminants, as the dry dock cleaning BMPs appear to be able to do, would greatly contribute to meeting sediment quality goals for Sinclair Inlet and recovery of the Puget Sound.

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9.0 Appendices

Appendix A: Appendix A Data Reports

(Available on distribution CD)

A.1 Appendix A.1 SQV Analytical Chemistry Data Report

ApdxA-1_SQV_Analytical_Chemistry_Data_Report_2012_05_28.pdf

A.2 Appendix A.2 Rapid Sediment Characterization Data Report

ApdxA-2_RSC_2010_FPXRF_Metals_Results_OUBMv2.xls

ApdxA-2_RSC_2010_PAH_Data_Report.xls

ApdxA-2_RSC_2010_PCB_Pier7_DataReport.xls

A.3 Appendix A.3 Grain Size Analysis Data Report

ApdxA-3_GrainSizeAnalysisReport.pdf

A.4 Appendix A.4 Sediment Toxicity Data Report

ApdxA-4_SedimentToxReport_BB05.pdf

A.5 Appendix A.5 Dry Dock Silt Data Report

ApdxA-5_DDASilt_2014_DataReport.pdf

ApdxA-5_DDASilt_2014_FinalDataTable3462_silt.xls

A.6 Appendix A.6 Hg Distribution in Puget Sound Surface Sediments

ApdxA-6_Hg_in_the_Puget_Sound.pdf

Appendix B: Appendix B Raw Data

(Available on distribution CD)

B.1 Study

B.2 Location

Data\EIM_Location_PSNS_SQV2011.xlsx

B.3 Results

Data\EIM_Result_PSNS_SQV2011_09_BB06.xlsx

(Applied Ecological Solutions 2019)

Appendix C Appendix C Pre- and Post-Construction Comparison

Available on distribution CD

ApdxC-Pre-Post-Construction.pdf

Appendix D: Appendix Summary Data Tables

D.1 Appendix D.1 Confirmation and Verification Analysis Results

Table D1. Summary of Verification and Confirmation Results for OUBM grids. Data are summarized for RSC screening, ICP or GC/MS confirmation, and definitive results from samples collected in 2003, 2007, and 2010 for Cu, Pb, Zn and total PAH. Individual metals and PAH compounds are compared to SQG where applicable.

CERCLA Grid ID	47122	2010 Exceeds SQS	2010 Exceeds MCC	Screening Cu_{RSC} (mg/Kg dry wt.)			Confirmation Cu_ICP (mg/Kg dry wt.)			Reported Cu (mg/Kg dry wt.) Definitive		
site	303d Grid	exclude Hg	exclude Hg	2003	2007	2010	2003	2007	2010	2003	2007	2010
SIN-G01	F6C9			63	47	12	102	31.8	28.3	102.0	31.8	28.3
SIN-G02	F6C8, F6C9			23	40	25				43.2	62.7	22.0
SIN-G03	F6C8, F6D8			36	41	7			20.3	58.1	64.2	20.3
SIN-G04	F6C8, F6D8			21	40	25				41.0	62.7	22.0
SIN-G05	F6D8, F6D7			74	89	78				102.4	119.9	102.4
SIN-G06	F6D7			78	108	109				106.3	141.1	148.8
SIN-G07	F6D7			92	114	89	130	132		130.0	131.8	118.8
SIN-G08	F6E7			100	152	125				132.5	192.6	172.7
SIN-G09	F6D7, F6D6			86	145	110				115.7	184.2	149.6
SIN-G10	F6E7			79	101	106				107.7	133.4	143.8
SIN-G11	F6E6			85	99	91				114.7	131.6	121.8
SIN-G12				33	41	9			21.3	54.8	64.2	21.7
SIN-G13	F6E6			69	104	76	116	126		116.0	126.3	98.4
SIN-G14	F6E5			73	75	77		123		100.5	123.1	114.0
SIN-G15	F6E5			79	97	75				107.8	129.2	97.9
SIN-G16				76	149	113				104.1	189.2	154.0
SIN-G17	F6E5			75	129	94		122		103.1	121.5	125.5
SIN-G18	F6E4, F6E5			88	118	112	117			117.0	152.6	153.2
SIN-G19	F6E4			69	93	98			110	96.8	124.3	110.0
SIN-G20	F6F5			63	125	111				89.1	161.6	151.3
SIN-G21	F6E4			75	104	76	102	120		102.0	119.7	97.9
SIN-G22	F6E4			65	110	89			96.3	91.3	143.5	96.3
SIN-G23	F6E3			62	119	44			67.0	88.3	153.9	75.1
SIN-G24	F6F3			84	124	89	107	103	98.1	107.0	103.1	98.1
SIN-G25	F6E3			60	24	31		55.9	41.8	85.5	55.9	41.8
SIN-G26	F6E2			16	19	25	11.7	12.7		11.7	12.7	22.0
SIN-G27	F6F3			58	106	82	72.5	80.2	96.3	72.5	80.2	96.3
SIN-G28	F6F2, F6F3			69	81	42	76.1	73.5		76.1	73.5	46.9
SIN-G29	F6F2			42	19	18			90.4	65.6	38.5	90.4
SIN-G30				15	20	25				34.0	39.5	22.0
SIN-G31	F6F2			62	55	51		73.1		88.0	73.1	61.2
SIN-G32	F6F2	Y		45	62	25			48.0	68.4	88.3	48.0
OUBM-G01	F6E6			99	163	95				131.5	205.6	126.7
OUBM-G02	F6E6			94	90	116				125.0	120.6	158.2
OUBM-G03	F6E6			71	110	71				99.2	144.2	91.3
OUBM-G04	F6E6			87	117	96				117.6	152.4	129.3
OUBM-G05	F6E6			78	137	96				106.8	175.6	128.1
OUBM-G06	F6E6			106	126	101				139.7	161.9	136.8
OUBM-G07	F6E6			78	90	89				107.4	120.8	117.6
OUBM-G08	F6E6			105	128	106				138.6	164.5	143.6
OUBM-G09	F6E6, F6E5			108	109	89				141.5	142.6	118.8
OUBM-G10	F6E6			63	55	34		69.2		89.9	69.2	35.3
OUBM-G11	F6E6			65	115	70				91.8	149.3	83.9
OUBM-G12	F6E5, F6E6			46	49	82		83.3	91.6	70.2	83.3	91.6
OUBM-G13	F6E5			80	90	63				108.6	121.1	79.1
OUBM-G14	F6F6, F6F5			69	50	12			36.7	96.8	74.9	36.7
OUBM-G15	F6E6, F6F6			58		66				83.3	16.6	84.2
OUBM-G16	F6E5			51	69	69				75.7	96.8	87.6
OUBM-G17	F6E5			68	113	88		107		95.7	107.0	116.1
OUBM-G18	F6F6, F6F5			57	55	44				82.1	80.5	50.5
OUBM-G19	F6F5			62	112	80		131	107	87.8	130.9	107.0
OUBM-G20	F6F5, F6F6			66	60	69				92.5	86.3	88.5
OUBM-G21	F6F5			78	83	51				107.0	112.6	60.8
OUBM-G22	F6F5			79	136	127				107.8	174.1	175.2
OUBM-G23	F6F5			92	90	137				122.6	120.7	190.2
OUBM-G24	F6F5			114	170	137				148.5	213.7	189.7
OUBM-G25	F6F5			134	215	150				171.6	265.0	210.5
OUBM-G26	F6F5			138	166	163				176.0	208.7	229.2
OUBM-G27	F6F5			83	138	116				113.1	176.5	159.3
OUBM-G28	F6F5			122	198	193				157.7	245.7	275.1
OUBM-G29	F6F5			146	268	206				185.3	326.3	294.1

Table D1 Continued

CERCLA Grid ID	47122	2010 Exceeds SQS	2010 Exceeds MCC	Screening Cu_{RSC} (mg/Kg dry wt.)			Confirmation Cu_ICP (mg/Kg dry wt.)			Reported Cu (mg/Kg dry wt.) Definitive		
site	303d Grid	exclude Hg	exclude Hg	2003	2007	2010	2003	2007	2010	2003	2007	2010
OUBM-G30	F6F4, F6F5			108	186	119		159	146	141.2	159.1	146.0
OUBM-G31	F6F4			83	123	99				112.6	158.6	132.9
OUBM-G32	F6F4			87	82	89				116.7	111.3	118.6
OUBM-G33	F6F5			135	219	163				172.8	270.0	229.8
OUBM-G34	F6F5, F6F4			138	191	187	171			171.0	238.1	266.1
OUBM-G35	F6F4			80	168	122				109.0	211.2	167.6
OUBM-G36	F6F4			105	212	148	150			150.0	262.3	207.3
OUBM-G37	F6F4			98	237	135				130.6	291.3	187.2
OUBM-G38	F6F4	Y	Y	97	207	203			297	129.2	255.9	297.0
OUBM-G39	F6F5	Y		181	195	111	173	205	203	173.0	205.2	203.0
OUBM-G40	F6F4			99	229	202	135			135.0	280.9	287.7
OUBM-G41	F6F4			89	203	174				119.7	251.2	245.6
OUBM-G42	F6F4			100	176	145	180			180.0	220.6	234.5
OUBM-G43	F6F4	Y		106	165	183	155	157	216	155.0	156.9	216.0
OUBM-G44	F6F3, F6F4			85	145	98			114	114.9	184.5	114.0
OUBM-G45	F6F4			114	254	208	154			154.0	310.4	297.9
OUBM-G46	F6F4, F6F3			133	117	32	142		72.1	142.0	151.5	72.1
OUBM-G47	F6F3			84	80	96				113.4	109.6	128.9
OUBM-G48	F6F3			70	108	101				97.7	141.6	136.3
OUBM-G49	F6F4, F6F3			146	138	148				186.1	176.8	206.6
OUBM-G50	F6F3			92	127	106				123.5	163.1	143.9
OUBM-G51	F6F3			65	112	77			102	92.0	145.9	102.0
OUBM-G52	F6F3	Y		247	219	180	398	261	231	398.0	260.7	231.0
OUBM-G53	F6F3			74	38	94		101	95.2	102.8	101.1	95.2
OUBM-G54	F6F3			68	85	78			97.7	95.5	114.4	97.7
OUBM-G55	F6F3			133	198	157		178		170.6	177.5	220.1
OUBM-G56	F6F3	Y		122	168	172	194			194.0	211.4	243.6
OUBM-G57	F6F3			100	172	122				131.7	215.8	167.9
OUBM-G58	F6F3			71	81	81				98.8	110.6	106.1
OUBM-G59	F6F3			152	252	158	272	237		272.0	237.1	222.2
OUBM-G60	F6F3	Y	Y	126	351	211	200	413	1380	200.0	412.6	1380.0
OUBM-G61	F6F3, F6F2	Y		75	233	178		170	253	102.9	170.3	253.0
OUBM-G62	F6F2			67	108	62				94.2	141.9	77.5
OUBM-G63	F6F3			192	368	202		296		238.4	295.8	287.7
OUBM-G64	F6F3			149	248	167	230			230.0	303.9	235.8
OUBM-G65	F6F2, F6F3	Y		118	175	133		124	207	152.6	123.5	207.0
OUBM-G66	F6F2			87	115	65	227			227.0	150.1	81.6
OUBM-G67	F6G3	Y	Y	211	1618	283	710	683	584	710.0	682.7	584.0
OUBM-G68	F6G2			129	280	171	217	230	171	217.0	230.3	210.4
OUBM-G69	F6F2, F6G2			79	89	79				107.9	119.2	103.9
OUBM-G70	F6F2			69	88	60				97.0	118.5	74.0
OUBM-G71	F6G2			49	31	25		30.0	26.2	73.1	30.0	26.2
												Cu
									SQS (ug/g dw)			390
	2010 Predicted Equations:								MCUL			390
	Cu_{DEF} = 1.5074*Cu_{RSC} - 15.632, R^2 = 0.7902											
	Pb_{DEF} = 1.2686*Pb_{RSC} - 34.144, R^2 = 0.8069											
	Zn_{DEF} = 1.4699*Zn_{RSC} - 29.317, R^2 = 0.6642											
	PAH_{DEF} = 1.4757*PAH_{RSC} + 744.6, R^2 = 0.7810											

Table D1 Continued.

CERCLA Grid ID	Screening Pb_{RSC} (mg/Kg dry wt.)			Confirmation Pb_ICP (mg/Kg dry wt.)			Reported Pb (mg/Kg dry wt.) Definitive			Screening Zn_{RSC} (mg/Kg dry wt.)			Confirmation Zn_ICP (mg/Kg dry wt.)		
site	2003	2007	2010	2003	2007	2010	2003	2007	2010	2003	2007	2010	2003	2007	2010
SIN-G01	102	23	31	198	19.1	18.1	198.0	19.1	18.1	260	48	70	547	71.2	73.9
SIN-G02	13	46	29				38.1	67.5	3.2	42	29	47			
SIN-G03	13	16	24			14.7	38.5	41.3	14.7	53	31	65			53.7
SIN-G04	12	16	29				37.3	41.3	2.3	52	36	66			
SIN-G05	31	53	78				53.8	73.4	64.8	91	98	136			
SIN-G06	39	66	103				60.7	84.6	96.7	100	121	159			
SIN-G07	45	92	88	72.3	70.6		72.3	70.6	77.4	110	162	168	177	181	
SIN-G08	46	83	104				67.1	99.8	98.2	102	144	155			
SIN-G09	41	80	84				62.5	97.6	72.2	109	139	166			
SIN-G10	44	59	117				65.4	78.9	113.8	101	106	163			
SIN-G11	44	54	96				65.3	74.6	87.1	94	133	156			
SIN-G12	16	7	19			15.2	40.9	33.2	23.7	51	51	51			54.2
SIN-G13	49	96	79	83.8	79.7		83.8	79.7	65.6	114	161	155	164	170	
SIN-G14	40	78	91		73.4		62.4	73.4	84.9	116	121	148		165	
SIN-G15	39	57	93				61.3	76.7	84.4	96	114	159			
SIN-G16	39	60	86				60.9	80.0	74.4	114	168	201			
SIN-G17	46	113	87		78.3		67.2	78.3	75.6	97	108	157		168	
SIN-G18	44	84	73	75.1			75.1	100.7	58.5	100	149	157	159		
SIN-G19	43	96	90			62.0	65.0	111.2	62.0	101	120	163			163
SIN-G20	34	72	94				56.4	90.6	85.3	84	136	137			
SIN-G21	47	76	97	71.8	67.1		71.8	67.1	88.4	102	136	131	159	162	
SIN-G22	43	68	87			59.5	64.9	86.6	59.5	92	121	155			159
SIN-G23	31	53	74			42.1	54.1	73.9	44.7	79	104	126			128
SIN-G24	49	105	75	72.0	69.9	70.0	72.0	69.9	70.0	102	111	159	162	169	162
SIN-G25	32	63	53		42.1	31.6	55.2	42.1	31.6	87	436	102		101	83.2
SIN-G26	9	8	11	8.53	9.26		8.5	9.3	13.9	40	41	60	45.4	41.0	
SIN-G27	34	84	81	55.4	55.8	54.3	55.4	55.8	54.3	87	111	152	128	138	157
SIN-G28	39	80	94	58.4	55.7		58.4	55.7	84.7	99	117	134	141	142	
SIN-G29	27	36	57			33.1	50.7	58.9	33.1	79	64	113			103
SIN-G30	11	15	25				36.5	40.3	37.0	42	35	45			
SIN-G31	39	103	91		55.7		61.4	55.7	81.6	96	90	116		147	
SIN-G32	31	74	61			35.3	54.0	91.8	35.3	76	73	107			103
OUBM-G01	52	80	77				72.4	97.3	63.4	137	193	170			
OUBM-G02	48	54	94				69.4	74.3	84.9	96	125	164			
OUBM-G03	33	65	73				55.8	84.2	57.9	106	131	142			
OUBM-G04	45	111	96				66.6	124.8	87.8	99	137	162			
OUBM-G05	49	100	83				70.0	115.2	70.9	102	127	160			
OUBM-G06	59	100	99				78.9	115.1	91.4	129	165	168			
OUBM-G07	43	74	101				65.1	92.4	94.0	108	132	156			
OUBM-G08	50	99	115				70.6	114.3	111.1	115	96	168			
OUBM-G09	66	55	97				84.9	75.4	88.5	138	103	147			
OUBM-G10	31	51	63		38.5		54.5	38.5	46.3	89	101	128		104	
OUBM-G11	31	50	75				53.8	71.2	73.4	87	94	124			
OUBM-G12	25	53	96		55.3	57.2	49.1	55.3	57.2	76	102	154		127	151
OUBM-G13	51	91	99				71.4	106.8	91.2	110	106	136			
OUBM-G14	43	33	36			29.9	64.4	55.9	29.9	104	82	89			82.1
OUBM-G15	28		63				51.1	26.8	46.0	88		123			
OUBM-G16	28	38	63				51.8	60.3	45.2	83	84	152			
OUBM-G17	36	72	89		64.1		58.6	64.1	79.2	97	119	150		148	
OUBM-G18	31	74	68				53.9	92.0	51.9	76	70	110			
OUBM-G19	30	66	62		68.7	76.4	53.2	68.7	76.4	91	227	150		198	291
OUBM-G20	39	75	85				61.5	92.9	73.7	92	96	185			
OUBM-G21	31	41	54				54.3	62.8	34.7	85	103	129			
OUBM-G22	48	83	94				68.7	99.9	85.7	103	123	151			
OUBM-G23	45	72	103				66.3	90.2	96.7	102	97	176			
OUBM-G24	44	74	104				65.5	91.9	97.3	131	178	178			
OUBM-G25	80	112	85				97.2	125.3	73.3	181	178	203			
OUBM-G26	66	84	111				85.3	100.9	107.3	147	195	261			
OUBM-G27	41	89	101				63.1	105.4	94.0	106	184	169			
OUBM-G28	42	84	102				63.8	100.6	95.6	134	215	213			
OUBM-G29	102	115	138				116.3	127.7	141.1	166	250	248			

Table D1 Continued.

CERCLA Grid ID	Screening Pb_{RSC} (mg/Kg dry wt.)			Confirmation Pb_ICP (mg/Kg dry wt.)			Reported Pb (mg/Kg dry wt.) Definitive			Screening Zn_{RSC} (mg/Kg dry wt.)			Confirmation Zn_ICP (mg/Kg dry wt.)		
site	2003	2007	2010	2003	2007	2010	2003	2007	2010	2003	2007	2010	2003	2007	2010
OUBM-G30	49	167	82		74.6	82.5	70.3	74.6	82.5	120	522	178		250	182
OUBM-G31	45	114	98				66.4	126.8	90.0	101	152	169			
OUBM-G32	41	99	124				62.7	113.6	122.7	105	139	167			
OUBM-G33	64	126	121				83.1	137.5	119.2	168	191	204			
OUBM-G34	104	92	115	132			132.0	108.1	111.5	250	252	206	391		
OUBM-G35	43	107	116				64.5	120.8	112.8	93	149	208			
OUBM-G36	56	127	102	86.3			86.3	138.9	95.2	133	169	190	185		
OUBM-G37	55	135	94				75.4	145.7	84.8	132	183	178			
OUBM-G38	63	91	132			153	82.3	107.3	153.0	131	175	383			547
OUBM-G39	94	169	168	128	142	205	128.0	142.1	205.0	425	316	385	288	304	447
OUBM-G40	55	126	85	85			84.9	137.6	73.4	142	198	210	208		
OUBM-G41	47	90	134				68.1	106.4	136.5	125	203	239			
OUBM-G42	52	122	102	78			77.8	133.8	97.4	129	196	209	188		
OUBM-G43	49	135	138	74.3	82.3	149	74.3	82.3	149.0	148	217	440	241	307	769
OUBM-G44	46	80	88			60.6	67.3	96.8	60.6	113	164	181			175
OUBM-G45	60	121	124	90.0			90.0	133.2	123.6	151	175	223	238		
OUBM-G46	92	67	46	155		41.3	155.0	85.9	41.3	286	149	135	428		147
OUBM-G47	45	78	99				66.2	95.3	91.2	125	151	170			
OUBM-G48	34	91	72				57.2	107.3	57.5	90	180	149			
OUBM-G49	107	97	111				121.3	112.3	106.4	250	218	218			
OUBM-G50	38	92	85				60.5	107.4	73.9	113	174	174			
OUBM-G51	36	91	98			57.8	58.2	107.3	57.8	95	124	162			161
OUBM-G52	171	159	186	279	265	168	279.0	264.5	168.0	417	339	360	785	483	494
OUBM-G53	45	59	89		62.9	62.1	66.2	62.9	62.1	112	154	170		178	176
OUBM-G54	41	71	111			74.3	62.5	89.0	74.3	105	109	168			183
OUBM-G55	65	141	118		95.4		84.3	95.4	115.1	188	322	248		335	
OUBM-G56	61	116	147	105			105.0	128.6	152.7	166	239	300	324		
OUBM-G57	87	119	118				103.2	131.8	115.6	177	235	231			
OUBM-G58	41	34	80				62.9	56.8	67.3	104	150	148			
OUBM-G59	117	183	105	439	197		439.0	196.9	99.1	280	366	192	736	505	
OUBM-G60	75	488	188	180	320	298	180.0	319.5	298.0	291	931	345	1480	863	450
OUBM-G61	167	153	140		266	168	173.4	266.2	168.0	191	375	337		463	832
OUBM-G62	48	71	106				69.2	89.3	99.9	109	117	147			
OUBM-G63	107	174	96		140		121.2	140.1	87.3	253	386	221		383	
OUBM-G64	113	126	127	209			209.0	137.9	127.4	279	292	286	425		
OUBM-G65	70	73	129		131	153	88.3	131.3	153.0	197	315	348		381	485
OUBM-G66	66	106	114	159			159.0	119.8	111.0	249	166	185	428		
OUBM-G67	140	378	211	204	281	265	204.0	281.0	265.0	283	863	382	547	954	576
OUBM-G68	67	146	125	144	605	112	144.0	605.3	116.4	558	347	292	526	2632	296
OUBM-G69	50	79	85				70.9	96.2	73.2	117	107	225			
OUBM-G70	43	100	85				64.6	115.2	73.1	103	144	136			
OUBM-G71	27	13	43		26.0	25.8	50.4	26.0	25.8	61	49	84		66.5	59.0
									Pb						
									450						
									530						

Table D1 Continued.

CERCLA Grid ID	Reported Zn (mg/Kg dry wt.) Definitive			Screening PAH_{RSC} (mg/Kg)			Conf. PAH_T (mg/Kg DW)	Reported PAH_T (Definitive)	PAH_T (mg/Kg/OC)	% TOC (SILTM 2010)
site	2003	2007	2010	2006	2007	2010	2010	2010	2010	2010
SIN-G01	547.0	71.2	73.9	1220	1600	1219		2543	123.4	2.1
SIN-G02	98.9	82.0	39.8	897	980	1127		2408	95.9	2.51
SIN-G03	111.8	84.5	53.7	1159	1012	1198		2512	194.7	1.3
SIN-G04	110.3	91.3	67.5	997	962	1482		2932	418.3	0.701
SIN-G05	158.7	167.5	170.6	1620	2622	1847		3470	105.8	3.28
SIN-G06	169.7	195.7	204.7	2998	2727	2206		4000	683.8	0.585
SIN-G07	177.0	181.4	217.6	2003	3001	3206		5476	130.4	4.2
SIN-G08	171.6	224.1	197.8	1970	2553	2117		3869	156.0	2.48
SIN-G09	180.4	217.6	214.1	2896	3374	2596		4576	115.0	3.98
SIN-G10	170.7	177.4	210.9	2346	2402	2680		4699	131.6	3.57
SIN-G11	162.1	210.5	199.3	2535	3762	2478		4401	117.0	3.76
SIN-G12	109.7	109.1	58.5	1145	1457	2149		3303	417.6	0.8
SIN-G13	164.0	170.2	198.1	2541	3361	2535		4485	143.3	3.13
SIN-G14	189.4	165.1	194.8	1904	3339	3163		5195	141.9	3.66
SIN-G15	164.7	186.4	204.4	2824	2902	2563		4527	117.6	3.85
SIN-G16	186.5	253.6	265.8	3946	4507	4807		7838	181.0	4.33
SIN-G17	165.8	167.6	200.8	2849	3078	3305		5622	167.3	3.36
SIN-G18	159.0	229.4	201.8	2167	3238	3008		5184	150.7	3.44
SIN-G19	170.3	194.4	163.0	2258	3010	2552		4511	131.5	3.4
SIN-G20	149.6	214.3	171.7	2030	2944	2589		4565	156.3	2.92
SIN-G21	159.0	161.7	162.6	2315	3237	2237		4046	147.1	2.75
SIN-G22	159.5	195.9	159.0	1845	3137	2361		4229	139.1	3.0
SIN-G23	144.2	174.3	162.6	2350	2669	1636	3551	3762	167.9	2.2
SIN-G24	162.0	168.7	162.0	2282	3184	2067		3795	138.5	2.7
SIN-G25	153.2	101.3	83.2	2197	2267	2059	2084	2084	121.9	1.7
SIN-G26	45.4	41.0	58.4	929	915	917	389	389	108.0	0.36
SIN-G27	128.0	138.3	157.0	1960	2738	2825		4913	161.6	3.0
SIN-G28	141.0	142.1	167.3	2321	2832	2426		4325	157.3	2.75
SIN-G29	143.4	124.8	103.0	2014	2585	1744		3318	164.3	2.0
SIN-G30	98.4	89.8	37.0	845	1228	999		2219	564.6	0.393
SIN-G31	165.3	146.9	141.3	2510	3079	2748		4800	480.0	1
SIN-G32	140.7	136.2	103.0	2228	4247	2202	7817	7817	1021.8	0.8
OUBM-G01	215.5	283.6	220.9	3054	10612	3451	3828	3823	150.5	2.54
OUBM-G02	164.7	200.7	211.3	2339	3385	2843		4940	89.2	5.54
OUBM-G03	176.4	208.1	179.4	1894	2759	2432		4334	235.5	1.84
OUBM-G04	168.2	214.9	209.1	2301	3496	2460		4375	155.1	2.82
OUBM-G05	172.0	203.2	205.4	3497	3565	2742		4791	180.8	2.65
OUBM-G06	204.6	249.3	217.4	1969	3089	3167		5418	207.6	2.61
OUBM-G07	178.8	208.5	199.7	2267	3473	2326		4177	168.4	2.48
OUBM-G08	188.4	164.1	218.3	1892	3497	2727		4769	187.8	2.54
OUBM-G09	216.2	172.9	186.0	2537	3020	2524		4469	156.3	2.86
OUBM-G10	156.1	103.8	158.8	1747	3146	2007		3706	262.8	1.41
OUBM-G11	153.2	162.3	171.7	1984	3446	2940		5054	216.9	2.33
OUBM-G12	140.4	127.1	151.0	1842	3043	2631		4627	180.0	2.6
OUBM-G13	181.7	177.1	171.3	1878	3280	2651		4657	151.2	3.08
OUBM-G14	174.7	147.7	82.1	2177	2134	2755		4810	620.6	0.8
OUBM-G15	154.2	46.8	150.8	1420	na	2073		3804	170.6	2.23
OUBM-G16	148.4	150.4	193.8	1813	2827	2333	2998	2998	115.3	2.60
OUBM-G17	165.8	147.7	190.5	2512	3083	2138		3900	151.8	2.57
OUBM-G18	139.6	133.2	131.7	2206	8193	1862	1916	1916	163.7	1.17
OUBM-G19	158.8	198.1	291.0	1572	3869	2199	2082	2082	122.5	1.7
OUBM-G20	159.4	164.4	243.0	2409	3556	2372		4245	145.4	2.92
OUBM-G21	150.9	173.5	160.6	2077	2668	2173		3951	203.7	1.94
OUBM-G22	173.1	198.4	192.4	1930	4014	2539		4491	134.5	3.34
OUBM-G23	172.3	165.5	229.0	3007	4418	3056		5254	177.5	2.96
OUBM-G24	207.2	264.7	232.9	2837	5908	3838		6408	187.9	3.41
OUBM-G25	268.8	265.6	268.9	2646	4241	2958		5110	71.0	7.2
OUBM-G26	226.9	286.4	354.2	2557	5004	2931	4772	4772	135.9	3.51
OUBM-G27	176.7	272.2	218.9	2058	4123	2501		4435	149.3	2.97
OUBM-G28	211.3	311.0	283.1	3260	7416	3882		6473	176.9	3.66
OUBM-G29	250.7	353.8	335.3	2613	5066	3822		6385	169.4	3.77

Table D1 Continued

CERCLA Grid ID	Reported Zn (mg/Kg dry wt.) Definitive			Screening PAH_{RSC} (mg/Kg)			Conf. PAH_T (mg/Kg DW)	Reported PAH_T (Definitive)	PAH_T (mg/Kg/OC)	% TOC (SILTM 2010)
site	2003	2007	2010	2006	2007	2010	2010	2010	2010	2010
OUBM-G30	194.3	249.6	182.0	3355	4924	3344		5679	242.7	2.3
OUBM-G31	170.8	233.9	218.7	2278	4663	3198		5464	200.1	2.73
OUBM-G32	175.7	217.9	216.0	2594	3605	3330		5659	180.8	3.13
OUBM-G33	252.6	281.2	270.2	3464	8121	7567		11911	363.1	3.28
OUBM-G34	391.0	356.0	272.9	4417	5012	4392		7226	232.3	3.11
OUBM-G35	160.4	230.0	276.6	3694	5600	3564		6004	235.5	2.55
OUBM-G36	185.0	254.4	249.3	2504	6458	3828		6394	196.7	3.25
OUBM-G37	208.4	271.4	231.7	5176	7358	4317		7115	279.0	2.55
OUBM-G38	207.7	261.7	547.0	2083	3850	2518		4460	238.5	1.9
OUBM-G39	288.0	303.8	447.0	43927	19895	9099	15072	15072	396.6	3.8
OUBM-G40	208.0	289.4	279.7	3261	13284	5147	9688	9688	295.4	3.28
OUBM-G41	200.6	296.4	321.3	5300	10507	9654		14991	416.4	3.6
OUBM-G42	188.0	287.4	277.4	2696	12214	4862	5509	6991	247.9	2.82
OUBM-G43	241.0	306.5	769.0	2459	7556	4724	4270	4270	195.9	2.2
OUBM-G44	185.5	248.7	175.0	2432	4968	3969		6602	247.3	2.7
OUBM-G45	238.0	261.1	297.9	22583	11985	4965	9185	9185	291.6	3.15
OUBM-G46	428.0	229.6	147.0	2123	3424	2327		4179	259.6	1.6
OUBM-G47	200.8	232.1	220.5	2307	4947	4366		7188	247.0	2.91
OUBM-G48	157.9	268.1	190.3	2326	6078	2949	4357	4357	158.4	2.75
OUBM-G49	354.2	314.1	291.6	7236	6717	2980	9060	9060	283.1	3.20
OUBM-G50	185.2	260.9	226.0	2719	6110	5560		8949	374.4	2.39
OUBM-G51	163.4	198.9	161.0	3190	4407	2514		4455	151.5	2.9
OUBM-G52	785.0	482.5	494.0	7098	10881	5754		9236	328.7	2.8
OUBM-G53	184.2	177.7	176.0	2776	6132	2967		5123	209.1	2.5
OUBM-G54	175.3	181.1	183.0	2597	5600	3620		6087	210.6	2.9
OUBM-G55	277.1	334.8	334.8	20968	8714	5123	10493	10493	277.6	3.78
OUBM-G56	324.0	340.0	411.7	7331	12488	4276	8369	8369	243.3	3.44
OUBM-G57	263.9	335.8	310.7	2733	8549	5776	8394	8394	284.5	2.95
OUBM-G58	174.5	231.0	188.9	3673	5740	4216		6966	226.2	3.08
OUBM-G59	736.0	505.4	253.5	4143	16033	4365	5868	5868	183.9	3.19
OUBM-G60	1480.0	862.8	450.0	28403	21452	8415	14664	14664	362.1	4.1
OUBM-G61	280.7	463.3	832.0	14017	23252	11121	18404	18404	371.8	5.0
OUBM-G62	181.0	190.8	187.2	4237	8738	4817		7853	289.8	2.71
OUBM-G63	356.8	383.2	295.5	19148	11440	6131	10557	10557	305.1	3.46
OUBM-G64	425.0	404.7	390.5	7382	13548	8015		12572	384.5	3.27
OUBM-G65	288.9	381.1	485.0	3123	6521	8024		12586	441.6	2.9
OUBM-G66	428.0	250.2	242.9	7825	10888	5030		8167	309.4	2.64
OUBM-G67	547.0	953.5	576.0	7180	29692	9360	12159	12159	170.1	7.2
OUBM-G68	526.0	2631.6	346.2	3552	7684	5484		10661	405.4	2.6
OUBM-G69	190.4	178.3	301.2	5193	12468	4994	6629	7371	481.8	1.53
OUBM-G70	173.6	223.8	170.2	2792	6725	3685		6183	234.2	2.64
OUBM-G71	121.9	66.5	59.0	1974	5505	2074	4769	4769	407.6	1.2
			410						**1330**	
			960						**6080**	

Table D1 Continued.

CERCLA Grid ID	Hg	Cr	Ag	Cd	As	LPAH mg/Kg/OC	HPAH mg/Kg/OC	Naphthalene	Biphenyl m	Acenaphthylene	Acenaphthene	Fluorene m
site	2010	2010	2010	2010	2010	2010	2010	2010	2010	2010	2010	2010
SIN-G01	0.06	103.96	0.36	0.26	3.03							
SIN-G02	0.08											
SIN-G03	0.07	75.98	0.25	0.25	2.93							
SIN-G04	0.06											
SIN-G05	0.50											
SIN-G06	0.70											
SIN-G07	0.64											
SIN-G08	0.74											
SIN-G09	0.65											
SIN-G10	0.70											
SIN-G11	0.77											
SIN-G12	0.14	63.79	0.29	0.59	3.37							
SIN-G13	0.82											
SIN-G14	0.70											
SIN-G15	0.63											
SIN-G16	0.56											
SIN-G17	0.72											
SIN-G18	0.66											
SIN-G19	0.56	90.77	1.03	1.59	11.40							
SIN-G20	0.61											
SIN-G21	0.65											
SIN-G22	0.51	94.91	0.85	1.06	10.80							
SIN-G23	0.34	85.39	0.59	1.33	7.46	9	78	1.60	0.46	1.41	0.22	0.57
SIN-G24	0.51	86.25	0.73	0.95	11.20							
SIN-G25	0.28	68.65	0.42	0.66	6.64	6	51	1.39	0.22	0.70	0.18	0.30
SIN-G26	0.03					10	59	1.45	1.37	1.42	0.00	1.12
SIN-G27	0.55	90.25	0.66	1.10	10.40							
SIN-G28	0.36											
SIN-G29	0.24	44.79	0.43	0.80	7.12							
SIN-G30	0.05											
SIN-G31	0.39											
SIN-G32	0.35	74.67	0.36	0.58	6.00	70	517	6.34	1.22	6.98	3.06	3.58
OUBM-G01	0.69					9	53	1.60	0.65	0.94	0.46	0.86
OUBM-G02	0.77											
OUBM-G03	0.28											
OUBM-G04	0.68											
OUBM-G05	0.78											
OUBM-G06	0.76											
OUBM-G07	0.70											
OUBM-G08	1.10											
OUBM-G09	0.81											
OUBM-G10	0.40											
OUBM-G11	0.74											
OUBM-G12	0.92	123.08	0.65	1.44	10.30							
OUBM-G13	0.68											
OUBM-G14	0.24	74.64	0.42	0.56	4.11							
OUBM-G15	0.46											
OUBM-G16	0.61					7	51	1.05	0.17	0.87	0.14	0.46
OUBM-G17	0.76											
OUBM-G18	0.49					11	69	1.76	0.40	0.45	0.36	0.69
OUBM-G19	0.50	86.94	0.54	0.99	14.40	9	49	2.96	0.36	0.55	0.22	0.59
OUBM-G20	0.72											
OUBM-G21	0.35											
OUBM-G22	0.68											
OUBM-G23	0.93											
OUBM-G24	0.52											
OUBM-G25	0.82											
OUBM-G26	0.67					7	59	1.33	0.03	0.56	0.23	0.36
OUBM-G27	0.68											
OUBM-G28	0.78											
OUBM-G29	0.79											

Table D1 Continued.

CERCLA Grid ID	Hg	Cr	Ag	Cd	As	LPAH mg/Kg/OC	HPAH mg/Kg/OC	Naphthalene	Biphenyl m	Acenaphthylene	Acenaphthene	Fluorene m
site	2010	2010	2010	2010	2010	2010	2010	2010	2010	2010	2010	2010
OUBM-G30	0.62	96.37	0.87	1.39	11.20							
OUBM-G31	0.53											
OUBM-G32	0.65											
OUBM-G33	0.75											
OUBM-G34	0.82											
OUBM-G35	0.53											
OUBM-G36	0.74											
OUBM-G37	0.55											
OUBM-G38	0.46	115.36	0.85	1.07	194.00							
OUBM-G39	4.30	86.30	1.03	1.44	6.00	24	223	2.49	0.44	1.04	0.93	1.63
OUBM-G40	0.93					21	149	2.33	0.50	1.14	1.20	1.67
OUBM-G41	0.56											
OUBM-G42	0.69					9	84	1.86	0.26	1.04	0.68	0.61
OUBM-G43	0.51	93.97	1.04	1.14	17.50	14	90	1.79	0.36	0.74	0.93	1.26
OUBM-G44	0.56	96.08	0.77	1.12	11.20							
OUBM-G45	0.95					14	160	3.15	0.71	1.28	0.41	0.79
OUBM-G46	0.22	102.91	0.35	0.54	5.79							
OUBM-G47	0.57											
OUBM-G48	0.63					9	69	1.14	0.47	1.27	0.48	0.90
OUBM-G49	0.66					21	151	0.85	0.17	0.55	2.04	1.08
OUBM-G50	0.88											
OUBM-G51	0.76	88.82	0.75	1.14	11.60							
OUBM-G52	0.69	109.32	1.10	1.32	19.00							
OUBM-G53	0.62	89.71	0.57	1.14	11.80							
OUBM-G54	0.68	85.67	0.63	1.03	11.80							
OUBM-G55	1.00					23	136	2.75	0.73	1.33	1.81	2.65
OUBM-G56	1.30					16	108	2.18	0.59	1.28	0.81	1.16
OUBM-G57	0.76					16	152	2.19	0.67	1.84	0.66	1.21
OUBM-G58	0.55											
OUBM-G59	0.69					13	82	2.89	0.71	1.27	0.64	1.11
OUBM-G60	0.94	87.05	0.68	1.79	19.70	23	192	2.16	0.61	1.92	1.02	1.62
OUBM-G61	0.42	119.64	1.20	1.82	19.60	33	214	1.67	0.51	3.27	1.63	2.10
OUBM-G62	0.57											
OUBM-G63	1.10					21	158	1.86	0.76	2.28	0.96	2.02
OUBM-G64	0.88											
OUBM-G65	0.79	111.00	3.05	1.69	19.90							
OUBM-G66	0.50											
OUBM-G67	0.64	99.67	0.79	1.65	18.30	9	74	0.85	0.26	0.53	0.42	0.60
OUBM-G68	1.50	85.01	0.62	1.44	14.00							
OUBM-G69	0.58					35	231	2.74	0.97	2.24	2.13	3.29
OUBM-G70	0.52											
OUBM-G71	0.19	50.29	0.21	0.38	4.12	58	200	4.48	1.21	2.24	2.88	4.05
	0.41	**260**	**6.1**	**5.1**	**57**	**370**	**960**	**99**		**66**	**16**	**23**
	0.59	**270**	**6.1**	**6.7**	**93**	**780**	**5300**	**170**		**66**	**57**	**79**

The LPAH criterion represents the sum of the following "low molecular weight polynuclear aromatic hydrocarbon" compounds: Naphthalene, Acenaphthylene, Acenaphthene, Fluorene, Phenanthrene, & Anthracene

The HPAH criterion represents the sum of the following "high molecular weight polynuclear aromatic hydrocarbon" compounds: Fluoranthene, Pyrene, Benz(a)anthracene, Chrysene, Total Benzofluoranthenes, Benzo(a)pyrene, Indeno(1,2,3,-c,d)pyrene, Dibenzo(a,h)anthracene, and Benzo (g,h,i)perylene.

The TOTAL BENZOFLUORANTHENES criterion represents the sum of the concentrations of the "B," J, and "K" isomers.

The non-detect summation rules in SQS were used.

PAH results converted to DW/OC corrected using the following equation: dry-weight concentration = wet weight concentration/(sample percent dry weight/100)

Table D1 Continued.

CERCLA Grid ID	Anthracene	Phenanthrene	Dibenzothiophene mg/Kg/OC	Fluoranthene mg/Kg/OC	Pyrene mg/Kg/OC	Benzo(a)anthracene mg/Kg/OC	Chrysene mg/Kg/OC	Total Benzo mg/Kg/OC	Benzo(b) fluoranthene mg/Kg/OC
site	2010	2010	2010	2010	2010	2010	2010	2010	2010
SIN-G01									
SIN-G02									
SIN-G03									
SIN-G04									
SIN-G05									
SIN-G06									
SIN-G07									
SIN-G08									
SIN-G09									
SIN-G10									
SIN-G11									
SIN-G12									
SIN-G13									
SIN-G14									
SIN-G15									
SIN-G16									
SIN-G17									
SIN-G18									
SIN-G19									
SIN-G20									
SIN-G21									
SIN-G22									
SIN-G23	2.18	3.14	0.46	8.80	12.32	8.56	12.86	21.73	16.78
SIN-G24									
SIN-G25	1.66	2.13	0.27	6.29	8.94	4.74	5.47	9.53	6.89
SIN-G26	1.84	4.04	0.73	10.47	9.18	5.06	5.90	12.77	9.26
SIN-G27									
SIN-G28									
SIN-G29									
SIN-G30									
SIN-G31									
SIN-G32	13.12	37.28	1.99	72.32	92.70	50.20	53.43	98.41	72.32
OUBM-G01	1.53	3.61	0.46	6.94	9.96	3.90	4.70	11.88	9.04
OUBM-G02									
OUBM-G03									
OUBM-G04									
OUBM-G05									
OUBM-G06									
OUBM-G07									
OUBM-G08									
OUBM-G09									
OUBM-G10									
OUBM-G11									
OUBM-G12									
OUBM-G13									
OUBM-G14									
OUBM-G15									
OUBM-G16	1.49	2.67	0.33	5.52	6.97	5.09	6.18	12.77	9.44
OUBM-G17									
OUBM-G18	2.12	5.31	0.61	10.48	12.33	6.35	5.68	14.63	11.10
OUBM-G19	1.57	3.21	0.43	5.61	8.10	4.61	4.29	11.56	8.76
OUBM-G20									
OUBM-G21									
OUBM-G22									
OUBM-G23									
OUBM-G24									
OUBM-G25									
OUBM-G26	1.30	2.92	0.33	10.75	12.17	3.32	6.01	11.94	8.32
OUBM-G27									
OUBM-G28									
OUBM-G29									

Table D1 Continued.

CERCLA Grid ID	Anthracene	Phenanthrene	Dibenzothiophene mg/Kg/OC	Fluoranthene mg/Kg/OC	Pyrene mg/Kg/OC	Benzo(a)anthracene mg/Kg/OC	Chrysene mg/Kg/OC	Total Benzo mg/Kg/OC	Benzo(b) fluoranthene mg/Kg/OC
site	2010	2010	2010	2010	2010	2010	2010	2010	2010
OUBM-G30									
OUBM-G31									
OUBM-G32									
OUBM-G33									
OUBM-G34									
OUBM-G35									
OUBM-G36									
OUBM-G37									
OUBM-G38									
OUBM-G39	4.76	13.00	0.88	44.40	53.80	17.00	22.61	42.45	31.36
OUBM-G40	4.78	10.16	0.52	22.23	25.05	14.38	18.81	32.35	23.13
OUBM-G41									
OUBM-G42	1.97	3.06	0.43	10.82	15.31	6.35	8.99	18.29	13.14
OUBM-G43	2.60	7.00	0.57	16.30	17.97	7.45	9.45	17.11	12.22
OUBM-G44									
OUBM-G45	2.87	5.02	0.55	19.55	21.68	13.99	21.58	38.24	27.13
OUBM-G46									
OUBM-G47									
OUBM-G48	1.88	3.51	0.40	9.81	12.12	5.74	8.21	14.13	9.93
OUBM-G49	4.21	12.41	0.73	27.47	29.02	13.85	18.06	26.93	19.16
OUBM-G50									
OUBM-G51									
OUBM-G52									
OUBM-G53									
OUBM-G54									
OUBM-G55	4.45	9.74	0.90	26.02	27.40	11.89	16.89	24.29	17.75
OUBM-G56	3.07	7.84	0.80	19.50	21.65	8.34	16.10	18.70	13.60
OUBM-G57	4.47	5.81	0.58	19.27	23.74	13.31	21.40	31.65	23.21
OUBM-G58									
OUBM-G59	2.41	4.26	0.56	12.07	16.52	5.85	10.23	17.01	12.53
OUBM-G60	7.32	8.51	0.80	23.58	30.91	17.35	29.05	41.77	30.82
OUBM-G61	7.17	17.29	0.98	36.59	43.10	14.09	35.20	44.65	33.09
OUBM-G62									
OUBM-G63	6.21	7.48	0.70	16.04	20.67	15.47	23.94	36.30	26.88
OUBM-G64									
OUBM-G65									
OUBM-G66									
OUBM-G67	3.41	3.09	0.32	8.69	13.45	7.40	9.63	16.40	12.32
OUBM-G68									
OUBM-G69	8.91	15.91	1.39	31.41	37.20	23.45	30.19	47.53	35.05
OUBM-G70									
OUBM-G71	6.05	38.07	1.69	54.14	40.64	9.81	20.25	36.77	26.87
	220	**100**		**160**	**1000**	**110**	**110**	**230**	
	1200	**480**		**1200**	**1400**	**270**	**460**	**450**	

Table D1 Continued.

CERCLA Grid ID	Benzo(k) fluoranthene mg/Kg/OC	Benzo(e) pyrene mg/Kg/OC	Benzo(a) pyrene mg/Kg/OC	Perylene mg/Kg/OC	Indeno(1,2,3-cd) pyrene mg/Kg/OC	Dibenz(a,h) anthracene mg/Kg/OC	Benzo(g,h,i) perylene mg/Kg/OC		LPAH ng/g DW	HPAH ng/g DW
site	2010	2010	2010	2010	2010	2010	2010		2010	2010
SIN-G01										
SIN-G02										
SIN-G03										
SIN-G04										
SIN-G05										
SIN-G06										
SIN-G07										
SIN-G08										
SIN-G09										
SIN-G10										
SIN-G11										
SIN-G12										
SIN-G13										
SIN-G14										
SIN-G15										
SIN-G16										
SIN-G17										
SIN-G18										
SIN-G19										
SIN-G20										
SIN-G21										
SIN-G22										
SIN-G23	4.95	7.37	7.01	2.21	2.76	1.08	2.70		204.05	1743.04
SIN-G24										
SIN-G25	2.64	4.53	5.65	1.99	4.35	0.83	4.71		108.68	863.72
SIN-G26	3.51	4.69	6.69	3.02	4.61	0.91	3.51		35.55	212.76
SIN-G27										
SIN-G28										
SIN-G29										
SIN-G30										
SIN-G31										
SIN-G32	26.09	43.74	57.41	13.32	41.00	10.26	41.00		538.21	3953.04
OUBM-G01	2.84	5.67	6.05	2.63	4.28	0.89	4.10		228.64	1338.74
OUBM-G02										
OUBM-G03										
OUBM-G04										
OUBM-G05										
OUBM-G06										
OUBM-G07										
OUBM-G08										
OUBM-G09										
OUBM-G10										
OUBM-G11										
OUBM-G12										
OUBM-G13										
OUBM-G14										
OUBM-G15										
OUBM-G16	3.32	4.66	5.57	2.12	4.08	0.99	3.64		173.34	1320.90
OUBM-G17										
OUBM-G18	3.53	5.73	6.54	4.01	5.86	1.45	5.96		125.12	810.69
OUBM-G19	2.80	4.71	5.05	3.01	4.29	1.06	4.00		154.85	825.49
OUBM-G20										
OUBM-G21										
OUBM-G22										
OUBM-G23										
OUBM-G24										
OUBM-G25										
OUBM-G26	3.62	4.99	5.31	1.54	4.26	0.81	4.27		235.68	2065.15
OUBM-G27										
OUBM-G28										
OUBM-G29										

Table D1 Continued.

CERCLA Grid ID	Benzo(k) fluoranthene mg/Kg/OC	Benzo(e) pyrene mg/Kg/OC	Benzo(a) pyrene mg/Kg/OC	Perylene mg/Kg/OC	Indeno(1,2,3-cd) pyrene mg/Kg/OC	Dibenz(a,h) anthracene mg/Kg/OC	Benzo(g,h,i) perylene mg/Kg/OC		LPAH ng/g DW	HPAH ng/g DW
site	2010	2010	2010	2010	2010	2010	2010		2010	2010
OUBM-G30										
OUBM-G31										
OUBM-G32										
OUBM-G33										
OUBM-G34										
OUBM-G35										
OUBM-G36										
OUBM-G37										
OUBM-G38										
OUBM-G39	11.09	16.49	17.17	3.54	11.69	2.89	10.62		906.51	8459.55
OUBM-G40	9.21	12.37	14.69	3.20	10.03	2.26	9.42		697.79	4894.42
OUBM-G41										
OUBM-G42	5.15	7.44	8.48	2.70	8.32	1.35	5.74		259.78	2359.06
OUBM-G43	4.89	7.07	8.36	2.54	6.08	1.33	5.74		311.96	1957.68
OUBM-G44										
OUBM-G45	11.11	15.06	16.98	3.56	15.06	2.51	10.90		426.04	5055.52
OUBM-G46										
OUBM-G47										
OUBM-G48	4.20	5.87	7.44	2.11	5.82	1.04	5.12		252.19	1909.63
OUBM-G49	7.77	10.15	13.85	3.22	10.70	2.23	9.26		676.14	4843.67
OUBM-G50										
OUBM-G51										
OUBM-G52										
OUBM-G53										
OUBM-G54										
OUBM-G55	6.54	10.00	11.72	2.77	8.27	2.09	7.76		858.96	5153.75
OUBM-G56	5.11	7.93	9.03	2.30	6.47	1.59	6.42		562.12	3708.31
OUBM-G57	8.44	14.05	16.93	3.56	11.50	2.85	11.71		477.58	4494.66
OUBM-G58										
OUBM-G59	4.47	7.23	8.06	1.98	5.75	1.37	5.53		401.61	2627.80
OUBM-G60	10.95	17.52	20.46	4.60	13.47	3.66	12.13		912.69	7791.61
OUBM-G61	11.56	17.55	18.68	3.12	10.43	2.97	8.26		1639.75	10591.47
OUBM-G62										
OUBM-G63	9.42	15.47	18.30	4.00	12.20	3.13	11.52		720.36	5451.74
OUBM-G64										
OUBM-G65										
OUBM-G66										
OUBM-G67	4.08	7.06	8.01	1.83	4.57	1.39	4.19		636.14	5272.29
OUBM-G68										
OUBM-G69	12.48	19.41	25.07	5.57	16.04	4.46	15.37		538.67	3530.01
OUBM-G70										
OUBM-G71	9.91	14.31	17.55	3.63	9.60	2.70	8.07		675.88	2334.54
			99		**34**	**12**	**31**			
			210		**88**	**33**	**78**			

D.1.1 **Appendix D.1.1 Regression analysis for Fe**

Table D1.1 Raw Data for Fe from RSC and ICP-OES analysis:

	Fe_RSC	Fe_ICP	
Sample_ID	RSC-FPXRF	SQV_ICP-OES	units
OUBM2010OUB-12	34139	34196	ug/g
OUBM2010OUB-14	24675	23069	ug/g
OUBM2010OUB-19	31209	31029	ug/g
OUBM2010OUB-30	35292	34773	ug/g
OUBM2010OUB-38	41095	43051	ug/g
OUBM2010OUB-39	27460	25694	ug/g
OUBM2010OUB-43	39695	39792	ug/g
OUBM2010OUB-44	36020	34837	ug/g
OUBM2010OUB-46	26962	25678	ug/g
OUBM2010OUB-51	35316	35186	ug/g
OUBM2010OUB-52	37373	36567	ug/g
OUBM2010OUB-53	36474	34184	ug/g
OUBM2010OUB-54	35278	33918	ug/g
OUBM2010OUB-60	38807	34263	ug/g
OUBM2010OUB-61	41367	38586	ug/g
OUBM2010OUB-65	33958	31956	ug/g
OUBM2010OUB-67	38486	37032	ug/g
OUBM2010OUB-68	35067	31265	ug/g
OUBM2010OUB-71	20633	19230	ug/g
OUBM2010SIN-01	29108	28363	ug/g
OUBM2010SIN-03	22911	20921	ug/g
OUBM2010SIN-12	19230	17963	ug/g
OUBM2010SIN-19	33270	35492	ug/g
OUBM2010SIN-22	35295	34942	ug/g
OUBM2010SIN-23	26768	26416	ug/g
OUBM2010SIN-24	34147	34702	ug/g
OUBM2010SIN-25	25922	22344	ug/g
OUBM2010SIN-27	33798	34997	ug/g
OUBM2010SIN-29	28026	27345	ug/g
OUBM2010SIN-32	25539	24670	ug/g
SQV06-013	22017	29528	ug/g
SQV06-021	25663	26756	ug/g
SQV06-022	24507	24023	ug/g
SQV06-023	29509	17364	ug/g
SQV06-024	27107	18035	ug/g
SQV06-025	28658	29044	ug/g
SQV06-026	29662	28129	ug/g
SQV06-027	27990	29144	ug/g
SQV06-028	26430	13454	ug/g
SQV06-029	24110	19559	ug/g
SQV06-030	23486	17325	ug/g
SQV06-031	31491	28213	ug/g
SQV06-032	24433	26269	ug/g
SQV06-033	23335	26523	ug/g
SQV06-034	20736	35699	ug/g
SQV06-035	20477	20118	ug/g
SQV06-036	23179	22887	ug/g
SQV06-037	22965	24864	ug/g
SQV06-038	21122	22771	ug/g
SQV06-039	24705	21827	ug/g
SQV06-040	18154	19567	ug/g
SQV06-041	21648	19996	ug/g

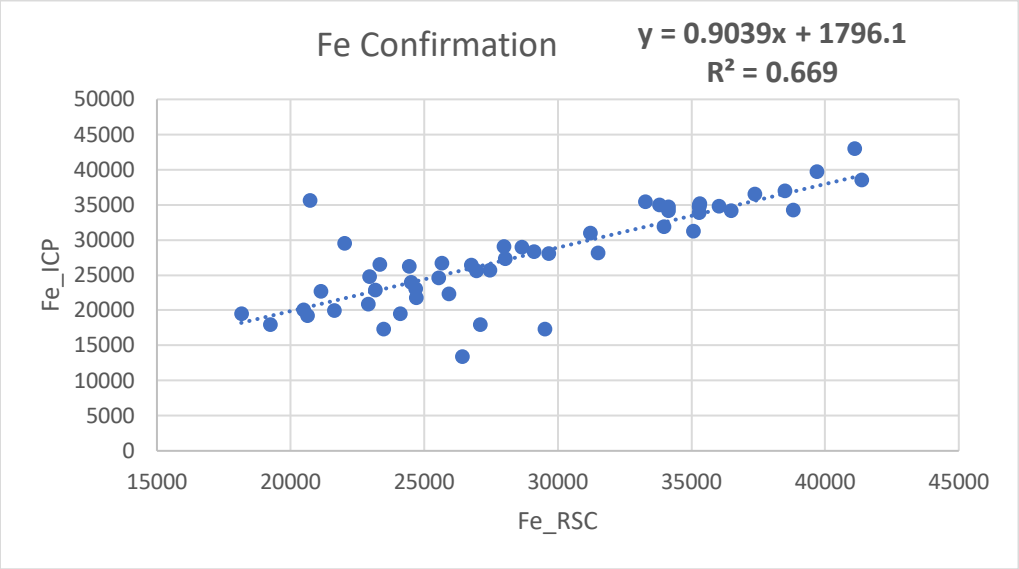
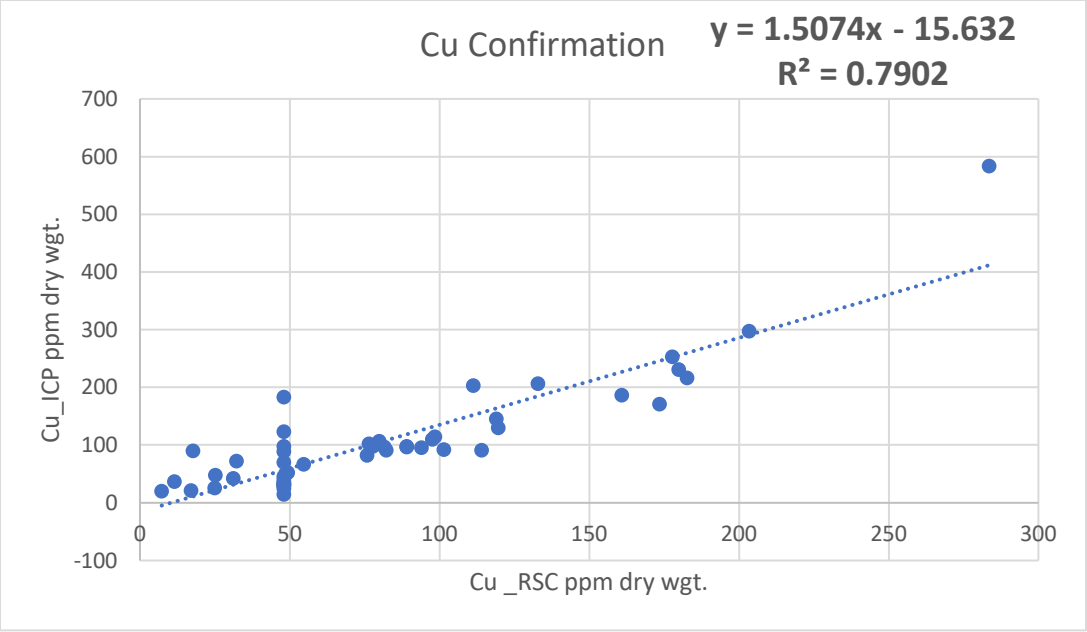


Figure Appendix D.1.1 Fe confirmation results from least squares regression between Fe analyzed by XRF (Fe_{RSC}) and ICP-MS (Fe_{ICP}) in ppm dry weight.

D.1.2 **Appendix D.1.2 Regression analysis for Cu**

Table D1.2 Raw data for Cu from RSC and ICP-OES analysis;

	CuRSC		CuRCS-nd=0		CuICP		LabID
OUBM-G12	82	J	82.20954	82.20954	92	ug/g	3151-48
OUBM-G14	12	U	0		37	ug/g	3151-50
OUBM-G19	80	J	79.89416	79.89416	107	ug/g	3151-55
OUBM-G30	119		119.0474	119.0474	146	ug/g	3151-66
OUBM-G38	203		203.4164	203.4164	297	ug/g	3151-74
OUBM-G39	111		111.3887	111.3887	203	ug/g	3151-75
OUBM-G43	183		182.6033	182.6033	216	ug/g	3151-80
OUBM-G44	98	J	98.38961	98.38961	114	ug/g	3151-81
OUBM-G46	32	U	0		72	ug/g	3151-83
OUBM-G51	77	J	76.50901	76.50901	102	ug/g	3151-88
OUBM-G52	180		179.9226	179.9226	231	ug/g	3151-89
OUBM-G53	94	J	94.00937	94.00937	95	ug/g	3151-90
OUBM-G54	78	J	77.66884	77.66884	98	ug/g	3151-91
OUBM-G61	178		177.6786	177.6786	253	ug/g	3151-98
OUBM-G65	133		132.9058	132.9058	207	ug/g	3151-102
OUBM-G67	283		283.4582	283.4582	584	ug/g	3151-104
OUBM-G68avg	174		173.5495	173.5495	171	ug/g	3151-105
OUBM-G71	25	U	0		26	ug/g	3151-109
OOUB-G3	7	U	0		20	ug/g	3151-3
OOUB-G12avg	17	U	0		21	ug/g	3151-12
OOUB-G19	98	J	97.68034	97.68034	110	ug/g	3151-21
OOUB-G22	89	J	89.11365	89.11365	96	ug/g	3151-24
OOUB-G23avg	55	U	0		67	ug/g	3151-25
OOUB-G24	89	J	89.05359	89.05359	98	ug/g	3151-27
OOUB-G25	31	U	0		42	ug/g	3151-28
OOUB-G27	82	J	81.65896	81.65896	96	ug/g	3151-30
OOUB-G29	18	U	0		90	ug/g	3151-32
OOUB-G32	25	U	0		48	ug/g	3151-35
P7-T4-1	48	U	0		183	ug/g	3151-585
P7-T5-5	48	U	0		24	ug/g	3151-594
P7-T6-1	101		101.4814	101.4814	93	ug/g	3151-595
P7-T6-2	114		114.0273	114.0273	91	ug/g	3151-596
P7-T6-3	161		160.9408	160.9408	186	ug/g	3151-597
P7-T6-4	48	U	0		98	ug/g	3151-598
P7-T6-5	76	J	75.86934	75.86934	82	ug/g	3151-599 I
P7-T7-1	49	J	49.3469	49.3469	52	ug/g	3151-600
P7-T7-2	48	U	0		89	ug/g	3151-601
P7-T7-3	48	U	0		30	ug/g	3151-602
P7-T7-4	120		119.681	119.681	130	ug/g	3151-603
P7-T7-5	48	U	0		123	ug/g	3151-604
P7-T7-6	48	U	0		35	ug/g	3151-605
P7-T8-1	48	U	0		41	ug/g	3151-606
P7-T8-2	48	U	0		30	ug/g	3151-607
P7-T8-3	48	U	0		46	ug/g	3151-608
P7-T9-1	48	U	0		30	ug/g	3151-609
P7-T9-2	48	U	0		71	ug/g	3050-610
P7-T9-3	48	U	0		33	ug/g	3151-611
P7-T9-4	48	U	0		15	ug/g	3151-612
P7-T9-5	48	U	0		34	ug/g	3151-613
OUTLIERS							
OUBM-G60	211				1380	ug/g	3151-97
P7-T5-4	70	J			979	ug/g	3151-593



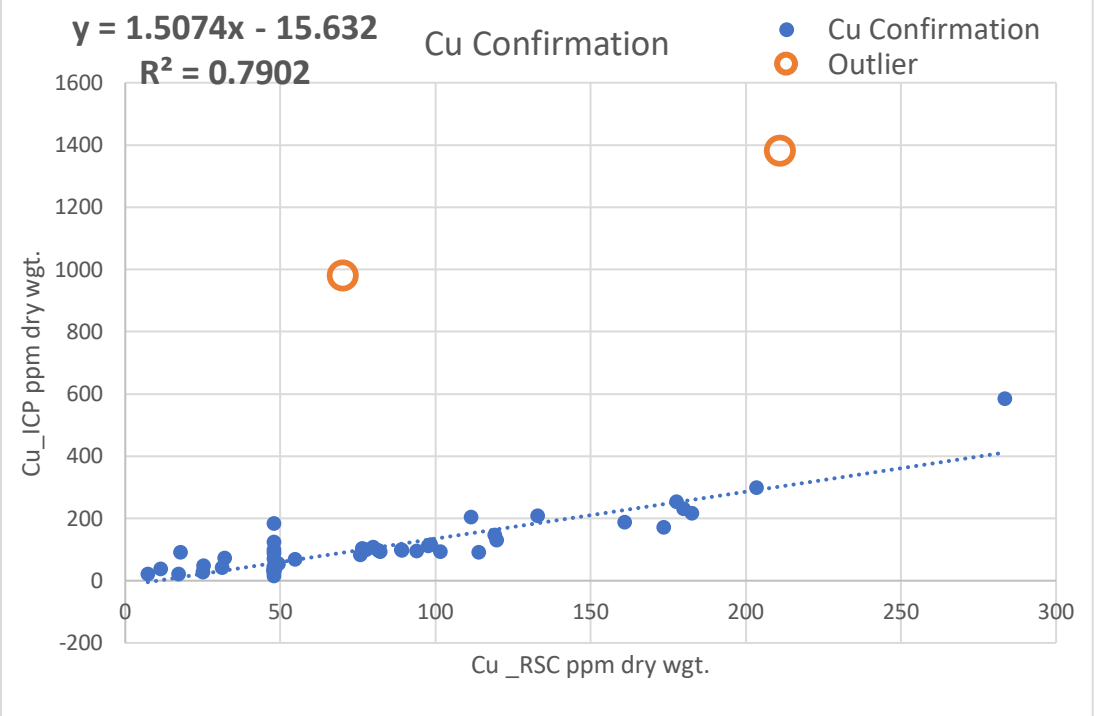


Figure Appendix D.1.2 Cu confirmation results from least squares regression between Cu analyzed by XRF ($Cu_{\_RSC}$) and ICP-OES ($Cu_{\_ICP}$) in ppm dry weight. Lower plot shows outliers not used in regression.

D.1.3 **Appendix D.1.3 Regression analysis for Pb**

Table D1.3 Raw data for Pb from RSC and ICP-MS analysis.

	Pb_rsc			Pb_ICP	units	LabID
OUBM-G12	95.6 J	OUB12	LEAD	57.2	ug/g	3151-48
OUBM-G14	35.8 U	OUB14	LEAD	29.9	ug/g	3151-50
OUBM-G19	62.4 J	OUB19	LEAD	76.4	ug/g	3151-55
OUBM-G30	81.9 J	OUB30	LEAD	82.5	ug/g	3151-66
OUBM-G38	132.3	OUB38	LEAD	153.0	ug/g	3151-74
OUBM-G39	167.9	OUB39	LEAD	205.0	ug/g	3151-75
OUBM-G43	138.4	OUB43	LEAD	149.0	ug/g	3151-80
OUBM-G44	88.5 J	OUB44	LEAD	60.6	ug/g	3151-81
OUBM-G46	45.9 U	OUB46	LEAD	41.3	ug/g	3151-83
OUBM-G51	97.5 J	OUB51	LEAD	57.8	ug/g	3151-88
OUBM-G52	185.6	OUB52	LEAD	168.0	ug/g	3151-89
OUBM-G53	88.7 J	OUB53	LEAD	62.1	ug/g	3151-90
OUBM-G54	111.1	OUB54	LEAD	74.3	ug/g	3151-91
OUBM-G60	187.5	OUB60	LEAD	298.0	ug/g	
OUBM-G61	139.8	OUB61	LEAD	168.0	ug/g	3151-98
OUBM-G65	129.4	OUB65	LEAD	153.0	ug/g	3151-102
OUBM-G67	210.8	OUB67	LEAD	265.0	ug/g	3151-104
OUBM-G68avg	123.6	OUB68	LEAD	112.0	ug/g	3151-105
OUBM-G71	42.8 U	OUB71	LEAD	25.8	ug/g	3151-109
OOUB-G1	31.5 U	SIN01	LEAD	18.1	ug/g	3151-3
OOUB-G3	23.7 U	SIN03	LEAD	14.7	ug/g	3151-12
OOUB-G12avg	22.2 U	SIN12	LEAD	15.2	ug/g	3151-21
OOUB-G19	90.5 J	SIN19	LEAD	62.0	ug/g	3151-24
OOUB-G22	87.4 J	SIN22	LEAD	59.5	ug/g	3151-25
OOUB-G23avg	69.0 J	SIN23	LEAD	42.1	ug/g	3151-27
OOUB-G24	75.4 J	SIN24	LEAD	70.0	ug/g	3151-28
OOUB-G25	53.1 J	SIN25	LEAD	31.6	ug/g	3151-30
OOUB-G27	80.9 J	SIN27	LEAD	54.3	ug/g	3151-32
OOUB-G29	57.2 J	SIN29	LEAD	33.1	ug/g	3151-35
OOUB-G32	61.1 J	SIN32	LEAD	35.3	ug/g	3151-585
P7-T5-4	60.4 J	T5-4	LEAD	45.1	ug/g	3151-594
P7-T5-5	38.2 U	T5-5	LEAD	16.3	ug/g	3151-595
P7-T6-1	146.9	T6-1	LEAD	79.7	ug/g	3151-596
P7-T6-2	74.9 J	T6-2	LEAD	54.7	ug/g	3151-597
P7-T6-5	57.1 J	T6-5	LEAD	55.4	ug/g	3151-600
P7-T7-1	115.3	T7-1	LEAD	31.3	ug/g	3151-601
P7-T7-2	73.3 J	T7-2	LEAD	70.4	ug/g	3151-602
P7-T7-3	52.2 J	T7-3	LEAD	23.1	ug/g	3151-603
P7-T7-4	109.3	T7-4	LEAD	94.1	ug/g	3151-604
P7-T7-5	50.0 U	T7-5	LEAD	39.3	ug/g	3151-605
P7-T7-6	51.3 J	T7-6	LEAD	25.7	ug/g	3151-606
P7-T8-1	65.9 J	T8-1	LEAD	22.5	ug/g	3151-607
P7-T8-2	50.0 U	T8-2	LEAD	24.0	ug/g	3151-608
P7-T8-3	53.4 J	T8-3	LEAD	43.2	ug/g	3151-609
P7-T9-1	52.0 J	T9-1	LEAD	16.1	ug/g	3050-610
P7-T9-2	50.0 U	T9-2	LEAD	69.1	ug/g	3151-611
P7-T9-3	50.0 U	T9-3	LEAD	31.7	ug/g	3151-612
P7-T9-4	50.0 U	T9-4	LEAD	13.5	ug/g	3151-613
P7-T9-5	50.0 U	T9-5	LEAD	57.5	ug/g	
OUTLIERS						
P7-T6-4	137.755	T6-4	LEAD	628.0	ug/g	3151-599 R1
P7-T6-3	107.324	T6-3	LEAD	419.0	ug/g	3151-598
P7-T4-1	50.0 U	T4-1	LEAD	212.0	ug/g	

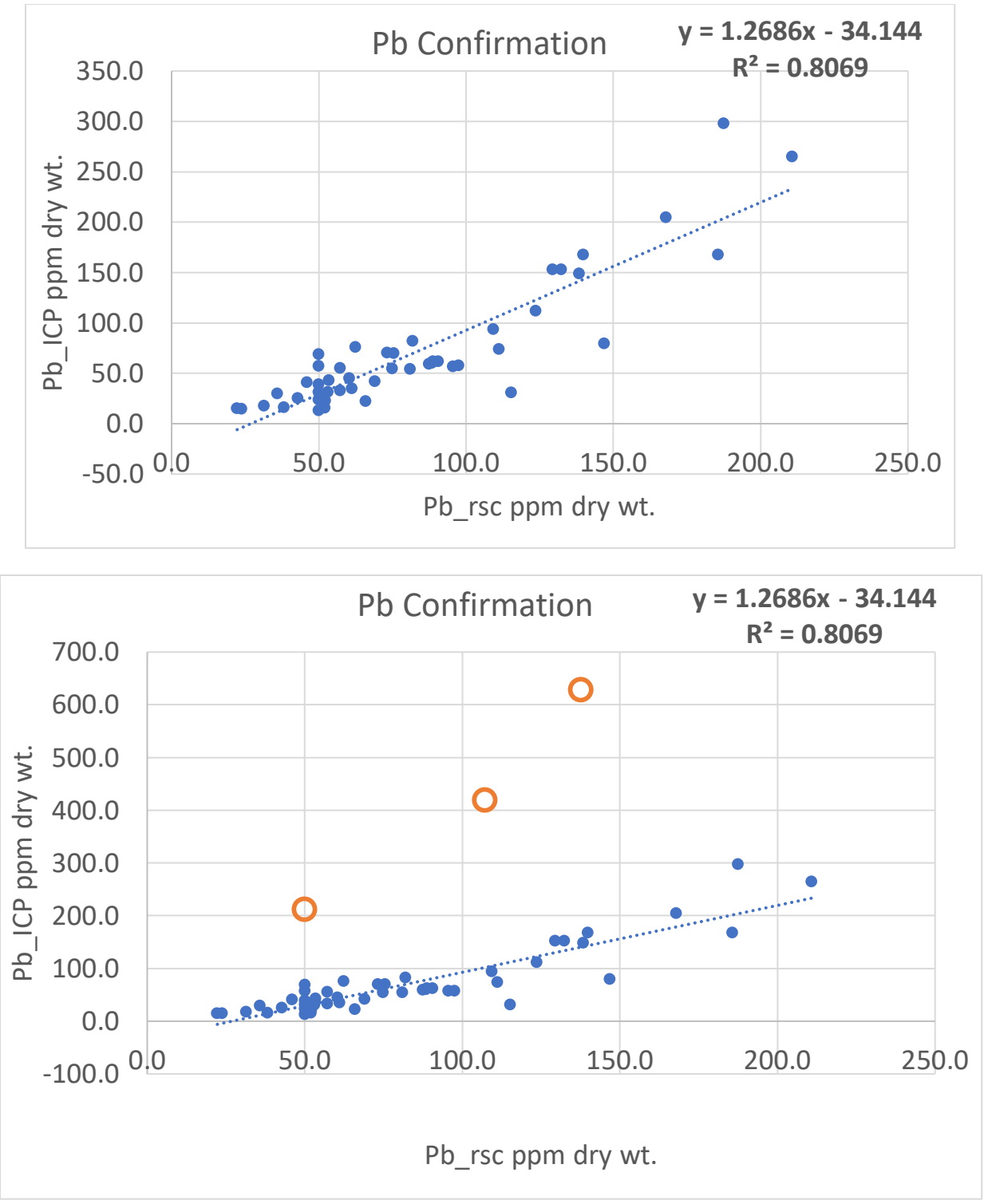


Figure Appendix D.1.3 Pb confirmation results from least squares regression between Pb analyzed by XRF (Pb_{RSC}) and ICP-MS (Pb_{ICP}) in ppm dry weight. Lower plot shows outliers not used in regression.

D.1.4 **Appendix D.1.4 Regression analysis for Zn**

Table D1.4 Raw data for Zn from RSC and ICP-OES analysis

	Zn_rsc				Zn_ICP		units	LabID
OUBM-G12	153.8		OUB12	ZINC	151.0		ug/g	3151-48
OUBM-G14	89.3	J	OUB14	ZINC	82.1		ug/g	3151-50
OUBM-G19	150.4		OUB19	ZINC	291.0		ug/g	3151-55
OUBM-G30	177.8		OUB30	ZINC	182.0		ug/g	3151-66
OUBM-G38	383.1		OUB38	ZINC	547.0		ug/g	3151-74
OUBM-G39	384.8		OUB39	ZINC	447.0		ug/g	3151-75
OUBM-G43	439.9		OUB43	ZINC	769.0		ug/g	3151-80
OUBM-G44	180.7		OUB44	ZINC	175.0		ug/g	3151-81
OUBM-G46	135.1		OUB46	ZINC	147.0		ug/g	3151-83
OUBM-G51	162.5		OUB51	ZINC	161.0		ug/g	3151-88
OUBM-G52	359.6		OUB52	ZINC	494.0		ug/g	3151-89
OUBM-G53	170.1		OUB53	ZINC	176.0		ug/g	3151-90
OUBM-G54	168.3		OUB54	ZINC	183.0		ug/g	3151-91
OUBM-G60	345.1		OUB60	ZINC	450.0		ug/g	
OUBM-G61	336.6		OUB61	ZINC	832.0		ug/g	3151-98
OUBM-G65	347.8		OUB65	ZINC	485.0		ug/g	3151-102
OUBM-G67	382.0		OUB67	ZINC	576.0		ug/g	3151-104
OUBM-G68avg	290.6		OUB68	ZINC	296.0		ug/g	3151-105
OUBM-G71	84.5	J	OUB71	ZINC	59.0		ug/g	3151-109
OOUB-G1	69.6	J	SIN01	ZINC	73.9		ug/g	3151-3
OOUB-G3	65.0	J	SIN03	ZINC	53.7		ug/g	3151-12
OOUB-G12avg	56.7	J	SIN12	ZINC	54.2		ug/g	3151-21
OOUB-G19	163.0		SIN19	ZINC	163.0		ug/g	3151-24
OOUB-G22	155.4		SIN22	ZINC	159.0		ug/g	3151-25
OOUB-G23avg	139.8		SIN23	ZINC	128.0		ug/g	3151-27
OOUB-G24	159.0		SIN24	ZINC	162.0		ug/g	3151-28
OOUB-G25	102.5		SIN25	ZINC	83.2		ug/g	3151-30
OOUB-G27	151.9		SIN27	ZINC	157.0		ug/g	3151-32
OOUB-G29	112.6		SIN29	ZINC	103.0		ug/g	3151-35
OOUB-G32	106.5		SIN32	ZINC	103.0		ug/g	3151-585
P7-T4-1	83.7		T4-1	ZINC	439.0		ug/g	
P7-T5-4	154.0		T5-4	ZINC	378.0		ug/g	3151-594
P7-T5-5	112.2		T5-5	ZINC	81.4		ug/g	3151-595
P7-T6-1	339.6		T6-1	ZINC	239.0		ug/g	3151-596
P7-T6-2	186.9		T6-2	ZINC	239.0		ug/g	3151-597
P7-T6-3	272.2		T6-3	ZINC	395.0		ug/g	3151-598
P7-T6-4	162.9		T6-4	ZINC	391.0		ug/g	3151-599 F
P7-T6-5	161.3		T6-5	ZINC	182.0		ug/g	3151-600
P7-T7-1	177.5		T7-1	ZINC	111.0		ug/g	3151-601
P7-T7-2	169.3		T7-2	ZINC	181.0		ug/g	3151-602
P7-T7-3	156.3		T7-3	ZINC	147.0		ug/g	3151-603
P7-T7-4	236.7		T7-4	ZINC	225.0		ug/g	3151-604
P7-T7-5	142.5		T7-5	ZINC	168.0		ug/g	3151-605
P7-T7-6	117.4		T7-6	ZINC	136.0		ug/g	3151-606
P7-T8-1	135.8		T8-1	ZINC	119.0		ug/g	3151-607
P7-T8-2	94.9		T8-2	ZINC	149.0		ug/g	3151-608
P7-T8-3	116.8		T8-3	ZINC	161.0		ug/g	3151-609
P7-T9-1	93.1		T9-1	ZINC	79.0		ug/g	3050-610
P7-T9-2	170.3		T9-2	ZINC	183.0		ug/g	3151-611
P7-T9-3	136.0		T9-3	ZINC	131.0		ug/g	3151-612
P7-T9-4	56.3	J	T9-4	ZINC	67.4		ug/g	3151-613
P7-T9-5	90.5		T9-5	ZINC	334.0		ug/g	
NO OUTLIERS								

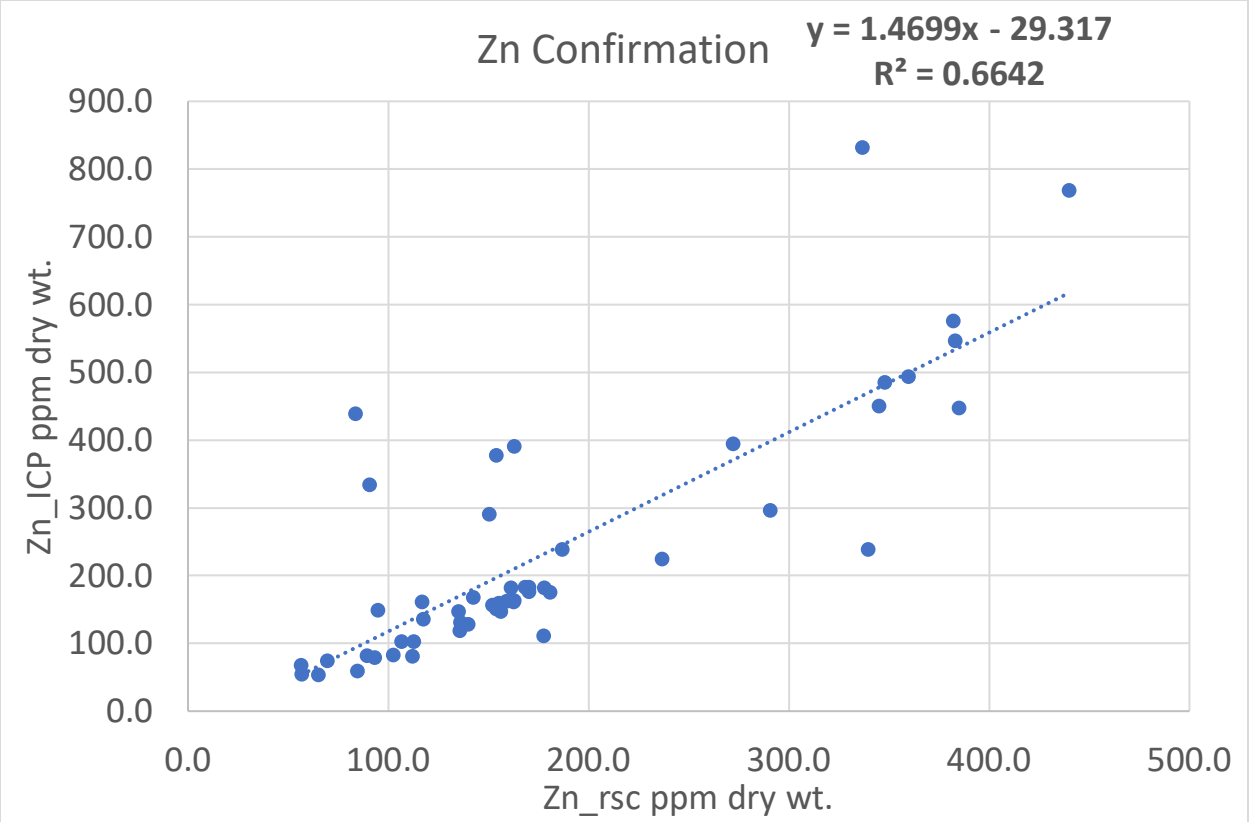


Figure Appendix D.1.4 Zn confirmation results from least squares regression between Zn analyzed by XRF ($Zn_{\_RSC}$) and ICP-OES ($Zn_{\_ICP}$) in ppm dry weight.

D.1.5 **Appendix D.1.5 Regression analysis for Total PAH**

Table D1.5 Raw data for Total PAH from RSC and GC/MS analysis.

					PAH-GC/M	PAHrsc	
D3	PSNS_SQV2011	OUBM2010-SIN23	SIN23	PAH_TOTAL	3551	1912	ng/g
D3	PSNS_SQV2011	OUBM2010-SIN25	SIN25	PAH_TOTAL	2084	2059	ng/g
D3	PSNS_SQV2011	OUBM2010-SIN26	SIN26	PAH_TOTAL	389	917	ng/g
D3	PSNS_SQV2011	OUBM2010-SIN32	SIN32	PAH_TOTAL	7817	2202	ng/g
D3	PSNS_SQV2011	OUBM2010-OUB01	OUB01	PAH_TOTAL	3823	3451	ng/g
D3	PSNS_SQV2011	OUBM2010-OUB16	OUB16	PAH_TOTAL	2998	2333	ng/g
D3	PSNS_SQV2011	OUBM2010-OUB18	OUB18	PAH_TOTAL	1916	1862	ng/g
D3	PSNS_SQV2011	OUBM2010-OUB19	OUB19	PAH_TOTAL	2082	2199	ng/g
D3	PSNS_SQV2011	OUBM2010-OUB26	OUB26	PAH_TOTAL	4772	2931	ng/g
D3	PSNS_SQV2011	OUBM2010-OUB39	OUB39	PAH_TOTAL	15072	9099	ng/g
D3	PSNS_SQV2011	OUBM2010-OUB40	OUB40	PAH_TOTAL	9688	5147	ng/g
D3	PSNS_SQV2011	OUBM2010-OUB42	OUB42	PAH_TOTAL	5509	5050	ng/g
D3	PSNS_SQV2011	OUBM2010-OUB43	OUB43	PAH_TOTAL	4270	4724	ng/g
D3	PSNS_SQV2011	OUBM2010-OUB45	OUB45	PAH_TOTAL	9185	4965	ng/g
D3	PSNS_SQV2011	OUBM2010-OUB48	OUB48	PAH_TOTAL	4357	2949	ng/g
D3	PSNS_SQV2011	OUBM2010-OUB49	OUB49	PAH_TOTAL	9060	2980	ng/g
D3	PSNS_SQV2011	OUBM2010-OUB55	OUB55	PAH_TOTAL	10493	5123	ng/g
D3	PSNS_SQV2011	OUBM2010-OUB56	OUB56	PAH_TOTAL	8369	4276	ng/g
D3	PSNS_SQV2011	OUBM2010-OUB57	OUB57	PAH_TOTAL	8394	5776	ng/g
D3	PSNS_SQV2011	OUBM2010-OUB59	OUB59	PAH_TOTAL	5868	4365	ng/g
D3	PSNS_SQV2011	OUBM2010-OUB60	OUB60	PAH_TOTAL	14664	8415	ng/g
D3	PSNS_SQV2011	OUBM2010-OUB61	OUB61	PAH_TOTAL	18404	11121	ng/g
D3	PSNS_SQV2011	OUBM2010-OUB63	OUB63	PAH_TOTAL	10557	6131	ng/g
D3	PSNS_SQV2011	OUBM2010-OUB67	OUB67	PAH_TOTAL	12159	9360	ng/g
D3	PSNS_SQV2011	OUBM2010-OUB69	OUB69	PAH_TOTAL	6629	4994	ng/g
D3	PSNS_SQV2011	OUBM2010-OUB71	OUB71	PAH_TOTAL	4769	2074	ng/g
D3	PSNS_SQV2011	PSNS015_Apr2011	PSNS015	PAH_TOTAL	6665	1113	ng/g
OUTLIERS							
D3	PSNS_SQV2011	PSNS096_Apr2011	PSNS096	PAH_TOTAL	1571	39306	ng/g
D3	PSNS_SQV2011	PSNS008_Apr2011	PSNS008	PAH_TOTAL	268923	4752	ng/g
					(samples probably switched)		

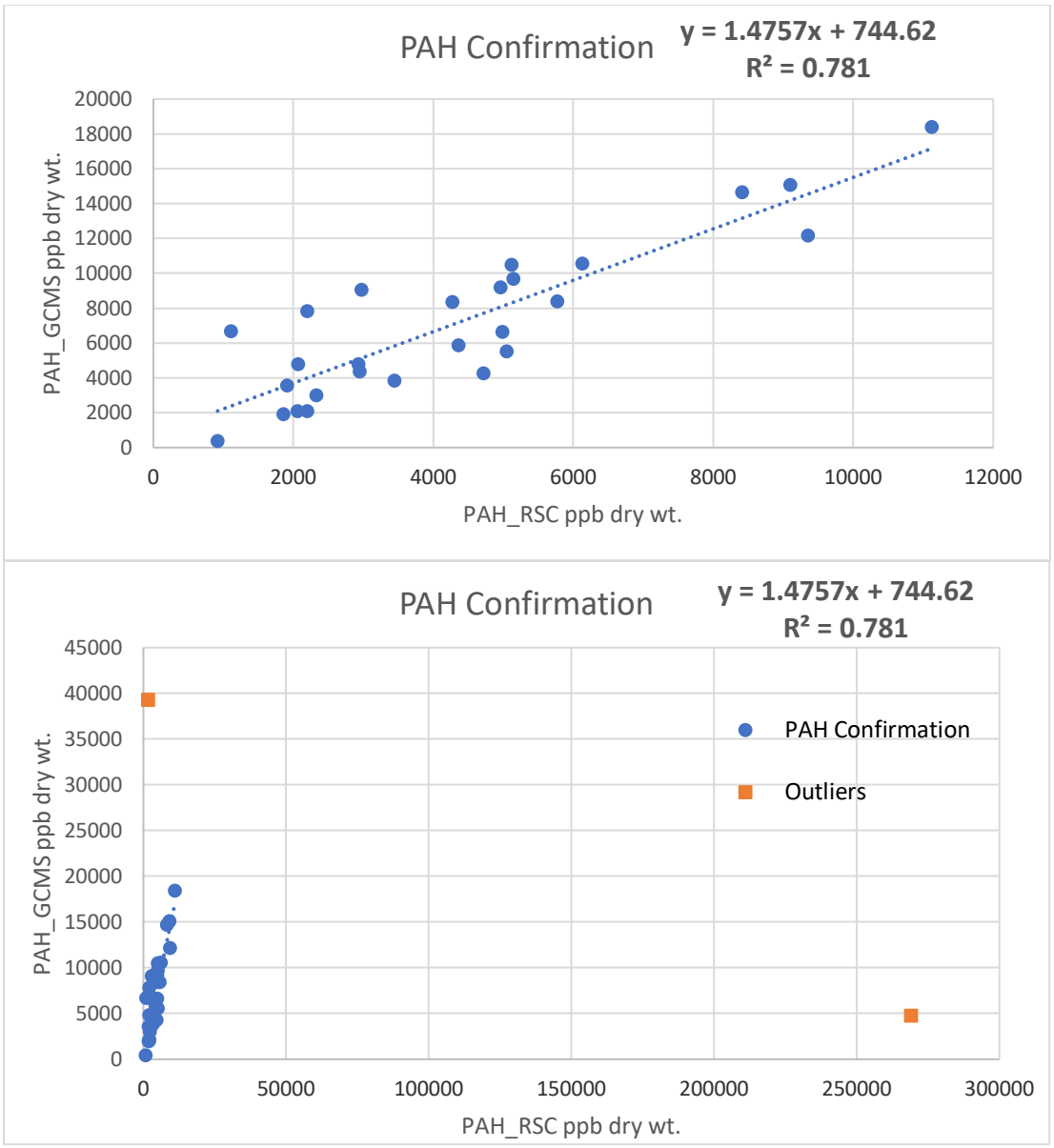


Figure Appendix D.1.5 Total PAH confirmation results from least squares regression between PAH analyzed by amino assay (PAH_{RSC}) and GC/MS (PAH_{ICP}) in ppb dry weight. Lower plot shows outliers not used in regression.

D.2 Appendix D.2 Focus Area Results

D.2.1 **Appendix D2.1 Sediment Concentrations and SQG Quotients**

Appendix D2. Focus Area Results		Ag	Al	As	Cd	Cr	Cu	Fe	Hg	Mn	Ni
		6.1		57	5.1	260	390		0.41		
Location_ID	Field_Collection_Comment	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g
PS03	core 00-03cm	1.490	58535	13.7	1.87	83.8	167.0	30073	1.780	391	41.1
	core 03-06cm	0.774	58129	11.2	1.62	81.2	144	28332	0.913	402	37.2
	core 06-09cm	1.360	58133	14.6	2.02	87.0	191	33254	1.490	409	41.9
	core 09-13cm	1.200	60260	14.6	2.01	107.0	184	36791	1.670	464	70.1
	core 13-19cm	1.480	65006	16.3	2.14	99.9	221	37544	1.710	476	52.2
	core 19-25cm	2.000	65847	19.3	2.36	110.0	287	38817	1.870	482	54.4
	Diver collected Grab	0.799	39445	11.6	1.71	65.9	324	32492	4.570	315	35.3
		1.040	56333	11.6	2.18	97.6	187	33271	5.360	404	41.4
		1.420	44786	10.4	1.77	107.0	291	26385	3.430	345	31.5
		1.310	39525	11.2	1.33	73.5	300	24158	4.720	357	29.4
		0.983	53821	13.8	1.77	82.6	349	32526	5.620	394	41.9
		0.030	775	2.1	0.49	23.1	56	4010	1.000	161	13.2
PS06	core 00-03cm	0.654	63030	18.2	1.15	92.9	193	35701	0.705	588	39.5
	core 03-06cm	0.701	63966	19.2	1.13	97.3	196	35294	0.651	502	40.5
	core 06-09cm	0.852	63583	17.6	1.12	112.0	182	35076	0.940	496	43.4
	core 09-13cm	0.936	66167	24.1	0.93	114.0	229	40324	0.739	574	46.3
	core 13-19cm	1.700	66359	45.5	1.13	101.0	261	40497	1.250	567	46.6
	core 19-25cm	1.450	62714	47.6	0.76	106.0	242	42281	1.240	968	39.7
	Diver collected Grab	0.762	63869	14.7	1.76	82.5	151	35645	0.728	486	41.9
		0.719	65460	15.6	1.68	85.3	155	35661	0.758	465	42.9
		0.740	62723	15.7	1.64	92.5	260	39572	0.746	484	46.7
		0.329	65484	10.1	0.61	86.3	67	29282	0.279	435	35.2
		0.682	55194	16.1	1.49	95.8	234	34149	0.675	450	39.4
		1.550	38593	58.8	0.99	143.0	234	27906	0.569	440	34.7
PS07	core 00-03cm	0.690	62893	14.9	2.03	76.8	138	34357	0.583	492	41.4
	core 03-06cm	0.697	62306	14.8	2.51	78.6	141	34728	0.584	452	42.1
	core 06-09cm	0.719	63335	14.7	2.21	80.5	143	35792	0.560	455	43.1
	core 09-13cm	0.737	64444	15.5	2.31	82.4	146	36183	0.730	461	43.1
	core 13-19cm	0.803	66358	13.9	2.03	86.8	157	36887	0.738	489	45.1
	core 19-25cm	0.802	65520	14.5	1.90	85.6	161	36949	0.787	488	45.2
	Diver collected Grab	0.360	52108	8.1	0.72	58.9	73	23789	0.443	409	30.0
		0.520	60192	11.5	1.16	75.1	102	29607	0.453	448	37.5
		0.749	60265	16.8	2.00	82.6	149	33758	0.656	483	41.6
		0.773	60403	14.2	1.94	80.9	146	33186	0.775	462	39.6
		0.653	57997	14.1	2.07	73.9	126	32343	0.593	412	39.1
		0.444	60580	11.3	1.28	69.7	86	27676	0.341	405	35.9
PS08	core 00-03cm	0.670	56932	16.2	1.56	94.3	206	35576	2.710	466	43.9
	core 03-06cm	0.520	49226	11.9	1.40	81.7	164	30655	0.995	379	39.4
	core 06-09cm	0.982	56675	14.0	1.47	94.1	184	33459	0.785	432	41.3
	core 09-13cm	0.592	55049	14.5	1.39	91.0	228	34455	0.909	403	41.3
	core 13-19cm	0.891	59692	16.9	1.52	103.0	702	39870	0.874	480	49.9
	core 19-25cm	0.966	58912	19.0	1.29	100.0	239	37106	1.020	456	49.6
	Diver collected Grab	0.787	59416	13.2	1.51	91.3	180	36506	4.600	451	67.1
		0.573	44956	20.8	1.68	92.6	531	29753	5.430	456	36.6
		0.718	63656	17.1	4.80	89.0	215	38233	5.310	510	52.1
		0.700	61467	15.9	1.73	90.2	175	36318	5.190	492	46.8
		0.712	61652	15.0	1.82	85.4	172	35814	6.480	475	42.4
		0.749	63059	15.5	1.63	88.6	169	36194	5.770	480	43.3

Appendix D2-1 Continued.

		Pb	TOC	Zn	PCB_T	PAH_Total	GS-Mean	GS-Fines	PCB/OC	PAH/OC
		450		410					12	1330
Location_ID	Field_Collection_Comment	ug/g	%	ug/g	ng/g	ng/g	Phi	%	mg/Kg OC	mg/Kg OC
PS03	core 00-03cm	82.0	3.27	235	564.9	30377	4.903	70.07	17.3	929.0
	core 03-06cm	69.6	7.12	194	616.6	49843	4.855	69.78	8.7	700.0
	core 06-09cm	89.0	3.43	241	439.7	27884	5.233	78.48	12.8	812.9
	core 09-13cm	110.0	2.54	324	359.6	22666	5.470	81.95	14.2	892.4
	core 13-19cm	123.0	3.57	280	552.4	19983	5.451	81.61	15.5	559.7
	core 19-25cm	154.0	3.43	323	584.9	39544	5.515	81.54	17.1	1152.9
	Diver collected Grab	71.0	7.18	238	211.1	43736	5.094	73.98	2.9	609.1
		92.8	4.94	311	283.7	48267	4.957	69.74	5.7	977.1
		181.0	4.68	483	294.5	36910	4.601	58.07	6.3	788.7
		119.0	7.18	280	284.5	29022	4.793	65.69	4.0	404.2
		78.2	4.15	247	257.0	24915	5.242	77.13	6.2	600.4
		5.6	9.23	143	124.1	2816	4.943	70.35	1.3	30.5
PS06	core 00-03cm	101.0	2.14	383	223.3	12208	4.822	65.73	10.4	570.5
	core 03-06cm	104.0	2.36	321	253.6	11272	4.694	62.50	10.7	477.6
	core 06-09cm	177.0	2.34	330	247.4	11945	5.402	85.31	10.6	510.5
	core 09-13cm	116.0	2.07	414	269.3	9007	5.332	83.06	13.0	435.1
	core 13-19cm	209.0	2.43	502	366.6	11728	5.282	81.44	15.1	482.6
	core 19-25cm	303.0	1.66	1031	553.2	13952	5.454	86.61	33.3	840.5
	Diver collected Grab	64.1	3.15	211	263.7	9699	4.148	50.82	8.4	307.9
		71.0	2.89	215	247.7	8862	4.820	65.59	8.6	306.6
		69.9	2.83	278	257.3	13475	5.464	84.15	9.1	476.1
		37.7	0.98	153	149.1	3733	5.310	81.52	15.2	381.7
		116.0	3.07	420	311.5	11712	5.376	83.35	10.1	381.5
		250.0	2.66	540	285.6	14135	4.791	66.12	10.7	531.4
PS07	core 00-03cm	64.9	3.36	189	257.3	10155	5.430	82.84	7.7	302.2
	core 03-06cm	68.1	3.35	206	255.0	8865	5.321	79.00	7.6	264.6
	core 06-09cm	70.4	3.36	211	232.1	8095	5.247	75.73	6.9	240.9
	core 09-13cm	72.5	3.24	210	216.2	9980	4.088	45.71	6.7	308.0
	core 13-19cm	83.5	3.12	222	408.9	9681	4.973	70.46	13.1	310.3
	core 19-25cm	80.8	3.03	217	245.5	10384	4.446	57.71	8.1	342.7
	Diver collected Grab	52.8	1.05	139	223.4	31044	5.216	78.04	21.3	2956.6
		67.6	2.09	179	310.6	13198	4.830	68.33	14.9	631.5
		88.8	3.04	229	256.2	11150	4.929	69.79	8.4	366.8
		81.5	3.11	220	224.0	8353	5.166	75.49	7.2	268.6
		65.0	3.01	189	263.0	2169	5.173	74.75	8.7	72.1
		50.8	1.92	148	234.3	8191	5.056	72.89	12.2	426.6
PS08	core 00-03cm	93.2	3.00	338	300.2	19542	5.159	80.13	10.0	651.4
	core 03-06cm	84.5	2.45	375	286.2	17252	5.097	74.07	11.7	704.2
	core 06-09cm	85.6	2.77	329	298.6	19713	5.205	77.49	10.8	711.7
	core 09-13cm	82.0	2.64	353	462.8	18549	5.104	74.81	17.5	702.6
	core 13-19cm	110.0	2.72	495	478.3	13660	5.230	77.71	17.6	502.2
	core 19-25cm	121.0	2.44	351	455.6	12816	5.114	74.01	18.7	525.2
	Diver collected Grab	83.3	2.81	266	236.1	11592	5.315	80.97	8.4	412.5
		87.6	8.79	606	271.9	39551	5.064	72.49	3.1	450.0
		84.3	2.76	418	242.3	16018	5.108	73.73	8.8	580.4
		77.5	2.34	318	268.9	17966	5.156	76.57	11.5	767.8
		79.5	2.90	295	246.8	11739	5.433	84.28	8.5	404.8
		80.8	2.85	257	175.4	9190	5.430	83.58	6.2	322.5

Appendix D2-1 Continued. Shaded cells indicate SQGq or mSQGq > 2.0

		Sediment Quality Guideline Quotients													
		SQGq	SQGq	SQGq	SQGq	SQGq	SQGq	SQGq	SQGq	SQGq	SQGq		CV	CV	CV
Location_ID	Field_Collection	Ag	As	Cd	Cr	Cu	Hg	Pb	Zn	PCB/OC	PAH/OC	mSQGq	Profile	Grabs	All
PS03	core 00-03cm	0.24	0.24	0.37	0.32	0.43	4.34	0.18	0.57	1.44	0.70	0.88	19%	39%	42%
	core 03-06cm	0.13	0.20	0.32	0.31	0.37	2.23	0.15	0.47	0.72	0.53	0.54			
	core 06-09cm	0.22	0.26	0.40	0.33	0.49	3.63	0.20	0.59	1.07	0.61	0.78			
	core 09-13cm	0.20	0.26	0.39	0.41	0.47	4.07	0.24	0.79	1.18	0.67	0.87			
	core 13-19cm	0.24	0.29	0.42	0.38	0.57	4.17	0.27	0.68	1.29	0.42	0.87			
	core 19-25cm	0.33	0.34	0.46	0.42	0.74	4.56	0.34	0.79	1.42	0.87	1.03			
	Diver collected Grab	0.13	0.20	0.34	0.25	0.83	11.15	0.16	0.58	0.25	0.46	1.43			
		0.17	0.20	0.43	0.38	0.48	13.07	0.21	0.76	0.48	0.73	1.69			
		0.23	0.18	0.35	0.41	0.75	8.37	0.40	1.18	0.52	0.59	1.30			
		0.21	0.20	0.26	0.28	0.77	11.51	0.26	0.68	0.33	0.30	1.48			
		0.16	0.24	0.35	0.32	0.89	13.71	0.17	0.60	0.52	0.45	1.74			
		0.00	0.04	0.10	0.09	0.14	2.44	0.01	0.35	0.11	0.02	0.33			
PS06	core 00-03cm	0.11	0.32	0.23	0.36	0.49	1.72	0.22	0.93	0.87	0.43	0.57	34%	23%	34%
	core 03-06cm	0.11	0.34	0.22	0.37	0.50	1.59	0.23	0.78	0.90	0.36	0.54			
	core 06-09cm	0.14	0.31	0.22	0.43	0.47	2.29	0.39	0.80	0.88	0.38	0.63			
	core 09-13cm	0.15	0.42	0.18	0.44	0.59	1.80	0.26	1.01	1.08	0.33	0.63			
	core 13-19cm	0.28	0.80	0.22	0.39	0.67	3.05	0.46	1.22	1.26	0.36	0.87			
	core 19-25cm	0.24	0.84	0.15	0.41	0.62	3.02	0.67	2.51	2.78	0.63	1.19			
	Diver collected Grab	0.12	0.26	0.35	0.32	0.39	1.78	0.14	0.51	0.70	0.23	0.48			
		0.12	0.27	0.33	0.33	0.40	1.85	0.16	0.52	0.71	0.23	0.49			
		0.12	0.28	0.32	0.36	0.67	1.82	0.16	0.68	0.76	0.36	0.55			
		0.05	0.18	0.12	0.33	0.17	0.68	0.08	0.37	1.27	0.29	0.35			
		0.11	0.28	0.29	0.37	0.60	1.65	0.26	1.02	0.85	0.29	0.57			
		0.25	1.03	0.19	0.55	0.60	1.39	0.56	1.32	0.89	0.40	0.72			
PS07	core 00-03cm	0.11	0.26	0.40	0.30	0.35	1.42	0.14	0.46	0.64	0.23	0.43	9%	19%	14%
	core 03-06cm	0.11	0.26	0.49	0.30	0.36	1.42	0.15	0.50	0.63	0.20	0.44			
	core 06-09cm	0.12	0.26	0.43	0.31	0.37	1.37	0.16	0.51	0.58	0.18	0.43			
	core 09-13cm	0.12	0.27	0.45	0.32	0.37	1.78	0.16	0.51	0.56	0.23	0.48			
	core 13-19cm	0.13	0.24	0.40	0.33	0.40	1.80	0.19	0.54	1.09	0.23	0.54			
	core 19-25cm	0.13	0.25	0.37	0.33	0.41	1.92	0.18	0.53	0.68	0.26	0.51			
	Diver collected Grab	0.06	0.14	0.14	0.23	0.19	1.08	0.12	0.34	1.77	2.22	0.63			
		0.09	0.20	0.23	0.29	0.26	1.10	0.15	0.44	1.24	0.47	0.45			
		0.12	0.29	0.39	0.32	0.38	1.60	0.20	0.56	0.70	0.28	0.48			
		0.13	0.25	0.38	0.31	0.37	1.89	0.18	0.54	0.60	0.20	0.49			
		0.11	0.25	0.41	0.28	0.32	1.45	0.14	0.46	0.73	0.05	0.42			
		0.07	0.20	0.25	0.27	0.22	0.83	0.11	0.36	1.02	0.32	0.37			
PS08	core 00-03cm	0.11	0.28	0.31	0.36	0.53	6.61	0.21	0.82	0.83	0.49	1.06	23%	9%	43%
	core 03-06cm	0.09	0.21	0.27	0.31	0.42	2.43	0.19	0.91	0.97	0.53	0.63			
	core 06-09cm	0.16	0.25	0.29	0.36	0.47	1.91	0.19	0.80	0.90	0.54	0.59			
	core 09-13cm	0.10	0.25	0.27	0.35	0.58	2.22	0.18	0.86	1.46	0.53	0.68			
	core 13-19cm	0.15	0.30	0.30	0.40	1.80	2.13	0.24	1.21	1.47	0.38	0.84			
	core 19-25cm	0.16	0.33	0.25	0.38	0.61	2.49	0.27	0.86	1.56	0.39	0.73			
	Diver collected Grab	0.13	0.23	0.30	0.35	0.46	11.22	0.19	0.65	0.70	0.31	1.45			
		0.09	0.36	0.33	0.36	1.36	13.24	0.19	1.48	0.26	0.34	1.80			
		0.12	0.30	0.94	0.34	0.55	12.95	0.19	1.02	0.73	0.44	1.76			
		0.11	0.28	0.34	0.35	0.45	12.66	0.17	0.78	0.96	0.58	1.67			
		0.12	0.26	0.36	0.33	0.44	15.80	0.18	0.72	0.71	0.30	1.92			
		0.12	0.27	0.32	0.34	0.43	14.07	0.18	0.63	0.51	0.24	1.71			

Appendix D2-1 Continued.

		Ag	Al	As	Cd	Cr	Cu	Fe	Hg	Mn	Ni
		6.1		57	5.1	260	390		0.41		
Location_ID	Field_Collection	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g
PS09	core 00-03cm	0.667	62505	16.2	2.16	87.0	230	35572	0.907	614	48.0
	core 03-06cm	0.775	63068	23.6	4.09	116.0	351	36175	1.790	462	55.3
	core 06-09cm	0.743	61433	17.2	2.67	98.4	275	36278	1.220	458	56.0
	core 09-13cm	0.875	65490	19.3	2.18	116.0	310	38233	1.980	516	62.9
	core 13-19cm	0.926	66081	23.2	1.69	109.0	337	40073	1.880	577	59.9
	core 19-23cm	0.833	66883	32.5	1.51	115.0	451	36644	2.060	560	56.0
	Diver collected Grab	0.742	23149	39.2	1.59	129.0	584	33427	3.410	456	107.0
		1.260	46941	223.0	2.63	193.0	874	63645	5.130	1015	154.0
		1.150	53477	28.3	8.98	139.0	748	54582	7.790	561	133.0
		0.476	21931	32.1	1.29	64.4	341	19699	3.520	352	31.5
		0.693	58914	15.7	1.78	99.5	263	35245	5.410	462	57.1
		0.603	57006	15.2	2.04	84.5	269	34246	5.630	630	44.9
PS10	core 00-03cm	0.679	60135	17.6	1.73	79.9	156	33353	0.787	420	41.5
	core 03-06cm	0.718	60352	13.3	1.61	78.0	144	32818	0.810	425	39.1
	core 06-09cm	0.749	63522	15.7	1.80	82.4	170	35552	0.890	474	44.0
	core 09-13cm	0.933	63900	18.2	1.88	88.2	189	37488	1.190	487	46.3
	core 13-19cm	0.998	64766	18.6	1.83	99.7	229	36490	4.700	510	48.9
	core 19-25cm	1.250	64175	31.7	2.53	117.0	424	39797	10.600	602	61.3
	Diver collected Grab	1.030	50666	18.2	2.00	103.0	308	32572	6.730	454	58.6
		0.691	54995	14.4	2.55	77.5	173	32867	6.970	430	41.1
		1.010	58294	23.3	2.16	101.0	398	38025	7.630	534	58.0
		1.220	55639	15.8	2.74	93.6	285	33866	10.600	414	44.6
		0.830	49598	12.3	1.83	66.8	130	29835	5.980	419	35.3
		0.622	53852	13.0	1.96	72.0	139	32299	7.260	407	37.9
PS10.1	core 00-03cm	0.863	60154	17.6	1.63	93.1	181	34074	1.240	471	45.2
	core 03-06cm	0.802	59579	16.3	1.80	93.6	204	36953	1.080	410	44.9
	core 06-09cm	0.892	62834	18.6	1.49	99.7	220	37294	1.620	433	49.5
	core 09-13cm	1.050	63159	19.8	1.70	104.0	254	38605	3.900	455	52.9
	core 13-19cm	1.320	62226	25.5	1.72	156.0	326	38847	3.200	498	84.2
	core 19-24cm	1.410	62730	26.2	1.51	110.0	299	39243	2.280	492	57.5
	Diver collected Grab	0.836	55639	16.8	2.12	101.0	433	33938	6.500	425	47.9
		1.240	54952	21.0	2.62	124.0	357	34614	10.300	488	53.0
		0.717	52824	16.3	1.89	83.5	248	32251	5.880	442	42.0
		0.664	53604	16.6	1.56	98.7	182	31852	4.450	451	47.5
		1.020	57018	14.6	2.23	96.8	204	34237	6.810	484	43.9
		0.317	22364	4.2	0.78	48.8	101	14376	1.910	350	20.4
PS11	core 00-03cm	0.635	59670	12.9	1.87	81.1	136	34782	0.819	436	41.2
	core 03-06cm	0.553	58434	14.2	1.61	81.3	136	34453	0.852	420	40.7
	core 06-09cm	0.606	60147	16.2	1.62	86.8	148	36298	0.702	530	45.6
	core 09-13cm	0.614	60723	13.9	1.85	80.4	141	35867	0.741	410	41.3
	core 13-19cm	0.669	59929	12.4	1.65	82.6	136	34881	0.710	396	42.5
	core 19-25cm	0.730	62715	13.6	1.98	85.8	166	37154	1.050	424	44.8
	Diver collected Grab	0.772	55478	24.9	2.36	88.2	270	34662	7.250	420	47.7
		0.879	55974	36.6	1.42	110.0	366	34357	3.550	703	45.2
		0.845	57891	23.5	1.71	118.0	336	32899	3.650	532	51.2
		0.694	56651	15.4	2.25	84.5	222	33903	8.090	405	43.9
		0.758	58036	13.2	1.65	80.5	156	33947	6.210	457	41.1
		0.656	58606	10.8	1.65	81.4	139	33909	5.670	434	40.2

Appendix D2-1 Continued

		Pb	TOC	Zn	PCB_T	PAH_Total	GS-Mean	GS-Fines	PCB/OC	PAH/OC
	SQS	450		410					12	1330
Location_ID	Field_Collection	ug/g	%	ug/g	ng/g	ng/g	Phi	%	mg/Kg OC	mg/Kg OC
PS09	core 00-03cm	74.0	3.34	279	284.5	17591	4.942	72.51	8.5	526.7
	core 03-06cm	101.0	3.60	461	265.3	15935	4.824	67.69	7.4	442.6
	core 06-09cm	82.7	3.25	344	341.3	19399	5.047	73.29	10.5	596.9
	core 09-13cm	111.0	2.97	348	396.3	17824	5.122	75.78	13.3	600.1
	core 13-19cm	119.0	2.25	342	362.1	14106	5.370	80.16	16.1	626.9
	core 19-23cm	143.0	2.03	417	465.6	19009	4.795	65.03	22.9	936.4
	Diver collected Grab	190.0	6.73	719	434.7	45758	4.165	50.77	6.5	679.9
		390.0	1.91	2172	231.1	30234	-0.005	10.41	12.1	1582.9
		140.0	2.04	1363	333.8	46465	5.093	74.15	16.4	2277.7
		124.0	8.31	489	404.7	28058	4.719	65.17	4.9	337.6
		89.3	2.85	328	272.0	16557	5.028	72.39	9.5	580.9
		72.0	3.35	320	206.1	16380	5.529	84.17	6.2	489.0
PS10	core 00-03cm	72.7	3.59	225	379.7	15933	5.306	83.72	10.6	443.8
	core 03-06cm	74.9	3.38	210	244.5	10061	5.286	81.46	7.2	297.7
	core 06-09cm	82.5	3.48	243	260.3	3172	5.325	80.06	7.5	91.1
	core 09-13cm	107.0	3.36	273	319.6	17559	5.569	85.51	9.5	522.6
	core 13-19cm	148.0	0.32	324	346.3	13812	5.349	81.64	107.9	4302.8
	core 19-25cm	475.0	1.80	757	375.5	17393	4.756	63.98	20.9	966.3
	Diver collected Grab	150.0	3.79	446	534.9	40451	4.493	59.98	14.1	1067.3
		76.7	3.47	266	193.6	12829	5.431	84.91	5.6	369.7
		192.0	3.25	485	362.1	23585	5.163	76.18	11.1	725.7
		129.0	3.74	411	383.8	25867	5.095	74.16	10.3	691.6
		58.2	3.00	192	196.1	16324	5.418	85.14	6.5	544.1
		64.3	3.28	216	174.4	17008	5.417	84.62	5.3	518.5
PS10.1	core 00-03cm	112.0	3.48	270	252.0	12969	5.153	77.61	7.2	372.7
	core 03-06cm	126.0	3.74	301	279.5	14628	5.335	79.75	7.5	391.1
	core 06-09cm	116.0	2.65	312	292.9	15987	5.319	78.84	11.1	603.3
	core 09-13cm	258.0	5.10	374	302.9	18556	5.208	76.48	5.9	363.8
	core 13-19cm	189.0	3.10	416	344.6	13211	5.339	81.10	11.1	426.2
	core 19-24cm	165.0	4.84	383	514.8	18583	5.363	80.14	10.6	383.9
	Diver collected Grab	171.0	3.12	673	288.7	37492	5.004	71.37	9.3	1201.7
		352.0	3.68	718	404.7	25706	4.903	71.27	11.0	698.5
		93.9	2.02	374	222.8	17150	4.937	69.47	11.0	849.0
		91.5	2.78	280	258.7	16321	5.142	74.32	9.3	587.1
		116.0	3.36	336	234.5	17550	5.291	79.85	7.0	522.3
		60.3	8.70	166	116.6	9544	4.131	55.85	1.3	109.7
PS11	core 00-03cm	69.4	3.48	230	199.4	10843	5.199	79.41	5.7	311.6
	core 03-06cm	71.7	3.41	259	296.3	15785	5.362	81.93	8.7	462.9
	core 06-09cm	68.0	3.60	235	183.8	12924	5.379	81.91	5.1	359.0
	core 09-13cm	72.7	3.45	236	278.9	10822	5.276	78.34	8.1	313.7
	core 13-19cm	70.4	3.50	223	247.1	12671	5.354	82.53	7.1	362.0
	core 19-25cm	84.9	3.23	254	249.7	12051	5.209	77.55	7.7	373.1
	Diver collected Grab	113.0	3.79	428	259.1	26348	4.783	66.46	6.8	695.2
		1180.0	1.41	795	258.0	15456	0.692	10.22	18.3	1096.2
		184.0	3.52	503	238.9	16480	4.267	51.38	6.8	468.2
		99.7	3.70	373	289.2	30827	4.803	66.89	7.8	833.2
		78.3	2.88	243	198.1	13487	5.237	76.38	6.9	468.3
		76.7	2.93	228	198.2	13111	5.223	77.42	6.8	447.5

Appendix D2-1 Continued. Shaded cells indicate SQGq or mSQGq > 2.0

		Sediment Quality Guideline Quotients													
	SQS	SQGq	SQGq	SQGq	SQGq	SQGq	SQGq	SQGq	SQGq	SQGq	SQGq		CV	CV	CV
Location_ID	Field_Collection	Ag	As	Cd	Cr	Cu	Hg	Pb	Zn	PCB/OC	PAH/OC	mSQGq	Profile	Grabs	All
PS09	core 00-03cm	0.11	0.28	0.42	0.33	0.59	2.21	0.16	0.68	0.71	0.40	0.59	22%	37%	54%
	core 03-06cm	0.13	0.41	0.80	0.45	0.90	4.37	0.22	1.12	0.61	0.33	0.94			
	core 06-09cm	0.12	0.30	0.52	0.38	0.71	2.98	0.18	0.84	0.88	0.45	0.74			
	core 09-13cm	0.14	0.34	0.43	0.45	0.79	4.83	0.25	0.85	1.11	0.45	0.96			
	core 13-19cm	0.15	0.41	0.33	0.42	0.86	4.59	0.26	0.83	1.34	0.47	0.97			
	core 19-23cm	0.14	0.57	0.30	0.44	1.16	5.02	0.32	1.02	1.91	0.70	1.16			
	Diver collected Grab	0.12	0.69	0.31	0.50	1.50	8.32	0.42	1.75	0.54	0.51	1.47			
		0.21	3.91	0.52	0.74	2.24	12.51	0.87	5.30	1.01	1.19	2.85			
		0.19	0.50	1.76	0.53	1.92	19.00	0.31	3.32	1.36	1.71	3.06			
		0.08	0.56	0.25	0.25	0.87	8.59	0.28	1.19	0.41	0.25	1.27			
		0.11	0.28	0.35	0.38	0.67	13.20	0.20	0.80	0.80	0.44	1.72			
		0.10	0.27	0.40	0.33	0.69	13.73	0.16	0.78	0.51	0.37	1.73			
PS10	core 00-03cm	0.11	0.31	0.34	0.31	0.40	1.92	0.16	0.55	0.88	0.33	0.53	95%	20%	57%
	core 03-06cm	0.12	0.23	0.32	0.30	0.37	1.98	0.17	0.51	0.60	0.22	0.48			
	core 06-09cm	0.12	0.28	0.35	0.32	0.44	2.17	0.18	0.59	0.62	0.07	0.51			
	core 09-13cm	0.15	0.32	0.37	0.34	0.48	2.90	0.24	0.67	0.79	0.39	0.67			
	core 13-19cm	0.16	0.33	0.36	0.38	0.59	11.46	0.33	0.79	8.99	3.24	2.66			
	core 19-25cm	0.20	0.56	0.50	0.45	1.09	25.85	1.06	1.85	1.74	0.73	3.40			
	Diver collected Grab	0.17	0.32	0.39	0.40	0.79	16.41	0.33	1.09	1.18	0.80	2.19			
		0.11	0.25	0.50	0.30	0.44	17.00	0.17	0.65	0.46	0.28	2.02			
		0.17	0.41	0.42	0.39	1.02	18.61	0.43	1.18	0.93	0.55	2.41			
		0.20	0.28	0.54	0.36	0.73	25.85	0.29	1.00	0.86	0.52	3.06			
		0.14	0.22	0.36	0.26	0.33	14.59	0.13	0.47	0.54	0.41	1.74			
		0.10	0.23	0.38	0.28	0.36	17.71	0.14	0.53	0.44	0.39	2.06			
PS10.1	core 00-03cm	0.14	0.31	0.32	0.36	0.46	3.02	0.25	0.66	0.60	0.28	0.64	34%	45%	55%
	core 03-06cm	0.13	0.29	0.35	0.36	0.52	2.63	0.28	0.73	0.62	0.29	0.62			
	core 06-09cm	0.15	0.33	0.29	0.38	0.56	3.95	0.26	0.76	0.92	0.45	0.81			
	core 09-13cm	0.17	0.35	0.33	0.40	0.65	9.51	0.57	0.91	0.49	0.27	1.37			
	core 13-19cm	0.22	0.45	0.34	0.60	0.84	7.80	0.42	1.01	0.93	0.32	1.29			
	core 19-24cm	0.23	0.46	0.30	0.42	0.77	5.56	0.37	0.93	0.89	0.29	1.02			
	Diver collected Grab	0.14	0.29	0.42	0.39	1.11	15.85	0.38	1.64	0.77	0.90	2.19			
		0.20	0.37	0.51	0.48	0.92	25.12	0.78	1.75	0.92	0.53	3.16			
		0.12	0.29	0.37	0.32	0.64	14.34	0.21	0.91	0.92	0.64	1.88			
		0.11	0.29	0.31	0.38	0.47	10.85	0.20	0.68	0.78	0.44	1.45			
		0.17	0.26	0.44	0.37	0.52	16.61	0.26	0.82	0.58	0.39	2.04			
		0.05	0.07	0.15	0.19	0.26	4.66	0.13	0.40	0.11	0.08	0.61			
PS11	core 00-03cm	0.10	0.23	0.37	0.31	0.35	2.00	0.15	0.56	0.48	0.23	0.48	10%	20%	64%
	core 03-06cm	0.09	0.25	0.32	0.31	0.35	2.08	0.16	0.63	0.72	0.35	0.53			
	core 06-09cm	0.10	0.28	0.32	0.33	0.38	1.71	0.15	0.57	0.43	0.27	0.45			
	core 09-13cm	0.10	0.24	0.36	0.31	0.36	1.81	0.16	0.58	0.67	0.24	0.48			
	core 13-19cm	0.11	0.22	0.32	0.32	0.35	1.73	0.16	0.54	0.59	0.27	0.46			
	core 19-25cm	0.12	0.24	0.39	0.33	0.43	2.56	0.19	0.62	0.64	0.28	0.58			
	Diver collected Grab	0.13	0.44	0.46	0.34	0.69	17.68	0.25	1.04	0.57	0.52	2.21			
		0.14	0.64	0.28	0.42	0.94	8.66	2.62	1.94	1.52	0.82	1.80			
		0.14	0.41	0.34	0.45	0.86	8.90	0.41	1.23	0.57	0.35	1.37			
		0.11	0.27	0.44	0.33	0.57	19.73	0.22	0.91	0.65	0.63	2.39			
		0.12	0.23	0.32	0.31	0.40	15.15	0.17	0.59	0.57	0.35	1.82			
		0.11	0.19	0.32	0.31	0.36	13.83	0.17	0.56	0.56	0.34	1.67			

Appendix D2-1 Continued

PIER 7 Transects	Fe	PCB_T	PAH_Total	PCB_T	PAH_Total	Hg	Cu	Pb	Zn
SQS->				12	1330	0.41	390	450	410
Location_ID	ug/g	ng/g	ng/g	ug/g OC	ug/g OC	ug/g	ug/g	ug/g	ug/g
T1-1	22470	195.5	38124	7.5	1466.3		94	75.1	305.6
T1-2	28909	160.1	18631	6.2	716.6	0.64	154.8	119.4	520.5
T1-3	26019	75.8	13730	2.9	528.1	0.402	99.7	29.3	199.8
T1-4	32827	38.1	3430	1.5	131.9	0.24	284.2	250.3	700.1
T1-5	28610	126.7	7913	4.9	304.3	0.621	127.5	71	234.3
T2-1	26072	147	21255	5.7	817.5	0.525	127.9	64.2	280.9
T2-2	24454	125.8	13037	4.8	501.4	0.2	99.7	29.3	255.1
T2-3	21230	23.1	2173	0.9	83.6		56.6	29.3	34.4
T2-4	27689	217.7	12668	8.4	487.2	0.703	185.2	140.3	557.2
T2-5	19780	48.4	4826	1.9	185.6	0.167	56.6	29.3	80.2
T3-1	28579	141.7	19230	5.5	739.6	0.428	63.8	80.8	250.5
T3-2	27370	80.3	13940	3.1	536.2	0.109	65.8	38.8	505.4
T3-3	29464	237.6	12035	9.1	462.9	0.734	140.8	98	302.7
T3-4	21737	61.9	5563	2.4	214	0.192	56.6	44.1	151.3
T3-5	24971	40.4	4672	1.6	179.7		56.6	29.3	149.6
T4-1	29528	284.3	16491	10.9	634.3	1.19	183	212	439
T4-2	20248	117.2	15122	4.5	581.6	0.289	65.7	65	203.9
T4-3	26082	94.4	10565	3.6	406.3	0.449	60.7	99.7	360.3
T4-4	28624	111.1	13004	4.3	500.2	0.574	102.4	77.1	227.1
T4-5	24246	9.2	5837	0.4	224.5	0.207	56.6	40.3	241.7
T5-1	26061	92.7	10798	3.6	415.3	0.206	84.2	41.6	380.3
T5-2	40135	495.6	16541	19.1	636.2	0.826	485.9	492.3	1212.4
T5-3	26214	132.9	14292	5.1	549.7	0.687	3753.8	73.2	578.1
T5-4	26756	125.2	15231	4.8	585.8	0.437	979	45.1	378
T5-5	24023	61.5	4560	2.4	175.4	0.494	24.2	16.3	81.4
T6-1	17364	203	12511	7.8	481.2	0.557	92.6	79.7	239
T6-2	18035	218.3	17699	8.4	680.7	0.495	91	54.7	239
T6-3post	25875	17064.48	23125	656.3	889.4	0.79	113	90	278
T6-4	28129	254.8	7765	9.8	298.7	0.358	97.9	628	391
T6-5	29144	366	13225	14.1	508.7	0.6	82	55.4	182
T7-1	13454	187.1	14711	7.2	565.8	0.325	52.4	31.3	111
T7-2	19559	218.1	17685	8.4	680.2	0.845	89.1	70.4	181
T7-3	17325	107.6	12011	4.1	462	0.142	29.6	23.1	147
T7-4	28213	546.2	14088	21	541.8	0.688	130	94.1	225
T7-5	26269	160.9	6537	6.2	251.4	0.344	123	39.3	168
T7-6	26523	87.6	4984	3.4	191.7	0.256	34.8	25.7	136
T8-1	35699	189.2	16145	7.3	621	0.121	40.5	22.5	119
T8-2	20118	107.8	5931	4.1	228.1	0.166	29.8	24	149
T8-3	22887	135.7	6887	5.2	264.9	0.278	45.5	43.2	161
T9-1	24864	76.3	9400	2.9	361.5	0.316	29.8	16.1	79
T9-2	22771	61.7	13194	2.4	507.5	0.35	70.5	69.1	183
T9-3	21827	62	10857	2.4	417.6	0.168	32.8	31.7	131
T9-4	19567	61.2	4645	2.4	178.7	0.0768	15	13.5	67.4
T9-5	19996	70.4	9656	2.7	371.4	0.184	34.4	57.5	334
T9-6	18678	66.9	8646	2.6	332.5	0.202	56.6	29.3	85.1
T10-1	24772	134.2	13256	5.2	509.8	0.67	56.6	47.1	238.8
T10-2	25148	19.7	3532	0.8	135.8	0.0579	56.6	29.3	90.1
T10-3	24647	105.5	9404	4.1	361.7	0.44	62.3	31.3	174.4
T10-4	22809	76.4	5689	2.9	218.8	0.812	56.6	29.3	126.3
T10-5	24146	112.1		4.3		0.924	56.6	29.3	298.8
T10-6	25762	96.3		3.7		0.998	56.6	29.3	86.3

Appendix D2-1 Continued. Shaded cells indicate SQGq or mSQGq > 2.0

	Sediment Quality Guideline Quotient							
PIER 7 Transects	PCB_T	PAH_Total	Hg	Cu	Pb	Zn		CV
Location_ID	SQGq	SQGq	SQGq	SQGq	SQGq	SQGq	mSQGq6	All
T1-1	0.6250	1.1025		0.2410	0.1669	0.7454	0.5762	193%
T1-2	0.5167	0.5388	1.5610	0.3969	0.2653	1.2695	0.7580	
T1-3	0.2417	0.3971	0.9805	0.2556	0.0651	0.4873	0.4045	
T1-4	0.1250	0.0992	0.5854	0.7287	0.5562	1.7076	0.6337	
T1-5	0.4083	0.2288	1.5146	0.3269	0.1578	0.5715	0.5347	
T2-1	0.4750	0.6147	1.2805	0.3279	0.1427	0.6851	0.5876	
T2-2	0.4000	0.3770	0.4878	0.2556	0.0651	0.6222	0.3680	
T2-3	0.0750	0.0629		0.1451	0.0651	0.0839	0.0864	
T2-4	0.7000	0.3663	1.7146	0.4749	0.3118	1.3590	0.8211	
T2-5	0.1583	0.1395	0.4073	0.1451	0.0651	0.1956	0.1852	
T3-1	0.4583	0.5561	1.0439	0.1636	0.1796	0.6110	0.5021	
T3-2	0.2583	0.4032	0.2659	0.1687	0.0862	1.2327	0.4025	
T3-3	0.7583	0.3480	1.7902	0.3610	0.2178	0.7383	0.7023	
T3-4	0.2000	0.1609	0.4683	0.1451	0.0980	0.3690	0.2402	
T3-5	0.1333	0.1351		0.1451	0.0651	0.3649	0.1687	
T4-1	0.9083	0.4769	2.9024	0.4692	0.4711	1.0707	1.0498	
T4-2	0.3750	0.4373	0.7049	0.1685	0.1444	0.4973	0.3879	
T4-3	0.3000	0.3055	1.0951	0.1556	0.2216	0.8788	0.4928	
T4-4	0.3583	0.3761	1.4000	0.2626	0.1713	0.5539	0.5204	
T4-5	0.0333	0.1688	0.5049	0.1451	0.0896	0.5895	0.2552	
T5-1	0.3000	0.3123	0.5024	0.2159	0.0924	0.9276	0.3918	
T5-2	1.5917	0.4783	2.0146	1.2459	1.0940	2.9571	1.5636	
T5-3	0.4250	0.4133	1.6756	9.6251	0.1627	1.4100	2.2853	
T5-4	0.4000	0.4405	1.0659	2.5103	0.1002	0.9220	0.9065	
T5-5	0.2000	0.1319	1.2049	0.0621	0.0362	0.1985	0.3056	
T6-1	0.6500	0.3618	1.3585	0.2374	0.1771	0.5829	0.5613	
T6-2	0.7000	0.5118	1.2073	0.2333	0.1216	0.5829	0.5595	
T6-3post	54.6917	0.6687	1.9268	0.2897	0.2000	0.6780	9.7425	
T6-4	0.8167	0.2246	0.8732	0.2510	1.3956	0.9537	0.7524	
T6-5	1.1750	0.3825	1.4634	0.2103	0.1231	0.4439	0.6330	
T7-1	0.6000	0.4254	0.7927	0.1344	0.0696	0.2707	0.3821	
T7-2	0.7000	0.5114	2.0610	0.2285	0.1564	0.4415	0.6831	
T7-3	0.3417	0.3474	0.3463	0.0759	0.0513	0.3585	0.2535	
T7-4	1.7500	0.4074	1.6780	0.3333	0.2091	0.5488	0.8211	
T7-5	0.5167	0.1890	0.8390	0.3154	0.0873	0.4098	0.3929	
T7-6	0.2833	0.1441	0.6244	0.0892	0.0571	0.3317	0.2550	
T8-1	0.6083	0.4669	0.2951	0.1038	0.0500	0.2902	0.3024	
T8-2	0.3417	0.1715	0.4049	0.0764	0.0533	0.3634	0.2352	
T8-3	0.4333	0.1992	0.6780	0.1167	0.0960	0.3927	0.3193	
T9-1	0.2417	0.2718	0.7707	0.0764	0.0358	0.1927	0.2648	
T9-2	0.2000	0.3816	0.8537	0.1808	0.1536	0.4463	0.3693	
T9-3	0.2000	0.3140	0.4098	0.0841	0.0704	0.3195	0.2330	
T9-4	0.2000	0.1344	0.1873	0.0385	0.0300	0.1644	0.1258	
T9-5	0.2250	0.2792	0.4488	0.0882	0.1278	0.8146	0.3306	
T9-6	0.2167	0.2500	0.4927	0.1451	0.0651	0.2076	0.2295	
T10-1	0.4333	0.3833	1.6341	0.1451	0.1047	0.5824	0.5472	
T10-2	0.0667	0.1021	0.1412	0.1451	0.0651	0.2198	0.1233	
T10-3	0.3417	0.2720	1.0732	0.1597	0.0696	0.4254	0.3902	
T10-4	0.2417	0.1645	1.9805	0.1451	0.0651	0.3080	0.4842	
T10-5	0.3583		2.2537	0.1451	0.0651	0.7288	0.7102	
T10-6	0.3083		2.4341	0.1451	0.0651	0.2105	0.6326	

D.2.2 Appendix D2.2 Results for SEM and AVS

Appendix D2-2. Focus Area resutls for AVS and SEM				AVS	TOC	Hg_SEM	Cd_SEM	Ag_SEM	Pb_SEM	Zn_SEM	Cu_SEM	Ni_SEM	∑SEM	∑SEM-AVS	$(\sum SEM\text{-}AVS)/f_{OC}$	Fe_SEM	Mn_SEM
Location_ID	Location	Field_Collection	depth	umol/g	%	umol/g	umol/g	umol/g	umol/g	umol/g	umol/g	umol/g	umol/g	umol/g	umol/g OC	umol/g	umol/g
SQVPS03-CC	PS03	core 00-03cm	1.5	42.6	3.27	0.00067	0.0126	0.0034	0.30	2.29	0.75	0.14	3.50	-39.10	-1195.76	1.02	1.22
SQVPS03-CC	PS03	core 03-06cm	4.5	49.6	7.12	0.00013	0.0140	0.0021	0.27	2.43	0.48	0.13	3.34	-46.26	-649.79	0.84	0.96
SQVPS03-CC	PS03	core 06-09cm	7.5	55.7	3.43	0.00015	0.0130	0.0033	0.36	2.48	0.65	0.14	3.65	-52.00	-1515.91	1.04	1.03
SQVPS03-CC	PS03	core 09-13cm	12.5	55.7	2.54	0.00015	0.0130	0.0033	0.36	2.48	0.65	0.14	3.65	-52.00	-2047.07	1.04	1.03
SQVPS03-CC	PS03	core 13-19cm	17.5	48.2	3.57	0.00020	0.0166	0.0043	0.52	3.24	0.81	0.14	4.74	-43.46	-1217.50	1.02	1.01
SQVPS03-CC	PS03	core 19-25cm	22.5	62.6	3.43	0.00014	0.0162	0.0053	0.53	3.18	1.38	0.22	5.33	-57.27	-1669.72	1.18	1.02
SQVPS06-CC	PS06	core 00-03cm	1.5	6.1	2.14	0.00015	0.0084	0.0019	0.31	3.21	0.94	0.73	5.20	-0.90	-42.27	1.64	2.99
SQVPS06-CC	PS06	core 03-06cm	4.5	25.3	2.36	0.00010	0.0094	0.0016	0.24	2.31	0.71	0.36	3.63	-21.67	-918.18	1.23	1.91
SQVPS06-CC	PS06	core 06-09cm	7.5	22.9	2.34	0.00005	0.0109	0.0023	0.25	2.91	0.75	2.15	6.08	-16.82	-718.84	3.15	3.00
SQVPS06-CC	PS06	core 09-13cm	10.5	22.5	2.07	0.00005	0.0071	0.0024	0.25	2.80	0.77	0.16	3.98	-18.52	-894.52	0.91	2.10
SQVPS06-CC	PS06	core 13-19cm	13.5	38.6	2.43	0.00005	0.0066	0.0046	0.53	5.32	1.14	0.27	7.26	-31.34	-1289.66	1.25	4.35
SQVPS06-CC	PS06	core 19-25cm	16.5	112.0	1.66	0.00008	0.0014	0.0015	0.25	2.95	0.44	0.09	3.74	-108.26	-6521.81	1.04	2.43
SQVPS06-CC(DUP)	PS06	core 00-03cm	1.5	3.6	1.90	0.00007	0.0070	0.0017	0.21	2.37	0.86	0.14	3.59	-0.01	-0.28	0.85	2.60
SQVPS06-CC(DUP)	PS06	core 03-06cm	4.5	6.1	2.08	0.00004	0.0076	0.0017	0.24	3.29	0.90	0.13	4.57	-1.56	-74.79	0.86	2.41
SQVPS07-CC	PS07	core 00-03cm	1.5	34.5	3.36	0.00004	0.0220	0.0035	0.32	2.51	1.34	0.68	4.87	-29.63	-881.71	1.85	2.58
SQVPS07-CC	PS07	core 03-06cm	4.5	85.8	3.35	0.00012	0.0246	0.0029	0.33	2.74	1.01	0.86	4.97	-80.83	-2412.91	2.40	2.47
SQVPS07-CC	PS07	core 06-09cm	7.5	75.2	3.36	0.00004	0.0175	0.0027	0.24	1.97	0.64	0.25	3.12	-72.08	-2145.32	1.55	1.63
SQVPS07-CC	PS07	core 09-13cm	12.5	77.3	3.24	0.00002	0.0188	0.0033	0.29	2.39	0.82	0.46	3.98	-73.27	-2261.51	1.57	1.43
SQVPS07-CC	PS07	core 13-19cm	17.5	67.9	3.12	0.00004	0.0228	0.0038	0.33	3.10	1.03	2.21	6.69	-61.21	-1961.81	3.62	2.05
SQVPS07-CC	PS07	core 19-25cm	22.5	54.9	3.03	0.00002	0.0116	0.0006	0.25	1.71	0.42	0.14	2.53	-52.37	-1728.51	0.89	1.00
SQVPS08-CC	PS08	core 00-03cm	1.5	24.7	3.00	0.00039	0.0130	0.0027	0.35	3.05	1.61	0.32	5.34	-19.36	-645.30	1.40	3.34
SQVPS08-CC	PS08	core 03-06cm	4.5	34.8	2.45	0.00009	0.0129	0.0023	0.30	3.10	1.17	0.16	4.75	-30.05	-1226.56	1.06	2.18
SQVPS08-CC	PS08	core 06-09cm	7.5	79.9	2.77	0.00010	0.0142	0.0018	0.30	4.00	0.83	0.19	5.33	-74.57	-2691.91	1.08	2.11
SQVPS08-CC	PS08	core 09-13cm	12.5	62.2	2.64	0.00025	0.0113	0.0026	0.29	3.27	0.93	0.20	4.71	-57.49	-2177.72	1.09	1.69
SQVPS08-CC	PS08	core 13-19cm	17.5	53.0	2.72	0.00005	0.0107	0.0017	0.31	3.14	0.56	0.18	4.20	-48.80	-1794.17	0.95	1.68
SQVPS08-CC	PS08	core 19-25cm	22.5	36.3	2.44	0.00006	0.0115	0.0021	0.36	3.49	0.71	0.14	4.71	-31.59	-1294.64	0.90	1.46
SQVPS09-CC	PS09	core 00-03cm	1.5	62.8	3.34	0.00023	0.0185	0.0022	0.28	3.34	1.02	0.30	4.96	-57.84	-1731.68	1.46	1.62
SQVPS09-CC	PS09	core 03-06cm	4.5	104.0	3.60	0.00004	0.0662	0.0023	0.31	28.20	0.55	0.18	29.31	-74.69	-2074.82	1.23	1.19
SQVPS09-CC	PS09	core 06-09cm	7.5	64.2	3.25	0.00014	0.0144	0.0042	0.34	4.00	1.42	0.25	6.03	-58.17	-1789.82	1.50	1.58
SQVPS09-CC	PS09	core 09-13cm	12.5	98.8	2.97	0.00014	0.0207	0.0020	0.30	4.14	0.80	0.23	5.49	-93.31	-3141.72	1.50	1.74
SQVPS09-CC	PS09	core 13-19cm	17.5	51.9	2.25	0.00018	0.0108	0.0020	0.40	3.87	1.25	0.18	5.70	-46.15	-2050.98	1.10	1.74
SQVPS09-CC	PS09	core 19-23cm	22.5	48.0	2.03	0.00008	0.0094	0.0015	0.32	3.47	0.61	0.13	4.54	-43.46	-2140.98	0.86	1.35
SQVPS10.1-CC	PS10.1	core 00-03cm	1.5	39.1	3.48	0.00016	0.0135	0.0030	0.49	3.10	1.31	0.16	5.07	-34.03	-977.91	1.20	2.43
SQVPS10.1-CC	PS10.1	core 03-06cm	4.5	76.2	3.74	0.00008	0.0126	0.0029	0.41	3.71	1.05	0.22	5.41	-70.79	-1892.90	1.55	2.16
SQVPS10.1-CC	PS10.1	core 06-09cm	7.5	65.6	2.65	0.00015	0.0108	0.0025	0.43	3.08	1.04	0.14	4.70	-60.90	-2297.98	1.12	1.51
SQVPS10.1-CC	PS10.1	core 09-13cm	12.5	52.1	5.10	0.00010	0.0121	0.0031	0.51	3.53	0.99	0.21	5.25	-46.85	-918.62	1.27	1.81
SQVPS10.1-CC	PS10.1	core 13-19cm	17.5	50.0	3.10	0.00034	0.0135	0.0044	0.57	4.29	1.66	4.38	10.92	-39.08	-1260.67	5.88	2.70
SQVPS10.1-CC	PS10.1	core 19-24cm	22.5	40.3	4.84	0.00016	0.0071	0.0034	0.47	3.24	1.27	0.33	5.32	-34.98	-722.67	1.17	1.80
SQVPS10-CC	PS10	core 00-03cm	1.5	107.0	3.59	0.00017	0.0152	0.0033	0.26	2.54	0.72	0.20	3.74	-103.26	-2876.30	1.54	1.65
SQVPS10-CC	PS10	core 03-06cm	4.5	74.0	3.38	0.00006	0.0118	0.0024	0.30	2.65	0.54	0.15	3.66	-70.34	-2081.06	1.16	1.64
SQVPS10-CC	PS10	core 06-09cm	7.5	80.7	3.48	0.00011	0.0155	0.0038	0.31	2.83	0.76	0.17	4.10	-76.60	-2201.28	1.40	1.93
SQVPS10-CC	PS10	core 09-13cm	12.5	58.4	3.36	0.00031	0.0126	0.0029	0.41	3.09	0.84	0.17	4.53	-53.87	-1603.34	1.35	1.93
SQVPS10-CC	PS10	core 13-19cm	17.5	58.3	0.32	0.00030	0.0123	0.0026	0.67	3.96	1.07	0.14	5.86	-52.39	-16321.45	0.99	1.56
SQVPS10-CC	PS10	core 19-25cm	22.5	22.3	1.80	0.00009	0.0156	0.0024	0.86	4.49	1.09	0.31	6.77	-15.53	-862.61	0.85	1.26
SQVPS11-CC	PS11	core 00-03cm	1.5	56.5	3.48	0.00015	0.0154	0.0048	0.28	2.43	1.13	0.77	4.63	-51.87	-1490.48	2.25	3.05
SQVPS11-CC	PS11	core 03-06cm	4.5	99.6	3.41	0.00023	0.0161	0.0030	0.28	2.50	0.92	0.24	3.96	-95.64	-2804.68	1.73	2.04
SQVPS11-CC	PS11	core 06-09cm	7.5	8.2	3.60	0.00011	0.0112	0.0024	0.27	2.31	1.25	0.16	4.00	-4.17	-115.93	1.48	5.04
SQVPS11-CC	PS11	core 09-13cm	12.5	80.2	3.45	0.00005	0.0149	0.0032	0.28	2.16	0.72	0.23	3.41	-76.74	-2224.26	1.27	1.91
SQVPS11-CC	PS11	core 13-19cm	17.5	120.0	3.50	0.00005	0.0156	0.0031	0.27	2.16	0.79	0.21	3.46	-116.54	-3329.84	1.52	1.47
SQVPS11-CC	PS11	core 19-25cm	22.5	108.0	3.23	0.00003	0.0148	0.0020	0.29	2.36	0.76	0.19	3.61	-104.39	-3231.89	1.15	1.13

D.2.3 **Appendix D2.3 Porewater Results**

Appendix D2-3. Porewater Concentrations		Chronic ug/L		9.3	50.0	3.1	0.0	8.2	8.1	81.0			
		Acute ug/L		42.0	1100.0	4.6	1.8	74.0	210.0	90.0			
		Atomic Weight g/mole		112.41	51.996	63.546	200.59	58.693	207.2	65.39		55.845	54.938
Average of Result_Value			RESULT_P	Result_Value_Units									
			AVS	Cd	Cr	Cu	Hg	Ni	Pb	Zn		Fe	Mn
Location_ID	Study_Specific_Location_ID	Field_Collection_Comment	umol/mL	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L		ug/L	ug/L
SQVPS03-SQ	PS03SQ	POREWATER Sqz Core 00-03cm	0.0323	0.036	2.22	1.120	0.00314	4.85	0.03	6.28		520	590
		POREWATER Sqz Core 03-06cm	0.322	0.036	3.84	1.220	0.00347	6.11	0.03	1.92		26.2	168
		POREWATER Sqz Core 06-09cm	0.453	0.036	5.08	1.110	0.00227	6.76	0.03	1.93		17.8	80.5
		POREWATER Sqz Core 09-13cm	0.782	0.036	6.48	0.905	0.00195	6.49	0.03	1.78		10	37.5
		POREWATER Sqz Core 13-19cm	1.14	0.036	8.38	0.818	0.00508	5.50	0.03	1.99		10	1.7
		POREWATER Sqz Core 19-25cm	1.28	0.036	8.83	0.374	0.00658	5.68	0.03	2.12		11.6	0.5
SQVPS09-SQ	PS09SQ	POREWATER Sqz Core 00-03cm	0.027	0.036	4.85	1.550	0.00191	7.30	0.03	10.6		406	370
		POREWATER Sqz Core 03-06cm	0.0593	0.036	5.06	1.880	0.00202	7.02	0.03	2.57		32.3	133
		POREWATER Sqz Core 06-09cm	0.188	0.036	5.47	1.800	0.00253	6.93	0.03	3.33		18.4	92.4
		POREWATER Sqz Core 09-13cm	0.122	0.036	5.28	1.810	0.00499	6.79	0.03	6.83		13.9	75.2
		POREWATER Sqz Core 13-19cm	0.172	0.036	5.34	1.910	0.00304	5.36	0.03	3.08		23.8	84.7
		POREWATER Sqz Core 19-25cm	0.034	0.036	4.52	2.050	0.018	6.51	0.03	4.22		28	131
			AVS	Cd	Cr	Cu	Hg	Ni	Pb	Zn	∑Metal		
			umol/L	umol/L	umol/L	umol/L	umol/L	umol/L	umol/L	umol/L	umol/L		
SQVPS03-SQ	PS03SQ	POREWATER Sqz Core 00-03cm	32.3	0.000320	0.042696	0.017625	0.000016	0.082633	0.000145	0.096039	0.239474		
		POREWATER Sqz Core 03-06cm	322.0	0.000320	0.073852	0.019199	0.000017	0.104101	0.000145	0.029362	0.226996		
		POREWATER Sqz Core 06-09cm	453.0	0.000320	0.097700	0.017468	0.000011	0.115176	0.000145	0.029515	0.260335		
		POREWATER Sqz Core 09-13cm	782.0	0.000320	0.124625	0.014242	0.000010	0.110575	0.000145	0.027221	0.277138		
		POREWATER Sqz Core 13-19cm	1140.0	0.000320	0.161166	0.012873	0.000025	0.093708	0.000145	0.030433	0.298670		
		POREWATER Sqz Core 19-25cm	1280.0	0.000320	0.169821	0.005886	0.000033	0.096775	0.000145	0.032421	0.305400		
SQVPS09-SQ	PS09SQ	POREWATER Sqz Core 00-03cm	27.0	0.000320	0.093276	0.024392	0.000010	0.124376	0.000145	0.162104	0.404623		
		POREWATER Sqz Core 03-06cm	59.3	0.000320	0.097315	0.029585	0.000010	0.119605	0.000145	0.039303	0.286283		
		POREWATER Sqz Core 06-09cm	188.0	0.000320	0.105200	0.028326	0.000013	0.118072	0.000145	0.050925	0.303001		
		POREWATER Sqz Core 09-13cm	122.0	0.000320	0.101546	0.028483	0.000025	0.115687	0.000145	0.104450	0.350656		
		POREWATER Sqz Core 13-19cm	172.0	0.000320	0.102700	0.030057	0.000015	0.091323	0.000145	0.047102	0.271662		
		POREWATER Sqz Core 19-25cm	34.0	0.000320	0.086930	0.032260	0.000090	0.110916	0.000145	0.064536	0.295197		

D.2.4 Appendix D2.4 Surface Grab Summary

		Ag	Al	As	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb
		ug/g	mg/g	ug/g	ug/g	ug/g	ug/g	mg/g	ug/g	ug/g	ug/g	ug/g
PS03	n	6	6	6	6	6	6	6	6	6	6	6
	Min	0.03	0.78	2.10	0.49	23.10	55.50	4.01	1.00	161.00	13.20	5.55
	Max	1.42	56.33	13.80	2.18	107.00	349.00	33.27	5.62	404.00	41.90	181.00
	Mean	0.93	39.11	10.12	1.54	74.95	251.08	25.47	4.12	329.33	32.12	91.26
	Stdev	0.50	20.08	4.09	0.58	29.57	110.68	11.16	1.71	88.67	10.56	57.88
	CV	53%	51%	40%	38%	39%	44%	44%	41%	27%	33%	63%
PS06	n	6	6	6	6	6	6	6	6	6	6	6
	Min	0.33	38.59	10.10	0.61	82.50	66.50	27.91	0.28	435.00	34.70	37.70
	Max	1.55	65.48	58.80	1.76	143.00	260.00	39.57	0.76	486.00	46.70	250.00
	Mean	0.80	58.55	21.83	1.36	97.57	183.42	33.70	0.63	460.00	40.13	101.45
	Stdev	0.40	10.50	18.25	0.46	22.79	72.82	4.37	0.18	21.92	4.65	77.02
	CV	50%	18%	84%	34%	23%	40%	13%	29%	5%	12%	76%
PS07	n	6	6	6	6	6	6	6	6	6	6	6
	Min	0.36	52.11	8.10	0.72	58.90	72.60	23.79	0.34	405.00	30.00	50.80
	Max	0.77	60.58	16.80	2.07	82.60	149.00	33.76	0.78	483.00	41.60	88.80
	Mean	0.58	58.59	12.67	1.53	73.52	113.65	30.06	0.54	436.50	37.28	67.75
	Stdev	0.17	3.32	3.02	0.56	8.58	31.68	3.84	0.16	32.54	4.06	15.17
	CV	29%	6%	24%	36%	12%	28%	13%	29%	7%	11%	22%
PS08	n	6	6	6	6	6	6	6	6	6	6	6
	Min	0.57	44.96	13.20	1.51	85.40	169.00	29.75	4.60	451.00	36.60	77.50
	Max	0.79	63.66	20.80	4.80	92.60	531.00	38.23	6.48	510.00	67.10	87.60
	Mean	0.71	59.03	16.25	2.20	89.52	240.33	35.47	5.46	477.33	48.05	82.17
	Stdev	0.07	7.05	2.57	1.28	2.50	143.38	2.92	0.63	22.11	10.64	3.64
	CV	10%	12%	16%	58%	3%	60%	8%	11%	5%	22%	4%
PS09	n	6	6	6	6	6	6	6	6	6	6	6
	Min	0.48	21.93	15.20	1.29	64.40	263.00	19.70	3.41	352.00	31.50	72.00
	Max	1.26	58.91	223.00	8.98	193.00	874.00	63.65	7.79	1015.00	154.00	390.00
	Mean	0.82	43.57	58.92	3.05	118.23	513.17	40.14	5.15	579.33	87.92	167.55
	Stdev	0.31	16.80	80.93	2.94	45.88	261.61	16.02	1.61	233.82	50.49	116.53
	CV	38%	39%	137%	96%	39%	51%	40%	31%	40%	57%	70%
PS10	n	6	6	6	6	6	6	6	6	6	6	6
	Min	0.62	49.60	12.30	1.83	66.80	130.00	29.84	5.98	407.00	35.30	58.20
	Max	1.22	58.29	23.30	2.74	103.00	398.00	38.03	10.60	534.00	58.60	192.00
	Mean	0.90	53.84	16.17	2.21	85.65	238.83	33.24	7.53	443.00	45.92	111.70
	Stdev	0.23	3.24	4.08	0.36	15.54	108.07	2.70	1.60	47.51	10.09	53.94
	CV	25%	6%	25%	16%	18%	45%	8%	21%	11%	22%	48%
PS10.1	n	6	6	6	6	6	6	6	6	6	6	6
	Min	0.32	22.36	4.20	0.78	48.80	101.00	14.38	1.91	350.00	20.40	60.30
	Max	1.24	57.02	21.00	2.62	124.00	433.00	34.61	10.30	488.00	53.00	352.00
	Mean	0.80	49.40	14.92	1.87	92.13	254.17	30.21	5.98	440.00	42.45	147.45
	Stdev	0.32	13.33	5.66	0.64	24.95	121.47	7.84	2.78	50.38	11.45	106.75
	CV	40%	27%	38%	34%	27%	48%	26%	46%	11%	27%	72%
PS11	n	6	6	6	6	6	6	6	6	6	6	6
	Min	0.66	55.48	10.80	1.42	80.50	139.00	32.90	3.55	405.00	40.20	76.70
	Max	0.88	58.61	36.60	2.36	118.00	366.00	34.66	8.09	703.00	51.20	1180.00
	Mean	0.77	57.11	20.73	1.84	93.77	248.17	33.95	5.74	491.83	44.88	288.62
	Stdev	0.09	1.25	9.60	0.38	16.10	92.92	0.60	1.85	112.66	4.13	438.45
	CV	11%	2%	46%	20%	17%	37%	2%	32%	23%	9%	152%
PIER 7	n	22	22	22	22	22	51	51	48	22	22	51
	Min	0.13	23.48	6.20	0.22	29.10	15.00	13.45	0.06	280.00	15.40	13.50
	Max	0.94	63.31	25.20	1.55	123.00	3753.80	40.14	1.19	704.00	78.50	628.00
	Mean	0.30	51.09	9.45	0.85	69.06	178.46	24.82	0.45	428.15	30.06	78.15
	Stdev	0.18	11.80	4.12	0.33	26.86	530.90	4.73	0.27	88.16	12.89	109.06
	CV	61%	23%	44%	39%	39%	297%	19%	61%	21%	43%	140%

Appendix D2.4 Surface Grab Summary (Continued)

		Zn	PCB_T	PAH_Total	TOC	GS-Mean	GS-Sort	GS-Skew	GS-Gravel	GS-Sand	GS-Fines	PCB_T	PAH_Total
		ug/g	ng/g	ug/g	%	Phi	Phi	Phi	%	%	%	mg/Kg OC	mg/Kg OC
PS03	n	6	6	6	6	6	6	6	6	6	6		
	Min	143.00	124.10	2.82	4.15	4.60	1.76	-0.45	0.00	22.87	58.07		
	Max	483.00	294.50	48.27	9.23	5.24	2.22	-0.03	0.00	41.93	77.13		
	Mean	283.67	242.48	30.94	6.23	4.94	1.99	-0.29	0.00	30.84	69.16	3.89	496.96
	Stdev	112.88	65.39	16.31	1.96	0.22	0.20	0.14	0.00	6.69	6.69		
	CV	40%	27%	53%	31%	5%	10%	-48%		22%	10%		
PS06	n	6	6	6	6	6	6	6	6	6	6		
	Min	153.00	149.10	3.73	0.98	4.15	1.51	-0.52	0.00	15.85	50.82		
	Max	540.00	311.50	14.14	3.15	5.46	2.18	0.16	0.00	49.18	84.15		
	Mean	302.83	252.48	10.27	2.60	4.98	1.75	-0.26	0.00	28.08	71.93	9.72	395.53
	Stdev	147.78	55.57	3.80	0.81	0.50	0.27	0.26	0.00	13.35	13.35		
	CV	49%	22%	37%	31%	10%	15%	-101%		48%	19%		
PS07	n	6	6	6	6	6	6	6	6	6	6		
	Min	139.00	223.40	2.17	1.05	4.83	1.71	-0.41	0.00	21.96	68.33		
	Max	229.00	310.60	31.04	3.11	5.22	1.89	-0.24	0.00	31.67	78.04		
	Mean	184.00	251.92	12.35	2.37	5.06	1.80	-0.30	0.00	26.79	73.22	10.63	521.13
	Stdev	36.58	33.13	9.88	0.83	0.15	0.06	0.07	0.00	3.65	3.65		
	CV	20%	13%	80%	35%	3%	4%	-23%		14%	5%		
PS08	n	6	6	6	6	6	6	6	6	6	6		
	Min	257.00	175.40	9.19	2.34	5.06	1.46	-0.40	0.00	15.72	72.49		
	Max	606.00	271.90	39.55	8.79	5.43	1.87	-0.28	0.00	27.51	84.28		
	Mean	360.00	240.23	17.68	3.74	5.25	1.63	-0.33	0.00	21.40	78.60	6.42	472.41
	Stdev	133.65	34.91	11.19	2.48	0.16	0.17	0.04	0.00	5.06	5.06		
	CV	37%	15%	63%	66%	3%	11%	-13%		24%	6%		
PS09	n	6	6	6	6	6	6	6	6	6	6		
	Min	320.00	206.10	16.38	1.91	-0.01	1.49	-0.41	0.00	15.83	10.41		
	Max	2172.00	434.70	46.47	8.31	5.53	2.59	1.82	61.71	49.23	84.17		
	Mean	898.50	313.73	30.58	4.20	4.09	1.94	0.15	10.29	30.21	59.51	7.47	728.27
	Stdev	734.52	93.24	13.32	2.67	2.06	0.36	0.84	25.19	11.15	26.49		
	CV	82%	30%	44%	64%	50%	19%	550%		37%	45%		
PS10	n	6	6	6	6	6	6	6	6	6	6		
	Min	192.00	174.40	12.83	3.00	4.49	1.41	-0.44	0.00	14.86	59.98		
	Max	485.00	534.90	40.45	3.79	5.43	1.95	-0.08	0.00	40.02	85.14		
	Mean	336.00	307.48	22.68	3.42	5.17	1.61	-0.33	0.00	22.50	77.50	8.99	662.76
	Stdev	126.46	143.95	9.96	0.31	0.36	0.22	0.13	0.00	9.84	9.84		
	CV	38%	47%	44%	9%	7%	14%	-40%		44%	13%		
PS10.1	n	6	6	6	6	6	6	6	6	6	6		
	Min	166.00	116.60	9.54	2.02	4.13	1.58	-0.38	0.00	20.15	55.85		
	Max	718.00	404.70	37.49	8.70	5.29	2.35	-0.16	0.00	44.15	79.85		
	Mean	424.50	254.33	20.63	3.94	4.90	1.88	-0.29	0.00	29.65	70.36	6.45	523.09
	Stdev	221.80	93.99	9.73	2.40	0.40	0.27	0.08	0.00	7.99	7.99		
	CV	52%	37%	47%	61%	8%	14%	-28%		27%	11%		
PS11	n	6	6	6	6	6	6	6	6	6	6		
	Min	228.00	198.10	13.11	1.41	0.69	1.61	-0.27	0.00	22.58	10.22		
	Max	795.00	289.20	30.83	3.79	5.24	2.71	1.34	57.91	48.62	77.42		
	Mean	428.33	240.25	19.28	3.04	4.17	2.03	0.09	9.65	32.22	58.13	7.91	634.72
	Stdev	208.60	36.37	7.45	0.89	1.74	0.39	0.64	23.64	9.36	25.27		
	CV	49%	15%	39%	29%	42%	19%	731%		29%	43%		
PIER 7	n	51	51	49		46	46	46	46	46	46	51	49
	Min	34.40	9.20	2.17		2.75	1.70	-0.41	0.00	22.48	24.26	0.4	83.6
	Max	1212.40	17064.48	38.12		5.40	2.44	1.03	0.00	75.74	77.52	656.3	1466.3
	Mean	259.81	471.25	11.74		4.30	2.08	0.13	0.00	46.17	53.83	18.1	451.5
	Stdev	199.43	2372.36	6.37		0.64	0.18	0.36	0.00	13.78	13.78	91.2	244.9
	CV	77%	503%	54%		15%	8%	271%		30%	26%	503%	54%

D.3 Appendix D.3 Dry Dock Silt Data Summaries

D.3.1 **Appendix D.3.1 Caisson and Dry Dock Silts Sampled in 2009 and 2010**

Size fractions measured for caisson and dry dock silt samples collected in 2009 and 2010.

				large >2mm	coarse	fine	clay	all	GS-Mean	GS-Sort
Location_ID	Study_Spe	Field_Collection_Comment	Date	%	%	%	%	%	Phi	Phi
CASS-09	CDD2	Diver collected dry dock silt from apron of dry dock	7/15/2009	0.02	42.73	55.39	1.46	99.6	4.567	2.201
CASS-10	CDD2	Diver collected dry dock silt from apron of dry dock	7/15/2009	0	38.39	59.85	1.52	99.76	4.799	2.097
CASS-07	CDD3	Diver collected dry dock silt from apron of dry dock	7/15/2009	0.14	52.18	45.82	1.02	99.16	4.125	2.228
CASS-08	CDD3	Diver collected dry dock silt from apron of dry dock	7/15/2009	0.04	44.73	53.25	1.36	99.38	4.4	2.304
CASS-01	CDD4	Diver collected dry dock silt from apron of dry dock	7/15/2009	0.01	40.8	57.44	1.63	99.88	4.683	2.183
CASS-02	CDD4	Diver collected dry dock silt from apron of dry dock	7/15/2009	0	42.19	57.04	1.48	100.71	4.723	2.044
CASS-04	CDD4	Diver collected dry dock silt from apron of dry dock	7/15/2009	0	39.83	59.13	1.54	100.5	4.798	2.03
CASS-05	CDD4	Diver collected dry dock silt from apron of dry dock	7/15/2009	0	42.54	55.45	1.58	99.57	4.586	2.216
CASS-06	CDD4	Diver collected dry dock silt from apron of dry dock	7/15/2009	0	41.39	57.75	1.41	100.55	4.763	2.017
CASS-11	CDD6	Diver collected dry dock silt from apron of dry dock	7/15/2009	0	41.65	56.27	1.62	99.54	4.63	2.212
CASS-12	CDD6	Diver collected dry dock silt from apron of dry dock	7/15/2009	0	50.45	46.87	0.7	98.02	4.086	2.219
DD6_Jul2010-1	DD6-1	Diver collected dry dock silt before dewatering	7/15/2010	0	39.71	58.65	1.53	99.89	4.733	2.04
DD6_Jul2010-4	DD6-4	Diver collected dry dock silt before dewatering	7/15/2010	0.66	64.48	30.48	0.77	96.39	3.008	2.398
DD6_Jul2010-7	DD6-7	Dry Dock silt collected from dry dock floor after dewatering	7/15/2010	0	17.38	82.62	0.94	100.94	5.586	1.362
PS09_PQ1	PS09	Ponar grab from barge	7/15/2010	0	18.9	81.11	0.89	100.9	5.529	1.328
PS09_PQ2	PS09	Ponar grab from barge	7/15/2010	0	24.14	75.87	0.71	100.72	5.315	1.268
PS09_PQ3	PS09	Ponar grab from barge	7/15/2010							

Chemical concentrations measured in caisson and dry dock silt samples collected in 2009 and 2010. Concentration is in dry weight.

					Cu	Fe	Hg	Pb	Zn	PCB_T	PAH_Total
Location_ID	Study_Spe	Field_Collection_Comment	Date	Field_Colle	ug/g	ug/g	ug/g	ug/g	ug/g	ng/g	ng/g
CASS-09	CDD2	Diver collected dry dock silt from apron of dry dock	7/15/2009		488.8	30007		132.3	929.4	326.4	
CASS-10	CDD2	Diver collected dry dock silt from apron of dry dock	7/15/2009		324.3	28767		113.6	1108.0	335.3	
CASS-07	CDD3	Diver collected dry dock silt from apron of dry dock	7/15/2009		228.4	21174		124.9	1550.8	154.2	
CASS-08	CDD3	Diver collected dry dock silt from apron of dry dock	7/15/2009		330.5	24417		86.7	2131.5	190.8	
CASS-01	CDD4	Diver collected dry dock silt from apron of dry dock	7/15/2009		293.5	24024		79.8	609.4	218.2	
CASS-02	CDD4	Diver collected dry dock silt from apron of dry dock	7/15/2009		440.9	22393		100.5	757.6	261.4	
CASS-04	CDD4	Diver collected dry dock silt from apron of dry dock	7/15/2009		640.6	30616		112.3	1300.9	257.7	
CASS-05	CDD4	Diver collected dry dock silt from apron of dry dock	7/15/2009		406.0	26709		103.8	543.0	303.2	
CASS-06	CDD4	Diver collected dry dock silt from apron of dry dock	7/15/2009		357.5	26886		122.0	533.1	262.3	
CASS-11	CDD6	Diver collected dry dock silt from apron of dry dock	7/15/2009		293.3	26807		46.8	430.6	160.4	
CASS-12	CDD6	Diver collected dry dock silt from apron of dry dock	7/15/2009		214.3	26284		72.8	448.9	186.4	
DD6_Jul2010-1	DD6-1	Diver collected dry dock silt before dewatering	7/15/2010		154.0	29159	0.38	83.0	304.0		
DD6_Jul2010-4	DD6-4	Diver collected dry dock silt before dewatering	7/15/2010		191.0	30029	0.42	49.0	295.0		
DD6_Jul2010-7	DD6-7	Dry Dock silt collected from dry dock floor after dewatering	7/15/2010		512.0	31231	0.43	62.0	744.0		4769
PS09_PQ1	PS09	Ponar grab from barge	7/15/2010		522.0	35118	0.90	72.0	619.0		23974
PS09_PQ2	PS09	Ponar grab from barge	7/15/2010		1498.0	54139	2.44	464.0	2142.0		34504
PS09_PQ3	PS09	Ponar grab from barge	7/15/2010		698.0	35311		145.0	1010.0		

D.3.2 Appendix D.3.2 Dry Dock Silts Sampled 2012-2014

D.3.2.1 Variables used in the dry dock silt data set.

Variable	Units	Comment
LocationID		Location identifier
SampleID		Sample identifier
Station		Station name
C_Date		Collection date
f_solids		fraction of solids
f_TOC		fraction of total organic carbon
f_>2mm		fraction greater than or equal to 2 mm
f_coarse		fraction coarse less than 2 mm but greater than or equal to 63 um
f_fine		fraction fine less than 63 um
C_coarse	ug/g	concentration of chemical measured in coarse fraction
C_fines	ug/g	concentration of chemical measured in fine fraction
L_coarse	ug/g	loading concentration of coarse fraction L_coarse = f_coarse × C_coarse
L_fines	ug/g	loading concentration of fine fraction L_fines = f_fines × C_fines
T_load	ug/g	total loading concentration T_load = L_coarse + L_fines
BulkC*	ug/g	concentration of chemical in bulk sample analyzed by PSNS&IMF c/134*

* A subset of samples was analyzed for bulk metals using ICP-MS by the Shipyard laboratory PSNS&IMF c/134.

Table D.3.2.1. Summary of texture characteristics measured in dry dock silt samples.

		f_solids	f_TOC	f_>2mm	f_coarse	f_fine
ALL	n	25	26	25	25	25
	Average	0.30	0.05	0.11	0.28	0.64
	CV	64%	59%	155%	87%	49%
	min	0.09	0.01	0.00	0.03	0.02
	max	0.98	0.14	0.72	0.97	1.17
DD1	n	8	8	8	8	8
	Average	0.23	0.07	0.11	0.23	0.68
	CV	29%	52%	134%	81%	41%
	min	0.15	0.04	0.00	0.03	0.23
	max	0.37	0.14	0.38	0.57	1.01
DD5	n	10	11	10	10	10
	Average	0.27	0.05	0.12	0.28	0.66
	CV	47%	71%	121%	87%	47%
	min	0.09	0.02	0.00	0.07	0.14
	max	0.52	0.11	0.72	0.83	0.98
DD6	n	6	6	6	6	6
	Average	0.34	0.04	0.10	0.23	0.65
	CV	45%	44%	261%	120%	45%
	min	0.13	0.01	0.00	0.07	0.06
	max	0.72	0.09	0.21	0.58	1.17

D.3.2.2 Fe size fraction data

Fe Concentration by Size Class													
								Fe ug/g dry wt.					
LocationID	SampleID	C_Date	f_solids	f_TOC	f_>2mm	f_coarse	f_fine	C_coarse	C_fines	L_coarse	L_fines	T_load	BulkC
BG	DDS022	3/15/2013	0.98	0.01	0.01	0.97	0.02	742420	511342	719330	12948	732278.4	768000
DD1-d1	DDS001	12/10/2012	0.25	0.04	0.31	0.20	0.77	43661	40956	8606	6592	15197.4	28600
DD1-d2	DDS002	12/10/2012	0.30	0.04	0.00	0.04	1.01	50550	36542	1855	1876	3730.8	37700
DD1-d3	DDS003	12/10/2012	0.20	0.05	0.00	0.03	0.93	63401	42305	1763	1637	3400.0	41300
DD1-1	DDS010	1/9/2013	0.15	0.12	0.02	0.20	0.75	60550	44966	12074	9031	21104.9	21800
DD1-2	DDS009	1/9/2013	0.19	0.10	0.03	0.16	0.67	165308	56344	26152	17391	43542.7	
DD1-3	DDS008	1/9/2013	0.37	0.05	0.12	0.57	0.31	77862	66848	43992	13638	57629.7	
DD1-3	DDS013	2/6/2013	0.20	0.14	0.38	0.46	0.23	35971	61687	16554	3741	20294.9	4340
DD1-1	DDS021	6/5/2013	0.22	0.06	0.04	0.22	0.80	50930	39248	11220	9010	20229.4	35500
DD5-1	DDS004	12/21/2012	0.26	0.11	0.02	0.27	0.73	80783	91291	22022	16120	38141.3	63800
DD5-2	DDS005	12/21/2012	0.24	0.07	0.00	0.20	0.78	108089	70871	22050	17265	39315.4	
DD5-4	DDS007	12/21/2012	0.28	0.05	0.31	0.23	0.68	95484	50612	21942	14855	36797.0	
DD5-1	DDS018	5/15/2013	0.09	0.04	0.00	0.07	0.98	65074	26040	4399	4315	8714.5	181000
DD5-2	DDS019	5/15/2013	0.52	0.02	0.07	0.83	0.14	117193	72312	97669	13771	111440.0	
DD5-1	DDS026	6/7/2013	0.23	0.03	0.72	0.26	0.47	72544	33779	19152	9059	28210.4	89800
DD5-2	DDS027	6/7/2013	0.47	0.07	0.01	0.56	0.37	132094	65711	74105	27122	101226.9	
DD5-1	DDS2014-001	10/1/2014	0.20	0.06	0.06	0.22	0.71	108736	42218	23694	16704	40397.7	
DD5-2	DDS2014-002	10/1/2014	0.21	0.04	0.00	0.08	0.88	108173	35310	8340	7364	15704.5	
DD5-3	DDS2014-003	10/1/2014	0.19	0.05	0.00	0.11	0.84	61769	39850	6547	5500	12047.4	
DD6-1	DDS014	2/7/2013	0.72	0.01	0.20	0.58	0.06	592761	289936	345461	20728	366189.0	68100
DD6-3	DDS016	2/7/2013	0.35	0.05	0.06	0.31	0.68	102529	54544	31866	21669	53534.9	
DD6-4	DDS017	2/7/2013	0.28	0.09	0.06	0.16	0.86	61590	76069	9811	8399	18209.9	
DD6-1	DDS023	6/28/2013	0.13	0.04	0.00	0.07	1.17	66039	40647	4709	5486	10194.1	23400
DD6-2	DDS024	6/28/2013	0.36	0.03	0.21	0.17	0.27	85616	41690	14315	3879	18194.5	
DD6-3	DDS025	6/28/2013	0.21	0.03	0.09	0.10	0.86	41854	33679	4039	3490	7528.6	

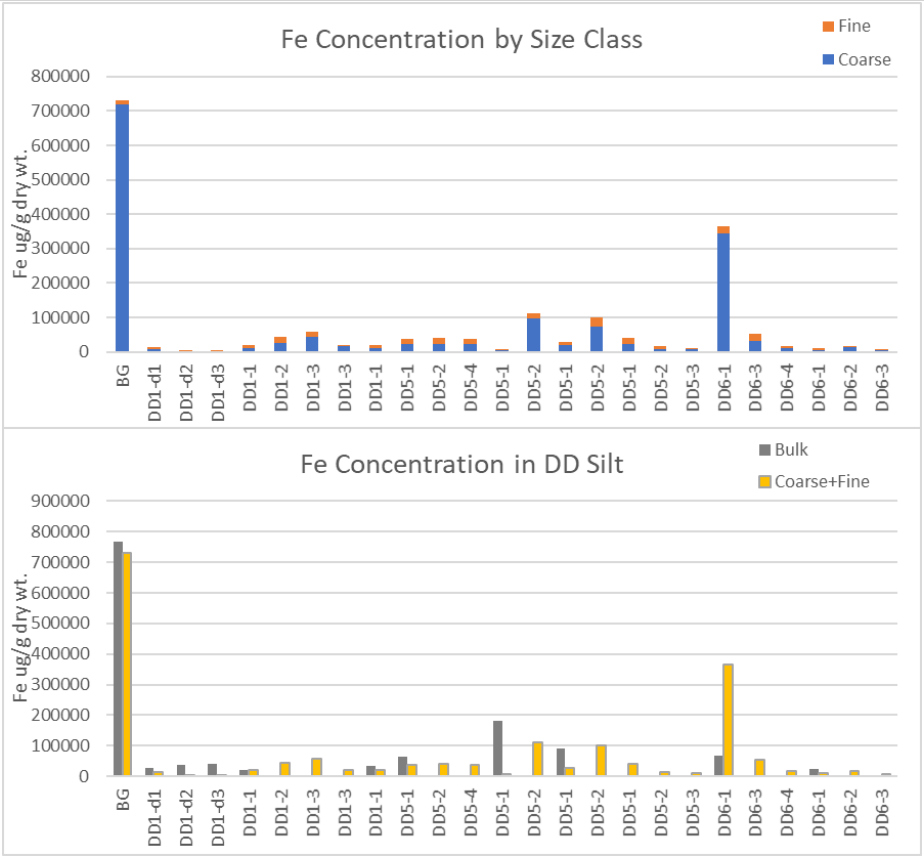


Fig D.3.2.2. Fe concentrations by size class for blasting grit (BG) and dry dock silt samples plotted by sample for fine and coarse fractions (upper panel) and bulk and coarse+fine concentration (lower panel).

D.3.2.3 Cu size fraction data

Cu Concentration by Size Class								Cu ug/g dry wt.					
LocationID	SampleID	C_Date	f_solids	f_TOC	f_>2mm	f_coarse	f_fine	C_coarse	C_fines	L_coarse	L_fines	T_load	BulkC
BG	DDS022	3/15/2013	0.98	0.01	0.01	0.97	0.02	2812.7	3932.5	2725.249	49.054	2774.3	4010
DD1-d1	DDS001	12/10/2012	0.25	0.04	0.31	0.20	0.77	351.6	247.4	69.303	53.086	122.4	233
DD1-d2	DDS002	12/10/2012	0.30	0.04	0.00	0.04	1.01	464.8	264.5	17.059	17.247	34.3	331
DD1-d3	DDS003	12/10/2012	0.20	0.05	0.00	0.03	0.93	1037.7	432.6	28.847	26.799	55.6	587
DD1-1	DDS010	1/9/2013	0.15	0.12	0.02	0.20	0.75	1614.4	828.2	321.903	240.783	562.7	724
DD1-2	DDS009	1/9/2013	0.19	0.10	0.03	0.16	0.67	2102.0	712.2	332.531	221.133	553.7	
DD1-3	DDS008	1/9/2013	0.37	0.05	0.12	0.57	0.31	1300.4	949.4	734.705	227.759	962.5	
DD1-3	DDS013	2/6/2013	0.20	0.14	0.38	0.46	0.23	1131.6	1534.2	520.782	117.697	638.5	246
DD1-1	DDS021	6/5/2013	0.22	0.06	0.04	0.22	0.80	1979.6	1075.2	436.116	350.201	786.3	1150
DD5-1	DDS004	12/21/2012	0.26	0.11	0.02	0.27	0.73	1928.0	2794.6	525.581	384.725	910.3	2120
DD5-2	DDS005	12/21/2012	0.24	0.07	0.00	0.20	0.78	4047.1	2614.8	825.618	646.459	1472.1	
DD5-4	DDS007	12/21/2012	0.28	0.05	0.31	0.23	0.68	2290.1	1607.3	526.256	356.275	882.5	
DD5-1	DDS018	5/15/2013	0.09	0.04	0.00	0.07	0.98	1723.2	593.1	116.486	114.273	230.8	5130
DD5-2	DDS019	5/15/2013	0.52	0.02	0.07	0.83	0.14	1082.2	4531.6	901.904	127.168	1029.1	
DD5-1	DDS026	6/7/2013	0.23	0.03	0.72	0.26	0.47	1076.4	494.8	284.172	134.413	418.6	4100
DD5-2	DDS027	6/7/2013	0.47	0.07	0.01	0.56	0.37	3467.4	3753.9	1945.218	711.950	2657.2	
DD5-1	DDS2014-001	10/1/2014	0.20	0.06	0.06	0.22	0.71	2270.8	1620.7	494.803	348.836	843.6	
DD5-2	DDS2014-002	10/1/2014	0.21	0.04	0.00	0.08	0.88	3204.8	306.3	247.092	218.182	465.3	
DD5-3	DDS2014-003	10/1/2014	0.19	0.05	0.00	0.11	0.84	3765.8	1425.3	399.172	335.304	734.5	
DD6-1	DDS014	2/7/2013	0.72	0.01	0.20	0.58	0.06	1634.0	1702.5	952.268	57.136	1009.4	2640
DD6-3	DDS016	2/7/2013	0.35	0.05	0.06	0.31	0.68	4724.3	2584.3	1468.304	998.447	2466.8	
DD6-4	DDS017	2/7/2013	0.28	0.09	0.06	0.16	0.86	3061.8	2566.7	487.742	417.507	905.2	
DD6-1	DDS023	6/28/2013	0.13	0.04	0.00	0.07	1.17	3238.4	1196.3	230.898	268.996	499.9	715
DD6-2	DDS024	6/28/2013	0.36	0.03	0.21	0.17	0.27	1702.5	1004.3	284.656	77.142	361.8	
DD6-3	DDS025	6/28/2013	0.21	0.03	0.09	0.10	0.86	895.1	442.1	86.376	74.629	161.0	

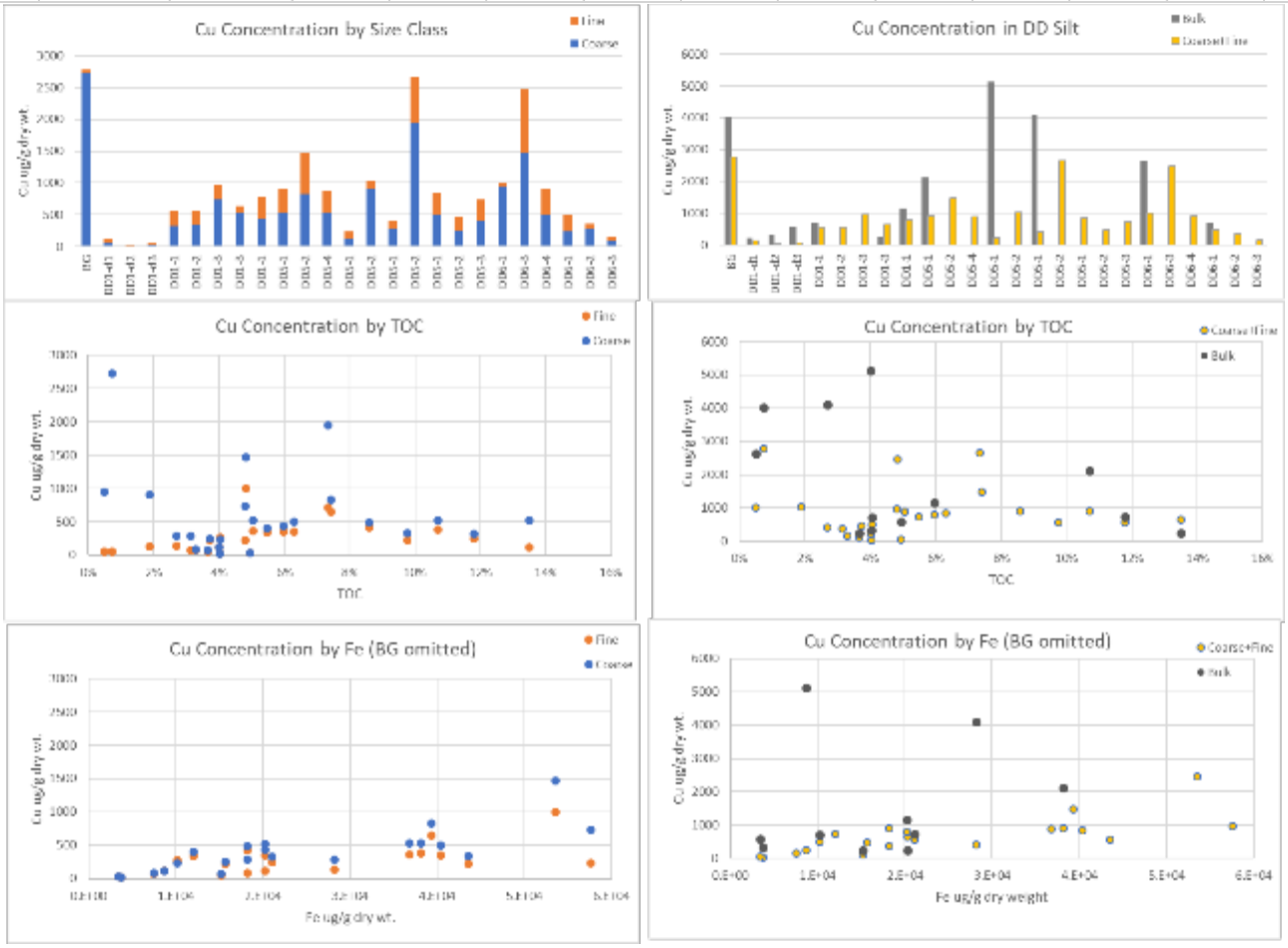


Fig D.3.2.3. Cu concentrations by size class for blasting grit (BG) and dry dock silt samples plotted by sample (upper panels), TOC (middle panels), and Fe (lower panels).

D.3.2.4 Hg size fraction data

Hg Concentration by Size Class														
								Hg ug/g dry wt.						
LocationID	SampleID	C_Date	f_solids	f_TOC	f_>2mm	f_coarse	f_fine	C_coarse	C_fines	L_coarse	L_fines	T_load	f_TOC	BulkC
BG	DDS022	3/15/2013	0.98	0.01	0.01	0.97	0.02	0.002	0.002	0.002	0.000	0.002	0.01	0.05
DD1-d1	DDS001	12/10/2012	0.25	0.04	0.31	0.20	0.77	1.051	0.789	0.207	0.159	0.366	0.04	0.6
DD1-d2	DDS002	12/10/2012	0.30	0.04	0.00	0.04	1.01	1.333	1.009	0.049	0.049	0.098	0.04	0.84
DD1-d3	DDS003	12/10/2012	0.20	0.05	0.00	0.03	0.93	1.283	0.761	0.036	0.033	0.069	0.05	0.89
DD1-1	DDS010	1/9/2013	0.15	0.12	0.02	0.20	0.75	1.019	0.908	0.203	0.152	0.355	0.12	0.79
DD1-2	DDS009	1/9/2013	0.19	0.10	0.03	0.16	0.67	1.191	1.120	0.188	0.125	0.314		
DD1-3	DDS008	1/9/2013	0.37	0.05	0.12	0.57	0.31	0.821	1.149	0.464	0.144	0.608		
DD1-3	DDS013	2/6/2013	0.20	0.14	0.38	0.46	0.23	1.996	1.794	0.918	0.208	1.126	0.14	0.27
DD1-1	DDS021	6/5/2013	0.22	0.06	0.04	0.22	0.80	1.076	1.095	0.237	0.190	0.428	0.06	0.97
DD5-1	DDS004	12/21/2012	0.26	0.11	0.02	0.27	0.73	0.650	0.603	0.177	0.130	0.307	0.11	0.48
DD5-2	DDS005	12/21/2012	0.24	0.07	0.00	0.20	0.78	0.434	0.480	0.088	0.069	0.158		
DD5-4	DDS007	12/21/2012	0.28	0.05	0.31	0.23	0.68	0.165	0.571	0.038	0.026	0.063		
DD5-1	DDS018	5/15/2013	0.09	0.04	0.00	0.07	0.98	1.030	0.322	0.070	0.068	0.138	0.04	0.25
DD5-2	DDS019	5/15/2013	0.52	0.02	0.07	0.83	0.14	0.103	0.601	0.085	0.012	0.097		
DD5-1	DDS026	6/7/2013	0.23	0.03	0.72	0.26	0.47	0.402	0.412	0.106	0.050	0.156	0.03	0.54
DD5-2	DDS027	6/7/2013	0.47	0.07	0.01	0.56	0.37	0.326	0.746	0.183	0.067	0.250		
DD5-1	DDS2014-001	10/1/2014	0.20	0.06	0.06	0.22	0.71	1.544	0.716	0.336	0.237	0.574		
DD5-2	DDS2014-002	10/1/2014	0.21	0.04	0.00	0.08	0.88	1.616	0.558	0.125	0.110	0.235		
DD5-3	DDS2014-003	10/1/2014	0.19	0.05	0.00	0.11	0.84	0.956	0.625	0.101	0.085	0.186		
DD6-1	DDS014	2/7/2013	0.72	0.01	0.20	0.58	0.06	0.184	0.220	0.107	0.006	0.114	0.01	0.39
DD6-3	DDS016	2/7/2013	0.35	0.05	0.06	0.31	0.68	0.411	0.586	0.128	0.087	0.214		
DD6-4	DDS017	2/7/2013	0.28	0.09	0.06	0.16	0.86	0.464	0.564	0.074	0.063	0.137		
DD6-1	DDS023	6/28/2013	0.13	0.04	0.00	0.07	1.17	1.287	0.531	0.092	0.107	0.199	0.04	0.4
DD6-2	DDS024	6/28/2013	0.36	0.03	0.21	0.17	0.27	0.213	0.431	0.036	0.010	0.045		
DD6-3	DDS025	6/28/2013	0.21	0.03	0.09	0.10	0.86	0.668	0.577	0.064	0.056	0.120		

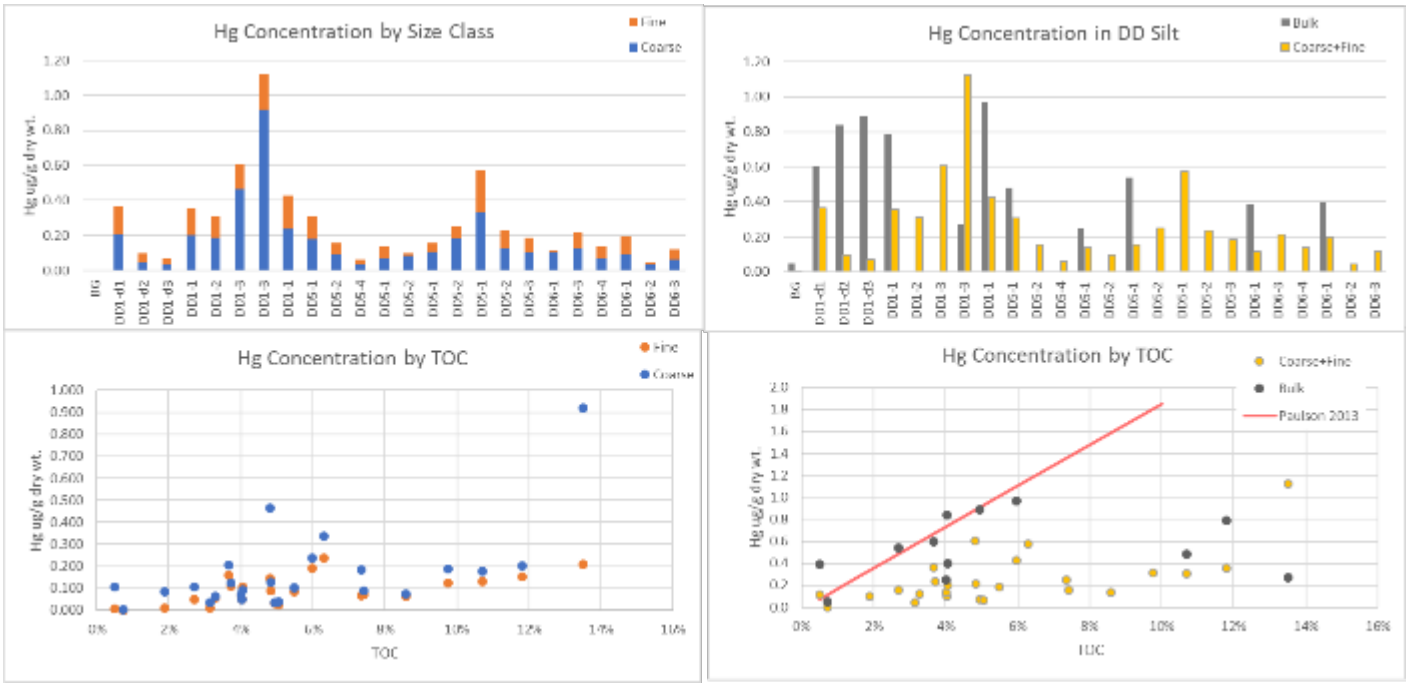


Fig D.3.2.4. Hg concentrations by size class for blasting grit (BG) and dry dock silt samples plotted by sample (upper panel) and TOC (lower panel).

D.3.2.5 Zn size fraction data

Zn Concentration by Size Class													
								Zn ug/g dry wt.					
LocationID	SampleID	C_Date	f_solids	f_TOC	f_>2mm	f_coarse	f_fine	C_coarse	C_fines	L_coarse	L_fines	T_load	BulkC
BG	DDS022	3/15/2013	0.98	0.01	0.01	0.97	0.02	682.4	1190.1	661.214	11.902	673.1	805
DD1-d1	DDS001	12/10/2012	0.25	0.04	0.31	0.20	0.77	785.4	569.0	154.808	118.583	273.4	500
DD1-d2	DDS002	12/10/2012	0.30	0.04	0.00	0.04	1.01	999.7	555.2	36.690	37.093	73.8	509
DD1-d3	DDS003	12/10/2012	0.20	0.05	0.00	0.03	0.93	1440.2	661.2	40.039	37.196	77.2	732
DD1-1	DDS010	1/9/2013	0.15	0.12	0.02	0.20	0.75	4029.0	1896.9	803.383	600.931	1404.3	1860
DD1-2	DDS009	1/9/2013	0.19	0.10	0.03	0.16	0.67	4621.5	2137.6	731.119	486.194	1217.3	
DD1-3	DDS008	1/9/2013	0.37	0.05	0.12	0.57	0.31	2539.9	3081.5	1435.071	444.872	1879.9	
DD1-3	DDS013	2/6/2013	0.20	0.14	0.38	0.46	0.23	2666.6	4323.6	1227.165	277.339	1504.5	417
DD1-1	DDS021	6/5/2013	0.22	0.06	0.04	0.22	0.80	2782.4	1828.0	612.953	492.201	1105.2	1720
DD5-1	DDS004	12/21/2012	0.26	0.11	0.02	0.27	0.73	6609.8	6367.5	1801.820	1318.932	3120.8	6319
DD5-2	DDS005	12/21/2012	0.24	0.07	0.00	0.20	0.78	13427.9	9133.2	2739.299	2144.871	4884.2	
DD5-4	DDS007	12/21/2012	0.28	0.05	0.31	0.23	0.68	8295.9	4163.2	1906.390	1290.626	3197.0	
DD5-1	DDS018	5/15/2013	0.09	0.04	0.00	0.07	0.98	4934.9	1710.0	333.600	327.261	660.9	14700
DD5-2	DDS019	5/15/2013	0.52	0.02	0.07	0.83	0.14	7642.1	11035.4	6368.899	898.015	7266.9	
DD5-1	DDS026	6/7/2013	0.23	0.03	0.72	0.26	0.47	3241.7	1553.3	855.816	404.801	1260.6	16000
DD5-2	DDS027	6/7/2013	0.47	0.07	0.01	0.56	0.37	17477.2	15180.7	9804.701	3588.521	13393.2	
DD5-1	DDS2014-001	10/1/2014	0.20	0.06	0.06	0.22	0.71	7354.7	2010.9	1602.579	1129.818	2732.4	
DD5-2	DDS2014-002	10/1/2014	0.21	0.04	0.00	0.08	0.88	11442.6	380.0	882.223	779.003	1661.2	
DD5-3	DDS2014-003	10/1/2014	0.19	0.05	0.00	0.11	0.84	5863.2	1361.5	621.500	522.060	1143.6	
DD6-1	DDS014	2/7/2013	0.72	0.01	0.20	0.58	0.06	2885.0	3387.2	1681.356	100.881	1782.2	5270
DD6-3	DDS016	2/7/2013	0.35	0.05	0.06	0.31	0.68	14704.4	4421.6	4570.141	3107.696	7677.8	
DD6-4	DDS017	2/7/2013	0.28	0.09	0.06	0.16	0.86	17603.2	7795.5	2804.196	2400.392	5204.6	
DD6-1	DDS023	6/28/2013	0.13	0.04	0.00	0.07	1.17	2620.3	1080.1	186.826	217.652	404.5	709
DD6-2	DDS024	6/28/2013	0.36	0.03	0.21	0.17	0.27	9878.8	2897.2	1651.736	447.620	2099.4	
DD6-3	DDS025	6/28/2013	0.21	0.03	0.09	0.10	0.86	951.3	432.7	91.799	79.314	171.1	

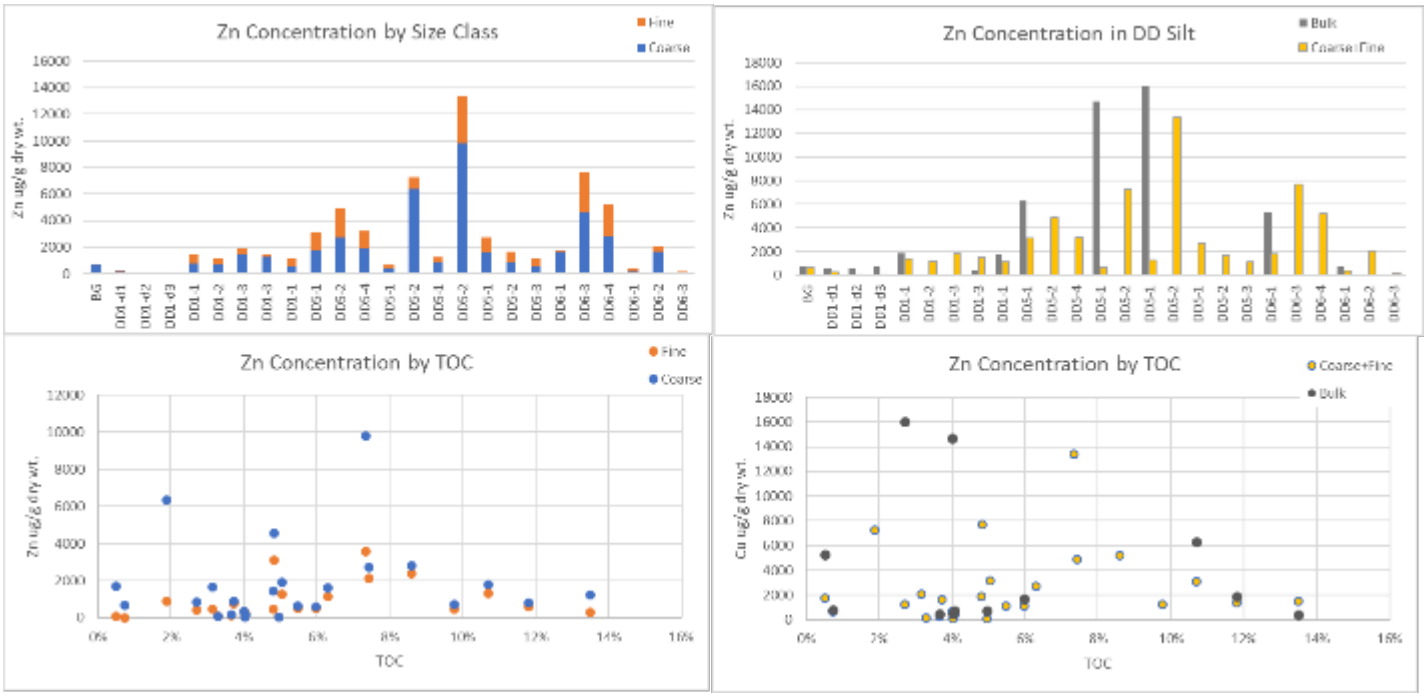


Fig D.3.2.5. Zn concentrations by size class for blasting grit (BG) and dry dock silt samples plotted by sample (upper panel) and TOC (lower panel).

D.3.2.6 Pb size fraction data

Pb Concentration by Size Class													
								Pb ug/g dry wt.					
LocationID	SampleID	C_Date	f_solids	f_TOC	f_>2mm	f_coarse	f_fine	C_coarse	C_fines	L_coarse	L_fines	T_load	BulkC
BG	DDS022	3/15/2013	0.98	0.01	0.01	0.97	0.02	42.4	33.7	41	1	42	35
DD1-d1	DDS001	12/10/2012	0.25	0.04	0.31	0.20	0.77	567.3	94.5	112	86	197	81
DD1-d2	DDS002	12/10/2012	0.30	0.04	0.00	0.04	1.01	121.6	81.9	4	5	9	86
DD1-d3	DDS003	12/10/2012	0.20	0.05	0.00	0.03	0.93	157.7	93.3	4	4	8	90
DD1-1	DDS010	1/9/2013	0.15	0.12	0.02	0.20	0.75	228.4	126.4	46	34	80	112
DD1-2	DDS009	1/9/2013	0.19	0.10	0.03	0.16	0.67	158.2	123.0	25	17	42	
DD1-3	DDS008	1/9/2013	0.37	0.05	0.12	0.57	0.31	165.8	171.8	94	29	123	
DD1-3	DDS013	2/6/2013	0.20	0.14	0.38	0.46	0.23	149.4	225.5	69	16	84	28
DD1-1	DDS021	6/5/2013	0.22	0.06	0.04	0.22	0.80	272.1	121.5	60	48	108	128
DD5-1	DDS004	12/21/2012	0.26	0.11	0.02	0.27	0.73	370.6	401.0	101	74	175	180
DD5-2	DDS005	12/21/2012	0.24	0.07	0.00	0.20	0.78	377.6	213.3	77	60	137	
DD5-4	DDS007	12/21/2012	0.28	0.05	0.31	0.23	0.68	175.6	132.0	40	27	68	
DD5-1	DDS018	5/15/2013	0.09	0.04	0.00	0.07	0.98	245.1	60.3	17	16	33	948
DD5-2	DDS019	5/15/2013	0.52	0.02	0.07	0.83	0.14	187.8	310.0	157	22	179	
DD5-1	DDS026	6/7/2013	0.23	0.03	0.72	0.26	0.47	192.9	71.3	51	24	75	239
DD5-2	DDS027	6/7/2013	0.47	0.07	0.01	0.56	0.37	328.3	227.0	184	67	252	
DD5-1	DDS2014-001	10/1/2014	0.20	0.06	0.06	0.22	0.71	507.5	128.8	111	78	189	
DD5-2	DDS2014-002	10/1/2014	0.21	0.04	0.00	0.08	0.88	365.4	59.0	28	25	53	
DD5-3	DDS2014-003	10/1/2014	0.19	0.05	0.00	0.11	0.84	274.3	96.1	29	24	53	
DD6-1	DDS014	2/7/2013	0.72	0.01	0.20	0.58	0.06	53.1	45.0	31	2	33	93
DD6-3	DDS016	2/7/2013	0.35	0.05	0.06	0.31	0.68	310.3	93.1	96	66	162	
DD6-4	DDS017	2/7/2013	0.28	0.09	0.06	0.16	0.86	137.4	107.0	22	19	41	
DD6-1	DDS023	6/28/2013	0.13	0.04	0.00	0.07	1.17	140.3	68.7	10	12	22	46
DD6-2	DDS024	6/28/2013	0.36	0.03	0.21	0.17	0.27	431.8	59.6	72	20	92	
DD6-3	DDS025	6/28/2013	0.21	0.03	0.09	0.10	0.86	118.1	53.2	11	10	21	

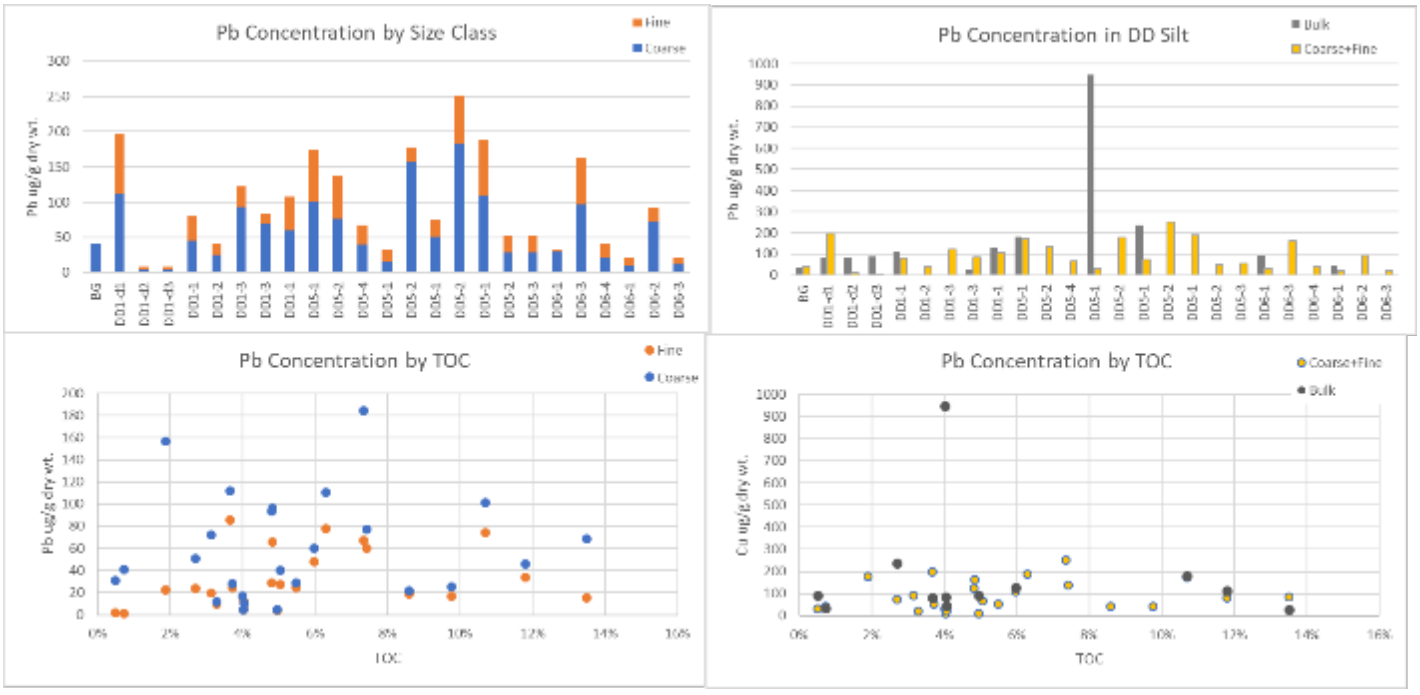


Fig D.3.2.6. Pb concentrations by size class for blasting grit (BG) and dry dock silt samples plotted by sample (upper panel) and TOC (lower panel).

D.3.2.7 Ni size fraction data

Ni Concentration by Size Class													
								Ni ug/g dry wt.					
LocationID	SampleID	C_Date	f_solids	f_TOC	f_>2mm	f_coarse	f_fine	C_coarse	C_fines	L_coarse	L_fines	T_load	BulkC
BG	DDS022	3/15/2013	0.98	0.01	0.01	0.97	0.02	713.0	431.3	691	12	703	605
DD1-d1	DDS001	12/10/2012	0.25	0.04	0.31	0.20	0.77	94.6	71.8	19	14	33	55
DD1-d2	DDS002	12/10/2012	0.30	0.04	0.00	0.04	1.01	221.0	113.3	8	8	16	259
DD1-d3	DDS003	12/10/2012	0.20	0.05	0.00	0.03	0.93	334.6	137.2	9	9	18	168
DD1-1	DDS010	1/9/2013	0.15	0.12	0.02	0.20	0.75	443.3	258.4	88	66	155	230
DD1-2	DDS009	1/9/2013	0.19	0.10	0.03	0.16	0.67	1351.5	296.3	214	142	356	
DD1-3	DDS008	1/9/2013	0.37	0.05	0.12	0.57	0.31	604.5	449.6	342	106	447	
DD1-3	DDS013	2/6/2013	0.20	0.14	0.38	0.46	0.23	156.0	261.4	72	16	88	20
DD1-1	DDS021	6/5/2013	0.22	0.06	0.04	0.22	0.80	309.5	101.0	68	55	123	136
DD5-1	DDS004	12/21/2012	0.26	0.11	0.02	0.27	0.73	612.4	561.3	167	122	289	226
DD5-2	DDS005	12/21/2012	0.24	0.07	0.00	0.20	0.78	558.6	184.5	114	89	203	
DD5-4	DDS007	12/21/2012	0.28	0.05	0.31	0.23	0.68	358.8	144.5	82	56	138	
DD5-1	DDS018	5/15/2013	0.09	0.04	0.00	0.07	0.98	202.4	67.3	14	13	27	1140
DD5-2	DDS019	5/15/2013	0.52	0.02	0.07	0.83	0.14	1041.6	336.7	868	122	990	
DD5-1	DDS026	6/7/2013	0.23	0.03	0.72	0.26	0.47	268.9	79.5	71	34	105	309
DD5-2	DDS027	6/7/2013	0.47	0.07	0.01	0.56	0.37	422.2	327.3	237	87	324	
DD5-1	DDS2014-001	10/1/2014	0.20	0.06	0.06	0.22	0.71	264.3	117.3	58	41	98	
DD5-2	DDS2014-002	10/1/2014	0.21	0.04	0.00	0.08	0.88	220.2	42.7	17	15	32	
DD5-3	DDS2014-003	10/1/2014	0.19	0.05	0.00	0.11	0.84	278.7	84.5	30	25	54	
DD6-1	DDS014	2/7/2013	0.72	0.01	0.20	0.58	0.06	550.7	207.0	321	19	340	108
DD6-3	DDS016	2/7/2013	0.35	0.05	0.06	0.31	0.68	355.2	119.4	110	75	185	
DD6-4	DDS017	2/7/2013	0.28	0.09	0.06	0.16	0.86	155.9	123.6	25	21	46	
DD6-1	DDS023	6/28/2013	0.13	0.04	0.00	0.07	1.17	267.8	102.7	19	22	41	56
DD6-2	DDS024	6/28/2013	0.36	0.03	0.21	0.17	0.27	209.0	73.8	35	9	44	
DD6-3	DDS025	6/28/2013	0.21	0.03	0.09	0.10	0.86	115.6	48.8	11	10	21	

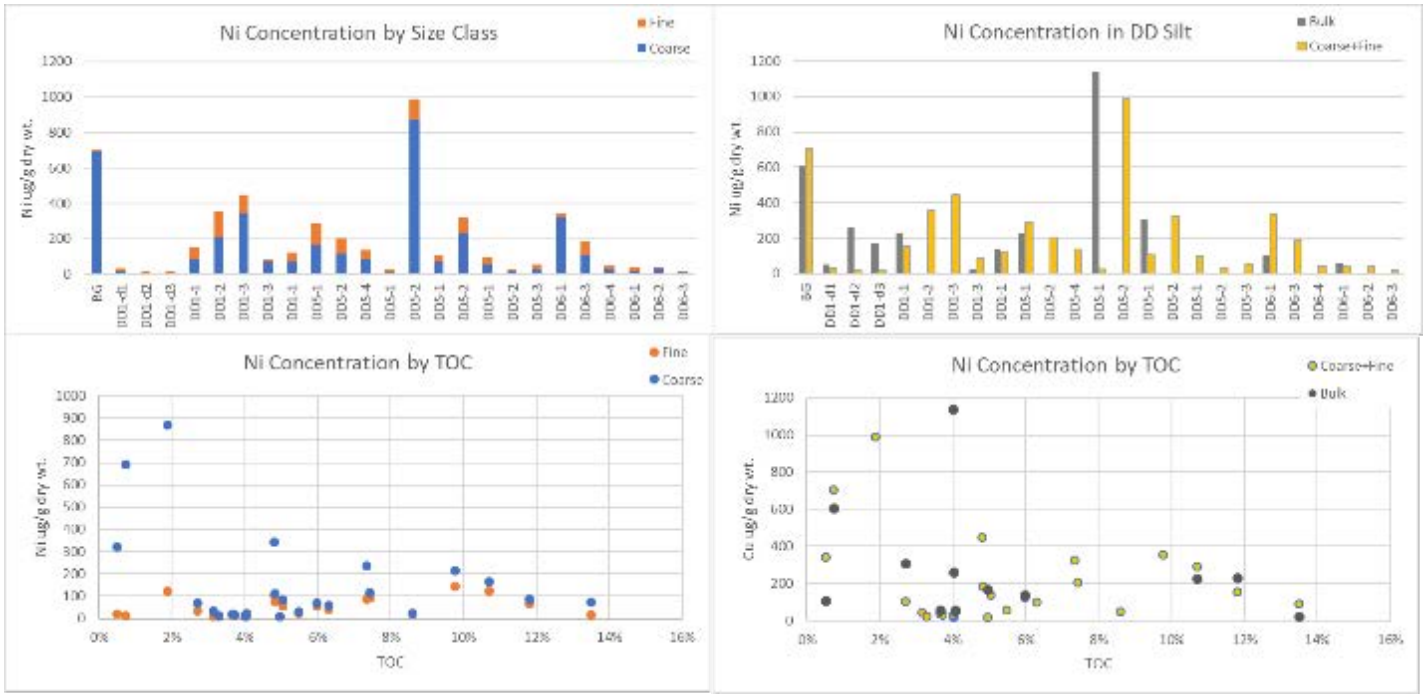


Fig D.3.2.7. Ni concentrations by size class for blasting grit (BG) and dry dock silt samples plotted by sample (upper panel) and TOC (lower panel).

D.3.2.8 Cr size fraction data

Cr Concentration by Size Class												
								Cr ug/g dry wt.				
LocationID	SampleID	C_Date	f_solids	f_TOC	f_>2mm	f_coarse	f_fine	C_coarse	C_fines	L_coarse	L_fines	T_load
BG	DDS022	3/15/2013	0.98	0.01	0.01	0.97	0.02	1974.4	830.5	1912.964	34.433	1947.4
DD1-d1	DDS001	12/10/2012	0.25	0.04	0.31	0.20	0.77	105.5	85.8	20.793	15.927	36.7
DD1-d2	DDS002	12/10/2012	0.30	0.04	0.00	0.04	1.01	198.9	96.3	7.298	7.378	14.7
DD1-d3	DDS003	12/10/2012	0.20	0.05	0.00	0.03	0.93	263.4	111.8	7.324	6.804	14.1
DD1-1	DDS010	1/9/2013	0.15	0.12	0.02	0.20	0.75	241.5	158.6	48.145	36.013	84.2
DD1-2	DDS009	1/9/2013	0.19	0.10	0.03	0.16	0.67	1132.4	165.0	179.145	119.132	298.3
DD1-3	DDS008	1/9/2013	0.37	0.05	0.12	0.57	0.31	527.6	454.7	298.105	92.412	390.5
DD1-3	DDS013	2/6/2013	0.20	0.14	0.38	0.46	0.23	132.0	205.8	60.741	13.728	74.5
DD1-1	DDS021	6/5/2013	0.22	0.06	0.04	0.22	0.80	242.6	101.3	53.445	42.916	96.4
DD5-1	DDS004	12/21/2012	0.26	0.11	0.02	0.27	0.73	448.9	404.9	122.382	89.584	212.0
DD5-2	DDS005	12/21/2012	0.24	0.07	0.00	0.20	0.78	437.3	150.5	89.200	69.843	159.0
DD5-4	DDS007	12/21/2012	0.28	0.05	0.31	0.23	0.68	325.6	143.8	74.833	50.662	125.5
DD5-1	DDS018	5/15/2013	0.09	0.04	0.00	0.07	0.98	170.7	64.5	11.541	11.322	22.9
DD5-2	DDS019	5/15/2013	0.52	0.02	0.07	0.83	0.14	1058.2	177.5	881.897	124.347	1006.2
DD5-1	DDS026	6/7/2013	0.23	0.03	0.72	0.26	0.47	253.5	75.6	66.932	31.659	98.6
DD5-2	DDS027	6/7/2013	0.47	0.07	0.01	0.56	0.37	444.2	184.7	249.219	91.214	340.4
DD5-1	DDS2014-001	10/1/2014	0.20	0.06	0.06	0.22	0.71	299.0	121.2	65.162	45.939	111.1
DD5-2	DDS2014-002	10/1/2014	0.21	0.04	0.00	0.08	0.88	278.3	84.1	21.457	18.946	40.4
DD5-3	DDS2014-003	10/1/2014	0.19	0.05	0.00	0.11	0.84	212.1	110.7	22.480	18.883	41.4
DD6-1	DDS014	2/7/2013	0.72	0.01	0.20	0.58	0.06	765.6	198.4	446.200	26.772	473.0
DD6-3	DDS016	2/7/2013	0.35	0.05	0.06	0.31	0.68	386.8	115.3	120.224	81.752	202.0
DD6-4	DDS017	2/7/2013	0.28	0.09	0.06	0.16	0.86	129.2	135.4	20.581	17.618	38.2
DD6-1	DDS023	6/28/2013	0.13	0.04	0.00	0.07	1.17	172.7	94.5	12.310	14.341	26.7
DD6-2	DDS024	6/28/2013	0.36	0.03	0.21	0.17	0.27	325.8	87.1	54.468	14.761	69.2
DD6-3	DDS025	6/28/2013	0.21	0.03	0.09	0.10	0.86	149.9	79.6	14.468	12.500	27.0

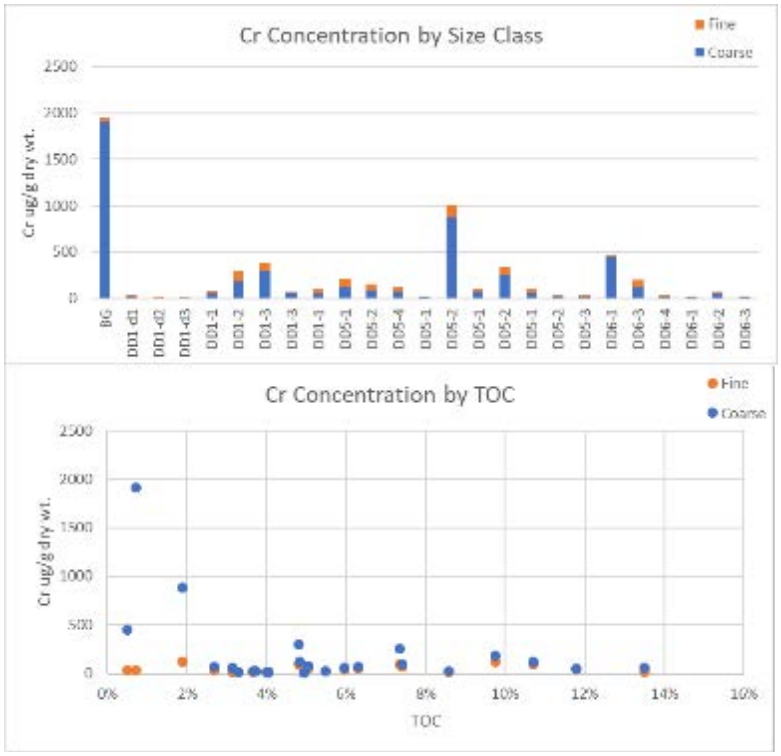


Fig D.3.2.8. Cr concentrations by size class for blasting grit (BG) and dry dock silt samples plotted by sample (upper panel) and TOC (lower panel).

D.3.2.9 Al size fraction data

Al Concentration by Size Class													
								Al ug/g dry wt.					
LocationID	SampleID	C_Date	f_solids	f_TOC	f_>2mm	f_coarse	f_fine	C_coarse	C_fines	L_coarse	L_fines	T_load	BulkC
BG	DDS022	3/15/2013	0.98	0.01	0.01	0.97	0.02	370.8	1225.9	359	6	366	244
DD1-d1	DDS001	12/10/2012	0.25	0.04	0.31	0.20	0.77	42915.1	49101.4	8459	6479	14938	13600
DD1-d2	DDS002	12/10/2012	0.30	0.04	0.00	0.04	1.01	61084.0	51659.2	2242	2266	4508	19100
DD1-d3	DDS003	12/10/2012	0.20	0.05	0.00	0.03	0.93	55836.4	52671.3	1552	1442	2994	17900
DD1-1	DDS010	1/9/2013	0.15	0.12	0.02	0.20	0.75	36326.4	46545.7	7243	5418	12662	9900
DD1-2	DDS009	1/9/2013	0.19	0.10	0.03	0.16	0.67	25606.8	46153.5	4051	2694	6745	
DD1-3	DDS008	1/9/2013	0.37	0.05	0.12	0.57	0.31	34637.8	49857.5	19570	6067	25637	
DD1-3	DDS013	2/6/2013	0.20	0.14	0.38	0.46	0.23	26383.6	50630.3	12142	2744	14886	1580
DD1-1	DDS021	6/5/2013	0.22	0.06	0.04	0.22	0.80	39252.2	48492.6	8647	6944	15591	14200
DD5-1	DDS004	12/21/2012	0.26	0.11	0.02	0.27	0.73	33756.8	46132.7	9202	6736	15938	17800
DD5-2	DDS005	12/21/2012	0.24	0.07	0.00	0.20	0.78	31827.8	44077.2	6493	5084	11577	
DD5-4	DDS007	12/21/2012	0.28	0.05	0.31	0.23	0.68	40807.2	54044.9	9378	6349	15726	
DD5-1	DDS018	5/15/2013	0.09	0.04	0.00	0.07	0.98	45585.5	30782.3	3082	3023	6105	18400
DD5-2	DDS019	5/15/2013	0.52	0.02	0.07	0.83	0.14	44243.7	33211.5	36873	5199	42072	
DD5-1	DDS026	6/7/2013	0.23	0.03	0.72	0.26	0.47	46710.4	43073.9	12332	5833	18164	12500
DD5-2	DDS027	6/7/2013	0.47	0.07	0.01	0.56	0.37	32386.6	34851.6	18169	6650	24819	
DD5-1	DDS2014-001	10/1/2014	0.20	0.06	0.06	0.22	0.71	40617.7	46184.9	8851	6240	15090	
DD5-2	DDS2014-002	10/1/2014	0.21	0.04	0.00	0.08	0.88	42772.4	57857.5	3298	2912	6210	
DD5-3	DDS2014-003	10/1/2014	0.19	0.05	0.00	0.11	0.84	42923.7	54095.4	4550	3822	8372	
DD6-1	DDS014	2/7/2013	0.72	0.01	0.20	0.58	0.06	2315.3	4064.2	1349	81	1430	18800
DD6-3	DDS016	2/7/2013	0.35	0.05	0.06	0.31	0.68	28277.4	54272.8	8789	5976	14765	
DD6-4	DDS017	2/7/2013	0.28	0.09	0.06	0.16	0.86	23156.8	52453.4	3689	3158	6847	
DD6-1	DDS023	6/28/2013	0.13	0.04	0.00	0.07	1.17	44810.2	51506.6	3195	3722	6917	11400
DD6-2	DDS024	6/28/2013	0.36	0.03	0.21	0.17	0.27	25801.4	51835.7	4314	1169	5483	
DD6-3	DDS025	6/28/2013	0.21	0.03	0.09	0.10	0.86	55159.2	53842.6	5323	4599	9922	

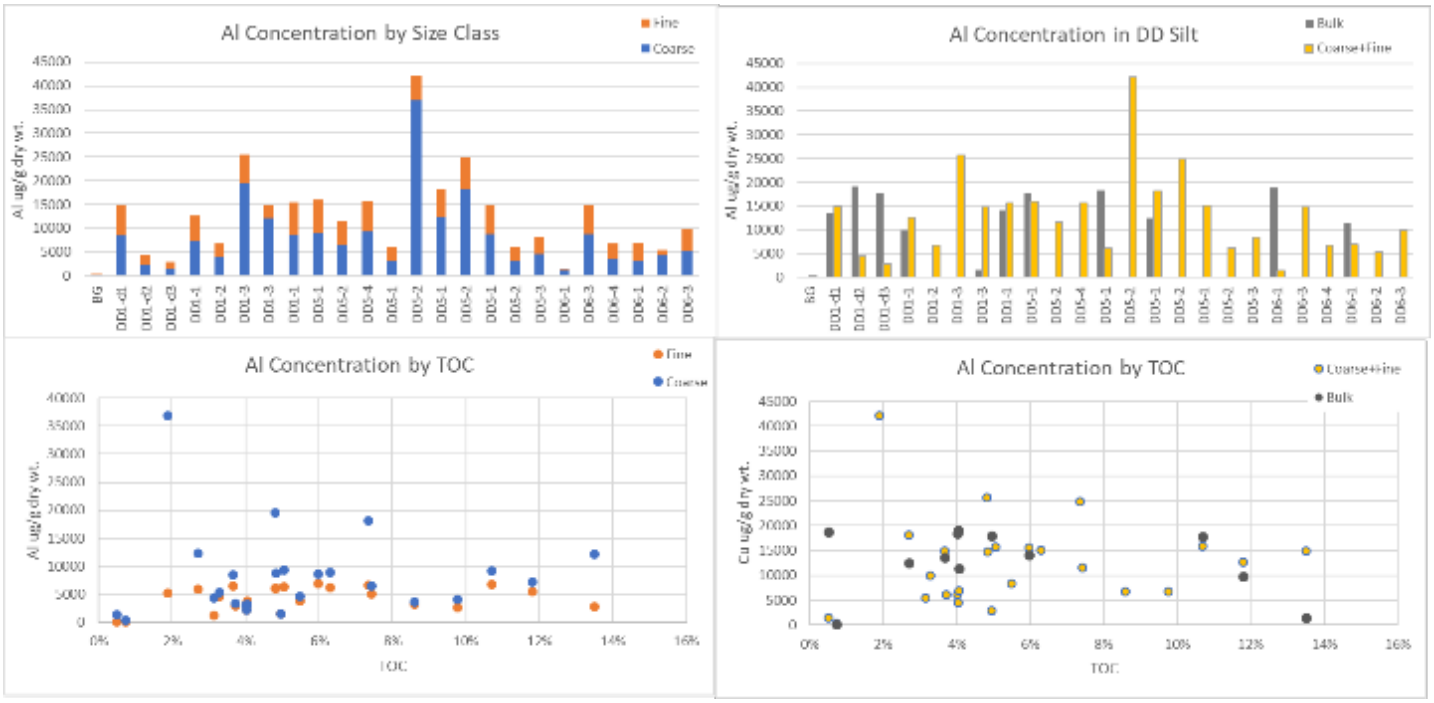
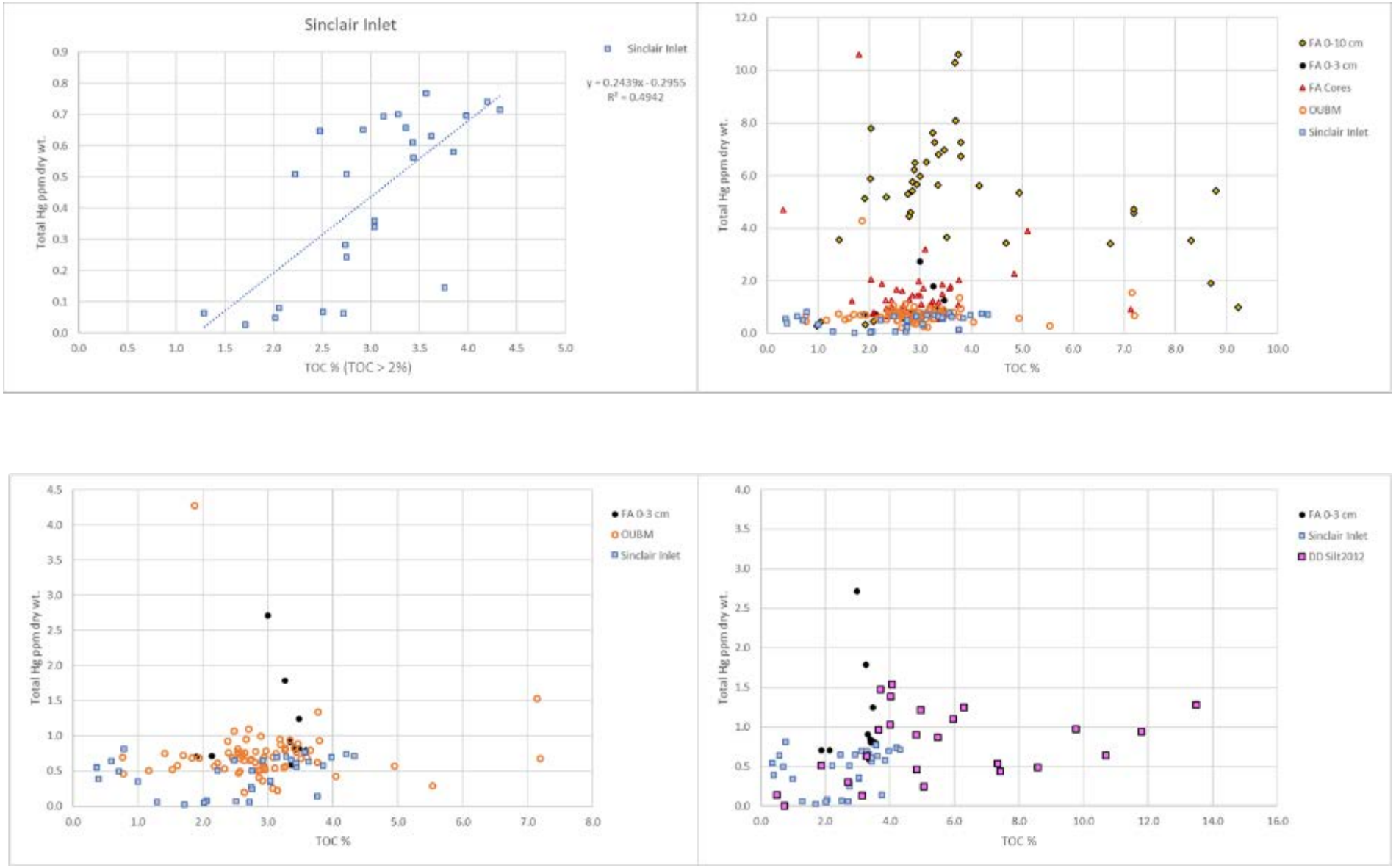
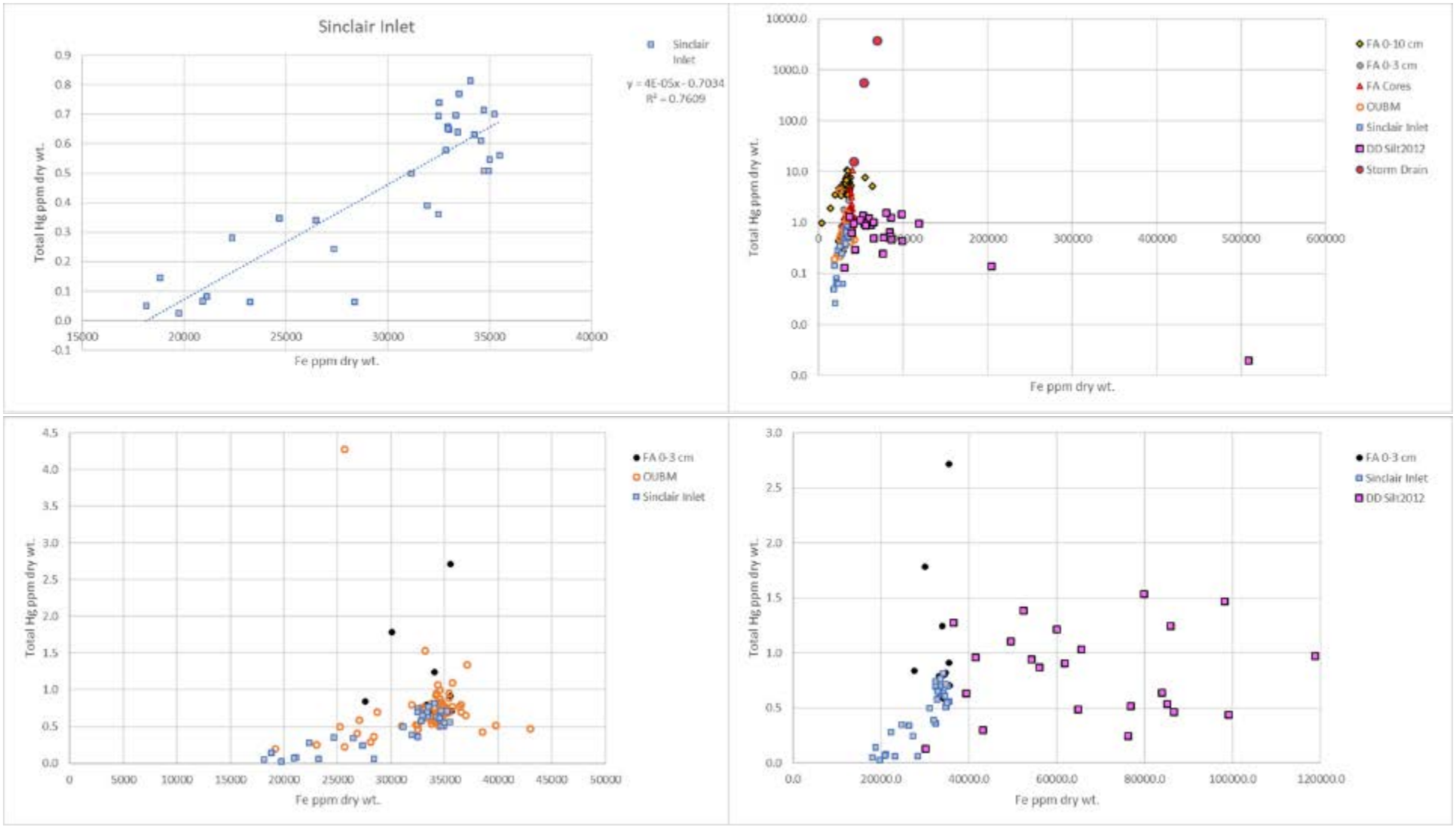


Fig D.3.2.9. Al concentrations by size class for blasting grit (BG) and dry dock silt samples plotted by sample (upper panel) and TOC (lower panel).

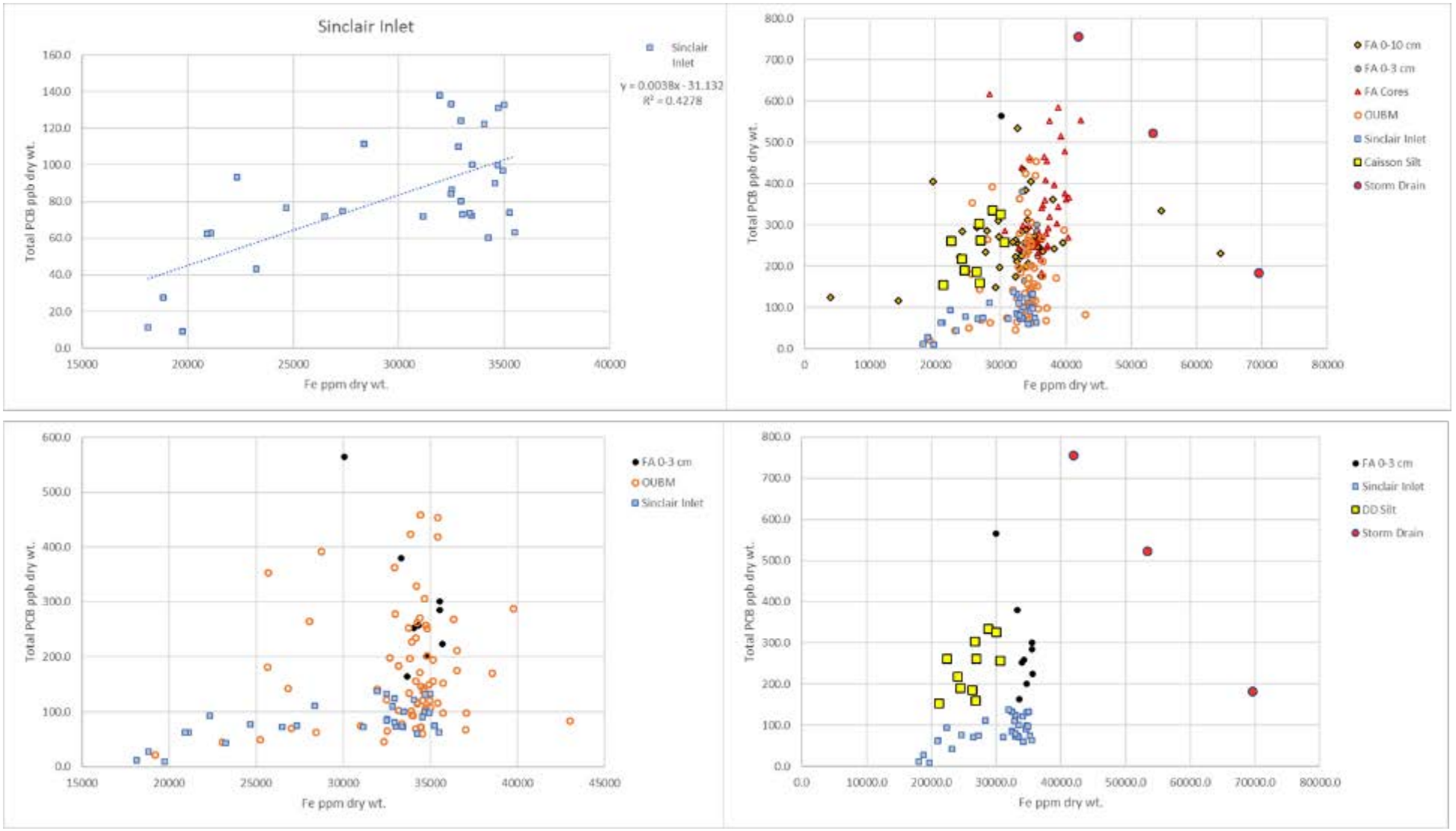
D.4 Appendix D.4 Geochemical Distributions



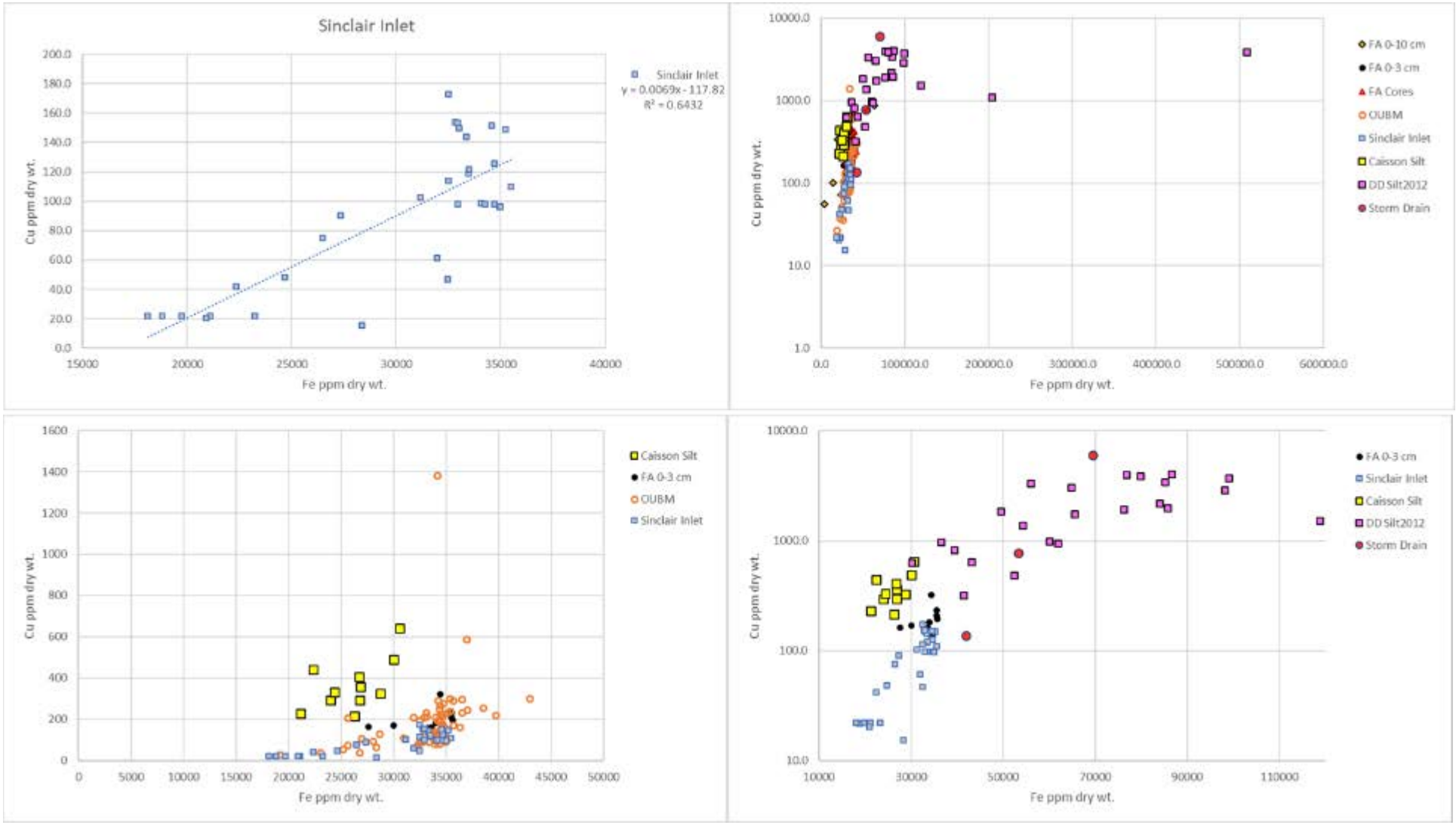
Total Hg as a function of TOC for Sinclair Inlet 1500 ft grids and least squares trend line (upper left panel), including OUBM 500 ft grids and focus area (FA) 0-3 cm sections (lower left panel), including FA 0-10 cm grabs and FA core sections deeper than 3 cm (upper right panel), and DD silt samples collected after 2012 (lower right panel).



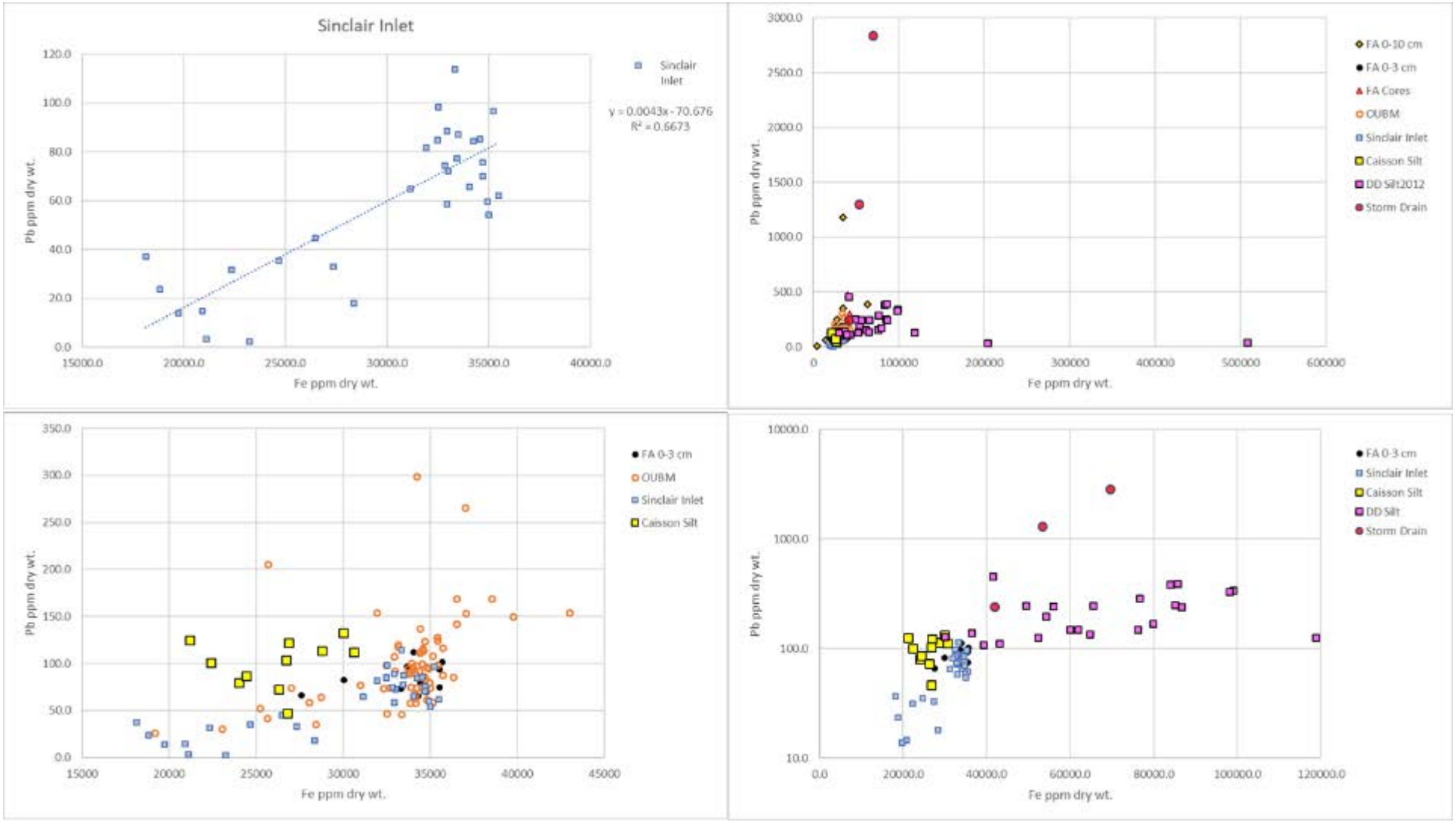
Total Hg as a function of Fe for Sinclair Inlet 1500 ft grids and least squares trend line (upper left panel), including OUBM 500 ft grids and focus area (FA) 0-3 cm sections (lower left panel), including FA 0-10 cm grabs, FA core sections deeper than 3 cm, and Storm Drain samples (upper right panel), and DD silt samples collected after 2012 (lower right panel).



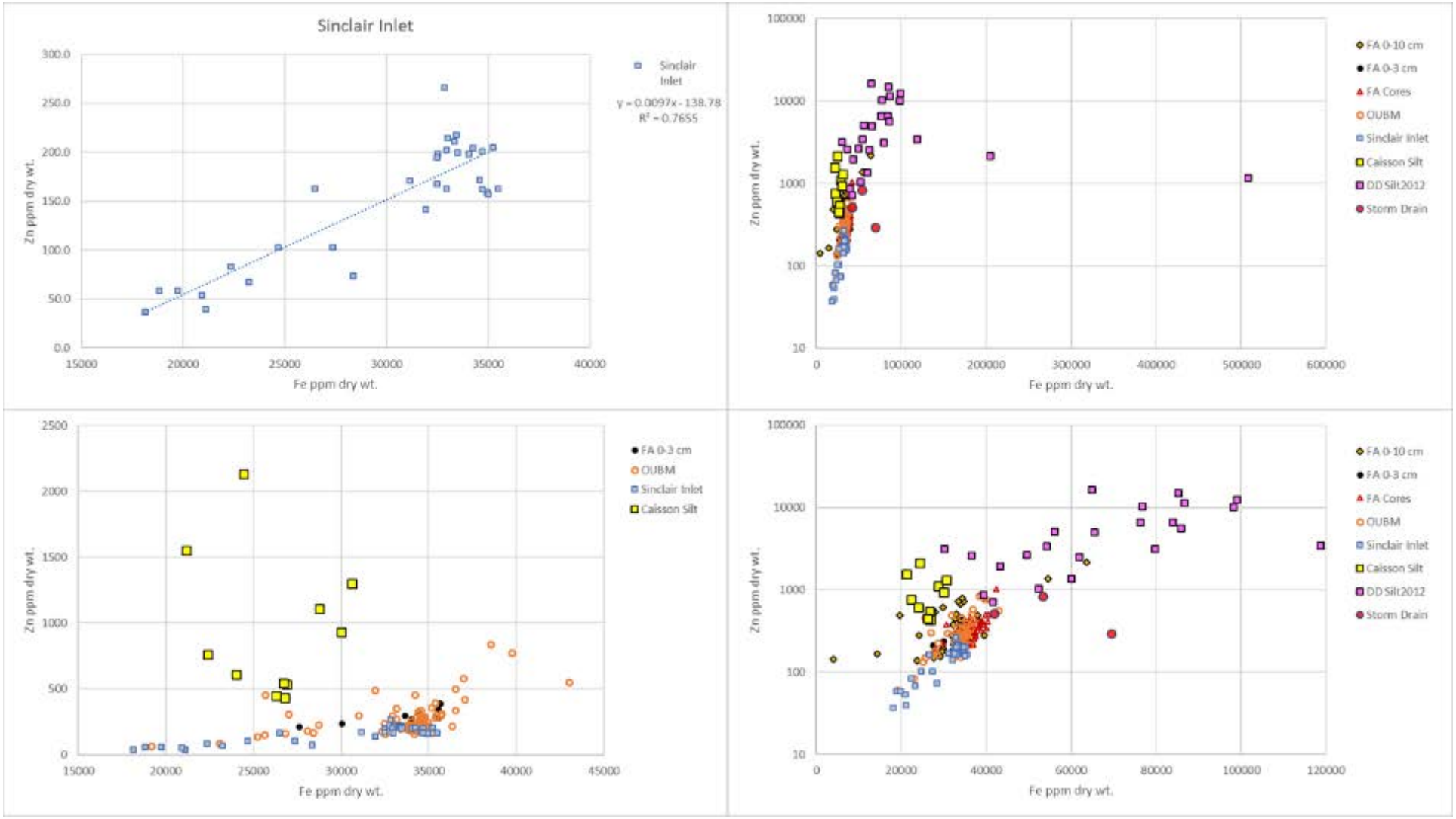
Total PCB as a function of Fe for Sinclair Inlet 1500 ft grids and least squares trend line (upper left panel), including OUBM 500 ft grids and focus area (FA) 0-3 cm sections (lower left panel), including FA 0-10 cm grabs, FA core sections deeper than 3 cm, Storm Drain, and Caisson Silt samples (upper right panel), and selected samples (lower right panel).



Cu as a function of Fe for Sinclair Inlet 1500 ft grids and least squares trend line (upper left panel), including OUBM 500 ft grids and focus area (FA) 0-3 cm sections, and Caisson Silt samples (lower left panel), including FA 0-10 cm grabs, FA core sections deeper than 3 cm, Storm Drain, and DD Silt samples, (upper right panel), and selected samples (lower right panel).



Pb as a function of Fe for Sinclair Inlet 1500 ft grids and least squares trend line (upper left panel), including OUBM 500 ft grids and focus area (FA) 0-3 cm sections, and Caisson Silt samples (lower left panel), including FA 0-10 cm grabs, FA core sections deeper than 3 cm, Storm Drain, and DD Silt samples, (upper right panel), and selected samples (lower right panel).



Zn as a function of Fe for Sinclair Inlet 1500 ft grids and least squares trend line (upper left panel), including OUBM 500 ft grids and focus area (FA) 0-3 cm sections, and Caisson Silt samples (lower left panel), including FA 0-10 cm grabs, FA core sections deeper than 3 cm, Storm Drain, and DD Silt samples, (upper right panel), and selected samples (lower right panel).

Appendix E : Appendix E Spatial Distribution of Mercury in Puget Sound Sediments

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