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Annual Report: 2010-2011 Storm Season Sampling for None-Dry Dock Stormwater Monitoring for Puget Sound Naval Shipyard, Bremerton WA

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September 2012

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FINAL

Annual Report: 2010-2011 Storm Season Sampling

For

NON-DRY DOCK STORMWATER MONITORING FOR PUGET SOUND NAVAL SHIPYARD, BREMERTON, WA

PSNS Project ENVVEST Study Area

September 2012

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And

Taylor Associates Division of TEC

Contract No.: N4523A10MP00034 Amendment 1

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ACROYNMS

Ag	Silver
Al	Aluminum
As	Arsenic
BLM	Biotic Ligand Model
BMP	Best Management Practice
BNC	Bremerton Naval Complex
C&I	Commercial and Industrial Land-use and Land-cover
CAS	Columbia Analytical Services
CIA	Controlled Industrial Area
CFR	Codes of Federal Registration
Cd	Cadmium
CDMA	Code Division Multiple Access
COC	Chain-of-Custody
Cu	Copper
CWA	Clean Water Act
DI	Deionized Water
DME	Dissolved Metals
DOC	Dissolved Organic Carbon
DOD	Department of Defense
DRO	Diesel Range TPH
DUP	Laboratory Duplicate
EB	Equipment Blank
Ecology	Washington State Department of Ecology
EMC	Event Mean Composite

ENVVEST	Project Environmental Investment (U.S. Navy)
ES&H	Field Environmental Health and Safety Plan
FC	Fecal Coliform
GFF	Glass Fiber Filter
Hg	Mercury
HRD	Hardness
HSPF	Hydrological Simulation Model Program Fortran
ICP-MS	Inductively Coupled Plasma/ Mass Spectrometer
INW	Instrumentations Northwest Inc.
LCS	Laboratory Control Sample
LDPE	Low Density Polyethylene
LULC	Land-use and Land-cover
MDL	Method Detection Limit
MS	Matrix Spike
MSD	Matrix Spike Duplicate
MLLW	Mean Lower Low Water
NBK	Naval Base Kitsap
NPDES	National Pollutant Discharge Elimination System
NWTPH-Dx	Northwest Total Petroleum Hydrocarbons – Diesel fraction
Pb	Lead
PME	Particulate Metals
PNNL	Pacific Northwest National Laboratories
PP	Polypropylene
PPB	Parts-per-billion
PPT	Parts-per-thousand
PSNS&IMF	Puget Sound Naval Shipyard & Intermediate Maintenance Facility

PVDF Polyvinylidene Fluoride

PWP Project Work Plan

QAPP Quality Assurance Project Plan (documented in the PWP)

QA/QC Quality Assurance/Quality Control

RCM Runoff Coefficient Method

RL Reporting Limit

RO Storm Runoff

RPD Relative Percent Difference

RRO Residual Range TPH

SRM Standard Reference Material

TMDL Total Maximum Daily Load

TME Total Metals

TOC Total Organic Carbon

TPH Total Petroleum Hydrocarbon

TR or TRM Total Recoverable Metals

TSS Total Suspended Solids

USEPA U.S. Environmental Protection Agency

USGS United Stated Geological Survey

Zn Zinc

1.0 INTRODUCTION

The Puget Sound Naval Shipyard & Intermediate Maintenance Facility (PSNS&IMF) and Naval Base Kitsap-Bremerton (NBK-Bremerton) located in Bremerton, WA are committed to a culture of continuous process improvement for all aspects of shipyard operations, including reducing the release of hazardous substances in stormwater discharges. The facilities are collectively known as the Bremerton Naval Complex (BNC) and referred to as the Shipyard, for brevity. The Shipyard is located about 15 miles west of Seattle, Washington along the northern shore of Sinclair Inlet on Puget Sound and is bounded by the City of Bremerton (Figure 1). The complex covers approximately 350 acres of land and an additional 340 acres of tidelands along 11,000 feet of shoreline and contains over 300 buildings and structures consisting of industrial, supply and base facilities, a steam plant, six dry docks, piers and numerous moorings. The predominant land cover within the Shipyard is rooftops, paved areas (roads, parking areas, sidewalks, and concrete working areas), and piers.

The Shipyard is divided into two areas: 1) Controlled Industrial Area (CIA) and 2) NBK (Figure 2). The CIA is one of Washington State's largest industrial installations and is responsible for overhaul, maintenance, docking, refueling, and decommissioning of naval vessels, as well as, dismantling of ships and submarines. The NBK provides base operating services, including support for home-ported surface ships and submarines. Support areas include housing, parking, shopping, entertainment, and recreation facilities. The stormwater system draining these two areas includes 156 distinct storm drainage systems, many of which serve small drainage areas. There are more than 1,000 catch basins and track drains on piers draining into Sinclair Inlet and an extensive rail system, which provides a pathway for stormwater to seep through the subsurface. Depending on the flow rate and whether the track drains become clogged, this runoff will ultimately discharge directly into the Sinclair Inlet (Jabloner 2009).

Industrial facility and municipal stormwater runoff has a number of unique attributes that make the identification of stormwater contaminant problems and their associated solutions difficult to determine. Stormwater contains a broad variety of pollutants whose concentrations can vary widely depending on storm event size, LULC, and a number of other local and regional factors. The quality of stormwater runoff can often be difficult to manage due to the seasonal, sporadic nature of surface water discharges and the character and unpredictability of storm events. Most industrial facilities and municipal areas have a large number of stormwater outfalls, with a wide diversity of locations and outfall types. Monitoring stormwater discharges within the Shipyard presents additional challenges unique to a facility located within an industrial waterfront:

- Stormwater runoff from all BNC non-dry dock properties drains directly into adjacent marine receiving water.
- Most of the drainage basins are tidally influenced.
- The non-dry dock stormwater drainage systems are relatively short in length (from head to bay outfall), and many systems have limited access, eliminating the opportunity to conduct monitoring in non-tidally influenced areas.
- Industrial processes occurring within the sampling area must be isolated from the water sampled from the conveyance. Contamination of the composite sample during or after collection with process specific contaminants would not represent their concentration in the conveyance during a storm event.

Therefore, the United States Environmental Protection Agency Region X (USEPA), Washington State Department of Ecology (Ecology), and the Shipyard are working to renew the National Pollution Discharge Elimination System (NPDES) permit for discharges into Sinclair Inlet, Puget Sound, WA (USEPA 2008a,b). The discharge of stormwater from Shipyard operations is permitted by the USEPA Region 10 under the Clean Water Act (CWA; NPDES permit WA-00206-2, 1994). Under the NPDES program, the Shipyard is required to implement Best Management Practices (BMPs) designed to reduce, treat, and control discharges of contaminants from Shipyard operations (Jabloner 2009).

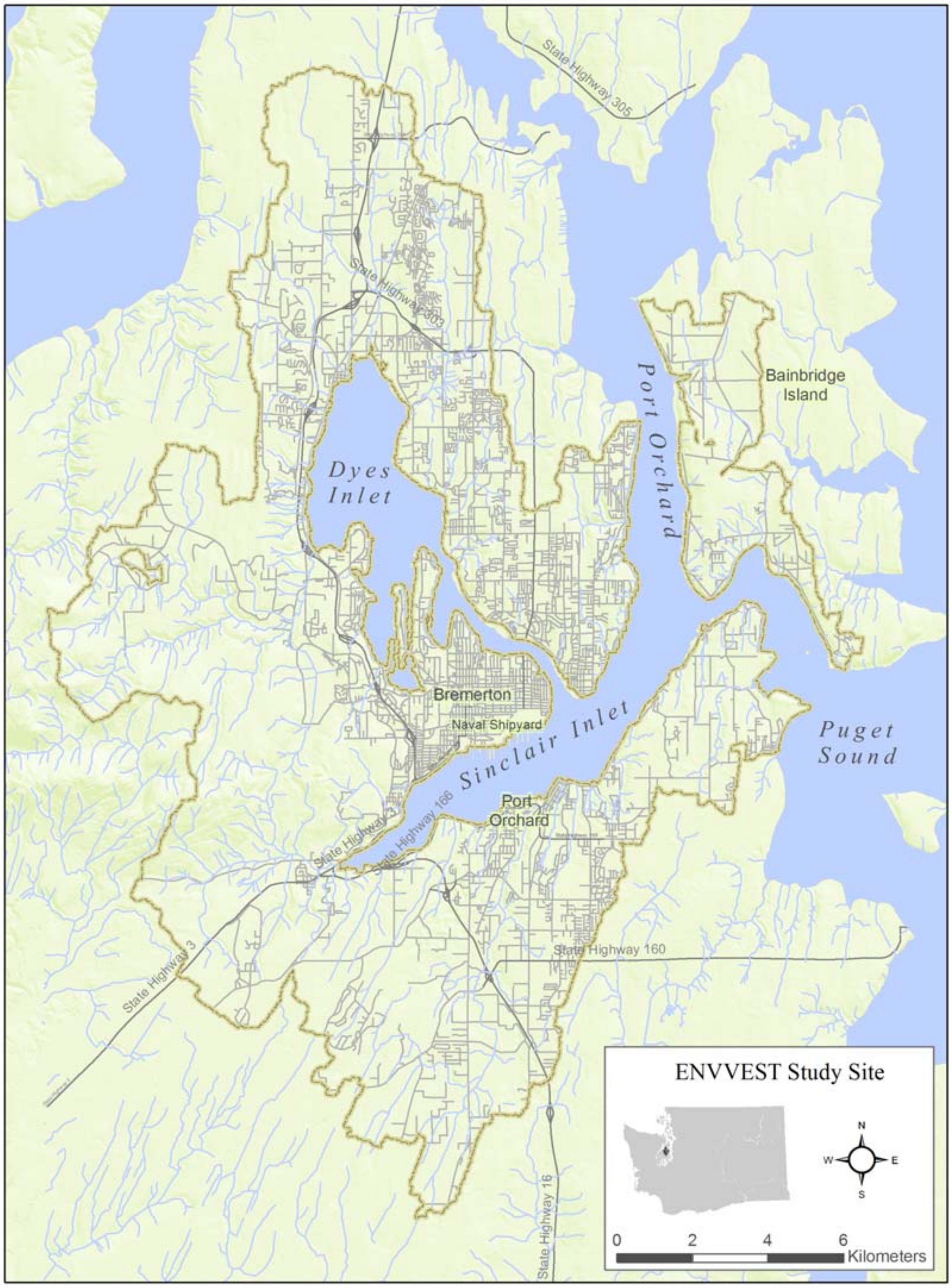

Figure 1. Location of the Puget Sound Naval Shipyard & Intermediate Maintenance Facility (Naval Shipyard) on Sinclair Inlet. The study region for the Navy ENVVEST project is the watershed boundary supporting the receiving waters of Sinclair Inlet, Dyes Inlet, and the passage ways to the main basin of Puget Sound.

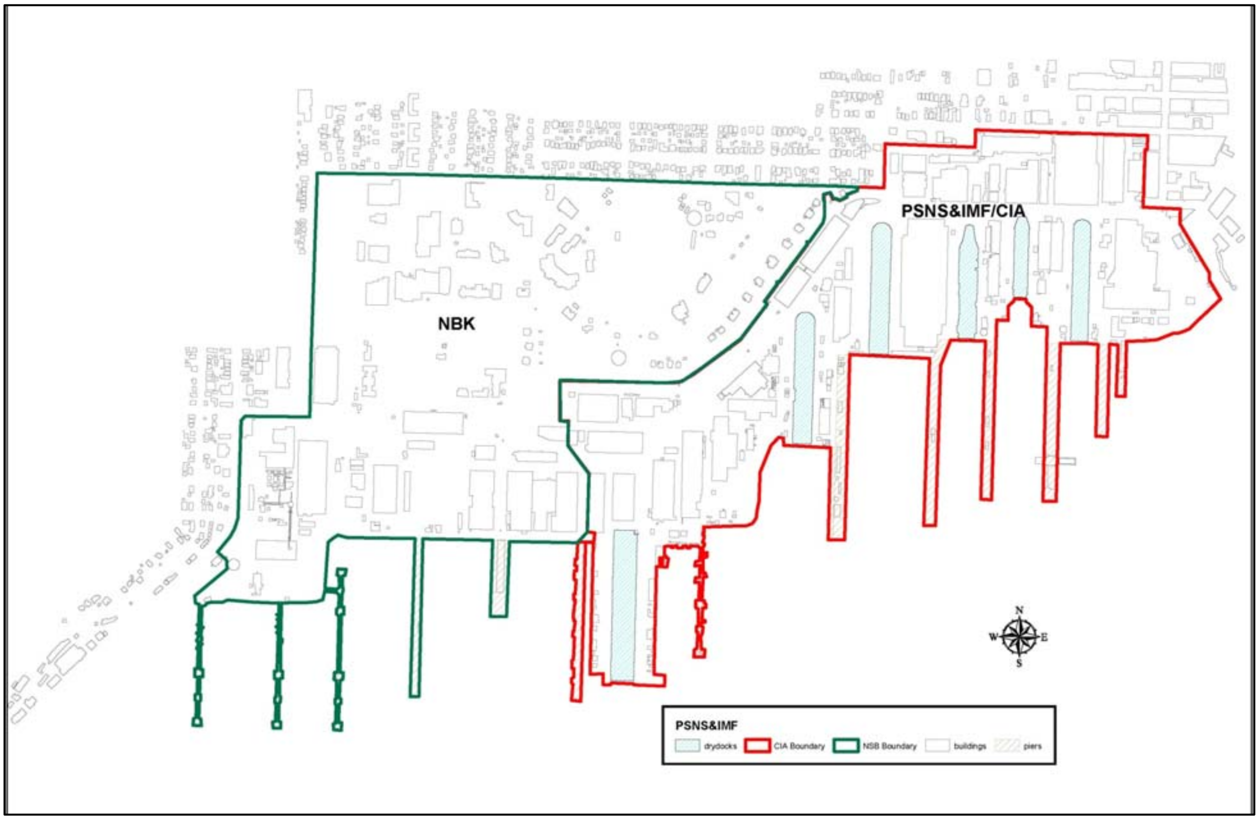

Figure 2. Bremerton Naval Complex with the industrial area (CIA) in red and Naval Base Kitsap (NBK) in green.

This interim report summarizes the stormwater monitoring conducted for non-dry dock outfalls in both the CIA and the NBK. This includes the collection, analyses, and descriptive statistics for stormwater sampling conducted from November 2010 through April 2011. Seven stormwater basins within the Shipyard were sampled during at least three storm events to characterize non-dry dock stormwater discharges at selected stormwater drains located within the facility (Figure 3). This serves as the Phase I component of the project and Phase II is planned for the 2011-2012 storm season. These data will assist the Navy, USEPA, Ecology and other stakeholders in understanding the nature and condition of stormwater discharges from the Shipyard and helps inform the permitting process (USEPA 2008a, b).

This report summarizes the current stormwater data available from the Shipyard, Sinclair/Dyes Inlet watershed, and Puget Sound in order to support technical investigations for the Draft NPDES permit. The permit would require storm event sampling at selected stormwater drains located within the Shipyard. However, the data must be considered on multiple scales to truly understand potential impairments to beneficial uses within Sinclair and Dyes Inlets. The results from the 2010-2011 sampling, reported herein, are synthesized with the existing regional data and will eventually be combined with additional stormwater data collection currently in progress.

1.1 Regional Background

In 2000, A cooperative ENVironmental inVESTment Project (ENVVEST) was created in partnership with the Shipyard, USEPA, Ecology, and local stakeholders to support the development of a Total Maximum Daily Load (TMDLs) for fecal coliform (FC) and other contaminants entering the Sinclair and Dyes Inlet watershed (Figure 1, ENVVEST 2002a, b, 2006). As part of Project ENVVEST, 13 stormwater drainage basins within the watershed, including three basins within the Shipyard, were monitored for flow and sampled during storm events (Brandenberger et al. 2007a, b). The stormwater outfalls selected for flow monitoring were determined by a technical evaluation of 35 stormwater outfalls (including streams and other urbanized natural drainage areas) located within the City of Bremerton, City of Port Orchard, City of Bainbridge Island, Kitsap County, and the Shipyard (TEC 2003a, b, c). This work resulted in a calibrated and verified Hydrological Simulation Program Fortan (HSPF) for drainage basins within the watershed including the Shipyard (Skahill and LaHatte 2007) and estimates of stream and storm event runoff quality as a function of upstream land use and cover (LULC) and storm intensity (Brandenberger et al. 2007a, b; Cullinan et al. 2007). This provided the ENVVEST data to develop a contaminant mass balance for heavy metals, PAHs, PCBs, and nutrients where all sources and sinks were considered to allow a relative evaluation of the dominant sources (Brandenberger et al. 2008).

The integrated watershed assessment approach of Project ENVVEST provided data on the current quality of the water, sediment, and biota present in both Sinclair and Dyes Inlets. Establishing a solid baseline and understanding the variability on a spatial and seasonal scale provides a means from which to assess process improvements within the Shipyard and bound the data in terms of regional sources of contaminants. This ENVVEST approach implements scientific methodologies to be employed in stormwater monitoring efforts, including analytical chemistry, marine geochemical analysis, watershed analysis, urban stream ecology, salmonid habitat assessment, watershed monitoring, and the documentation of scientific findings and results. The data from this interim report of non-dry dock stormwater sampling improves the estimate of ENVVEST stormwater loading, the mass balance of chemical contaminants from the Shipyard, and augments the ambient monitoring to demonstrate ongoing environmental performance in support of NPDES requirements (Johnston et al. 2010).

An evaluation of existing stormwater monitoring data for the Shipyard and a review of technical and regulatory requirements was conducted and reported in the Quality Assurance Project Plan (QAPP) for non-dry dock stormwater monitoring conducted under the NPDES (Taylor Associates Inc. 2009). This report documents the technical strategy and procedures for monitoring non-dry dock stormwater basins within the Shipyard. The Phase I stormwater monitoring plan recommended sampling seven representative storm drains within the Shipyard followed by Phase II focused within the CIA. A Project Work Plan (PWP often referred to as a QAPP) was written to detail the field methodology, collection protocol, and laboratory methods necessary to conduct stormwater monitoring at the seven selected monitoring locations for Phase I during at least three qualifying storm events from November 2010 to April 2011 (Figure 3, TEC and PNNL, 2011). The annual PWP provided the supporting documentation, which includes the environmental health and safety plan (ES&H) and details on sample collection and analyses methods.

1.2 GOALS & OBJECTIVES

The goal of Phase I was to collect and characterize non-dry dock stormwater and associated data from the selected locations within the Shipyard to provide preliminary data in support of the (Working Draft) NPDES Permit Number WA-00206-2 (USEPA 2008a, b). In addition, these data support development of the ENVVEST LULC stormwater relational model (Brandenberger et al. 2007a, b; Cullinan et al. 2007) as part of the contaminant mass balance for Sinclair and Dyes Inlet (Brandenberger et al. 2008).

The Phase I objectives were

1. Document logistics and site information for all seven Phase I stations along with field and laboratory quality control procedures necessary to allow the non-dry dock stormwater data to be comparable to the ENVVEST stormwater data set;
2. Collect grab and composite stormwater samples during three qualifying storm events at each of the seven stormwater sampling locations consistent with methodology reported by ENVVEST;
3. Conduct chemical analyses utilizing appropriate analytical techniques to ensure data are representative of storm water quality;
4. Prepare field-sampling reports documenting the results of each storm event sampling including ancillary data (rainfall, temperature, salinity, etc.); and
5. Prepare an annual report summarizing the results of chemical analysis relative to other regional data and providing the status of non-dry dock stormwater

monitoring at the Shipyard to inform the stormwater management program and future permit requirements (USEPA 2008a).

1.3 BNC STUDY AREA DESCRIPTION

Design features and conditions of the stormwater drainage infrastructure were assessed at selected basins for stormwater monitoring logistics. Sampling sites were selected that maximized the upstream drainage area, minimized tidal effects and accounted for operational constraints (see PWP; TEC and PNNL, 2011). Figure 3 illustrates the Phase I location in both the CIA and non-industrial NBK. They represent the main industrial operations and processes at PSNS&IMF and support functions in the surrounding NBK. These basins were selected because of their relatively large size (in comparison to other basins with similar activity); heavy industrial use (for applicable primary work tasks); close proximity to legacy sites; and contained unique and/or representative land use. Table 1 list the drainage basins selected for monitoring and their associated stormwater outfall number, geographical area and primary work activity.

Figure 3. Phase I stormwater sampling locations at PSNS&IMF.

Table 1. Drainage basins selected for monitoring and the associated primary work activity.

PSNS&IMF Outfall #	Geographical Area	Primary Work Activity
126	East CIA, Southwest B460 along “C” Street, east of DD3	Materials storage (outdoor)
096	Mid CIA, west of DD4, southeast of Bldg 457 along “N” St	Vessel maintenance
082.5	West CIA, southeast of B851, RMTS Area	Vessel, equipment and materials recycling
081.1	West CIA, NE of DD6 and NW of Pier 9, south side of Bldg 462	Non-aircraft carrier support services
032	East NBK, NW corner of B514	Aircraft carrier support services
015	Mid NBK, south side of McDonalds, east side of drive-through lane	Municipal/commercial/residential services
008	West NBK, east side of Inactive Fleet B550	Parking/steam plant/truck traffic

As described in the AKART study (Jabloner 2009), the BNC stormwater system is composed primarily of clay pipe with a mixture of concrete, PVC, steel, and cement-asbestos pipe. Stormwater is collected from buildings and roofs by rain gutters and roof drains, which then discharge into storm drainage pipes or into catch basins located around the buildings. On the piers and other surfaces located directly over the water there are drain holes in the deck that deposit the rainwater directly into Sinclair Inlet. The ground surfaces around the buildings are generally impervious, made up of either asphalt, concrete, or concrete base with asphalt over it. There are various cracks, breaks and holes in some of the surface cover, as well as crane track pathways and a sloped vegetated hillside (the northern boundary of the CIA) that infiltrates a small portion of precipitation and surface runoff within the CIA. However, because the vast majority of the CIA contains no unpaved or pervious areas, stormwater infiltration is assumed to be minimal.

The depth of the stormwater system ranges 1-20 ft. below ground surface. Most of the stormwater outfalls discharge to Sinclair Inlet below mean lower low water (MLLW). The Shipyard is only a few feet above high tide; therefore most of the stormwater piping is tidally influenced. Table 2 provides the specific attributes of the drainage basins and details are provided in the PWP (TEC and PNNL 2011).

Table 2. Drainage basin attributes for the Phase I outfall sampling events 2010-2011.

PSNS Outfall No.	Outfall Location	[1]Monitoring Location	Total Basin Area (acres)[6]	Basin Impervious Surface Area (acres)	Basin Pervious Surface Area (acres)	Monitoring Location Manhole ID	[2]Manhole Rim Elevation (Ft)	[2]Approx. Elev. of Sampling Intake (Ft)	[3]Effective Tide Height (Ft)
126	47°33'37"N, 122°37'36"W	47°33'42"N, 122°37'42"W	15.22	15.00	0.22	5110	18.22	8.60	+9
096	47°33'35"N, 122°38'11"W	47°33'37"N, 122°38'11"W	16.48	15.99	0.49	3878	17.46	2.94	+3.0
082.5	47°33'28"N, 122°38'20"W	47°33'26"N, 122°38'23"W	[5]2.00	[5]2.00	0.00	CBS-6	17.91	9.87	+12[4]
081.1	47°33'21"N, 122°38'31"W	47°33'23"N, 122°38'32"W	22.16	21.51	0.65	SD-1	17.71	3.85	+4
032	47°33'21"N, 122°38'50"W	47°33'27"N, 122°38'49"W	4.79	4.65	0.14	5961	18.46	9.40	+9.5
015	47°33'21"N, 122°39'02"W	47°33'29"N, 122°39'03"W	92.26	46.13	46.13	A42	17.21	1.96	+2
008	47°33'15"N, 122°39'17"W	47°33'19"N, 122°39'16"W	12.71	11.95	0.76	2179	17.95	9.91	+10

[1]Coordinates for the monitoring location were determined using a Trimble GPS.
[2]Referenced to Mean Lower Low Water (historical PSNS&IMF documents 1994-2008).
[3]Expected tidal height based on NOAA tide predications that would cause tidewater, under non-storm conditions, to be detected at a certain monitoring location.
[4]The effective tide height at 082.5 is significantly higher than the approximate elevation of the sampling intake due to the design of the piping system at this location. A Tideflex valve is located in the manhole downstream from CBS-6, which only allows tide water to back up into CBS-6 at higher tidal ranges.
[5]This is an estimate of the area draining through CBS-6. CBS-6 drains only a portion of the total PSNS&IMF 082.5 basin area (14.56 acres).
[6]Total basin areas are included in the Basin Description Table and were determined on calculation supplied by the Navy.

1.4 PSNS &IMF NPDES PERMIT OVERVIEW

The Shipyard's first NPDES permit was issued in September 1986 and then reissued in April 1994. This 1994 permit is the current effectual stormwater discharge guidance for the Shipyard. The USEPA, Ecology, and the Shipyard are working together to renew the PSNS &IMF's current NPDES permit for discharges into Sinclair Inlet, Puget Sound, WA (USEPA 2008a,b). In accordance with the NPDES permit, PSNS&IMF is required to monitor discharge from the following three operations:

- Dry dock discharges (covered separately; Johnston et al. 2009);
- Steam plant discharges (covered separately; Johnston et al. 2009); and
- Stormwater and miscellaneous runoff from non-dry dock areas.

In May 2008 the USEPA issued a *Working Draft NPDES Permit* for the Shipyards' consideration, review and preparation. In the 2008 *Working Draft NPDES Permit*, one stipulation addresses the characterization and assessment of non-dry dock stormwater runoff. Table 3 details the proposed permit requirements (per Permit §I.C.3 and §III.A) for non-dry dock stormwater monitoring assessment parameters, maximum daily effluent limits, sample frequency and sample type.

Table 3. Proposed stormwater monitoring requirements and final effluent limitations.

Parameter	Maximum Daily Effluent Limit	Sample Frequency	Sample Type
Copper, total recoverable	5.8 µg/L	Quarterly	Composite.
Lead, total recoverable	221 µg/L	Quarterly	Composite
Mercury, total recoverable	2.1 µg/L	Quarterly	Composite
Zinc, total recoverable	95 µg/L	Quarterly	Composite
Arsenic, total recoverable	69 µg/L	Quarterly	Composite
Total Suspended Solids	-----	Quarterly	Composite
Oil and Grease (NW-TPH-D)	-----	Quarterly	Grab
Oily Sheen	No oily sheen	Quarterly	Visual Observation
Turbidity	5 NTU above background	Quarterly	Composite

Taylor Associates Inc. (2009) evaluated existing stormwater monitoring data for the Shipyard and reviewed technical and regulatory requirements prior to recommending the technical strategy and procedures for monitoring non-dry dock stormwater basins within the Shipyard. Phase I, reported herein, provides the stormwater quality measured within seven distinct storm drainage systems that are representative of the seven main work activity types within the Shipyard (TEC and PNNL 2011). The primary activities include:

(1) Materials storage
(2) Vessel, equipment and materials recycling
(3) Vessel maintenance
(4) Non-aircraft carrier vessel support services
(5) Aircraft carrier support services
(6) Parking/steam plant (stormwater discharges only)/truck traffic
(7) Municipal/commercial/residential services

This report provides the first year of monitoring for the non-dry dock stormwater from stormwater outfalls or conveyances that represent the primary work activities performed within the non-dry dock areas. In order to leverage the three years of existing stomrwater data conducted by ENVVEST within the Sinclair/Dyes Inlet watershed, the list of parameters was expanded from those in Table 3 to remain consistent with the ENVVEST program. The list of parameters are total recoverable and dissolved aluminum (Al), silver (Ag), arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg) and zinc (Zn); hardness; total organic carbon (TOC); dissolved organic carbon (DOC); total suspended solids (TSS); turbidity; conductivity and temperature.

Data from these monitoring efforts provide the first assessment of stormwater quality from non-dry dock outfalls considered in the draft NPDES permit. They may also be used to evaluate the effectiveness of BMPs, develop future effluent limitations, help identify sources of pollution potentially affecting the quality of stormwater discharges associated with industrial activity from the facility, and may lead to recommendations for implementation of measures to minimize pollutants in stormwater discharges.

2.0 FIELD COLLECTION METHODS

Consistent with the requirements specified in the draft NPDES permit, grab samples and automated, tidally-compensated, time-paced composite samples were collected at selected representative outfalls during Phase 1. Field collection methods for the 2010-11 stormwater sampling events followed guidance described in Taylor Associates (2009) and detailed in the PWP (TEC and PNNL 2011). A brief description of field collection methodologies is provided below. See Appendix A for detailed individual storm event reports.

2.1 QUALIFYING STORM EVENTS

Stormwater events were targeted from November 2010 through April 2011. Three qualifying storm events from each of the seven monitoring stations were successfully collected. Due to equipment limitations the outfalls were divided into two groups: four CIA stations and three

NBK stations. The storm events at the CIA stations were collected from October through December then the equipment was demobilized and re-deployed at the NBK stations. Storms were sampled at the NBK sations from January through May. Qualitying storm events were targeted based on small modifications from the ENVVEST program criteria for wet season sampling. The criteria used for the 2010-11 qualifying storm events are listed in Table 4.

The ENVVEST storm event sampling from 2003-2005 provided a range of water quality concentrations for both streams and stormwater outfalls as a function of level of development within the subasin and storm event size. The critical gap in the sampling was larger storm events (≥1.0”) in urban and industrial basins. Therefore, the criteria were modified to add a conditional 24-hour antecedent qualification as necessary. The conditional qualification allows for the capture of discrete storm events during the more intensive wet season when the frequency of rain events is high. For example, this alteration is overwhelmed by the total storm volume, as long as, the antecedent rainfall is less than 10% of the associated total storm event volume. The larger storm volumes would have the potential to release and/or expose sources that otherwise may not occur during smaller events. This conditional antecedent qualification was applied on a station specific basis for each targeted event.

Table 4. Qualifying storm event criteria.

Criteria	Wet Season	Dry Season
Seasonal Period	October 1 – April 30	May 1 – September 30
Targeted Storm Size and Probability	≥0.20” in 24-hours ≥70% forecasted probability of occurrence 24-hours prior	≥0.10” in 24-hours ≥50% forecasted probability of occurrence 24-hours prior
Qualifying Storm Size	≥0.10”, or a sufficient amount for sampling to have occurred for at least 2 hours during stormwater runoff	≥0.10”, or a sufficient amount for sampling to have occurred for at least 2 hours during stormwater runoff
Antecedent Precipitation Conditions	Less than or equal to 0.1” rain in previous 24-hours No rain in previous 6 hours	Less than or equal to 0.02” rain previous 72-hours No rain in previous 6 hours
Conditional 24-hr Antecedent Qualification	If there is greater than 0.1” rain in a 24-hr antecedent period, the overage should not exceed 10% of the overall storm event rainfall total. The 6-hr condition is unchanged	Does not apply for Dry Season
Inter-event Dry Period(1)	6 hours minimum, 12 hours maximum	6 hours minimum, 12 hours maximum

(1) A storm event can be considered completed once there has been a 6-hour period with no precipitation. However water sampling could continue, as long as runoff is occurring or the station hydrograph is elevated above pre-storm conditions, for up to a 12-hour period with no precipitation, at which time the storm would be considered complete.

Storm targeting procedures were detailed in the 2010-11 PWP and are briefly outlined here:

1. Weather forecasts for the Bremerton, WA area were checked weekly to determine if a qualifying storm event could occur during the next 7-day period.
2. If a forecast suggested a qualifying storm, the team conferred to decide if the storm should be considered for targeting and continued tracking. If yes, then forecasts were reviewed at least daily.
3. Precipitation forecasts were reviewed at 72 - 24 hours prior to targeted storm and team made final “go/no-go” decision.
4. If a “go” then a sample event lead was designated.
5. The lead scheduled field team pre-storm site setup activities and was in control until all samples were delivered to the laboratory.
6. Internet-based forecasts were archived to document targeting decisions.

Prior to the start of the storm, the field team visited each sampling location to prepare the monitoring equipment for data and stormwater collection. Prior to deployment, autosampler bottles were pre-cleaned by the PNNL analytical laboratory, as described in the PWP (TEC and PNNL 2011). During the pre-storm site visit, the field team checked/modified the autosampler programs as detailed in each storm event report, conducted necessary maintenance and calibration activities, and placed sample bottles into the autosamplers. All setup, maintenance, and calibration activities were recorded on field data sheets, along with associated notes of other relevant site conditions (Appendix A).

2.2 In-Situ Data Collection

At each of the monitoring stations a variety of in-situ data were collected. Data types included: precipitation (rain amount and intensity), water level in the associated piping systems (level responses due to both runoff/process inputs and tidal influences), temperature, conductivity, salinity and sample collection information. In-situ data were collected with sensors, gauges and autosamplers that were connected to, logged by, and/or controlled with a station-specific datalogger and telemetric control system. These in-situ data types and data collection, storage and management procedures are described in detail in the PWP and briefly summarized below.

2.2.1 Precipitation Monitoring

Precipitation was monitored via a network of rain gauges installed at each monitoring station and atop Building 427 (official PSNS gauge) within the CIA. Data from the monitoring station rain gauges were collected and stored on dataloggers and was accessible by either direct download or remotely through a telemetric network. Precipitation amounts (depth) and intensity were continuously monitored at each site. A continuous rainfall record allowed for the establishment of a rainfall/runoff relationship at each site. This relationship was used to estimate the total storm volume discharge, calculate the discharge volume for the sampling duration at each station using a variation of the Runoff Coefficient Method (RCM), and classify the storm event size consistent with the ENVVEST database. The RCM was previously used for volume estimation purposes during implementation of the 1994 PSNS NPDES compliance monitoring. The RCM method is an accepted industry standard and is an effective calculation method for providing an estimate of storm flow volumes in the absence of dedicated flow monitoring equipment. Section 7.4 of the PWP (TEC and PNNL 2011) detailed the application, selection of coefficients and calculation of the RCM.

Briefly, the RCM method uses the total storm rainfall, pervious and impervious drainage area size, and a runoff coefficient to calculate the total runoff volume in cubic feet. Runoff coefficients for the selected monitoring sites where chosen from published values for the following surface types: heavy (0.6-0.9) and light (0.5-0.8) industrial areas, railroad lines (0.2-0.4), continuous concrete or asphalt cover (0.7-0.95), heavy soil (0.18-0.22) and residential/suburban (0.25-0.4). The coefficient range gives latitude for consideration of particular basin characteristics. Typically the upper end of the coefficient range values are applied to the more impervious portions and the lower end of the coefficient range values are applied to the more pervious portions of a certain surface type when calculating runoff volumes. The formula below was slightly modified from the standard RCM so that it accounts for the effective runoff from both pervious and impervious areas from each monitored outfall drainage basin (Navy 1996):

$$\text{Total Runoff Volume (V)} = R \times [(A_i \times C_i) + (A_p \times C_p)]$$

Where V is total runoff volume (ft^3), R is total rainfall (ft.), A_i is total impervious drainage area (ft.^{2}), A_p is total pervious drainage area (ft.^{2}), C_i is runoff coefficient for impervious area of the drainage basin, and C_p is the runoff coefficient for pervious area of drainage basin. Table 5 presents this information for the monitored drainage basins, their percent pervious and impervious areas, runoff coefficient value ranges for the basin surface types and the total discharge volume estimation equations. The upper range of coefficient values were used in all RCM calculations during the 2010-11 storm events.

In addition, the rain gauges were used for storm event tracking, identifying the event start (to schedule grab sampling) and end (to retrieve composite samples). Rain data were also used for enabling the autosamplers and in the validation of the storm events based on the criteria presented above. Rain gauges were maintained per established methods of data assessment and comparison, scheduled maintenance and appropriate calibration. The official PSNS rain gauge was maintained, serviced and downloaded by the Navy.

2.2.2 Water Level, Temperature, Conductivity, and Salinity Monitoring

Water level data from within the drainage pipes or associated vaults were continuously recorded (except during maintenance or replacement periods) using pressure transducers installed at each monitoring station. These sensors measured both water level and temperature. Water level and temperature data were stored on dataloggers. This information was accessible by either direct download or remotely through a telemetric network. Water level data were used for several key functions including: autosampler enabling, stormwater hydrograph assessment and tidal inundation assessment. Pressure transducers were inspected and serviced as recommended by the manufacturer at least once each month and/or prior to targeted storm events, whichever was more frequent.

Conductivity was continuously measured at each of the monitoring stations during each targeted storm event. Conductivity data were used to enable the autosamplers at each station during sampling activities. Conductivity was also measured at the monitoring stations during non-storm periods to determine a relationship between conductivity and the tidal backwater conditions at that station. Salinity values were determined either by a post-processed calculation (based on conductivity and temperature) completed by the datalogger or recorded directly from a multi-parameter sonde. The method of salinity value generation was determined by the particular monitoring gear utilized at each station.

Table 5. Stormwater outfall basin attributes and total discharge volume.

PSNS Drainage Basin ID	Total Basin Area (ft^2)	Type of Surface	Percentage of Drainage Basin Surface Type	Area of Basin Surface Type (ft^2)	[1]Runoff Coefficient Range	Area of Basin Surface Type with Maximum Coefficient Value Applied (ft^2)	[2]Total Discharge Volume (ft^3)
126	662,986	Impervious	98.55	653,373	0.6 – 0.9	588,036	R(591,881)
		Pervious	1.45	9,613	0.2 – 0.4	3,845	
096	717,872	Impervious	97	696,336	0.6 – 0.9	626,702	R(635,317)
		Pervious	3	21,536	0.2 – 0.4	8,615	
082.5	87,120	Impervious	100	87120	0.7 - 0.95	82,764	R(82,764)
081.1	965,294	Impervious	97	936,335	0.6 – 0.9	842703	R(849,074)
		Pervious	3	28,959	0.18 – 0.22	6,371	
032	208,653	Impervious	97	202,393	0.6 – 0.9	182,154	R(184,658)
		Pervious	3	6,260	0.2 – 0.4	2,504	
015	4,018,862	Impervious	50	2,009,431	0.5 – 0.8	1,607,549	R(2,411,317)
		Pervious	50	2,009,431	0.25 – 0.4	803,772	
008	553,650	Impervious	94	520,431	0.5 – 0.8	416349	R(429,637)
		Pervious	6	33,219	0.2 – 0.4	13,288	

[1]These values are derived from various published sources regarding the RCM,

[2] Rainfall (R) is in feet for calculation of total discharge volume

2.2.3 Autosampler Collection Information

The autosampler units were also a source of system operations feedback. Each autosampler was connected to a Campbell Scientific datalogger and telemetry system, which allowed sample processing information to be immediately available to the storm lead. Necessary adjustments could be made from remotely. Feedback information from the autosamplers served as a record of setup and unit operation and was included in the storm reports (Appendix A). The autosampler downloads included programming data; enable date and time, sample marker designations, bottle information, pump cycle counts, aliquot success and associated source error codes, and sample completion date and time.

2.2.4 Data Collection, Storage and Management

There were primarily three types of data generated during this project: (1) field activity data, including non-sampling field task operations, sample collection tasks and monitoring equipment maintenance activities; (2) in-situ monitoring data, including precipitation, water level, temperature, conductivity, salinity and autosampler collection information; and (3) laboratory chemistry data. The procedures for hard copy and electronic data handling, quality review, and archival were detailed in the PWP (TEC and PNNL 2011). The field notes and ancillary data were provided in Appendix A. In-situ monitoring data were electronic stored. Data were typically transferred via telemetry to a data server on the TEC network, where it was archived. Rainfall data from the Navy's gauge atop Building 427 and autosampler report collection information were manually downloaded and also stored on the TEC network. Field data were split into raw and comma-delimited formats. The raw data were stored "as-is", remaining static and unedited, serving as an archive and backup to the field monitoring data. The comma-delimited data were maintained as .DAT files that were updated by deleting older data once uploaded to the database. This provided storage space for more recent data. Comma-delimited files were uploaded to a proprietary water quality data management and display database (e.g. Isco® Flowlink, v4.15). All electronic data were reviewed for errors, omissions and accuracy.

Laboratory generated data were also summarized for each storm event and provided in Appendix B. The data were also formatted for the electronic database submission into the ENVVEST database. Copies of analytical raw data are stored at the laboratory of generation and available upon request. All project data were maintained as part of the official project record and stored for a period as described in the PWP (TEC and PNNL 2011).

2.3 STORMWATER MONITORING SYSTEM / EQUIPMENT

The stormwater monitoring system at each station was comprised of various components. These components included telemetric communication modem, central datalogger / system controller, autosampler, rain gauge, pressure (water level) / temperature transducer, conductivity sensor, salinity sensor, solar panel charger and batteries, and housings and various mountings. All of the sensors and gauges were frequently (typically twice or more a month during their operational periods) calibrated and maintained to assure accurate level data. Diagrams of a general schematic of the monitoring system components are provided in Figure 4. These components are further described below.

Telemetric communication modem: A telemetry communication system was installed at each station and provided remote communication access through the datalogger. Sierra Wireless AirLink Raven XT cellular modems (Campbell Scientific Inc., Logan, Utah), with Code Division Multiple Access (CDMA) digital technology, were utilized as the communication link between the remote user or server and the datalogger. This allowed for either transmission of collected data to an offsite computer and system status checks on a scheduled or on-demand basis or for execution of incoming system commands (e.g. setting or correcting enabling condition thresholds, changing a sample pacing rate, etc.). The use of the Raven XT modem in its project–specific configuration provided highly secure data transmissions, which was of the utmost importance to PSNS&IMF. Formal security permission was obtained for the modems and dataloggers (see PWP) used in this project. The security permission forms and other pertinent information were also included in each telemetry box.

Datalogger / system controller: Campbell Scientific, Inc. CR1000 (Logan, Utah) custom programmable dataloggers were utilized as the central “brains” of each monitoring system. The CR1000 is capable of storing large quantities of time-series data, as well as, performing a wide range of system control functions. All of the system components, including sensors, autosamplers and peripherals (e.g. batteries and solar charging system) were connected through the datalogger. Calibration of all project sensors, as well as, controlling the enabling conditions for the autosampler was facilitated through the datalogger. Connection to the datalogger could be accomplished either directly or remotely via proprietary software. All field data were automatically stored on the CR1000 datalogger at five-minute intervals. Dataloggers were programmed to download, via the telemetry system, to a base station computer at the TEC office on a schedule of at least once per day; more frequent downloads occurred during times of need (e.g. storm events, calibrations, etc.).

Autosampler: Stormwater samples were collected using automatic water samplers (autosamplers) installed at each site. Water sampling equipment included Teledyne-Isco® 6700 series samplers (Lincoln, NE), Teflon™-lined polyethylene sampler suction line, and siliconized Tygon™ pump and distributor arm tubing. Autosamplers were deployed in an off-the-shelf configuration equipped with 24 1L polypropylene wedge bottles. Each sampler was identically programmed (TEC and PNNL, 2011). The associated dataloggers controlled activation and sample collection pacing. Sampler reports were also remotely downloaded and included in Appendix A.

Rain gauge: Teledyne-Isco® 674 (Lincoln, NE) tipping bucket rain gauges were used to collect rainfall data. These instruments measured rainfall at 0.01-inch increments. Rainfall data was downloaded via telemetry at least once each day and more frequently during and following targeted storm events. Each rain gauge was connected to its associated datalogger, which recorded rainfall data at 5-minute intervals.

Water level and Temperature: Pressure transducers were used at each monitoring station to record water level and temperature to measure the water level within a selected pipe or vault. Two different types of pressure transducers were used for monitoring and sample collection. These were the Campbell Scientific CS450 and the Instrumentations Northwest Inc. (INW, Kirkland, WA) CT2X. Each of these units measured pressure and temperature to very similar specifications. Water level and temperature were both measured and reported to 1/100 of a foot and degree Celsius, respectively.

Conductivity: Specific conductivity was measured at each station by two different sensor types. The INW CT2X (Kirkland, WA) and YSI (Yellow Springs, OH) 6820 multi-meter sonde were used to collect specific conductivity data. The INW CT2X specific conductivity sensor was incorporated into its associated pressure transducer (each CT2X measured pressure, temperature and specific conductivity). The YSI 6820 is a stand-alone unit that was used in combination with the CS450 transducer. The YSI 6820 also provided redundant temperature data. Both specific conductivity probes recorded values to the nearest 1/100 micromhos (µmho/cm), but were reported to the nearest whole number.

Salinity: Salinity values were generated based on non-temperature compensated conductivity measurements and temperature readings. Stations that utilized the INW CT2X transducer generated salinity data after post-processing through the datalogger using published algorithms. Salinity reported from the YSI 6820 was calculated directly by the multi-meter sonde using the same conversion algorithms. Salinity values from both sensors were recorded to the nearest 1/100 of a part/thousand (ppt) and reported as a whole number.

Solar panel charger and batteries: The telemetry system, datalogger and all associated water quality monitoring components were powered by 12v deep cycle marine batteries. Typically each station used two batteries; one to power the datalogger, sensors and telemetry system and one to power the autosampler. Campbell Scientific SP20 regulated 20-watt solar panels were used to recharge the battery associated with the datalogger and its connected components. Depending on available sunlight exposure at a particular station, it was sometimes necessary to have two batteries connected in parallel powering the datalogger. The stand-alone autosampler battery was removed from the equipment housing after each sampling event, re-charged and replaced prior to the next sampling event.

Housings and mountings: Monitoring stations were designed with modularity and mobility as their main tenets. Each station had the ability of being moved to a new location with minimal setup and demobilization. Sturdy steel, lockable equipment enclosures were used to house the various monitoring system components and to provide a stable platform from which to mount open-air items. Attached 10-foot tall masts supported the solar panels, omni-directional antennas and rain gauges at each of the housings. Each equipment housing was placed as close to the outfall location as possible. All stations were above-ground setups with conduit lines leading from the housing to the vaults and sampling points. A number of monitoring system components were installed underground at all of the sites. Transmission cables for the pressure transducers and conductivity meters, as well as, the sampler suction lines ran from the equipment housings into the associated vault through heavy-duty plastic conduit. Inside each vault, the sampler suction lines ran along the wall and terminated at the sampler strainers, which were generally installed in the invert of the outlet pipe.

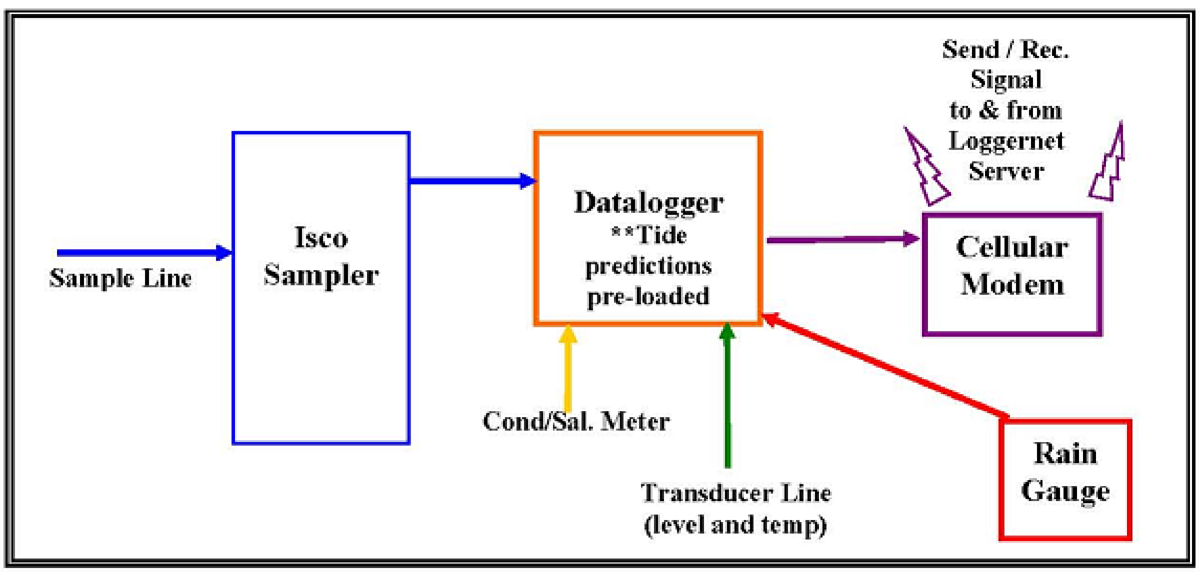

Figure 4. Generalized schematic of monitoring station components.

2.4 STORMWATER SAMPLE COLLECTION

Seven validated stormwater events were sampled during the 2010-11 field season based on the criteria discussed above. Table 6 presents the date for each storm event, station identification, the number of samples collected during each event, the number of total samples collected at each station, and type of sample (e.g. grab or composite). All sample collection and management followed the guidance contained in the PWP (TEC and PNNL 2011). In brief, two types of stormwater samples were collected at each monitoring site: (1) manual grab samples and (2) time-proportionate composite samples. All sample containers and (non-metal) equipment were pre-cleaned as outlined in the PWP Appendix F (TEC and PNNL 2011). The collection containers, pump tubing, and other non-metal sampling equipment were pre-cleaned and packaged to maintain cleanliness (e.g. double bagged and ends of sampling tubing were closed together using silicon tubing). Equipment blanks and field blanks were periodically collected to ensure sampling equipment and collection methods were not a source of contamination.

Routine grab samples were collected into laboratory clean amber glass bottles for total petroleum hydrocarbon – diesel range extended (TPH-Dx) analysis via laboratory cleaned stainless steel cups. Time-paces composites were collected into pre-cleaned polypropylene (PP) containers (wedge bottles) using ISCO pumps equipped with siliconized Tygon™ pump head tubing, Teflon™-lined suction line, and Teflon™ or stainless steel strainers and various connectors/fittings. The event mean composites (EMCs) were composited in a pre-cleaned 10 L glass bottle with Teflon™ lined lid.

Four stations were targeted for all events for a total of 60 samples (30 grab and 30 composite samples). During Phase I, four field duplicate sets were collected (two each grab and composites). Of the 60 potential samples, 50 were collected (22 grab and 28 composite samples), for a success rate of 73% for grabs and 93% for composites. When combined, a total of 50 out of 60 samples were collected, for an overall success rate of 83%.

Deviations from the PWP and corrective actions conducted during individual storms were documented in the storm reports (Appendix A). The anomalies of note included the following: 1) during SW01 a grab sample was collected from PSNS096, but the tidal conditions prevented the collection of the composite sample, 2) during SW05 the tidal conditions again prevented the collection of any samples at PSNS096, and 3) during SW06 a telemetry setting miscue caused the autosampler at PSNS015 to stay disabled, thus preventing the collection of the composite sample.

Table 6. The outfalls, sample types, and storm event dates sampled during 2010-2011 season.

Station	SW	01	02	03	04	05	06	07	
	Date	11/17/2010	11/29/2010	12/11/2010	3/1/2011	3/8/2011	3/9/2011	4/13/2011	
	No. Grabs	3	4	5	4	4	2	0	22
	No. Comp.	4	4	5	4	4	2	5	28
PSNS126				Dup-Comp	NT	NT	NT	NT	7
PSNS096		Grab only						Comp only	10
PSNS082.5				Dup-Grab	NT	NT	NT	NT	7
PSNS081.1					NT	NT	NT	NT	6
PSNS032		NT	NT	NT		Dup-Grab		Comp only	8
PSNS015		NT	NT	NT				Comp only	5
PSNS008		NT	NT	NT		Dup Comp	NT	Comp only / Dup	7

(green) = Stations sampled during a particular SW
(yellow) = Stations with anomalies of note during a storm event that prevented sample collection
NT = Not Targeted

2.4.1 Grab Sampling

Fecal coliform and TPH samples were collected using a manual grab sampler. Grab samples were collected at each station as soon as possible after runoff had commenced and conductivity levels were below 2,000 µmho/cm. Qualifying stormwater conditions (runoff occurrence/hydrograph response and water quality) were verified prior to grab sample collection at each station. A sterilized and pre-cleaned, stainless steel sample vessel was dipped into the flow stream (typically by using an extension pole). The TPH samplers were stored in two separate amber glass containers containing preservative. Fecal coliform samples were collected and managed as described in the *Fecal Coliform Monitoring Assessment and Control - Water Year 2011 Quality Assurance Project Plan* (Johnston, et al, 2010). Attempts were made to collect both grab and composite samples as an associated pair from the same storm event at each site.

2.4.2 Automated Time-Proportionate Composite Sampling

Time-proportionate composite samples were collected using autosamplers at each station during qualifying storm events as described above. Autosamplers were configured to begin sampling when a given combination of rain, and/or water level and/or conductivity conditions met the established criteria. Composite samples were collected for at least the first two hours of non-tidally effected runoff and up to 24-hours. No storm event sampled during the 2010-11 sampling season lasted less than two hours. The PWP details the collection, handling, analytical, and quality control procedures associated with the composite sampling. The following sections briefly described the procedures.

The autosamplers were programmed to collect sequential samples over the course of a sample event. Programming in this manner, while using a 24-bottle configuration, allowed for the greatest amount of sampling resolution. The sequential program allowed for the possibility of selecting a subset of filled bottles (depending on total sample volume needed for the targeted event), which represented the volume and nature of the storm flow and exclusion of sample bottles that were largely filled with tidal flow. Upon completion of a sample event, the contents of each bottle representing the storm flow were composited to produce a single storm event sample or EMC.

The autosamplers were set to initiate their sampling program when a series of enabling conditions were met that indicated storm runoff was occurring and that there was minimal or no tidal influence. These enabling conditions included rainfall, water level, and conductivity. Specifically, the rain gauge must have detected a rain intensity of at least 0.03 inches of precipitation in a one-hour period and the autosampler recorded an increase in the water level as measured by the pressure transducer indicating the storm produced adequate runoff.

The enabling water level was determined from background water level measurements taken at each station when not affected by storm runoff or tides plus an upward water level change beyond the sensitivity (i.e., noise) of the instrument. This water level change value was typically 0.03 to 0.1 ft. The final enabling condition was the conductivity sensor recorded less than 2,000 µmho/cm. A variation of the conductivity enable condition was the “repeatable enable”. This is where the sampler program was toggled on and off based on the 2,000 µmho/cm threshold – such that only qualified water would be collected. Various combinations of these enabling conditions were used throughout the individual storm sampling events (see Appendix A).

2.4.3 Field Sample Validation, Preservation, and Handling

Prior to creating the storm EMC samples, the individual time-composites (wedge bottles) were validated against criteria presented in Section 2.1. Validation activities for the grab and composite samples are presented below.

Grab Samples

- Reviewed field forms and the precipitation, water level, and conductivity data to ensure the grab samples were collected during storm runoff;
- Reviewed field notes to determine whether anomalous conditions were encountered that would disqualify the grab samples; and
- Inspected the grab sample containers to ensure they were properly filled and labeled.

Composite Samples

- Determined if storm runoff occurred during the sample event;
- Reviewed the storm event hyetograph, hydrograph and timing of the sample aliquot collection to ensure that the composite samples were collected within the first two hours of non-tidally influenced runoff;
- Reviewed field notes to determine whether anomalous conditions were encountered that would disqualify the composite sample;
- Tested the conductivity of each 1L wedge bottle using a hand-held conductivity meter to ensure levels were below 2,000 µmhos/cm;
- Confirmed the overall composite sample would consist of at least eight 1L wedge bottles; and
- Inspected the composite sample containers to ensure they were properly filled and labeled.

The EMC samples (final composite) were prepared in a 10L pre-cleaned glass jar stored at 4±2˚C until hand delivered to PNNL. Grab samples collected for TPH were stored at 4±2˚C and hand delivered to PNNL. Table 7 lists required sample containers, preservatives, and analytical holding times. Upon receipt at PNNL, the condition of all the samples was verified as acceptable and tracked back to the field chain of custody (COC). In the clean laboratory at PNNL, each glass composite sample was shaken vigorously (prior and between aliquot removal) and aliquots were poured into the following types of containers:

1. 500 mL Teflon bottle for total metals (TME);
2. 500 mL 0.45µm polyvinylidene fluoride (PVDF) filter unit, vacuum filtered in a class 100 clean bench and then poured into a 500 mL Teflon bottle for dissolved metals;
3. 250 mL low-density polyethylene (LDPE) bottle precharged with nitric acid preservative for samples to be analyzed for hardness (HRD);
4. 500 mL LDPE container with sulfuric acid preservative for the analysis of TOC;
5. 60 mL syringe and ashed glass fiber filter (GFF) in a cleaned filter holder and filtered into a 250 mL LDPE container with sulfuric acid preservative for the analysis of DOC;
6. 500 mL or 1L LDPE bottle for the analysis of TSS.

The total metal and dissolved metal fractions were acidified inside a Class 100 clean bench to a pH of < 2.0 with double distilled nitric acid. The samples were then assigned a central file identification number (3174) and were entered into the Pacific Northwest National Laboratory (PNNL) sample tracking system. The total petroleum hydrocarbon (TPH) grab samples and composites for TOC, DOC, hardness, and TSS were all forwarded to Columbia Analytical Laboratory Services (CAS) for analyses. Appendix B provides the documentation for the sample receipt and handling and the chemistry results for each storm event.

Table 7. Sample container types, preservatives, recommended handling, and holding times.

Parameter	Container Type	Handling / Preservation	Holding Time
Chemicals of Concern			
NWTPH-Dx (grab)	(2) 1L Amber Glass	4°C ± 2°C, H_2SO_4	7 days for extraction, 40 days for analysis
Total Recoverable Metals (Al, As, Cu, Cr, Cd, Pb, Zn, Hg)	1L Teflon	4°C ± 2°C; pH < 2.0 with nitric acid	90 days Hg and 6 months for all others
Dissolved Metals (Cu, Cr, Cd, Pb, Zn, Hg)	Filtrate 500mL Teflon	4°C ± 2°C; pH < 2.0 with nitric acid after filtration	Filter (0.45µm) within 48 hours of composite; once preserved same as above
Conventional Parameters			
Turbidity	From glass composite	4°C ± 2°C	48 hours
TSS	1L LDPE	4°C ± 2°C	7 days
Hardness, Total (as $CaCO_3$)	250mL LDPE	4°C ± 2°C	14 days
TOC	250 or 500mL LDPE w/Pres.	4°C ± 2°C, H_2SO_4	28 days
DOC	250 or 500mL LDPE w/Pres.	4°C ± 2°C, H_2SO_4	After field filtration using GFF filter, 28 days

3.0 ANALYTICAL METHODS

The chemicals of concern for this project included total recoverable and dissolved Al, As, Cu, Cr, Cd, Pb, Zn, Hg, and TPH (see Table 7). Ancillary parameters included turbidity, TSS, hardness, TOC, and DOC. The sample collection, handling, and analyses methods incorporated aspects of the USEPA Method 1669 (USEPA 1995) for clean hands sample collection and ambient water quality analyses methods [USEPA 1638 for metals (1996a) and USEPA 1631 for Hg (2002b)] to adequately represent ambient water chemistry. Although stormwater is not considered ambient water, it was critical to incorporate these protocols as industrial areas often have other sources of contamination at the outfall sampling locations.

Once a sample is collected, it must be isolated from the industrial processes occurring around the manhole as contamination of the sample would no longer represent the chemistry of the stormwater transferred through the piped conveyance. Additionally, these parameters allow the assessment of bioavailability of the metals and the application of the biotic ligand model (BLM). The BLM has been developed to account for the ancillary parameters like DOC that affect Cu bioavailability in freshwater (USEPA 2007) and saltwater (USDOD/EPA 2011; Hydroqual 2011).

The PWP detailed the preparation and analytical methods, method detection limit (MDL), and reporting limit (RL) for each parameter and Table 8 summarizes this information. Appendix B provides the individual chemistry reports for each storm event. These reports include a brief description of the methods, all quality control samples analyzed, and any impacts to the data quality. The methods were either standard methods or modifications of EPA methods. For the metals, one modification was all samples were digested following the total recoverable metal (TRM) method established in USEPA Method 1640 (1996b) prior to analysis by inductively coupled plasma mass spectrometer (ICP-MS). Both the filtered and unfiltered fractions were prepared using this method to destroy any colloidal particles remaining in the dissolved fraction.

Table 8. Preparation and analytical methods for the non-dry dock stormwater samples.

Parameter	Preparation Method	Analytical Method	Method Detection Limit (MDL)	Reporting Limit (RL)
TSS	NA	USEPA 160.2	5.0 mg/L	5.0 mg/L
Turbidity	NA	180.1	0.1 NTU	0.1 NTU
Hardness (as $CaCO_3$)	NA	STM2340C	0.8 mg/L	2 mg/L
TOC	SM5310C	SM5310C	0.07 mg/L	0.50 mg/L
DOC	Ashed GFF filtration	SM5310C	0.07 mg/L	0.50 mg/L
TPH (Diesel Range)	EPA 3510C	NWTPH-Dx	11-13 µg/L[1]	250 µg/L
TPH (Residual Range)	EPA 3510C	NWTPH-Dx	19-22 µg/L[1]	500 µg/L
Al	TRM EPA 1640m	EPA 1638m	0.3 µg/L	1.0 µg/L
As	TRM EPA 1640m	EPA 1638m	0.03 µg/L	0.1 µg/L
Cu	TRM EPA 1640m	EPA 1638m	0.007 µg/L	0.02 µg/L
Cr	TRM EPA 1640m	EPA 1638m	0.08 µg/L	0.3 µg/L
Cd	TRM EPA 1640m	EPA 1638m	0.004 µg/L	0.01 µg/L
Pb	TRM EPA 1640m	EPA 1638m	0.002 µg/L	0.006 µg/L
Zn	TRM EPA 1640m	EPA 1638m	0.05 µg/L	0.2 µg/L
Hg	EPA 1631 Rev E	EPA 1631 Rev E	0.1 ng/L	0.3 ng/L

The MDL was reported from the annually verified MDL study as determined by seven replicates of deionized water spiked at appropriate concentrations and prepared using the TRM method. The RL = 3.18 x MDL.
[1] MDLs were sample specific based on the volume extracted. See data table for individual MDLs.

4.0 QUALITY ASSURANCE AND QUALITY CONTROL

The objective for the usability, quality, type, and output of data collected, as stipulated in the PWP, is to achieve the requirements specified in the draft NPDES permit. The data will also satisfy requirements for non-dry dock stormwater outfalls and provide comparable data into the ENVVEST runoff model. The quality and usability of laboratory data generated in this investigation were evaluated for precision, accuracy (bias), representativeness, comparability, completeness, and sensitivity. The data were found to have acceptable measures of each of these variables with 93% completeness as discussed above. The overall precision was evaluated using the field duplicates, laboratory duplicates, and duplicate matrix spikes. The accuracy was evaluated using the equipment blank results, matrix spikes (MS), laboratory control standards (LCS), and standard reference material (SRM). The representativeness, comparability, and sensitivity were derived from the laboratory method blanks, MDL, RL, and comparable methodology in collection and analytical procedures.

4.1 FIELD QUALITY CONTROL

Field quality control (QC) conducted during this project included documented procedures specific to field activities including calibrating field equipment, documentation, sample collection, QC samples, data review and verification, field team performance and system audits and possible corrective actions for activities. These elements were described in the PWP and are briefly summarized below.

Original field records are maintained in designated binders and databases for all monitoring and field related activities using project-specific forms and established procedures. Field documentation included, but not limited to, stormwater sample event field sheets, maintenance activity logs, instrument calibration logs, work permits for confined space, COC forms, raw data from continuous monitoring instrumentation, and other documentation. These records were included in the storm event reports (Appendix A).

The sampling efforts for this program employed the following field QC procedures to ensure consistency, reduce contamination, and ensure representative samples:

- Collected composite water samples using automatic samplers.
- Collected samples in certified contaminant-free or properly decontaminated containers.
- Stored sampling containers in clean, sealed boxes or bags prior to use.
- Used “clean hands/dirty hands” sampling techniques (e.g., one team member performs “dirty tasks” such as lifting manhole covers and handling samplers with batteries, while the other member performs “clean tasks” such as handling sample intake lines and sample collection bottles).
- Periodically cleaned or replaced Teflon-lined sampler tubing and sampler strainers.
- Backflushed sampler tubing with deionized water prior to a sampling event.
- Held samples on ice in coolers during retrieval and delivery to laboratory.
- Delivered samples to laboratory with proper COC forms and within recommended holding times.

Field QC samples were used to assess sample collection procedures, environmental conditions during sample collection, storage, and transport to the laboratory, and the adequacy of equipment and sampling container decontamination. The types of field QC samples collected were field duplicate samples, field blanks, and equipment blanks (including tubing blanks and filtration blanks). Field QC samples were labeled and tracked as samples. The collection frequency was greater than the target of 10% of the environmental samples collected for chemicals of concern (e.g. metals and TPH).

4.1.1 Field Duplicates

The purpose of collecting and analyzing field duplicates was to demonstrate the precision of field sampling and sample processing. All field duplicate samples were collected in an identical manner to the primary “parent” and received an independent sample identification code. The field duplicate samples were used to evaluate if environmental conditions are more variable than the sampling design could accommodate.

Field duplicates consisted of an “internal” duplicate, which included a replicate (composite stormwater) sample collected at the same time using a single autosampler configuration. The autosampler was programmed to collect sequential aliquots of stormwater and deliver them to two separate sets of bottles (see PWP Section 8.2.5). Additionally, field duplicates were collected for those parameters that require grab samples (i.e. TPH, fecal coliform) by filling an additional set of grab sample bottles in rapid succession.

Twenty-four stormwater composite samples were collected plus six field duplicates for the metals. The relative percent differences (RPD) between the parent and duplicate sample were all less ≤ 32% RPD. This meets the data quality objective of ≤ 40% RPD suggesting the methodology accurately captures variability at a particular station within a given storm event. In fact, the average RPD was ≤ 15% RPD. For TPH, 21 storm grabs were collected plus two field duplicates. The RPD values were also ≤ 40% RPD with an average of 11% RPD.

4.1.2 Field Blanks

Field collected equipment blanks (EB) exceeded a frequency of 1 out of every 10 samples. They were used to check for possible contamination of laboratory-cleaned grab sample equipment, autosampler equipment and sample containers for the chemicals of concern (TPH and metals). The EBs were also used to detect contamination from the surroundings or cross-contamination during transportation and/or storage. For TPH, two equipment blanks (December and March) were collected by pouring deionized water (DI) into the stainless steel sampling cup and then into an amber glass sample container while at two randomly selected outfall locations. The TPH concentrations in the EBs were not detected above the RL.

For the metals, a total of 18 EBs were collected to evaluate the composite autosampler system. This included blanks from the Teflon® sample line tubing, autosampler pump and distributor arm tubing, wedge bottles and glass composite jars. The EBs included two tubing blanks, eight autosampler system blanks, and eight filtration blanks. The two tubing blanks had metal concentrations less than the MDL and reflected only laboratory cleaning since they were not field deployed. In order to incorporate field conditions, eight field blanks were collected with four in October 2010 prior to the onset of storm event sampling and another four in February after station moves. Deionized water was pumped through the deployed tubing, autosampler, laboratory cleaned sample intake line and strainer and into the pre-cleaned glass composite jar. The EB samples were assigned a unique sample identification code, labeled, and delivered to the laboratory as a sample.

At the laboratory, they were filtered for dissolved metals and analyzed with the other storm event samples. All the EBs were less than the RL for Hg, As, and Ag. Detectable concentrations of Cd, Cr, Cu, Pb, and Zn triggered the corrective action, which included a review of the analytical method blanks to rule out lab contamination, a review of the clean hands sampling protocol, and all data were evaluated if the storm event concentrations were <5 times the EB concentrations. Table 9 summarizes the mean EB concentrations compared to the MDL, RL, and if there were sample concentrations <5 times the mean EB. The laboratory analyses included a method blank with each analytical batch of samples. The method blank is a sample carried through the preparation and analytical methods to ensure there is no significant contamination from the chemical reagents, laboratory handling or analytical equipment. The method blanks results did not suggest a laboratory contamination issue. A review of the sampling equipment identified a stainless steel strainer as the potential problem for Cr and this was replaced with a plastic strainer after the first set of EB samples were collected. The second set verified the corrective action worked and the overall impact to the data quality was not significant.

Table 9. The summary of equipment blank concentrations for the metals.

	MDL	**RL**	**EB Mean**	**Standard Deviation**	**No. Samples < 5 times EB Mean**
Hg (ng/L)	0.1	0.3	0.115 J	0.080	NA
Ag (µg/L)	0.002	0.006	0.002 U	--	NA
As (µg/L)	0.03	0.1	0.03 U	--	NA
Cd (µg/L)	0.004	0.01	0.006 J	0.007	NA
Cr (µg/L)	0.08	0.3	0.553	1.08	29
Cu (µg/L)	0.007	0.02	0.149	0.278	0
Pb (µg/L)	0.002	0.006	0.0210	0.0273	0
Zn (µg/L)	0.05	0.2	0.608	0.456	0

NA – not appropriate because equipment blanks were less than RL.
U Value not detected above the MDL.
J Estimated concentration below the RL.

4.1.3 Field Data Review and Verification

Field data were reviewed and verified following the guidance provided by the USEPA (2002a). The verification included computer entries to field data sheets, calculations, and raw data review for outliers or nonsensical readings. The field data were reviewed on a monthly basis and after each successfully sampled storm event. This included rainfall, water level, temperature, conductivity and salinity data review for gross errors such as spikes or data gaps to determine completeness of the data set. Rainfall, water level, temperature and conductivity measurements were checked as follows:

- Identified data gaps and determined if they could be filled with alternate data.
- Identified data anomalies or spikes for unrealistic conditions.
- Cross checked data sets against field sheets and calibration records. Determined if data sets needed to be adjusted based on instrument calibration or field staff observations.
- Inspected patterns/yields for a particular basin/area based on previous project or historic data. Comparison of hyetograph to the hydrograph for water level response to rainfall.

The TEC and PNNL reviewed the procedures implemented in the field for consistency with the established protocols. Members of the Navy Project Team also perform field procedural reviews. Sample collection, preservation, labeling, and other procedures were checked for completeness. Where procedures were not in compliance with the established protocols, these deviations were documented and reported in the storm or chemistry reports (Appendices A and B, respectively).

4.2 LABORATORY QUALITY CONTROL

The PWP detailed the laboratory procedures necessary to achieve the data quality objectives through appropriate analytical methods, QA/QC, and data validation. The QC samples analyzed with each batch of 20 or fewer field samples included method blanks, LCS, MS, matrix spike duplicates (MSD), laboratory duplicate (DUP), and SRM for the metals. The TPH samples included method blanks, LCS, and lab duplicates. The QC data were provided in the individual storm chemistry reports (Appendix B) and summarized in Table 10 for all the parameters. Overall, data met the required QC requirements for the project. The laboratory duplicate from PSNS015 during SW05 was highly variable for total Hg (RPD 80%). Six individual aliquots of this sample were prepared and analyzed. All six maintained a high degree of variability. This was not attributed to the laboratory procedures since all other forms of QA/QC were acceptable during all other storm events. Additional studies are required for this outfall to understand the source and chemical form (e.g. particulate or dissolved) of Hg.

Table 10. Laboratory quality control sample summary.

QC Type		Hg	As	Ag	Cd	Cr	Cu	Pb	Zn	TPH DRO	TPH RRO
MB	n =	28	8	8	8	8	8	8	8	4	4
MB	Mean	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	< RL	< RL
MB	Stdev	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Percent Recovery (%)											
LCS	n =	14	6	6	6	6	6	6	6	6	6
LCS	Mean	100%	101%	99%	100%	105%	101%	102%	103%	97%	92%
MS	n =	16	13	6	6	6	6	6	6	NA	NA
MS	Mean	98%	103%	96%	101%	101%	97%	103%	103%	NA	NA
SRM	n =	6	13	6	6	6	6	6	6	NA	NA
SRM	Mean	95%	98%	92%	99%	95%	98%	98%	95%	NA	NA
Relative Percent Difference (RPD)											
Lab Dup	n =	10	7	7	7	7	7	7	7	3	3
Lab Dup	Mean	21%a	2%	10%	4%	3%	1%	2%	1%	13%	12%
Field Dup	n =	6	6	6	6	6	6	6	6	2	2
Field Dup	Mean	15%	12%	5%	4%	7%	4%	13%	6%	14%	7%
Ancillary Parameters											
QC Type		**DOC**	**TOC**	**TSS**	**Hardness**						
MB	n =	6	10	14	7						
MB	Mean	< RL	<MDL	<MDL	<MDL						
MB	Stdev	NA	NA	NA	NA						
Percent Recovery (%)											
LCS	n =	6	10	7	12						
LCS	Mean	102%	102%	107%	97%						
MS	n =	5	3	NA	NA						
MS	Mean	101%	100%	NA	NA						
Relative Percent Difference (RPD)											
Lab Dup	n =	5	4	2	6						
Lab Dup	Mean	8%	13%	9%	2%						
Field Dup	n =	2	2	2	2						
Field Dup	Mean	19%	14%	7%	27%						

a Righ RPD for PSNS015. Alternate duplicates show this is not attributed to laboratory precision

EB = Equipment Blank; MB = Method Blank; LCS = Laboratory Control Sample; MS = Matrix Spike

SRM = Standard Reference Material; Lab Dup = Laboratory Duplicate; Field Dup = Field Duplicate; TPH = Total Petroleum Hydrocarbons; DRO = Diesel Range Organics; RRO = Residual Range Organics

5.0 RESULTS AND DISCUSSION

Seven qualifying storm events were sampled from November 1, 2010 through April 15, 2011 (Table 6). The field collection details for each storm were reported in Appendix A. The chemistry data were reported in Appendix B. Each event report (field and chemistry) contained a summary of storm event specific qualification parameters, sample collection criteria, QC information, and storm and sample validation checklist items (Appendix A and B). The following sections provide a synopsis of this information.

5.1 RAINFALL DATA

Rainfall data was collected from each station and from the PSNS gauge atop Building 427 inside of the CIA. Table 11 presents a summary of the rainfall data collected during the 2010-11 season for both storm events and stations. The table also provides rainfall averages, minimum / maximum depths and the Project ENVVEST storm size classification. Table 12 presents more detailed rainfall and water quality data measured from within the vaults at each site and storm including maximum one-hour rainfall intensity and event average one-hour rainfall intensity (both in inches/hour). Sample event rainfall was also assessed in 5-minute intervals. The 5-minute intervals provide a greater resolution when comparing storms of similar size.

There are some nuances to this type of data including: vault levels that may be negative due to transducer placement; negative conductivity values due to calibration issues typically associated with stations where the conductivity values are in the tens of thousands for a majority of the storm; salinity values constrained to values between 2 and 42 ppt for the stations utilizing the CT2X transducer due to the conductivity to salinity conversion algorithm used for post-calculation (although the conductivity values were not constrained by this algorithm); and salinity data collected via the YSI 6820 multi-parameter sonde was capable of calculating values outside of the 2 to 42 ppt range mentioned above. See Appendix A for more detailed discussions of data nuances for each storm.

Historic rainfall records have been maintained for the Bremerton, WA area since 1899. These data sets are available through the Western Regional Climate Center (http://www.wrcc.dri.edu/). Table 13 presents monthly statistical rainfall summary data for Bremerton, WA (station 450872). The “wet season” in western Washington is from October through April, with a monthly range of 2.7 inches in April to 7.7 inches in December. The yearly average is 47.9 inches. The project sampling season was conducted for nearly the entire duration of the 2010-11 wet season; November 1, 2010 through April 15, 2011. During that five and a half month period 106 days of at least 0.01” in a 24-hour period of rain were recorded by the PSNS gauge at B427. The project site experienced a slightly wetter than average period (6.3% above average) for the 2010-11 sampling duration with 36.98” compared to the historic data, which was 34.78” for the same period. The months of December and March had notably higher amounts of rainfall than average, while the other months were below average. Table 14 details the total rainfall at the PSNS site for the Phase I sampling period along with the descriptive statistics.

Table 11. Total rainfall for each storm event and the ENVVEST storm size classification.

Station	SW	01	02	03	04	05	06	07
	Date	11/17/2010	11/29/2010	12/11/2010	3/1/2011	3/8/2011	3/9/2011	4/13/2011
B427 - Navy Gauge		0.57	1.32	4.79	0.60	0.19	2.60	0.78
PSNS126		0.51	1.23	3.71	Na	na	Na	Na
PSNS096		0.61	1.18	4.47	0.59	0.16	2.39	0.75
PSNS082.5		0.59	1.25	4.44	Na	na	Na	Na
PSNS081.1		0.46	1.05	3.57	Na	na	Na	Na
PSNS032		na	Na	na	0.53	0.17	2.05	0.73
PSNS015		na	Na	na	0.54	0.17	2.21	0.75
PSNS008		na	Na	na	0.66	0.19	Na	0.86
Storm Average (in.)		0.55	1.21	4.20	0.58	0.18	2.31	0.77

Min (in.)	0.46	1.05	3.57	0.53	0.16	2.05	0.73
Max (in.)	0.61	1.32	4.79	0.66	0.19	2.60	0.86
[2]ENVVEST Storm Size Classification (Brandenberger et al. 2007a)	Medium	Med-Large	Large	Medium	Small	Large	Medium

[1]Rainfall units are in inches
[2]Storm Size Classification: Small = <0.5", Medium = 0.5 – 1.0", Med-Large = 1.0 – 2.0", Large = ≥ 2.0"
Na = Not sampled during that storm event.

Table 12. Storm event rainfall descriptive summary for each 2010-11 storm and station.

Storm	Parameter	Statistic	B427	PSNS126	PSNS096	PSNS082.5	PSNS081.1	PSNS015	PSNS008	PSNS032
SW01 11/17/2010	Total Rainfall (in)		0.57	0.51	0.61	0.59	0.46			
	Max 1-hr Rainfall Intensity (in/hr)		0.14	0.14	0.15	0.15	0.17			
	Average 1-hr Rainfall Intensity (in/hr)		0.018	0.017	0.020	0.020	0.016			
	Rainfall 5-min Interval (in)	Min		0	0	0	0			
		Max		0.04	0.04	0.04	0.03			
		Median		0.00	0.21	0.00	0.00			
	Vault level (ft)	Min		0.09	4.15	0.01	-0.21			
		Max		4.07	7.92	3.23	8.49			
		Median		0.30	6.10	0.33	4.66			
	Salinity (ppt)	Min		2	2	0.02	2			
		Max		2	42	0.08	41			
		Median		2	42	0.05	2			
	Temp (°C)	Min		5.58	7.36	5.91	6.63			
		Max		12.05	11.4	11.24	21.13			
		Median		11.07	10.96	9.53	11.97			

Storm	Parameter	Statistic	B427	PSNS126	PSNS096	PSNS082.5	PSNS081.1
SW02 (11/29/2010)	Total Rainfall (in)		1.32	1.23	1.18	1.25	1.05
	Max 1-hr Rainfall Intensity (in/hr)		0.12	0.12	0.11	0.13	0.1
	Average 1-hr Rainfall Intensity (in/hr)		0.055	0.050	0.049	0.052	0.044
	Rainfall 5-min Interval (in)	Min		0	0	0	0
		Max		0.02	0.02	0.02	0.02
		Median		0.00	0.00	0.00	0.00
	Vault level (ft)	Min		0.04	0.04	0.18	0.03
		Max		5	10.53	3.88	9.74
		Median		0.20	4.48	0.35	3.73
	Salinity (ppt)	Min		2	2	0	2
		Max		2	42	1	2
		Median		2	42	0	2
	Temp (°C)	Min		6.26	7.26	4.72	6.83
		Max		9.82	14.06	6.72	15.04
		Median		7.75	9.75	5.25	8.34

Table 12. Continued.

Event	Parameter	Statistic	B427	PSNS126	PSNS096	PSNS082.5	PSNS081.1	PSNS015	PSNS008	PSNS032
SW03 (12/11/2010)	Total Rainfall (in)		4.79	3.71	4.47	4.44	3.57			
	Max 1-hr Rainfall Intensity (in/hr)		0.41	0.33	0.43	0.42	0.34			
	Average 1-hr Rainfall Intensity (in/hr)		0.184	0.152	0.171	0.174	0.136			
	Rainfall 5-min Interval (in)	Min		0	0	0	0			
		Max		0.04	0.05	0.05	0.04			
		Median		0.01	0.010	0.010	0.01			
	Vault level (ft)	Min		0.1	0.6	0.21	0.17			
		Max		5.3	10.82	5.2	10.54			
		Median		0.39	4.49	0.39	4.06			
	Salinity (ppt)	Min		2	2	0	2			
		Max		2	42	1	2			
		Median		2	2	0	2			
	Temp (°C)	Min		6.7	7.34	5.7	7.01			
		Max		12.6	12.83	11.16	13.09			
		Median		10.22	10.18	7.46	10.45			

Event	Parameter	Statistic	B427		PSNS096			PSNS015	PSNS008	PSNS032
SW04 (3/1/2011)	Total Rainfall (in)		0.6		0.59			0.54	0.66	0.53
	Max 1-hr Rainfall Intensity (in/hr)		0.06		0.07			0.06	0.08	0.06
	Average 1-hr Rainfall Intensity (in/hr)		0.019		0.018			0.018	0.021	0.018
	Rainfall 5-min Interval (in)	Min			0			0	0	0
		Max			0.01			0.01	0.02	0.01
		Median			0			0	0	0
	Vault level (ft)	Min			0			0.18	0	0
		Max			9.8			8.48	2.74	3.32
		Median			4.49			4.17	0.22	0.29
	Salinity (ppt)	Min			0			2	2	2
		Max			41			42	42	42
		Median			40			2	2	2
	Temp (°C)	Min			6.79			4.78	4.29	4.68
		Max			12.29			9.68	9.11	8.44
		Median			7.13			7.18	6.58	7.24

Table 12. Continued.

Event	Parameter	Statistic	B427		PSNS096			PSNS015	PSNS008	PSNS032
SW05 (3/8/2011)	Total Rainfall (in)		0.19		0.16			0.17	0.19	0.17
	Max 1-hr Rainfall Intensity (in/hr)		0.07		0.07			0.07	0.07	0.06
	Average 1-hr Rainfall Intensity (in/hr)		0.029		0.052			0.057	0.057	0.040
	Rainfall 5-min Interval (in)	Min						0	0	0
		Max						0.01	0.01	0.01
		Median						0.00	0.00	0.00
	Vault level (ft)	Min						0.32	0.32	0.23
		Max						8.23	2.65	2.73
		Median						6.7	1.9	2.02
	Salinity (ppt)	Min						2	2	2
		Max						2	2	2
		Median						2	2	2
	Temp (°C)	Min						6.51	5.37	6.13
		Max						10.61	6.39	8.1
		Median						6.76	5.63	6.73

Event	Parameter	Statistic	B427		PSNS096			PSNS015		PSNS032
SW06 (3/9/2011)	Total Rainfall (in)		2.6		2.39			2.21		2.05
	Max 1-hr Rainfall Intensity (in/hr)		0.33		0.36			0.32		0.29
	Average 1-hr Rainfall Intensity (in/hr)		0.067		0.084			0.055		0.052
	Rainfall 5-min Interval (in)	Min			0					0
		Max			0.09					0.08
		Median			0.00					0.00
	Vault level (ft)	Min			0.14					-0.09
		Max			8.99					6.04
		Median			5.63					0.51
	Salinity (ppt)	Min			0					2
		Max			41					37
		Median			3					2
	Temp (°C)	Min			7.5					7.43
		Max			13.17					10.76
		Median			9.01					9.5

Table 12. Continued.

			B427		PSNS096			PSNS015	PSNS008	PSNS032
SW07 (4/13/2011)	Total Rainfall (in)		0.78		0.75			0.75	0.86	0.73
	Max 1-hr Rainfall Intensity (in/hr)		0.16		0.14			0.14	0.14	0.13
	Average 1-hr Rainfall Intensity (in/hr)		0.23		0.028			0.028	0.030	0.027
	Rainfall 5-min Interval (in)	Min						0	0	0
		Max						0.02	0.02	0.02
		Median						0	0	0
	Vault level (ft)	Min						0.37	0.07	0.04
		Max						7.97	2.17	2.74
		Median						3.78	0.31	0.09
	Salinity (ppt)	Min						2	2	2
		Max						41	42	2
		Median						2	2	2
	Temp (°C)	Min						7.55	6.46	7.56
		Max						11.29	9.14	11.63
		Median						9.65	8.22	9.67

Table 13. Historical monthly rainfall summary (inches) for Bremerton, WA (450872) from 1899 to 2010 (http://www.wrcc.dri.edu/).

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
AVE	7.26	5.33	4.54	2.7	1.81	1.44	0.72	0.87	1.65	3.99	7.25	7.7	45.25
MAX	20.08	18.03	12.19	7.67	5.46	4.52	3.11	3.97	7.09	14.12	21.64	16.22	75.81
MIN	0.61	0.27	0.27	0.26	0.13	0.04	0	0	0	0.16	0.83	0.44	22.73
No. YRS	95	99	98	104	105	106	103	104	106	101	94	96	63

Period of Record: 5/1/1899 to 12/31/2010. Percent of possible observations for period of record; Precipitation = 96.2%.

Table 14. PSNS Building 427 monthly rain gauge summary for 2010-11 sampling period.

B427 Rain Gauge Statistics	Nov	Dec	Jan	Feb	Mar	Apr[1]
Days of rain (#)	18	21	13	14	26	14
Total Rainfall (in)	5.81	12.27	4.04	4.16	9.35	1.35
Daily average (in)	0.32	0.58	0.31	0.30	0.36	0.10
Daily Min (in)	0.01	0.01	0.01	0.01	0.01	0.01
Daily Max (in)	1.52	3.01	1.53	1.25	1.93	0.62
Median (in)	0.18	0.34	0.13	0.1	0.17	0.05

[1]only 16 days used for calculation of monthly totals

5.2 SAMPLE EVENT RUNOFF

A continuous rainfall record allowed for the establishment of a rainfall/runoff relationship at each station. These relationships were used to estimate the total volume of discharge sampled using the RCM calculations discussed previously in Section 2.2.1. This method uses the total storm rainfall, pervious and impervious drainage area size, and a runoff coefficient to calculate the total runoff volume in cubic feet. Runoff coefficients for the selected stations where chosen from published values and were provided in Table 5 along with total basin area, type of surface, percentage of drainage basin surface type, area of surface type, runoff coefficient range, area of basin surface type with maximum coefficient value applied and total discharge volume formula for each Phase I station.

The coefficient range gives latitude for consideration of particular basin characteristics. Typically the maximum coefficient range values are applied to the more impervious portions and the lower end of the coefficient range values are applied to the more pervious portions of a certain surface type when calculating runoff volumes. In all cases, when calculating runoff volumes for Phase I, the maximum coefficient values were applied due to the high proportion of impervious surface in each drainage basin. Table 15 lists the storm runoff volumes for each station and sampled storm event. Tidal effects at PSNS096 caused very brief sampling opportunities.

Table 15. Station runoff (RO) summary for each storm event.

Station	SW	01	02	03	04	05	06	07	TOTAL
	Date	11/17/2010	11/29/2010	12/11/2010	3/1/2011	3/8/2011	3/9/2011	4/13/2011	
PSNS126	Storm RO ($ft.^3$)	25,155	60,668	182,989	-	-	-	-	268,811
PSNS096	Storm RO ($ft.^3$)	32,295	62,473	236,655	31,236	8,471	126,533	39,707	537,370
PSNS082.5	Storm RO ($ft.^3$)	4,069	8,621	30,623	-	-	-	-	43,313
PSNS081.1	Storm RO ($ft.^3$)	32,548	74,294	252,598	-	-	-	-	359,440
PSNS032	Storm RO ($ft.^3$)	-	-	-	8,156	2,616	31,546	11,233	53,551
PSNS015	Storm RO ($ft.^3$)	-	-	-	108,509	34,160	444,083	150,707	737,459
PSNS008	Storm RO ($ft.^3$)	-	-	-	23,630	6,803	-	30,791	61,223
TOTAL	Storm RO ($ft.^3$)	94,067	206,055	702,865	171,531	52,050	602,162	232,438	2,061,167

5.3 STORMWATER CHEMISTRY

The descriptive statistics for the metals chemistry are summarized in Tables 16 for the metals listed in the draft permit and Table 17 for additional metals that support the Navy mass balance calculations for Sinclair and Dyes Inlets (Brandenberger et al. 2008). The statistics were calculated on the pooled data from all stations and storms and then individual stations. The total recoverable (TR) draft permit limits were provided in Table 16 and statistics exceeding the draft permit concentrations were highlighted. The stormwater EMCs for TR Cu and Zn exceeded the draft permit guidance at select stations. The distribution of the data from all stations and storms shows a high probability for the TR Cu to exceed the draft permit even 25% of the time for outfalls with basin characteristics similar to those in this Phase I study. The TR Zn data for all stations and storms shows the EMCs might exceed the draft permit value 50% of the time. The distribution of the data for all metals was highly variable (Figure 5) and not normally distributed. Therefore, the median should be used for evaluating overall trends and metal loads.

Evaluating the data on a station level supports identification of critical areas for further investigation and process improvement. Figures 6 and 7 illustrate the inter-storm and station variability for Cu and Zn. The existing and draft permit concentrations are provided for reference. For Cu, all stations and storms would exceed the draft permit concentration. Two of the 24 stormwater sampled collected would exceed the NPDES permit of 33 µg/L TR Cu. The stations that either exceeded or were within 10% of the NPDES permit concentration were PSNS081.1, 081.5, and 096. Although the permit is based on TR Cu (top of the bars), the figures also show the partitioning of the chemistry between particulate and dissolved phases.

The fraction of the TR Cu occurring as dissolved Cu ranged from 10-68%. The fraction of dissolved can be used to identify the types of Cu entering the systems, predict the best management practices for a particular stormwater system, and evaluate the fate of the Cu once it enters the marine receiving waters of Sinclair Inlet. The TR Cu concentrations in Sinclair Inlet ambient waters are 60-90% d Cu (Brandenberger et al. 2008). Therefore stations with less than 50% d Cu might be targeted for particulate Cu sources, especially those such as metal particles that do not really dissolved in seawater. Since all but two storm events and stations had > 50% d Cu, the stations with less than 30% d Cu were PSNS082.5, 081.1, 032, and 096. The percentage of TR Zn occurring as dissolved ranged from 29-79%. In seawater, Zn occurs as 90-100% dissolved and would be expected to readily dissolve after entering seawater. Stations with < 50% d Zn were PSNS082.5, 032, and 096. All of these stations except PSNS032 are in the CIA and support vessel maintenance.

The Phase I data can be compared to other regional data, which will be discussed in detail later. Outfall PSNS126 was sampled during the ENVVEST 2003-2005 stormwater quality project (Brandenberger et al. 2007 a, b) using the same time-paced, autosampler collection methods. The TR Cu concentrations for ENVVEST ranged 27-55 µg/L (ppb or parts – per-billion) at this station compared to the 7.64-15.0 µg/L reported for the 2010-11 sampling. The TR Zn concentrations from ENVVEST ranged 88-96 µg/L (ppb) for PSNS126 compared to the 2010-11 range of 49-62 µg/L. The variability is too high to assess a significant decrease in concentrations. However, the Cu data suggests a measure of process improvement in the sub-basin and additional information on changes in practices may be useful to qualitatively evaluate BMPs.

Figures 8 illustrate the inter-storm and station variability for dissolved, particulate, and TR Hg. The concentrations are well below the draft permit concentration of 2100 ng/L TR Hg; however, they are significantly elevated in the NBK region of the shipyard and particularly PSNS015 and 032. The fraction of the TR Hg in the ambient waters of Sinclair/Dyes Inlet that occur as d Hg averages approximately 50% with a range from 30-80%. The Phase I stormwater EMCs averaged 24% d Hg with stations PSNS081.1, 096, 015 and 032 showing the highest fraction of particulate Hg with d Hg < 10%. The Phase I sampling also identified PSNS015 and PSNS032 as critical outfall sub-basins for further Hg studies. Additional studies by U.S. Geological Survey (USGS) and PNNL are underway to understand the sources of Hg in the region of NBK. In addition, sediment samples from the storm drains were collected during Phase II to further support the understanding of links between the sediment, regional mussel watch data, ambient water column data, and non-dry dock stormwater data.

Table 16. Descriptive statistics for Phase I Event Mean Composite (EMC) stormwater samples. The draft permit concentrations are included for reference and all concentrations greater than the draft permit concentration are highlighted orange.

Station		Hg	Hg	As	As	Cu	Cu	Pb	Pb	Zn	Zn
Fraction		Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total
Units: µg/L											
Draft Permit			**2.1**		**69**		**5.8**		**221**		**95**
All	**Mean**	**0.00272**	**0.0237**	**1.26**	**1.59**	**6.88**	**19.6**	**0.472**	**7.93**	**57.0**	**102**
All	Stdev.	0.00144	0.0384	1.12	1.14	4.57	11.6	0.499	3.72	22.4	34.3
All	25th	0.00183	0.00797	0.690	0.977	4.67	11.5	0.179	4.49	45.0	75.9
All	Median	0.00221	0.0107	0.870	1.35	5.26	15.7	0.301	7.66	50.1	103
All	75th	0.00314	0.0135	1.43	1.81	7.10	25.8	0.479	11.4	62.5	120
All	n	24	24	24	24	24	24	24	24	24	24
PSNS008	**Mean**	**0.00197**	**0.0109**	**2.18**	**2.47**	**5.45**	**14.3**	**0.228**	**5.11**	**99.6**	**141**
PSNS008	Stdev.	0.000252	0.00201	3.05	3.17	0.744	2.28	0.110	1.05	14.5	12.9
PSNS008	Min	0.00181	0.0087	0.380	0.586	4.92	12.9	0.139	3.95	82.8	132
PSNS008	Max	0.00226	0.0126	5.70	6.13	6.30	16.9	0.351	6.00	108	156
PSNS008	n	3	3	3	3	3	3	3	3	3	3
PSNS015	**Mean**	**0.00487**	**0.0961**	**0.874**	**1.07**	**5.17**	**10.2**	**1.68**	**10.8**	**48.7**	**72.6**
PSNS015	Stdev.	0.00135	0.0730	0.152	0.208	0.167	1.83	0.264	2.33	1.56	6.58
PSNS015	Min	0.00332	0.0182	0.781	0.918	4.98	8.23	1.38	8.12	47.3	65.0
PSNS015	Max	0.00584	0.163	1.05	1.31	5.30	11.8	1.86	12.5	50.4	76.4
PSNS015	n	3	3	3	3	3	3	3	3	3	3
PSNS032	**Mean**	**0.00391**	**0.0284**	**0.753**	**1.24**	**3.12**	**10.1**	**0.322**	**8.62**	**33.6**	**95.3**
PSNS032	Stdev.	0.00196	0.0349	0.221	0.289	0.845	2.58	0.207	3.61	2.71	24.0
PSNS032	Min	0.00246	0.00669	0.480	0.936	1.92	6.97	0.179	4.17	30.4	71.8
PSNS032	Max	0.00681	0.0806	1.00	1.63	3.90	12.4	0.623	11.8	37.0	118
PSNS032	n	4	4	4	4	4	4	4	4	4	4

Table 16. Descriptive statistics for Phase I Event Mean Composite (EMC) stormwater samples. The draft permit concentrations are included for reference and all concentrations greater than the draft permit concentration are highlighted orange.

Station		**Hg**	**Hg**	**As**	**As**	**Cu**	**Cu**	**Pb**	**Pb**	**Zn**	**Zn**
Fraction		**Dissolved**	**Total**	**Dissolved**	**Total**	**Dissolved**	**Total**	**Dissolved**	**Total**	**Dissolved**	**Total**
PSNS081.1	**Mean**	**0.00259**	**0.0167**	**1.15**	**1.48**	**13.9**	**34.8**	**0.367**	**10.8**	**82.2**	**138**
PSNS081.1	Stdev.	0.000446	0.00872	0.411	0.434	6.24	6.87	0.179	4.54	10.3	31.4
PSNS081.1	Min	0.00216	0.00981	0.679	1	7.23	30.6	0.198	6.05	71.6	116
PSNS081.1	Max	0.00305	0.0265	1.40	1.85	19.6	42.7	0.555	15.1	92.1	174
PSNS081.1	n	3	3	3	3	3	3	3	3	3	3
PSNS082.5	**Mean**	**0.00189**	**0.00724**	**0.572**	**0.791**	**10.7**	**30.4**	**0.343**	**6.01**	**51.3**	**119**
PSNS082.5	Stdev.	0.000216	0.00401	0.268	0.394	6.79	18.0	0.318	4.16	1.65	38.9
PSNS082.5	Min	0.00164	0.0037	0.292	0.383	6.44	16.4	0.149	2.74	49.7	80.2
PSNS082.5	Max	0.00204	0.0116	0.827	1.17	18.5	50.7	0.710	10.7	53.0	158
PSNS082.5	n	3	3	3	3	3	3	3	3	3	3
PSNS096	**Mean**	**0.00168**	**0.00917**	**1.25**	**1.73**	**5.37**	**25.5**	**0.279**	**9.47**	**53.2**	**98.5**
PSNS096	Stdev.	0.000476	0.00306	0.429	0.345	1.68	5.72	0.121	2.77	5.05	15.3
PSNS096	Min	0.00100	0.00472	0.730	1.38	3.05	17.8	0.149	5.35	47.5	74.5
PSNS096	Max	0.00227	0.0133	1.77	2.23	7.65	32.5	0.453	12.2	59.5	116
PSNS096	n	5	5	5	5	5	5	5	5	5	5
PSNS126	**Mean**	**0.00244**	**0.00570**	**2.25**	**2.38**	**6.74**	**10.8**	**0.256**	**3.46**	**40.8**	**54.9**
PSNS126	Stdev.	0.000951	0.00234	0.532	0.509	3.43	3.78	0.0985	0.745	5.74	6.85
PSNS126	Min	0.00166	0.00435	1.64	1.8	3.35	7.64	0.159	2.60	34.7	48.8
PSNS126	Max	0.00350	0.0084	2.62	2.75	10.2	15.0	0.356	3.90	46.1	62.3
PSNS126	n	3	3	3	3	3	3	3	3	3	3

Table 17. Descriptive statistics for composite stormwater samples collected during the Phase I 2010-11 storm season. The metals are not included in the draft permit, but provided for project ENVVEST mass balance calculations.

Station		**Ag**	**Ag**	**Cd**	**Cd**	**Cr**	**Cr**
Fraction		**Dissolved**	**Total**	**Dissolved**	**Total**	**Dissolved**	**Total**
Units: µg/L							
All	**Mean**	**0.00517**	**0.0312**	**0.156**	**0.340**	**1.82**	**6.61**
All	Stdev.	0.00434	0.0189	0.109	0.274	1.10	12.6
All	25th	0.00200	0.0239	0.101	0.195	1.18	2.62
All	Median	0.00315	0.0271	0.111	0.272	1.45	3.35
All	75th	0.00546	0.0349	0.187	0.367	2.08	5.00
All	n	24	24	24	24	24	24
PSNS008	**Mean**	**0.00288**	**0.0162**	**0.187**	**0.327**	**1.62**	**3.86**
PSNS008	Stdev.	0.000901	0.0125	0.0443	0.0344	0.771	0.675
PSNS008	Min	0.00200	0.002	0.148	0.300	0.946	3.2
PSNS008	Max	0.00380	0.0251	0.235	0.366	2.46	4.55
PSNS008	n	3	3	3	3	3	3
PSNS015	**Mean**	**0.00346**	**0.0457**	**0.0353**	**0.0658**	**1.94**	**3.01**
PSNS015	Stdev.	0.00118	0.0418	0.00386	0.0134	0.867	1.26
PSNS015	Min	0.00272	0.014	0.0325	0.0556	1.36	2.22
PSNS015	Max	0.00482	0.0931	0.0397	0.0810	2.94	4.46
PSNS015	n	3	3	3	3	3	3
PSNS032	**Mean**	**0.00325**	**0.0260**	**0.102**	**0.239**	**0.986**	**2.80**
PSNS032	Stdev.	0.00155	0.00602	0.00564	0.0608	0.486	0.769
PSNS032	Min	0.00200	0.0199	0.0931	0.184	0.412	1.74
PSNS032	Max	0.00520	0.0343	0.105	0.317	1.58	3.50
PSNS032	n	4	4	4	4	4	4

Table 17. Descriptive statistics for composite stormwater samples collected during the Phase I 2010-11 storm season. The metals are not included in the draft permit, but provided for project ENVVEST mass balance calculations.

Station		Ag	Ag	Cd	Cd	Cr	Cr
Fraction		**Dissolved**	**Total**	**Dissolved**	**Total**	**Dissolved**	**Total**
PSNS081.1	**Mean**	**0.0104**	**0.0467**	**0.157**	**0.345**	**2.55**	**7.36**
PSNS081.1	Stdev.	0.00376	0.0221	0.0558	0.0703	1.54	1.39
PSNS081.1	Min	0.00624	0.0288	0.109	0.266	1.44	5.99
PSNS081.1	Max	0.01350	0.0714	0.218	0.4	4.31	8.76
PSNS081.1	n	3	3	3	3	3	3
PSNS082.5	**Mean**	**0.00291**	**0.0298**	**0.317**	**0.892**	**1.59**	**3.97**
PSNS082.5	Stdev.	0.00158	0.0184	0.0617	0.331	0.351	1.59
PSNS082.5	Min	0.00200	0.012	0.277	0.596	1.35	2.31
PSNS082.5	Max	0.00474	0.0488	0.388	1.25	1.99	5.49
PSNS082.5	n	3	3	3	3	3	3
PSNS096	**Mean**	**0.00246**	**0.0258**	**0.183**	**0.363**	**2.44**	**17.4**
PSNS096	Stdev.	0.000656	0.00908	0.165	0.230	1.68	26.7
PSNS096	Min	0.00200	0.0138	0.0845	0.208	1.10	2.71
PSNS096	Max	0.00341	0.0394	0.476	0.77	5.19	64.7
PSNS096	n	5	5	5	5	5	5
PSNS126	**Mean**	**0.0132**	**0.0337**	**0.109**	**0.169**	**1.48**	**2.03**
PSNS126	Stdev.	0.00301	0.00320	0.0356	0.0391	0.818	0.828
PSNS126	Min	0.00979	0.0304	0.0712	0.139	0.744	1.32
PSNS126	Max	0.0155	0.0368	0.142	0.213	2.36	2.94
PSNS126	n	3	3	3	3	3	3

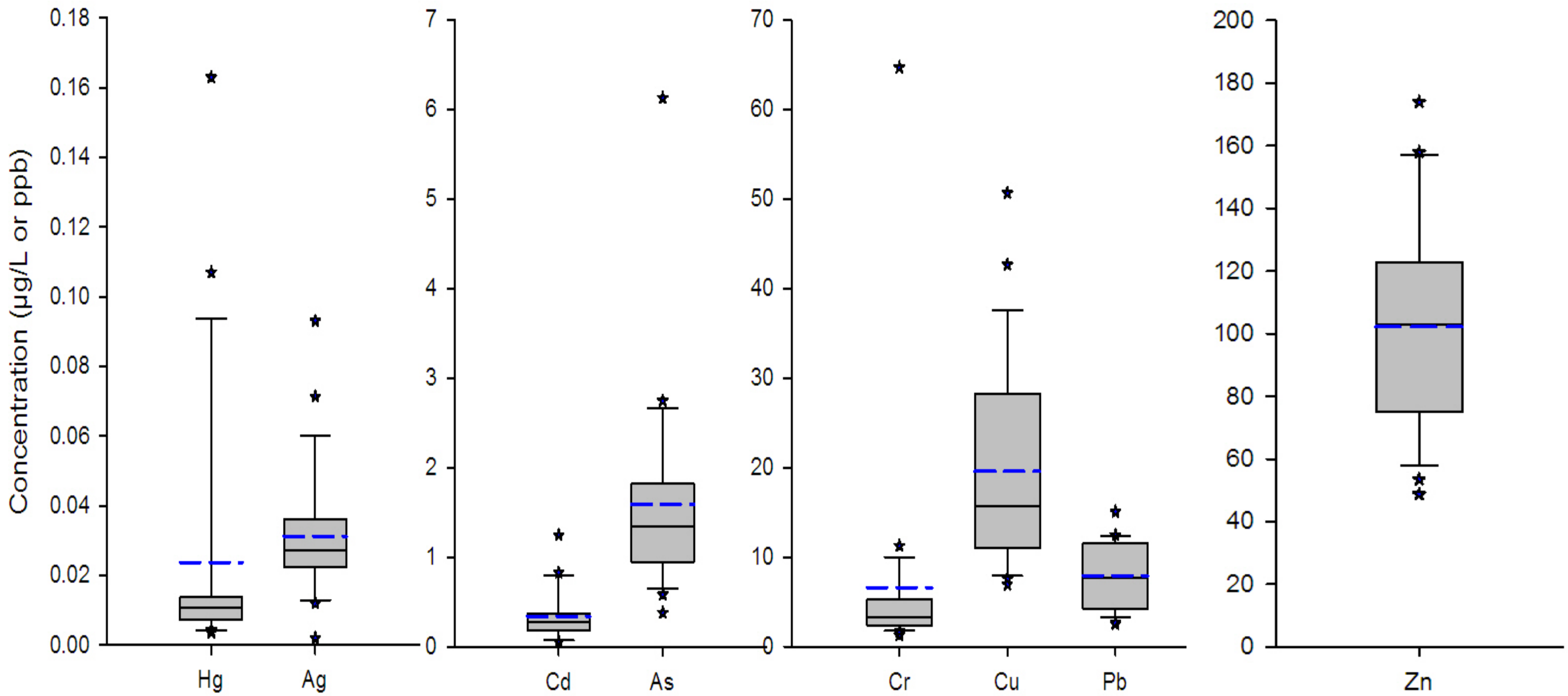

Figure 5. Total metal event mean concentrations (EMCs) in stormwater collected from the seven Phase I outfalls during seven storm events. The top, middle black line, and bottom of the box represent the 75th percentile, 50th, and 25th percentile, respectively. The whiskers are the 5th and 95th percentile and the asterisks are outliers in this sampling set (n = 24). The blue dashed line is the average.

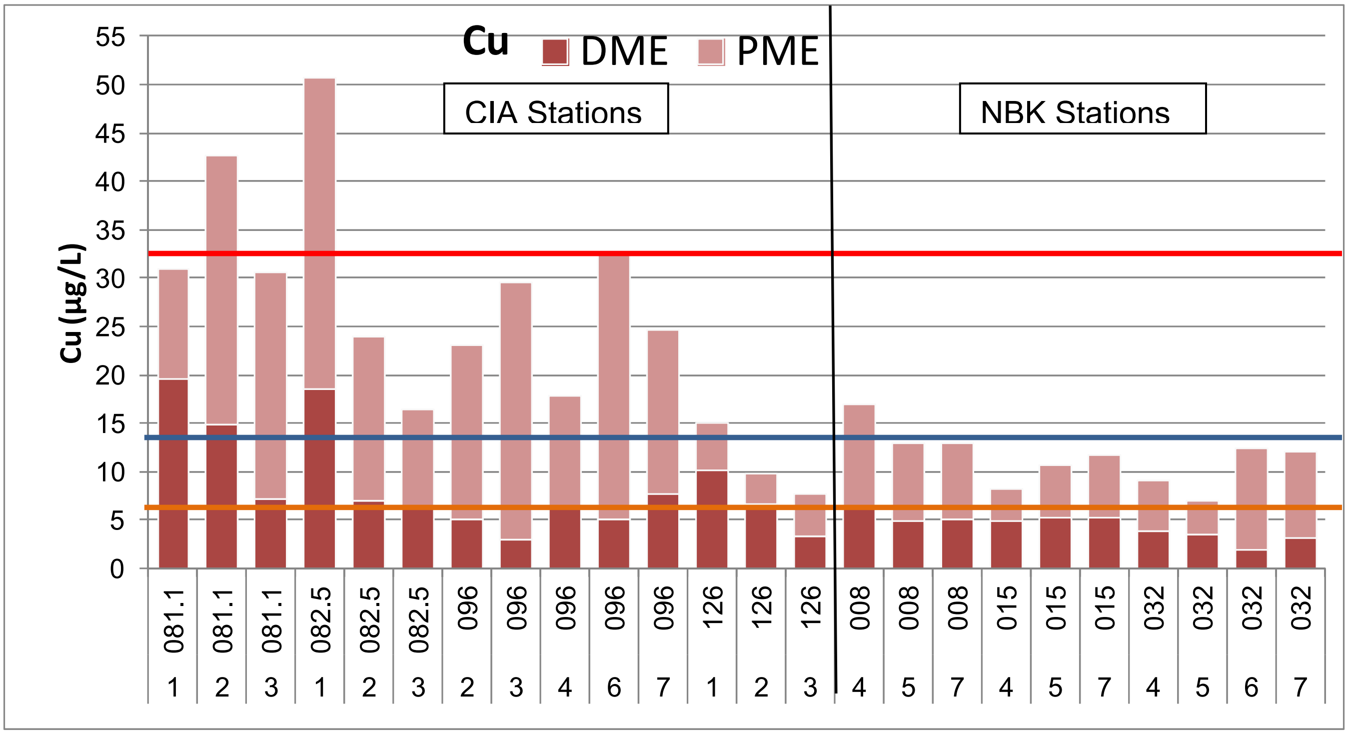

Figure 6. The concentrations of dissolved (DME) and particulate (PME) Cu measured in event mean concentration samples from CIA and NBK outfalls. The storm event number (SW01, etc.) is on the x-axis below the station name. The tops of each column represent the total recoverable (TR) Cu. The reference lines are the NPDES outfall permit concentration (red = 33 µg/L), Navy General Permit (blue = 14 µg/L) and draft permit for (orange = 5.8 µg/L) for TR Cu.

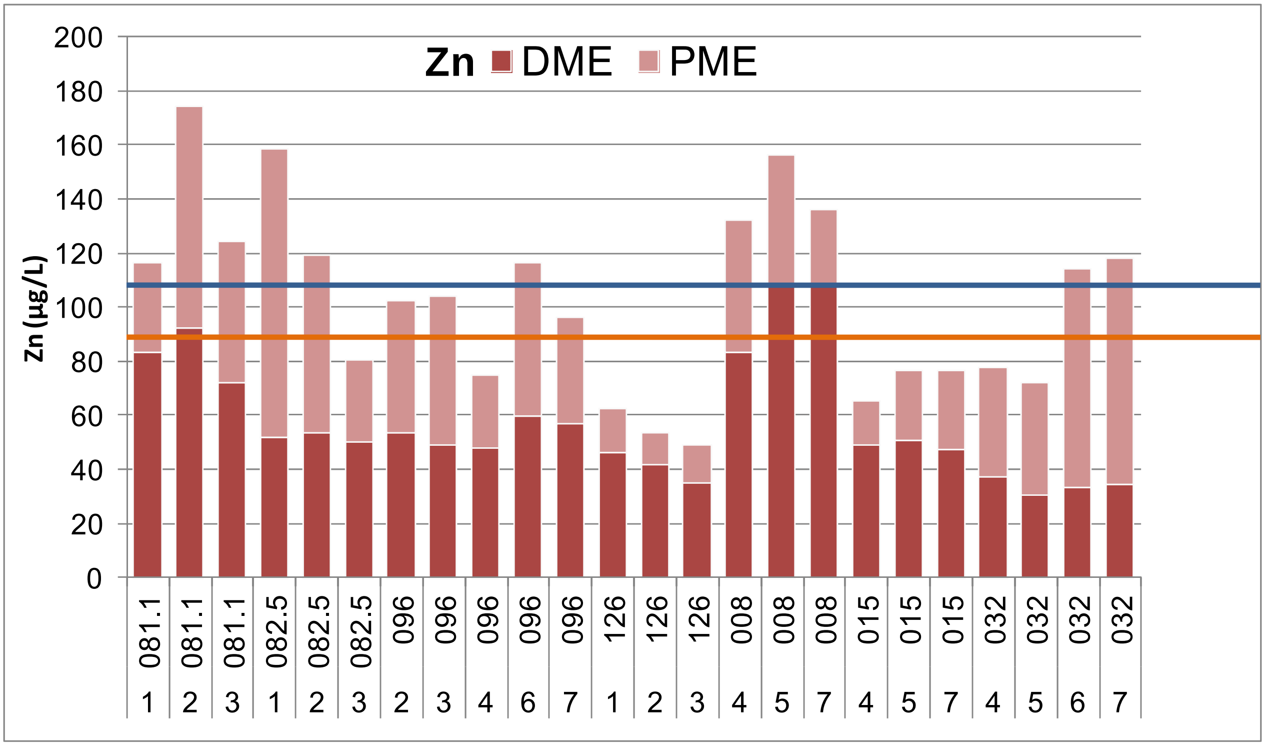

Figure 7. The concentrations of dissolved (DME) and particulate (PME) Zn measured in event mean concentration samples from CIA and NBK outfalls. The storm event number (SW01, etc.) is on the x-axis below the station name. The tops of each column represent the total recoverable (TR) Zn. The reference lines are the Navy General Permit (blue = 117.0 µg/L) and draft permit for (orange = 95.0 µg/L) for TR Zn.

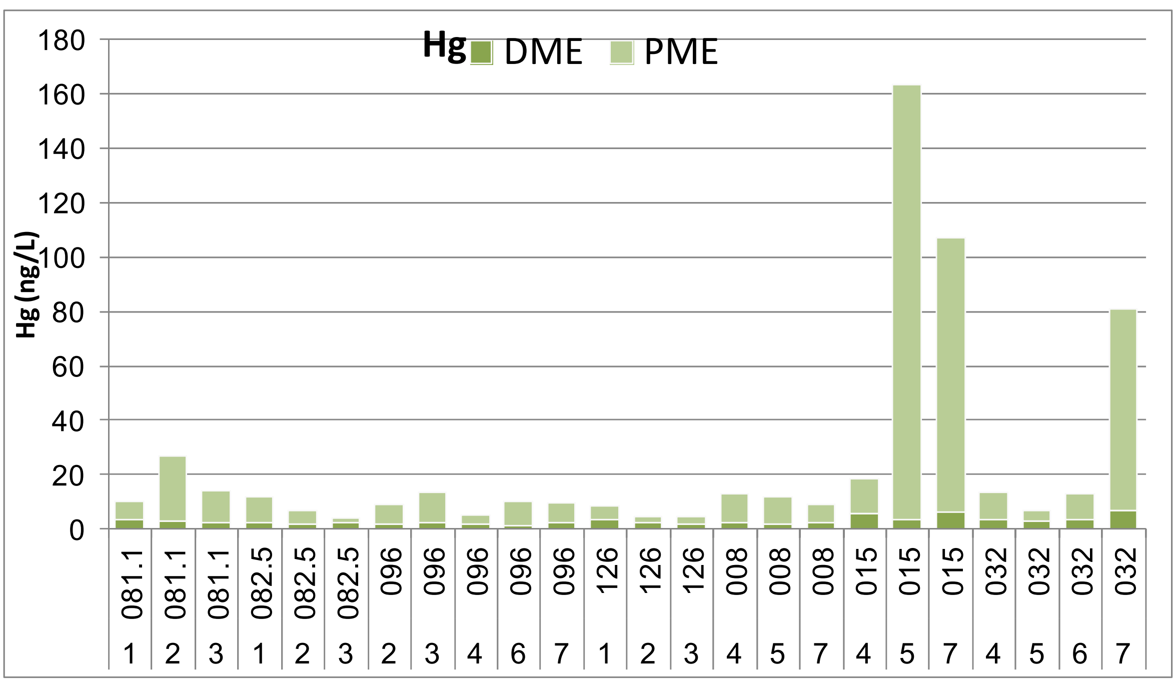

Figure 8. The concentrations of dissolved (DME) and particulate (PME) Hg measured in event mean concentration samples from CIA and NBK outfalls. The storm event number (SW01, etc.) is on the x-axis below the station name. The tops of each column represent the total recoverable (TR) Hg.

The ancillary parameters are necessary to establish potential fate and transport pathways, transformation upon entering the seawater, and also bioavailability to evaluate potential impacts to beneficial uses. These analyses will be conducted in the final report with the full set of data and are not discussed in detail in this interim report. Table 24 provides the descriptive statistics for the TPH (diesel and residual range) and ancillary parameters for all stations and storms. The TPH data are all qualified as either less than the RL or there is an interference that could bias the results due to a false positive.

Table 18. Descriptive statistics for total petroleum (TPH) diesel range (DRO) and residual range (RRO) along with the ancillary parameters for all stations.

Station		TPH (DRO)	TPH (RRO)	Hardness (as $CaCO_3$)	TOC	DOC	TSS
	Units:	µg/L	µg/L	mg/L	mg/L	mg/L	mg/L
All	Mean	159	391	71	2.68	3.12	22
All	Stdev.	215	341	161	1.78	1.83	11
All	25th	75.5	188	14	1.51	2.00	14
All	50th	100	280	23	2.17	2.71	19
All	75th	170	448	40	2.86	3.18	27

6.0 CONCLUSION AND RECOMMENDATIONS

The study design focused the data quality objectives to answer the following questions:

1. Are discharges from shipyard industrial outfalls and storm drains protective of beneficial uses of Sinclair Inlet?
2. How does the water quality of storm water runoff compare between various drainage basins in the Shipyard that support different types of activities (e.g. CIA versus NBK)?
3. What is the status and trend of stormwater quality relative to previous Shipyard stormwater sampling in 2003-2005 and/or other Puget Sound industrial areas?

Since this is an interim report only for Phase I, the data will not be completely synthesized to address these questions. However, the 2010-11 dataset can be used to inform the Phase II sampling, other stormwater sampling programs, and also identify areas of concern for future studies. Table 19 summarizes the data from the Phase I 2010-11 PSNS outfall sampling compared to the draft stromwater permit, the Navy general permit and other regional commercial/industrial stormwater outfall sampling. Multiple lines of evidence may be used to assess recommended actions for the Phase I outfalls and inform other outfall sampling. Table

20 summarizes the major activities within each outfall sub-basin and recommendations for each outfall. The lines of evidence include: 1) exceedence of draft permit, 2) exceedence of Navy General Permit, 3) loading of metals relative to other outfalls, 4) potential for particulate versus dissolved sources, and 5) comments relative to historical or regional data. Seven of the seven sampled outfalls exceeded the draft permit concentration for TR Cu during the storms sampled. For Zn, five out of seven outfalls had at least one EMC greater than the draft permit. Using the Navy General Permit as guidance (Table 19), five of the seven outfalls contained at least one EMC greater than the permit for Cu and four out of seven for Zn (Table 20).

The next line of evidence was the loading from specific outfalls relative to all other outfalls sampled. Appendix C summarizes the loads calculated for each storm event sampled from each outfall. The relative contribution from a specific outfall compared to the others sampled was calculated and used to identify basins that contributed more than 25% of the load for each metal. The fraction of this load contributed to the particulate phase versus the dissolved phase was also used as a line of evidence. Figure 9 illustrates the outfalls with a high fraction of particulate metal versus dissolved, which would provide a means to select a BMP appropriate for the dominant metal phase.

There are three points of reference that can be used to bound these data with respect to regional and comparable LULC stormwater data. The first the 2003-2005 PSNS outfall stormwater sampling conducted by ENVVEST (Brandenberger et al. 2007 a, b). These data were collected using similar methodologies for both collection and analyses. The range of concentrations reported in the Phase I 2010-11 PSNS outfalls sampling were overall lower than the 2003-2005 ENVVEST study. No definitive conclusions can be drawn, but additional information will be synthesized in the final report on efforts for process improvement.

The second study was the recent Ecology report on stormwater concentrations measured in two basins of Puget Sound (Puyallup and Snohomish) with specific LULC distributions with sub-basins (Herrera Environmental Consultants, Inc. 2011). The median for the commercial/industrial LULC provides a measure of regional comparison. Overall the concentrations from the PSNS outfalls were higher, but the data should be compared with caution. Herrera Environmental Consultants Inc. (2011) reports stormwater concentration based on grab samples that were composited to reflect a storm event concentration, therefore, the data are not directly comparable.

The third study was the ENVVEST 2003-2005 Urban stormwater collected from stormwater outfalls within the Sinclair/Dyes Inlet study area. In many cases the data sets overlap, suggesting the sources may not be specific to Shipyard activities and may be driven more by activities occurring in both urban and industrial settings (e.g. vehicle, roof runoff, etc.).

Table 19. Comparison of 2010-11 stormwater concentrations with regional urban stormwater outfall and commercial/industrial (C&I) land use/cover stormwater concentrations.

TR Conc.	Cu (µg/L)	Zn (µg/L)	Pb (µg/L)	As (µg/L)	Hg (ng/L)
PSNS Draft Permit	5.8	95	221	69	2100
Navy General Permit	14.0	117			
2010-11 PSNS Median (range)	15.7 (7.0-51)	103 (49-174)	7.7 (2.6-15)	1.4 (0.38-6.1)	10.7 (3.7-163)
ENVVEST 2003-05 PSNS Outfalls[1]	12-123	35-257	4-32	1-12	12-123
ENVVEST Urban Outfalls[1]	5-27	18-140	3-25	0.5-14	6-56
Herrera 2011 Median C&I [2]	3.84	37.2	1.68	0.92	7

[1] Brandenberger et al. (2007 a, b) and Cullinan et al. (2007)

[2] Herrera Environmental Consultants, Inc. (2011)

Table 20. The lines of evidence used to prioritize the Phase I stations including: 1) total number of event mean concentrations (EMC) greater than the draft NPDES permit; 2) Navy General Permit; 3) high relative load for permitted metals; and 4) high fraction of particulate versus dissolved metals.

Outfall	Area	No. > Draft NPDES[1]	No. > Navy General Permit	Metal Load Relative to Other Outfalls[2]	Particulate Versus Dissolved[3]
126	CIA	3/3 Cu	1/3 Cu	< 25% for all metals	> 43% dissolved
096	CIA	5/5 Cu 4/5 Zn	5/5 Cu	81% Cr 42-42% Cu, Cd 32-37% As, Pb, Zn	Particle driven for Cu, Hg < 25% dissolved
082.5	CIA	3/3 Cu 2/3 Zn	3/3 Cu 2/3 Zn	< 8% for all metals	Particle driven average 38% dissolved
081.1	CIA	3/3 Cu, Zn	3/3 Cu, Zn	31-35% Cu, Zn 26-29% Ag, Cd, Pb	Particle driven for Hg < 19% dissolved
032	NBK	4/4 Cu 2/4 Zn	1/4 Zn	< 4% for all metals	Particle driven average 31% dissolved
015	NBK	3/3 Cu		62% Hg 29% Ag	Particle driven for Hg < 12% dissolved
008	NBK	3/3 Cu, Zn	1/3 Cu 3/3 Zn	< 9% for all metals	Particle driven for Cu, Hg < 28% dissolved

[1] No. exceedences out of total number EMCs sampled at each outfall.

[3] Metals not listed have percent loads < 25%.

[2] Based on average statistics for Cu, Zn, and Hg.

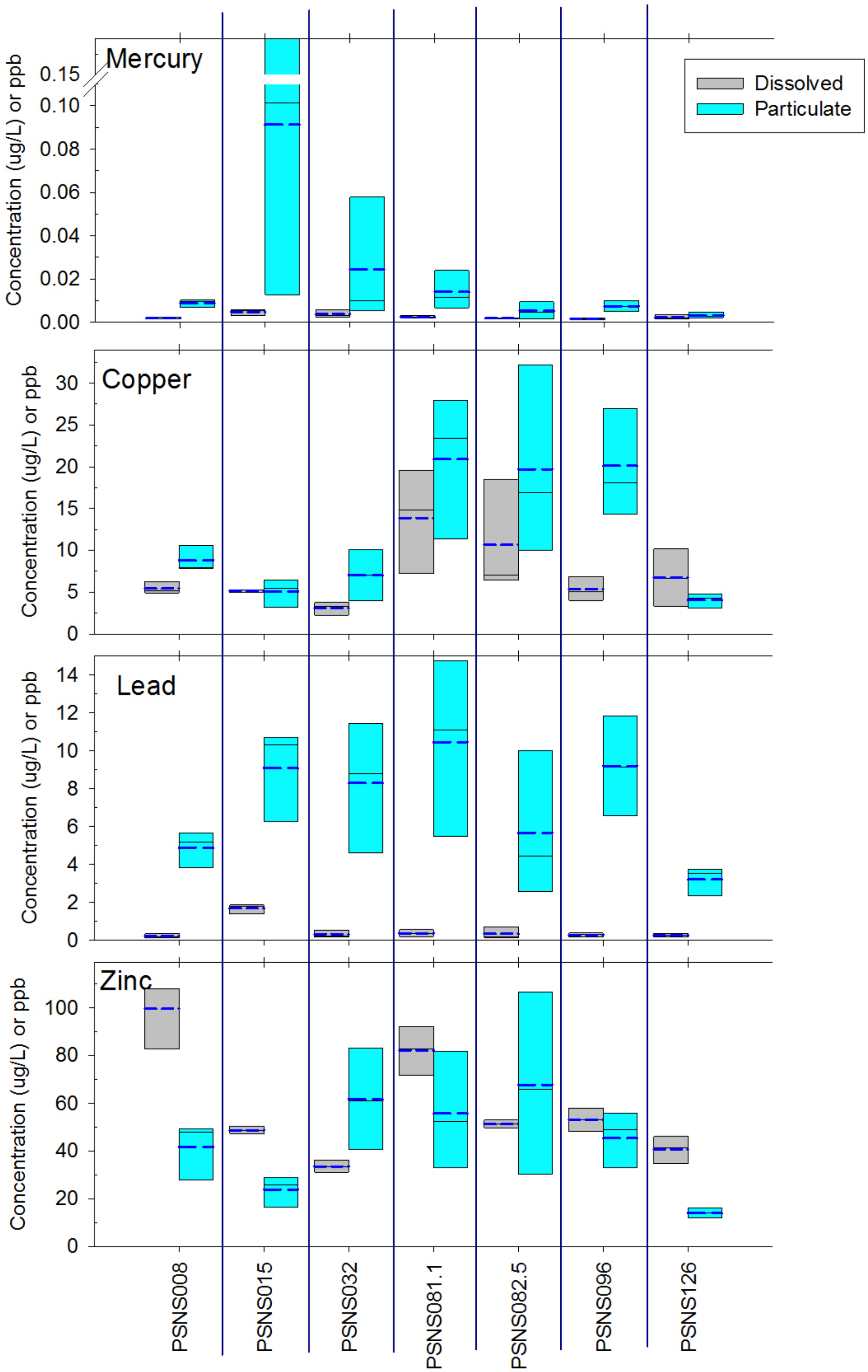

Figure 9. The particulate versus dissolved concentration ranges for each outfall during Phase I.

The Phase I results suggest additional studies are required to provide scientific credibility in support of or to refute the draft permit limits for Cu and Zn as a function of actual bioavailability instead of TR (e.g. implementing the BLM for site specific criteria) and if there are truly impairments to beneficial uses within Sinclair/Dyes Inlet. Specific areas of the Shipyard identified for further study included the CIA for sources of Cu and Zn and NBK for sources of Hg at PSNS015 and PSNS032. The final report will provide specific recommendation when all the stormwater data have been collected and synthesized with information on Shipyard practices within each sub-basin.

Due to the expense of collecting composite stormwater samples, this study was designed to allow direct comparable across collection and analytical methods for ENVVEST Relational Runoff Model (Brandenberger et al. 2007 a, b; Cullinan et al. 2007). This allows a vast in-kind contribution both to the evaluation of stormwater outfalls within the Shipyard, but also the watershed-scale loading studies for Sinclair/Dyes Inlet. All stormwater collection studies including the Remedial Investigation monitoring for OUB should follow similar protocol to increase the sample size and statistical power of the ENVVEST dataset and models that relate stormwater quality with event size and LULC within the sub-basin to allow some measure of predictive simulations for outfalls. Examples of the relational model are provided in Figures 10 and 11. The relationship between storm size and TR and d Cu along with the level of development within a sub-basin are used to develop relationship and build predictions for outfalls and storm events of similar characteristics. Figure 11 shows the prediction for the 2010-11 outfall samples relative to measured concentration. The model contains many gaps and therefore incorporating additional data will help to build a more robust model that would provide a predictive concentration for all outfalls, as all outfalls cannot be sampled for each storm.

The final recommendation derived from the Phase I study was that careful field collection in industrial areas where post collection contamination is easier must be a factor incorporate into the planning and collection of the Shipyard outfall stormwater. The water in the piped conveyance could easily be contaminated after collection due to industrial activities surrounding the manhole. All sample containers should be left closed while removing from the autosamler and carried back to the stormwater lab for compositing. The concentrations of the draft permit are approaching levels measured in streams during storm conditions; therefore additional precautions should be taken to ensure that the samples represent the chemistry of the water in the conveyance and not of particles that may contaminant a small volume of sample after collection.

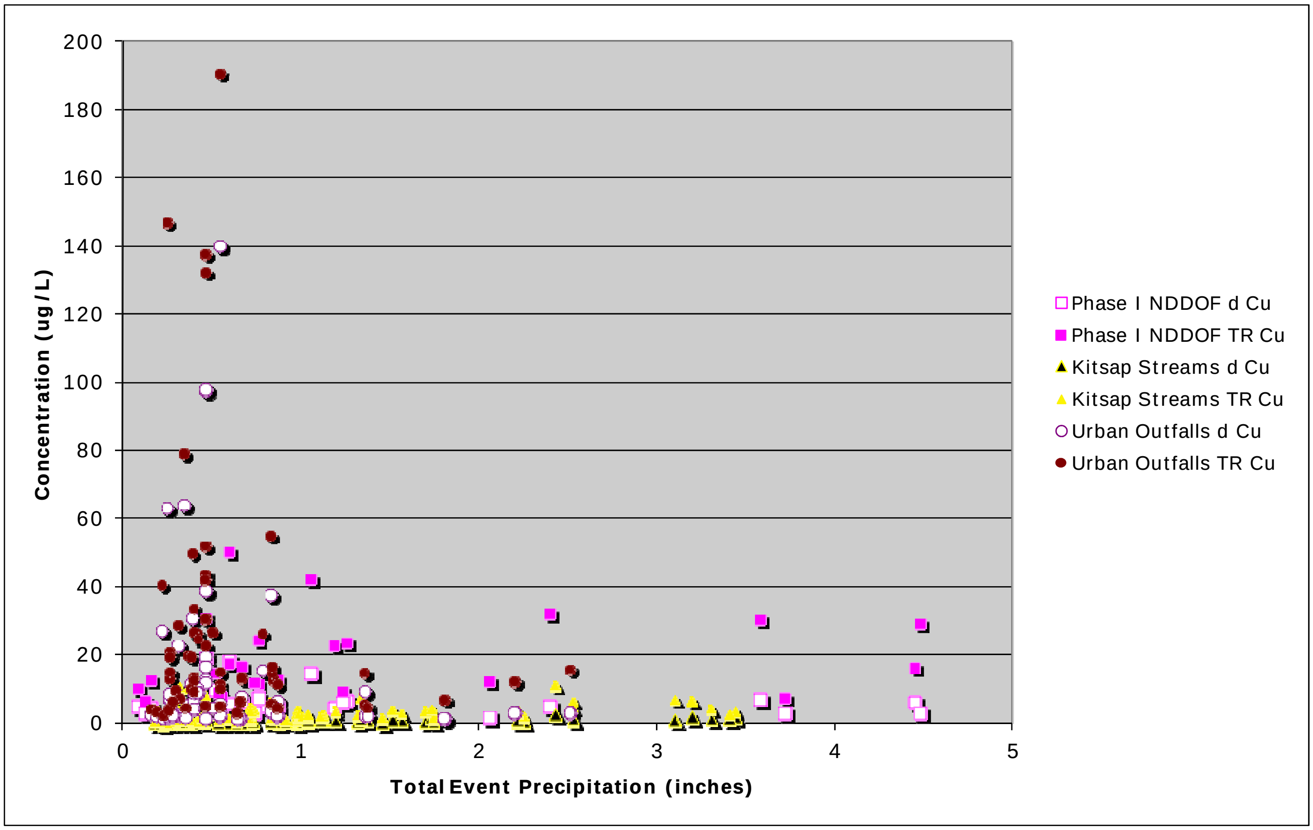

Figure 10. The total recoverable (TR) and dissolved (d) Cu from the Phase I 2010-11, Kitsap County streams, and Urban outfalls from Kitsap County as a function of storm size.

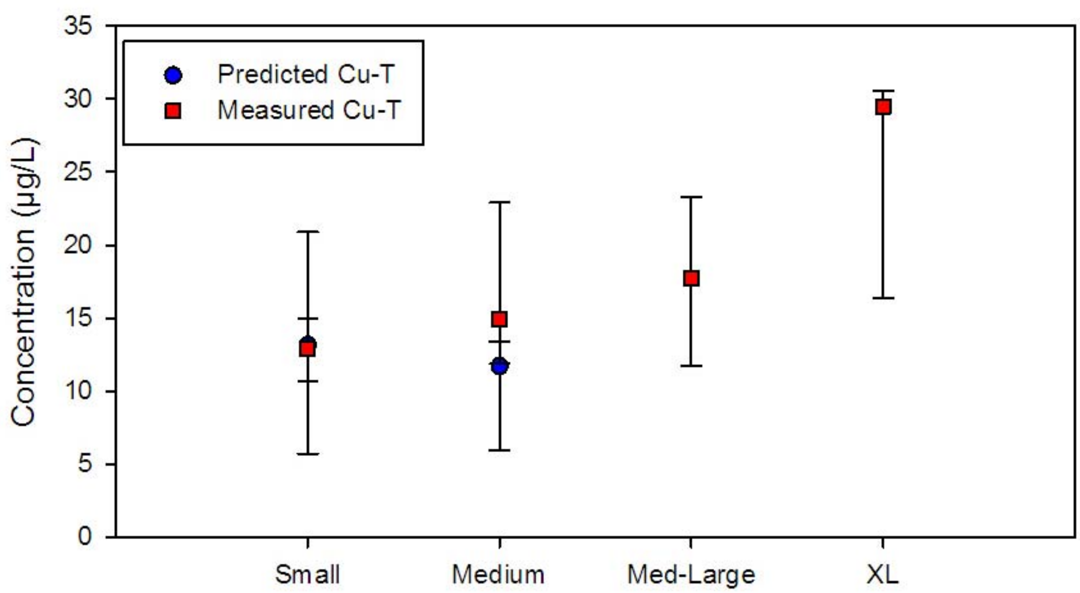

Figure 11. The ENVVEST relational model (Cullinan et al. 2007) predicted concentrations and Phase I 2010-11 measured total recoverable Cu concentrations in industrial outfalls. The existing relational model does not have sufficient data to predict concentrations for larger storm sizes.

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