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Annual Report: 2011-2012 Storm Season Sampling, Non-Dry Dock Stormwater Monitoring for Puget Sound Naval Shipyard, Bremerton, WA

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Phase II Annual Report: 2011-2012 Storm Season Sampling

for

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

PSNS Project ENVVEST Study Area

December 2012

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Contents

TABLE OF FIGURES

TABLE OF TABLES

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

LISST Laser In-Situ Scattering and Transmissiometry

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

NDDSW Non-Dry Dock Stormwater Outfall Study

NPDES National Pollutant Discharge Elimination System

NWTPH-Dx Northwest Total Petroleum Hydrocarbons – Diesel fraction

Pb Lead

PME Particulate Metals

PNNL Pacific Northwest National Laboratory

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
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 (Figure 1) 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 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) and conduct stormwater monitoring from representative storm drains within the Shipyard to ensure compliance with the NPDES.

The Shipyard and other industrial facilities have a number of unique attributes that make the identification of stormwater pollutant 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, predominant industrial activities, land-use and land-cover (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. 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 stormwater conveyance. Contamination of the sample

during or after collection with process specific contaminants at the collection site would not represent the concentration of such contaminants at the point of discharge.

Therefore this project is designed to characterize the Non-dry Dock Stormwater (NDDSW) outfall quality and to assist the Navy, USEPA, Ecology and other stakeholders in understanding the nature and condition of stormwater discharges from the Shipyard and help inform the permitting process (USEPA 2008a, b). The project is being conducted in phases with each phase informed by the previous. Stations for each phase were or will be selected based on the results of the previous phases, representativeness of the sampling location (e.g. ensure that all major work activities are represented by the entire dataset), and planned construction activities.

This interim report summarizes the stormwater monitoring conducted for Phase II NDDSW outfall monitoring. It supplements the Phase I report that covered storm event sampling during 2010-11. This report includes the collection, analyses, and descriptive statistics for Phase II stormwater sampling conducted from November 2011 through April 2012. In Phase II, six stormwater basins within the Shipyard were sampled during at least four storm events to characterize non-dry dock stormwater discharges at selected stormwater drains located within the facility. Based on Phase I data, a fifth storm event was monitored at station PSNS015 to further define the mercury (Hg) concentrations in the stormwater as a function of the stage of the storm and the tide.

Additionally, this report summarizes the current stormwater data available from the Shipyard, Sinclair/Dyes Inlet watershed, and Puget Sound in order to put the data into a regional context. The data must be considered on multiple scales (e.g. watershed scale and mass balance scale for individual contaminants) in order to truly understand the potential stormwater runoff impairments to beneficial uses within Sinclair and Dyes Inlets. Therefore, the results from the 2011-2012 sampling, reported herein, are synthesized with the existing regional data and the Phase I study to provide the current data on stormwater quality and recommendations to address knowledge gaps and inform the NPDES process.

Figure 1. Location of the Puget Sound Naval Shipyard & Intermediate Maintenance Facility (Naval Shipyard) on Sinclair Inlet, WA. 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.

1.1 REGIONAL STORMWATER INFORMATION

There are two primary sources of information on stormwater quality for the Shipyard region: 1) U.S. Navy ENVironmental inVESTment Project (ENVVEST) and 2) the Phase I Non-Dry Dock Stormwater study. The data from both of these projects along with the broader Puget Sound data were used to place the data into a comparative context to other industrial stormwater and non-industrial locations including municiptal outfalls, streams, rivers, and piped stream outfalls (e.g. high density urban).

In 2000, 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 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 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).

One gap identified by ENVVEST was the characterization of stormwater quality within the various basins of the Shipyard. Therefore, 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). Phase I of the NDDSW study was conducted during 2010-11 storm season and the interim report (Brandenberger et al. 2012) documented the technical strategy, stormwater quality results, and the recommendations for subsequent phases of the NDDSW. Seven representative stormwater outfalls were sampled during three storm events estimated to be greater than 1 inch in 24 hours.

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. The objective was to establish a solid baseline and understand the variability on a spatial and seasonal scale to provide a means from which to assess process improvements within the Shipyard and bound the data in terms of regional sources of the contaminants present in stormwater runoff. The data from the Phase I and II (reported herein) 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).

1.2 PHASE II OBJECTIVES

The goal of Phase II was to collect and characterize NDDSW 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). The Phase II study supplements the Phase I data by providing additional sampling that represents activities within the industrial area of the Shipyard and provides additional data to address gaps identified during Phase I (e.g. Hg concentrations at PSNS015). 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 specific Phase II objectives are stated as:

1. Document logistics and site information for all six Phase II stations along with field and laboratory quality control procedures necessary to allow the NDDSW data to be comparable to the ENVVEST stormwater data set;
2. Collect grab and composite stormwater samples during a minimum of four qualifying storm events at each of the six stormwater sampling locations consistent with methodology reported by ENVVEST;
3. Conduct chemical analyses utilizing appropriate analytical techniques to ensure data are representative of stormwater 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 NDDSW monitoring at the Shipyard to inform the stormwater management program and future permit requirements (USEPA 2008a).

1.3 BNC Study area Description

The Shipyard is located along the northern shore of Sinclair Inlet, a subasin of Puget Sound, and is bounded by the City of Bremerton. It covers approximately 350 acres of land and an additional 340 acres of tidelands along 11,000 feet of shoreline. There are 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. 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).

As described in the AKART study (Jabloner 2009), the Shipyard 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.

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 NDDSW basins within the Shipyard. Phase I and Phase II (reported herein) provided the stormwater quality measured within eleven distinct storm drainage systems that are representative of the main work activity types within the Shipyard (TEC and PNNL 2011; 2012). 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

Municipal/commercial/residential services

Sampling sites were selected that maximized the upstream drainage area, minimized tidal effects and accounted for operational constraints (see PWP; TEC and PNNL, 2011; 2012). Figure 2 illustrates the Phase II locations in both the CIA and non-industrial NBK. In combination with Phase I locations, 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 includes both the Phase I and II drainage basins selected for monitoring and their associated stormwater outfall number, geographical area and primary work activity. The stations PSNS015 and PSNS126 were sampled during both Phase I and II. The new stations added in Phase II were PSNS084.1, PSNS115.1, PSNS124, and PSNS124.1. Table 2 provides the specific attributes for the Phase II drainage basins with additional details provided in the PWP (TEC and PNNL 2012).

Figure 2. The Phase II Sampling locations for 2011-12 Non-dry Dock Stormwater Outfall Study.

Table 1. Phase I and II drainage basins selected for monitoring and their primary work activity.

PSNS&IMF Outfall #	Geographical Area	Primary Work Activity
Phase I		
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
Phase II		

PSNS&IMF Outfall #	Geographical Area	Primary Work Activity
126[1]	East CIA, Southwest B460 along "C" Street, east of DD3	Materials storage (outdoor)
124.1	Southwest of Bldg 460, west of Bldg 495, east of DD3	Dry-dock support activities, crane, vehicle and equipment traffic, laydown and staging areas
124	Northwest corner of Bldg. 357, west of DD3	Material storage, Pipe/Boiler/Forge/ Nuclear Repair Shops, Chem Lab, DD3 cutting facility
115.1	South-southeast of Bldg 879, east of DD4	Materials storage (outdoors), various shops and training center, water front support activities
084.1	Southeast section of Bldg 983, west of DD5	Vehicle and equip. traffic, rad. work builds, outside equip. storage, paint shop, recycling, indust. waste pretreatment
015[1]	Mid NBK, south side of McDonalds, east side of drive-through lane	Municipal/commercial/residential services
[1] Sampled during both Phase I and II.		

Table 2. Drainage basin attributes for the Phase II 2011-12 outfall sampling.

PSNS Outfall No.	Outfall Location	Monitoring Location[1]	Total Basin Area (acres)[2]	Basin Impervious Surface Area (acres)	Basin Pervious Surface Area (acres)	Monitoring Location Manhole ID	Manhole Rim Elevation (ft)[3]	Approx. Elev. of Sampling Intake (ft)[3]	Effective Tide Height (ft)[4]
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
124.1	47°33’36”N, 122°37’44”W	47°33’39”N, 122°37’45”W	2.66	2.52	0.14	5880	17.15	8.19	+8
124	47°33’36”N, 122°37’47”W	47°33’39.2”N, 122°37’48”W	10.42	9.85	0.57	5881	17.75	5.27	+5
115.1	47°33’39”N, 122°37’54”W	47°33’40.4”N, 122°37’55”W	9.50	9.22	0.28	4860	17.72	1.27	+1
84.1	47°33’30”N, 122°38’20”W	47°33’31.3”N, 122°38’20”W	0.55	0.55	0.0	551	17.69	5.61	+5.5
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

[1]Coordinates for the monitoring location were determined using a Trimble GPS.
[2]Total basin areas are included in the Basin Description Table and were determined on calculation supplied by the Navy.
[3]Referenced to Mean Lower Low Water (historical PSNS&IMF documents 1994-2008).
[4]Expected tidal height based on NOAA tide predications that would cause tidewater, under non-storm conditions, to be detected at a certain monitoring location.

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 (NDDSW).

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 NDDSW runoff. Table 3 details the proposed permit requirements (per Permit §I.C.3 and §III.A) for NDDSW monitoring assessment parameters, maximum daily effluent limits, sample frequency and sample type. In order to leverage the three years of existing stormwater data conducted by ENVVEST within the Sinclair/Dyes Inlet watershed, the list of permit required parameters was expanded as noted in Table 3 to remain consistent with the ENVVEST program. Therefore, the comprehensive 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.

Table 3. Proposed stormwater monitoring requirements and final effluent limitations for non-dry dock stormwater outfalls and additional ENVVEST parameters.

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

Additional ENVVEST Parameters
Aluminum, total recoverable and dissolved
Silver, total recoverable and dissolved
Arsenic, total recoverable and dissolved
Cadmium, total recoverable and dissolved
Chromium, total recoverable and dissolved
Copper, total recoverable and dissolved
Lead, total recoverable and dissolved
Mercury, total recoverable and dissolved
Zinc, total recoverable and dissolved
Ancillary Parameters
Hardness
Total and dissolved organic carbon (TOC/DOC)
Conductivity and Temperature

This Phase II report provides the second year of monitoring for the NDDSW outfalls or conveyances that represent the primary work activities performed within the non-dry dock areas. Data from both Phase I and II collectively support NDDSW outfall considerations for 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, provide a baseline to evaluate process improvement, 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 (only TPH and fecal coliform) and automated, tidally-compensated, time-paced composite samples were collected at six representative outfalls during Phase II. Field collection methods for the 2011-12 stormwater sampling events followed guidance described in Taylor Associates (2009) and detailed in the Phase II PWP (TEC and PNNL 2012). A brief description of field collection methodologies is provided below. Detailed field activities and documentation for each storm event (SW08 – SW12) are provided in Appendix A Storm Event Reports.

2.1 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. The PWP provided a general schematic diagram of the monitoring system components. 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 stored 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 2012). 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: Transducers were used at each monitoring station to record water level and temperature within a selected pipe or vault. Two different types of transducers were used for monitoring and sample collection. They 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 continuously 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 integrated into its associated 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/cm (µmho/cm), but were reported to the nearest whole number. 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: Salinity values were generated based on temperature compensated conductivity measurements and temperature readings. For the CT2X units salinity was calculated using conductivity and temperature readings. For the YSI, salinity was reported directly from the meter. The calculations for both units were based on the Standard Methods 2520B equation. Salinity values from both sensors were recorded to the nearest 1/100 of a part/thousand (ppt) and reported as a whole number.

In-Situ Particle size and volume: A Laser In-Situ Scattering and Transmissiometry (LISST) analyzer from Sequoia Scientific (www.sequoiasci.com) was deployed on April 13, 2012, prior to the SW12 event. The LISST-StreamSide unit was used to generate real-time data on the particle size distribution and volume through the progression of a storm (see Appendix A SW12 Storm Report for more details).

Solar panel charger and batteries: The telemetry system, datalogger and all associated water quality monitoring components were powered by 12-V 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. 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 station. Each housing was placed as close to the outfall monitoring 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/lines for the transducers, conductivity meters, and sampler suction 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 intake anchor point, which was generally installed in the invert of the outlet pipe.

2.2 QUALIFYING STORM EVENTS

Stormwater events were targeted from November 2011 through April 2012. Phase II included the collection of four qualifying storm events (SW08 – SW11) from each of the six monitoring stations and a fifth storm event (SW12) at PSNS015 to target the storm chemistry dynamics. Unlike the previous sampling season where monitoring sites were split into two distinct groups; samples from all six Phase II monitoring stations were collected concurrently during each of the targeted storm events (except SW12). Equipment was mobilized and installed at all six monitoring stations between October and November 2011 and demobilized between April and September 2012. Qualifying storm events were targeted based on small modifications from the ENVVEST program criteria for wet season sampling. Table 4 lists the qualifying criteria for Phase II.

Table 4. Phase II 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. in 24-hours ≥70% forecasted probability of occurrence 24-hours prior	≥0.10 in. in 24-hours ≥50% forecasted probability of occurrence 24-hours prior
Qualifying Storm Size	≥0.10 in. or a sufficient amount for sampling to have occurred for at least 2 hours during stormwater runoff	≥0.10 in., 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 0.1in. rain in previous 24-hours No rain in previous 6 hours	Less than or equal to 0.02 in. rain previous 72-hours No rain in previous 6 hours
Conditional 24-hr Antecedent Qualification	If there is greater than 0.1in. rain in a 24-hr antecedent period, the combined 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.

The critical gap identified in the ENVVEST (2003-2005) sampling was larger storm events (≥1.0”) in urban and industrial drainage 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 event.

Storm targeting procedures were detailed in the 2011-12 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. 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).

2.3 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 as described above. These equipment 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.

2.3.1 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's 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 and to calculate the discharge volume for the sampling duration at each station using a variation of the Runoff Coefficient Method (RCM). The station's storm rainfall totals were used to classify the storm event size based on criteria consistent with ENVVEST (Brandenberger et al. 2007). The RCM was previously used for volume estimation purposes during implementation of the 1994 PSNS NPDES compliance monitoring and Phase I. The RCM is an accepted industry standard and is an effective tool 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 2012) detailed the application, selection of coefficients and calculation of the RCM.

Briefly, the RCM method uses the total sampling period rainfall, pervious and impervious drainage area size, and a land cover 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 2011-12 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 to enable the autosamplers and validate 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.

2.3.2 Other Monitoring Data

Water level, temperature, conductivity, salinity, and autosampler operation data were also recorded by the equipment discussed above in Section 2.1. The data were 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. 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.

The autosampler units were connected to a Campbell Scientific datalogger and telemetry system, which allowed sample processing information to be immediately available to the storm lead. Necessary adjustments to sample timing could be made remotely. Feedback information from the autosamplers served as a record of setup and unit operation and was included in the individual 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.

For SW12 only, the LISST was deployed *in-situ* six days prior to the event and provided a near continuous log of the particle size and volume at PSNS015. Thirty-two size classifications are collected by the LISST, but the data were post-processed to aggregate them into the following size fractions: clay/silt (<63µm), very fine/fine grain sand (64-234µm) and medium grain sand (235-386µm).

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)	Runoff Coefficient Range[1]	Area of Basin Surface Type with Maximum Coefficient Value Applied (ft^2)	Total Discharge Volume (ft^3) [2]
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	
124.1	116,000	Impervious	94.56	109,690	0.6 – 0.9	98,721	R(101,245)
		Pervious	5.44	6310	0.2 – 0.4	2,524	
124	454,000	Impervious	94.56	429,302	0.6 – 0.9	386,372	R(396,251)
		Pervious	5.44	24,698	0.2 – 0.4	9,879	
115.1	463,042	Impervious	97	449,104	0.6 – 0.9	361,422	R(366,390)
		Pervious	3	13,938	0.2 -0.40	4,968	
084.1	23,958	Impervious	100	23,958	0.6 – 0.9	21,562	R(21,562)
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	

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

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

2.4 STORMWATER SAMPLE COLLECTION

Five validated stormwater events were sampled during the Phase II 2011-12 field season based on the criteria discussed above. Six stations were targeted for four events and a single station was targeted for an additional event for a total of 52 samples. During Phase II, three field duplicate sets were collected (three each of grabs and composites). Of the 52 potential samples, 52 were collected (27 grab and 28 composite samples), for a success rate of 100%. Table 6 lists 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, type of sample (e.g. grab or composite), and rainfall information. The rainfall information includes the antecedent dry period duration prior to each storm, the total duration of the storm event, and the total precipitation. The antecedent dry period was defined as the period prior to the onset of a qualifying event where rainfall did not cause runoff to occur. In general, the stations require ≥ 0.03" rainfall without 3-hr gap to trigger runoff in the storm drains. Storm summary reports were written for each event and are compiled in Appendix A for storms SW08 through SW12.

All sample collection and management followed the guidance contained in the PWP (TEC and PNNL 2012). 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 2012). 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 (see Section 4.1.2). The following sections summarize the collection procedures for each Phase II storm event and any anomalies.

Table 6. The non-dry dock stormwater outfalls sampled during each storm, storm event identification and dates, antecedent dry period, storm sampling duration, number of grab and composite samples, and total event rainfall.

Station	Storm ID: SW	08	09	10	11	12	
	Date	11/21/11	1/20/12	2/28/12	3/14/12	4/19/12	Totals
	Total No. Grabs	6	6	7	8	0	27
	Total No. Comp.	6	7	7	7	1	28
PSNS126	Antecedent (d:hr) Sampling (hr:min) # Samples Rainfall (in.)	3:11 28:03 1 and 1 1.36	9:22 23:44 1 and 2* 1.03	3:17 19:44 2* and 2* 0.45	1:10 30:44 1 and 1 1.29		**4 storms**
PSNS124.1	Antecedent (d:hr) Sampling (hr:min) # Samples Rainfall (in.)	3:12 26:51 1 and 1 1.99	9:00 10:42 1 and 1 1.13	3:17 1:44 1 and 1 0.23	0:18 28:14 2* and 1 1.52		**4 storms**
PSNS124	Antecedent (d:hr) Sampling (hr:min) # Samples Rainfall (in.)	3:13 28:01 1 and 1 1.22	9:23 18:41 1 and 1 1.18	3:17 1:44 1 and 1 0.19	1:10 26:06 2* and 1 1.23		**4 storms**
PSNS115.1	Antecedent (d:hr) Sampling (hr:min) # Samples Rainfall (in.)	3:11 28:15 1 and 1 1.45	9:21 21:42 1 and 1 1.17	3:18 20:44 1 and 1 0.46	1:10 31:13 1 and 1 1.17		**4 storms**
PSNS084.1	Antecedent (d:hr) Sampling (hr:min) # Samples Rainfall (in.)	3:09 25:51 1 and 1 1.69	9:22 20:42 1 and 1 1.13	3:17 18:59 1 and 1 0.55	0:19 30:14 1 and 1 1.58		**4 storms**
PSNS015	Antecedent (d:hr) Sampling (hr:min) # Samples Rainfall (in.)	3:12 28:21 1 and 1 1.82	9:22 20:42 1 and 1 1.29	3:17 20:44 1 and 1 0.58	0:18 29:43 1 and 2* 1.75	1:10 17:05 0 and 1 0.46	**5 storms**

Antecedent duration provides the number of days and hours since precipitation caused runoff.
Sampling period duration is provided in hours and minutes (hr:min).
Samples = Number of grab and composite samples, respectively. An * indicates field duplicates were collected.
Rainfall (in.) is the total sampling period rainfall.

2.4.1 Storm Event Summaries

The storm event reports provide a detailed overview of the field activities including any deviations from the PWP and corrective actions. They were summarized and reported as Appendix A. No major anomalies were observed or otherwise noted during Phase II sampling. Minor anomalies such as labeling corrections, changes to start and stop conditions, and grab sample collection timing were documented. Several changes of note are discussed below.

The method for rainfall statistics, namely average, minimum, maximum and median were previously calculated on static 1-hour segments. For all of Phase II, the statistics were calculated on a “rolling 1-hour data window’ in an attempt to provide a more accurate and representative assessment of the actual rainfall conditions. In addition, most of the CT2X transducers and associated stainless steel pipe ring band showed signs of corrosion due to saltwater immersion. Therefore, they were upgraded to titanium to strengthen the earth grounds of all monitoring systems and to electrically isolate the transducers for all other metal components. This maintenance issue did not affect data collection or quality.

During SW10, the composite samples for PSNS124 and PSNS124.1 were comprised of a single discrete wedge bottle. Freshwater conditions only occurred at these monitoring stations during one collection period with all other bottles dominated by saline water. The 2011-12 PWP stipulates that composite samples should represent at least 2 hours of duration and contain a minimum of 8 aliquots. The resulting samples represented 1 hour duration and 4 aliquots. The samples were conditionally accepted and analyses progressed as they were considered representative of the stormwater conditions that existed at the stations and did not include dilution from incoming tidal water.

During SW11, pacing rates for each of the six stations were initially set at 15 minutes. The storm particulars included two fronts pushing through. In order to capture the bulk of the second front, the pacing rates were adjusted to 30 minutes after the first front pushed through. The pacing rate was adjusted back to 15 minutes prior to the second front. The composite sample formulation accounted for these changes accordingly (see the addendum to the field forms with detailed composite formulation notes). Table 7 provides an account of these pacing rates changes.

Table 7. The SW11 composite sample pacing rate information.

Station ID	Pacing Rate Changed to 30 min. (Date/Time)	Bottle Where Change Occurred	Pacing Rate Switched Back to 15 min. (Date/Time)	Bottle Where Change Back Occurred
PSNS015[1]	3/14/12 1600	7/8	3/15/12 0430	13/14
PSNS084.1	3/14/12 1530	6	3/15/12 0500	13
PSNS115.1	3/14/12 1530	7	3/15/12 0500	14
PSNS124	3/14/12 1540	5	3/15/12 0500	12
PSNS124.1	3/14/12 1530	4	3/15/12 0500	11
PSNS126	3/14/12 1730	8	3/15/12 0430	14

[1]The duplicate collected at PSNS015 was simultaneously collected by splitting the autosampler setup into two sets of bottle groups (e.g. 1-12 parent samples and 13-24 duplicate). Therefore any changes affect both the parent and the duplicate

In response to the Phase I and II data for PSNS015, an additional storm sampling event was added (SW12; see SOW addendum) to quantify the metal concentrations at this station in both the individual one hour time-paced samples and the EMC. The modifications from the PWP were documented in the addendum (see Appendix B chemistry report for SW12) and included: 1) sampling only at PSNS015, 2) collecting 18 samples from the individual wedge bottles prior to creation of the composite, and 3) reducing the parameter list to total and dissolved metals, DOC, TSS, salinity, and turbidity. All other collection and compositing procedures remained consistent with the PWP (TEC and PNNL 2012).

2.4.2 Grab Sampling

Fecal coliform and TPH samples were collected using a manual grab sampler. The precipitation and water level data were used to guide the field team to collect grabs during the rising limb of the storm if possible. In some cases the grab samples were collected on the falling limb due to tidal conditions. After runoff commenced and conductivity levels were less than 2,000 µmho/cm grab samples were collected. Qualifying stormwater conditions (runoff occurrence/hydrograph response and water quality) were also verified prior to grab sample collection at each station. Specific times and details are provided in the individual storm event reports along with the event hydrograph for each station and storm combination (Appendix A). No grab samples were collected for SW12.

A sterilized and pre-cleaned, stainless steel cup was dipped into the flow stream (typically by using an extension pole). A new stainless steel cup was used at each station. The TPH samplers were poured into two separate pre-cleaned amber glass containers each containing preservative (see Table 8). 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). Samples were stored in a cooler at 4°C until transport to the analytical labs. Grab and composite samples were collected as an associated pair during each storm event.

2.4.3 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 or until the storm precipitation dropped below 0.03 inches in an hour. Time-paced composites were collected into pre-cleaned polypropylene (PP) containers (wedge bottles) using Isco autosampler pumps equipped with siliconized Tygon pump head tubing, Teflon-lined suction tubing, and various connectors/fittings. 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 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 a corresponding increase in the water level sensor indicated 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 typically changed from 0.03 to 0.3 ft, with final enabling conditions occurring when conductivity was 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).

The autosamplers were programmed to collect sequential samples over the course of a targeted event. A 24-bottle configuration was used to provide adequate sampling resolution. In this configuration, each discreet sample (i.e. wedge bottle) represented an approximately 1 hour composite. The conductivity of each discrete sample was measured and only samples with conductivity less than 2,000 µmho/cm were included in the EMC. The acceptable discrete samples were then equally composited in a 10L pre-cleaned glass jar. A detailed description of the compositing formulation was provided in Section 8 of the 2011-12 PWP. The SW12 event is the only one where individual discrete samples were collected along with an EMC.

2.4.4 Field Sample Validation, Preservation, and Handling

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

Grab samples were validated through the following actions:

- 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 were validated through the following actions:

- 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 EMC consisted of at least eight 1L wedge bottles; and
- Inspected the 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 8 lists the sample containers, preservatives, and analytical holding times for each parameter. 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 TPH grab samples and composites for TOC, DOC, hardness, and TSS were all forwarded to Columbia Analytical Laboratory Services (CAS) for analyses. The only exception was the SW12 samples for TOC, DOC, and TSS were analyzed at PNNL as lower detection limits were required. Appendix B provides the documentation for the sample receipt and handling and the chemistry results for each storm event.

Table 8. Sample container types, preservatives, recommended handling, and holding times.

Parameter	Container Type	Handling / Preservation	Holding Time
Chemicals of Concern			
TPH (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)	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	10 L Glass	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

Parameter	Container Type	Handling / Preservation	Holding Time
TOC	250 mL LDPE w/Pres. or glass	4°C ± 2°C, H_2SO_4 or frozen	28 days
DOC	250 mL LDPE w/Pres. or glass	4°C ± 2°C, H_2SO_4 or frozen	After field filtration using GFF filter, 28 days

3.0 LABORATORY METHODS AND QUALITY CONTROL RESULTS

The chemicals of concern for this project included total recoverable and dissolved Al, As, Cu, Cr, Cd, Pb, Zn, Hg, and TPH (see Table 8). Ancillary parameters included turbidity, TSS, hardness, TOC, and DOC. Table 9 lists the sample preparation and analytical methods along with the method detection limit (MDL) and reporting limit (RL). Collectively, these methods incorporate 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 and 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. A short synopsis of method modification is provided below. The PNNL maintains a National Environmental Laboratory accreditation for the modified methods. Methods not described below follow the EPA protocol exactly (i.e. Hg).

Samples were analyzed for metals by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) in accordance with Battelle SOP MSL-I-022, Determination of Elements in Aqueous and Digestate Samples by ICP/MS. The base methods for this procedure are EPA Method 1638 and EPA Method 1640. Freshwater samples (defined as salinity < 2ppt) were digested following the TRM method established in EPA Method 1640 prior to analysis by ICP-MS. Both the filtered and unfiltered fractions were prepared using this method to destroy any colloidal particles remaining in the filtered (aka. dissolved) fraction.

Seawater samples were preconcentrated via a precipitation step followed by reconstituted in a salt free solution in accordance with Battelle SOP MSL-I-025, Methods of Sample Preconcentration: Iron and Palladium/APDC Coprecipitation and Borohydride Reductive Precipitation for Trace Metals Analysis in Water. Preconcentrated seawater samples were analyzed for Al, Ag, Cd, Cr, Cu, Pb and Zn by ICP-MS. Seawater data were reported as reagent corrected for the metals requiring Fe/Pd preconcentration (Al, Ag, Cd, Cr, Cu, Pb, and Zn) and denoted with a b-flag. The required preconcentration procedure for ICP-MS analyses includes the addition of chelating agents to induce precipitation of metals under specific conditions. Subsequently, reagents added to the samples should be of the purest quality to result in zero addition of metals to the seawater samples. Required reagents have trace impurities of these metals; therefore, the data were blank corrected for these elements. Results were corrected using the mean batch reagent blank identified for each preparation batch (BMRB_analysis date) and provided in Appendix B for each storm.

For events SW08 through SW11, the TOC/DOC method was the Standard Method for wet oxidation (SM5310C). The DOC samples for SW12 were analyzed using a High Temperature Catalytic Oxidation (HTCO) method. The instrument is specially equipped with high-salt sample combustion tube kit and halogen scrubber for seawater analysis. Seawater samples were acidified to pH <2 by concentrated hydrochloric acid prior to analysis then sparged for 2 minutes to remove inorganic carbon (IC). The non-purgeable organic carbons (NPOC) in samples were further converted to CO_2 by oxidation at 680°C with a platinum catalyst. A non-dispersive infrared detector (NDIR) was used to detect the converted CO_2 for quantification of NPOC. The data were reported as both mg/L and µM.

Table 9. 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[2]	5.0 mg/L[2]
Turbidity	NA	180.1	0.1 NTU	0.1 NTU

Parameter	Preparation Method	Analytical Method	Method Detection Limit (MDL)	Reporting Limit (RL)
Hardness (as $CaCO_3$)	NA	STM2340C	0.8 mg/L	2 mg/L
TOC	SM5310C	SM5310C	0.07 mg/L[2]	0.50 mg/L[2]
DOC	Ashed GFF filtration	SM5310C	0.07 mg/L[2]	0.50 mg/L[2]
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.

[2] The SW12 event utilized ultra low-level DOC/TOC analyses with MDL = 0.03 mg/L and RL = 0.095 mg/L. The TSS MDL = 0.49 mg/L.

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 NDDSW outfalls and provide comparable data for 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. 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 (e.g. time-paced composites vs. grab samples).

3.1 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 were 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, storm controller work 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).

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 and equipment blanks (including tubing blanks, composite bottles, and sample bottles). Field QC samples were labeled and tracked as individual 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).

In addition, other field QC procedures used to ensure consistency, reduce contamination, and ensure representative samples were:

- collected composite samples using automatic samplers for all parameters except TPH (grabs due to container requirements) consistent with previous studies;
- collected samples in certified contaminant-free or properly decontaminated containers as demonstrated by the equipment blank samples;
- 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; and
- delivered samples to laboratory with proper COC forms, appropriate preservation and within recommended holding times.

3.1.1 Field Duplicates

Field duplicates provided a measure of field variability due to sample processing and handling. All field duplicate samples were collected in an identical manner to the primary or “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 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-five EMC samples were collected plus three field duplicates for the metals and ancillary parameters. For the metals, the relative percent differences (RPD) between the parent and duplicate sample were all less ≤ 40% 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 for all metals was ≤ 8% RPD. The highest RPD values were noted for Hg at stations PSNS015 and PSNS126. The average RPD for Hg alone, was ≤ 16% RPD. The variability was driven by the particulate fraction of Hg and discussed further in Section 4.3.

The RPDs for the ancillary parameters were ≤ 67% RPD with an average of 12%. The one high RPD (67%) was noted for TSS during SW09 at station PSNS126. A second field duplicate was collected at this station during SW10 with 10% RPD for TSS. The SW09 event was a large storm (> 1 in.) and therefore not unusual to have high TSS with large variability.

Twenty-five storm grabs were collected plus three field duplicates. The RPD values for the diesel range organics (DRO) were ≤ 53% RPD with an average of 36% RPD. The RPD values for the residual range organics (RRO) were ≤ 89% RPD with an average of 57% RPD. The RPDs were high as the sample concentration were either less than the RL or qualified due to the chromatographic fingerprint resembling a petroleum product, but the elution pattern suggested the presence of heavier molecular weight constituents than the calibration standard or the fingerprint does not match the calibration standard.

3.1.2 Field Blanks

Field collected equipment blanks (EB) exceeded a frequency of 1 out of every 10 samples for metals and 1 per sample container lot for TPH. 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, one equipment blank was collected by pouring deionized water (DI) into the stainless steel sampling cup and then into an amber glass sample container while at one randomly selected outfall location. The TPH concentration in the EB was not detected above the RL.

For the metals, an EB was collected at each station for a total of 6 EBs. The blanks represented the Teflon sample line tubing, autosampler pump and distributor arm tubing, and glass composite jars. 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 handled as a sample and split into pre-cleaned Teflon bottles for total metals. All the EBs were less than the RL for Hg, As, Ag, Cd, and Cr. This 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 10 summarizes the mean EB concentrations compared to the MDL, RL, and shows that no sample concentrations were <5 times the mean EB. In fact, all sample concentrations were at least an order of magnitude above the detected blanks for Cu, Pb, and Zn. The data were not significantly impacted by the detected blanks.

Table 10. The summary of equipment blank concentrations for the metals and any sample impacts.

	MDL	**RL**	**EB Mean**	**Standard Deviation**	**No. Samples < 5 times EB Mean (only applied if mean EB > RL)**
Hg (ng/L)	0.1	0.3	0.179 J	0.043	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	0.004 U	--	NA
Cr (µg/L)	0.08	0.3	0.08 U	--	NA
Cu (µg/L)	0.007	0.02	0.122	0.0941	0
Pb (µg/L)	0.002	0.006	0.00894	0.00727	0
Zn (µg/L)	0.05	0.2	0.241	0.164	0

NA – not applicable, U Value not detected above the MDL, and J Estimated concentration below the RL.

3.1.3 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. In addition, the vault and rainfall data were subjected to additional review and analysis, at a minimum frequency of every event (see Telemetry Data Summary Report (TDSR)s included in Appendix A).

The rainfall, water level, temperature, and conductivity data were reviewed monthly and after each sampled storm event. Data were reviewed for gross errors such as spikes or data gaps to determine completeness of the data set. They were also reviewed to identify data gaps and determine if they could be filled with alternate data. Data were also verified against field sheets and calibration records and evaluated to determine if instrument calibrations demonstrated a need for data qualification or re-calculation.

The TEC and PNNL reviewed the procedures implemented in the field for consistency with the established protocols. The patterns/yields for a particular basin were reviewed against previous project data and the hyetograph was compared to the hydrograph for water level response to rainfall. Members of the Navy Project Team also performed field procedural reviews. Sample collection, preservation, labeling, and other procedures were checked for completeness. No significant deviations were noted, minor deviations were documented in the field storm event or chemistry reports (Appendices A and B, respectively).

3.2 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 11 for all the parameters. The summary included both freshwater and seawater methods required for SW12, as both discrete intervals of the storm, as well, as the EMC were analyzed.

All the data met the required QC requirements. As was noted in Phase I, the field duplicates from PSNS015 were highly variable for the total Hg fraction (Phase II ranged 2-40% RPD). The average RPD was reduced from 80% in Phase I to 16% in Phase II. The total and dissolved pairs for each field duplicate suggest the heterogeneity is associated with the particulate fraction with the total Hg field duplicates averaging 28% RPD while the dissolved averaged (4% RPD).

Table 11. Laboratory quality control sample summary.

QC Type		Hg	As	Ag	Cd	Cr	Cu	Pb	Zn	TPH DRO	TPH RRO
MB	n =	18	7	10	10	10	10	10	10	5	5
MB	Mean	<RL	<MDL	<MDL	<MDL	<RL	<RL	<RL	<RL	<MDL	< RL
MB	Stdev	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Percent Recovery (%)											
LCS	n =	12	7	7	7	7	7	7	7	5	5
LCS	Mean	102%	98%	98%	100%	102%	99%	100%	98%	112%	100%
MS	n =	24	12	10	12	12	12	12	12	NA	NA
MS	Mean	101%	100%	95%	99%	100%	99%	103%	100%	NA	NA
SRM[1]	n =	6	7	7	9	8	9	8	9	NA	NA
SRM[1]	Mean	97%	96%	90%	96%	97%	95%	96%	94%	NA	NA
Relative Percent Difference (RPD)											
Lab Dup	n =	7	7	7	7	7	7	7	7	5	5
Lab Dup	Mean	11%	3%	18%	3%	3%	1%	1%	1%	12%	13%
Field Dup[2]	n =	6	6	6	6	6	6	6	6	3	3
Field Dup	Mean	16%	3%	11%	10%	8%	4%	9%	3%	36%	57%
Ancillary Parameters[3]											
QC Type		**DOC**	**TOC**	**TSS**	**Hardness**						
MB	n =	12	6	8	5						
MB	Mean	< RL	<MDL	<MDL	<MDL						
Percent Recovery (%)											
LCS	n =	7	8	6	5						
LCS	Mean	96%	95%	97%	102%						
MS	n =	4	4	NA	NA						
MS	Mean	98%	101%	NA	NA						
SRM	n =	4	NA	NA	NA						
SRM	Mean	98%	NA	NA	NA						
Relative Percent Difference (RPD)											
Lab Dup	n =	27	34	NA	4						
Lab Dup	Mean	5%	3%	NA	3%						
Field Dup	n =	3	3	3	3						
Field Dup	Mean	4%	8%	30%	5%						

[1] Includes freshwater SRMs for SW08-SW12 and seawater SRMs for SW12.

[2] Field duplicate count for metals includes both total and dissolved fractions.

[3] Includes the QC samples analyzed by CAS for SW08-SW11 and PNNL for SW12.

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

3.3 DATA COLLECTION, STORAGE AND MANAGEMENT

There were 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 2012). Field notes and ancillary data were provided in Appendix A. In-situ monitoring data were provided to the Navy and archived electronically 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. 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. The TDSR (for certain time periods before, during and after storm events) and a 2011-12 Telemetry Collection Metadata Report (entire monitoring period) summarized basic sensor specifications, location particulars and collection issues. Appendix A contains the TDSRs and the Metadata Report are available via the Navy.

Appendix B contains all laboratory generated data. The data were also formatted for the electronic database submission into the ENVVEST database. Copies of analytical raw data were 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 2012).

4.0 RESULTS AND DISCUSSION

Five qualifying storm events were sampled from November 2, 2011 through April 19, 2012 (see 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. The following sections provide a synopsis of this information.

4.1 RAINFALL AND RUNOFF DATA

Rainfall data were collected from each station and from the PSNS gauge (B427). Table 12 presents a summary of the rainfall data collected at the Phase II stations, B427 and the calculated runoff for each basin and storm event. The table also provides the average and range of rainfall across the PSNS sampling locations to illustrate the variability even within PSNS during a given storm. The average rainfall was used to classify the storm based on the

ENVVEST storm size classification (Brandenberger et al. 2007a). During Phase II, two small and three medium-large storms were sampled. Classifying the storms based on size, basin LULC, and water quality parameters provides a means to further develop relationships between metrics that are easily acquired such as LULC data and the associated contaminant concentrations. This is discussed further in the stormwater chemistry and conclusions.

A rainfall and runoff relationship for each station was established using a continuous rainfall record. These relationships were used to estimate the total volume of discharge during the sampling period 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 the descriptive information for each basin (e.g. basin area, type of surface, etc.).

The coefficient ranges give latitude for consideration of particular basin characteristic. Typically the maximum coefficient range values are applied to the more impervious portions and the lower end of the coefficient range applied to the more pervious portions of a certain surface type. Phase II runoff volume calculations used the maximum coefficient values due to the high proportion of impervious surface in each drainage basin.

Table 13 presents a more detailed analysis of the rainfall and associated in-situ data measured from within the vaults. This includes the maximum one-hour rainfall intensity and event average one-hour rainfall intensity (both in inches/hour). Sample event vault data was also assessed in 5-minute intervals (in one-hour rolling average). As discussed above for Table 12, these data illustrate the variability in the rainfall statistics across the PSNS stations. However, although the maximum intensity and averages may vary significantly, the median intensities are quite similar indicating the data are not significantly biased by the higher intensities.

Table 12 also includes the vault level, salinity, and temperature data. These data provide a measure of the tidal influence during a given storm and the associated water level changes in the pipe. There are some nuances to this type of data including PSNS084.1 and PSNS115.1 recorded negative vault levels due to transducer placement. The negative values were replaced with a zero. The salinity data for all stations except PSNS084.1 recorded a minimum of 2ppt, which is due to the difference between the CT2X and YSI sensors. Salinity greater than 5 ppt is considered seawater when selecting the appropriate analytical method (e.g. metals by ICP-MS suffer salt interferences and methods must address this or false positives are possible). All outfalls recorded tidal water reaching the sampling station during a particular storm event, except PSNS126 during SW10. The water level and salinity data were used in the storm composite formulation (e.g. EMC). In all cases, the EMC was formulated to represent only the freshwater or storm event runoff and not the incoming tidal water.

Also SW08 and SW10 were considered bimodal storms with intra-event dry periods of 6-8 hours. Although there was an intra-event dry period, the two modes were considered part of the same storm and summed to provide the total event rainfall. See Appendix A for more detailed discussions of data nuances for each storm.

The rainfall patterns during the Phase II 2011-12 season were evaluate to determine if they were representative of average conditions. The Phase II rainfall data were compared to historic rainfall records maintained for the Bremerton, WA area since 1899 and available through the Western Regional Climate Center (http://www.wrcc.dri.edu/). Table 14 presents monthly statistical rainfall summary data for Bremerton, WA (station 450872) along with the PSNS monthly statistics for the Phase II sampling period.

The “wet season” in western Washington is from October through April with an average annual precipitation of 45.39 inches. Phase II sampling from November 2011 through April 2012 recorded 80 days of at least 0.01 inches of rain in a 24-hour period at the PSNS B427 rain gauge. The total rainfall at PSNS during this time was lower than average (39% below average) with 26.67 inches of rainfall compared to the historic data with 38.85 inches for the same period. The months of November and March had notably higher amounts of rainfall than average, while the other months (especially December) were below average.

Table 12. Total rainfall (inches) for each storm event, calculated runoff, and the ENVVEST storm size classification.

Station	SW	08	09	10	11	12
	Date	11/21/11	1/20/12	2/28/12	3/14/12	4/19/12
B427 - Navy Gauge		1.83	1.74[1]	0.57	1.42	0.47
PSNS126	Rainfall (in.)	1.36	1.03	0.45	1.29	--
	Runoff (ft^3)	67,080	50,803	22,196	63,627	--
PSNS124.1	Rainfall (in.)	1.99	1.13	0.23	1.52	--
	Runoff (ft^3)	16,790	9,534	1,941	12,824	--
PSNS124	Rainfall (in.)	1.22	1.18	0.19	1.23	--
	Runoff (ft^3)	40,286	38,965	6,274	40,616	--
PSNS115.1	Rainfall (in.)	1.45	1.17	0.46	1.17	--
	Runoff (ft^3)	44,272	35,723	14,045	35,723	--
PSNS084.1	Rainfall (in.)	1.69	1.13	0.55	1.58	--
	Runoff (ft^3)	3,037	2,030	988	2,839	--
PSNS015	Rainfall (in.)	1.82	1.29	0.58	1.75	0.46
	Runoff (ft^3)	365,717	259,217	116,547	351,651	92,434
Storm Average Rainfall (in.)[2]		1.59	1.16	0.41	1.42	0.46
Min (in.)		1.22	1.03	0.19	1.17	0.46
Max (in.)		1.99	1.74	0.58	1.75	0.47
ENVVEST Storm Size Classification[3]		Med-Large	Med-Large	Small	Med-Large	Small

[1] The B427 rain gauge was likely initially clogged with snow pack. The gauge didn't record its first tip until approximately 5 hrs after the monitoring sites recorded their first tips and the total rain amount is much greater than any station.

[2] Rain total averages do not include data from the B427 gauge.

[3] Storm Size Classification (Brandenberger et al. 2007a): Small = <0.5", Medium = 0.5 – 1.0", Med-Large = 1.0 – 2.0", Large = ≥ 2.0"

-- = Not Sampled

Table 13. Storm event rainfall descriptive summary for each 2011-12 storm and station.

Storm	Parameter	Statistic	B427	PSNS126	PSNS124.1	PSNS124	PSNS115.1	PSNS084.1	PSNS015
SW08 (11/21/11)	Total Rainfall (in)		1.83	1.36	1.99	1.22	1.45	1.69	1.82
	Max 1-hr Rainfall Intensity (in/hr)		0.20						
	Average 1-hr Rainfall Intensity (in/hr)		0.065						
	Rainfall 5-min Interval (in)	Min		0.00	0.00	0.00	0.00	0.00	0.00
		Max		0.16	0.30	0.16	0.19	0.21	0.20
		Average		0.04	0.06	0.04	0.05	0.05	0.06
		Median		0.02	0.03	0.02	0.02	0.03	0.03
	Vault level (ft)	Min		0.04	0.17	0.22	0	0	0.39
		Max		5.02	4.81	8.54	12.19	8.04	9.25
		Average		1.18	1.12	3.45	6.69	2.92	4.17
		Median		0.32	0.30	3.16	7.00	2.69	4.08
	Salinity (ppt)	Min		2.00	2.00	2.00	2.00	0.05	2.00
		Max		42.00	42.00	42.00	42.00	34.33	42.00
		Average		7.10	17.00	18.66	11.47	9.48	12.67
		Median		2.00	2.00	4.11	2.00	0.22	2.00
	Temp (°C)	Min		4.40	5.11	4.80	4.47	5.37	4.27
		Max		10.96	11.61	13.07	12.51	19.27	13.15
		Average		9.31	9.52	9.77	9.24	11.06	8.91
		Median		9.64	9.64	9.82	9.47	10.48	9.15
SW09 (1/20/12)	Total Rainfall (in)		1.74	1.03	1.13	1.18	1.17	1.13	1.29
	Max 1-hr Rainfall Intensity (in/hr)		0.28						
	Average 1-hr Rainfall Intensity (in/hr)		0.116						
	Rainfall 5-min Interval (in)	Min		0.00	0.00	0.00	0.00	0.00	0.00
		Max		0.14	0.17	0.20	0.17	0.15	0.16
		Average		0.03	0.05	0.05	0.04	0.04	0.04
		Median		0.02	0.04	0.03	0.03	0.03	0.04
	Vault level (ft)	Min		0.31	0.10	0.30	0.06	0	0.12
		Max		5.54	4.00	8.67	12.70	8.47	9.20
		Average		2.10	1.24	4.44	7.75	4.11	5.05
		Median		1.67	0.40	4.66	8.53	4.19	5.50
	Salinity (ppt)	Min		2.00	2.00	2.00	2.00	0.02	2.00

		Max		42.00	42.00	42.00	42.00	44.70	42.00
		Average		3.62	26.44	11.86	2.76	6.78	9.87
		Median		2.00	42.00	2.00	2.00	0.10	2.00
	Temp (°C)	Min		1.68	2.10	2.11	1.49	3.13	1.66
		Max		7.71	8.38	9.14	9.07	14.77	10.30
		Average		4.32	5.10	4.60	3.77	6.57	4.45
		Median		4.37	3.78	3.76	2.66	4.44	2.76
SW10 (2/28/12)	Total Rainfall (in)		0.57	0.45	0.23	0.19	0.46	0.55	0.58
	Max 1-hr Rainfall Intensity (in/hr)		0.10						
	Average 1-hr Rainfall Intensity (in/hr)		0.027						
	Rainfall 5-min Interval (in)	Min		0.00	0.00	0.00	0.00	0.00	0.00
		Max		0.10	0.10	0.10	0.09	0.11	0.12
		Average		0.02	0.04	0.04	0.02	0.02	0.02
		Median		0.01	0.03	0.04	0.00	0.01	0.01
	Vault level (ft)	Min		0.14	0.12	0.16	0.72	0	0.12
		Max		2.56	0.69	2.32	9.77	5.47	6.67
		Average		0.90	0.20	0.58	5.94	2.53	3.62
		Median		0.47	0.19	0.49	6.97	2.88	4.15
	Salinity (ppt)	Min		2.00	2.00	2.00	2.00	0.16	2.00
		Max		2.00	42.00	11.62	42.00	26.92	42.00
		Average		2.00	30.48	5.73	7.73	4.46	3.71
		Median		2.00	41.74	4.27	2.00	0.41	2.00
	Temp (°C)	Min		4.12	6.06	5.54	3.96	7.07	4.08
		Max		9.32	8.33	11.22	9.55	36.43	12.02
		Average		7.04	7.41	8.27	6.90	11.77	7.08
		Median		7.43	7.52	10.00	7.06	8.84	6.92
SW11 (3/14/12)	Total Rainfall (in)		1.42	1.29	1.21	1.23	1.17	1.58	1.75
	Max 1-hr Rainfall Intensity (in/hr)		0.15						
	Average 1-hr Rainfall Intensity (in/hr)		0.059						
	Rainfall 5-min Interval (in)	Min		0.00	0.00	0.00	0.00	0.00	0.00
		Max		0.19	0.27	0.19	0.17	0.22	0.21
		Average		0.04	0.04	0.04	0.03	0.05	0.05
		Median		0.02	0.03	0.03	0.02	0.03	0.04
	Vault level (ft)	Min		0.02	0.08	0.21	0.12	0	0.35

		Max		3.91	3.25	7.31	11.25	7.00	8.28
		Average		1.44	1.06	4.26	7.15	3.55	4.78
		Median		1.06	0.33	4.88	8.27	4.13	5.51
	Salinity (ppt)	Min		2.00	2.00	2.00	2.00	0.01	2.00
		Max		42.00	42.00	42.00	42.00	48.44	31.69
		Average		3.77	10.80	13.53	5.00	4.27	3.80
		Median		2.00	2.00	2.34	2.00	0.09	2.00
	Temp (°C)	Min		5.45	5.64	5.77	4.75	6.85	4.68
		Max		10.93	8.48	10.15	10.67	16.97	10.93
		Average		8.44	7.45	8.17	7.78	10.02	7.84
		Median		8.45	7.53	8.11	7.86	9.46	7.85
SW12 (4/19/12)	Total Rainfall (in)		0.47						0.46
	Max 1-hr Rainfall Intensity (in/hr)								
	Average 1-hr Rainfall Intensity (in/hr)								
	Rainfall 5-min Interval (in)	Min							0.00
		Max							0.13
		Average							0.02
		Median							0.01
	Vault level (ft)	Min							0.18
		Max							7.43
		Average							4.02
		Median							4.30
	Salinity (ppt)	Min							2.00
		Max							42.00
		Average							7.63
		Median							2.00
	Temp (°C)	Min							9.94
		Max							16.17
		Average							12.45
		Median							12.83

Table 14. Historical monthly total rainfall (inches) for Bremerton, WA (Station ID 450872) from 5/1/1899 to 8/31/2012 compared to the PSNS monthly rain gauge rainfall statistics for the 2011-12 sampling period.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
Avg.[1]	3.99	7.28	7.65	7.24	5.3	4.66	2.73	1.83	1.44	0.73	0.86	1.67	45.39
Min.	0.16	0.83	0.44	0.61	0.27	0.27	0.26	0.13	0.04	0	0	0	22.73
Max.	14.12	21.6	16.22	20.08	18.03	12.19	7.67	5.46	4.52	3.11	3.97	7.09	75.81
No. Yrs.	102	95	97	96	101	100	106	107	108	105	106	107	64
PSNS B427 Rain Gauge Statistics[2]													
Rainfall		8.72	0.02	5.74	3.13	7.71	1.35						
Daily avg.		0.73	0.01	0.32	0.21	0.34	0.14						
Daily Min		0.04	0.01	0.01	0.01	0.01	0.01						
Daily Max		2.88	0.01	1.50	0.39	1.53	0.39						
Median		0.47	0.01	0.15	0.21	0.16	0.10						

[1] Historical rainfall downloaded from Western Regional Climate Center http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?wa0872

[2] PSNS data included the following notes: 27 days were used to calculate the April monthly total, only days with measurable rain were used in the statistical calculations, and Dec 1 – Dec 23, 2011 the actual rainfall was higher but the rain gauge was obstructed by snow on some days.

4.2 Event Mean Composite Chemistry

The descriptive statistics for the SW08 through SW12 EMC samples are summarized in Table 15 for the metals listed in the draft permit and Table 16 for the additional metals that support the Navy mass balance calculations for Sinclair and Dyes Inlets (Brandenberger et al. 2008). These data represent only the EMCs and not the discrete data collected during SW12 (see Section 4.3). The statistics were calculated on the pooled EMC data from all stations and storms and then individual stations. The NPDES stormwater draft permit and Navy general permit limits are provided in Table 15 and statistics exceeding them are highlighted. The distribution of the data for all metals was highly variable (Figure 3).

The TR Cu EMCs exceeded the Navy general permit at a majority of the stations and storms with a few exceptions. Stations PSNS126 (CIA) and PSNS015 (NBK) showed the 25th percentile TR Cu EMCs was less than the Navy general permit. However, as was noted during Phase I, all storms and stations exceeded the draft permit limit. Therefore, the data distribution suggest a high probability for stormwater collected in both CIA and NBK to exceed the NPDES draft permit for TR Cu and a minimum of 50% probability to exceed the general permit.

The TR Zn EMCs exceeded the general permit during all storms at PSNS084.1 and 115.1. Stations PSNS124 and 124.1 exceeded the general permit more than 50% of the time and the 25th percentile at PSNS124 exceeded the draft permit. Stations PSNS126 and 015 did not exceed either of the permit limits for TR Zn. The TR Zn data for all stations and storms suggest the EMCs would exceed both permits at least 50% of the time.

Evaluating the data on a station level supports identification of critical areas for further investigation and process improvement. Figures 4 and 5 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. Twenty-one TR Cu EMCs would exceed the Navy general permit and 11 would exceed the NPDES permit of 33 µg/L TR Cu. The stations PSNS0115.1, 124.1 and 124 had the highest frequency and magnitude of permit exceedences. Although the permit is based on TR Cu (top of the bars), Figure 4 also shows the partitioning of the chemistry between particulate and dissolved phases. This is important for the evaluation of biological availability of Cu and also to understanding the types of BMPs that would be most effective (e.g. particulate removal versus dissolved metal).

The fraction of the TR Cu occurring as dissolved Cu ranged from 15-87%. The fraction of dissolved can be used to identify the types of Cu entering the systems, predict the most effective BMPs for a particular drainage basin, 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 seawater ranges 60-90% dissolved Cu (Brandenberger et al. 2008). Therefore stations with less than 50% dissolved Cu might be targeted for particulate Cu sources.

For TR Zn, 15 EMCs exceeded the NPDES stormwater draft permit and 13 exceeded the Navy general permit. The stations with the highest frequency of exceedences were PSNS124.1, 124, 115.1, and 084.1. In seawater, Zn occurs as 90-100% dissolved and would be expected to be highly soluble after entering seawater. The percentage of TR Zn occurring as dissolved ranged from 36-92%. Station PSNS124 was the only station with two EMCs < 50% dissolved Zn suggesting particulate BMPs may be the most effective.

Figure 6 illustrates the inter-storm and station variability for dissolved, particulate, and TR Hg EMCs. The EMCs are well below the NPDES stormwater draft permit concentration of 2100 ng/L TR Hg. As was seen in Phase I, the TR Hg was significantly elevated above other stations at PSNS015 in NBK and within the CIA station PSNS124 during SW10 (total precipitation = 0.19 inches). The fraction of the TR Hg occurring as dissolved in the ambient waters of Sinclair/Dyes Inlet averages approximately 50% with a range of 30-80%. The Phase II stormwater EMCs averaged 29% dissolved Hg (Phase I was 24%) with stations PSNS124, 115.1, and 015 showing the highest fraction of particulate Hg with < 10% dissolved Hg.

Table 15. Descriptive statistics for Phase II Event Mean Composite (EMC) stormwater samples. The draft permit and Navy General Permit concentrations are included for reference. The concentrations greater than the Navy General Permit are highlighted blue and the draft permit 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											
MDL			**0.0001**		**0.03**		**0.007**		**0.002**		**0.05**
RL			**0.0003**		**0.1**		**0.02**		**0.006**		**0.2**
NPDES Stormwater Draft Permit			**2.1**		**69**		**5.8**		**221**		**95**
Navy General Permit							**14.0**				**117**
All	**Mean**	**0.00304**	**0.0142**	**1.64**	**1.91**	**14.1**	**33.7**	**0.574**	**9.70**	**85.6**	**135**
All	Stdev.	0.00306	0.0121	1.79	1.77	20.2	33.4	0.507	6.86	36.2	76.3
All	25th	0.00175	0.00568	0.542	0.932	5.88	14.7	0.26	4.56	54.5	76.6
All	Median	0.00194	0.0118	0.840	1.22	9.04	22.7	0.375	8.91	71.1	127
All	75th	0.00325	0.0186	1.55	2.14	15.3	39.5	0.631	12.9	117	177
All	n	25	25	25	25	25	25	25	25	25	25
PSNS126	**Mean**	**0.00450**	**0.00954**	**3.86**	**3.98**	**12.4**	**17.2**	**0.308**	**3.90**	**55.0**	**73.6**
PSNS126	Stdev.	0.00370	0.00565	1.81	1.70	7.97	7.42	0.0451	0.764	7.29	8.04
PSNS126	Min	0.00185	0.00396	2.03	2.14	4.78	8.98	0.255	3.00	48.1	61.9
PSNS126	Max	0.00982	0.0159	6.34	6.22	23.6	27	0.359	4.56	61.5	80.3
PSNS126	n	4	4	4	4	4	4	4	4	4	4
PSNS124.1	**Mean**	**0.00234**	**0.00563**	**0.834**	**1.07**	**13.1**	**42.8**	**0.601**	**11.9**	**105**	**172**
PSNS124.1	Stdev.	0.00101	0.00165	0.480	0.386	5.27	10.6	0.175	3.96	24.0	48.3
PSNS124.1	Min	0.00130	0.00330	0.532	0.724	7.65	34.6	0.371	6.04	71.1	100
PSNS124.1	Max	0.00357	0.00701	1.55	1.62	20.3	57.5	0.797	14.8	127	201
PSNS124.1	n	4	4	4	4	4	4	4	4	4	4

Table 15. Descriptive statistics for Phase II Event Mean Composite (EMC) stormwater samples. The draft permit and Navy General Permit concentrations are included for reference. The concentrations greater than the Navy General Permit are highlighted blue and the draft permit 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											
PSNS124	**Mean**	**0.00520**	**0.0227**	**2.77**	**3.21**	**39.5**	**84.5**	**0.348**	**9.62**	**83.2**	**188**
PSNS124	Stdev.	0.00660	0.0174	3.05	3.01	45.0	58.8	0.232	3.97	41.6	150
PSNS124	Min	0.00183	0.00727	0.851	1.37	15.3	39.5	0.193	4.95	54.5	76.6
PSNS124	Max	0.0151	0.0476	7.32	7.69	107	170	0.694	14.5	145	408
PSNS124	n	4	4	4	4	4	4	4	4	4	4
PSNS115.1	**Mean**	**0.00220**	**0.0141**	**1.18**	**1.71**	**10.6**	**35.1**	**0.434**	**16.7**	**118**	**175**
PSNS115.1	Stdev.	0.000930	0.00438	0.760	0.691	4.62	11.7	0.0666	14.0	16.6	34.1
PSNS115.1	Min	0.00153	0.00912	0.455	1.16	7.47	22.7	0.339	2.59	98.3	127
PSNS115.1	Max	0.00357	0.0186	2.22	2.65	17.5	51	0.487	35.7	139	206
PSNS115.1	n	4	4	4	4	4	4	4	4	4	4
PSNS084.1	**Mean**	**0.00128**	**0.00411**	**0.902**	**1.07**	**7.16**	**18.1**	**0.258**	**5.58**	**119**	**150**
PSNS084.1	Stdev.	0.000312	0.000314	0.405	0.343	2.83	2.7	0.0809	2.29	11.6	16.4
PSNS084.1	Min	0.00096	0.00381	0.489	0.768	4.41	14.7	0.201	3.88	106	135
PSNS084.1	Max	0.00171	0.00455	1.46	1.56	11.0	21.1	0.375	8.91	134	169
PSNS084.1	n	4	4	4	4	4	4	4	4	4	4
PSNS015	**Mean**	**0.00280**	**0.0264**	**0.545**	**0.732**	**4.32**	**10.3**	**1.31**	**10.4**	**43.8**	**69.4**
PSNS015	Stdev.	0.000867	0.0126	0.166	0.165	1.66	2.50	0.737	2.05	9.03	8.23
PSNS015	Min	0.00180	0.0119	0.356	0.606	2.80	8.05	0.393	8.40	35.5	56.8
PSNS015	Max	0.00398	0.0462	0.812	1.01	6.89	14.4	2.35	13.1	57.2	78.4
PSNS015	n	5	5	5	5	5	5	5	5	5	5

Table 16. Descriptive statistics for even mean composite (EMC) stormwater samples collected during the Phase II 2011-12 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				
MDL			**0.002**		**0.004**		**0.08**
RL			**0.006**		**0.01**		**0.3**
All	**Mean**	**0.0170**	**0.0587**	**0.191**	**0.382**	**2.16**	**4.26**
All	Stdev.	0.0313	0.0609	0.154	0.314	2.51	3.06
All	25th	0.00200	0.0190	0.0976	0.163	0.917	2.09
All	Median	0.00468	0.0311	0.170	0.255	1.49	3.10
All	75th	0.0113	0.0666	0.228	0.531	1.97	5.94
All	N	25	25	25	25	25	25
PSNS126	**Mean**	**0.0539**	**0.0993**	**0.129**	**0.211**	**1.19**	**1.80**
PSNS126	Stdev.	0.0564	0.0829	0.0500	0.0592	0.423	0.310
PSNS126	Min	0.00200	0.0175	0.0724	0.130	0.720	1.54
PSNS126	Max	0.128	0.190	0.194	0.256	1.56	2.22
PSNS126	N	4	4	4	4	4	4
PSNS124.1	**Mean**	**0.00347**	**0.0283**	**0.474**	**0.875**	**2.53**	**6.65**
PSNS124.1	Stdev.	0.00172	0.00922	0.115	0.288	0.871	1.71
PSNS124.1	Min	0.00200	0.0191	0.309	0.631	1.70	4.57
PSNS124.1	Max	0.00532	0.0399	0.566	1.21	3.62	8.07
PSNS124.1	N	4	4	4	4	4	4
PSNS124	**Mean**	**0.0277**	**0.115**	**0.231**	**0.549**	**3.25**	**5.88**
PSNS124	Stdev.	0.0427	0.0997	0.0605	0.292	2.23	1.01
PSNS124	Min	0.00200	0.0179	0.181	0.286	1.05	4.65
PSNS124	Max	0.0913	0.227	0.319	0.945	5.33	7.08
PSNS124	N	4	4	4	4	4	4
PSNS115.1	**Mean**	**0.0122**	**0.0749**	**0.216**	**0.443**	**3.80**	**6.45**
PSNS115.1	Stdev.	0.00829	0.0225	0.0434	0.141	5.87	5.97
PSNS115.1	Min	0.00354	0.0529	0.170	0.232	0.764	1.65
PSNS115.1	Max	0.02350	0.106	0.270	0.531	12.6	14.9
PSNS115.1	N	4	4	4	4	4	4

Table 16. Descriptive statistics for even mean composite (EMC) stormwater samples collected during the Phase II 2011-12 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				
PSNS084.1	**Mean**	**0.00444**	**0.0181**	**0.104**	**0.185**	**1.25**	**2.76**
PSNS084.1	Stdev.	0.00283	0.00346	0.00627	0.0476	0.648	0.962
PSNS084.1	Min	0.00200	0.0134	0.0976	0.150	0.732	1.88
PSNS084.1	Max	0.00795	0.0217	0.112	0.255	2.20	3.96
PSNS084.1	N	4	4	4	4	4	4
PSNS015	**Mean**	**0.00352**	**0.0251**	**0.0312**	**0.0986**	**1.17**	**2.46**
PSNS015	Stdev.	0.00168	0.0118	0.00479	0.0626	0.392	0.471
PSNS015	Min	0.00200	0.0163	0.0264	0.0518	0.876	1.92
PSNS015	Max	0.00579	0.0445	0.0386	0.207	1.70	3.20
PSNS015	N	5	5	5	5	5	5

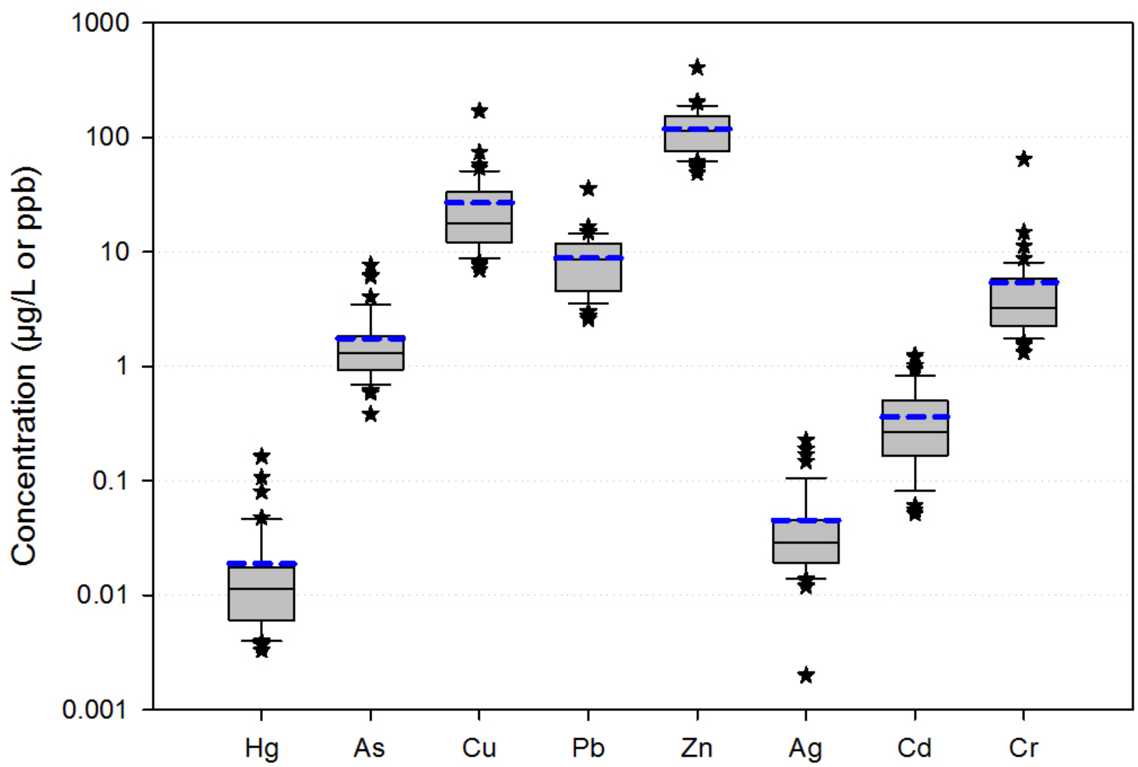

Figure 3. Total event mean concentrations (EMCs) in stormwater collected during Phase I and Phase II. The top, middle, and bottom solid black lines of the box represent the 75th percentile, 50th, and 25th percentile, respectively. The whiskers are the 5th and 95th percentile and the asterisks fall outside the 5th and 95th percentiles (n = 49). The blue dashed line is the average.

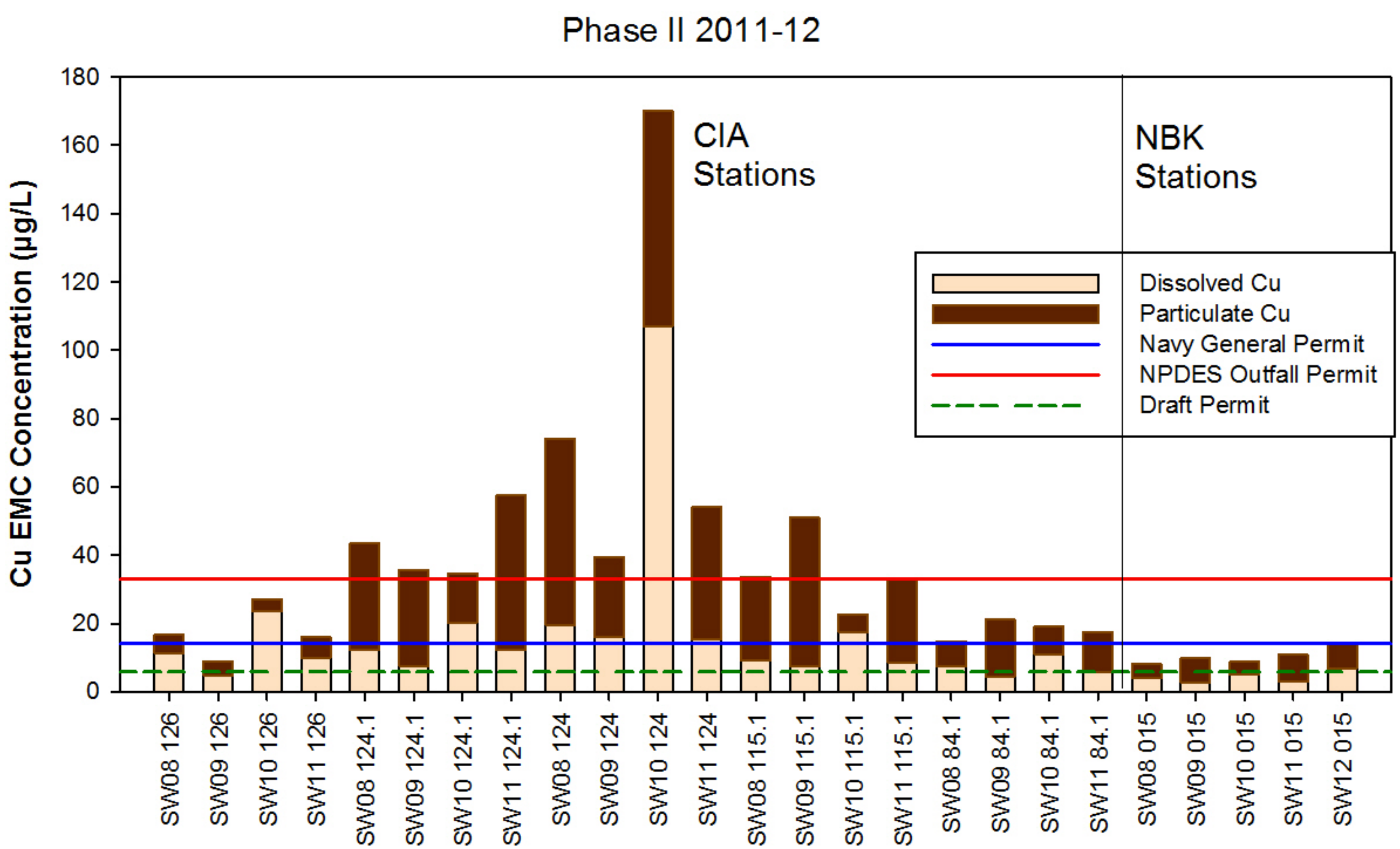

Figure 4. The concentrations of dissolved (DME) and particulate (PME) Cu measured in event mean concentration samples from CIA and NBK outfalls. The storm event number (SW01, etc.) and station ID are on the x-axis. The tops of each column represent the total recoverable (TR) Cu. The reference lines are the NPDES outfall permit concentration (red = 33 µg/L), Navy General Permit (blue = 14 µg/L) and draft permit for (dashed green = 5.8 µg/L) for TR Cu.

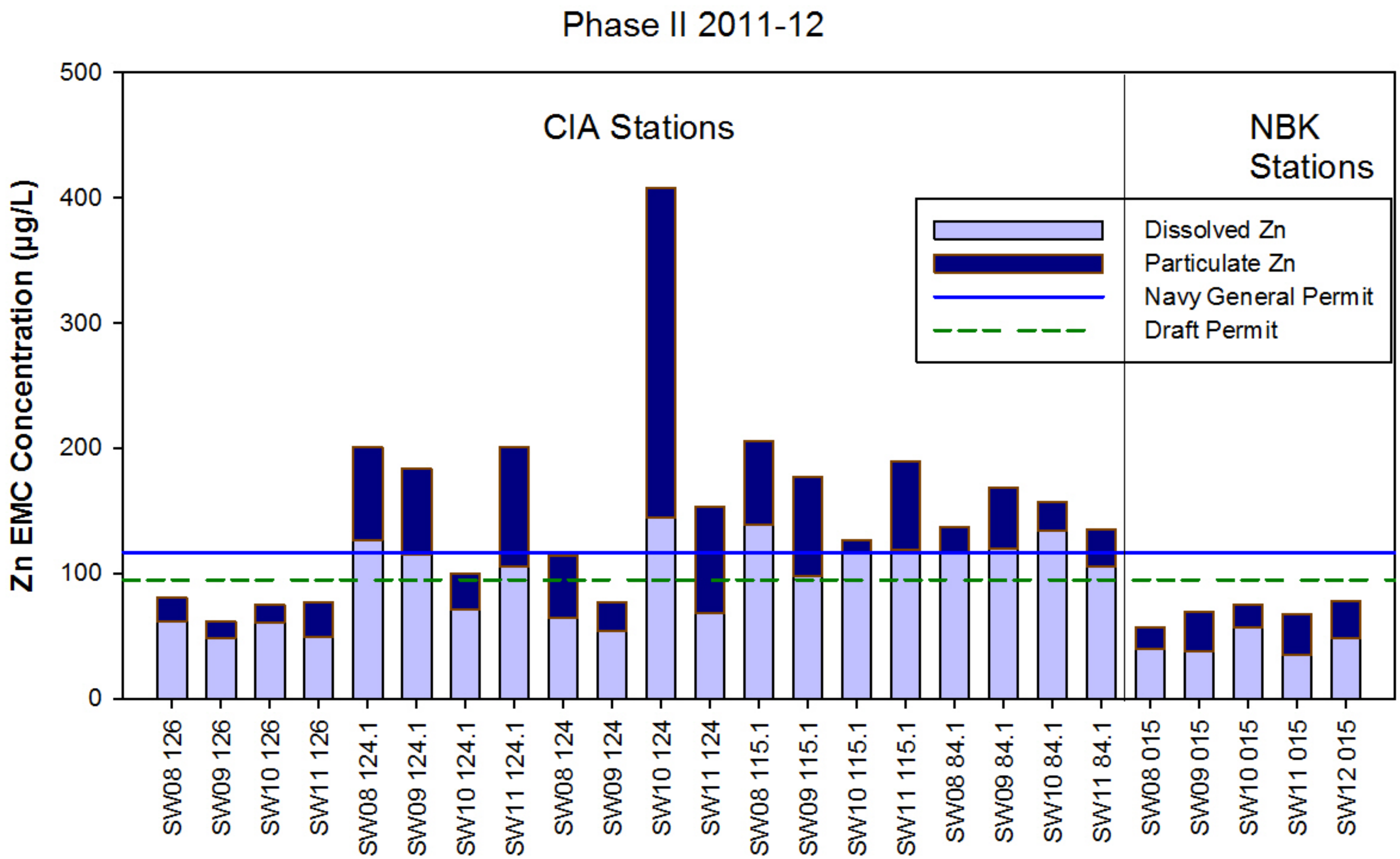

Figure 5. The concentrations of dissolved (DME) and particulate (PME) Zn measured in event mean concentration samples from CIA and NBK outfalls. The storm event number (SW01, etc.) and station ID are on the x-axis. The tops of each column represent the total recoverable (TR) Zn. The reference lines are the Navy General Permit (blue = 117.0 µg/L) and draft permit for (dashed green = 95.0 µg/L) for TR Zn.

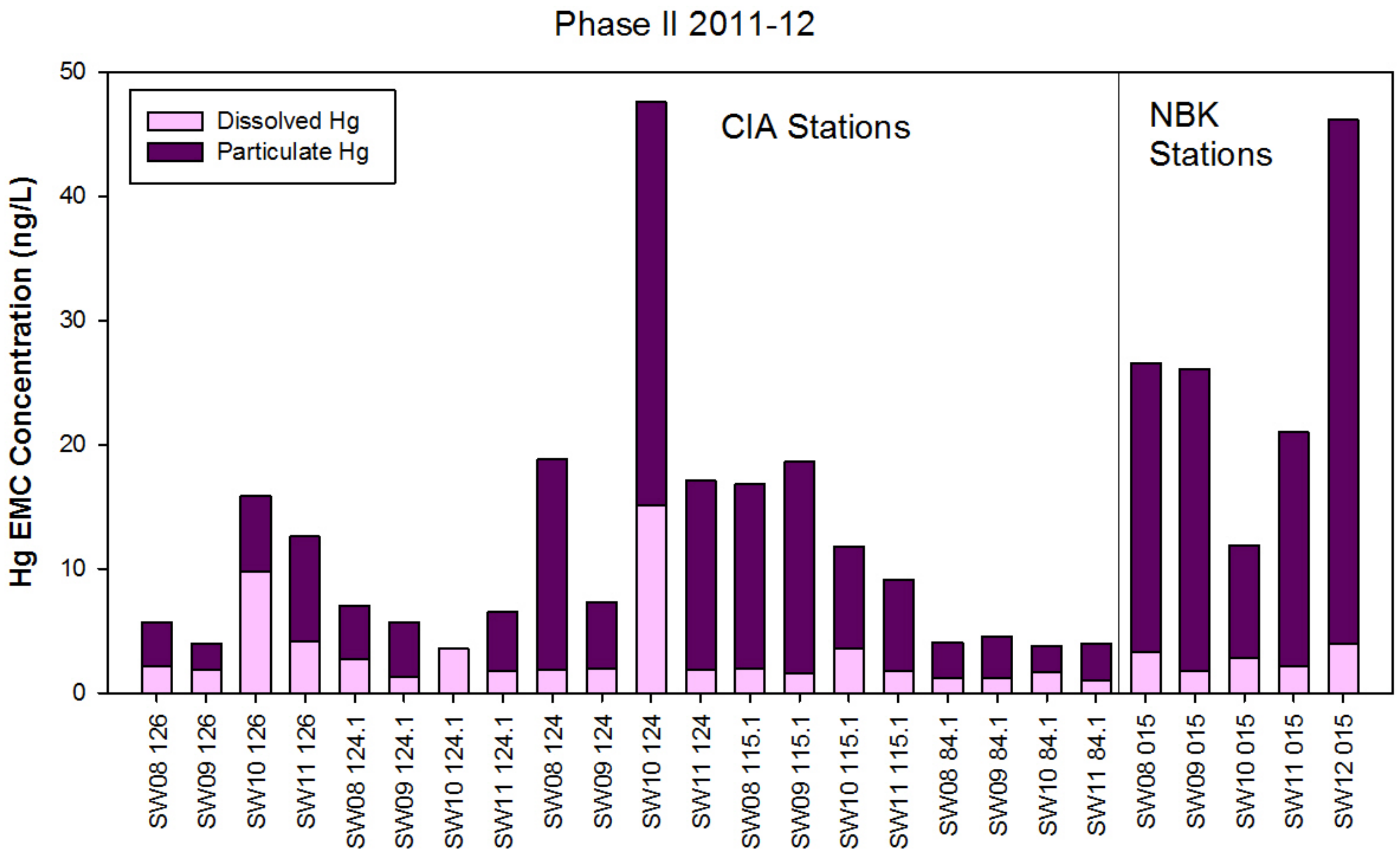

Figure 6. The concentrations of dissolved (DME) and particulate (PME) Hg measured in event mean concentration samples from CIA and NBK outfalls. The storm event number (SW08, etc.) and station code are on the x-axis. The tops of each column represent the total recoverable (TR) Hg.

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 17 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.

Natural waters tend to have a hardness of around 100 mg/L, therefore, on average the stormwater has a relatively low hardness with only stations PSNS124, 124.1, and 115.1 at or near 100 mg/L. The contribution of $CaCO_3$ within these drainage basins may be attributed to the industrial activities. The DOC concentrations were consistently higher at the NBK station PSNS015 (average = 2.1 mg/L), which is not unusual since the primary work activities are municipal/commercial/residential services with a higher percentage of pervious surface area. However, stations PSNS126 (materials storage) and PSNS124 (material storage and cutting facility) averaged 24 mg/L during SW10. This was a small event (total rainfall = 0.19-0.45 inches).

Table 17. 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	155 J	488 J	44.3	3.94	3.61	18.0
All	Stdev.	121	510	36.2	7.19	6.63	11.3
All	Min	65.0 J	170 J	12.0	1.03	0.89	5.00
All	Max	600 H	2600 O	162	33.9	31.5	48.0
All	N	24	24	24	24	24	24

J = Analyte detected above the MDL, but less than the RL.

H =The chromatographic fingerprint of the sample resembles a petroleum product, but the elution pattern indicates the presence of a greater amount of heavier molecular weight constituents than the calibration standard.

O =The chromatographic fingerprint of the sample resembles an oil, but does not match the calibration standard.

4.3 PSNS015 Detailed Storm Chemistry (SW12)

Phase I identified PSNS015 as critical drainage basin for further Hg studies. Therefore, it was included in the Phase II study and the focus of the SW12 detailed storm event. Figure 7 illustrates the results of the precipitation (inches), water level in the pipe (ft.), total concentration of particles as measured by the Laser In-Situ Scattering and Transmissometry (LISST; µL/L) and mean particle size (µm) during the progression of the SW12 event. The *in-situ* sensors also collected conductivity and more detailed size measurements of particles during the progression of the storm. The LISST data was captured as 32 size classifications then post processed to group the data into three size classes: < 63 µm (silt/clay), 63-234 µm (very fine and fine sand), and 234-386 µm (medium sand). All the size classification data and the grouped data are available in Appendix D.

These *in-situ* measurements were then plotted again the concentrations of DOC and particulate and dissolved Hg (Figure 8) determined during the intervals of the storm. The TR Hg concentrations in the discrete samples of the storm are equal to the top of the stacked bars. The *in-situ* measurements were collected at roughly 15 minute intervals, while the chemistry data were determined from the one hour composites collected by the ISCO. The data show that as the rainfall begins you have smaller particles moving through the outfall and the Hg concentration does not begin to increase until about 4 hours into the storm event. The first increase in Hg occurs around the time there is a peak in the size and volume of particles moving through the outfall around 23:00 to 24:00. By this time the precipitation volumes have begun to decrease and the tide begins to move into the pipe with conductivity rising around 03:00. While the denser salt water is filling the pipe, the fresh stormwater is trapped behind the salt water and the DOC concentrations are closer to those measured in the ambient seawater (~1-2 mg/L).

As the tide recedes, the DOC goes up and there is a peak in the TR Hg concentration along with a peak in the silt/clay and fine sand size classifications. After this peak, the Hg concentrations go down. However, the portion of the total Hg that is in the dissolved phase increases to as much as 57% compared to earlier values averaging 23%. The pulse of particulates traveling through the pipe during the collection of discrete sample 16 around 0900 on 20 April 2012 is reflected in all the metals as a spike in the particulate fraction (Table 18).

Table 18. The event mean composite (EMC) and discrete sample concentrations for SW12. Each discrete sample is a one hour time-paced composite.

Station	Collected	Conductivity	TSS	DOC	Hg	Hg	Cu	Cu	Pb	Pb
Fraction	Date/Time				Dissolved	Total	Dissolved	Total	Dissolved	Total
Units		µS/cm	mg/L	mg/L	ng/L	ng/L	µg/L	µg/L	µg/L	µg/L
EMC		**338**	**60.3**	**3.07**	**3.98**	**46.2**	**6.89**	**14.4**	**1.55**	**12.0**
PSNS015-1	4/19/12 17:46	1200	41.8	4.01	3.40	19.7	7.43	17.4	0.872	14.4
PSNS015-2	4/19/12 18:46	70	23.3	3.47	3.04	11.9	6.02	12.3	1.18	9.77
PSNS015-3	4/19/12 19:46	42	14.6	3.71	2.58	13.7	5.77	9.9	1.54	9.39
PSNS015-4	4/19/12 20:46	67	11.9	3.27	3.71	39.6	7.18	11.2	2.28	9.73
PSNS015-5	4/19/12 21:46	168	58.3	4.67	4.34	47.8	7.38	14.8	1.67	12.3
PSNS015-6	4/19/12 22:46	304	13.8	3.10	3.09	25.7	7.08	12.6	1.84	9.75
PSNS015-7	4/19/12 23:46	417	3.34	4.55	5.27	12.9	7.13	9.5	2.22	6.12
PSNS015-8	4/20/12 0:46	228	6.34	3.22	3.43	10.3	7.22	10.1	2.32	7.06
PSNS015-9	4/20/12 1:46	581	5.70	3.27	5.29	14.2	7.32	9.67	2.18	6.45
PSNS015-10	4/20/12 2:46	8300	10.6	3.12	4.97	21.9	4.49	8.95	1.49	6.43
PSNS015-11	4/20/12 3:46	40100	6.57	1.87	2.37	17.3	1.68	3.49	0.470	2.70
PSNS015-12	4/20/12 4:46	42350	4.14	1.36	1.31	10.1	1.41	2.87	0.301	1.91
PSNS015-13	4/20/12 5:46	15750	1.90	2.96	5.49	14.3	5.45	7.73	1.34	5.07
PSNS015-14	4/20/12 6:46	1065	2.95	3.14	5.25	14.0	8.06	10.7	1.79	6.08
PSNS015-15	4/20/12 7:46	311	5.57	3.44	2.83	12.4	6.71	8.95	3.55	8.34
PSNS015-16	4/20/12 9:01	236	181	1.65	13.0	271	2.96	28.5	0.350	22.5
PSNS015-17	4/20/12 10:01	158	8.41	3.45	8.35	28.4	6.07	8.69	1.58	5.40
PSNS015-18	4/20/12 10:54	186	8.90	4.38	7.23	12.6	7.51	10.0	2.29	5.70

Table 18. The event mean composite (EMC) and discrete sample concentrations for SW12. Each discrete sample is a one hour time-paced composite.

Station	Collected	Zn	Zn	Ag	Ag	Cd	Cd	Cr	Cr
Fraction	Date	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total
Units	Time	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
EMC		**48.7**	**78.4**	**0.00468**	**0.0445**	**0.0277**	**0.0610**	**0.888**	**2.32**
PSNS015-1	4/19/12 17:46	43.7	76.2	0.00369	0.0296	0.0569	0.117	0.949	2.69
PSNS015-2	4/19/12 18:46	34.2	62.6	0.00200	0.0192	0.0183	0.0594	0.746	1.61
PSNS015-3	4/19/12 19:46	37.5	57.1	0.00311	0.0138	0.0146	0.0459	0.715	1.28
PSNS015-4	4/19/12 20:46	52.5	70.6	0.00241	0.0331	0.0260	0.0453	0.801	1.36
PSNS015-5	4/19/12 21:46	54.0	84.8	0.00249	0.0433	0.0198	0.0588	0.782	1.93
PSNS015-6	4/19/12 22:46	51.8	76.1	0.00448	0.0241	0.0261	0.0722	0.950	1.60
PSNS015-7	4/19/12 23:46	55.6	64.4	0.00427	0.0144	0.0284	0.0378	1.39	1.73
PSNS015-8	4/20/12 0:46	79.20	92.80	0.00474	0.0148	0.0314	0.0463	1.21	1.63
PSNS015-9	4/20/12 1:46	72.2	82.1	0.00531	0.0133	0.0332	0.0408	1.40	1.87
PSNS015-10	4/20/12 2:46	71.0	92.0	0.00526	0.0512	0.0732	0.0962	0.698	1.37
PSNS015-11	4/20/12 3:46	65.1	70.5	0.00420	0.0225	0.204	0.224	0.119	0.420
PSNS015-12	4/20/12 4:46	30.3	32.8	0.00420	0.0122	0.128	0.141	0.138	0.378
PSNS015-13	4/20/12 5:46	79.4	83.3	0.00519	0.0204	0.120	0.128	0.694	0.968
PSNS015-14	4/20/12 6:46	61.7	69.9	0.00493	0.0125	0.0301	0.0382	1.02	1.39
PSNS015-15	4/20/12 7:46	87.6	98.5	0.00332	0.0118	0.0329	0.0394	0.774	0.970
PSNS015-16	4/20/12 9:01	22.1	108	0.00200	0.129	0.0200	0.125	0.411	3.38
PSNS015-17	4/20/12 10:01	65.7	80.7	0.00926	0.0242	0.0279	0.0434	0.687	0.971
PSNS015-18	4/20/12 10:54	68.0	80.7	0.0103	0.0220	0.0282	0.0470	0.740	1.06

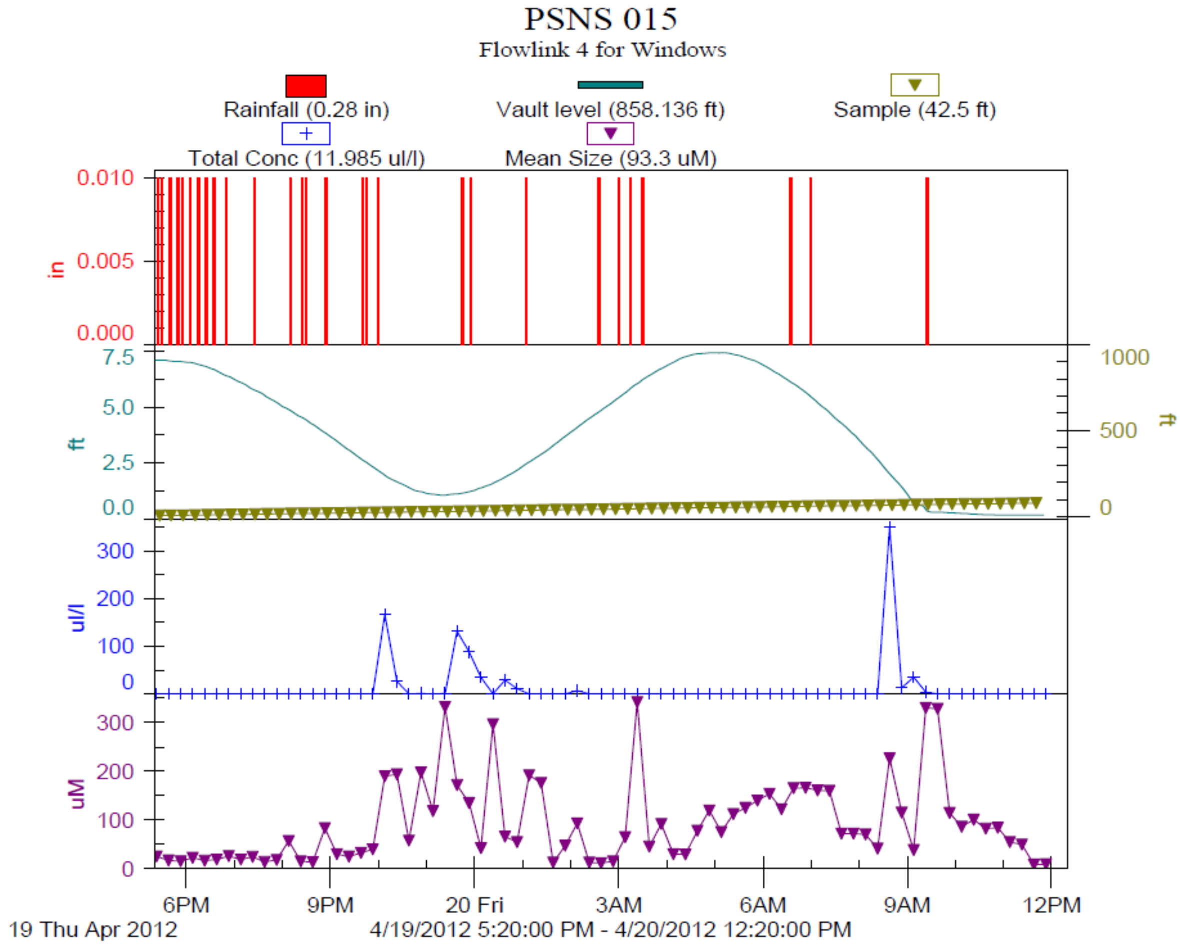

Figure 7. From top to bottom, graphs of the precipitation (inches), water level in the pipe (ft.), total concentration of particles as measured by the Laser In-Situ Scattering and Transmissometry (LISST; µL/L) and mean particle size (µm) of the stormwater during the SW12 event.

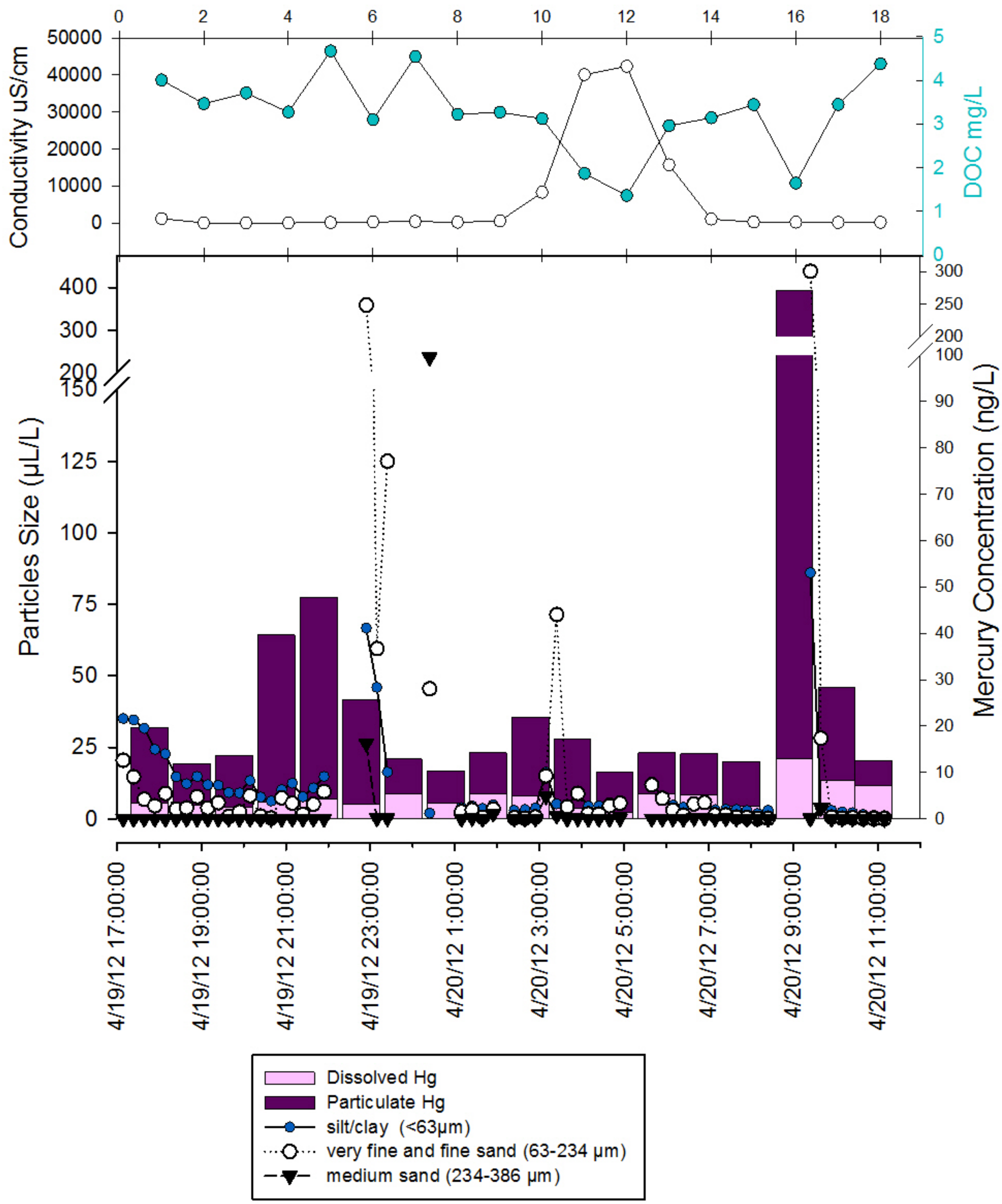

Figure 8. The top graph is the conductivity and dissolved organic carbon (DOC) during SW12. The bottom graph shows the discrete sample concentrations of particulate and dissolved Hg. The silt/clay, fine sand, and medium sand data collected from the LISST are plotted. The top of the bar represents total recoverable Hg.

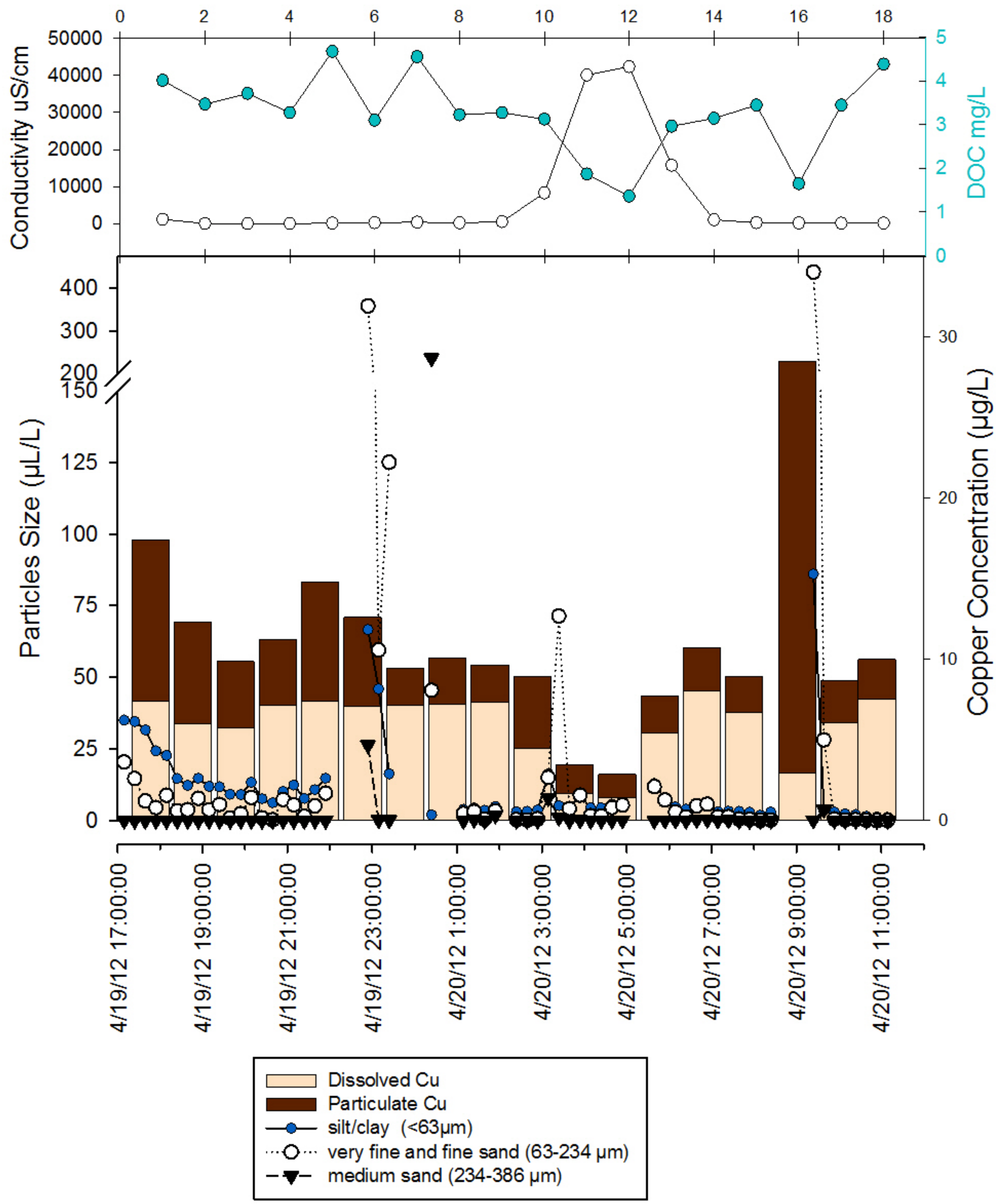

Figure 9. The top graph is the conductivity and dissolved organic carbon (DOC) during SW12. The bottom graph shows the discrete sample concentrations of particulate and dissolved Cu. The silt/clay, fine sand, and medium sand data collected from the LISST are plotted. The top of the bar represents total recoverable Cu.

5.0 CONCLUSION AND RECOMMENDATIONS

This report summarizes the findings for Phase I and II to provide the current information on stormwater chemistry within the Shipyard. The overall goal of the NDDSW study is to provide a good characterization of the stormwater quality in Shipyard drainage basins, assess the probability of permit compliance, and the rational of the proposed draft NPDES stormwater permit limits. Although this is an interim report and the data will not be completely synthesized to address these questions, Phase I and II datasets were used to inform the Phase III sampling (2012-13 wet season), identify drainage basins likely to exceed the draft permit, and evaluate if the draft permit limits were reasonable when compared to other stormwater outfall chemistry data. The later can be used to build a case that the proposed limits are either not feasibility attainable or practical for the protections of beneficial uses in Sinclair Inlet. The potential for many sources of stormwater to enter Sinclair Inlet and potentially impair beneficial uses, suggests the need for a mass balance or total maximum daily load type approach to management. In addition, the stormwater partitioning chemistry provided a means to begin summarizing recommended actions for each drainage basin and suggesting potential BMP actions for stormwater managers. The final project report will provide the overall recommendations for action and address 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 sampling (e.g. Phase I in 2010-11 and ENVVEST in 2003-2005) and/or other Puget Sound industrial areas?

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Based on the Phase I and II data, the probabilities for stormwater EMCs collected from drainage basins in the Shipyard to exceed the draft NPDES stormwater permit limits were 100% for Cu, 59% for Zn, and 0% for all other metals. The probability for the EMCs to exceed the Navy general permits for Cu and Zn were 67% and 43%, respectively. The median and ranges for the combined Phase I 2010-11 and Phase II 2011-12 NDDSW study were then compared to other regional urban, commercial, and industrial stormwater data (Table 19). This provides three points of reference with respect to regional and comparable LULC stormwater chemistry. The first being the ENVVEST 2003-2005 stormwater data collected from PSNS outfalls, the second was ENVVEST stormwater data collected from urban outfalls in Kitsap County, and the third was a Puget Sound stormwater study on specific LULCs. The data are presented in Table 19 and discussed below.

Table 19. Comparison of 2010-12 (Phase I and II) stormwater event mean concentrations (EMCs) with regional urban stormwater outfall and commercial/industrial (C&I) land use/cover stormwater concentrations for total recoverable metals (note the unit change for Hg to ng/L).

TR Conc.	TR Cu (µg/L)	TR Zn (µg/L)	TR Pb (µg/L)	TR As (µg/L)	TR Hg (ng/L)
PSNS Draft NPDES Stormwater Permit	5.8	95	221	69	2100
Navy General Permit	14.0	117			
Phase I & II 2010-12 PSNS Median EMCs (range) n=70	14.8 (2.9-170)	82.7 (33-408)	8.2 (2.0-36)	1.2 (0.38-7.7)	12.6 (3.3-271)
ENVVEST 2003-05 PSNS Outfalls Median (range)[1] n=19	42.4 (12-123)	113 (35-257)	11 (4-32)	4.3 (1-12)	28 (12-123)
ENVVEST Urban Outfalls Median (range)[1] n=40	11 (5-27)	62 (18-140)	9.8 (3-25)	0.97 (0.5-14)	11 (6-56)
Puget Sound C&I [2] Median n= 6	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)

The ENVVEST 2003-2005 PSNS stormwater outfall study sampled PSNS015, 124, 008, and 101 using similar methodologies (Brandenberger et al. 2007 a, b). The median concentrations for Phase I and II were all lower than the median for the 2003-2005 PSNS outfall dataset. This suggests a measurable decrease in the overall concentration of these metals in the stormwater at the Shipyard and points to successes in process improvements.

The ENVVEST 2003-2005 study also collected stormwater from urban outfalls and streams (during storm events) within the Sinclair/Dyes Inlet study area. In many cases the medians are very similar and the ranges overlap for the outfall data. Figure 10 illustrates the data sets and suggests that for some metals their sources may not be specific to Shipyard activities and may be driven more by activities occurring in both urban and industrial settings (e.g. vehicles, roof runoff, etc.). In fact, Brandenberger et al. (2010) found the Puget Sound concentrations of Cu and Hg in rainfall ranged 0.29-5.5 µg/L and 4.1-9.4 ng/L, respectively. For Hg, this is consistent with the data sets across all the studies where stream concentrations during storm events are within a factor of two of the industrial and urban stormwater outfall chemistry.

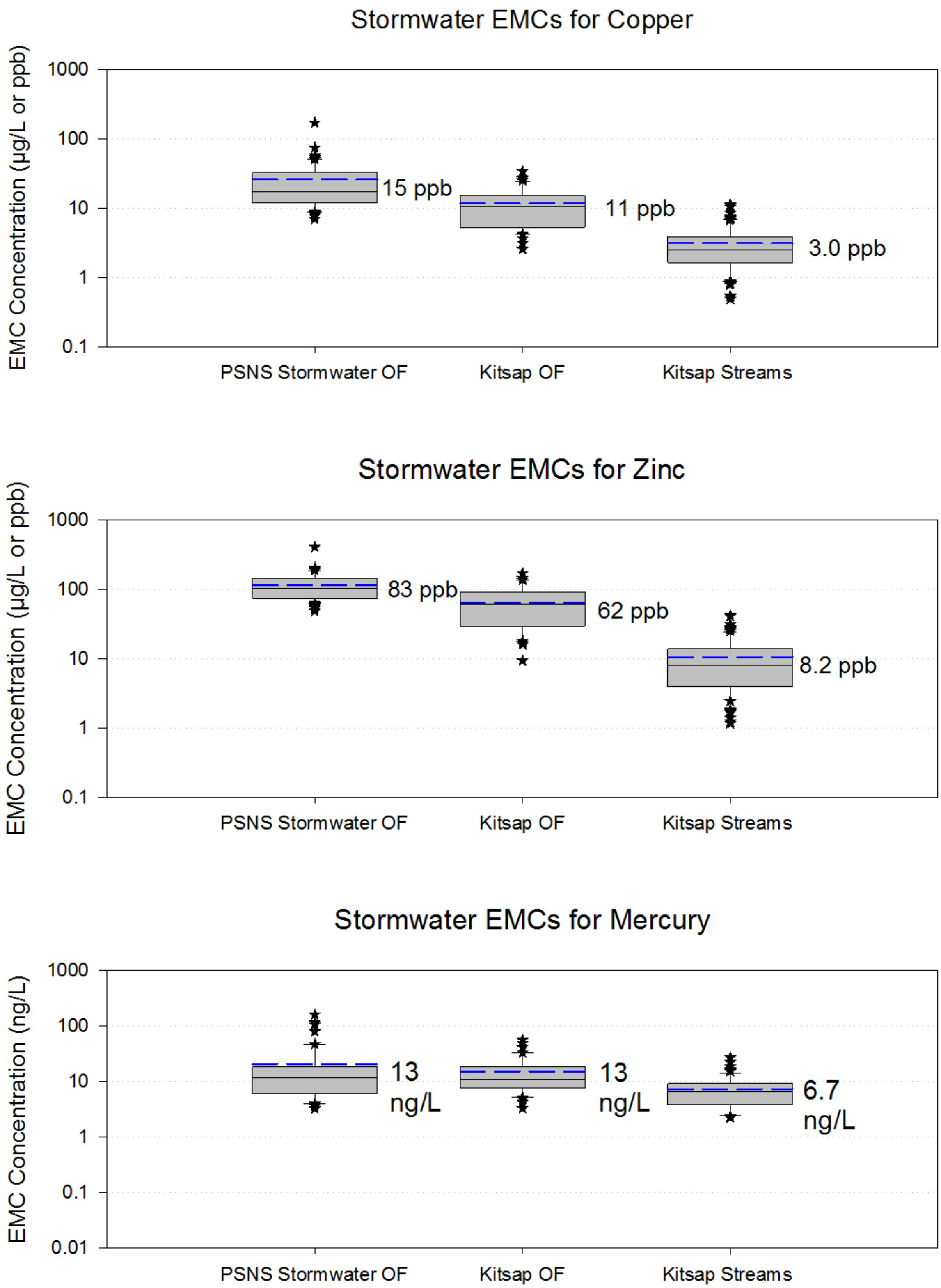

Figure 10. Data distributions for the Phase I and II PSNS non-dry dock stormwater outfalls, the ENVVEST 2003-2005 Kitsap County urban stormwater outfalls, and Kitsap streams during storm events (Brandenberger et al. 2007 a, b). The median concentrations are numerically noted on the graphs and the blue dashed line is the average concentration.

The third point of reference is the Ecology report on stormwater concentrations measured in two basins of Puget Sound (Puyallup and Snohomish) which targeted specific LULC distributions (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) reported stormwater concentrations based on grab samples that were composited to reflect a storm event concentration; therefore, the data are not directly comparable.

Multiple lines of evidence were used to assess recommended actions thus far based on Phase I and II sampling. Table 20 uses four lines of evidence to summarize the NDDSW data including: 1) probability of that basin to exceed the NPDEs stormwater draft permit, 2) probability to exceed the Navy general permit, 3) loading of metals relative to other outfalls, and 4) dominance of particulate versus dissolved metals in the stormwater. These lines of evidence were used to provide some prioritized recommendation for each drainage basin.

The probabilities to exceed the permit limits were assessed at a station level. As discussed above, many had a high probability to exceed the limits for Cu. The metal load for each storm event and station was calculated and presented in Appendix C. The storm loads for each station were then summed and presented relative to the loads from all stations and storms. This approach provided for a ranking of drainage basins contributing the largest load of metals. Collectively this information provided an opportunity to recommend some BMP actions. The stormwater metals chemistry suggests that a majority of the stations are dominated by particulate phase metals (e.g. SW10 at PSNS124). Therefore recommendations focused on particulate removal, such as street sweeping or stormwater treatment optimized for particle removal. A review of the specific processes within each drainage basin would provide information on particle sources for those basins. However, stations PSNS084.1 and 126 showed a higher fraction of dissolved metals, which require a more complex review of the chemistry, potential sources, and effective BMPs.

One recommendation for all drainage basins is any stormwater sampling at the Shipyard must include collection and analytical methods that compensate for the tidal intrusion into the drainage system. As was noted in the SW12 detailed storm analyses, the influence of the tide on the stormwater chemistry at PSNS015 was significant. Salinity, as low as 5 ppt, results in analytical artifacts and dilution of the storm event derived runoff. In addition, the tide “holds” up the stormwater resulting in a delay in the freshwater runoff independent of precipitation trends. In addition, the detailed chemistry as a function of rainfall, volume of stormwater runoff, and tide further highlighted the need to collect composite samples rather than only grab samples.

Table 20. The lines of evidence used to prioritize the Phase I and II stations include: 1) total number of event mean concentrations (EMC) greater than the draft NPDES stormwater permit; 2) Navy general permit; 3) relative load for permitted metals, and 4) relative proportion of dissolved and particulate. Stations are listed in priority order.

Outfall (n)[1]	Area	Probability of > Draft NPDES SW	Probability > Navy General Permit	Metal Load Relative to Other Stations[2]	Recommendations[3]
096 (n=5)	CIA	100% Cu 80% Zn	100% Cu	Cu=22%; Pb=17%; Zn=17%	Particulate driven: Street sweeping; High particulate load BMPs
081.1 (n=3)	CIA	100% Cu 100% Zn	100% Cu 100% Zn	Cu=19%; Pb=13%; Zn=16%	Particulate driven: Review activities generating particulate metal; Street sweeping; High particulate load BMPs
124 (n=4)	CIA	100% Cu 75% Zn	100% Cu 50% Zn	Cu=12%	Particulate driven: Street sweeping; High particulate load BMPs
115.1 (n=4)	CIA	100% Cu 100% Zn	100% Cu 100% Zn	All < 9%	Particulate driven: Street sweeping; High particulate load BMPs
124.1 (n=4)	CIA	100% Cu 100% Zn	100% Cu 75% Zn	All < 6%	Particulate driven: Street sweeping; High particulate load BMPs
084.1 (n=4)	CIA	100% Cu 100% Zn	100% Cu 100% Zn	All < 1%	Mixed: Street sweeping; High particulate load BMPs and cover outside materials
082.5 (n=3)	CIA	100% Cu 67% Zn	100% Cu 67% Zn	All <2 %	Particulate driven: Review recycling activities; Street sweeping; High particulate load BMPs
126 (n=7)	CIA	100% Cu	57% Cu	As=29%	Dissolved driven: Cover metal materials in outside storage; tidal gate
008 (n=3)	NBK	100% Cu 100% Zn	33% Cu 100% Zn	All < 5%	Particulate driven: Street sweeping; High particulate load BMPs; vehicle sources
015 (n=8)	NBK	100% Cu		Cu=23%; Pb=48%; Zn=34%; Hg=72%; As=26%	Particle driven and special study on tidal impacts on storm drain discharges and sub-surface sources of metals specifically Hg.
032 (n=4)	NBK	100% Cu 50% Zn	25% Zn	All <2 %	Particulate driven: Street sweeping; High particulate load BMPs; vehicle sources

[1] The n value is the total number of EMCs sampled during Phase I and II at this station.

[2] Relative percent of the total load based on total metal EMCs for all stations sampled in Phase I and II. Only permitted metals with loads >10% reported in the table.

[3] The recommendations were based on the probability of the EMC exceeding the permit and the stormwater chemistry primarily for Cu. The influence of the tide on the metal chemistry is significant and all basins should be reviewed for potential tidal gates.

The dominance of particulate or dissolved metal fraction is also a function of the total precipitation during the storm. Table 21 lists the average percent dissolved for each metal as a function of storm size. As would be expected the larger storms have a larger fraction of particulate metals, while small storms are dominated by the dissolved fraction. If the dissolved

Table 21. The average percent dissolved metal in the Phase I and II stormwater EMCs as a function of storm size.

	Cu	Zn	Hg	Pb
Small (<0.5 inches)	60%	72%	30%	19%
Medium (0.5-1.0 inches)	45%	62%	25%	9%
Med-Large (1-2.0 inches)	36%	63%	23%	6%
Large (> 2.0 inches)	25%	53%	26%	3%

The Phase I and II 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. Even with adequate justification, the permit limit may never exceed the current NPDES permit limit for the dry dock of 33 µg/L TR Cu. With this assumption, specific outfalls with EMCs repeatedly above this concentration should be targeted for further monitoring and process evaluations. The outfalls in priority order include PSNS124, 124.1, 115.1, and 081.1. In addition, NBK stations PSNS015 and PSNS032 should be evaluated for sources of Hg.

The final recommendation is field collection procedures for the Shipyard stormwater outfalls must include methodology to limit the potential for post collection contamination. The metals are ubiquitous in shipyard operations and thus trigger the need to ensure the water collected during sampling adequately represents the water being discharged, and not contamination introduced to the sample itself during or after collection (i.e. at the manhole) and/or during laboratory analyses. The concentrations of the draft permit are approaching levels measured in streams during storm conditions and rainfall directly; therefore additional precautions should be taken to ensure that the samples represent the chemistry of the water in the conveyance.

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