T-91 HISTORICAL REVIEW REPORT

DRAFT

January 31, 2017

Prepared by:

200 West Mercer Street, Suite 401
Seattle, Washington s 98119

Table of Contents

Tables

Figures

Maps

Acronyms

2LAET	second lowest apparent effects threshold
AO	Agreed Order
AOC	Area of Concern
BEI	Burlington Environmental Inc.
BNSF	Burling Northern Santa Fe
CAP	cleanup action plan
Chempro	Chemical Processors Inc.
City	City of Seattle
City Ice	City Ice Cold Storage
CSL	cleanup screening level
CSO	combined sewer overflow
DAS	Distribution and Auto Services
DDT	dichlorodiphenyltrichloroethane
DL	detection limit
DMM	discarded military munitions
DMMP	Dredged Material Management Program
DNR	Department of Natural Resources
dw	dry weight
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management
EPA	US Environmental Protection Agency
FAMM	Fuel and Marine Marketing
FS	feasibility study
HPAH	high-molecular-weight polycyclic aromatic hydrocarbon
ISGP	industrial stormwater general permit
HPAH	high-molecular-weight polycyclic aromatic hydrocarbon
LAET	lowest apparent effects threshold
LNAPL	light non-aqueous phase liquid
LPAH	low-molecular-weight polycyclic aromatic hydrocarbon
MLLW	mean lower low water

MRA	munitions response area
MTCA	Model Toxics Control Act
NPDES	National Pollutant Discharge Elimination System
O&M	operation and maintenance
OC	organic carbon
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PNO	Pacific Northern Oil Corporation
Port	Port of Seattle
PSAMP	Puget Sound Assessment and Monitoring Program
PSC	Philip Services Corp
RCRA	Resource Conservation and Recovery Act
RI	remedial investigation
SCL	Seattle City Light
SCO	sediment cleanup objective
SLA	Submerged Lands Area
SMS	Washington State Sediment Management Standards
SPU	Seattle Public Utilities
SQS	sediment quality standards
SWMU	Solid Waste Management Unit
T-91	Terminal 91
TBT	tributyltin
TCRA	time-critical removal action
TEQ	toxic equivalent
TFAA	Tank Farm Affected Area
TFLP	Tank Farm Lease Area
TOC	total organic carbon
TPH	total petroleum hydrocarbons
USACE	United States Army Corp of Engineers
UST	underground storage tank
VCP	Voluntary Cleanup Program

1 Introduction

Terminal 91 (T-91) is an approximately 210-ac property owned by the Port of Seattle (Port), located at 2001 West Garfield Street in the Interbay neighborhood of Seattle, Washington. The property consists of an upland area, two piers (Piers 90 and 91), and about 35 ac of submerged lands around the piers (i.e., Submerged Lands Area [SLA]) (Map 1). The property has hosted a variety of land uses and businesses and played an important role in the City of Seattle's (City's) development since around the turn of the 20th century.

T-91 is regulated under both a Dangerous Waste Management Permit and a Model Toxics Control Act (MTCA) Agreed Order (AO). The Dangerous Waste Management Permit is issued by the Washington State Department Ecology (Ecology) and establishes corrective action requirements pursuant to the federal Resource Conservation and Recovery Act (RCRA). RCRA requires corrective action to address releases at permitted hazardous waste treatment, storage, and disposal facilities. Corrective action requirements for T-91 are due solely to the former presence of a tenant-operated dangerous waste treatment and storage facility on a 4-ac parcel within T-91. That former facility's regulatory status subjects all contiguous Port-owned property comprising T-91 to corrective action requirements.

Ecology employs MTCA authority and procedures to implement RCRA corrective action requirements. Ecology and the Port have conducted site investigations and cleanups under a series of AOs since Ecology took over RCRA corrective action oversight responsibilities for T-91 from the US Environmental Protection Agency (EPA) in 1998. These AOs and their requirements are summarized below.

- **<u>1998 Agreed Order (Tank Farm Affected Area) and Voluntary Cleanup Program Work (Discrete Units)</u>.** The first AO for T-91 was signed in 1998 (Ecology 1998). It required the Port and other parties[1] to conduct a remedial investigation (RI) and feasibility study (FS) for the former Burlington Environmental, Inc. (BEI) dangerous waste treatment and storage facility, commonly referred to as the Tank Farm. The study area extended beyond the 4-acre Tank Farm boundaries to include any area determined to have been affected by releases from the facility. Investigations conducted since 1998 have determined the extent of the Tank Farm Affected Area (TFAA). Generally, it extends southward from the Tank Farm onto Piers 90 and 91, but it does not include the adjacent Port-owned marine sediment (SLA).

  Separately from the 1998 AO, the Port undertook investigations and cleanups, as appropriate, at other known or suspected release areas on T-91 that were

[1] In addition to the Port and Ecology, parties to the 1998 AO included BEI (dba Philip Services Corporation) and Pacific Northern Oil Corporation (PNO).

not within the TFAA. There were approximately 38 of these separate units, referred to as Discrete Units. Most of the Discrete Units had been identified by EPA as a result of a RCRA Facility Assessment study in 1994, the purpose of which had been to identify all areas at T-91 affected by hazardous substances releases (EPA 1994). Based on Port records regarding management of T-91, the Port identified additional Discrete Units in 1997 (Kennedy/Jenks 1997). None of the Discrete Units were located within the SLA. All were located within the upland area, so the Port's corrective actions to address the Discrete Units involved only the upland area. Ecology and the Port addressed the Discrete Units under Ecology's voluntary cleanup program.

- **2010 Agreed Order.** Ecology and the Port[2] entered a replacement AO in 2010 (Ecology 2010). The 2010 AO required the Port to complete the work that had been requisite under the 1998 AO (Ecology 1998), including the development of a draft cleanup action plan (CAP) for the TFAA. It also extended the site to include the rest of the contiguously owned Port property (i.e., all 216 ac[3] of T-91) in order to align with the RCRA requirement calling for corrective action with respect to the entire "facility," defined as including the former Tank Farm dangerous waste facility and all contiguously owned property. The 2010 AO also listed all previously identified Discrete Units for T-91 and set requirements for the Port to address them. Although the 2010 AO included the SLA, no Discrete Units were located there; accordingly, the 2010 AO deferred the need to consider investigation or remediation of the SLA. Meanwhile, investigations of subsurface contamination from the Tank Farm and Discrete Units revealed no evidence that such contamination had migrated to or otherwise affected the SLA.
- **2012 Agreed Order.** In 2012, the Port and Ecology signed a new AO, which required the Port to carry out the CAP with respect to the TFAA and an adjacent Discrete Unit (Solid Waste Management Unit [SWMU 30]), and to continue work on the remaining Discrete Units (Ecology 2012a). By 2015, the Port had completed active work (i.e., construction of the remedial features) at the TFAA and SWMU 30; by mid-2016, Ecology had approved all but one Discrete Unit as having been adequately addressed.

[2] The other parties to the 1998 AO, BEI and PNO, were not parties to the 2010 AO. BEI had declared bankruptcy in 2003, and PNO had ceased operations in 1995.

[3] T-91 comprised 216 acres from the time of the 1998 AO until 2013, when approximately 6 acres were removed by conveyance to King County for use in constructing wastewater management facilities.

- **2016 Agreed Order Amendment.** In January 2016, Ecology and the Port entered an Amendment to the 2012 AO (First Amendment), which required the Port to conduct two new, separate tasks (Ecology 2016b):
  - Task 1 – Regrade the accumulated shoal material along the southeast portion of Pier 91 in the SLA. This task, known as the Regrade Project, was completed in April 2016.
  - Task 2 – Conduct a preliminary site investigation in the SLA. The purpose of the investigation is to provide information to help determine whether further remedial actions will be required; such information will include indications of historical and current sources of contamination and identification of potentially responsible parties.

This draft historical review report for T-91 is the first deliverable required for Task 2 of the 2016 AO Amendment. This report summarizes the available historical background of T-91, including site operations and a preliminary research-based evaluation of potential contaminant pathways from the upland area to the SLA. In addition, a summary of the existing sediment sampling data for the SLA is provided.

In order to compile the draft historical review report, Windward reviewed relevant reports provided by the Port. Additional information was obtained from public records as needed. The sediment data provided by the Port and Ecology's Environmental Information Management (EIM) database were also used to identify relevant data.

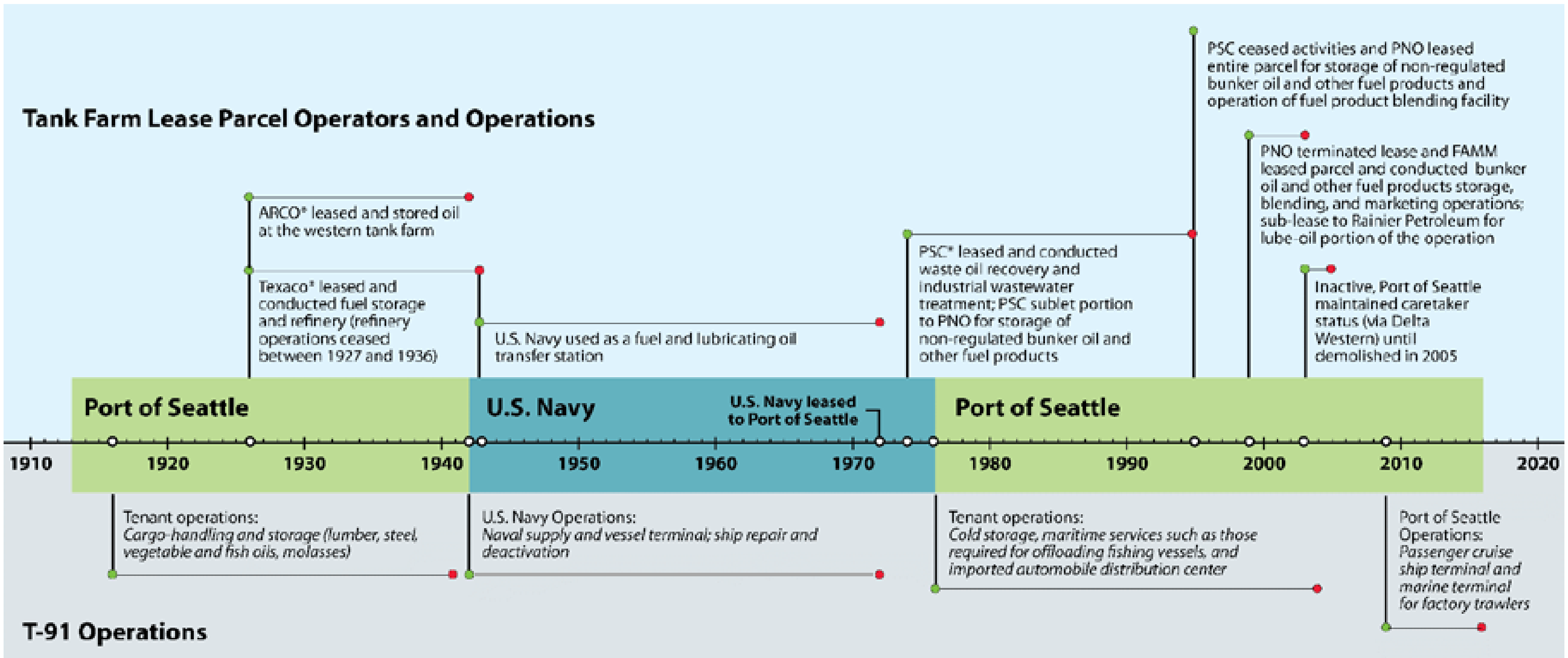
2 Background of Terminal 91

This section summarizes the development of and significant historical operations at T-91, Piers 90 and 91, and the surrounding properties, as well as cleanup operations that have occurred at the site.

The ownership of T-91 can be divided into three periods:

1. Initially, the Port owned T-91 from 1913 to 1942, although the extent of the Port-owned property was only a portion of the present-day T-91. During that time, upland areas were used by a variety of tenants for different purposes, including the storage of petroleum in tank farm storage areas.
2. The US Navy took over ownership of the site from 1942 to 1976, during which time it enlarged T-91 to encompass all of the property it includes today.
3. The US Navy transferred ownership of the site back to the Port in approximately 1976.

The timeline of site ownership and associated operations is provided in Figure 1. The following sections provide detailed discussions of the operations that occurred during each of these time periods, as well as information regarding potential contaminant pathways from these operations to the SLA of T-91.



Note: Texaco includes the Texas Company and the Olympic Calpet Refining Company. Philip Services Corporation (PSC) includes Chemical Processors Inc. (Chempro) and its successor, Burlington Environmental Inc. (BEI). ARCO includes Richfield Oil Company

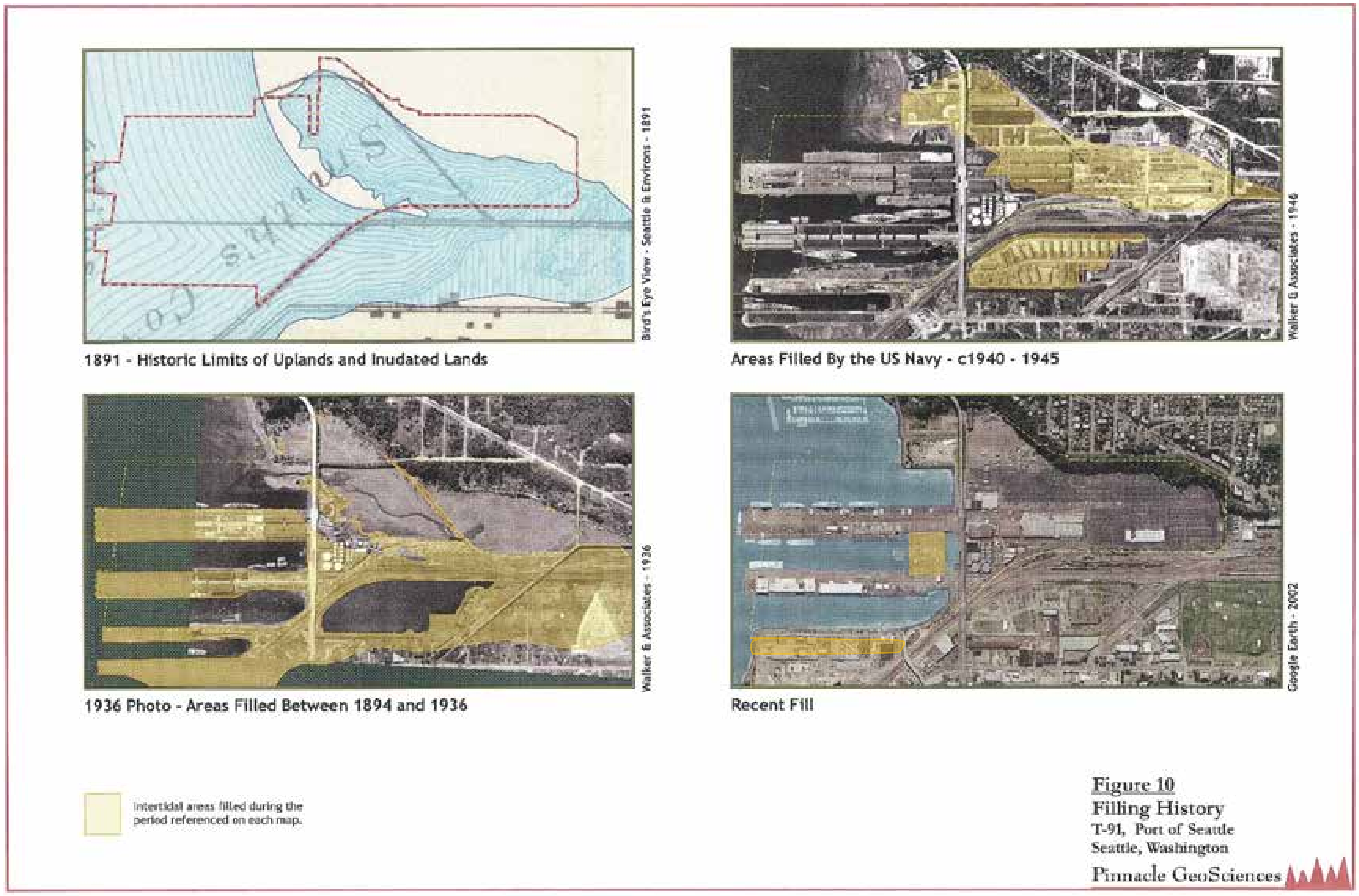
Figure 1. Timeline of T-91 ownership and operations

2.1 Initial Port of Seattle Ownership: 1913–1942

When settlers moved into Smith Cove in 1853, the area was comprised of non-navigable tide flats with areas of dry land near the entrance (Pinnacle 2006). In the late 1800s and early 1900s, prior to the Port's ownership of T-91, various companies began to establish operations in the area. The initial Garfield Street Viaduct (later Magnolia Bridge) was constructed in 1912 (Pinnacle 2006). Early owners of the future T-91 complex included various railroads, land development companies, and private individuals (Port of Seattle 2010). The Great Northern Railway developed the area by filling in portions of the tide flats between Magnolia Bluff and Queen Anne Hill through 1920 (Port of Seattle 2010).

In 1913, the Port acquired property at the south end of Smith Cove, and in 1913 and 1919, respectively, built Piers 90 and 91 in Smith Cove[4] (Pinnacle 2006). The areas filled between 1894 and 1936, including the areas where the piers were constructed, are shown in Figure 2.

[4] Piers 90 and 91 were originally known as Piers 40 and 41, respectively, until 1942; they will be referred to as Piers 90 and 91 throughout this report regardless of the date being referenced.



Adapted from: Pinnacle (2006)

Figure 2. T-91 filling T-91 filling history

Initially, Piers 90 and 91 were used for loading and unloading shipped lumber, steel, coal, and other materials (Pinnacle 2006). Two large underground concrete tanks (each with an 8,000-barrel capacity) were constructed within Pier 90 for vegetable oil storage (later these were used to store fish oil and molasses) (Pinnacle 2006; Port of Seattle 2010). Cargo moved to and from the pier by rail (Pinnacle 2006).

The area now known as the Tank Farm Lease Parcel (TFLP) comprises approximately 4 ac on the northern side of West Garfield Street. It was first developed in the early to mid-1920s (Port of Seattle 2010).[5] In 1919, the Kuhara Trading Company constructed four aboveground tanks (two 50,000-gal. tanks and two 250,000-gal. tanks) for the storage of vegetable oil in the area that later became the Tank Farm (Pinnacle 2006). Pipelines connecting the storage tanks to the dock were constructed at the same time. Proctor & Gamble Company also had a large aboveground tank that stored vegetable oil on adjacent property to the north of the T-91 tank farm (Pinnacle 2006). A pipeline ran from the tank to Pier 90 via Port property (Pinnacle 2006). This tank shows up in a 1931 figure (Pinnacle 2006).

Around the mid- to late 1920s, operations at the TFLP shifted from storing vegetable and fish oils to refining and storing petroleum. In 1925, the Olympic Calpet Refining Company (later acquired by Texaco) built and began operating an oil refinery at the TFLP. The oil refinery operations terminated sometime between 1927 and 1936, after which operations were limited to the storage and distribution of refined petroleum products (Pinnacle 2006).

A second aboveground tank farm was constructed in the late 1920s to the west of the TFLP. This western tank farm (known as Area of Concern 11, or AOC11, in remediation documents) was originally used for vegetable oil storage; it was later converted to petroleum oil storage under the operation of the Richfield Oil Company (presently ARCO) (Pinnacle 2006). By 1936, the western tank farm consisted of eight smaller tanks and one large tank (Pinnacle 2006). The US Navy demolished the western tank farm when it took possession of the site in 1942 (Port of Seattle 2010). The Texas Company continued to operate on the TFLP until 1943 as a tenant of the US Navy.

2.2 US Navy Ownership: 1942–1972

In 1942, the US Navy took over ownership (through condemnation) of most of T-91, as well as additional adjacent properties and tideland, and in 1944 purchased and consolidated the remaining portions (Pinnacle 2006). It immediately changed the names of the piers to Piers 90 and 91 (Pinnacle 2006). During World War II and into the early 1950s, the US Navy conducted extensive operations at the site, which was turned into an active naval station (USACE 2013). Vast numbers of personnel, troops,

[5] The 2012 AO notes that a tank farm was built on the TFLP circa 1926 (Ecology 2012a).

and materials came to the property, and a wide variety of activities took place on-site (Clay 1971; Pinnacle 2006).

The US Navy used the TFLP primarily as a fuel and lubricating oil transfer station and built up the surrounding TFAA to support active wartime naval operations. It constructed more than 100 buildings including warehouses and supply depots, vehicle and locomotive maintenance shops, administration buildings, a heating plant, barracks, and cold storage facilities (Clay 1971; Pinnacle 2006).

The US Navy also conducted extensive naval craft mooring, repair, and deactivation activities, including hull maintenance; sandblasting and painting; and electrical, plumbing, and mechanical repairs (Bureau of Ships 1947, 1950a, b; Clay 1971). Materials such as paints and thinners (containing metals and likely polychlorinated biphenyls [PCBs]), oils, caulking compounds (likely containing PCBs), and anti-corrosives were used in these processes at the piers, and stored in warehouses located in the TFAA and upland area (Bureau of Ships 1947, 1950a, b; Clay 1971; Kennedy/Jenks 1997).[6] Bilge water pumped from the ships (likely containing heavy oils, metals, PCBs, and solvents) was processed at the Tank Farm or dumped into the harbor, and ship repair activities took place both on land and at the piers (including the dry dock at Pier 90; Map 1)(Port of Seattle 1974).

Although there was a substantial reduction in activity after the conclusion of the Korean War, many operations at the piers and upland area continued during the next decade (Clay 1971). Both US Coast Guard and Military Sea Transportation Services ships moored at the US Navy berths; vessel deactivation and repair and bulk liquid storage and processing took place at the TFLP; and a wide variety of provisions and equipment were stored and shipped during the Vietnam War.

The US Navy never used T-91 as an ammunition resupply or disposal facility, and there are no records of live fire actions ever occurring at the site (USACE 2013). Some US Navy documents do refer to a bomb disposal area at T-91, but this area is not identified in any drawings (Pinnacle 2006). US Navy operations at T-91 ceased in 1969.

2.3 CURRENT PORT OF SEATTLE OWNERSHIP: 1976–PRESENT

The US Navy began leasing portions of T-91 back to the Port in 1972; in June 1976, the US Navy deeded approximately 200 ac to the Port (Pinnacle 2006; Port of Seattle 2010). The remainder of the property was acquired by the Army National Guard (24.75 ac) and the North West Center (7.62 ac), while the US Navy retained 12.37 ac known as the T-91 Annex (USACE 2013).

[6] PCBs were manufactured between 1929 and 1979 and were commonly found on ships in oil-based paints, caulking, oils, bushings, insulation, transformers, capacitors, adhesives, light ballasts, and switches, among other sources (EPA 2000).

2.3.1 Tank Farm Lease Parcel

From approximately 1974 to 1995, the TFLP was leased to Chemical Processors Inc. (Chempro) and its successor BEI, currently known and hereafter referred to as Philip Services Corporation (PSC) (Port of Seattle 2010). PSC used the TFLP for waste oil recovery and wastewater treatment. PSC obtained a Dangerous Waste Management Permit authorizing it to treat and store dangerous wastes at the TFLP. Waste streams historically managed by PSC included oil and coolant emulsions, industrial wastewater, and industrial waste sludge (Roth Consulting 2007). Due to the PSC facility's Dangerous Waste Management Permit, the entire T-91 facility became subject to federal corrective action requirements.

PSC also sublet a portion of the TFLP to PNO, which used the property to store non-regulated bunker oil and other fuel products (Roth Consulting 2007). PNO used aboveground and underground piping systems at the site to transfer bunker oil and fuels from the TFLP to the piers, where these materials were transferred to vessels. PNO operations at the site included blending and storing marine boiler fuel, diesel, and other petroleum products. Additionally, bilge and ballast waters were received, primarily from ships, and transferred to the TFLP via pipeline; other wastes and wastewater were received via tankers or in drums (Roth Consulting 2007).

PSC ceased waste treatment and storage activities at the TFLP in 1995, at which point PNO began to lease the entire TFLP (Roth Consulting 2007). PNO operated a bunker oil, lube oil, and fuel product storage and blending facility on-site until 1999, when it terminated its lease with the Port. At that time, the TFLP was leased to Fuel and Marine Marketing (FAMM), which subleased the lube oil portion of the operation to Rainier Petroleum (Roth Consulting 2007). FAMM terminated its lease in 2003, at which point the Tank Farm became inactive. Delta Western was the caretaker of the inactive property until the Tank Farm aboveground structures (excluding the tank bases) were demolished in 2005 (Roth Consulting 2007).

2.3.2 Areas outside of the Tank Farm Lease Parcel

Between 1976 and 1977, the Port had demolished and removed all of the transit sheds on Pier 90 (Port of Seattle 1973, 1977). The majority of the transit and storage shed buildings on Pier 91 were removed by the Port between 1983 and 1988, along with a portion of the preexisting rail lines (Port of Seattle 1983, 1988). In 1986, the Port used moderately contaminated dredge spoils from the Pier 32 area (Pinnacle 2006) to fill about 400 ft of the landward portion of the central slip between Piers 90 and 91 , creating the Short Fill area (Map 1) (PES et al. 2009). This effort led to a small impoundment now known as the Short Fill Impoundment. The Short Fill project was completed under a consent agreement with Ecology (Kennedy/Jenks 1997). Computer modeling and groundwater monitoring were conducted and when performance criteria under the consent agreement were satisfied, monitoring was discontinued (Kennedy/Jenks 1997).

Recent T-91 Port tenants have included City Ice Cold Storage (City Ice) and Distribution and Auto Services (DAS). City Ice constructed new buildings on T-91 in 1987 and 1991 and also leased four existing buildings; DAS built one new building, leased four existing buildings, and used large on-site parking areas to store and prepare new cars for delivery to dealers (Pinnacle 2006).

To prepare for the cruise ship terminal operations planned for 2009, a new terminal building and drop-off/pickup waiting area shelters were built in 2007 on Pier 91 to accommodate travelers. In 2007, the Port built a new warehouse building on the northern portion of Pier 91 that was occupied by Carnitech USA (now Marel) for the manufacturing of seafood processing equipment. In addition, the berth west of Pier 91 was dredged in 2008 (Anchor 2008). The east, center, and west slips adjacent to the piers were maintained to dredged depths of about -35 ft mean lower low water (MLLW), with the exceptions of the landward ends of the east and west slips (USACE 2013). In 2013, the Port determined that the cruise berth on the southeast side of Pier 91 required maintenance dredging to accommodate cruise ships that used the pier during the May through September cruise ship season.

Outside of the TFLP, the most significant tenant operations on T-91 have been those of DAS, City Ice, Marel, the fishing fleet, and the cruise ship terminal. The operations conducted by recent Port tenants at T-91 have included cold storage; maritime services, such as those required for offloading fishing vessels; procedures at an imported automobile distribution center (Pinnacle 2006); and cruise provisioning and passenger movement.

In 2009, the Port began using Pier 91 as a passenger cruise ship terminal for cruises to Alaska. The terminal had 223 cruise ship visits and more than 858,000 passengers in 2010, making it an important economic feature of Seattle and adding more than $400 million to the local economy (USACE 2013).

2.4 Pathways to the Submerged Lands Unit

Throughout the history of operations at T-91, stormwater discharges, fuel or water pipeline releases, and surface runoff from incidental spills have been potential pathways for contaminants to enter the SLA.

Additionally, as referenced above, the US Navy's wartime operations included extensive naval maintenance and deactivation activities. Vessels were repaired while on dry docks or moored at the piers, and waste water and materials from these efforts was dumped directly into the water or processed at upland facilities.

2.4.1 Terminal 91 stormwater outfalls

There are presently two main points of ongoing stormwater discharge to the T-91 SLA: a 42-in.-diameter outfall (referred to herein as Outfall A) located at the head of the slip west of Pier 91 that drains the T-91 upland area and areas north of T-91, and a 96-in.-diameter outfall (referred to herein as Outfall 68) located east of Pier 90 that drains an upland area north and east of T-91 (Map 2). Prior to the current Port ownership of T-91, there were other discharge points at the same or similar locations as the two existing outfalls.

2.4.1.1 Outfall A

Stormwater from approximately 100 ac of the T-91 upland area discharges into Outfall A. Other inputs to the conveyance system that discharges to this outfall include those from the Seattle Public Utilities (SPU) Halladay Decant Facility, the mixed-use property north of T-91 (acreage unknown), surrounding residential/commercial-use areas, and potentially some portion of the Burlington Northern Santa Fe (BNSF) Balmer Yard (acreage unknown). In 1956 during US Navy ownership, approximately 38 ac, which included BNSF railroad yard buildings, discharged at a location corresponding to Outfall A (Pinnacle 2013).

2.4.1.2 Outfall 68/CSO

Outfall 68 is a City-owned outfall that discharges to Elliott Bay east of Pier 90 (Ecology 2016a). The existing Outfall 68 was likely installed sometime after 1971, but the location was an active combined storm and sewer discharge point prior to 1971 (Clay 1971). The stormwater drainage basins that currently discharge at Outfall 68 do not include the T-91 upland area, but do include the following areas to the north and east of T-91: 60 ac of the BNSF Balmer Yard; a portion of the BNSF Interbay Yard (acreage unknown); and 343 ac of mixed-use land, including the 55-ac Interbay sanitary landfill, that drains to the connected City conveyance system.

The City's Interbay landfill, which was in use from 1911 until 1968, historically drained to a pond that then discharged to the stormwater conveyance system leading to Outfall 68. The landfill was a disposal site for "all sorts of material," including military waste (Seattle-King County Department of Public Health 1984).

Outfall 68 is also a controlled City combined sewer overflow (CSO) for two sub-basins that account for a total of 290 ac of mostly residential land.

2.4.1.3 Other outfalls/discharge points

At T-91, there appear to be numerous deck drains and active outfalls or discharge points that drain Piers 90 and 91 (Map 2). The majority of the presumed outfalls are located on the northern portions of the piers and adjacent to the Short Fill area, and discharge to the west and east of the piers. Three outfalls (two Port and one City) are located at the head of the berth to the east of Pier 90 (Map 2). In addition, there are four 12-in.-diameter City outfalls that discharge to the eastern shoreline of the berth east of Pier 91 (City of Seattle 2001a, b) (Map 2).[7]

---

[7] The associated catch basins and storm drain lines are located on the adjacent street (16th Avenue West).

Under Port ownership, stormwater discharges at T-91 have been regulated primarily under the Port's Phase I National Pollutant Discharge Elimination System (NPDES) municipal stormwater general permit (WAR044701) since 2007, as well as industrial stormwater permits held by various tenants (Aspect 2014; Port of Seattle 2016). Between 1995 and 2007, earlier versions of the municipal stormwater general permit were in place. Prior to 1995, stormwater and industrial discharges were not regulated.

2.4.2 Pipeline releases

During the history of T-91, petroleum and other materials have been transferred between ships at Piers 90 and 91 and the Tank Farms, typically via aboveground and belowground pipelines (Port of Seattle 2010).

Prior to environmental regulations enacted in the 1970s, there were no reporting requirements for environmental spills or releases of fuel materials. Therefore, the documented releases are all associated with operations that have occurred since the 1970s. While it is likely that spills and releases occurred prior to the 1970s, there is no supporting documentation.

In 1990, a break occurred in the PNO-operated Bunker C fuel line south of building T-38 on Pier 91 (Kennedy/Jenks 1997) (Map 3). In 1991, a break occurred in the PNO-operated Bunker C fuel line at the south end of Pier 91. In both cases, contaminated soil was remediated, and soils samples from the bottom and sidewalls of the excavation generally did not exceed MTCA Method A cleanup levels. In addition, another small break occurred in the PNO-operated pipeline in 1996 and impacted soil was removed.

Also in 1999, a pipeline operated by PNO was identified as the source of a subsurface release of bunker oil to the north of Pier 90 (Kennedy/Jenks 2011) (Map 3). An emergency spill response and subsequent remedial action were performed. The remedial action included excavation of affected soil; however, the presence of underground structures (e.g., vaults, pipeline anchors, duct banks, and utilities) prohibited the removal of some soil beneath these structures. In February 2011, soil and groundwater samples collected in this area showed no indication of petroleum hydrocarbon impacts.

In all cases, these documented pipeline releases were remediated, and no evidence of contamination in the SLA was documented.

2.4.2.2 Fuel spills

Fuel spills can occur when maritime vessels are docked at Piers 90 and 91. Spills that were the result of fuel transfers on Piers 90 and 91 may have released fuel products via direct discharge or surface water runoff. While it is likely that such spills occurred prior to the 1970s, there is no supporting documentation.

In 2007, approximately 93 gal. of intermediate fuel were released from a ship anchored about a 0.5 mi south of Smith Cove (Ecology 2008). A cleanup effort was conducted; however, prior to the cleanup, a sheen was evident on the pilings under Pier 91 (Ecology 2008). In 2011, 177 gal. of diesel fuel were spilled into Elliott Bay while a fishing vessel was taking on fuel at Pier 90 (Ecology 2013). A cleanup response was conducted and an oil spill boom had been placed around the vessel prior to fueling, which prevented the fuel from spreading beyond the immediate vicinity of the vessel (Ecology 2013).

2.4.2.3 Former US Navy overwater activities

The US Navy conducted extensive naval craft mooring, repair, and deactivation activities at T-91, including hull maintenance; sandblasting and painting; and electrical, plumbing, and mechanical repairs (Bureau of Ships 1947, 1950a, b; Clay 1971). Many of these activities were conducted while vessels were on the dry dock (Map 1) or moored at the piers, and some of the associated wastes (e.g., paint and sandblast waste) are likely to have entered Elliott Bay. Furthermore, bilge water that was not processed at the Tank Farm was dumped into the bay (Port of Seattle 1974).

The US Navy did not use T-91 as an ammunition resupply facility. However, during a routine underwater inspection in April 2010, the Port Police Department Dive Team encountered discarded military munitions (DMMs) in sediments around Piers 90 and 91 (USACE 2013). In 2010, US Navy Explosive Ordnance Disposal personnel responded to seven subsequent incidents of DMM discovery in the sediment. As a result, in December 2010, the US Army Corps of Engineers (USACE) initiated an RI for Piers 90 and 91 to characterize the nature and extent of DMM occurrence in the munitions response area (MRA). The MRA totals 86.7 ac, including 74.1 ac of marine open areas around Piers 90 and 91 and 12.6 ac of accessible water areas under the piers.

A series of fieldwork efforts, such as acoustic surveys and geophysical data collection, was undertaken in 2010, which led to a time-critical removal action (TCRA) in the MRA (USACE 2013). The TCRA occurred between January and March 2011 and included the removal of DMMs from the sediment surface of 25.2 ac of the seafloor underneath and surrounding Pier 91 (referred to as Survey Area 1). The RI recommended a focused FS for Study Area 1 based on the finding of a low explosive hazard (USACE 2013). No action was recommended for the remaining 61.5 ac of the MRA (USACE 2013). The USACE issued an agency review draft FS dated May 2016 that was circulated for limited review, but as of the date of this report, the USACE has not issued a subsequent draft or final version.

2.5 Upland Contamination, Fuel Releases, and Remediation

Through a series of AOs with Ecology, the Port has carried out investigations and cleanup actions for all known release sites located within the T-91 upland area. These investigations and cleanups were found not to have affected the SLA, but are summarized herein for context.

2.5.1 Tank Farm Affected Area

The TFAA (approximately 17 ac) includes the TFLP and areas where hazardous substances originating from TFLP operations have come to be located.

2.5.1.1 Sources of contamination

The tank farm and associated operations have resulted in contamination in the TFAA (Map 1) (Port of Seattle 2010). Historically, chemicals of concern at the site have included petroleum products, volatile and semivolatile organic compounds (including PAHs), metals, and PCBs (Roth Consulting 2007; Ecology 2010). Likely sources of these chemicals have included leaks of fuel and wastes from tanks and other equipment, and leaks during fuel and waste handling and transfer operations (Roth Consulting 2007). No releases were documented prior to 1971, although unreported historical releases from the tank farm and the former western tank farm in AOC 11 are suspected (Port of Seattle 2010). A number of documented releases have occurred at the tank farm, including two large releases of petroleum hydrocarbons in 1978 (420,000 gal. of Bunker C) and 1980 (up to 113,000 gal. of oil) (Port of Seattle 2010). In both cases, the release was contained by concrete dikes, and the oil and impacted soil were removed to the extent practicable. A number of smaller releases of petroleum products and/or oily water have been documented, ranging in size from several hundred to 20,000 gallons, but in all cases, cleanup was documented.

In addition to the releases at the TFLP, approximately 340 to 1,370 gal. of fuel were released at SWMU 30 in 1989. After a series of investigations in 1989 and 1990, it was confirmed that the release was the result of a pipeline failure. The pipeline was repaired and a product recovery system was installed and operated between 1991 and 1994. Passive product recovery (i.e., bailing) was conducted beginning in 1994, recovering a limited volume of product.

The *Final Remedial Investigation Summary Report* (Roth Consulting 2007) completed in 2007 found that a light non-aqueous phase liquid (LNAPL) plume was present beneath and in the immediate vicinity of the TFLP, but did not appear to be expanding. A groundwater seepage evaluation was performed downgradient of the TFLP, including areas along Piers 90 and 91 (Roth Consulting 2007). As part of this effort, compliance wells were installed upgradient of the areas of significant seepage along Piers 90 and 91. Very low concentrations of only a few chemicals have been detected in these wells (Roth Consulting 2007).

2.5.1.1 Cleanup activities

Cleanup activities at T-91 have been driven by the presence of the PSC dangerous waste treatment and storage facility at the Tank Farm. Operations at the Tank Farm commenced under EPA oversight, with PSC performing various investigation work focused on the Tank Farm. The Port became involved after Ecology assumed primary regulatory oversight responsibility under the 1998 AO. Under the 1998 and subsequent AOs, the Port investigated soil and groundwater contamination that had originated at the TFLP, and determined the extent of migration (Roth Consulting 2007). That extent is reflected by the defined TFAA, which does not include the SLA.

The remedial actions at the TFLP associated with the final CAP began in 2014 and were completed in 2015 (PES Environmental 2015). Compliance monitoring and operation & maintenance (O&M) activities began in August 2015. The cleanup actions for the TFLP included: (1) removal of pipelines and any remaining aboveground structures within the TFLP and cleaning and grouting of existing fuel lines outside the TFLP, (2) installation of the subsurface cutoff wall around the perimeter of the former tank farm, (3) installation of the enhanced LNAPL recovery system (4) installation of the asphalt cover, and (5) installation of a stormwater management system. The final cleanup action for SWMU 30 was implemented in late 2013 and early 2014. The two areas where LNAPL had been observed in SWMU 30 were excavated, backfilled with concrete fill, and covered with asphalt.

In August 2015, after completion of the remedial actions, compliance monitoring and O&M activities were initiated (PES Environmental 2015). These activities included asphalt paving inspections and maintenance, LNAPL monitoring, passive recovery from the LNAPL recovery trenches and monitoring wells, and compliance and natural attenuation monitoring (PES Environmental 2015).

2.5.2 Areas outside the Tank Farm Affected Area

Ecology compiled a list of all T-91 Discrete Units (i.e., all known hazardous substance release sites outside of the TFAA) in the 2010 AO (Ecology 2010). The Port's responsibility was to investigate the releases (e.g., soil or groundwater monitoring), determine whether further action was necessary to protect human health and the environment, implement such action where warranted (e.g., excavation of contaminated soil, removal of inactive fuel lines or tanks), and obtain Ecology's concurrence that no further action was required. The Port's progress in addressing the Discrete Units has been tracked under the 2010 and 2012 AOs; by mid-2016 all but one Discrete Unit had achieved no further action status. The one remaining Discrete Unit is located on the north central portion of the upland area and is associated with an old underground storage tank (UST) for fuel; some soil contamination remains underneath utility lines. Investigations of Discrete Units do not indicate that contamination migrated from any of the Discrete Units to the SLA.

2.6 OPERATIONS AT ADJACENT PROPERTIES

Adjacent properties located to the north and east of the T-91 site have fairly complex histories of ownership and operations. It is relevant to document operations at these properties and the operations' potential influences on the sediment in the SLA due to:

- The types of substances used, stored, treated, or transferred on these properties
- The properties' proximity to the SLA
- The direction of surface and groundwater flow (i.e., toward Elliott Bay) at the properties
- The stormwater conveyance system connections between these properties and the T-91 SLA

Apart from T-91, the primary facilities of interest in relation to the SLA are the two BNSF railway yards (Balmer and Interbay Yards), the SPU Halliday Decant Facility, the Mehrer Drywall Facility, and the abandoned Interbay landfill. These properties and their operations are described in the following subsections.

2.6.1 BNSF Balmer and Interbay Yards

BNSF has operated 80 ac of railyard adjacent to T-91 since the 1970s (Pinnacle 2013). The Balmer Yard, which is the larger of the two railyards, is located north and east of T-91 (Map 1). The Interbay Yard has been active since the late 1800s and is located northeast of the Balmer Yard. The railyards include rail tracks, various repair and maintenance shops, an equipment storage yard, a fueling facility, fuel storage facilities, and office buildings. BNSF repairs and fuels locomotives (and other vehicles and equipment) and conducts switching operations at these railyards.

Ecology listed the Interbay Yard as a hazardous site in 1991. Historical fueling and maintenance operations at the Balmer Yard resulted in total petroleum hydrocarbons (TPH) soil and groundwater contamination; as a result, the Balmer Yard became a Voluntary Cleanup Program (VCP) site in 2005 (Pinnacle 2013). In 2011, BNSF was found liable for Clean Water Act violations, which were initially filed by Puget Soundkeeper Alliance in 2009. BNSF had been discharging industrial stormwater without a NPDES industrial stormwater general permit (ISGP), and had failed to implement pollution control measures at the Balmer Yard.

Stormwater at the Interbay Yard has been collected for on-site treatment since approximately the mid-1970s. The private stormwater conveyance system at the Balmer Yard ultimately discharges to Smith Cove at Outfall 68. Documented releases occurred in 1993, 2001, and 2012. In 1993, 250–500 gal. of diesel fuel were released by a locomotive fuel tank rupture during derailment (Pinnacle 2013). In 2001, 2,000 gal. of diesel fuel were released (Pinnacle 2013). In 2012, a locomotive derailed and 3,000 gal. of diesel oil spilled onto the ground and entered a drainage ditch (Ecology 2012b). Some of the oil entered the public sewer system, so oil containment materials were placed outside of a stormwater outfall pipe in Smith Cove as a precaution (Ecology 2012b).

2.6.2 SPU Halladay Decant Facility

The Halladay Decant Facility, which is located just north of T-91 (Map 1), is owned by the City and operated by SPU (Pinnacle 2013).[8] It was established in the late 1970s or early 1980s for the temporary storage and dewatering of vactor truck wastes. Formerly, the City used a small portion of T-91 (without a lease) as part of the facility. Vactor wastes handled at the facility were primarily stormwater solids from City catch basins. Seattle City Light (SCL) also dumped vactor wastes from transformer vaults at the facility until the early to late 2000s. It is unknown when this practice began.

Historically, vactor wastes were held in an Ecology block storage cell so that water could be decanted from settled wastes (Pinnacle 2013). Until the late 1980s or early 1990s, the SPU Halladay Decant Facility discharged decanted wastewater and stormwater runoff to a wetland pond. The pond drained to the stormwater conveyance system at T-91 that ultimately discharges to Elliott Bay via Outfall A located in the west slip. Currently, vactor wastes are contained in a decant pit that connects to an oil/water separator and the City sanitary sewer system. Vactor solids are dried on-site prior to disposal.

While decant water has not been directly discharged to the stormwater conveyance system since the late 1980s or early 1990s, there is a more recent history of source control violations at the Halladay Decant Facility (Pinnacle 2013). Between 2008 and 2011, facility issues included uncovered, unbermed vactor solids that were exposed to stormwater runoff, and vactor solids that were leaching through containment walls into catch basins. The facility was closed in 2013–2014 in order to implement modifications to address these source control issues.

Data for wastewater and solids samples collected in recent years (between the early 1990s and 2015) showed elevated concentrations of metals (e.g., copper, lead, mercury, and zinc) and petroleum hydrocarbons (Pinnacle 2013). Vactor solids were also a potential ongoing source of contaminants to stormwater prior to the facility's closure and modification in 2013–2014.

Vactor wastes from SCL transformer vaults were formerly handled at the Halladay Decant Facility, a practice that was discontinued between 2003 and 2008 (Pinnacle 2013). There was concern from the King County Industrial Waste Program about the use of the facility for transformer vault waste because PCBs were known to be potentially present in transformer oil. In addition to vactor wastes, soil contamination at the SPU Halladay Decant Facility includes petroleum hydrocarbons and lead.

[8] The facility is predominantly located on property adjacent to the T-91 site boundary; however, the drying area of the facility is located within the T-91 site boundary (Pinnacle 2013).

2.6.3 Mehrer Drywall Facility

The Mehrer Drywall Facility, a drywall and woodworking machinery facility that has been in operation since at least 1995, is located north of T-91 on two properties; the southern of the two properties is located adjacent to the SPU Halladay Decant Facility (Map 1).

Stormwater runoff from the southern Mehrer Drywall Facility property discharges to the wetland pond west of the Halladay property. This pond then discharges to the T-91 conveyance system and eventually to Elliott Bay at the outfall located at the head of the slip at Pier 91 (Outfall A). The northern Mehrer Drywall Facility property (office area) is contaminated with gasoline, benzene, and xylenes (soil and groundwater) due to a 1998 release from the on-site UST (Pinnacle 2013).

2.6.4 Abandoned Interbay sanitary landfill

The Interbay Golf Course, located northeast of T-91, was originally the location of the 55-ac Interbay Sanitary Landfill (Map 1). The landfill operated from approximately 1911 to 1968 and included residential, industrial, and military wastes (Seattle-King County Department of Public Health 1984).

Historically, the landfill drained to a pond that then discharged to the stormwater conveyance system leading to Outfall 68. Studies conducted in 1977 showed evidence of high groundwater levels (within 7 to 10 ft of ground surface) in places at the site, creating the potential for leachate formation (Seattle-King County Department of Public Health 1984). Halogenated organics, priority pollutant metals, pesticides, and polycyclic aromatic hydrocarbons (PAHs) are suspected contaminants in groundwater and soil at the landfill (Ecology 2016c).

3 Sediment Investigations

Sediment investigations have been conducted in the vicinity of T-91 for the purposes of dredged material characterization, post-dredge characterization, and Elliott Bay monitoring programs. None of the investigations were designed to characterize the sediment throughout the SLA of T-91. Sediment dredging and regrading was conducted to maintain adequate depth to accommodate cruise ships. Sediment was dredged in the berth west of Pier 91 in 1991 and in late fall 2007/early winter 2008 (Map 4). The berth east of Pier 91 was regraded from February 6 through 8, 2016 (Map 4).

Sediment investigations at T-91 and in its vicinity were conducted from 1985 through 2016 (Table 3-1; Map 4). These sediment investigations are described in the following subsections. The results from these sediment investigations are summarized in Section 4.

Table 3-1. Summary of T-91 sediment investigations

Sampling Event	No. of Sample Locations and Type	Purpose	Chemical Group	Source
1985 Elliott Bay Toxic Action Program	5 surface grabs	subset of samples (northern end of the berth west of Pier 91 and east of Pier 90; south and southeast of Pier 90) collected for the Elliott Bay Toxic Action Program to identify degraded areas amenable to restoration and to protect recreational uses	metals, semivolatile organics, pesticides, total solids, TPH, and grain size	Tetra Tech (1986)
1991 pre-dredge characterization	3 cores (composites)	pre-dredge sediment characterization for dredge disposal related to deepening the berth west of Pier 91 in conjunction with construction of a concrete apron	metals, PCBs, semivolatile and volatile organics, pesticides, total solids, TOC, total sulfides, and grain size	Hart Crowser (1992)
1998 Ecology Urban Bays Monitoring Program	3 surface grabs	subset of samples (one location in berth east of Pier 90 and 2 locations southeast of Pier 90) collected for the Ecology Urban Bays Monitoring Program to evaluate sediment condition over time using chemistry, toxicity, and benthic community indices	metals, PCBs, semivolatile organics, pesticides, total solids, TOC, grain size, and TBT	Ecology (2016d)

Table 3-1. Summary of T-91 sediment investigations

Sampling Event	No. of Sample Locations and Type	Purpose	Chemical Group	Source
2006 pre-dredge characterization	2 cores (composites)	pre-dredge sediment characterization for dredge disposal (for deepening berth west of Pier 91)	metals, PCBs, semivolatile and volatile organics, pesticides, total solids, total volatile solids, TOC, total sulfides, grain size, and TBT	Anchor (2006)
2007 King County DNR monitoring	1 surface grab	post-remediation monitoring for the Denny Way/Lake Union CSO control project conducted by King County DNR	metals, PCBs, semivolatile organics, pesticides, total solids, TOC, total sulfides, and grain size	DNR (2009)
2007 Ecology Urban Bays Monitoring Program	2 surface grabs	subset of samples (1 location each in berths east and southeast of Pier 90) collected for the Ecology Urban Bays Monitoring Program to evaluate sediment condition over time using chemistry, toxicity, and benthic community indices	metals, PCBs, semivolatile organics, pesticides, total solids, TOC, grain size, TBT, and dioxins/furans[a]	Ecology (2016d)
2008 post-dredge characterization	3 surface grabs	post-dredge surface characterization in the berth west of Pier 91	metals, PCBs, semivolatile and volatile organics, pesticides, total solids, total volatile solids, TOC, total sulfides, grain size, and TBT (porewater)	Anchor (2008)
2009 PSAMP spatial/temporal monitoring project	1 surface grab	subset of samples collected for PSAMP spatial/temporal monitoring to determine the spatial extent of toxicity and chemical contamination in Puget Sound surface sediments over time	metals, PCBs, semivolatile organics, pesticides, total solids, TOC, and grain size	Ecology and PSAMP (2009)
2013 pre-dredge characterization	5 cores (1 dredge material composite, 5 individual locations for z-layer)[b]	pre-dredge sediment characterization for dredge disposal and z-layer assessment in the berth east of Pier 91	metals, PCBs, semivolatile organics, pesticides, total solids, total volatile solids, TOC, total sulfides, grain size, TBT, and dioxins/furans	Windward (2014b)

Table 3-1. Summary of T-91 sediment investigations

Sampling Event	No. of Sample Locations and Type	Purpose	Chemical Group	Source
2013 Ecology Urban Bays Monitoring Program	3 surface grabs	subset of samples (1 location in berth east of Pier 90 and 2 locations southeast of Pier 90) collected for the Ecology Urban Bays Monitoring Program to evaluate sediment condition over time using chemistry, toxicity, and benthic community indices	metals, semivolatile organics, pesticides, total solids, TOC, grains size, and pharmaceuticals	Ecology (2016d)
2014 sediment characterization	6 cores[c]	characterization to determine the lateral distribution of total PCBs in the vicinity of the sample with the highest PCB concentration in the z-layer sediment in the east berth of Pier 91	PCBs	Windward (2014a)
2015 pre-sediment regrading characterization	6 surface grabs	pre-sediment regrading characterization in the berth east of Pier 91	metals, PCBs, semivolatile organics, pesticides, total solids, total volatile solids, TOC, total sulfides, grain size, TBT, and dioxins/furans	Windward (2015)
2016 post-sediment regrading characterization	10 surface grabs	post-sediment regrading characterization in the berth east of Pier 91	metals, PCBs, semivolatile organics, pesticides, total solids, total volatile solids, TOC, total sulfides, grain size, TBT, and dioxins/furans	Windward (2016)

Note: Shaded cells indicate that samples do not represent existing sediment conditions because of subsequent sediment regrading, dredging, or more recent samples collected in the same location.

a Dioxin/furan data were retained from the 2007 sampling event to represent existing sediment conditions, because the 2013 samples collected at the same locations were not analyzed for dioxins/furans.

b One of the five cores represents current conditions.

c Four of the six cores represent current conditions; two cores were located in the area that was regraded in 2016.

CSO – combined sewer overflow
DNR – Department of Natural Resources
Ecology – Washington State Department of Ecology
PCB – polychlorinated biphenyl
PSAMP – Puget Sound Assessment and Monitoring Program
T-91 – Terminal 91
TBT – tributyltin
TOC – total organic carbon
TPH – total petroleum hydrocarbons

3.1 1985 ELLIOTT BAY TOXIC ACTION PROGRAM

Five sediment samples were collected on September 27 and 28 and October 4 and 5, 1985, as part of the Elliott Bay Toxic Action Program (Map 4). This program assessed the marine and estuarine ecosystems of Elliott Bay and the Lower Duwamish River to identify degraded areas amenable to restoration and to protect recreational uses (Tetra Tech 1986). The subset of sediment samples collected at T-91 was analyzed for metals, semivolatile organics, pesticides, TPH, and conventional variables (Table 3-1).

3.2 1991 PRE-DREDGE CHARACTERIZATION

Sediment dredging was proposed for the berth west of Pier 91 in conjunction with the construction of a concrete apron on the west side of Pier 91 (Hart Crowser 1992). Three sediment samples were collected on November 5, 1991 (Map 4). Sediment samples were analyzed for Dredged Material Management Program (DMMP) standard chemicals and conventional variables (Table 3-1). In addition, bioassay analyses were conducted, including the 10-day amphipod, 10-day juvenile polychaete, 5-day echinoderm larvae, and Microtox tests.

3.3 1998/2007/2013 ECOLOGY URBAN BAYS MONITORING PROGRAM

Sediment samples were collected at three locations at T-91 for the Ecology Urban Bays Monitoring Program (Map 4). Sediment was collected from three locations on June 16 and 17 and July 1, 1998; from two locations on June 18 and 20, 2007; and from three locations on June 4, 2013 (Ecology 2016d). The goal of the monitoring program was to evaluate sediment conditions over time using chemistry, toxicity, and benthic community indices. The two samples collected in 2007 were also analyzed for dioxins/furans, and the three samples collected in 2013 were analyzed for pharmaceutical chemicals (Table 3-1). Bioassay tests (10-day amphipod mortality and sea urchin fertilization) and benthic invertebrate community assessments were also conducted on the 1998, 2007, and 2013 sediment samples.

3.4 2006 PRE-DREDGE CHARACTERIZATION

Sediment in the berths west and east of Pier 91 was proposed for dredging in order to maintain adequate depth to accommodate calling cruise ships (Anchor 2006). Eleven core samples were collected on June 7 and 8, 1991. Two composite samples were created from five to six cores each to characterize the material to be dredged in the berth west of Pier 91 (Map 4).[9] Samples were not collected in the berth east of Pier 91 because the hard, rocky substrate refused penetration. Sediment samples were analyzed for standard DMMP chemicals, conventional variables, and butyltins (Table 3-1). In addition, bioassay analysis was conducted on one sample for which the reporting limits for dichlorodiphenyltrichloroethane (DDT) exceeded the screening-level criterion. The 10-day amphipod mortality test, the larval

[9] The centroid of the individual cores is shown in Map 4-1.

mortality/abnormality test, and the 20-day juvenile polychaete biomass test were used.

3.5 2007 King County DNR Monitoring

The King County Department of Natural Resources (DNR) collected one surface sediment sample on June 26, 2007, in connection with post-remediation monitoring for the Denny Way/Lake Union CSO control project (DNR 2009). The sediment sample was analyzed for metals, PCBs, semivolatile organics, pesticides, and conventional parameters (Table 3-1).

3.6 2008 Post-dredge Characterization

Dredging in the berth west of Pier 91 was conducted in late fall 2007/early winter 2008. Sediment sampling was conducted on May 7, 2008, to characterize the post-dredge sediment (Map 4) (Anchor 2008). Three surface sediment samples were collected and analyzed for DMMP standard chemicals, conventional variables, and TBT (porewater) (Table 3-1).

3.7 2009 PSAMP Spatial/Temporal Monitoring Project

One sediment sample was collected on June 3, 2009, as part of the Puget Sound Assessment and Monitoring Program (PSAMP) spatial/temporal monitoring project (Map 4) (Ecology and PSAMP 2009). The goal of the monitoring project is to determine the spatial extent of toxicity and chemical contamination in Puget Sound surface sediments over time. The sediment sample collected at T-91 was analyzed for metals, PCBs, semivolatile organics, pesticides, and conventional variables (Table 3-1).

3.8 2013 Pre-dredge Characterization

Sediment in the berth east of Pier 91 was proposed for dredging in order to maintain adequate depth to accommodate calling cruise ships. Five sediment cores were collected from September 3 through 5, 2013, to characterize the material to be dredged and the sediment to be exposed by dredging (i.e., z-layer) (Windward 2014b). From the five sediment cores collected, five z-layer samples (-37 to -39 ft MLLW) and one dredge material composite sample were created. These samples all were analyzed for DMMP standard chemicals, conventional variables, butyltins, and dioxins/furans (Table 3-1).

3.9 2014 Sediment Characterization

The September 2013 pre-dredge characterization indicated that the post-dredge sediment (i.e., z-layer) in the berth east of Pier 91 had elevated PCB concentrations (Windward 2014b). Six cores were collected in February 2014 to determine the lateral distribution of total PCBs in the vicinity of the sample with the highest PCB concentration and below the z-layer sediment (-37 to -39 ft MLLW) (Windward

2014a). Following the collection of the sediment cores, the cores were sectioned into 1-ft intervals, a subset of which was analyzed for total PCBs. The intervals selected for analysis represented the sediment below the previous z-layer sample whenever possible, or the deepest available core intervals.

3.10 2015 Pre-Sediment Regrading Characterization

Sediment regrading was proposed in a small section of the berth east of Pier 91 in order to maintain adequate depth to accommodate calling cruise ships. Six surface sediment samples were collected to characterize the proposed sediment relocation area, regrading area, and depositional areas associated with scour areas (Windward 2015). The sediment samples were analyzed for DMMP standard chemicals, conventional variables, butyltins, and dioxins/furans (Table 3-1).

3.11 2016 Post-sediment Regrading Characterization

The berth east of Pier 91 was regraded from February 6 through 8, 2016, in order to maintain adequate depth to accommodate calling cruise ships. Surface sediment samples were collected on April 12 and 13, 2016, to characterize the sediment after regrading (Windward 2016). Specifically, 10 sediment samples were collected from among the sediment relocation area (T91-16-SS11, T91-16-SS12, T91-16-SS13, and T91-16-SS14), regrading area (T91-16-SS7, T91-16-SS8, T91-16-SS9, and T91-16-SS10), and depositional areas (T91-16-SS15 and T91-16-SS16) that were sampled in 2015. The sediment samples were analyzed for DMMP standard chemicals, conventional variables, butyltins, and dioxins/furans (Table 3-1).

4 Existing Sediment Chemistry

As described in Section 3, sediment characterization data at T-91 have been limited to dredging/regrading or as part of regional monitoring activities. Samples collected in areas that have been subsequently regraded or dredged, or where more recent samples have been collected, are not considered to represent existing sediment conditions for the purposes of this report (Table 3-1).[10] The sediment sample locations that were determined to represent existing conditions at T-91 and its vicinity are shown on Map 5.[11] The sediment chemistry representing existing conditions for T-91 is limited consequently, site-wide trends cannot be inferred from these data.

Sections 4.1 through 4.3 provide a summary of locations with concentrations above Washington State Sediment Management Standards (SMS) for metals, PAHs, and PCBs for those samples representing existing conditions. For each chemical, the SMS standards include a sediment cleanup objective (SCO) and cleanup screening level (CSL) value. Sediment values at or below the SCO are predicted to have no adverse effects on the benthic community, and sediment values above the CSL are expected to have minor adverse effects on the benthic community (Ecology 2015). A summary of the existing dioxin/furan toxic equivalent (TEQ) sediment data is provided in Section 4.4. Sediment chemistry results for each sample representing existing conditions are provided in Appendix A.

4.1 Metals

Sediment locations with metals concentrations above SMS values are shown on Map 6. Arsenic, copper, mercury, and zinc were detected at concentrations above their respective CSL values (Table 4-1). The majority of the locations with CSL exceedances for these metals are located in the berth east of Pier 91. Mercury had the greatest number of exceedances, with concentrations above the CSL at eight locations (Table 5-1). Of the eight locations with mercury exceedances, six were located in the berth east of Pier 91, one was located south of Pier 90, and one was located in the berth east of Pier 90. Two of the locations (T91-16-SS10 and T91-16-SS12) with mercury exceedances in the berth east of Pier 91 also included other metals that exceeded either their respective SCO or CSL.

---

[10] Z-layer samples collected prior to dredging or regrading were not considered to represent existing surface conditions.

[11] Sample location names for 2016 post-sediment regrading characterization events were truncated to include only the last three to four digits on all maps with sediment sample locations.

Table 4-1. Exceedances of SMS standards for metals in surface sediment samples

Sampling Event	Sample Location	Sample Concentration	SCO	CSL
Arsenic (mg/kg dw)				
2016 post-sediment regrading characterization	T91-16-SS12	**111 J**	57	93
Mercury (mg/kg dw)				
1985 Elliott Bay Toxic Action Program	NS-07	**0.662 J**	0.41	0.59
2013 Ecology Urban Bays monitoring program	UWI2013-115	**0.816**		
2016 post-sediment regrading characterization	T91-16-SS8	**1.24**		
	T91-16-SS10	**0.99**		
	T91-16-SS11	**1.15**		
	T91-16-SS12	**1.74**		
	T91-16-SS13	**1.16**		
	T91-16-SS14	**0.64**		
Copper (mg/kg dw)				
2016 post-sediment regrading characterization	T91-16-SS10	**462 J**	390	390
Lead (mg/kg dw)				
2016 post-sediment regrading characterization	T91-16-SS10	514 J	450	530
Zinc (mg/kg dw)				
2016 post-sediment regrading characterization	T91-16-SS10	**633**	410	960

Note: Concentrations in **bold** exceed both the SCO and CSL. Only samples representing existing conditions are included in this table (i.e., sample locations in areas that have been regraded or dredged after sample collection or where more recent samples have been collected are not included).

CSL – cleanup screening level
dw – dry weight
Ecology – Washington State Department of Ecology
J – estimated concentration
SCO – sediment cleanup objective
SMS – Washington State Sediment Management Standards

4.2 PAHs

Sediment locations with PAH concentrations above SMS values are shown on Map 7. The SCO and CSL standards for PAHs are in units normalized to the organic carbon (OC) content in the sediment sample (mg/kg OC). OC normalization is not considered to be appropriate for total organic carbon (TOC) concentrations ≤ 0.5 or ≥ 4.0%. In such cases, dry weight chemical concentrations were compared with the lowest apparent effects threshold (LAET), which is functionally equivalent to the

SCO, or the second lowest apparent effects threshold (2LAET), which is functionally equivalent to the CSL.

Fourteen sediment sample locations had detected PAH concentrations above SMS values; these concentrations included 17 PAHs (individual PAHs and PAH sums) (Table 4-2). Four locations had detected PAH concentrations above the CSL. Of these four locations, three (T91-16-SS8, T91-16-SS12, and T91-16-SS13) were in the berth east of Pier 91 and one (NS-07) was south of Pier 90. Samples located in the berth east of Pier 91 had multiple PAHs CSL exceedances , while the location south of Pier 90 had only one PAH CSL exceedance (dibenzo[a,h]anthracene). Sample location T91-16-SS8 had 8 CSL exceedances, T91-16-SS12 had 10 CSL exceedances, and T91-16-SS13 had 13 CSL exceedances.

Table 4-2. Exceedances of SMS standards for PAHs in surface sediment samples

Sampling Event	Sample Location	Sample Concentration	SCO/LAET	CSL/2LAET
Acenaphthene (mg/kg OC)				
1985 Elliott Bay Toxic Action Program	NS-06	**130 U**	16	57
	NS-08	33		
2016 post-sediment regrading characterization	T91-16-SS8	31		
	T91-16-SS10	35		
Acenaphthylene (mg/kg OC)				
1985 Elliott Bay Toxic Action Program	NS-06	**140 U**	66	66
Anthracene (mg/kg OC)				
2016 post-sediment regrading characterization	T91-16-SS13	**930 J**	220	1,200
Anthracene (µg/kg dw)				
2016 post-sediment regrading characterization	T91-16-SS12	**1,200 J**	960	960
Benzo(a)anthracene (mg/kg OC)				
1985 Elliott Bay Toxic Action Program	NS-07	150 J	110	270
2016 post-sediment regrading characterization	T91-16-SS8	**310**		
	T91-16-SS13	**2,200**		
Benzo(a)anthracene (µg/kg dw)				
2016 post-sediment regrading characterization	T91-16-SS12	**2,400**	1,300	1,600

Table 4-2. Exceedances of SMS standards for PAHs in surface sediment samples

Sampling Event	Sample Location	Sample Concentration	SCO/LAET	CSL/2LAET
Benzo(a)pyrene (mg/kg OC)				
1985 Elliott Bay Toxic Action Program	NS-07	110 J	99	210
2013 Ecology Urban Bays monitoring program	UWI2013-115	102		
2016 post-sediment regrading characterization	T91-16-SS8	**260 J**		
	T91-16-SS10	170 J		
	T91-16-SS11	120 J		
	T91-16-SS13	**1,900 J**		
	T91-16-SS14	110 J		
	T91-16-SS15	130 J		
	T91-16-SS16	110 J		
Benzo(a)pyrene (µg/kg dw)				
2016 post-sediment regrading characterization	T91-16-SS12	**4,000 J**	1,600	1,600
Benzo(g,h,i)perylene (mg/kg OC)				
1985 Elliott Bay Toxic Action Program	NS-06	38 U	31	78
	NS-07	75 J		
	NS-08	71 J		
2013 Ecology Urban Bays monitoring program	UWI2013-115	51.6		
	UWI2013-180	33.7		
2016 post-sediment regrading characterization	T91-16-SS8	**98**		
	T91-16-SS9	34		
	T91-16-SS10	71		
	T91-16-SS13	**830**		
	T91-16-SS14	40		
	T91-16-SS15	35		
	T91-16-SS16	36		
Benzo(g,h,i)perylene (µg/kg dw)				
2016 post-sediment regrading characterization	T91-16-SS12	**1,300**	670	720

Table 4-2. Exceedances of SMS standards for PAHs in surface sediment samples

Sampling Event	Sample Location	Sample Concentration	SCO/LAET	CSL/2LAET
Total benzofluoranthenes (mg/kg OC)				
1985 Elliott Bay Toxic Action Program	NS-07	250 J	230	450
2016 post-sediment regrading characterization	T91-16-SS8	670		
	T91-16-SS10	350		
	T91-16-SS11	260		
	T91-16-SS13	**3,600**		
	T91-16-SS15	250		
	T91-16-SS16	240		
Total benzofluoranthenes (µg/kg dw)				
2016 Post-sediment regrading characterization	T91-16-SS12	**8,600**	3,200	3,600
Chrysene (mg/kg OC)				
1985 Elliott Bay Toxic Action Program	NS-07	150 J	110	460
	NS-08	160		
2016 post-sediment regrading characterization	T91-16-SS8	**590**		
	T91-16-SS10	170		
	T91-16-SS11	150		
	T91-16-SS13	**3,900**		
	T91-16-SS15	120		
Chrysene (µg/kg dw)				
2016 post-sediment regrading characterization	T91-16-SS12	**4,400**	1,400	2,800
Dibenzo(a,h)anthracene (mg/kg OC)				
1985 Elliott Bay Toxic Action Program	NS-06	63 U	12	33
	NS-07	**42 J**		
	NS-08	25 J		
2016 post-sediment regrading characterization	T91-16-SS8	**42**		
	T91-16-SS9	13		
	T91-16-SS10	27		
	T91-16-SS13	**280**		
	T91-16-SS14	16		
	T91-16-SS15	15		
	T91-16-SS16	15		
Dibenzo(a,h)anthracene (µg/kg dw)				
2016 post-sediment regrading characterization	T91-16-SS12	**520**	230	230

Table 4-2. Exceedances of SMS standards for PAHs in surface sediment samples

Sampling Event	Sample Location	Sample Concentration	SCO/LAET	CSL/2LAET
Dibenzofuran (mg/kg OC)				
1985 Elliott Bay Toxic Action Program	NS-06	**83 U**	15	58
	NS-08	17 J		
2016 post-sediment regrading characterization	T91-16-SS10	26		
	T91-16-SS13	21		
Fluoranthene (mg/kg OC)				
1985 Elliott Bay Toxic Action Program	NS-07	530 J	160	1,200
	NS-08	170		
2016 post-sediment regrading characterization	T91-16-SS8	**1,400**		
	T91-16-SS10	180		
	T91-16-SS11	250		
	T91-16-SS13	**2,600**		
Fluoranthene (µg/kg dw)				
2016 post-sediment regrading characterization	T91-16-SS12	**4,400**	1,700	2,500
Fluorene (mg/kg OC)				
1985 Elliott Bay Toxic Action Program	NS-06	**130 U**	23	79
	NS-08	32 J		
2016 post-sediment regrading characterization	T91-16-SS10	35		
	T91-16-SS13	**94**		
Indeno(1,2,3-cd)pyrene (mg/kg OC)				
1985 Elliott Bay Toxic Action Program	NS-06	42 U	34	88
	NS-07	**100 J**		
	NS-08	87 J		
2013 Ecology Urban Bays monitoring program	UWI2013-115	46		
2016 post-sediment regrading characterization	T91-16-SS8	**93**		
	T91-16-SS10	64		
	T91-16-SS13	**770**		
	T91-16-SS14	37		
	T91-16-SS15	36		
	T91-16-SS16	37		
Indeno(1,2,3-cd)pyrene (µg/kg dw)				
2016 post-sediment regrading characterization	T91-16-SS12	**1,300**	600	690

Table 4-2. Exceedances of SMS standards for PAHs in surface sediment samples

Sampling Event	Sample Location	Sample Concentration	SCO/LAET	CSL/2LAET
Naphthalene (mg/kg OC)				
1985 Elliott Bay Toxic Action Program	NS-06	**560 U**	99	170
Phenanthrene (mg/kg OC)				
1985 Elliott Bay Toxic Action Program	NS-08	110	100	480
2016 post-sediment regrading characterization	T91-16-SS8	260		
	T91-16-SS10	120		
	T91-16-SS13	420		
Pyrene (mg/kg OC)				
2016 post-sediment regrading characterization	T91-16-SS8	**1,700**	1,000	1,400
	T91-16-SS13	**3,000**		
Pyrene (µg/kg dw)				
2016 post-sediment regrading characterization	T91-16-SS12	**18,000**	600	690
Total HPAHs (mg/kg OC)				
1985 Elliott Bay Toxic Action Program	NS-07	1,800 J	960	5,300
2016 post-sediment regrading characterization	T91-16-SS8	5,170 J		
	T91-16-SS10	1,600 J		
	T91-16-SS11	1,700 J		
	T91-16-SS13	**19,100 J**		
	T91-16-SS14	1,100 J		
	T91-16-SS15	1,240 J		
Total HPAHs (µg/kg dw)				
2016 post-sediment regrading characterization	T91-16-SS12	**45,000 J**	12,000	17,000
Total LPAHs (mg/kg OC)				
2016 post-sediment regrading characterization	T91-16-SS8	481 J	370	780
	T91-16-SS13	**1,540 J**		

Note: Concentrations in **bold** exceed both the SCO/LAET and CSL/2LAET. Only samples representing existing conditions are included (i.e., sample locations in areas that have been regraded or dredged after sample collection or where more recent samples have been collected are not included).

CSL – cleanup screening level
dw – dry weight
Ecology – Washington State Department of Ecology
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
LAET – lowest apparent effects threshold
2LAET – second lowest apparent effects threshold
J – estimated concentration
JN – estimated concentration with tentative identification
LPAH – low-molecular-weight polycyclic aromatic hydrocarbon
OC – organic carbon
PAH – polycyclic aromatic hydrocarbon
SCO – sediment cleanup objective
SMS – Washington State Sediment Management Standards
U – not detected at given concentration

4.3 PCBs

Sediment locations with total PCB concentrations (as the sum of PCB Aroclors) above SMS values are shown on Map 8. The sediment quality standards (SQS) and CSL standards for PCBs are in units normalized to the OC content in the sediment sample (mg/kg OC). Dry weight chemical concentrations were compared with the LAET (functionally equivalent to the SQS) or 2LAET (functionally equivalent to the CSL) when TOC concentrations were ≤ 0.5 or ≥ 4.0%.

Ten locations had total PCB concentrations in surface sediment that exceeded the SCO/LAET; no locations had PCB concentrations in surface sediment that exceeded the CSL/2LAET (Table 4-3). Of the 10 locations with PCB concentrations greater than the SCO/LAET, nine were located in the berth east of Pier 91 and one was located southeast of Pier 90 (Map 8).

Table 4-3. Exceedances of SMS standards for PCBs in surface sediment samples

Sampling Event	Sample Location	Sample Concentration	SCO/LAET	CSL/2LAET
Total PCB Arcolors (mg/kg OC) – zero DL				
2013 Ecology Urban Bays monitoring program	UWI2013-179	12.1	12	65
2016 post-sediment regrading characterization	T91-16-SS7	14		
	T91-16-SS8	35.7 J		
	T91-16-SS10	24 J		
	T91-16-SS11	24 JN		
	T91-16-SS13	24 J		
	T91-16-SS14	22		
	T91-16-SS15	17		
	T91-16-SS16	28 JN		
Total PCB Aroclors (µg/kg dw) – zero DL				
2016 post-sediment regrading characterization	T91-16-SS12	570 JN	130	1,000

Note: Only samples representing existing conditions are included (i.e., sample locations in areas that have been regraded or dredged after sample collection or where more recent samples have been collected are not included).

CSL – cleanup screening level
dw – dry weight
DL – detection limit
Ecology – Washington State Department of Ecology
LAET – lowest apparent effects threshold
2LAET – second lowest apparent effects threshold
J – estimated concentration
JN – estimated concentration with tentative identification
OC – organic carbon
PCB – polychlorinated biphenyl
SCO – sediment cleanup objective
SMS – Washington State Sediment Management Standards

The highest total PCB concentration (47,000 µg/kg dry weight [dw]) was found in a z-layer sample (T91-13-06) collected in 2013 in the berth east of Pier 91 at a depth of -37 to -39 ft MLLW (Map 8). Samples collected at locations in the vicinity of the highest total PCB concentration had detected concentrations ranging from 47 to 10,100 µg/kg dw. Total PCB concentrations decreased with depth at each sample location for which multiple depth increments were sampled (Table 4-4).

Table 4-4. Subsurface sediment PCB concentrations

Sampling Event	Sample Location	Depth Interval (ft MLLW)	Total PCBs (µg/kg dw)
2013 Pre-dredge characterization	T91-13-06	-37 to -39	47,000
2014 Spatial characterization	T91-14-06	-35 to -36	9,100
		-36 to -37	4,600
	T91-14-07	-34.5 to -35.5	10,100
		-35.5 to -36.5	6,200
		-36.5 to -37	2,600
	T91-14-08	-40 to -41	1,050
		-41 to -42	47
		-42 to -43	18 U
	T91-14-09	-41 to -42	910

Note: Only samples representing existing conditions are included (i.e., sample locations in areas that have been regraded or dredged after sample collection or where more recent samples have been collected are not included).

dw – dry weight
PCB – polychlorinated biphenyl
MLLW – mean lower low water

4.4 Dioxin/Furan

Dioxin/furan TEQs are shown in Map 9 and provided in Table 4-5.[12] TEQs ranged from 2.68 to 50.0 ng/kg dw. Five locations in the southern end of the berth east of Pier 91 and one location in the berth east of Pier 90 had sediment dioxin/furan TEQs that were greater than 25 ng/kg dw. The sample (T91-16-SS8) with the highest TEQ (50.0 ng/kg dw) was located adjacent to Pier 91. There are no SMS standards for dioxin/furan TEQ. However, a dioxin/furan TEQ value of 4 ng/kg has been identified as a natural background value in the most recent Ecology guidance (Ecology 2015). All of the T-91 sediment dioxin/furan TEQ values are above 4 ng/kg.

[12] For samples with multiple results at a given location, the map shows the higher of the two results.

Table 4-5. Dioxin/furan TEQs in surface sediment samples

Sampling Event	Sample Location	Sample Concentration (ng/kg dw)
Dioxin/furan TEQ - mammal (half DL)		
2007 Ecology Urban Bays monitoring program	UWI2013-115/EB-115 (0-2 cm)[a]	4.47
	UWI2013-115/EB-115 (0-10 cm)[a]	26.6
	UWI2013-180/EB-180 (0-2 cm)[b]	6.45
	UWI2013-180/EB-180 (0-10 cm)[b]	4.52
2016 post-sediment regrading characterization	T91-16-SS7	2.68 J
	T91-16-SS8	50.0 J
	T91-16-SS9	8.43 J
	T91-16-SS10	34.9 J
	T91-16-SS11	28.6 J
	T91-16-SS12	27.1 J
	T91-16-SS13	13.9 J
	T91-16-SS14	26.1 J
	T91-16-SS15	15.3 J
	T91-16-SS16	4.86 J

Note: Only samples representing existing conditions are included (i.e., sample locations in areas that have been regraded or dredged after sample collection or where more recent samples have been collected are not included).

[a] Sample locations EB-115 and UWI2013-115 represent the same sampling location, with sediments collected in 2007 and 2013, respectively. Chemistry results from the 2013 samples were retained to represent current conditions, with the exception of the dioxin/furan data. Dioxin/furan data were retained from the 2007 samples to represent existing sediment conditions because the 2013 samples were not analyzed for dioxin/furans.

[b] Sample locations EB-180 and UWI2013-180 represent the same sampling location, with sediments collected in 2007 and 2013, respectively. Chemistry results from the 2013 samples were retained to represent current conditions, with the exception of the dioxin/furan data. Dioxin/furan data were retained from the 2007 samples to represent existing sediment conditions because the 2013 samples were not analyzed for dioxin/furans.

dw – dry weight
DL – detection limit
J – estimated concentration
TEQ – toxic equivalent

5 Conclusion

The upland portions of T-91 have a long history of industrial uses. The Port owned the property from 1913 to 1942, during which time the TFLP was developed; the facility was used initially for the storage of vegetable and fish oils, then ultimately for the storage of petroleum. The US Navy took ownership of T-91 from 1942 to 1972, converting the property into an active naval station with a wide range of activities including vessel fueling, vessel repair (including sandblasting and painting), vessel maintenance, and vessel deactivation. The TFLP was also used for fuel and lubricating oil storage during this time period. Finally, the Port reacquired the property from the US Navy in 1976. Since then, Port tenants have conducted a wide range of operations at T-91. The TFLP was leased to PSC, the operations of which included waste oil recovery and wastewater treatment.

There have been extensive investigations and remediation activities conducted in the T-91 upland area, including the TFAA and the Discrete Units. By 2015, the Port had completed the active remedial work for the TFAA; in 2016, Ecology concluded that all but one of the Discrete Units had been adequately addressed. Throughout the RI and remediation work, extensive soil and groundwater sampling was conducted. There was no evidence that contamination in the upland area had been transported to the SLA via groundwater.

The pathways most likely to have impacted the SLA are stormwater discharge from T-91 storm drains and the municipal outfalls located in the vicinity of T-91, and the release of contaminants associated with overwater activities conducted by the US Navy and PSC. Overwater activities, including vessel fueling and maintenance, were conducted by the U S Navy throughout its ownership. The presence of DMMs in T-91 sediment due to US Navy operations has been documented (USACE 2013).

The sediment chemistry available for T-91 submerged lands area is limited. The available surface sediment data have exceedances of SMS criteria for contaminants including PCBs, PAHs, and metals.

6 References

Anchor. 2006. Sediment characterization report, Port of Seattle Terminal 91. Anchor Environmental, LLC, Seattle, WA.

Anchor. 2008. Chemical analytical results for post-dredge surface grab samples at Port of Seattle Pier 91. Anchor Environmental, LLC, Seattle, WA.

Aspect. 2014. Seaport division vicinity map (north extent). Aspect Consulting.

Bureau of Ships. 1947. Departure report (voyage repairs) USS Moanahonga. Bureau of Ships.

Bureau of Ships. 1950a. Departure report (voyage repairs) USS YBB 22. Bureau of Ships.

Bureau of Ships. 1950b. Departure report (voyage repairs) USS YO 125. Bureau of Ships.

City of Seattle. 2001a. City of Seattle side sewer Card No. 2653-1. City of Seattle.

City of Seattle. 2001b. City of Seattle side sewer Card No. 2653-1A. City of Seattle.

Clay RJ. 1971. Naval Supply Center, Puget Sound Seattle Division (Pier 90-91), Washington, N-Wash-782A. US General Services Administration, Region 10, Auburn, WA.

DNR KC. 2009. Denny Way CSO and Elliott West CSO treatment facility, post-operation monitoring, Year 4. Denny Way SCO Areas A and B nearshore sediment remediation project, post-construction sediment monitoring, Year 1. Areas C, D, and E monitored natural redovery, Year 6. Sampling and analysis plan. King County Department of Natural Resources and Parks, Seattle, WA.

Ecology. 1998. Agreed Order No. DE 98HW-N108. Washington State Department of Ecology.

Ecology. 2008. *Songa Hua* Elliott Bay oil spill [online]. Washington State Department of Ecology, Seattle, WA. Updated May 12, 2008. Available from: http://www.ecy.wa.gov/programs/spills/incidents/songahua/songhua_main.html.

Ecology. 2010. Agreed Order No. DE 7321. Washington State Department of Ecology.

Ecology. 2012a. Agreed Order No. DE8938. Washington State Department of Ecology.

Ecology. 2012b. BNSF Emerson Street derailment [online]. Washington State Department of Ecology, Seattle, WA. Updated February 23, 2012. Available from: http://www.ecy.wa.gov/programs/spills/incidents/bnsf-emersonstderailment/bnsf-emersonstderailment.html.

Ecology. 2013. Fishing vessel owner fined for Seattle oil spill [online]. Washington State Department of Ecology. Updated May 1, 2013. Available from: http://www.ecy.wa.gov/news/2013/117.html.

Ecology. 2015. Draft sediment cleanup users manual II. Guidance for implementing the Cleanup Provisions of the Sediment Management Standards, Chapter 173-204 WAC. March 2015. Pub. no. 12-09-057. Toxics Cleanup Program, Washington State Department of Ecology, Olympia, WA.

Ecology. 2016a. Fact sheet for NPDES permit WA0031682. City of Seattle's combined sewer system. Washington State Department of Ecology.

Ecology. 2016b. First amendment to Agreed Order No. DE8938. Washington State Department of Ecology.

Ecology. 2016c. Interbay Landfill cleanup site details. Washington State Department of Ecology.

Ecology. 2016d. Urban bays monitoring 2013: sediment quality in Elliott Bay, Seattle WA. Washington State Department of Ecology, Olympia, WA.

Ecology, PSAMP. 2009. Quality assurance project plan. The Puget Sound assessment and monitoring program: sediment monitoring component. Publication no. 09-03-121. Washington State Department of Ecology and Puget Sound Assessment and Monitoring Program.

EPA. 1994. Port of Seattle/Burlington Environmental, Inc. Terminal 91 facility. Final resource conservation and recovery act facility assessment. US Environmental Protection Agency.

EPA. 2000. A guide for ship scrappers. Tips for regulatory compliance. EPA 315-B-00-001. US Environmental Protection Agency.

Hart Crowser. 1992. Sediment characterization report. Terminal 91 Apron Development Project. Seattle, Washington. Prepared for Port of Seattle. Hart Crowser, Seattle, WA.

Kennedy/Jenks. 1997. Terminal 91 baseline report. Kennedy/Jenks Consultants, Federal Way, WA.

Kennedy/Jenks. 2011. Investigation summary report, Piers 90 and 91. Kennedy/Jenks Consultants, Federal Way, WA.

PES, Roth, Pioneer. 2009. Final draft feasibility study report, Terminal 91 site. PES Environmental, Inc., Roth Consulting, and Pioneer Technologies Corporation, Seattle, WA.

PES Environmental. 2015. Construction report, Terminal 91 tank farm affected area, cleanup action, Seattle, Washington. PES Environmental, Inc., Seattle, WA.

Pinnacle. 2006. Historical research overview EPA Brownfields study. North Bay at Terminal 91, Seattle, Washington. Pinnacle Geosciences, Inc.

Pinnacle. 2013. Site history, northern end of parcel numbers 2325039046, 7666201146, 7666201516, 2325039018, and included vacated street right of way, Seattle, Washington, for Port of Seattle. Pinnacle Geosciences, Inc.

Port of Seattle. 1973. Port of Seattle marine facilities located on Elliott Bay and the Duwamish River. Port of Seattle Engineering Department, Seattle, WA.

Port of Seattle. 1974. Recycling oil at Pier 91. Port of Seattle, Seattle, WA.

Port of Seattle. 1977. Port of Seattle marine facilities located on Elliott Bay and the Duwamish Waterway. Port of Seattle Engineering Department, Seattle, WA.

Port of Seattle. 1983. Port of Seattle marine facilities - 1983. Port of Seattle Engineering Department, Seattle, WA.

Port of Seattle. 1988. Port of Seattle marine facilities. Port of Seattle Engineering Department, Seattle, WA.

Port of Seattle. 2010. Final cleanup action plan, Port of Seattle Terminal 91 site, Seattle, Washington. Port of Seattle, Seattle, WA.

Port of Seattle. 2016. Seaport's stormwater program [online]. Port of Seattle, Seattle, WA. Available from: https://www.portseattle.org/Environmental/Water-Wetlands-Wildlife/Stormwater/Pages/Seaport-Stormwater.aspx.

Roth Consulting. 2007. Final remedial investigation summary report, Terminal 91 tank farm site. Roth Consulting.

Seattle-King County Department of Public Health. 1984. Abandoned landfill study in the City of Seattle. Seattle-King County Department of Public Health, Seattle, WA.

Tetra Tech. 1986. Elliott Bay toxics action program. Initial data summaries and problem identification. Puget Sound Estuary Program. Tetra Tech, Inc.

USACE. 2013. Former Seattle Naval supply depot, Piers 91 and 91 - Port of Seattle. Formerly used defense site #F10WA012501. Remedial investigation, draft final report. US Army Corps of Engineers, Omaha Military Munitions Design Center, Omaha, NE.

Windward. 2014a. Sediment characterization data for T-91. Windward Environmental LLC, Seattle, WA.

Windward. 2014b. T-91 maintenance dredging. Pre-dredge characterization results. Windward Environmental LLC, Seattle, WA.

Windward. 2015. T-91 maintenance dredging. Sediment characterization results. Windward Environmental LLC, Seattle, WA.

Windward. 2016. T-91 maintenance dredging. Post-sediment regrading. Sediment characterization results. Windward Environmental LLC, Seattle, WA.