2022 Dickman Mill Sediment Investigation
Tacoma, Washington

Draft Report

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LIST OF ACRONYMS AND ABBREVIATIONS

AET	Apparent Effect Threshold
ARI	Analytical Resources, Inc.
aRPD	apparent redox potential discontinuity
bgs	below ground surface
bml	below mudline
BMP	Best Management Practice
CAB	cellulose acetate butyrate
COC	chemical of concern
CRM	Certified Reference Material
CSL	Cleanup Screening Level
CSM	Conceptual Site Model
DCA	disproportionate cost analysis
DGPS	differential Global Positioning System
DNR	Washington State Department of Natural Resources
DO	dissolved oxygen
DQO	data quality objective
DW	dry weight
DUP	duplicate
Ecology	Washington Department of Ecology
EDL	estimated detection limit
EIM	Environmental Information Management
GIS	Geographic Information System
HASP	Health and Safety Plan
HPAH	high molecular weight polycyclic aromatic hydrocarbon
LC_{50}	lethal concentration to 50 percent of organisms
LCS/LCSD	laboratory control sample/laboratory control sample duplicate
LPAH	low molecular weight polycyclic aromatic hydrocarbon
MDL	method detection limit
MLLW	mean lower low water
MTCA	Model Toxics Control Act
MS/MSD	matrix spike/matrix spike duplicate
NAD83	North American Datum 1983
NOAA	National Oceanic and Atmospheric Association
NTU	nephelometric turbidity unit
OC	organic carbon
PAH	polycyclic aromatic hydrocarbon
Parks	Metropolitan Parks District of Tacoma
PCB	polychlorinated biphenyl

PPE	personal protective equipment
PSEP	Puget Sound Estuary Program
PS-SRM	Puget Sound Sediment Reference Material
PV	plan view
QA	quality assurance
QA1	USEPA Stage 2b Data Validation
QAPP	Quality Assurance Project Plan
QC	quality control
RI/FS	Remedial Investigation/Feasibility Study
RIWP	Remedial Investigation Work Plan
RL	reporting limit
RM	reference material
RPD	relative percent difference
R/V	research vessel
SAP	Sampling and Analysis Plan
SCL	sediment cleanup level
SCO	sediment cleanup objective
SCUM	Sediment Cleanup User's Manual
SLR	sea level rise
SVOC	semi-volatile organic compound
SMARM	Sediment Management Annual Review Meeting
SMS	Sediment Management Standards
SOD	sediment oxygen demand
SOP	standard operating procedure
SPI	sediment profile imaging
SQS	Sediment Quality Standards
TEQ	toxic equivalency quotient
TPH	total petroleum hydrocarbons
TOC	total organic carbon
TRIP	triplicate
TVS	total volatile solids
USEPA	U.S. Environmental Protection Agency
ww	wet weight

1.0 INTRODUCTION

The Washington State Department of Natural Resources (DNR) is working toward full environmental restoration of the Dickman Mill sediment area in Tacoma, WA (Figure 1). Environmental restoration is expected to include the removal of creosote pilings, removal of all debris impacting benthic habitat health, and sediment remediation. Based on studies to date, DNR and the Washington Department of Ecology (Ecology) have determined that additional sediment characterization is warranted with a focus on the vertical extent of contamination and the possible impacts of wood waste before piling removal can proceed.

Previous site investigations have indicated that polycyclic aromatic hydrocarbons (PAHs) and dioxins/furans are the primary contaminants of concern (Mott MacDonald 2020, 2021). A brief history of the Dickman Mill site and summaries of prior investigations are provided in Section 2.0. Additional site details can be found in the 2017 Dickman Mill Periodic Review Report (Ecology 2017). Results of the present study, conducted by NewFields and Herrera, serve to characterize the nature and extent of contaminants (vertical and horizontal) as well as potential impacts of wood waste on the benthic habitat within the Dickman Mill sediment area. The results of this investigation will be used to inform the development of a Remedial Investigation/Feasibility Study (RI/FS), as necessary.

1.1 Project Scope and Objectives

The specific study objectives for the Dickman Mill sediment investigation were as follows:

1. Determine the nature and extent (vertical and horizontal) of contamination within the offshore areas of Dickman Mill, with a focus on PAHs and dioxins/furans;
2. Assess the potential impacts of wood debris to the benthic habitat;
3. Evaluate the toxicity of contaminants and wood debris in offshore sediment areas using bioassays; and
4. Evaluate the potential impact of piling removal on beach geomorphology.

These objectives were addressed by analyzing a comprehensive suite of physical and chemical parameters, as detailed in Section 2 of this report.

1.2 Document Organization

This report summarizes and evaluates the results of Dickman Mill sediment chemistry and benthic toxicity within the context of the project scope and study objectives. Section 2.0 of this document provides a summary of the history of Dickman Mill and prior sediment investigations. Section 3.0 describes the sampling design of the present study. Section 4.0 describes the methods used for physical, chemical, and biological data evaluation. Section 5.0 presents the results of the sediment physical, chemical, and biological analyses. Section 6.0 provides results of the geomorphologic evaluation of the erodibility of subtidal and intertidal sediment following removal of all pilings. Section 7.0 presents a discussion of the results of the study within the context of Washington Department of Ecology (Ecology) sediment cleanup guidance. Section 8.0 summarizes the conclusions that can be drawn from this study as well as recommendations for next steps. References are provided in Section 9.0.

2.0 DICKMAN MILL SITE OVERVIEW

2.1 Site Description

The Dickman Mill Site (Site) is located within the southwestern quadrant of Commencement Bay along the Ruston Way waterfront (Figure 1). The Dickman Mill property is a former lumber mill and modern-day park owned and operated by the Metropolitan Parks District of Tacoma (Parks). All upland structural remnants of historical lumber mill operations were demolished and removed by Parks in 1998. Remnants of in-water structures such as wooden planks and pilings from a large wharf and pier remain present at the Site.

2.2 Site History

The Dickman Mill Property was the location of a lumber mill operated continuously from 1889 until its decommissioning in 1977. The mill facility was built upon land created by fill placed into the tide flat of Commencement Bay. Structures on the property included a large overwater wharf at the west end of the Site, a boiler house, a sawmill building, office building, machine shop, auto shed, concrete water tank, decked area above tidelands at the east end of the Site, sawdust burner, and pier. The mill was initially powered by steam and converted to electric power generated by burning hog fuel in the sawdust burner between 1926 and 1927. The mill buildings were partially destroyed by fire in 1978.

Parks purchased the eastern portion of the property in 1991 and the western portion in 1993. Remaining remnants of the original sawmill buildings were demolished and removed from the Site in 1998 by Parks in preparation for developing the Site into a public park. Remnant creosote-treated pilings that once supported the overwater wharf, decked area, and pier remain today.

2.2.1 Prior Investigations – Upland

Environmental investigations conducted since 1985 have mapped the contamination of intertidal sediments and upland soils with metals (copper, lead, mercury, arsenic), individual PAH compounds, and cPAH concentrations in excess of Site cleanup standards.[1] Additionally, oil residues and sulfur oxidizing bacterial mats have been observed on upland and intertidal substrates (Ecology 2017). In 1999, Parks entered into an Agreed Order with Ecology to conduct remedial actions at the Site in support of future upland development (Ecology 1999).

Upland remedial activities were conducted at the Site in 2000 and 2001. The upper 1 foot of sediment containing concrete rubble and wood debris was excavated from the northwest beach and replaced with 1 foot of pea gravel to improve the habitat quality of the substrate. Confirmatory testing of the remaining

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[1] Site cleanup standards were defined by media and elevation relative to mean lower low water (MLLW). Intertidal sediments were evaluated for metals relative to Ecology-promulgated Sediment Quality Standards (SQS). Intertidal sediment PAH and PCB concentrations were screened against Commencement Bay Sediment Quality Objectives (SQOs) promulgated by the Environmental Protection Agency's 1989 Record of Decision for the Commencement Bay Superfund Site. Upland soils, defined as soils at elevations greater than +14 ft MLLW, were screened against soil cleanup standards defined by Washington's Model Toxics Control Act (MTCA) Methods A and B, depending on individual analyte. See Ecology 2017, Table 1.

sediment below the emplaced gravel showed no elevated chemicals of concern (COCs) (Hart Crowser 2001). A minimum of 2 feet of soil cover was placed in upland areas consisting of 1 foot of structural fill covered by 1 foot of topsoil. An estimated 1,675 cubic yards of contaminated materials, including shredded creosote timber, lead, and petroleum, were excavated from the upland tidal channel as part of the cleanup action (Hart Crowser 2001). Ultimately, complete removal of oily materials was unachievable within the tidal channel due to constraints of the tide, equipment, and stability of the excavation, and the tidal channel was capped with at least 2 feet of clean cap material. Two years of post-construction confirmational groundwater monitoring showed that construction activities did not appear to have significantly impacted groundwater quality at the Site and groundwater monitoring was discontinued (Ecology 2017). Post-construction sediment cap monitoring was conducted from 2003 through 2005 to determine erosion and stability of the cap. Ecology concluded there was no evidence of significant cap erosion and approved the discontinuation of post-construction cap monitoring (Ecology 2017).

Following remedial activities, Parks and Ecology entered into a Restrictive Covenant regarding the Dickman Mill property on February 1, 2007. The Restrictive Covenant was required as a result of decisions made during Remedial Action to leave residual concentrations of PAHs underneath the sediment cap in the tidal channel. The Restrictive Covenant dictates the limitations, restrictions, and uses of the property to ensure long-term protection for the cleanup completed at the Site (Ecology 2007).

2.2.2 Prior Investigations – In-water

Few studies have previously characterized contamination within the offshore sediments of the Site. Of the limited data available, two sediment surface samples (S-4 and S-3) collected by Hart Crowser in 1998 within the intertidal area just offshore of the former boiler building contained high concentrations of copper, lead, and mercury above SQS criteria (Ecology 2017) (Appendix A[2]). Hart Crowser representatives also observed sulfur oxidizing bacteria within the vicinity of sample S-3 indicating localized anoxic conditions (Ecology 2017). This intertidal region remained an area of unaddressed contamination with unknown spatial delineation.

In 2015, the DNR collected ten surface sediment samples within and surrounding the remnant piling fields adjacent to the Site (Figure 2) (Mott MacDonald 2020). Each sample was analyzed for metals, semi-volatile organic compounds (SVOCs) including PAHs, total petroleum hydrocarbons (TPH), polychlorinated biphenyls (PCBs), total organic carbon (TOC), sulfide, ammonia, total volatile solids (TVS), total solids, and grain size. Five samples were additionally analyzed for dioxins/furans. A slight sheen was observed in two samples within the northeast and southeast quadrants of the northwest pile field and two samples immediately adjacent to the seaward end of the relict pier. Heavy sheen was observed in one sample within the center of the northwest piling field. The cPAH concentration exceeded screening criteria in all samples and the dioxin concentration exceeded screening criteria in three of the five samples for which the analysis was conducted. In addition, one sample within the piling field (DMPR2015-D02) had detected concentrations of 1,2,4-trichlorobenzene, 1,2-dichlorobenzene, 1,4-dichlorobenzene, butyl benzyl phthalate, 2,4-dimethylphenol, 2-methylphenol, and pentachlorophenol that exceeded SQS or Cleanup Screening Level (CSL) criteria. Screening criteria were not exceeded in any of the ten surface sediment samples for TPH or PCBs. Of the metals, mercury exceeded the SQS of 0.41 mg/kg for two locations

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[2] Relevant figures from previous investigations showing sampling locations and chemical concentrations at the Site have been included in Appendix B of the SAP. References include Ecology (2017) and Mott MacDonald (2020).

(DMPR2015-03 = 0.51 mg/kg and DMPR2015-05 = 0.43 mg/kg). Subsurface sediments remained uncharacterized for potential contaminants of concern.

2.2.3 Dickman Mill Sediment Transport Study

The approximately 1,000 remaining creosote-treated timber pilings remaining in the intertidal and nearshore areas of the Site remain a suspected ongoing source of environmental contamination. In preparation for the removal of these pilings, DNR contracted with Mott MacDonald to evaluate the risk of releasing additional contaminants of concern and potential effects on nearby properties due to the removal of the pilings.

Mott MacDonald observed that the northwest beach displays a convex shape indicating the northeast pile field may be providing wave attenuation in the nearshore (Mott MacDonald 2020). Results of modeling the adjustment of the beach profile after large storms (*e.g.*, a 50-year storm) indicated localized areas of the beach could lower in elevation by approximately 4–8 inches after piling removal, potentially exposing material underneath the gravel cap (Mott MacDonald 2021). Limited sampling[3] during upland remedial construction indicated that COCs were not present at the base of the cap, though dioxins/furans were never analyzed (Hart Crowser 2001, Ecology 2017). Contaminants left in place below cap material within the tidal channel, located above the mean higher high water level, were not anticipated to be impacted by piling removal (Mott MacDonald 2021).

Modeling of sediment erosion within the piling field after piling removal demonstrated that a typical 2-year storm event would induce minimal erosion of sediments within the piling field and a more energetic 50-year storm would cause relatively mild erosion (Mott MacDonald 2021). Gravel and coarse sands were not anticipated to be significantly mobilized while finer sediment size fractions (*e.g.*, clay, silt, and remnant sawdust) were anticipated to be transported to the southeast into deeper water within Commencement Bay.

2.2.4 2022 Diver Survey

A subsampling of existing pilings within the northwest piling field were recently surveyed by DNR divers in support of characterizing the sediment, condition of pilings, and presence of eelgrass and benthic vegetation as well as any debris. More than 90 percent of the 42 pilings surveyed were observed to be intact and in good condition with minimal degradation (DNR 2022). The sediment type within the piling field was predominantly shell hash on either mud or sand substrate. Finer muds were predominant in the western portion of the piling field while the eastern portion was characterized by coarser sands with observations of a mixture of cobbles and shell hash in the shoreward edge of the piling field. Debris in the piling field included wood, metal rebar, and wood pieces with attached metal. Wood debris ranged in size from short stumps to whole pilings, with some large pieces silted in place on the sediment bed. Debris was present throughout the piling field but became more abundant proceeding southeastward across the field. The area

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[3] One (1) four-point composite verification sediment sample was collected within northwest intertidal beach area as part of the 2000/2001 Cleanup Action. The four-point composite verification sediment sample (Sed-3) targeted a limited 20 ft-by-20 ft area of the beach where over-excavation of material was necessary to remove arsenic at concentrations exceeding SQS criteria. After careful review of available and relevant Site documents, there is no evidence of additional sediment chemistry data available for the material below the cap within the intertidal beach.

to the west of the piling field was characterized by a healthy bed of eelgrass. Very little eelgrass was observed within the piling field.

3.0 DICKMAN MILL SAMPLING DESIGN

The Dickman Mill sediment area was divided into four (4) general study areas (Figure 3) based on site conditions:

1. Dense Pile Field
2. Eastern Pile Area
3. Outside Dense Pile Field
4. Intertidal Beach

The Dense Pile Field required a unique sampling approach that was dictated by ease of access to sampling locations and potential barriers to sediment sampling posed by metal and wood debris observed during the 2022 DNR diver survey. The areas east of the Dense Pile Field and surrounding the Dense Pile Field were anticipated to pose fewer obstacles to successful sediment sampling. Finally, the Intertidal Beach study area, located above 0 ft MLLW, necessitated the use of sub-aerial sampling equipment as opposed to in-water equipment. Sampling within the Intertidal Beach study area occurred at low tide to allow access to sampling locations without overlying water.

3.1 Sampling Approach

A comprehensive sampling approach utilizing sediment profile imaging (SPI) and plan view (PV) imaging and surface and subsurface sediment sampling was proposed to address the study objectives, as described below. A total of thirty (30) sampling locations were originally proposed within the four (4) study areas. Geographic coordinates and sampling requirements for the proposed and as-sampled locations are listed in Table 1. The rationale for the numbers and types of sampling are described in the following sections.

A sediment profile imaging (SPI) and plan view (PV) imaging survey of the Dickman Mill sediment site was conducted as the first element of the study to provide near real-time surface sediment/benthic habitat evaluation, including identification of wood and other debris and habitat impacts. SPI and PV imaging were reviewed following each field day and observations were used to add SPI and PV imaging locations and inform or modify the targeted sediment sampling locations, in coordination with DNR. A remotely controlled float frame (equipped with outboard motor, a-frame, and cable pulley) deployed from a primary sampling vessel was used to deploy the SPI system within the Dense Pile Field, as needed, when spacing of the pilings and other potential obstructions were such that the primary sampling vessel could not reach a designated sampling location. A total of twenty-six (26) SPI/PV stations were proposed to characterize the horizontal extent of wood debris in surface sediments and provide a baseline for benthic conditions within and proximal to the Dense Pile Field prior to pile removal (Figure 4).

Vibracore sediment sampling was conducted at selected locations within and outside the Dense Pile Field to evaluate subsurface sediment conditions including chemicals of concern (COC), physical parameters, and wood debris abundance (Figure 5). Cores up to 6 feet in length were collected, and samples for each core consisted of the top 1 foot (0-1 ft) and 2-foot intervals until the bottom of the core was sampled (1–3 ft, 3–5 ft, 5–7 ft) (Section 4.3). A remotely controlled float frame was used to deploy the vibracore within the Dense Pile Field, as needed, when spacing of the pilings and other potential obstructions were such that the primary sampling vessel could not reach a designated sampling location. In addition, a hand hammer corer was used to collect short cores up to 2 feet in length during a low tide within the Intertidal Beach Area. Sediments were collected from each station following procedures and methods described in Section 4.0.

Power grab sampling of surface sediments was conducted at nine (9) locations within and outside of the Dense Pile Field to evaluate surface sediment conditions, including verification of previously measured COCs, determination of grain size and contaminant load in areas of potential erosion (*e.g.*, the low tide terrace) and toxicity (bioassay) testing of sediments with contaminants and/or wood debris (tiered testing) (Figure 5). A remotely controlled float frame was used to deploy the power grab within the Dense Pile Field. Sediments were collected from each station following procedures and methods described in Section 3.0.

3.2 Rationale for Station Locations

As described in Section 3.1, the sampling strategy at the Site was designed to collect data at 30 sampling locations spanning the four (4) study area regions to characterize the vertical and horizontal extent of sediment contamination and provide a baseline for benthic conditions and sediment chemistry within and proximal to the Site prior to pile removal. Six (6) sampling locations within the four study areas reoccupied locations sampled by DNR in 2015 where exceedances of metals, PAHs, dioxins/furans, or detections of sheen were observed. Modifications to the sampling plan were necessary in limited circumstances due to surface and subsurface sediment obstructions that precluded sediment recovery as outlined in the sampling plan. These modifications can be found in Section 4.6 and are briefly noted in the following sections.

3.2.1 Dense Pile Field

Ten (10) SPI/PV stations were targeted within the Dense Pile Field to assess the benthic conditions within the area. Due to the conditions of the pile field—dense spacing of whole pilings, piling stubs, metal debris, fallen pilings, and remnant board decking—four (4) SPI/PV transects were chosen to cross the area and inform near real-time adjustments to targeted imaging locations. SPI/PV imaging was collected at one or more locations along each transect as accessibility and bottom conditions allowed. Adjustments to planned and sampled SPI/PV locations are catalogued in Table 1 and shown in Figure 4.

Eight (8) sediment sampling locations were targeted within the Dense Pile Field to delineate the horizontal and vertical extent of wood debris, PAHs, and dioxins/furans associated with the creosote-treated pilings. Semi-volatile organic compounds (SVOC), including polycyclic aromatic hydrocarbons (PAH), were analyzed at four (4) locations to specifically evaluate exceedances observed in the DNR 2015 study data. Locations were chosen to provide comprehensive spatial coverage within the Dense Pile Field. Eastern Pile Area

3.2.2 Eastern Pile Area

The Eastern Pile Area is proximal to a former hog fuel burner and former sawmill buildings that burned in a 1978 fire. Aerial imagery from 1931 showed that the Eastern Pile Area was historically used for log rafting and creosote pilings remain from a pier at the eastern boundary of the project area. Ten (10) SPI/PV stations were selected in the Eastern Pile Area to provide comprehensive spatial coverage of wood debris and catalogue the benthic habitat quality in this area. Additionally, seven (7) sediment sampling locations spanned the area to delineate the vertical and horizontal extent of wood debris, as well as impacts from metals, PAHs, and dioxins/furans.

3.2.3 Outside Pile Area

Four (4) SPI/PV stations located to the north and west of the Dense Pile Field were chosen to delineate the horizontal extent of wood debris and potential impacts to the benthic community. Four (4) sampling locations in the Outside Pile Area were chosen to delineate the horizontal extent of wood debris, PAHs, and dioxins/furans. Two (2) northern locations within this area (DM-12 and DM-19) reoccupied locations sampled by DNR in 2015 with metals and PAH surface sediment impacts.

3.2.4 Intertidal Beach Area

Four (4) sampling locations positioned between +1 and +5 feet MLLW were targeted for sediment sampling via hand hammer core along the Intertidal Beach proximal to the Dense Pile Field where erosion post-pile removal is modeled to be greatest (Mott MacDonald 2021). These sampling locations were selected to evaluate the quality and thickness of gravel cap material remaining after initial deposition in 2000 and 2001, and to collect samples of material present immediately below the gravel cap. Data from these locations will serve as a baseline for intertidal beach conditions in anticipation of possible enhanced erosion following removal of the dense pile field (Mott MacDonald 2021). Additionally, sediment recovered beneath the gravel cap was to be evaluated for metals due to the proximity near the former boiler building as well as PAH concentrations in light of observations made during a recent Site visit by representatives from Mott MacDonald and GeoEngineers indicating that material beneath the thinning gravel cap may contain a high concentration of remnant sawdust and wood waste.[4] Observations made during coring operations indicated that the gravel cap was ill-defined and significantly thinner than the anticipated 1 foot interval. Appropriate modifications to the sampling plan were made and the upper 1 foot of beach material was sampled as described in Section 4.6.

3.2.5 Additional Locations

Two additional sample locations were targeted outside of the four study areas. One sampling location, DM-01, was located to the southeast of the four study areas where sediment from within the dense piling area could migrate post-removal (Mott MacDonald 2021). Characterization of the substrate and surface chemistry at this location will serve as a baseline for possible future sediment impacts following piling removal. A final sampling location, DM-26, was located to the northwest of the Dense Pile Field to help bound the horizontal extent of existing wood debris and assess current benthic habitat.

3.3 Tiered Bioassay Testing

Surface sediment from ten (10) sampling locations spanning the three subtidal sampling areas were collected and archived for potential toxicity (bioassay) testing. Surface sediment samples with chemical concentrations exceeding SQS criteria and/or elevated conventional parameter results (e.g., total organic

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[4] Hart Crowser's Final Cleanup Completion Report (2001) noted that only the upper one foot of sediment, containing "abundant concrete rubble and wood", was excavated from the Northwest Beach ("Intertidal Beach Area") and replaced with one foot of imported pea gravel. In 2020, representatives from Mott MacDonald and GeoEngineers observed thinning of the gravel cap and the presence of sawdust and wood waste within the upper foot of the beach face at approximately +4 feet MLLW (Mott MacDonald 2020, Appendix D).

carbon, total volatile solids, ammonia, total sulfides) suggesting habitat impacts from wood debris accumulation (Ecology 2013, 2021).

4.0 METHODS

This section provides a summary of the data collection, sampling, and analysis methods for the 2022 Dickman Mill sediment investigation. All sediment profile imaging and plan view (SPI/PV) image collection and sediment sampling activities were conducted from November 14 through November 20, 2022, aboard the research vessel (R/V) *Tieton*, owned and operated by Gravity Environmental. The detailed sampling and analysis methods are provided in the Sampling and Analysis Plan (SAP) (Appendix A). Deviations encountered during the sediment sampling and analysis program or sampling plan modifications are described in Section 4.6.

4.1 Navigation and Positioning

A differential Global Positioning System (DGPS) was used for positioning and navigation during the 2022 sediment sampling program. The DGPS used a satellite-based differential correction signal, which provided an accuracy of ±1 meters. All samples were collected within 15 meters (50 feet) of the target locations. The geographic coordinates for SPI and sediment sampling stations are provided in Table 1.

4.2 SPI/PV Imaging Methods

The following sections provide an overview of the SPI and PV imaging systems and the image analysis process.

4.2.1 SPI System Overview

SPI images were collected using an Ocean Imaging Systems (OIS) Model 3731 sediment-profile camera (OIS, Pocasset, MA) (Figure 6). The sediment-profile camera consists of a wedge-shaped prism with a Plexiglas face plate and a back mirror mounted at a 45-degree angle. Light is provided by an internal strobe. The mirror reflects the image of the profile of the sediment-water interface up to a Nikon D7100 digital camera (24 megapixel) that is mounted horizontally on top of the prism. The camera can obtain images of up to 20 cm of the upper sediment column in profile.

The camera prism is mounted on an assembly that can be moved up and down within a stainless-steel frame by allowing tension or slack on the winch wire. As the camera is lowered, tension on the winch wire keeps the prism in the up position. Once the camera frame touches the bottom, slack on the winch wire allows the prism to vertically intersect the seafloor. The rate of fall of the prism (6 cm/second) is controlled by a passive hydraulic piston, which minimizes the disturbance of the sediment-water interface. A trigger is tripped on impact with the bottom, activating a 13 second time-delay on the shutter release; this gives the prism a chance to obtain maximum penetration before an image is obtained. After image collection, the camera is raised from the bottom, a wiper blade automatically cleans off any sediment adhering to the prism faceplate, and the strobes are recharged. The camera is then lowered to collect another replicate image.

Triplicate SPI images were collected at 33 locations across the Dickman Mill sediment investigation area (Figure 4). As noted in Section 4.6, SPI imaging planned nearshore of the Dense Pile Field could not be collected due to the presence of compact surface sands and shell hash, which impeded SPI penetration at eight stations.

4.2.2 SPI Image Analysis

Computer image analysis of SPI images followed a formal and standardized technique developed by Rhoads and Germano (1982, 1986). Physical and biological parameters were measured directly from the digital SPI images by an SPI analyst using a Geographic Information System (GIS) – based image analysis system. The image analysis parameters for this project included:

- Camera prism penetration depth (cm)
- Grain size major mode and range in phi sizes
- Presence of wood and other debris (estimate of percent coverage)
- Surface boundary roughness
- Depth of the apparent redox potential discontinuity (RPD) (cm)
- Infaunal successional stage
- Presence of methane
- Evidence of excessive organic loading and high sediment oxygen demand (SOD)
- Distribution of sulfate-reducing bacterial mats (e.g., *Beggiatoa*)

The SPI image analysis results for the Dickman Mill sediment investigation and the SPI image library are provided in Appendix B. The measurement techniques for the SPI image analysis parameters can be found in the SAP (Appendix A).

4.2.3 Plan View Imaging Overview

Plan view (seafloor surface) images were captured using a downward-facing underwater video camera, manufactured by GoPro. The GoPro was mounted on the frame of the SPI camera in a downward-looking orientation, recording continuous video during the SPI deployment. Scaling lasers were not included with the GoPro camera, but the base frame of the SPI system was within view of the camera and provided a relative scale.

Representative video image grabs from the GoPro video were obtained to provide PV imaging that was co-located with each SPI camera drop. Triplicate PV images were collected at 41 locations across the Dickman Mill sediment investigation area (Figure 4).

4.2.4 Plan View Image Analysis

Image analysis of the plan view images consisted of evaluating the images for evidence of physical disturbance (e.g., ripples, scour features), biological features (e.g., burrows, feeding structures), classification of surface type and grain size characteristics, presence of wood or man-made debris, and identification and enumeration of flora and fauna visible on the seafloor. The PV image analysis results for the Dickman Mill sediment investigation and the PV image library can be found in Appendix B.

4.3 Sediment Sample Collection

Surface sediment grab samples were collected using a 0.15-m^2 stainless steel powered grab sampler. Sediment core samples were collected using a vibracorer supplied by Gravity Environmental with 8-foot-long pre-cleaned Lexan core barrels with a cellulose acetate butyrate liner. Intertidal beach sediment was collected using a hand hammer corer manufactured by Aquatic Research Instruments fitted with 2- and 4-foot-long, 2

5/8-inch diameter, clear polycarbonate core tubes. Sediment sample handling, subsampling, judgment of sample acceptability, gear and utensil decontamination, compositing, storage, and chain-of-custody procedures followed the SAP (Appendix A). Sample descriptions for each grab sample are summarized in Section 5.2 and detailed in the Sample Log (Appendix C). Selected photos of field activities are also provided in Appendix C.

Sediment for benthic toxicity analysis was collected at nine stations and initially archived, and one location north of the Dense Pile Field (DM-S-19) was triggered for toxicity analysis (Table 2). Sediment was collected from the top 10 cm of the grab. Once sediment from the grab was collected, the sediment was mixed until homogeneous in color and texture and placed into a polyethylene bag and sealed with no headspace with a zip tie and sample tag. The sediment was stored in coolers at 4 ± 2 degrees Celsius (ºC) in darkness until delivery to the biological testing laboratory (EcoAnalysts, Port Gamble, WA), pending receipt of chemistry results under the toxicity testing approach.

Reference surface sediment was collected from Carr Inlet by EcoAnalysts on November 18, 2022 and received by the laboratory the following day.

4.4 Sediment Chemical Analytical Methods

Chemical analytical procedures were performed in accordance with PSEP guidelines (PSEP 1997a,b,c,d) with appropriate modifications as specified during the annual Sediment Management Annual Review Meeting (SMARM) process (Ecology 2021), and current laboratory recommendations, as detailed in the SAP (Appendix A). ARI conducted all sediment chemical analyses for this program. Sample preparation methods, analytical methods, method detection limits (MDLs), reporting limits (RLs), SQS criteria for the target conventionals, metals, PAHs, and dioxin/furan congeners, and laboratory QA/QC requirements are reported in Table 6 and Table 7 of the SAP (Appendix A).

ARI performed all method-required QC procedures specified in the SAP. The Puget Sound Sediment Reference Material (PS-SRM) was analyzed with the dioxins/furans and results are provided in Section 5.2.3.

4.5 Benthic Toxicity Testing Methods

Benthic toxicity (bioassay) testing was performed by EcoAnalysts of Port Gamble, WA. Test methods followed guidance provided by the Puget Sound Estuary Program (PSEP 1995) with appropriate modifications as specified during the Sediment Management Annual Review Meeting (SMARM) process, and the Sediment Cleanup User's Manual (SCUM) (Ecology 2021). All tests were conducted within the eight-week holding time.

4.6 SAP Deviations or Modifications

SPI/PV image collection occurred between November 14, 2022 through November 19, 2022. Twenty-six (26) SPI/PV stations were proposed in the SAP to define surface and subsurface benthic habitat quality across the Site. Fifteen (15) additional SPI/PV stations were added during sampling to narrow horizontal data gaps between stations. Locations of these additional stations are shown in Figure 4. Compact surface sands and shell hash impeded SPI penetration at stations within and nearshore of the Dense Pile Field (DM-16, DM-18, DM-20, DM-21, DM-22, DM-23, DM-33, and DM-34) (Figure 4). However, PV images were collected at these stations, which were shallower than -7 ft MLLW.

Sediment surface grab sampling at Stations DM-21, DM-22, and DM-23 was successful despite hard bottom conditions. Ten (10) attempts were made to collect a sediment surface grab sample at station DM-18 without success. The station was abandoned after consultation between the field crew and the NewFields Project Manager (see Appendix C).

Shallow hand hammer coring was conducted during a low tide on the evening of November 20, 2022, at four (4) stations along the Intertidal Beach Area placed an elevation between +1 ft and +5 ft MLLW. Two replicate cores were recovered at each station. Each core was advanced up to 2 ft below ground surface (bgs), or as deep as possible. Cores were anticipated to collect two feet of material—1 ft of gravel cap overlying 1 ft of sediment. Three (3) out of eight (8) cores were unable to penetrate deeper than 1.8 ft due to obstructions at depth. Visual observations of recovered material identified only inches of gravel at the surface of each core and sand with abundant shell hash and interspersed gravel below the ground surface (see Appendix C). After consultation with the NewFields Project Manager, core recovery of 1 foot or greater was considered adequate and the 0–1 ft interval was collected for analysis from each core since the 0–1 ft interval captured both the gravel cap and sand layers representative of modern beach conditions.

5.0 RESULTS

This section presents a summary of results for the 2022 Dickman Mill SPI and PV survey, the results of the intertidal and subtidal sediment chemistry analysis, and bioassay testing.

5.1 SPI and Plan View Imaging Survey

SPI and PV imaging was conducted to evaluate the surface sediment/benthic habitat conditions, including identification of wood debris and habitat impacts at the Dickman Mill sediment site.

5.1.1 Wood Debris Distribution

The estimate of percent wood debris in SPI images was determined visually using Munsell charts for estimating proportions of mottles and coarse fragments (GretagMacbeth 2000). The PV images identified the presence of large wood debris (e.g., logs) but were less useful for identifying small wood debris on the sediment surface due to the presence of abundant shell debris in the Dense Pile Field and abundant algae on the sediment surface in some areas.

Wood debris determined from SPI images at the Dickman Mill site consisted of very fine wood particles to larger wood pieces. The mean surface wood debris coverage at the Dickman Mill site is shown in Figure 7. Wood debris was observed at 67 percent of the SPI stations surveyed (22 of 33 stations) and ranged from trace amounts of small wood particles at several stations to a maximum of approximately 50 percent of fine wood particles on average at Station DM-31, within the Eastern Pile Field (Figure 8). The highest concentrations of wood debris (>20 percent by area in the SPI images) were observed at six stations, which included three stations in the Eastern Pile Field (DM-05, DM-07, and DM-31), one station in the Dense Pile Field (DM-39), one stations in the Outside Pile Area (DM-28), and one station in the Up/Down Current area (DM-27) (Figure 8).

The overall trend of wood debris in surface sediments observed at the Dickman Mill site consisted of smaller particles of wood debris in deeper offshore areas and larger wood debris in the nearshore areas. It is likely that small wood particles deposited in the nearshore areas are resuspended and transported away over time by wave activity and local currents. PV imaging identified logs or broken piles at two stations in the Dense Pile Field (DM-20 and DM-36) and two stations in the offshore portion of the Outside Pile Area (DM-19 and DM-29) (Figure 9).

5.1.2 Physical and Sedimentary Features

Physical and sedimentary features determined from SPI images included grain size major mode in phi sizes, camera prism penetration, and surface boundary roughness. Sedimentary features determined from PV images included the presence of surface ripples.

5.1.2.1 Grain Size Major Mode

Across the Dickman Mill sediment investigation area, the grain size major mode was mostly sand with fine sand (3 to 2 phi) present in 62% of the SPI images (41 of 79 images) and very fine sand (4 to 3 phi) in 35% of the SPI images (28 of 79 images) (Figure 10). Within the Dense Pile Field and Eastern Pile Field, the grain size major mode was mostly fine sand. Very fine sand was generally observed in deeper water areas, which included in the northern portion of the Outside Pile Area. Nearshore of the Dense Pile Field where SPI imaging could not be collected (no SPI prism penetration), the grain size was coarse-grained and likely ranged from coarse sands to gravels and pebbles. In the eastern nearshore areas, medium sand (2 to 1 phi) was observed at Station DM-01 and coarse sand (1 to 0 phi) was observed at Station DM-02.

5.1.2.2 Mean SPI Prism Penetration

SPI camera penetration depths varied across the site and followed a pattern similar to the grain size major mode. Across the Dickman Mill site, camera penetration depths averaged 8.41 cm (± 5.70 cm, n=89) with a range of 0.0 to 19.53 cm (Figure 11). The deepest penetration depths (15 to 20 cm) were generally observed in deeper offshore areas, and the lowest penetration depths were observed closer to shore. Camera penetration averages were similar in the Eastern Pile Field (10.54 cm ± 5.55 cm, n=36) and the Outside Pile Area (10.48 cm ± 6.30 cm, n=14), whereas camera penetration was lower in the Dense Pile Field (5.76 cm ± 4.62 cm, n=31) and the Up/Down Current stations (5.53 cm ± 3.04 cm, n=8) (Table 3). As noted in Section 4.6, several stations nearshore of the Dense Pile Field had no SPI camera penetration due to the presence of compact sediments.

5.1.2.3 Mean Bottom Boundary Roughness

Mean bottom boundary roughness measurements (surface relief) at the Dickman Mill site are shown in Figure 12. The average surface relief across the site was 1.80 cm (±1.53 cm, n=89) with a range of 0.0 cm to 10.0 cm. Higher surface relief measured at stations DM-24, DM-30, and DM-31 appeared to be attributed to an irregular surface created by the SPI prism intersecting surface wood debris or algae (*Ulva*). At Station DM-36, the higher surface relief appeared to be from the SPI prism penetrating a sloped surface of shell particles in sand. Within the Study Area Zones, surface relief ranged from an average of 1.13 cm (±0.93 cm, n=14) in the Outside Pile Area to an average of 2.37 cm (±1.38 cm, n=8) for the Up/Down Current stations (Table 3).

5.1.2.4 Surface Ripples

Sedimentary features such as surface ripples are not always apparent in SPI imaging but can be captured in PV images. At the Dickman Mill site, surface ripples, which provide an indication of localized sediment bedload transport, were observed in the nearshore areas generally shoreward of the State Lands/Metro Parks property line. PV imaging showed evidence of surface ripples at 12 stations, with well-developed ripples observed at nine of the nearshore stations (DM-01, DM-02, DM-06, DM-13, DM-16, DM-18, DM-20, DM-22, and DM-32) (see Figure 13).

5.1.3 Chemical and Biological Features

Chemical and biological parameters include the apparent RPD depth, benthic infaunal successional stage, evidence of high sediment oxygen demand, and presence of sedimentary methane determined from SPI images. In addition, the presence of thiophilic bacteria and fauna and flora were identified in PV imaging. These parameters contributed to an assessment of the overall health of the benthic habitat at the Dickman Mill site.

5.1.3.1 Apparent Redox Potential Discontinuity

The apparent RPD depth estimates the depth of oxygenation in the upper sediment column and provides an estimate of the biological mixing depth by infaunal organisms. It is a sensitive indicator of infaunal succession, sediment bioturbation activity, and sediment oxygen demand.

Mean apparent RPD depths across the Dickman Mill site ranged from 0.0 to 6.00 cm, with an average of 1.97 cm (± 1.24 cm, n=76) (Figure 14). Within the Study Area Zones, the apparent RPD depths were almost the same in the Eastern Pile Area, Dense Pile Area, and the Up/Down Stream zone averaging 1.9 cm in all three zones (Table 3). The Outside Pile Area had a slightly higher apparent RPD depth average of 2.5 cm. This range of apparent RPD depths measured at the Dickman Mill site (2.0 to 2.5 cm) would be considered typical for a nearshore subtidal region comprised of sands with periodic disturbances from waves and currents. In comparison, SPI imaging surveys conducted in areas around the dredged material disposal site located at the center of Commencement Bay have measured apparent RPD depth ranging from 2.5 to 3.0 cm in 2007 to 3.5 to 4.0 cm in 2013 (NewFields 2013). Sediments around the Commencement Bay site (outside of the disposal zone) are mostly comprised of silt/clay (>4 phi) and experience limited physical disturbance, resulting in deeper apparent RPD depths.

5.1.3.2 Infaunal Successional Stage

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

The SPI survey at the Dickman Mill site found Stage III succession at 67% of the stations (22 of 33 stations) (Figure 15). Six nearshore stations consisting of compact fine sands only exhibited Stage I or Stage II succession (DM-02, DM-03, DM-09, DM-13, DM-25, and DM-41). Stage I or Stage II succession may be the climax communities at these locations, as these compact sands are typically not a habitat type preferred by head-down deposit feeders. Of note, Stage III succession was observed at the six locations where greater than 20% wood debris by area was observed in surface sediments. Higher concentrations of wood debris present in some Dickman Mill sediment areas do not appear to be a significant hinderance for the establishment of a Stage III community consisting of long-lived deposit feeders.

5.1.3.3 Sedimentary Methane

Sedimentary methane was not observed in Dickman Mill sediments with the exception of one SPI replicate image collected at Station DM-08 (Figure 16). The methane was observed as a gas-filled void within the sediment column, and the methane had a glassy appearance due to reflection from the camera strobe. Benthic habitat quality at DM-08 did not appear to be impacted by the presence of methane (i.e., apparent RPD depths were well developed and feeding voids were visible, indicating the presence of head-down deposit feeding organisms). This suggested that the organic loading from wood debris and other natural sources to Dickman Mill sediments, combined with existing hydrodynamic conditions at the site (currents, waves, and water exchange) does not result in degraded benthic habitat conditions.

5.1.3.4 Evidence of Excessive Organic Loading and High Sediment Oxygen Demand (SOD)

The apparent RPD can provide an important indicator of high SOD and evidence of excessive organic loading. This indicator is the degree of contrast in reflectance values at the apparent RPD boundary. This contrast is related to the interactions among the degree of organic-loading in the sediment, bioturbation, and bottom-water dissolved oxygen levels. A high input of labile organic material increases sediment oxygen demand, stimulates the sulfate reduction rate, and results in sulfitic products. This results in more highly reduced (lower-reflectance) sediments at depth and higher RPD contrasts. In a region where generally low RPD contrasts exist, images with high RPD contrasts can indicate localized sites of relatively high inputs of organic-rich material, such as wood debris.

SPI images from the Dickman Mill site that showed higher apparent RPD contrasts did not correlate with the presence of wood debris. Some nearshore areas comprised of fine sands with little wood debris (stations DM-06, DM-08, DM-10, DM-25, and DM-41) showed higher apparent RPD contrast, which was considered typical for this substrate type given the absence of wood debris (Figure 17). Within the Dense Pile Field, four stations that showed higher apparent RPD contrast (DM-17, DM-35, DM-37, and DM-40) had abundant shell hash[5] in surface sediments but minimal wood debris (Figure 18). Overall, areas that showed higher concentrations of wood debris in SPI images also showed low apparent RPD contrast, which did not suggest high SOD created by organic loading from wood debris (see Figure 18).

5.1.3.5 Sulfate-Reducing Bacteria (Beggiatoa)

Sulfate-reducing bacterial mats such as *Beggiatoa* can appear as layers of white fibrous material or accumulations of light gray organic aggregations. *Beggiatoa* can exist at the interface between oxic and anoxic conditions and its presence on the sediment surface can indicate the lack of oxygen in underlying sediments.

Beggiatoa was not observed in any SPI images collected at the Dickman Mill site. However, PV imaging observed patches of *Beggiatoa* bacteria on the sediment surface at five stations within the Eastern Pile Field and seven stations with the Dense Pile Field (Figure 19). Interestingly, for each of the locations where co-located SPI images were collected (DM-06, DM-08, DM-11, DM-17, DM-30, DM-36, and DM-38), the SPI imaging identified the presence of Stage III organisms and apparent RPD depths similar to other stations within the piling fields (see Figure 20). The presence of *Beggiatoa* bacteria mats on the sediment surface at the Dickman Mill site does not appear to be correlated to degraded benthic habitat conditions.

5.1.3.6 Fauna and Flora

Fauna observed in PV images at the Dickman Mill site consisted primarily of kelp crabs observed in eelgrass beds, and cancer crabs and anemones found scattered across the site (Figure 19). Anemones (*Metridium*) were often associated with pilings or wood debris (see Figure 19). The cancer crabs (*Cancer productus* and *Metacarcinus gracilis*) were seen in both the piling fields and in areas with algae and eelgrass, and kelp crabs were present in the eelgrass beds (Figure 21).

PV imaging observed the presence of eelgrass at 12 stations at the Dickman Mill site, which included all Study Area Zones (Figure 19). Higher density fields of eelgrass were observed in the Eastern Pile Field, Outside Pile Area, and the Up/Down Current stations (see Figures 20 and 22). The presence of eelgrass patches within the Dense Pile Field, particularly at Station DM-21, is encouraging (Figure 22) and suggests that the removal of piles may improve the existing habitat and allow for eelgrass to be re-established in this Study Area Zone.

5.2 Sediment Chemistry Results

This section provides a summary of the conventional and contaminant chemistry results for the 2022 Dickman Mill Sediment Investigation. Sediment samples from nine subtidal sediment coring stations, nine in-water surface grab stations and two field triplicates, and four hammer core stations located along the intertidal beach

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[5] Pilings often provide a suitable substrate/habitat for organisms including barnacles and bivalves. Over time, the shells of these organisms accumulate in the sediments below creating layers of shells, shell particles, and shell hash.

were submitted for analysis (Figure 5). Field duplicate and triplicate samples from two surface sediment grab stations as well as equipment and rinsate blanks were also submitted for chemical evaluation as outlined in the SAP (Appendix A). Dioxin/furan congeners were calculated as toxic equivalents (TEQ) for each sample using the toxic equivalency factor (TEF) values for mammals from the World Health Organization (Van den Berg et al. 2006) (Table 4). Total dioxin/furan TEQ values were calculated according to the SAP (Appendix A), whereby non-detected results were replaced with ½ the estimated detection limit (EDL). A full summary of analytical results for sediment cores (depth intervals of 0–1 ft, 1–3 ft, and 3–5 ft, below mudline [bml] when applicable), grabs (0–10 cm bml), and intertidal cores (0–1 ft below ground surface [bgs]) are presented in Table 5. Sediment from the 1–3 ft bml interval of every core was submitted for chemical analysis. Subsurface obstructions impeded sediment penetration deeper than 3 ft bml at many stations; however, sediment from the 3–5 ft bml interval was successfully recovered and submitted for chemical analysis at Stations DM-06, DM-11,and DM-24. The full laboratory reports are provided electronically as Appendix D. In the following sections, “surface sediment” chemical results include the 0–1 ft bml interval of all sediment cores and the 0–10 cm bml interval of all surface grabs, and “subsurface sediment” chemical results include all results for the 1–3 ft bml depth intervals of every core and the 3–5 ft bml depth intervals from cores collected at Stations DM-06, DM-11, and DM-24.

An independent USEPA Stage 2B data validation was conducted by EcoChem Inc. The purpose of this validation was to verify that all samples were analyzed and reported in the correct units as well as to demonstrate that all quality assurance/quality control (QA/QC) samples were within either laboratory or programmatic control limits. The data, as qualified, were suitable for use in addressing the objectives of this investigation (Appendix E). Environmental Information Management (EIM) electronic data files of the validated data are provided as Appendix F.

5.2.1 Subtidal Sediment Chemistry

5.2.1.1 Sediment Conventional Parameters and Grain Size Distribution

Sediment samples collected during the 2022 survey were analyzed for grain size distribution, total solids, total volatile solids (TVS), total organic carbon (TOC), total sulfides, and ammonia (Table 5). Samples from 18 in-water target locations plus two field triplicates were submitted for analysis. Sample locations are shown in Figure 5.

The site is predominately sand in both surface and subsurface intervals. The percent composition of the fine sediment size fractions (*i.e.*, silt + clay) increases in a northward direction with increasing distance from the shallow southern portion of the Site.

Surface Sediment

Total sulfides were the highest at Station DM-10 with a concentration of 1,070 mg/kg dry weight (DW), followed by Station DM-11 (844 mg/kg DW), Station DM-08 (843 mg/kg DW), and Station DM-07 (831 mg/kg DW). All remaining concentrations ranged from 42.3 to 820 mg/kg DW, with an average of 318 mg/kg DW. TOC ranged from 0.18–23%, with an average of 6.9%. Total solids followed an inverse relationship to the distribution of percent fines. Total solids ranged from a low of 33.5% at ambient Station DM-11 to a high of 77.3% at Station DM-22. TVS ranged from a high of 45.2% at eastern Station DM-08, and a low of 0.97% at western Station DM-23. The average ammonia measured was 5.9 mg/kg NH_3-N DW, with Station DM-11 reporting the highest concentration at 15.8 mg/kg NH_3-N DW.

Subsurface Sediment

Station DM-17 had the highest subsurface total sulfide concentration of 479 mg/kg DW, followed by Station DM-08 at 422 mg/kg DW, and Station 24 at 392 mg/kg DW. Except for Station DM-13, total sulfide concentrations decreased with depth. In the subsurface, TOC ranged from 3.1-41.1% and had an average of 20.6%. Total solids ranged from 21.4% at Station 11 (3-5ft interval) to a high of 74.1% at Station DM-12. Inversely, Station DM-12 had the lowest measured TVS (4.04%) and Station DM-11 had the highest concentration of TVS (73.7%). For six of the nine subsurface cores, the concentration of ammonia increased with depth; average ammonia measured in subsurface samples was 8.4 mg/kg NH_3-N DW).

5.2.1.2 Metals

Eight metals (arsenic, cadmium, chromium, copper, lead, mercury, silver, and zinc) were analyzed for comparison to SQS criteria. Some concentrations of mercury and silver were reported as estimated as concentrations were less than the method reporting limit.

Surface Sediment

All metals were detected in the surface interval samples and, with the exception of mercury, all metal concentrations were below the SQS criteria. Stations DM-08 and DM-19 had mercury concentrations of 0.418 mg/kg DW and 0.432 mg/kg DW, respectively, and exceeded the 0.41 mg/kg DW SQS criteria (Figure 23).

Subsurface Sediment

All metals were detected in the subsurface interval samples. The mercury concentration at Station DM-06 measured at 0.527 mg/kg DW and exceeds the 0.41 mg/kg DW SQS criteria. The remaining metals and mercury concentrations were below the SQS criteria (Figure 23).

5.2.1.3 SVOCs

Semi-volatile organic compounds (SVOCs), including PAH, phthalates, and phenolic compounds, were analyzed in all samples. Included in the analysis were the 16 USEPA priority pollutant PAHs—a suite of six low molecular weight PAHs (LPAHs) and ten high molecular weight PAHs (HPAHs)—plus 2-methylnapthalene. Total PAH values in this report are presented as the sum of LPAH and HPAH compounds, *i.e.*, the sum of the 16 USEPA priority pollutant PAHs. A majority of SVOC analytes, primarily phthalates, were reported as non-detected or estimated when concentrations were detected at values less than the method reporting limit. Under guidance of the Sediment Cleanup User's Manual (SCUM), SVOC concentrations were compared to the Apparent Effect Threshold (AET) for dry weight. Where TOC was measured between 0.5% and 3.5% in the sample, SVOC concentrations were normalized for organic carbon (OC) and compared to the SQS (OC) criteria.

Surface interval

Multiple stations had a minimum of one analyte concentration that exceeded the AET criteria (Table 5). Fluoranthene concentrations commonly exceeded AET criteria at multiple stations (DM-03, DM-06, DM-15, DM-19, DM-20. Total PAHs in surface sediment across the Site ranged from 482.8 to 43,926 ug/kg. HPAH at Stations DM-19 exceeded AET criteria and both LPAH and HPAH AETs were exceeded at Station DM-20 (Figure 24). All other surface sediment samples were below AET and SQS criteria for SVOCs.

Pentachlorophenol was detected in surface sediments at Stations DM-06, DM-11, DM-13, DM-15, and DM-17. All concentrations were below SQS criteria and ranged from 2.5 µg/kg DW (Station DM-15-S) to 51.8 µg/kg DW (Station DM-17).

Subsurface interval

Five stations had a minimum of one analyte concentration that exceeded the AET criteria (Table 5). Subsurface HPAH concentrations exceeded AET criteria at two stations—Stations DM-08 (1–3 ft bml, HPAH =15,681 µg/kg DW) and DM-11 (1–3 ft bml, HPAH=31,857 µg/kg DW), both located in the Eastern Pile Field (Figure 5). Total PAH was highest at these two stations. Total subsurface sediment PAH concentrations ranged from 779 to 9,841 µg/kg DW at all remaining stations. With the exception of two stations (DM-12 and DM-20), Total PAH concentrations increased with depth.

Pentachlorophenol was detected in the 1-3 ft depth interval of Station DM-17 with a concentration of 171 µg/kg DW. This measured concentration indicates an increase in concentration with increasing depth at this station. Pentachlorophenol was not detected in all other subsurface sediment samples where phenols were analyzed (Stations DM-06 and DM-11).

5.2.1.4 Dioxins/Furans

Individual dioxin/furan congener concentrations and calculated Total TEQs are provided in Table 5. Total TEQ was calculated according to the procedure outlined in the SAP whereby non-detected congener concentrations were replaced with one-half the EDL (ND=½*EDL).

Surface interval

The highest dioxin/furan Total TEQ in surface sediment across the Site was measured at Station DM-11 (72.28 ng/kg TEQ), followed by Station DM-20 (45.63 ng/kg TEQ). Remaining surface concentrations ranged from 5.68 – 44.58 ng/kg TEQ (Figure 25). Average Total TEQ across all surface sediments analyzed at the Site is 26.31 ng/kg TEQ.

Subsurface interval

Subsurface sediment Total dioxin/furan TEQ was highest in the 1–3 ft bml depth interval of Station DM-17 in the Dense Pile Field where Total TEQ = 85.61 ng/kg. Station DM-17 was a reoccupation of DNR Station DMPR2015-D02 in 2015 where dioxin/furan Total TEQ was calculated to be 26.88 ng/kg in the surface sediment. Station 11 had the second highest concentration at 38.62 ng/kg TEQ at 1–3 ft bml. Remaining stations had subsurface Total TEQ had a range from 1.63 ng/kg to 20.96 ng/kg and averaged 18.93 ng/kg TEQ across all subsurface intervals analyzed at the Site (Figure 25). With the exception of DM-17, Total TEQ decreased with depth at all stations where subsurface sediment was analyzed for dioxins/furans.

5.2.2 Intertidal Beach Sediment Chemistry

Intertidal beach sediment chemical concentrations were compared to marine SQS screening levels because the four, 0–1 ft samples were collected at elevations between +1 and +5 feet MLLW. In prior investigations, marine SQS screening criteria were used for evaluation of sediment at elevations below +14 ft MLLW and MTCA Method A screening criteria were used for evaluating soil at elevations greater than +14 ft MLLW (see Ecology 2017).

5.2.2.1 Sediment Conventional Parameters and Grain Size Distribution

Samples from four intertidal beach locations were analyzed for grain size distribution, total solids, TVS, TOC, total sulfides, and ammonia (Table 5). Sample locations are shown in Figure 5.

The intertidal beach was dominated by a mixture of gravel (46-60%) and sand (37-51%) with low percent fines (≤ 3.3%).

Total sulfides were the highest at Station DM-C1 with a concentration of 30.7 mg/kg DW, followed by Station DM-C3 at 6.58 mg/kg DW. The remaining two stations have measured total sulfide concentrations of 4.66 mg/kg DW or less. The beach sediment was characterized by low organic carbon content with TOC concentrations measured between 0.12% and 0.17%. Due to the low concentration of percent fines, total solids were high ranging from 79.99% at Station DM-C1 to 89.97% at Station DM-C4. All concentrations of TVS were low at ≤0.94%, with no distinct spatial pattern. Ammonia was only detected at Station DM-C1 with a concentration of 0.48 mg/kg NH_3-N DW.

5.2.2.2 Metals

Analysis was performed for eight metals (arsenic, cadmium, chromium, copper, lead, mercury, silver, and zinc). Concentrations of silver were reported at estimated concentrations less than the method reporting limit. Mercury was not detected in the intertidal beach samples. Arsenic was detected at concentrations exceeding the SQS criteria of 57 mg/kg DW at all four stations. Arsenic concentrations ranged from 89.7 mg/kg DW at Station DM-C2 to 151 mg/kg DW at Station DM-C1. Concentrations of all remaining metals were detected below SQS thresholds.

5.2.2.3 SVOCs

USEPA Priority Pollutant PAHs were analyzed in the four intertidal beach samples and were predominantly not detected. No individual LPAH or HPAH compound, or their totals, exceeded AET criteria in any sample. The highest concentrations of Total LPAH and HPAH were measured at Station DM-C2 (88 and 287 µg/kg dry weight, respectively), followed by Station DM-C3 (22 and 169 µg/kg dry weight, respectively).

5.2.3 Puget Sound Sediment Reference Material

The PS-SRM was included in the analysis of the sediment samples. ARI analyzed the dioxins/furans under sample delivery groups (SDG) #22K0399 and #22B0054. The PS-SRM batch numbers and analytical results are listed in Table 6_PS-SRM Results. The PS-SRM analysis Form 1 from the laboratory reports and applicable data validation report sections are provided in Appendix I and D, respectively.

The PS-SRM guidance limits of 50%–150% were met with the exception of the following congener:

- The recovery for 1,2,3,7,8,9-HxCDF in SDG #22B0054 was greater than the upper control limit (162% recovery).

5.3 Bioassay Results

Biological toxicity (bioassay) testing was performed on the DM-19-S composite sample to evaluate larval development, amphipod mortality, and juvenile polychaete growth. Bioassay testing was triggered for sample DM-19-S due to exceedances of chemical criteria for mercury and HPAHs. Based on the review of SPI and PV imaging, presence of wood debris did not appear to show strong evidence of benthic habitat degradation and was not a trigger for bioassay testing. Bioassay testing was also conducted on a single reference sample collected from Carr Inlet. The 48-hour larval development bioassay was conducted using *Mytilus galloprovincialis* as the test species. The 10-day amphipod mortality bioassay was conducted using

Eohaustorius estuarius as the test species. The 20-day juvenile polychaete growth bioassay was conducted using *Neanthes arenaceodentata* as the test species.

All bioassay testing was conducted by EcoAnalysts of Port Gamble, WA. The bioassay laboratory report is provided in Appendix D. Bioassay results were evaluated for completeness, format, holding conditions, performance standards for negative and positive controls, and water quality control limits (PTI 1989). Bioassay QA1 review checklists are included with the data validation report in Appendix E. The data, as qualified, were suitable for use in addressing the objectives of this investigation. An Environmental Information Management (EIM) electronic data file of the validated data is provided as Appendix F. The following sections summarize the bioassay tissue results of the confirmatory biological testing.

5.3.1 Bioassay Water Quality Results

The water quality test condition protocols and summary of daily measurements are presented in Table 7. The temperature, salinity, dissolved oxygen (DO), and pH were all within control limits and acceptable ranges throughout the tests, with one minor exception. The temperature was slightly above the control limits for the amphipod mortality bioassays. However, this water quality deviation is not believed to have had any effect on the test results.

The water quality measurements for interstitial and overlying ammonia and interstitial sulfides are presented in Table 8. The total ammonia and sulfide concentrations were all below levels of potential concern in bioassay test results (Inouye et. al. 2015). Based on the water quality measurements, there is no reason to believe there were any adverse effects on test organisms due to laboratory test conditions.

5.3.2 Negative Control and Reference Sediment Performance Results

A reference composite sediment sample from Carr Inlet was used for comparison with the DM-19-S test sediment for interpreting the results of the bioassays. Carr Inlet is recognized as a suitable reference area for the collection of sediments for interpreting bioassay results (Ecology 2021).

Percent fines (silt and clay fractions) are used for pairing the appropriate reference sediment with a given test sediment. The test sediment had a grain size distribution of 16 percent fines compared to reference sediment “CARR-REF 7” with 25.7 percent fines.

The performance results of the negative control and reference sediments for each bioassay are presented in Table 9. The negative control and reference performance standards were met for all bioassays. Therefore, the test results for the larval development, amphipod mortality, and juvenile polychaete bioassays are considered valid for the purposes of the Sediment Management Standards (SMS) confirmatory biological tests.

5.3.3 Positive Control Results

The results of the reference toxicant tests for the bioassays are provided in Table 10. The LC_{50} values for all the bioassays fell within the acceptable range of the mean ± two standard deviations for historical reference toxicant data generated by the EcoAnalysts biological laboratory. The reference toxicant results indicate the test organisms are sufficiently sensitive for demonstrating a toxic response and sufficiently robust for laboratory testing. The reference control charts with both the current and running means and standard deviations are provided in Appendix D.

5.3.4 Larval Development

The larval development test was initiated on January 13, 2023, using the test organism (*Mytilus galloprovincialis*) provided by Taylor Shellfish, Shelton, WA. The results of the larval development bioassay are presented in Table 11.

The endpoint results for the larval development bioassay in the test sediment was 85.1 mean percent normal survival when compared to reference sediment. The test sediment passed both the Sediment Cleanup

Objective (SCO) and Cleanup Screening Level (CSL) criteria defined by Ecology (Ecology 2021).

5.3.5 Amphipod Mortality

The amphipod mortality tests were initiated on January 13, 2023, using the test organism (*E. estuarius*) obtained from Northwest Amphipod (Newport, OR). The results of the amphipod mortality bioassay are presented in Table 12.

The mean amphipod mortality was 11.0% (± 8.2) mortality for the test sediment. The test sediment passed both the SCO and CSL criteria.

5.3.6 Juvenile Polychaete Growth

The juvenile polychaete growth tests were initiated on January 13, 2023, using the test organism (*N. arenaceodentata*) obtained from Aquatic Toxicology Support, Bremerton, WA. The results of the juvenile polychaete growth bioassay are presented in Table 13.

The endpoint result of the juvenile polychaete growth bioassay was 0.704 mean individual growth (mg/individual/day, ash-free dry weight) for the test sediment. The test sediment passed the SCO and CSL biological interpretive criteria for the juvenile polychaete growth test.

5.3.7 Summary of Bioassay Results

Water quality measurements, negative controls, positive controls, and the reference sediment passed the performance criteria for the three biological tests performed for this investigation. The test sediment passed the SCO and CSL biological interpretive criteria for all three bioassays. Based on the results of the biological testing conducted for this investigation the sediment represented by the sample DM-19-S are not considered to exhibit toxic effects to benthic receptors.

6.0 BEACH GEOMORPHOLOGY EVALUATION

This section presents a summary of previous studies related to the shape and stability of the intertidal beach as well as a geomorphic assessment of the beach performed by Herrera as a part of the present study. This summary is particularly focused on the stability of the restored beach and sediment cap from impacts due to pile field removal.

6.1 Summary of Previous Studies

Mott MacDonald performed a series of studies to assess the risk of additional erosion and release of COCs associated with pile field removal (Mott MacDonald 2020, 2021). The assessment was performed in two phases: Phase 1 was qualitative by design and presented an initial opinion on how pile field removal might affect the risk and level of potential contaminant spread outside the study area as well as the risk for potential impacts to the beach; Phase 2 built on the findings on Phase 1 and sought to better quantify the potential movement of COC-laden sediments and potential impacts to the adjacent tideland and shoreline properties following pile field removal. Key elements from these studies related to the potential for beach impacts from pile field removal include the following:

- A site reconnaissance visit and confirmatory survey data analysis describe the intertidal beach in the lee of the pile field as having a convex shape. The planform beach shape was interpreted to be an indication that the pile field may be providing wave attenuation in the nearshore. A Conceptual Site Model (CSM) with the pile field functioning as a “breakwater” indicated the risk that un-attenuated waves post removal might cause adjustment of the intertidal shoreline profile (Mott MacDonald 2020).

- Hand-dug test pits suggested the existing beach above MLLW may already be adjusting in response to storms since installation of capping material in 2000 (Mott MacDonald 2020).
- The tidal channel berm behind the convex beach area appeared to be narrower than adjacent areas. The risk for breach of the berm from pile field removal was determined to be low and increased for some sea level rise (SLR) scenarios (Mott MacDonald 2020).
- Beach profile readjustment from pile field removal was simulated using a 1-dimensional application of the XBeach-G numerical model. Using boundary conditions data taken from the larger-scale site transport models, a reduction factor was used to scale wave energy transmission through the pile field to the beach and compare with the post-removal scenario run with full incident wave heights. The simulated difference in beach profile readjustment was determined to be negligible for most storm conditions, with a 0.3-foot maximum difference in bed elevation change associated with rare extreme events (Mott MacDonald 2021).

Findings from the Mott MacDonald studies were considered as part of the Geomorphic Assessment performed by Herrera for the present study. The specific elements summarized above were directly considered for the assessment, with the exception of the tidal channel berm behind the restored beach which was determined to be at low risk of breach.

6.2 Geomorphic Assessment

A qualitative geomorphic assessment was performed by Herrera to evaluate the risk of endangering the restored beach sediment cap due to the potential for increased wave transmission to the beach following pile field removal (Herrera 2023, Appendix H). The emphasis and approach of the assessment were slightly different than previous work in that the mobility of the intertidal cap and how that may be affected by removal of the piles was examined in detail using direct observations of conditions and past geomorphic activity in intertidal areas. The assessment included an evaluation of existing modeling and documentation of wave conditions at the site, and an analysis of past geomorphic change at the site to determine the relative risk of cap loss and erosion. A site visit was conducted to observe wave transmission through the pile field during a northerly wind event, and test pits were excavated to examine the stratigraphy of capped and uncapped areas of the beach.

6.2.1 Assessment of Previous Work Applied to the Cap

Several key elements of the Mott MacDonald studies were examined as part of the geomorphic assessment performed by Herrera: (1) the pile field's potential role as a breakwater as shown in the CSM; (2) the simulation of wave energy transmission through the pile field; and (3) the simulation of beach profile readjustment using the 1-D application of the X-Beach G model. The examination of these elements is summarized as follows:

1. The idea that the pile field is functioning as a breakwater in the CSM is based on the convex planform shape of the beach. This general shape is typical for beaches adjacent to breakwaters found elsewhere in Puget Sound. However, it is unclear how past fill or other activities associated with the construction and operation of the mill may have contributed to the existing beach shape. It is uncertain how the current morphology of the beach is related to wave attenuation by the pile field as opposed to other factors.

2. The SWAN model used to simulate the wave field for the site is unable to accurately simulate closely spaced pile groups. Instead, an empirical model of transmission through the pile field was used to simulate wave energy arriving at the beach (Truitt and Herbich, 1986). For the stated purposes of the study and general consideration of effects at the site, Mott MacDonald's model is adequate. However, the wave field within and onshore of the pile field is highly simplified. Of particular concern is the actual wave attenuation during typical storm waves aligned parallel to the rows of pilings, and the assumptions made to arrive at the transmission efficiency that continue to change as the pile field degrades.
3. The 1-D application of the XBeach-G model used to predict beach profile readjustment under the post-removal scenario was based on wave energy transmission as detailed above. It is unclear how much wave energy the pile field is actually attenuating during northerly storm events. The model simulations used standard inputs of bed material based on design drawings for the restored beach rather than actual grainsize distribution from samples, and some of the physical processes associated with sediment transport when coarser material is present are largely missing from the model (*e.g.*, armoring). Considering the uncertainty in the input parameters and limitations of the model itself, the difference in simulated profile readjustment for the pile removal scenario may be inconclusive. Regardless, the maximum simulated differences reported by Mott MacDonald were negligible under normal storm conditions, and only approached 0.3 feet during 50-year storms.

6.2.2 Site Observations

The geomorphic assessment included a Site visit during a negative tide on February 14, 2023. The visit coincided with a period of sustained winds up to 8 mph from the north which allowed for a qualitative assessment of wave transmission through the Dense Pile Field. Four test pits spanning the entire length restored beach at an elevation of approximately +2 ft MLLW were excavated approximately 1–2 feet deep to examine geomorphic processes occurring near the base of the sediment cap at 0 feet MLLW. Historical aerial images of the site were also reviewed to determine that the beach has not significantly changed position since the placement of the cap in 2000–2001.

Observations of wave conditions during the site visit revealed that wave heights were not significantly reduced by the pilings, and that the maximum fetch and orientation of wave propagation were aligned with the piling rows. The observations further suggested that the orientation of the rows of pilings may play an important role in transmitting wave energy to the beach during storms. Although wave measurements were not made, wave transmission through the piles was estimated to exceed the 75% transmission efficiency used in the X-Beach G model simulations performed by Mott MacDonald (2021).

Beach conditions at the test pit locations revealed that cap material was not generally apparent from the surface, though some patches of gravel/cobble interpreted to be part of the cap could be seen along the beach. The beach surface was dominated by sand in most areas and cap material was obvious less than a few inches below the surface at the two central test pits. The bottom of the cap was not reached at either of the test pits (*i.e.*, cap material was present at the bottom of the pits), which was inconsistent with reports that cap thickness was as thin as 6 inches in some areas (Mott MacDonald 2020). Shell hash mixed with beach sand was found mixed into the cap material at the two central pits, indicating that the cap material is occasionally marginally mobile during large storm events and is consistent with the beach modeling predictions for very large storm events (Mott MacDonald, 2021). Cap material was not encountered at the westernmost test pit location, but was likely present below the bottom of the test pit as this location was generally finer grained than the other locations and interpreted to be depositional.

6.3 Geomorphic Assessment Findings

The geomorphic assessment prepared for this study did not find significant evidence that the present and predicted future condition of the Dense Pile Field would function as a breakwater for the restored beach. Observations derived from aerial photographs and supported by the beach test pit excavations support the conclusion that the cap has remained relatively stable since its construction, though may be subject to partial mobilization during large storms. The continued presence of the sediment cap without significant erosion, two decades after placement, and apparent minimal protection the pile field suggest the piles can be safely removed without causing significant erosion of the cap or other parts of the shoreline.

7.0 DISCUSSION

In this section, results of the benthic habitat and sediment chemistry analyses are discussed in the context of DNR's objective of full piling removal and the potential need for a full RI/FS investigation for sediment cleanup following piling removal. First, potential ongoing leaching of creosote from remnant pilings, and its impact on benthic organisms, is discussed. The presence and potential deleterious impacts of accumulated wood debris on benthic habitat quality is then evaluated following Ecology's Wood Waste Cleanup guidance for implementing the cleanup provisions of the SMS (Ecology 2013). The widespread presence of dioxins/furans in sediment across the Site is then discussed. Dioxin/furan contamination at the Site is compared to concentrations observed across Puget Sound and likely sources of the dioxins/furans are evaluated. Finally, observed arsenic concentrations in excess of SMS criteria along the Beach are reviewed and potential for movement of on-shore arsenic into the subtidal environment following piling removal is addressed.

7.1 Creosote Impacts

The approximately 1,000 pilings remaining at the Dickman Mill site are known to have been treated with creosote, a type of heavy oil used commonly for wood preservation, particularly for the preservation of marine pilings. Creosote is a "heavy" oil that is predominantly concentrated in HPAHs compared to LPAHs. Creosote-treated material is a concern for benthic habitat quality since creosote can continue to leach from treated wood for many decades. During sediment sampling by DNR in 2015, evidence of creosote was observed in the form of sheen within surface sediment collected from 5 of 10 locations across the Site (Figure 26). NewFields personnel also noticed oil residue during sediment core recovery at station DM-11 in the Eastern Pile Area during sampling efforts for the current study (Figure 26).

Chemical evidence of creosote contamination was spatially limited to four sediment samples that exceeded SMS criteria for HPAH—two subsurface samples at DM-08 and DM-11 and two surface samples at DM-20 and DM-19-S. Surface sediment from DM-19-S, sediment that also exceeded SQS criteria for mercury, underwent bioassay analysis and showed no ill effects on larval development, amphipod mortality, or juvenile polychaete growth. Bioassay analysis was unable to be performed on sediment from stations DM-08, DM-11, and DM-20 due to sediment volume limitations. Future targeted surface sediment sampling for bioassay testing following piling removal would aid in confirming that sediment associated with high HPAH concentrations do not impose deleterious impacts on benthic organisms.

7.2 Wood Waste Cleanup Evaluation

Although wood debris is naturally occurring in many aquatic environments, the introduction of large volumes of wood debris can overwhelm the assimilative capacity of the sediments, potentially harming the environment (Ecology 2013). The SPI and PV imaging survey conducted at the Dickman Mill sediment site provided information on the distribution and amount of wood debris present in the system and its impact to the benthic habitat. In Washington State, studies cited in Ecology (2013) suggested that 20 percent or more wood waste by volume could have a negative impact on the benthic community. The impact can come from three parameters:

1. Physical presence of wood waste, which prevents biota from living in a healthy substrate
2. Decreased dissolved oxygen due to microbial decomposition
3. Decomposition by-products such as sulfides, ammonia, and phenols, which can cause or contribute to toxicity

The SPI imaging conducted at the Dickman Mill site documented the presence of wood debris 20 percent or greater (by SPI image area) at six locations across the site. However, at each location, Stage III benthic infaunal organisms were observed living in sediments and apparent RPD depths were comparable to other nearby locations where wood debris was less or absent. Thus, the presence of wood debris at volumes that might cause concern (20 percent or greater) does not appear to be having a significant negative impact to the benthic community at the Dickman Mill site. The nature of the wood debris, aided by the currents and water exchange in the area, is such that the wood debris does not appear to smother established benthic organisms nor prevent other flora and fauna from colonizing the sediment.

As presented in Section 5.1.3, the range of apparent RPD depths measured at the Dickman Mill site (2.0 to 2.5 cm) was considered typical for a nearshore subtidal region comprised of sands with periodic bottom disturbances from waves and currents. High apparent RPD contrasts, which can provide an indication of high SOD in sediments, were not apparent at locations where wood debris was present. The presence of wood debris (and potential microbial decomposition) does not appear to be a significant source for decreased dissolved oxygen in Dickman Mill sediments.

Chemical analysis of surface sediments collected as part of this investigation measured elevated concentrations of total sulfides at some locations, which is likely attributed to the degradation of wood debris. The elevated concentrations of sulfides likely contributed to the presence of *Beggiatoa* observed at the Dickman Mill site. *Beggiatoa* is a chemosynthetic bacterium and oxidizes hydrogen sulfide as an energy source (Ecology 2013). However, the presence of elevated sulfides and surface patches of *Beggiatoa* bacteria was not correlated with degraded benthic habitat at the site. At the locations in the piling field where patches of *Beggiatoa* were observed in PV imaging, co-located SPI images showed the presence of Stage III organisms and apparent RPD depths were similar to other stations within the piling field.

The presence of Stage III organisms and relatively well-developed apparent RPD depths in Dickman Mill sediments suggests that the presence of wood debris is not having a significant impact on benthic habitat quality. The site is open to Commencement Bay and benefits from the wave action, nearshore currents, and water exchange that maintains dissolved oxygen levels near the seabed with periodically disturbance of the surface sediments. Planned removal of the pilings will significantly reduce the source of wood debris to Dickman Mill sediments and will likely improve the benthic habitat quality across the site.

7.3 Dioxin/Furan Source Assessment

Federal and State environmental regulatory and health agencies are interested in dioxins/furans due in part to the known toxic effects of their bioaccumulation in humans and other mammals and potential toxic effects of their bioaccumulation in other wildlife. Once released into the environment, dioxins/furans resist degradation, do not dissolve in water, and adhere to particles such as sediment, soil, and dust. This means that they are persistent and can be measured in the environment long after they have been released. Dioxins/furans can enter the environment from a variety of sources. Except for small quantities used in research, neither compound is created intentionally. Instead, dioxins/furans are byproducts of chemical manufacturing (*e.g.*, pentachlorophenol [PCP] and polychlorinated biphenyls [PCB]) and combustion or incineration processes involving chlorine compounds. For example, dioxins/furans can be produced during incineration of salt-laden wood such as logs transported via log rafting or stored in log ponds within salty water bodies such as Puget Sound.

Sediment Management Standards (WAC 173-204) do not include numeric criteria for protection of the benthic community for individual dioxin and furan congeners or total dioxin/furan TEQ. However, Ecology has identified a natural background sediment dioxin/furan threshold value of 4 ng/kg TEQ for all of Puget Sound that is used for a site hazard assessment and to establish a sediment cleanup objective (Ecology 2021) (Table 14). Different regions within Puget Sound may have a unique natural background dioxin/furan threshold value and this regional background value, if available, may be used to establish a cleanup screening levels for a sediment site within the same region (Ecology 2018a). Regional background threshold values have been established for total dioxin/furan in South Puget Sound (19 ng/kg TEQ), North Olympic Peninsula (5.0 ng/kg TEQ), and Bellingham Bay (15 ng/kg TEQ) (Ecology 2018a, Ecology 2016, Ecology 2015) (Table 14). No regional background values for dioxins/furans have been established for Commencement Bay or other areas of central Puget Sound.

Total TEQ values measured in Dickman Mill sediments range from 1.63–85.6 ng/kg and surface sediments alone range from 5.68–72.3 ng/kg TEQ, or up to 18 times greater than natural background. In other words, every surface sediment sample analyzed for dioxins/furans exceeded the natural background threshold for total dioxin/furan TEQ, regardless of location, and many surface sediment samples exceeded the South Puget Sound and Bellingham Bay regional background threshold values.

Since no regional background threshold value exists for Commencement Bay, surface sediment dioxin/furan data collected within Commencement Bay were reviewed for comparison with Dickman Mill dioxin/furan values. Few dioxin/furan data points exist for sediments within Commencement Bay. Two surface sediment samples collected by DNR in 2015 less than one mile northwest of the Site had a dioxin/furan Total TEQ of 3.5 ng/kg and 0.5 ng/kg, both well below natural background for Puget Sound (Figure 27). The two surface sediment samples collected approximately 50 feet offshore of the pile areas had moderate concentrations of total dioxin/furan TEQ concentrations (12 ng/kg at DM-12 and 13 ng/kg at DM-19) within the lower range observed within the pile areas (5.68–72.3 ng/kg). Dioxins/furans found at these two Outside Pile Area locations likely originated from the Site and do not represent local offsite background conditions. It is possible that regional background concentrations in the vicinity of Dickman Mill are elevated over natural background in Puget Sound from the numerous lumber mills that once operated along Ruston Way from the 1880s to the early 1900s (Tacoma Historical Society 2021).

Two potential sources of dioxins/furans associated with Dickman Mill operations include a hog fuel burner that operated on the site for electricity generation beginning in 1926–1927 and a structural fire that engulfed several upland buildings in 1978. Historical documents do not indicate that common dioxin-containing wood preservation chemicals, such as PCP, were ever applied to wood materials produced at the Site or present in any over-water structural wood, such as wharf deck planks. Despite the lack of documentation, PCP was detected in several samples at the Site.

PCP has been identified as a common dioxin/furan source in sediments at several active cleanup sites in Puget Sound including Port Angeles, Budd Inlet, and Oakland Bay (NewFields et al. 2013, NewFields 2015, NewFields 2014). Additional dioxin/furan sources common at these cleanup sites include combustion and, when present, PCBs. No PCBs are present in the intertidal or subtidal sediments at the Dickman Mill Site (Hart Crowser 2000); however, PCP and combustion are likely sources of dioxins/furans in Dickman Mill sediments due to the positive detection of PCP in Site sediments and the historical use of a hog fuel boiler for energy production at the former Mill.

Common dioxin/furan sources in Puget Sound, including PCB mixtures, PCP, and hog fuel boiler ash produce distinct yet variable mixtures of the 17 dioxin/furan congeners that comprise the Total TEQ. The abundance of these congeners relative to each other is known as a congener profile, or more simply, a dioxin/furan fingerprint. An example of the distinct variation in congener contribution to overall TEQ is shown in Figure 28, where three typical congener profiles are presented for comparison to the Dickman Mill profiles. To allow interpretation of the differences in congener fingerprints, raw congener concentrations are scaled by relative toxicity using the TEF values presented in Table 4. The TEF-scaled values for each sample were summed to obtain Total TEQ concentrations. Because forensic evaluation is concerned with the relative enrichment of congeners in one sample versus another rather than the TEQ magnitudes across sources and samples, the 17-congener profiles for samples were normalized by dividing each congener component by the sample total TEQ. The resulting values represent the fractional contribution to total sample TEQ from each congener, with the sum over 17 congeners equal to 1 for each individual sample in the dataset. These TEF-scaled, TEQ-normalized profiles are the congener profiles, or dioxin/furan “fingerprints”, that can be compared to source material profiles.

Congener profiles for each dioxin/furan sample analyzed in this study were compared with congener profiles of typical source materials including 1) a commercial PCB Aroclor® mixture, 2) PCP, and 3) hog fuel boiler ash (Figure 28) to aid in elucidating likely sources of dioxins/furans to Dickman Mill sediments. Congener profiles of the highest TEQ samples are most consistent with a PCP-dominant mixture of dioxins (Figure 29). This is apparent in the enrichment of two dioxin congeners most consistent with PCP—1,2,3,6,7,8-hexachlorodibenzo-p-dioxin (1,2,3,6,7,8-HxCDD), and 1,2,3,4,6,7,8-heptachlorodibenzo-p-dioxin (1,2,3,4,6,7,8-HpCDD)—and the absence of a significant contribution of furans. The lowest TEQ samples have dioxin/furan profiles consistent with a combustion source consistent with hog fuel boiler ash, as indicated by the enrichment of the low molecular weight congener 1,2,3,7,8-pentachlorodibenzo-p-dioxin (1,2,3,7,8-PeCDD) and relatively little-to-no contribution from high molecular weight dioxin congeners or furans.

It is unlikely that marine pilings would have been treated with PCP since, unlike creosote, PCP is not a chemical treatment appropriate for in-water wood preservation. However, it is possible that operations at the facility included treatment of wood with PCP, and likely possible that overhead decking planks used for the wharf and pier were treated with the chemical preservative. This decking has been in a state of continued degradation since the Dickman Mill ceased operations in 1978, with planks presumably falling into the water below. It is also possible, if slightly less likely, that pilings were first treated with PCP before being designated for in-water use and treated with an outer coating of creosote.

Across the dataset, dioxin/furan TEQs do not correlate with organic matter measured as TVS or TOC. Samples with the highest TOC concentrations are associated with TEQs of less than 20 ng/kg and present congener profiles consistent with hog fuel boiler ash (Figure 29). Samples with high Total TEQ at greater than 30 ng/kg contain low TOC at less than 15%. The presence of wood in samples is not strongly correlated with increased TEQ, indicating that PCP is not ubiquitous in the wood waste at the Site and dioxin/furan TEQ values greater than Puget Sound background are not due solely to a local PCP source at the Site. However, PCP is a dominant contributor to high TEQs across the Site, including in the highest TEQ locations within the Dense Pile Field (DM-17 and DM-20) and in the Eastern Pile Field (DM-11).

7.4 Arsenic in Beach Material

PAH and metals contamination, specifically arsenic, was found in surface sediment along the beach during

RI sampling in the late 1990s (Hart Crowser 2000). Remedial activities conducted in 2000 and 2001 included full removal of the upper 1 ft of sediment along the beach face and replacement with 1 ft of gravel cap material. Verification sampling of a limited area of the beach face evidenced no COC concentrations above screening criteria following remedial activities.

In November 2022, each of the four surface samples collected along the Intertidal Beach contained arsenic concentrations between 1.5 and 2.5 times greater than the SQS screening level of 57 mg/kg DW. Arsenic is a common contaminant in soils within Pierce County where nearly a century of arsenic-laden slag and emissions emitted from the Asarco lead and copper smelter in Ruston resulted in a “plume” of arsenic-contaminated surface soils spanning more than 1,000 square miles (Ecology 2018b) (Figure 30). Dickman Mill is located within the arsenic plume and positioned less than 3 miles southeast of the former Asarco, and is one of several beach areas along the western shoreline of Commencement Bay with arsenic concentrations exceeding cleanup criteria.[6] Though the Dickman Mill beach sediments contain arsenic contamination at levels consistent with other beaches located within the Asarco plume, beach sediments have undergone prior remedial action and arsenic concentrations are expected to be in compliance with SMS criteria in the absence of renewed or ongoing contamination.

Observations made during and following sampling activities as part of this investigation confirmed the presence of gravel and sand in approximately equal proportion to a depth of at least 1 ft. One potential pathway for recontamination of cap material with arsenic is remobilization of buried arsenic contamination below the initial removal action (*i.e.*, buried deeper than 1 ft below ground surface) via mixing. It is unknown whether metals contamination persisted beneath the 1 ft gravel cap emplaced in 2000/2001. The approximately equal proportion of sand and gravel in three of the four sampled stations indicates mixing of sand with the cap material over time in the high energy intertidal portion of the beach. Another potential pathway for arsenic recontamination is longshore migration of slag from offshore the former Asarco facility to the nearshore sediments of the Dickman Mill site. Slag from the former smelter contained arsenic at concentrations ranging from 100 mg/kg to 24,950 mg/kg and was retained on the upland smelter facility grounds and also disposed in Commencement Bay (EPA 2000, EPA 2018). Cleanup of slag within the sediments offshore the former Asarco facility has not yet begun. Additional sampling of sediments within ± 7 ft MLLW may be warranted to determine the extent of arsenic concentrations within sediment along the intertidal and subtidal nearshore region. Additional study is needed to determine the precise transport mechanism for arsenic contamination in beach sediments and to assess the potential for ongoing contamination.

8.0 CONCLUSIONS

The study provided sufficient data for characterizing the horizontal and vertical extent of wood waste, sediment contamination, and benthic invertebrate habitat within the Dickman Mill site. Low levels of sediment contamination were observed in surface and subsurface sediment samples except for elevated concentrations of HPAHs and dioxins at some locations. A surface sediment sample containing one of the highest HPAH concentrations passed bioassay testing, indicating that the elevated HPAHs do not appear to have a toxic effect on benthic invertebrates. A lack of HPAH impact was supported by benthic activity observed using SPI at the sample location as well as other site locations. The bioaccumulation potential for the moderate concentrations

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[6] For example, the Tacoma Fire Department Marine Security Operations Center (Ecology Cleanup Site ID #12608) and Puget Creek Beach (Ecology Cleanup Site ID #1458), located within 0.5 miles northwest of the Dickman Mill Site, are awaiting cleanup through Ecology’s Toxics Cleanup program for arsenic concentrations in excess of MTCA Method A cleanup levels in soil and sediment, respectively.

of dioxins observed throughout the site was not tested and the extent of dioxin contamination of sediments adjacent to the site is not known.

9.0 RECOMMENDATIONS

It is recommended that the pilings be removed in a timely fashion due to the ongoing piling decay and associated HPAH contamination of sediments. Conducting a remedial investigation/feasibility study (RI/FS) of sediment cleanup actions before piling removal does not appear warranted because the Site is not highly contaminated (Ecology 2021) and piling removal is not anticipated to substantially affect sediment transport because BMPs will be implemented to minimize sediment suspension and offsite sediment transport. It is recommended that an RI/FS be conducted following the piling removal to evaluate potential sediment cleanup action alternatives and guide the selection of any further potential cleanup action for the Dickman Mill Site.

9.1 Piling Removal

Removal of the approximately 1,000 creosote-treated timber pilings remaining in the intertidal and nearshore areas of the Site would eliminate ongoing releases of piling-associated contaminants to the sediments and overlying waters. The pilings are derelict and no longer in use. Removal of the pilings should follow best management practices (BMPs) consistent with guidelines provided by the Environmental Protection Agency (EPA 2016), DNR (DNR 2017), Ecology (Ecology 2021), and Washington Hydraulic Code Rules administered by the Department of Fish and Wildlife (WDFW 2022).

9.1.1 Pile Removal Methods and BMPs

Piles should be removed by an experienced contractor using the vibratory hammer method wherever possible. The selected contractor should submit a detailed Work Plan to the Ecology project manager that describes all BMPs to be used including equipment, sequencing, methods, and procedures for containment and disposal.

The vibratory hammer method utilizes a vibratory hammer suspended from a crane by a cable. It is expected that this method would be effective at removing nearly all pilings because the diver survey identified that more than 90 percent of the pilings are in good condition with no major areas of degradation (DNR 2022) (Figure 31). There is some debris throughout the Dense Piling Field that could present challenges to removal, including underwater cross members, subtidal pilings that are not visible from the surface, as well as metal rebar and wood pieces from former pilings throughout the field. Wood debris ranges in size from short stumps to whole pilings, with some large pieces silted in place on the sediment bed. Debris is present throughout the piling field but becomes more abundant proceeding southeastward across the field (DNR 2022) (see Figure 31).

The vibratory hammer method is recommended over the direct pull and clamshell bucket methods because it typically results in complete removal of the piling and the least disturbance to the bottom substrate. If the pile is too decayed or breaks during vibratory hammer removal, the piling can be grabbed up to 4 feet below the mudline, which may require sediment excavation. If vibratory hammer fails, a piling can be removed by direct pull followed by clamshell bucket and, if necessary, cutting the piling at least 2 feet below the mudline (Ecology 2021) (Figure 32).

Piles should be removed slowly to minimize turbidity in the water column and minimize sediment disturbance. Turbidity levels should be monitored during removal and remain within limits required by the Washington Surface Water Quality Standards (WAC 173-201A):

> Shall not exceed 5 nephelometric turbidity units (NTU) over background (up current) when the background turbidity is 50 NTU or less, or 10 percent over background when the background turbidity is greater than 50 NTU to be measured at the mixing zone boundary located down current at a radius of 150 feet from the piling removal area.

Removed piles should be placed directly and immediately in a containment basin (barge) within a staging area. Because all pilings are located in subtidal sediments (between -2 and -30 feet MLLW), it is assumed that the containment basin will be anchored offshore of the Dense Pile Field. Piles should not be shaken or hosed off to remove attached sediments. All treated wood materials, sediments, and metal debris removed during pulling should be contained along with associated contaminated water in the containment basin.

Floating surface booms should be installed to completely surround the pile removal area that will be equipped with absorbent pads to contain any oil sheens. Figure 33 presents an example of boom and containment barge at the Asarco site (Ecology 2021). Containment booms should remain in place until all sheens have dissipated. Pilings, sediments, and construction residue should be disposed of at an approved Subtitle D Landfill.

9.1.2 Estimated Cost of Piling Removal

Estimated costs for removing and disposing of 1,000 pilings from the Site are presented in Table 15. An engineering consulting firm should prepare a contractor bid package with plans and specifications for piling removal and BMPs, and provide engineering oversight and water quality monitoring to insure pilings are properly removed and do not impact the environment. A piling removal contractor should remove the piles over a period estimated to not exceed 8 weeks, implement the specified BMPs, and properly dispose of all pilings and associated debris. The total cost for piling removal is estimated at $1.5 million, which includes a 30 percent contingency and sales tax.

9.2 Remedial Investigation and Feasibility Study

Following the removal of the pilings, a RI/FS is recommended for the Site and should be developed according to the Sediment Management Standards (WAC 173-204-550). The objectives of the proposed RI would be to:

- Reassess and delineate the horizonal extent of the COCs (HPAHs and dioxins/furans) in the surface sediments after removal of the creosote-treated pilings in the area to evaluate potential effects of piling removal and spatial variability compared to results from this study;
- Evaluate offsite dioxin/furan concentrations northwest and southwest of the Site to support development of a cleanup level appropriate for Site sediments;
- Conduct additional bioassay testing where HPAH concentrations are elevated for comparison to the negative result from this study; and
- Perform dioxin/furan bioaccumulation testing to support development of an appropriate cleanup level.

Based on the results of the RI, the FS will develop and evaluate cleanup action alternatives to guide the selection of any further potential cleanup action for the Site.

9.2.1 Remedial Investigation Work Plan Preparation and Implementation

Prior to conducting the RI, an RI Work Plan (RIWP) would be submitted for approval by Ecology. As part of the RIWP, all available Site characterization data would be reviewed and summarized. Based on the available Site data, a conceptual site model (CSM) would be developed to describe the Site COCs, their sources, releases, transport pathways to sediment, presence in sediment prior to the removal of the Site pilings, and potential exposure pathways to human and ecological receptors. Using the available Site data and CSM, the RIWP would identify any data gaps and propose field investigations for data collection. The RIWP would also propose a schedule for completion of the RI/FS and cleanup action alternatives that are likely to be considered in the feasibility study.

A Sampling and Analysis Plan (SAP) would be included in the RIWP, describing the experimental design, sampling methods and locations, data quality objectives (DQOs), chemical analytical methods, method detection limits, bioassay testing methods, and bioaccumulation testing methods for the evaluation of sediment conditions and biological impacts in the on-site and off-site subtidal areas. The SAP would also include a Quality Assurance Project Plan (QAPP) and Health and Safety Plan (HASP).

For budgeting purposes, it was assumed that the experimental design would include the following elements summarized in Table 16:

- Only surface (0-10 cm) grab samples would be needed for the RI because the coring results collected for this study sufficiently characterized subsurface sediments and piling removal would not substantially change subsurface sediment contamination.
- Surface grab samples would be collected from the 0-10 cm depth interval at 10 locations. Sediment samples from four on-site stations would be analyzed for conventionals, PAHs, and dioxins/furans. Sediment from six stations located beyond the Dickman Mill Site boundary would be analyzed for dioxin/furan concentrations. Sediment samples from six off-site stations would be analyzed for dioxins/furans.
- The four on-site stations would be located within 100 feet of select stations tested for this study to evaluate potential effects of piling removal and spatial variability compared to results from this study.
- On-site locations would be located within an approximately 100-ft radius of select stations sampled as part of the current investigation: DM-11, DM-17, DM-19, and DM-20. Two on-site stations would target high concentrations of total HPAHs (greater than the CSL adjacent to DM-19 and DM-20 near the offshore and near shore portions, respectively, of the Dense Piling Field) and high total dioxins/furans (greater than 20 ng/kg TEQ at DM-17 and DM-20 near the center and nearshore portions, respectively, of the Dense Piling Field). Two on-site stations would target low concentrations total HPAHs (less than the SQS at DM-11 and DM-17 within the Eastern Pile Area and Dense Pile Field, respectively) and high total dioxins/furans (greater than 20 ng/kg TEQ DM-11 and DM-19 within the Eastern Pile Area and Dense Pile Field, respectively).
- The six off-site stations would include three subtidal locations northwest of the Site and three subtidal locations southeast of the Site that include one or more of abundant historical lumber mill sites along the 2-mile length of Ruston Way (*e.g.*, Hanson Ackerson Mill at Jack Hyde Park 1,500 feet southeast of Dickman Mill) (Hartman 2017).

- One reference sediment sample from Carr Inlet would be collected for analysis of conventionals, bioassay testing of three test organisms, and dioxin/furan bioaccumulation testing of two test organisms.
- Bioassay testing of three test organisms (amphipod mortality, larval mortality/abnormality, and juvenile polychaete 20-day growth) would be conducted on four on-site sediment samples identified above and one reference sediment sample from Carr Inlet to verify that locations with elevated HPAHs meet biological benthic criteria and do not require cleanup.
- Laboratory bioaccumulation testing of dioxins/furans with two 45-day tests would include one adult bivalve (*Macoma nasut*a) and one adult polychaete (*Alitta virens* [formerly known as *Nereis virens*], *Nepthys*, or *Arenicola marina*) for four on-site sediment samples identified above and one reference sediment sample from Carr Inlet would support development of a cleanup level for dioxins/furans.
- Field quality control samples would include a field triplicate for conventionals, field duplicate and equipment rinsate and rinsate blank for PAHs, and a field duplicate and Puget Sound sediment reference material for dioxins/furans.

9.2.2 Remedial Investigation and Feasibility Study Report

The RI/FS report would summarize all site data from sediment characterization, bioassays, and bioaccumulation testing following removal of the pilings. The report would refine the CSM, establish sediment cleanup objectives (SCO) and cleanup screening levels (CSL) for each COC in order to establish the sediment cleanup level (SCL), and evaluate any necessary future site cleanup activities. The RI/FS would include the following:

- A Site description and project background and summary of previous investigations
- Methods and results of the investigation work completed under the RIWP
- Updated text, data tables, and figures to present data for the Site
- A description of regional concentrations of COCs for the geographic area
- Establishment of sediment cleanup standards consistent with WAC 173-204-560
- An updated CSM
- Evaluation of sediment cleanup alternatives described below.
- Disproportionate cost analysis (DCA) that evaluates several sediment cleanup action alternatives including a no action alternative
- Feasibility study of the sediment cleanup alternatives
- Cleanup action plan for the preferred cleanup alternative
- Cleanup contractor plans and specifications
- Stakeholder involvement to include agency meetings, public meetings, and preparing project information for websites and factsheets.

Alternative sediment cleanup actions (WAC 173-204-570) may include:

- Dredging and disposal in an upland engineered facility for high levels of sediment contamination
- Dredging and disposal at an approved open-water disposal site approved for high to moderate levels of sediment contamination

- Containment of contaminated sediments in-place with an engineered cap for high to moderate levels of sediment contamination
- Enhanced natural recovery (thin cap) for moderate to low levels of sediment contamination
- Monitored natural recovery for low levels of sediment contamination
  Institutional controls and monitoring.

The report would include an executive summary, conclusions, an evaluation of cleanup action alternatives, and recommendations for the preferred alternative based on the DCA.

9.2.3 RI/FS Planning-Level Cost Estimate

Estimated costs for an environmental consulting firm to conduct a RI/FS are presented for five tasks in Table 17. The total estimated task cost is approximately $380,000, which includes $50,000 for preparing the RIWP, $144,000 for sampling and analysis, $134,000 for preparation of the RI/FS and cleanup action plan, $27,000 for stakeholder involvement, and $29,000 for project management.

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FIGURES

Figure 1. Dickman Mill Site Location

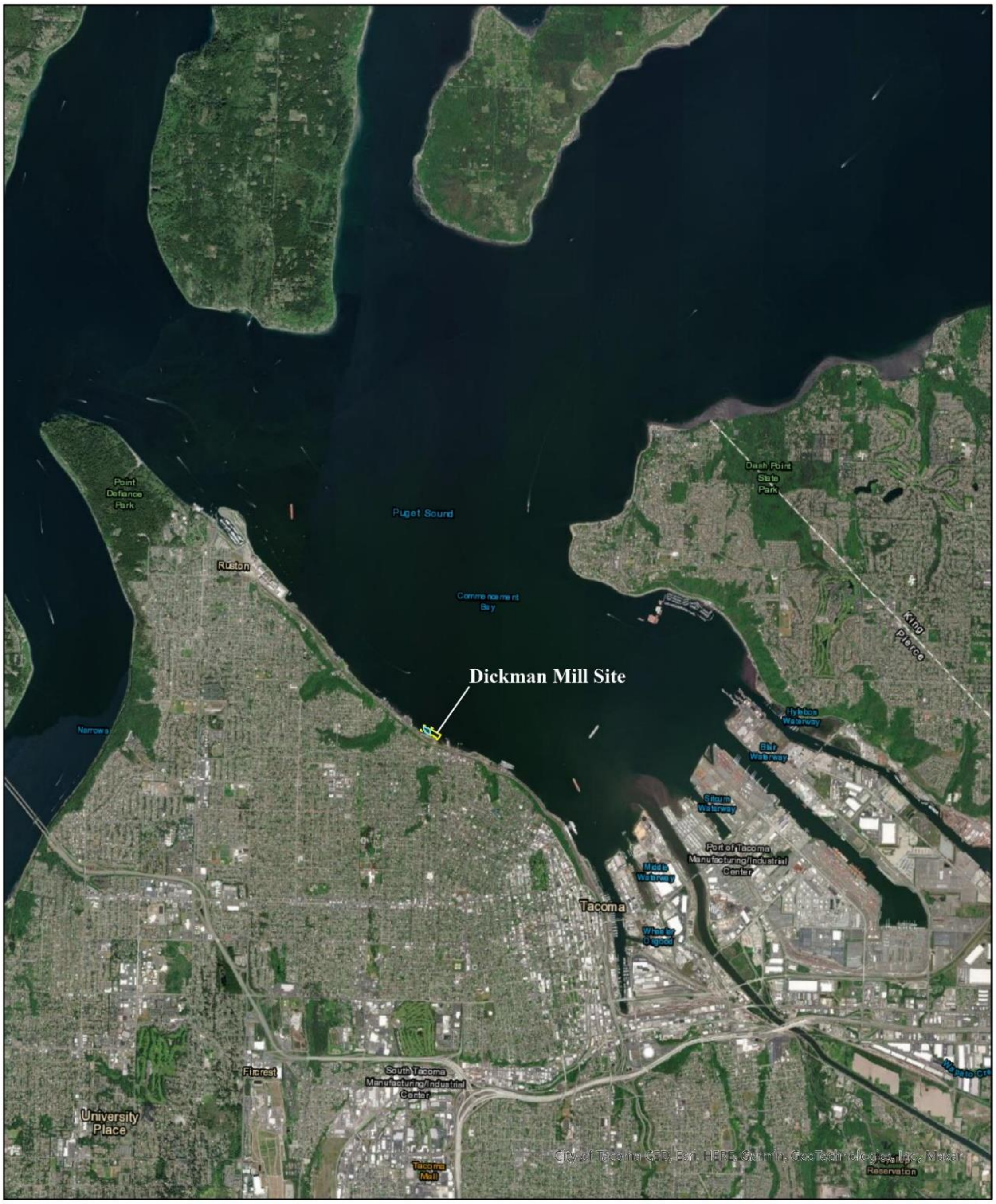


Figure 1: Dickman Mill Site Location

Figure 2.DNR 2015 Ruston Way Sediment Samples within Dickman Mill Site

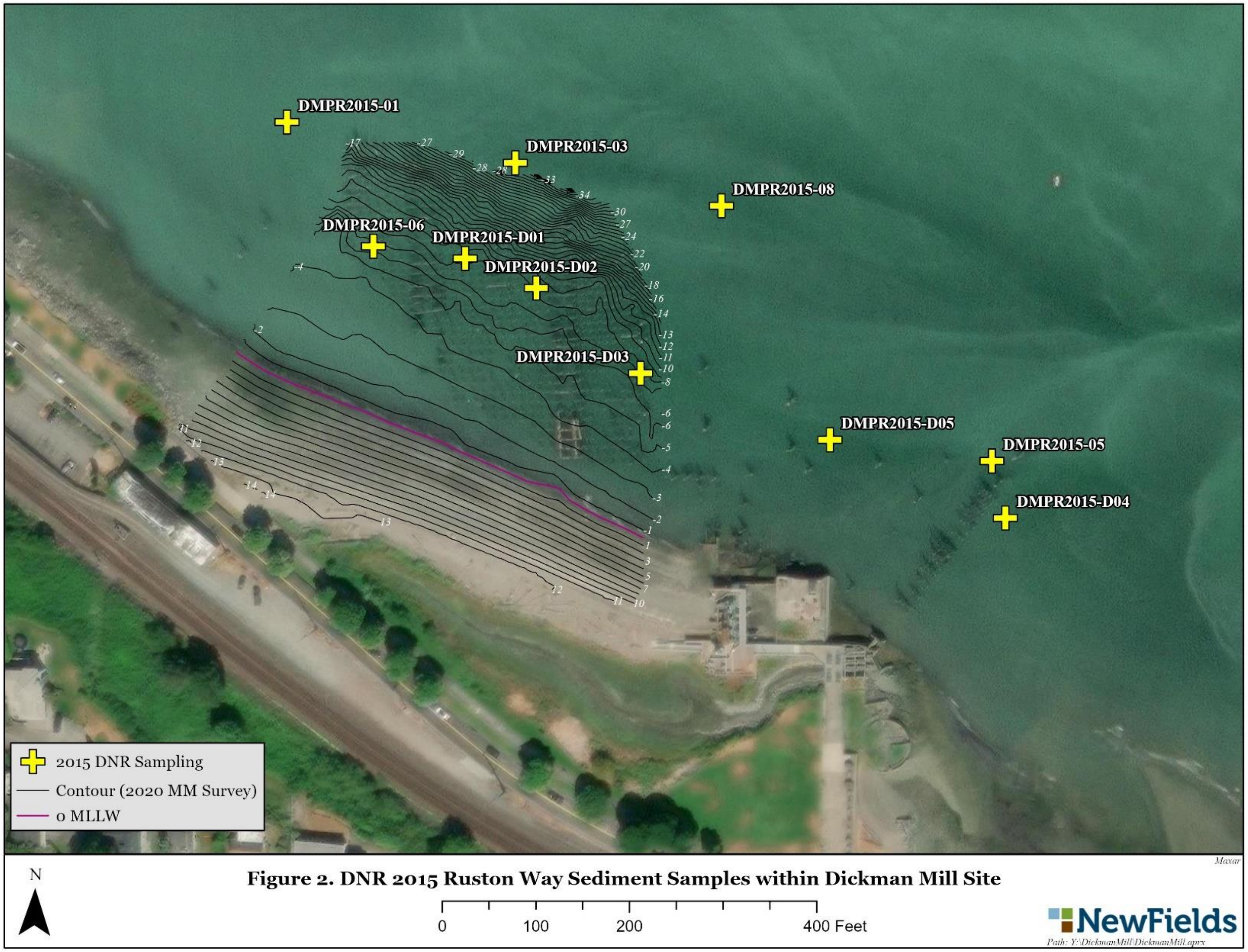


Figure 3.Dickman Mill Study Area Zones

Figure 4. SPI/PV Sampling Locations

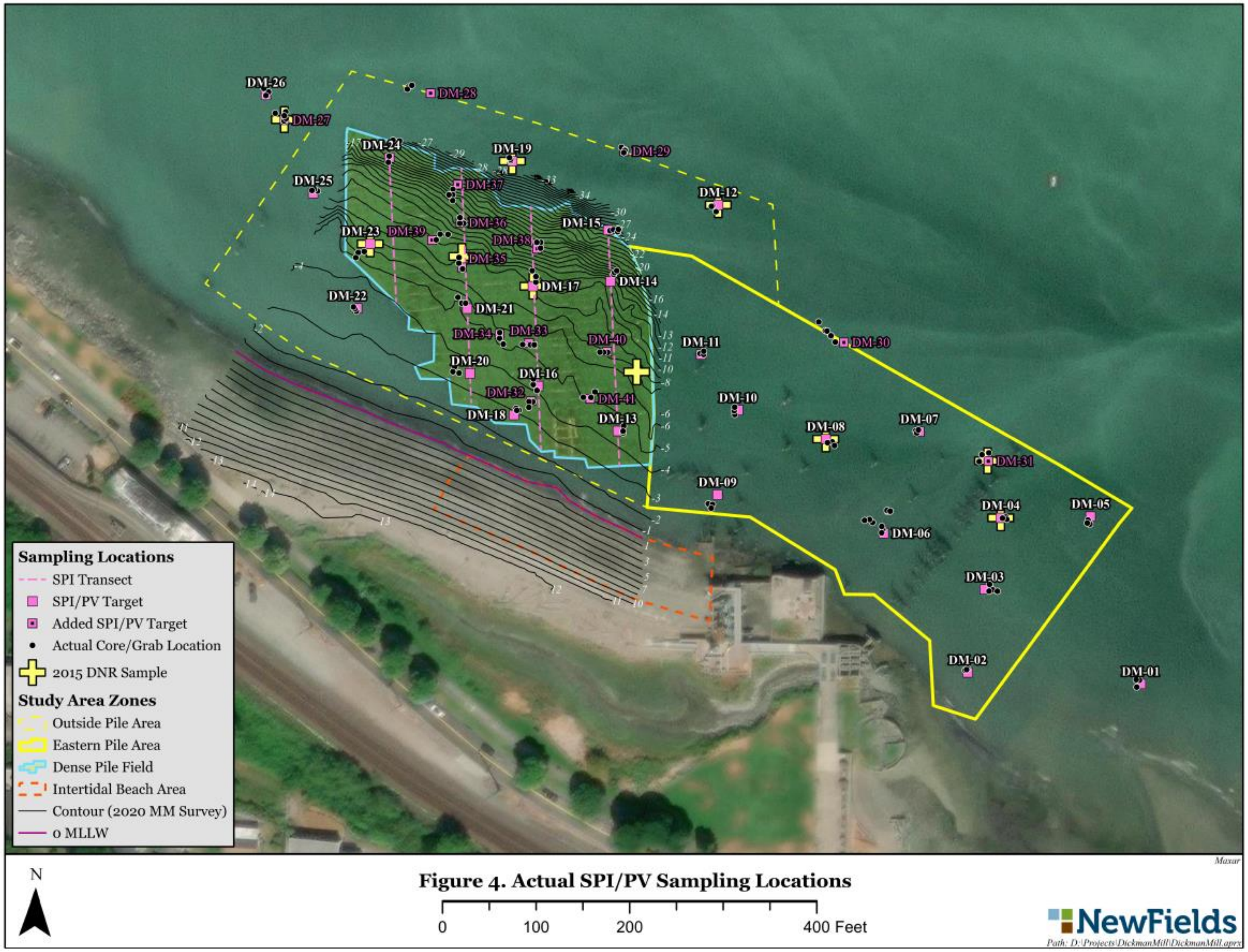
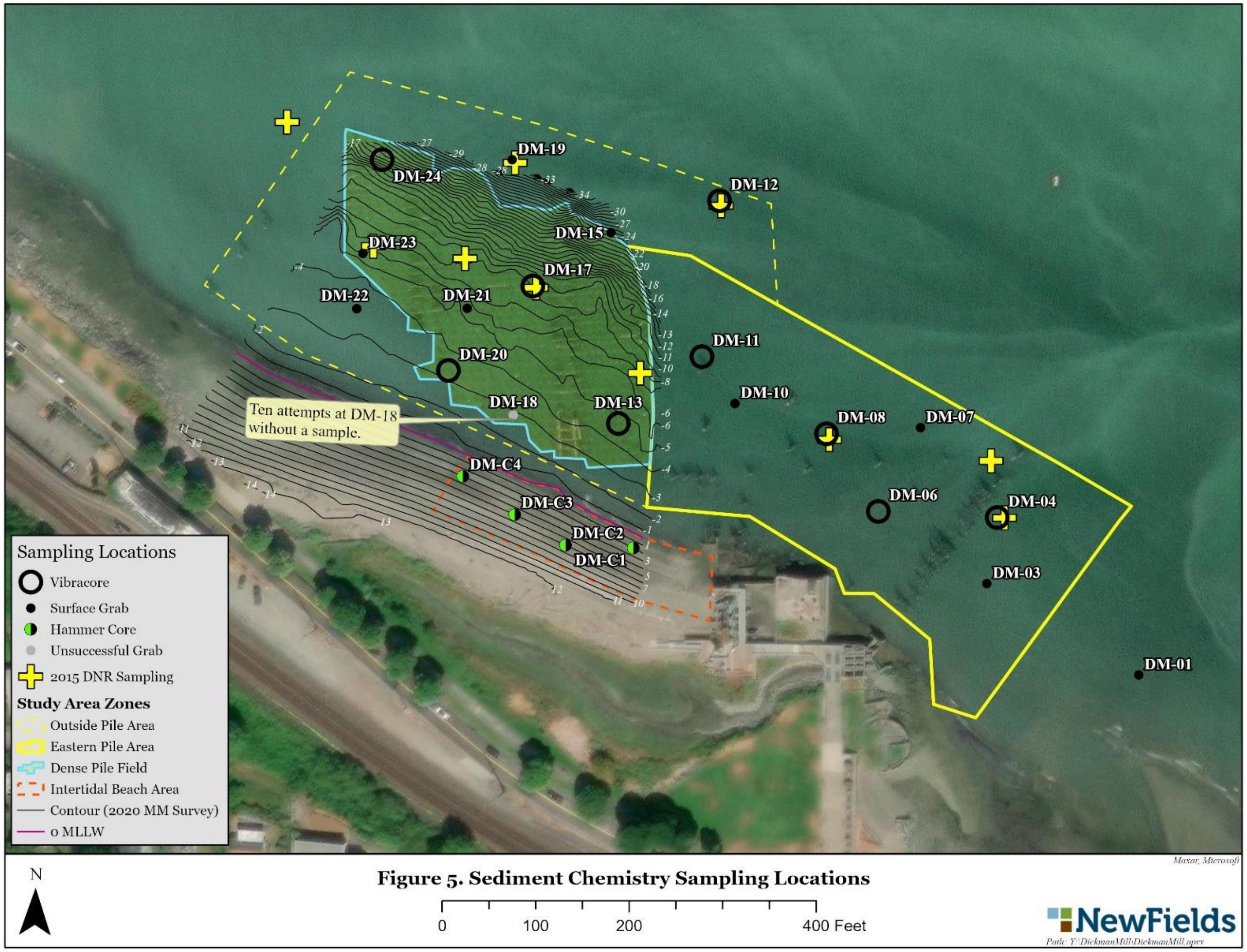


Figure 5. Sediment Chemistry Sampling Locations



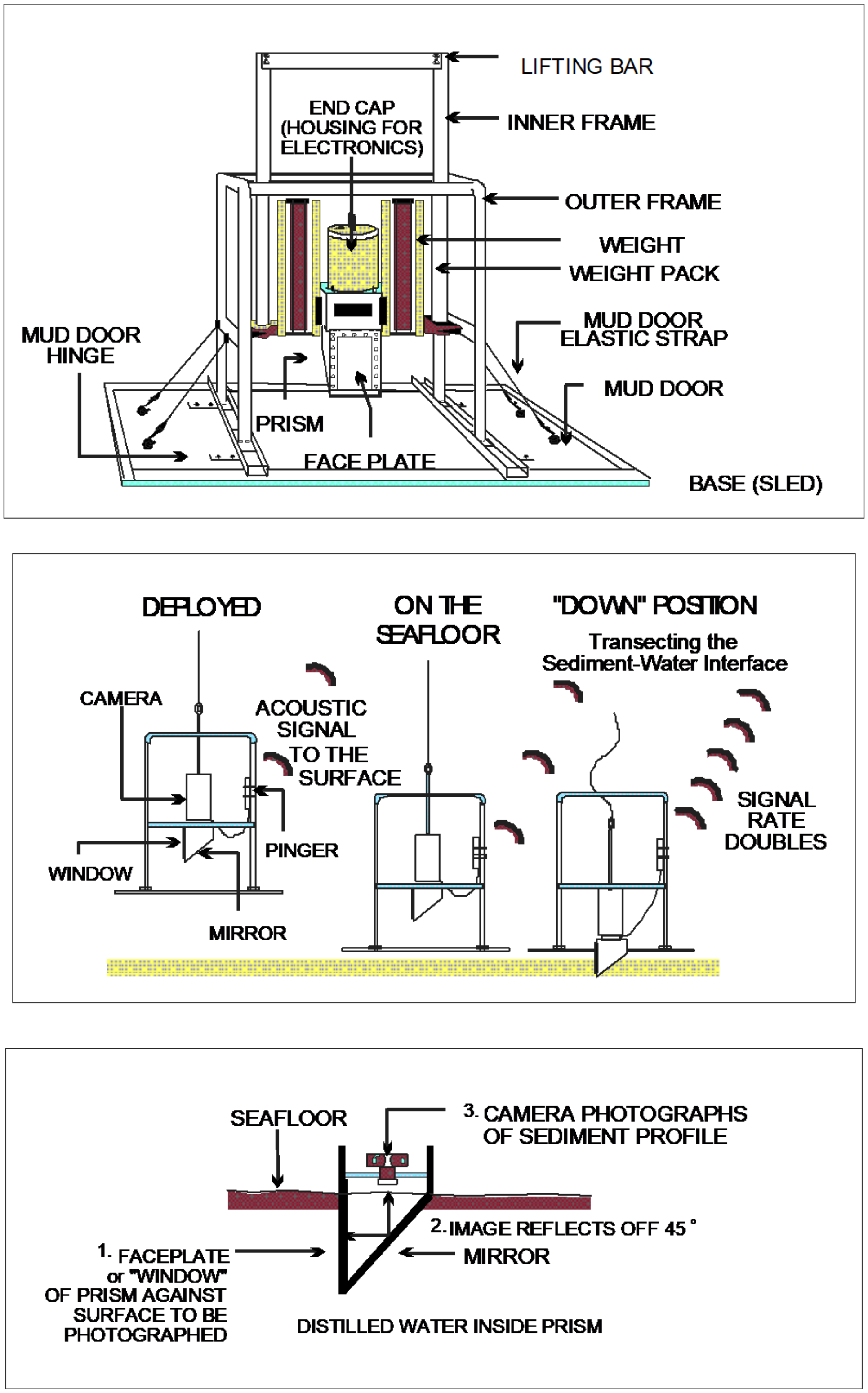


Figure 6. Schematic Diagram of the Sediment Profile Camera and Sequence of Operation on Deployment

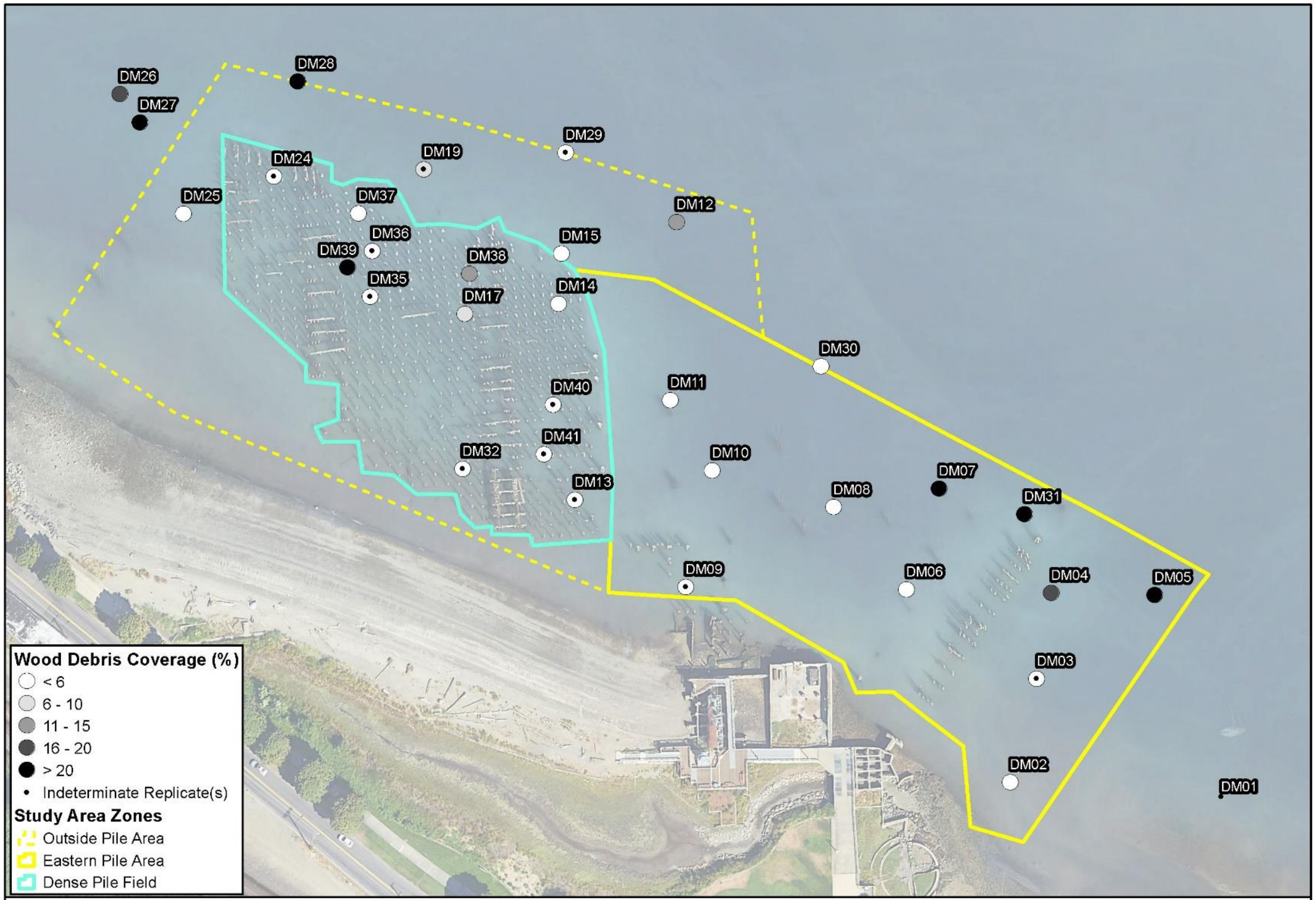
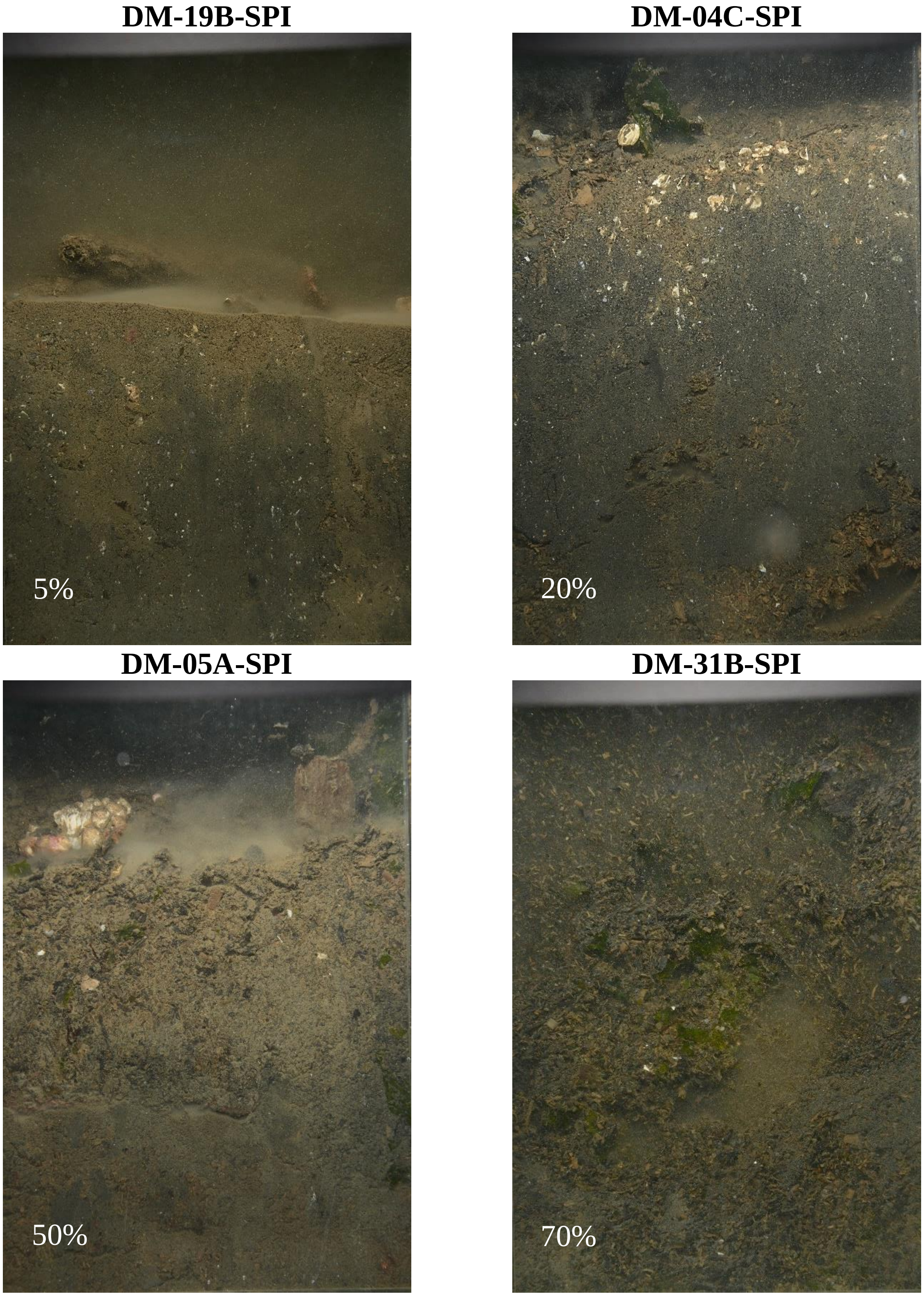


Figure 7. SPI Mean Surface Wood Debris Coverage

NewFields


DM-19B-SPI

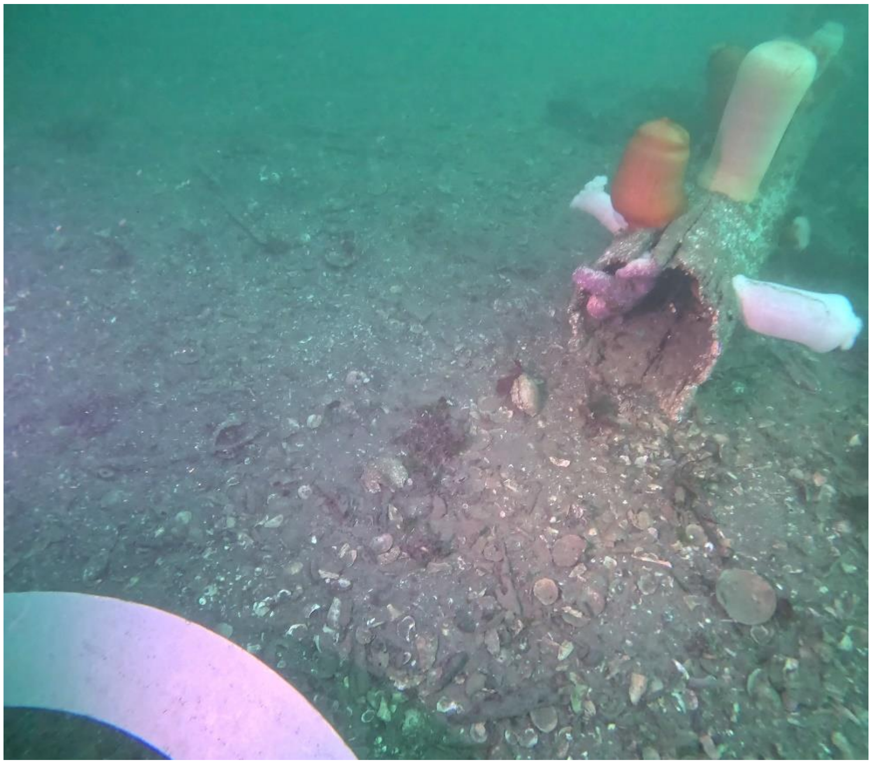
DM-04C-SPI

DM-05A-SPI

DM-31B-SPI

Figure 8. Dickman Mill SPI Images Showing Examples of Percent Wood Debris

DM-19A-PV



DM-36A-PV

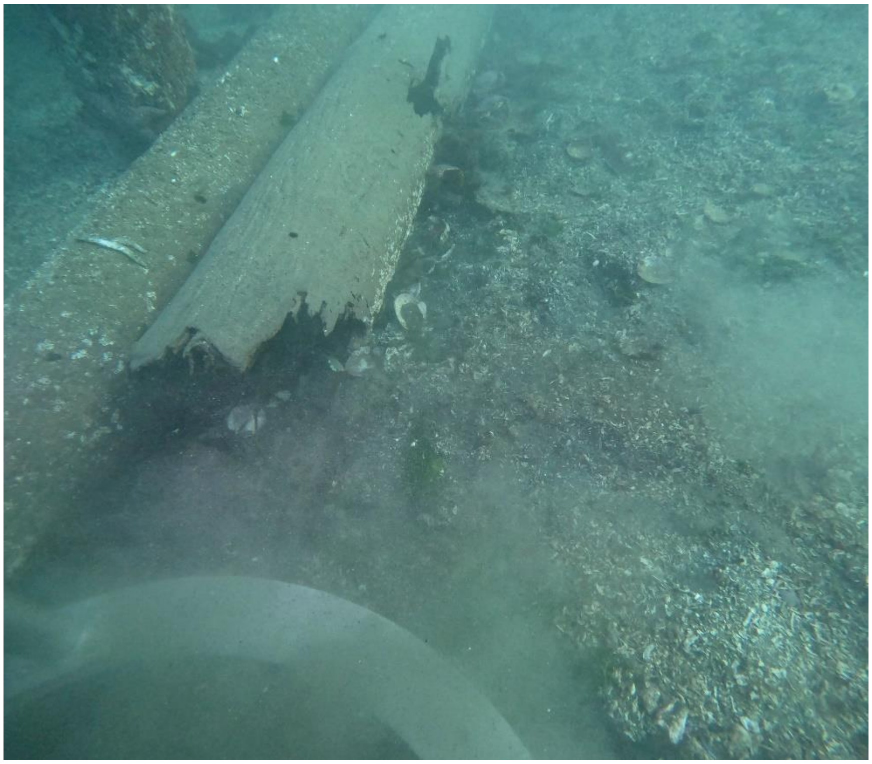


Figure 9. Dickman Mill PV Images Showing Submerged Logs Within or Near the Dense Pile Field

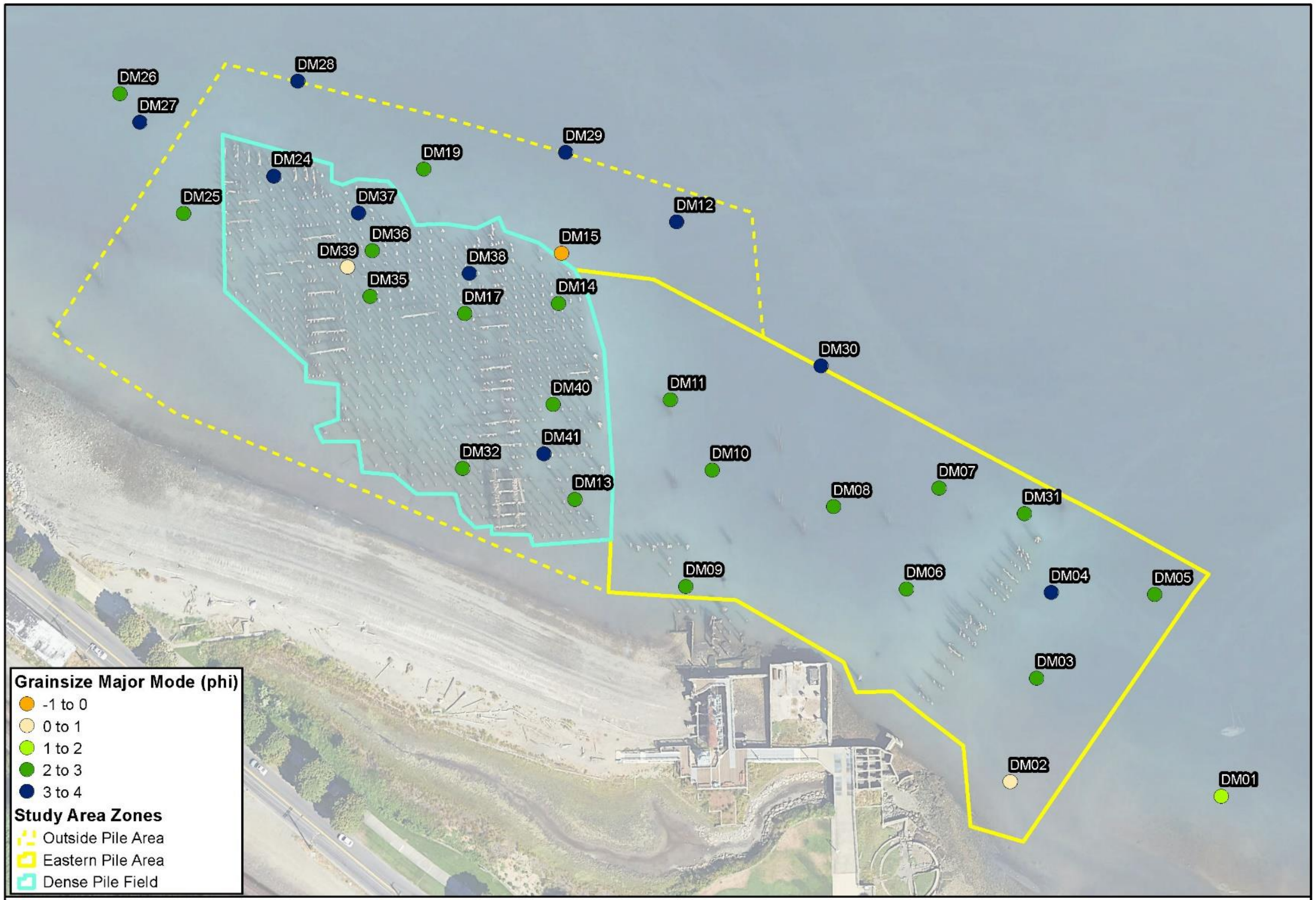


Figure 10. SPI Grain Size Major Mode

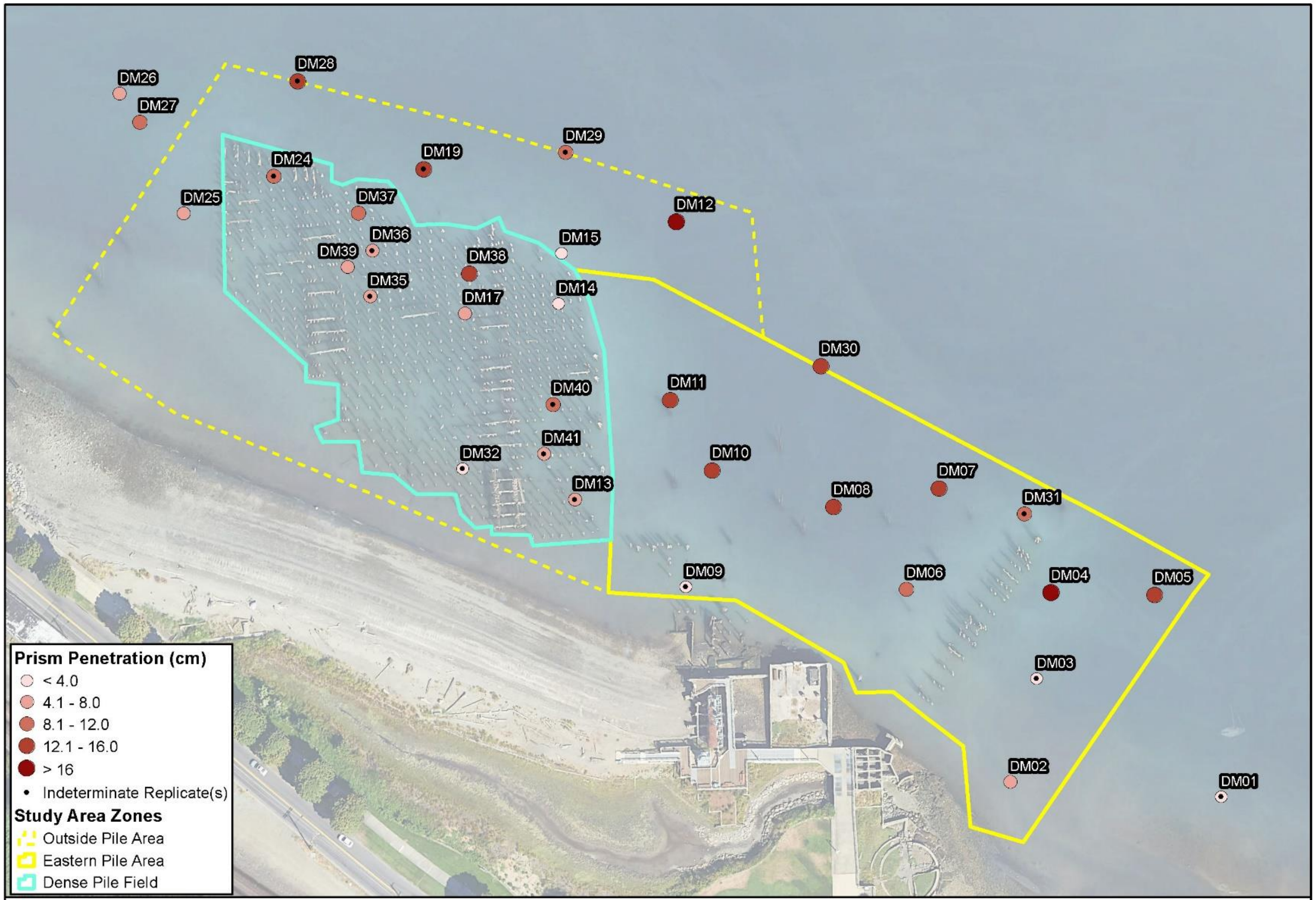


Figure 11. SPI Mean Prism Penetration

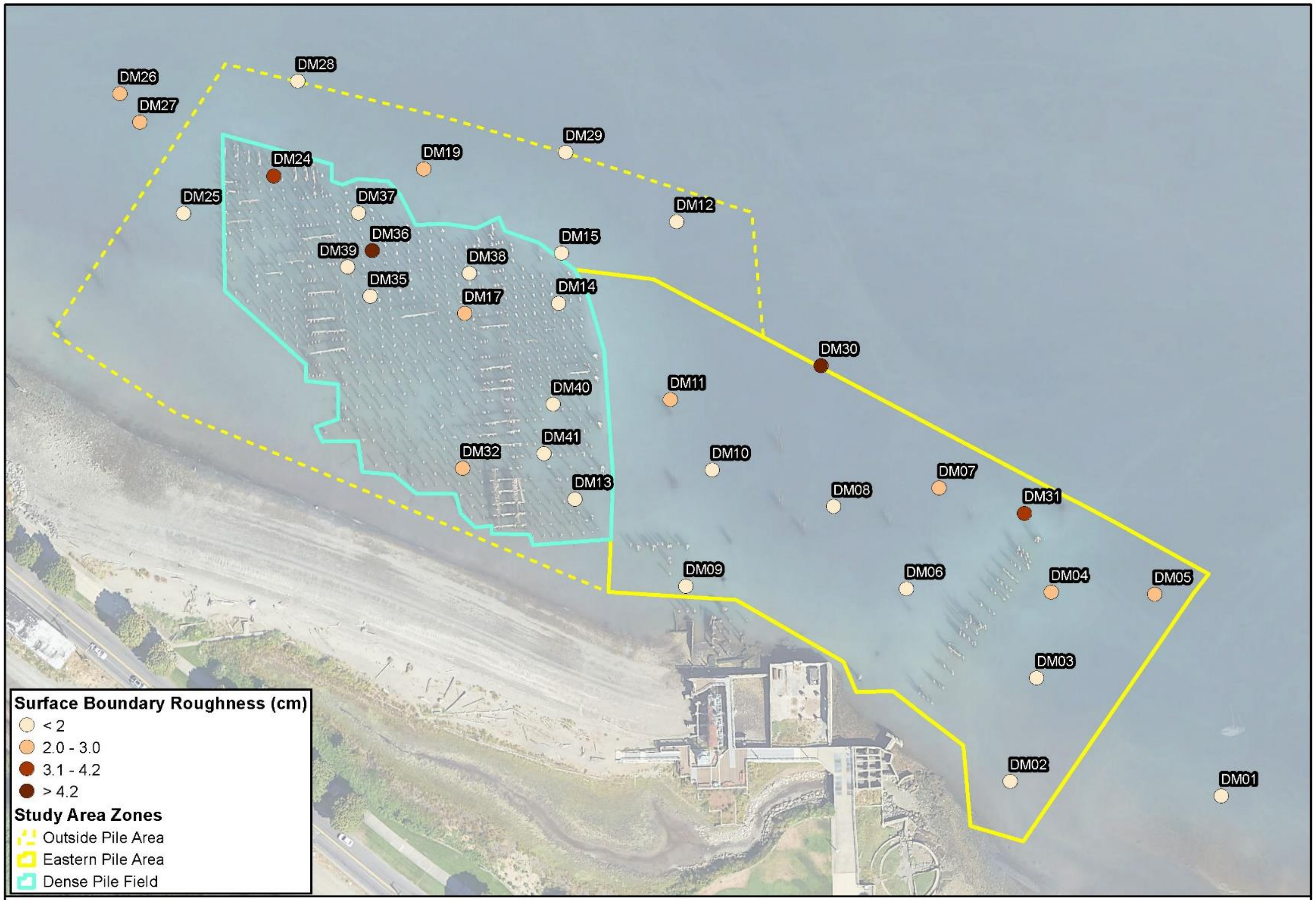
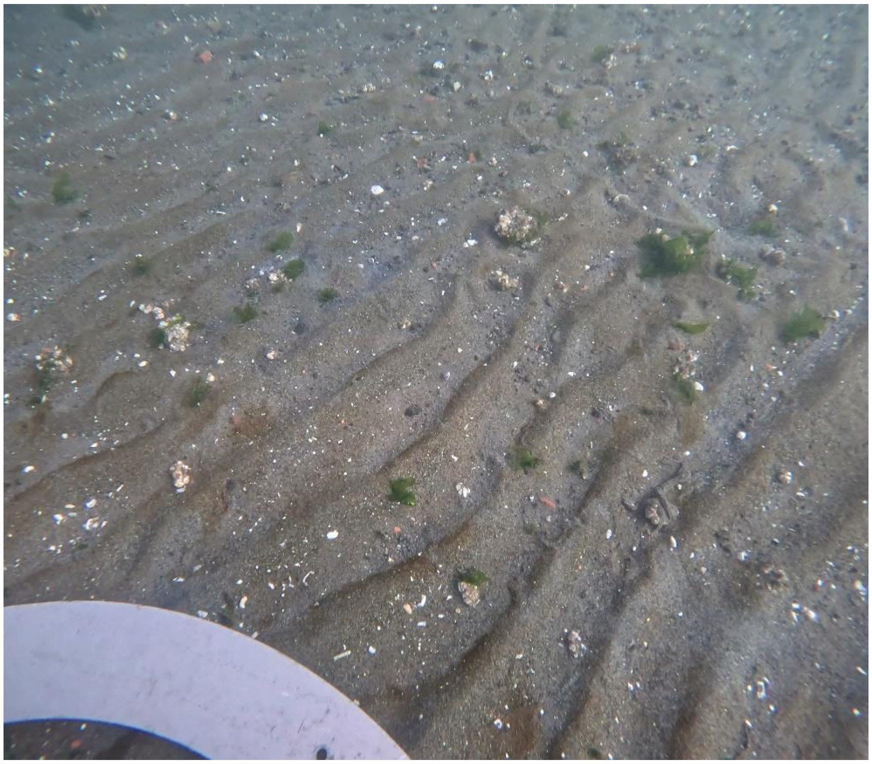


Figure 12. SPI Mean Surface Boundary Roughness

DM-02A-PV



DM-20A-PV

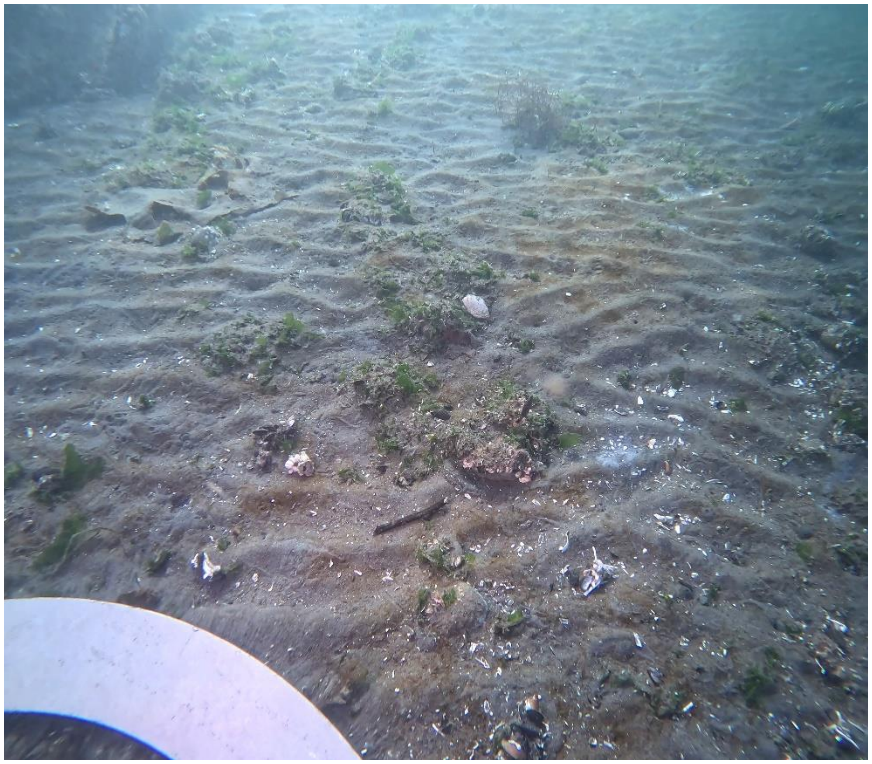


Figure 13. Dickman Mill PV Images in the Nearshore Showing Surface Ripples

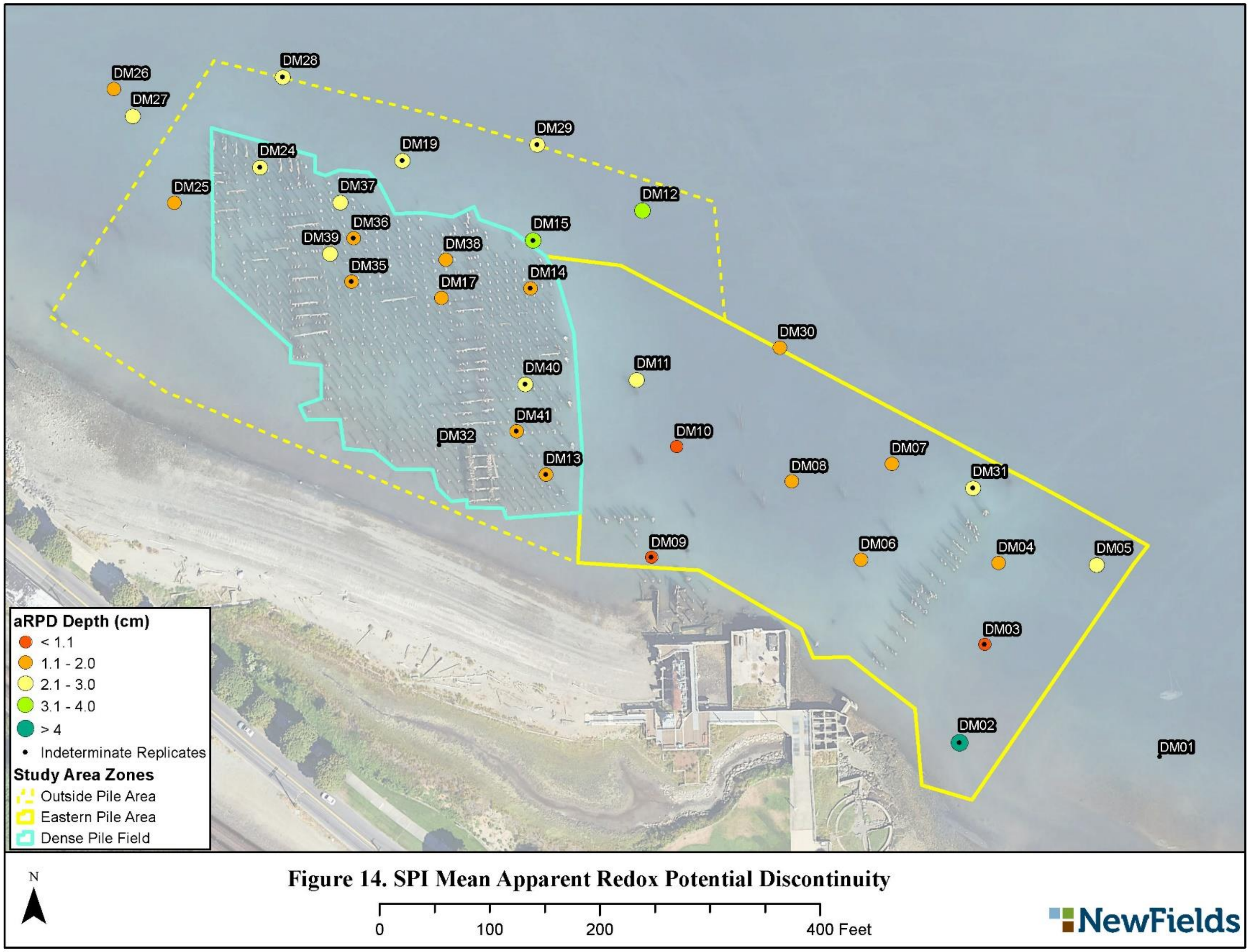


Figure 14. SPI Mean Apparent Redox Potential Discontinuity

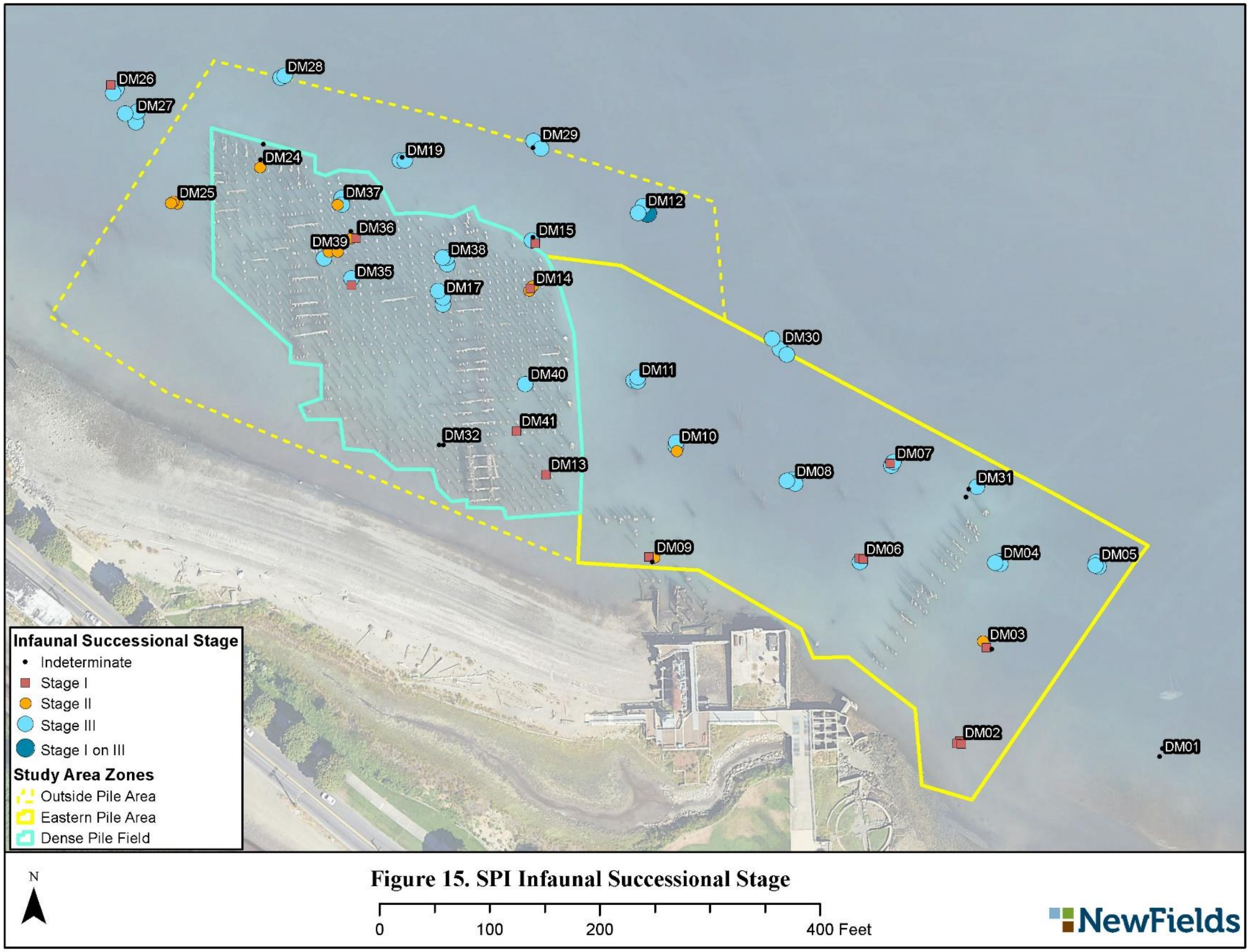
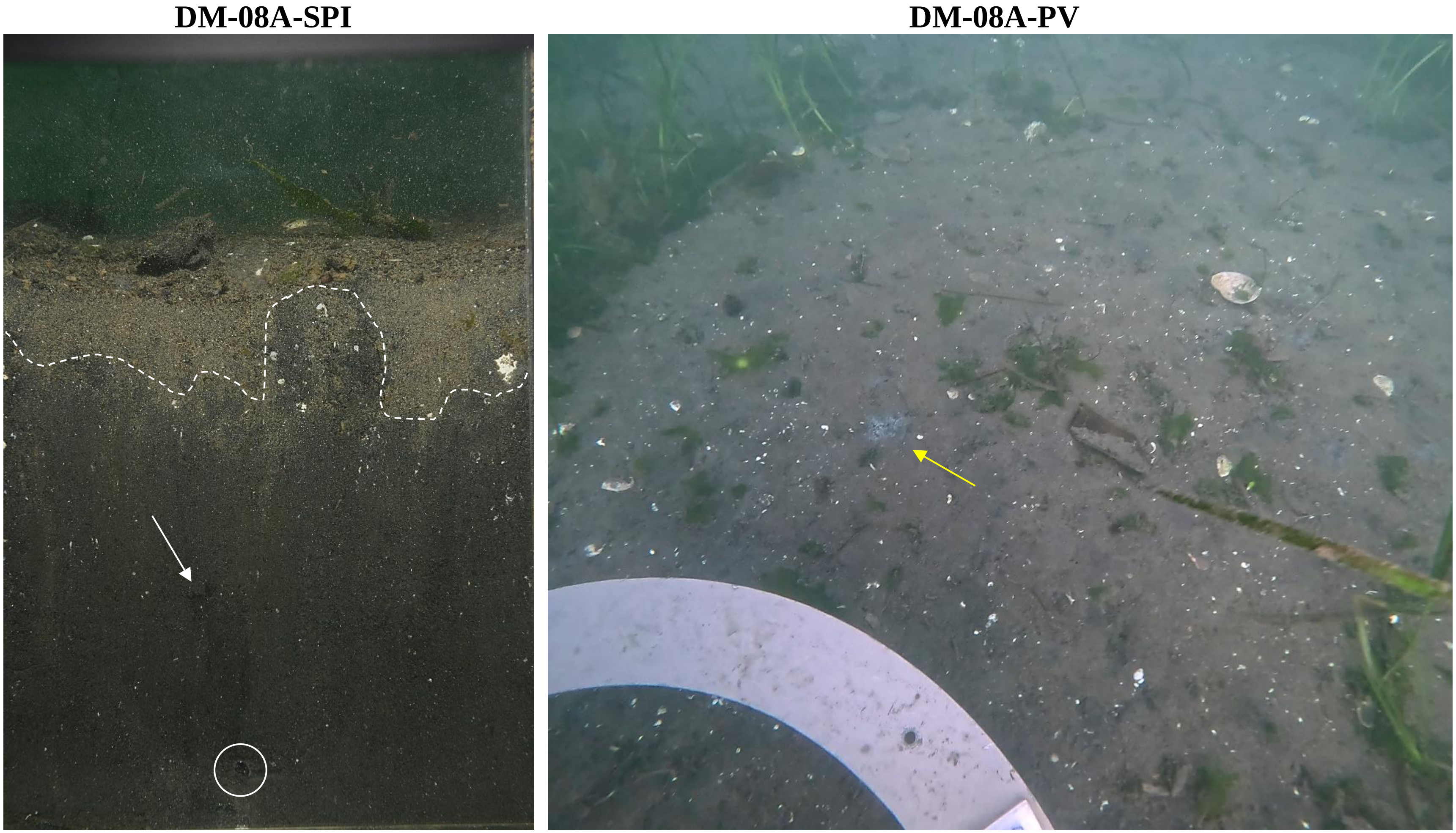


Figure 15. SPI Infaunal Successional Stage

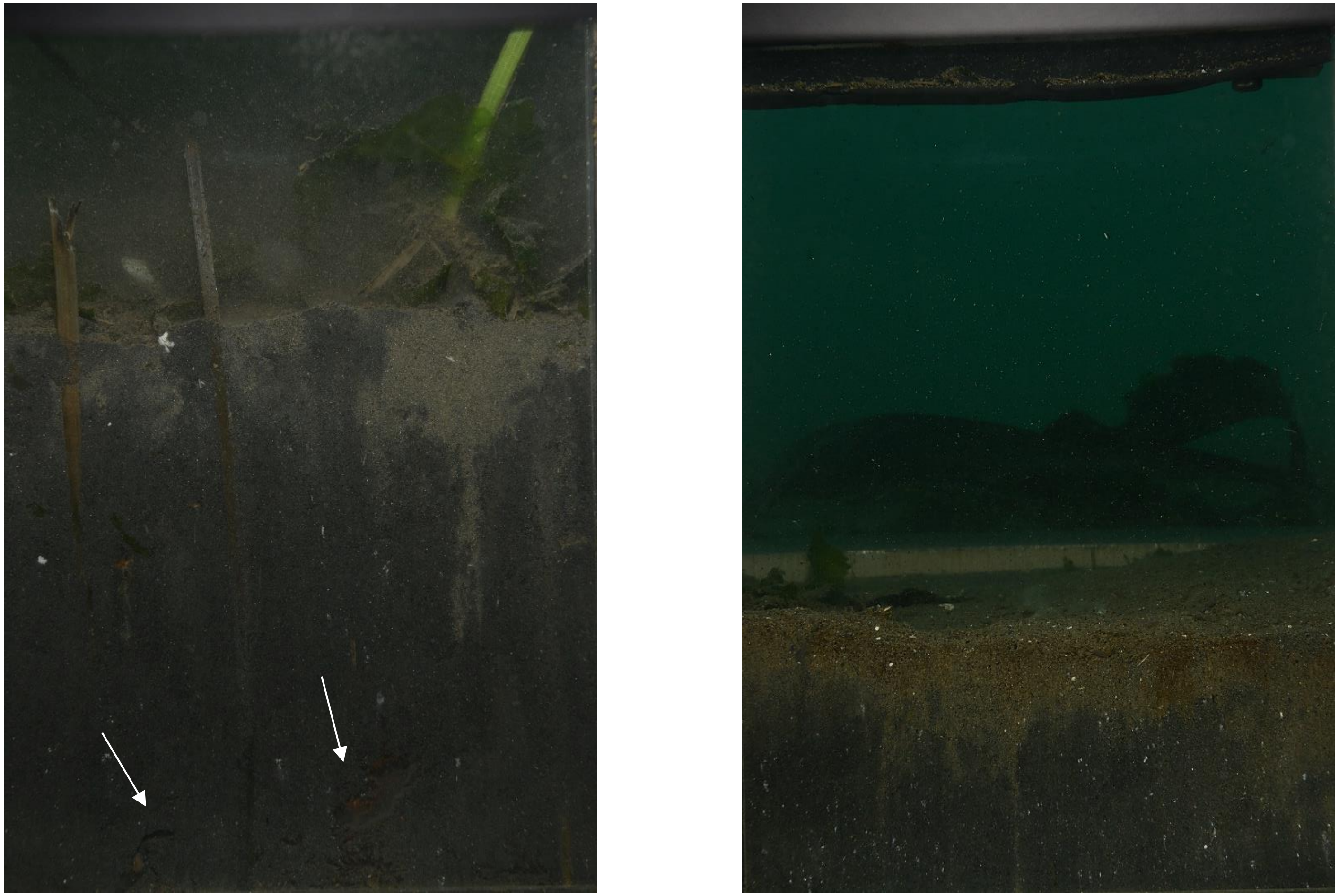


DM-08A-SPI

DM-08A-PV

Figure 16. SPI and PV Images from Station DM-08 within the Eastern Pile Area

Station DM-08, SPI replicate A, showed the only evidence of methane observed in Dickman Mill sediments. A feeding void (white arrow) was present indicating Stage III infaunal succession. The apparent RPD depth was relatively well developed and measured at approximately 2 cm (dashed white line). The PV image showed a small patch of *Beggiatoa* (yellow arrow) with algae, eelgrass, and shell particles present on the sediment surface. SPI image width is 14.6 cm.

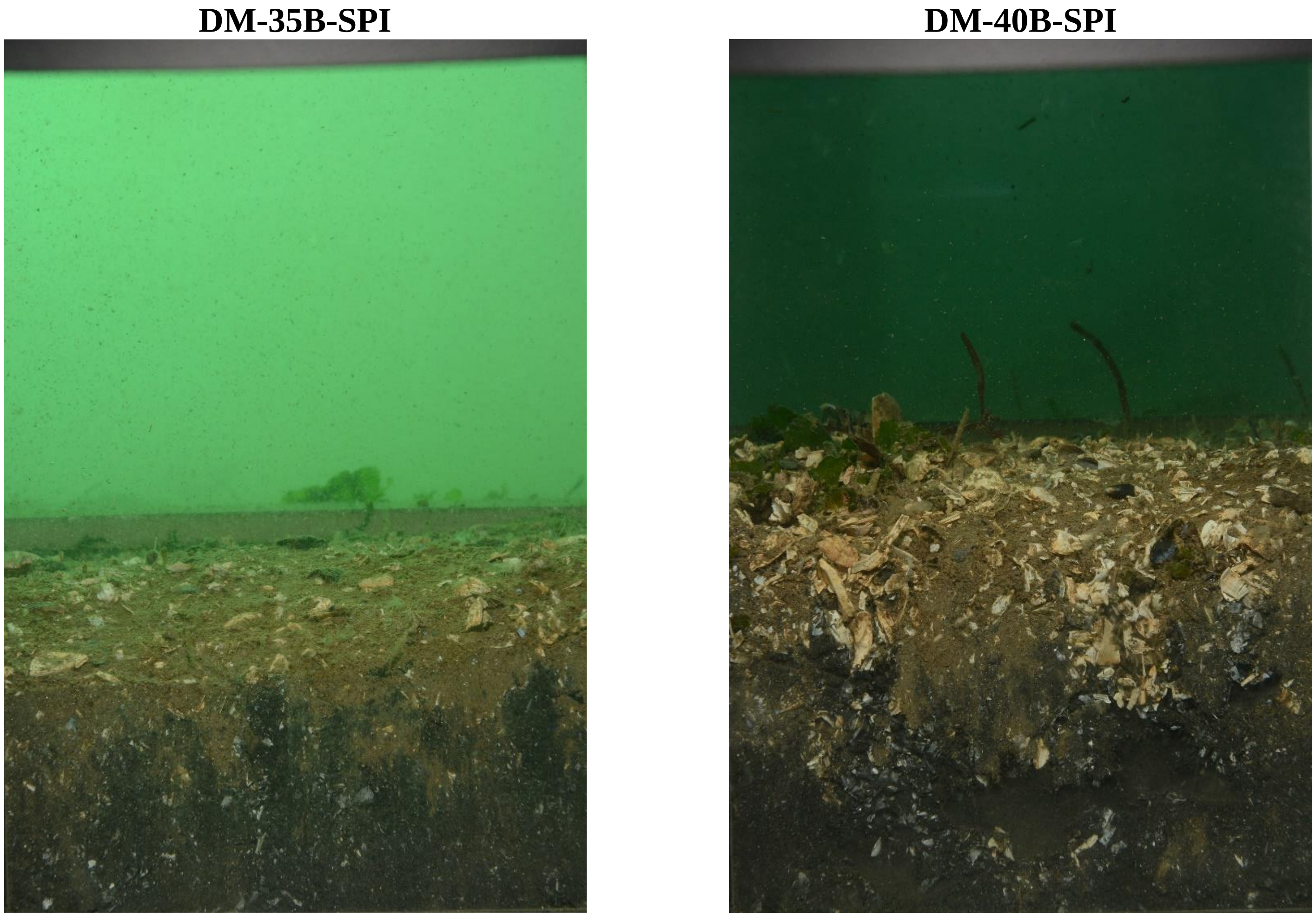


DM-10A-SPI

DM-25A-SPI

Figure 17. SPI Images from Stations DM-10 and DM-25 Showing High Apparent RPD Contrast

SPI images from stations DM-10 and DM-25 showed higher apparent RPD contrast but the presence of wood debris was not apparent. The high contrast was likely typical for this sandy substrate and location type. Eelgrass and feeding voids (white arrows) were visible at DM-10. SPI image width is 14.6 cm.



DM-35B-SPI

DM-40B-SPI

Figure 18. SPI Images from Stations DM-35 and DM-40 Showing High Apparent RPD Contrast

SPI images from stations DM-35 and DM-40 within the Dense Pile Field showed higher apparent RPD contrast in sediments with abundant shell debris. Wood debris was not apparent at DM-35 and trace amounts were present at DM-40. SPI image width is 14.6 cm.

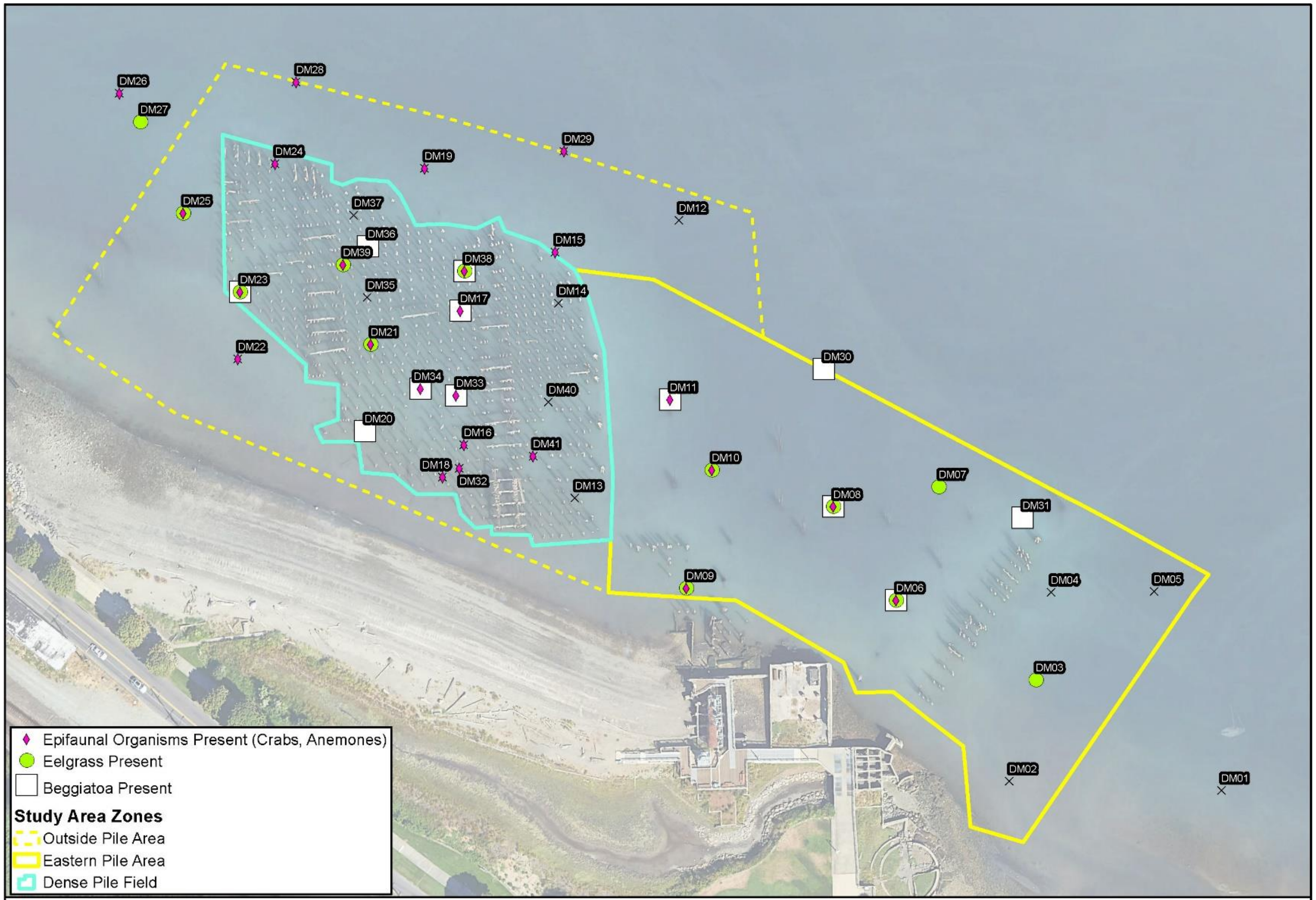


Figure 19. PV Presence of Eelgrass, Beggiatoa, and Epibenthos

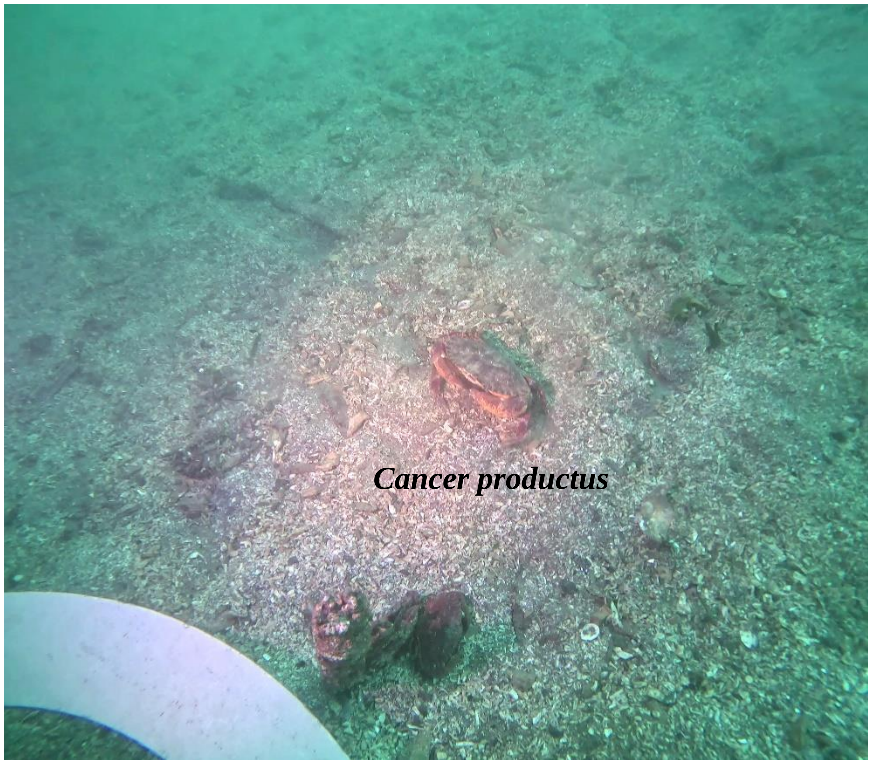
DM-06H-SPI

DM-06A-PV

Figure 20. SPI and PV Images from Station DM-06 within the Eastern Pile Area

Station DM-06, SPI replicate H, showed fine sands with an apparent RPD depth of 1.0 cm (white dashed line) and a feeding void/polychaete at depth (white arrows) indicating Stage III infaunal succession. The PV image showed patches of *Beggiatoa* on the surface, algae (*Ulva*), eelgrass, and shell particles present on the sediment surface. A small crab (*Metacarcinus gracilis*, white circle) was also present. SPI image width is 14.6 cm.

DM-15B-PV



DM-25A-PV

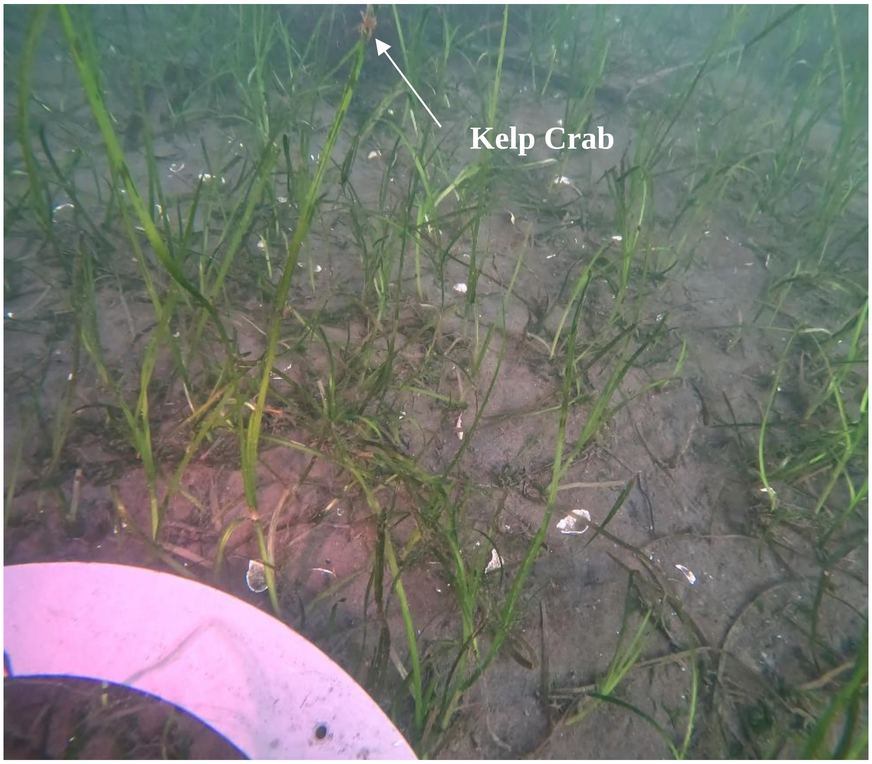


Figure 21. Dickman Mill PV Images Documenting the Presence of Crabs

DM-21C-PV

DM-23B-PV

Figure 22. Dickman Mill PV Images Documenting Presence of Eelgrass in the Dense Pile Field

Figure 23. Maximum Concentration of (A) Mercury and (B) Arsenic in Surface and Subsurface Sediments

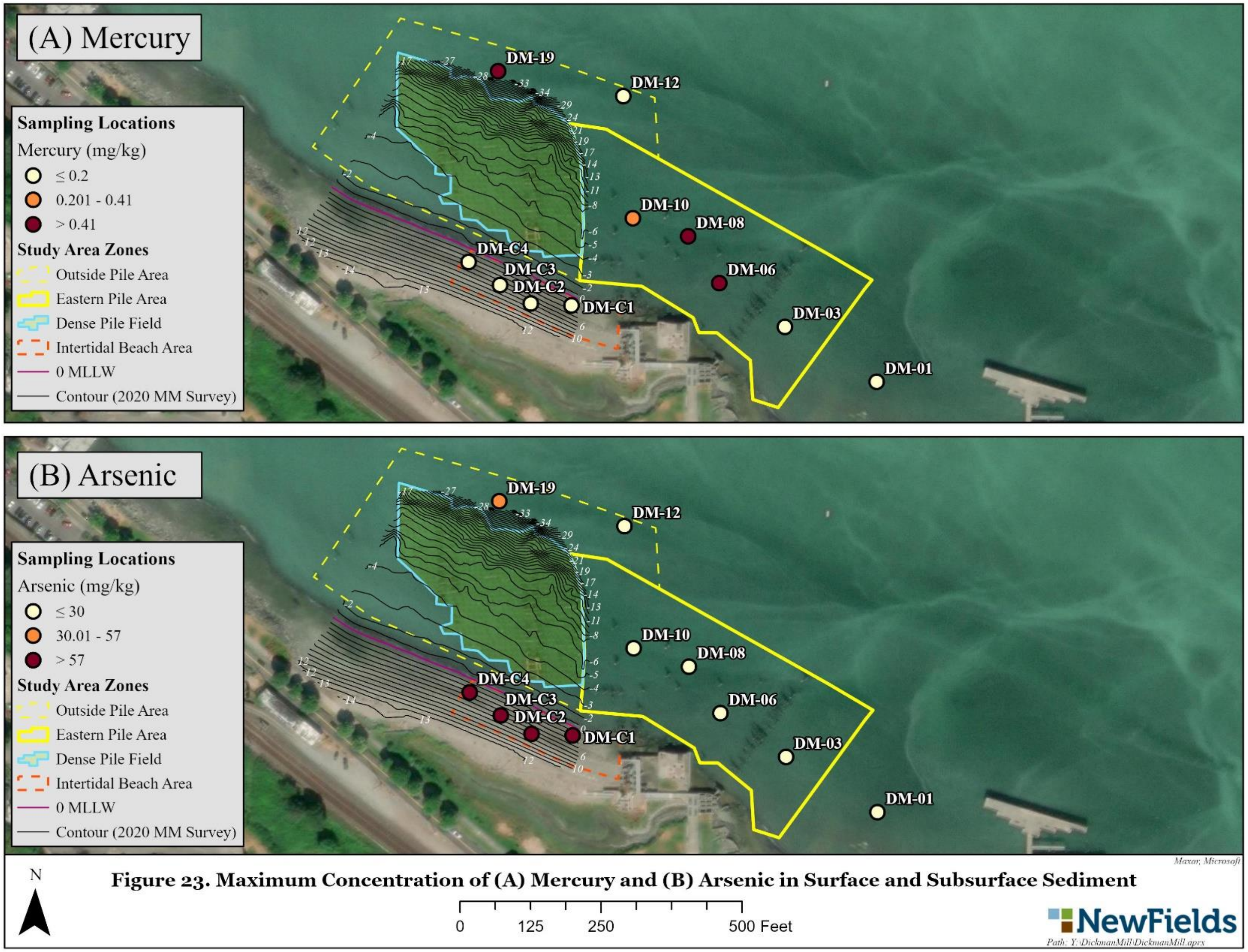


Figure 24. Maximum HPAH Concentrations in (A) Surface and (B) Subsurface Sediments

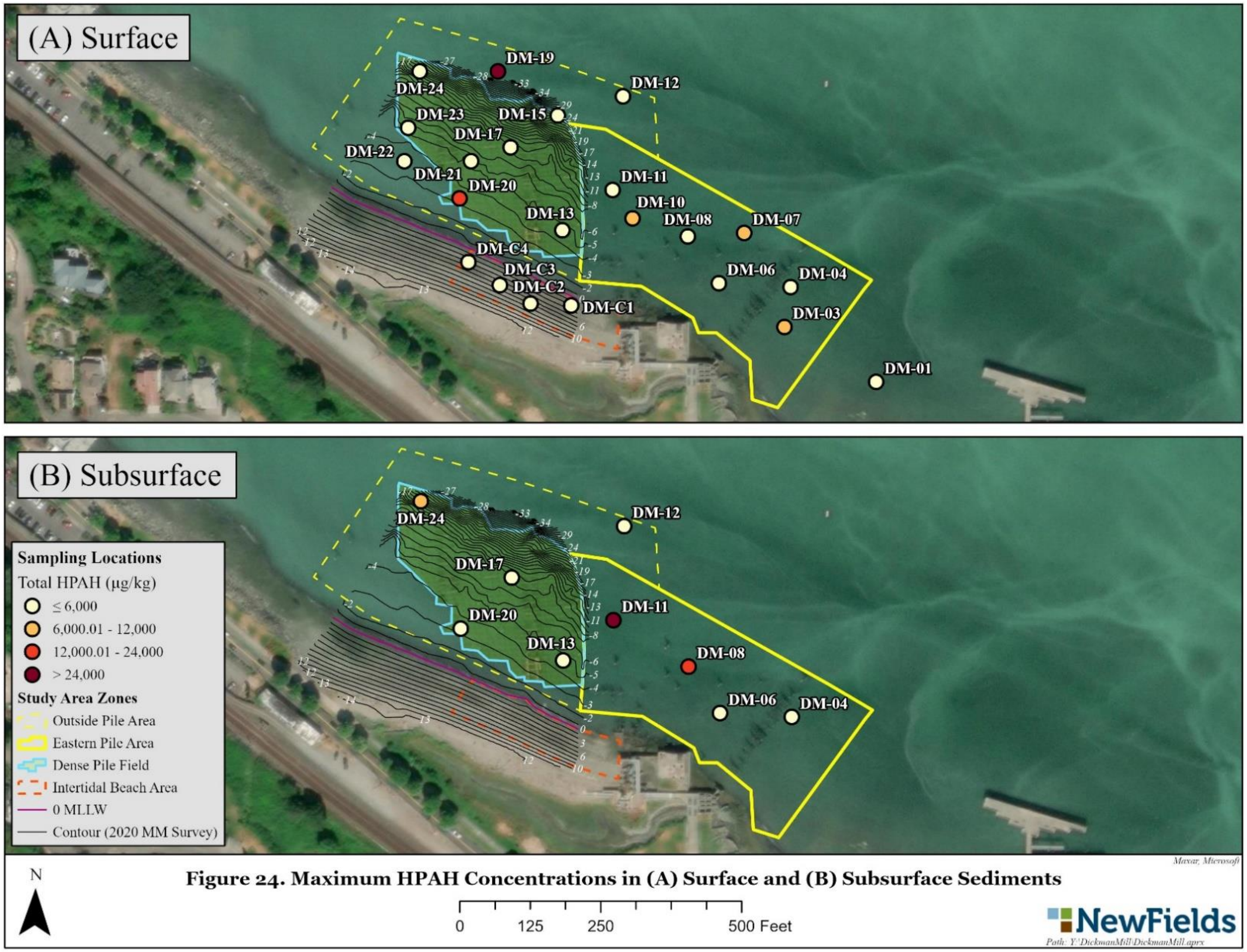


Figure 24. Maximum HPAH Concentrations in (A) Surface and (B) Subsurface Sediments

Figure 25. Maximum Dioxin/Furan Total TEQs in (A) Surface and (B) Subsurface Sediments

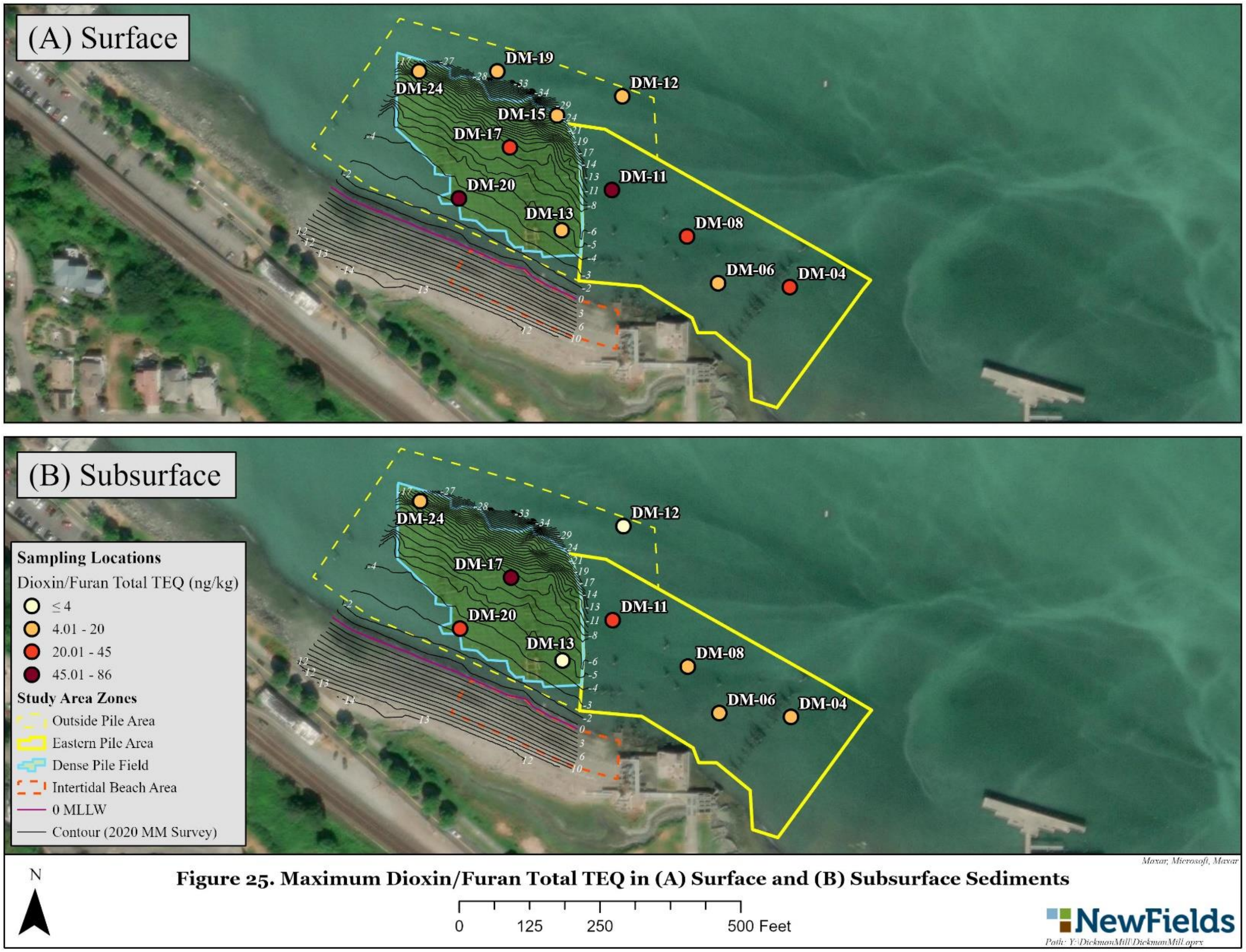


Figure 25. Maximum Dioxin/Furan Total TEQ in (A) Surface and (B) Subsurface Sediments

Figure 26. Locations of Observed Sheen from 2015 and 2022 Sediment Investigations

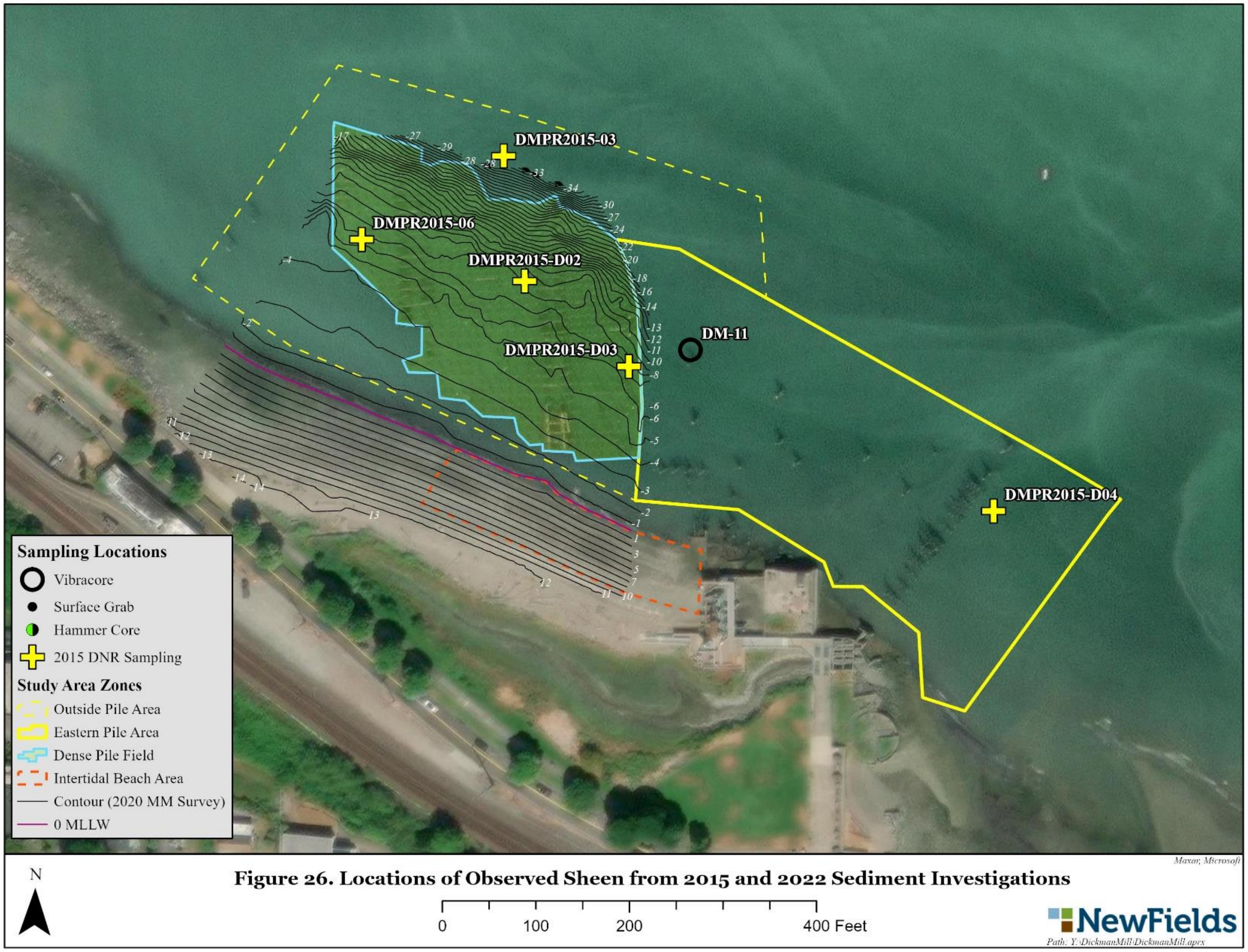


Figure 27. 2015 DNR Control Stations ≤ 1 mile NW of Dickman Mill

Figure 28. Example Congener Profiles of Common Dioxin/Furan Sources within Puget Sound Sediments

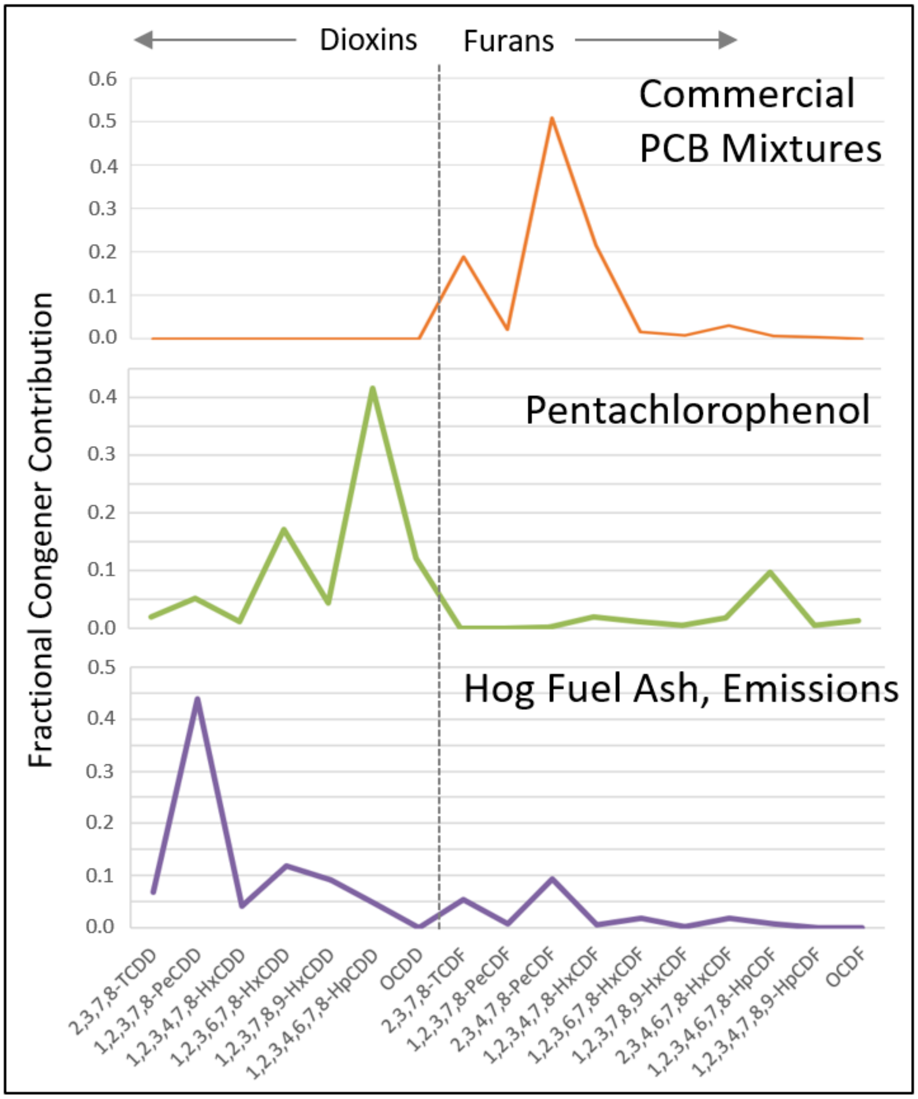


Figure 29. Correlation of Total TEQ and Total Organic Carbon (A) and Congener Profiles of High TEQ Samples (B), Moderate TEQ Samples (C), and Low TEQ Samples (D)

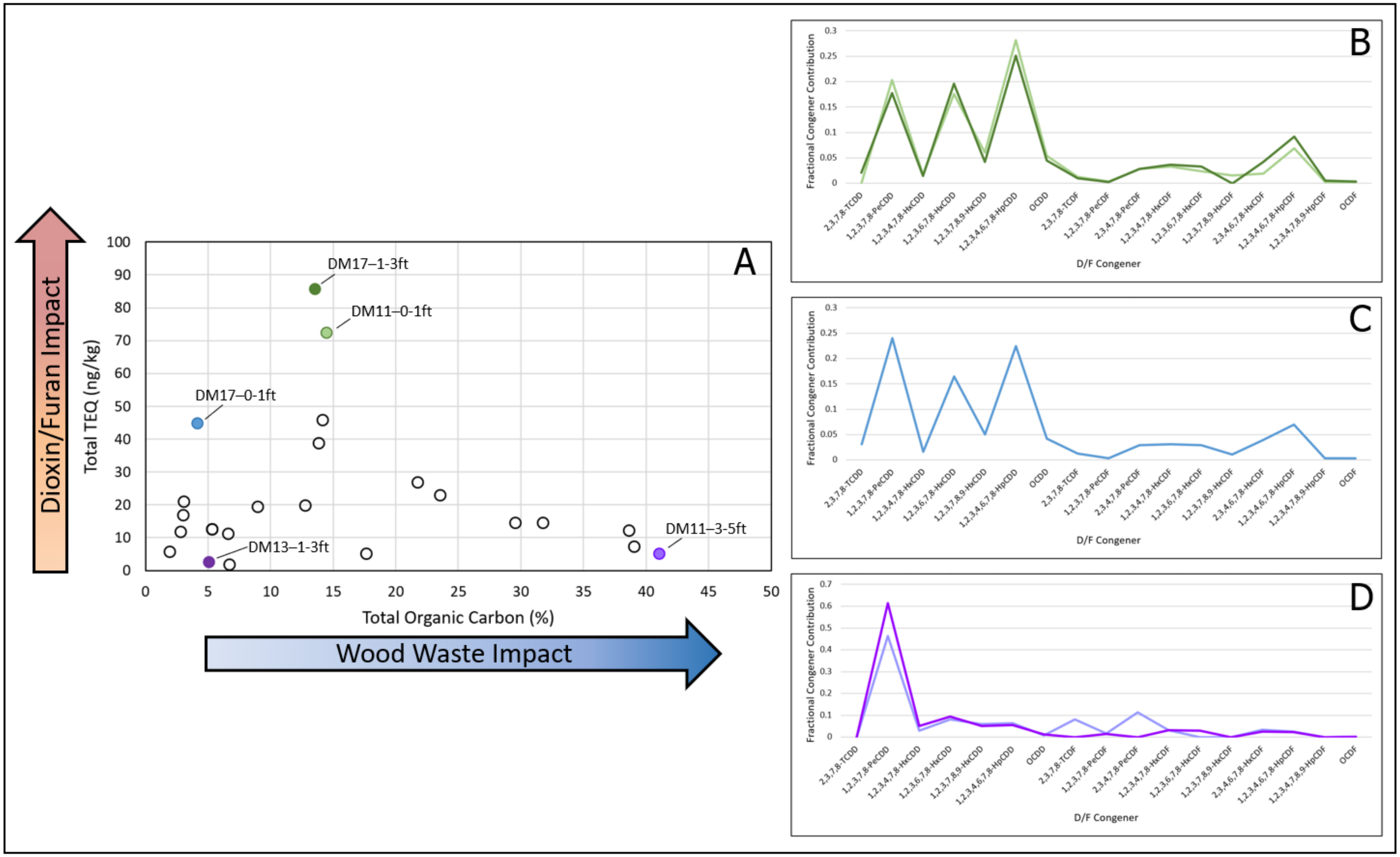
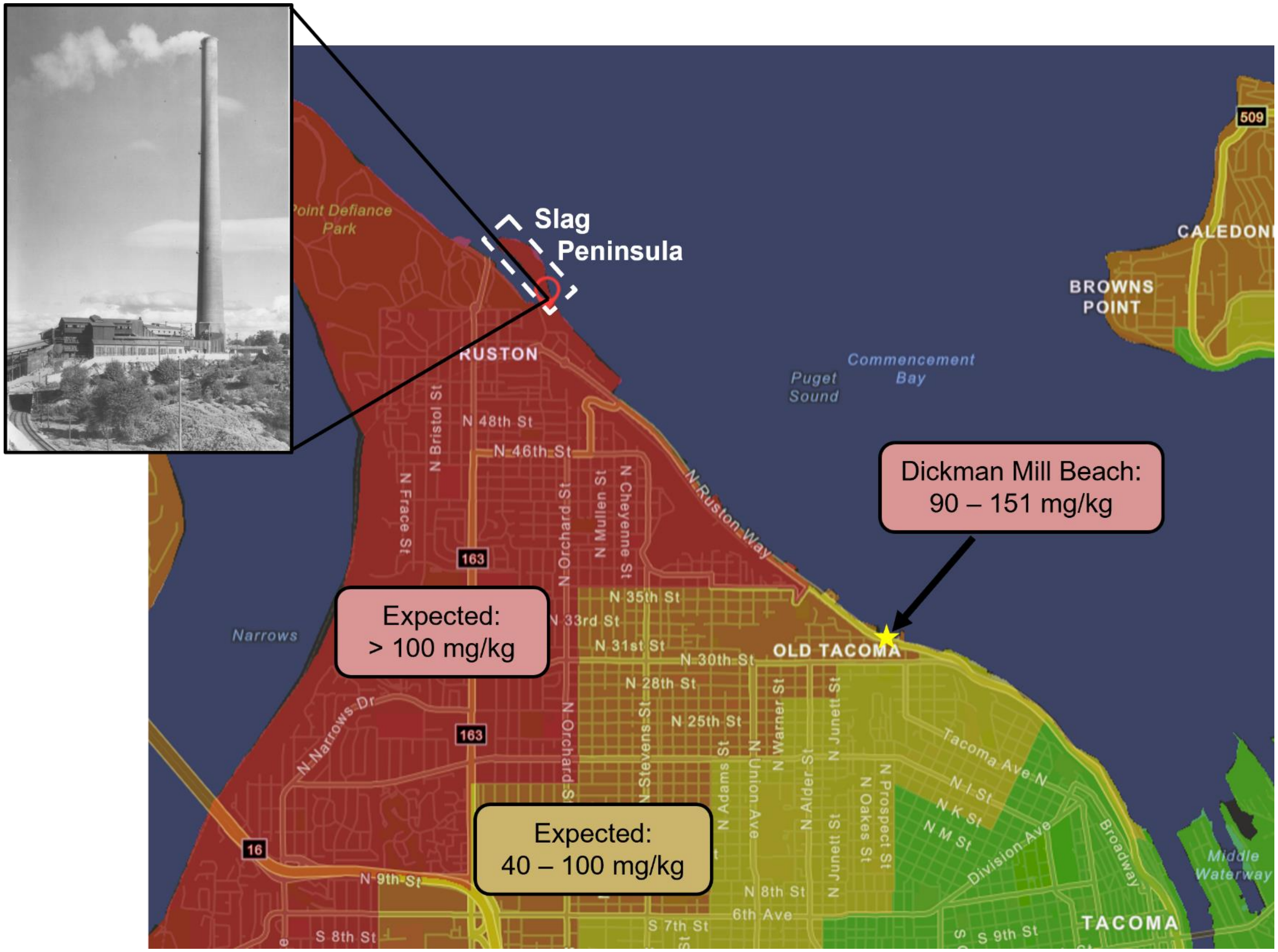


Figure 30. Map of Modeled Arsenic Soil Concentrations from Asarco Smelter (inset) in Areas Adjacent to Commencement Bay



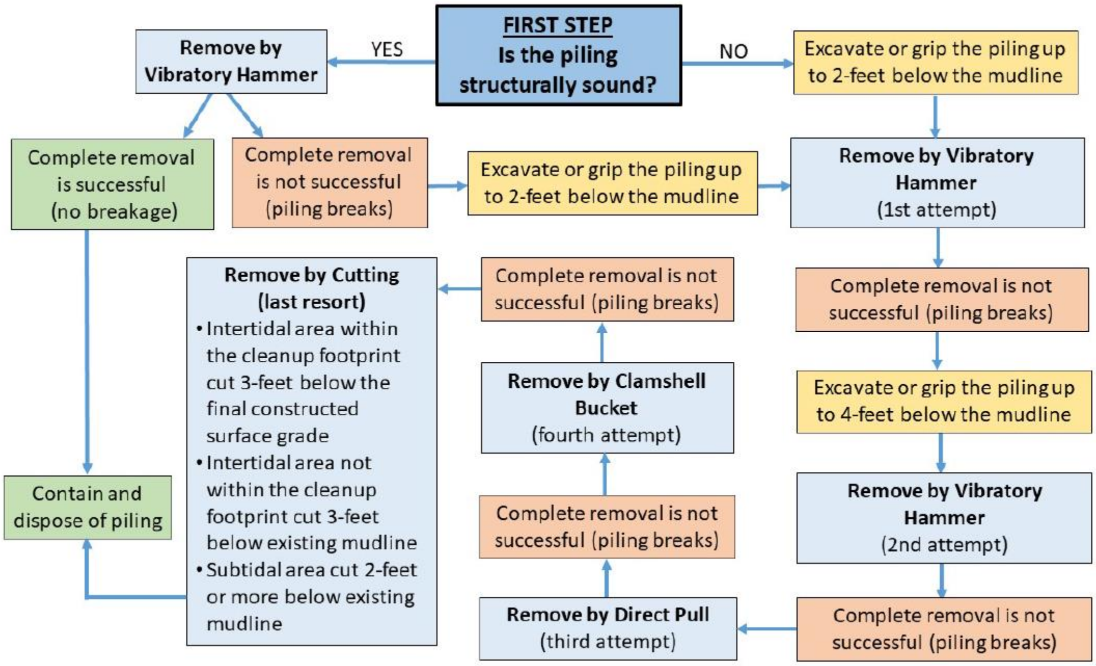
Source: Ecology . Inset photo from Ecology 2018b.

Figure 31. Pile Condition (top) and Debris (bottom) Observed During 2022 DNR Diver Survey

Piling condition rating: 1= not degraded, 2 = moderately degraded, 3 = very degraded

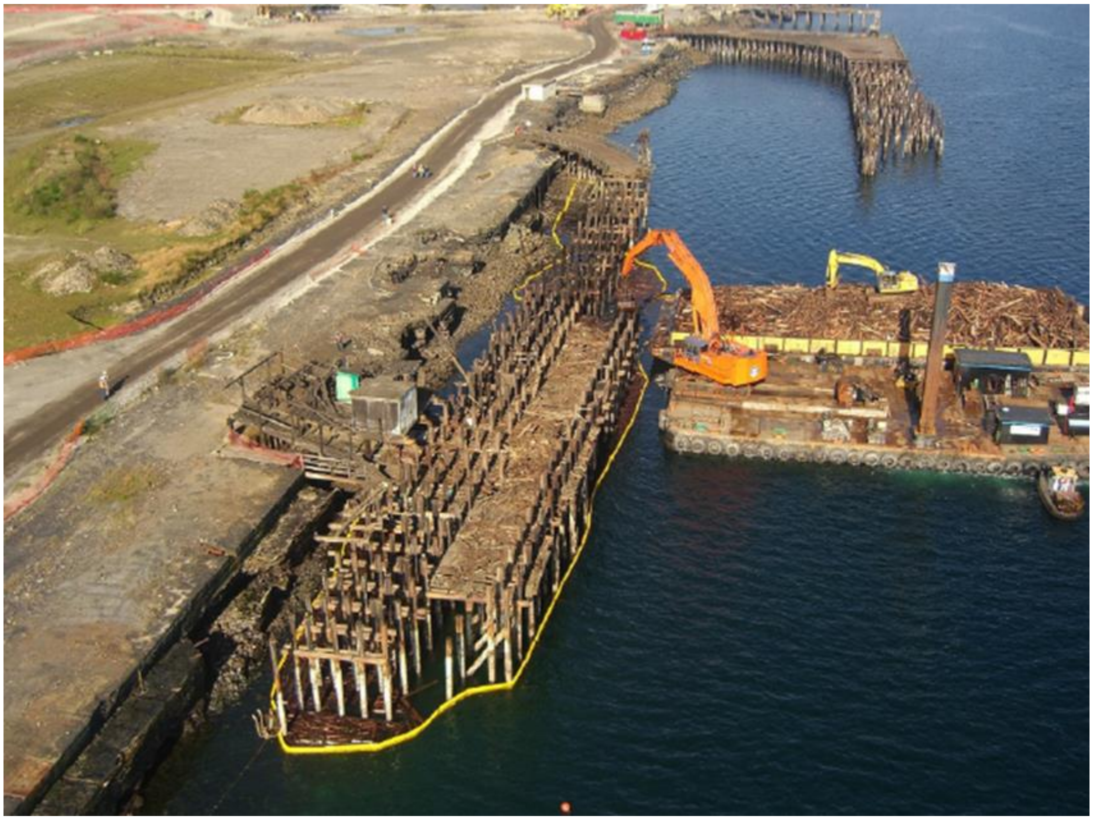
Source: DNR 2022

Figure 32. Piling Removal Process Chart with Sequencing of Different Methods



Source: Ecology 2021

Figure 33. Contaminant Boom Around Piling Removal Area at the Asarco Tacoma Smelter



Source: Ecology 2021

TABLES

Table 1. SPI and Sediment Sampling Station Coordinates

Station ID	Date	Local Time	Sample Rep	Coordinates (NAD83)	
				Latitude N	Longitude W
SPI/PV Sampling					
DM-01	11/15/2022	9:35	A	47.27742678	-122.46866196
DM-01	11/15/2022	9:36	B	47.27742836	-122.46867603
DM-01	11/15/2022	9:37	C	47.27740666	-122.46867285
DM-02	11/15/2022	9:47	A	47.27744847	-122.46940332
DM-02	11/15/2022	9:48	B	47.27744336	-122.46941368
DM-02	11/15/2022	9:49	C	47.27744540	-122.46940729
DM-03	11/14/2022	15:32	A	47.27769675	-122.46931703
DM-03	11/14/2022	15:32	B	47.27768115	-122.46930389
DM-03	11/14/2022	15:33	C	47.27767712	-122.46931892
DM-03	11/14/2022	15:34	D	47.27767750	-122.46928315
DM-04	11/14/2022	15:22	A	47.27789536	-122.46925438
DM-04	11/14/2022	15:22	B	47.27788848	-122.46925042
DM-04	11/14/2022	15:23	C	47.27789156	-122.46926913
DM-05	11/14/2022	15:44	A	47.27789256	-122.46890065
DM-05	11/14/2022	15:44	B	47.27788053	-122.46889217
DM-05	11/14/2022	15:45	C	47.27788360	-122.46890359
DM-06	11/14/2022	14:52	A	47.27784897	-122.46978285
DM-06	11/14/2022	14:52	B	47.27785849	-122.46978803
DM-06	11/14/2022	14:53	C	47.27784013	-122.46978766
DM-06	11/14/2022	15:06	D	47.27786948	-122.46982798
DM-06	11/14/2022	15:06	E	47.27787793	-122.46984130
DM-06	11/14/2022	15:07	F	47.27787510	-122.46986268
DM-06	11/15/2022	9:57	H	47.27790271	-122.46976399
DM-06	11/15/2022	9:59	I	47.27790605	-122.46976679
DM-06	11/15/2022	9:59	J	47.27790405	-122.46975307
DM-07	11/14/2022	14:36	A	47.27814156	-122.46965150
DM-07	11/14/2022	14:37	B	47.27813562	-122.46964712
DM-07	11/14/2022	14:38	C	47.27814430	-122.46964046
DM-08	11/14/2022	14:26	A	47.27810220	-122.47001004
DM-08	11/14/2022	14:27	B	47.27809187	-122.47000001
DM-08	11/14/2022	14:27	C	47.27809969	-122.47003039
DM-09	11/14/2022	13:33	A	47.27791236	-122.47053705
DM-09	11/14/2022	13:34	B	47.27791057	-122.47051879

Station ID	Date	Local Time	Sample Rep	Coordinates (NAD83)	
				Latitude N	Longitude W
DM-09	11/14/2022	13:34	C	47.27789952	-122.47052412
DM-10	11/14/2022	13:52	A	47.27818680	-122.47043596
DM-10	11/14/2022	13:53	B	47.27817582	-122.47043291
DM-10	11/14/2022	13:54	C	47.27819730	-122.47043427
DM-11	11/14/2022	14:05	A	47.27835161	-122.47058834
DM-11	11/14/2022	14:06	B	47.27834947	-122.47057377
DM-11	11/14/2022	14:06	C	47.27835907	-122.47057330
DM-12	11/14/2022	14:16	A	47.27878552	-122.47055061
DM-12	11/14/2022	14:16	B	47.27878375	-122.47055555
DM-12	11/14/2022	14:17	C	47.27876839	-122.47053513
DM-13	11/15/2022	11:48	A	47.27813389	-122.47091004
DM-13	11/15/2022	11:49	B	47.27811399	-122.47091163
DM-13	11/15/2022	11:50	C	47.27811906	-122.47091211
DM-14	11/15/2022	11:37	A	47.27857745	-122.47096912
DM-14	11/15/2022	11:37	B	47.27858268	-122.47096590
DM-14	11/15/2022	11:38	C	47.27858808	-122.47095639
DM-15	11/15/2022	11:19	A	47.27870452	-122.47098973
DM-15	11/15/2022	11:20	B	47.27870784	-122.47097473
DM-15	11/15/2022	11:21	C	47.27870089	-122.47095638
DM-15	11/15/2022	11:22	D	47.27870201	-122.47095681
DM-15	11/15/2022	11:22	E	47.27870944	-122.47095326
DM-16	11/16/2022	10:15	A	47.27822755	-122.47126878
DM-16	11/16/2022	10:16	B	47.27824422	-122.47128545
DM-16	11/16/2022	10:18	C	47.27826089	-122.47128545
DM-17	11/16/2022	13:28	A	47.27854422	-122.47128545
DM-17	11/16/2022	13:30	B	47.27856089	-122.47128545
DM-17	11/16/2022	13:32	C	47.27857755	-122.47130211
DM-18	11/15/2022	12:02	A	47.27817259	-122.47136216
DM-18	11/15/2022	12:03	B	47.27817789	-122.47137486
DM-18	11/15/2022	12:03	C	47.27817185	-122.47137161
DM-19	11/15/2022	11:05	A	47.27890257	-122.47142424
DM-19	11/15/2022	11:06	B	47.27890636	-122.47142513
DM-19	11/15/2022	11:07	C	47.27891158	-122.47143024
DM-20	11/15/2022	12:18	A	47.27829531	-122.47164309
DM-20	11/15/2022	12:19	B	47.27827695	-122.47162382
DM-20	11/15/2022	12:20	C	47.27828045	-122.47165093

Station ID	Date	Local Time	Sample Rep	Coordinates (NAD83)	
				Latitude N	Longitude W
DM-21	11/16/2022	11:55	A	47.27849422	-122.47161878
DM-21	11/16/2022	11:56	B	47.27847755	-122.47160211
DM-21	11/16/2022	11:57	C	47.27847755	-122.47158545
DM-22	11/15/2022	12:33	A	47.27845048	-122.47207312
DM-22	11/15/2022	12:34	B	47.27845757	-122.47207946
DM-22	11/15/2022	12:35	C	47.27846275	-122.47208547
DM-23	11/15/2022	12:44	A	47.27862575	-122.47204524
DM-23	11/15/2022	12:46	B	47.27862233	-122.47207100
DM-23	11/15/2022	12:47	C	47.27860721	-122.47208112
DM-24	11/15/2022	10:44	A	47.27888889	-122.47195141
DM-24	11/15/2022	10:44	B	47.27890740	-122.47194820
DM-24	11/15/2022	10:50	C	47.27894621	-122.47193773
DM-24	11/15/2022	10:51	D	47.27895427	-122.47193379
DM-24	11/15/2022	10:52	E	47.27895263	-122.47190538
DM-25	11/15/2022	10:33	A	47.27879977	-122.47225288
DM-25	11/15/2022	10:34	B	47.27880477	-122.47226693
DM-25	11/15/2022	10:35	C	47.27880117	-122.47227689
DM-26	11/15/2022	10:19	A	47.27908606	-122.47247446
DM-26	11/15/2022	10:20	B	47.27907551	-122.47248558
DM-26	11/15/2022	10:24	C	47.27909641	-122.47249493
DM-27	11/15/2022	13:16	A	47.27900282	-122.47240421
DM-27	11/15/2022	13:17	B	47.27900969	-122.47239576
DM-27	11/15/2022	13:18	C	47.27902923	-122.47239814
DM-27	11/15/2022	13:19	D	47.27901785	-122.47240411
DM-27	11/15/2022	13:19	E	47.27902452	-122.47244328
DM-28	11/15/2022	13:29	A	47.27911098	-122.47187322
DM-28	11/15/2022	13:30	B	47.27910476	-122.47187710
DM-28	11/15/2022	13:34	C	47.27911592	-122.47185827
DM-29	11/15/2022	13:43	A	47.27894978	-122.47094925
DM-29	11/15/2022	13:43	B	47.27894351	-122.47093350
DM-29	11/15/2022	13:44	C	47.27893951	-122.47093559
DM-29	11/15/2022	13:45	D	47.27894100	-122.47093435
DM-29	11/15/2022	13:45	E	47.27893474	-122.47093871
DM-30	11/15/2022	14:00	A	47.27842785	-122.47005213
DM-30	11/15/2022	14:01	B	47.27842711	-122.47004457
DM-30	11/15/2022	14:01	C	47.27845298	-122.47008128

Station ID	Date	Local Time	Sample Rep	Coordinates (NAD83)	
				Latitude N	Longitude W
DM-30	11/15/2022	14:02	D	47.27841329	-122.47002742
DM-30	11/15/2022	14:03	E	47.27839526	-122.47000768
DM-31	11/15/2022	14:13	A	47.27805556	-122.46937510
DM-31	11/15/2022	14:14	B	47.27807576	-122.46936449
DM-31	11/15/2022	14:15	C	47.27808179	-122.46933475
DM-32	11/16/2022	10:23	A	47.27819422	-122.47128545
DM-32	11/16/2022	10:24	B	47.27819422	-122.47130211
DM-32	11/16/2022	10:27	C	47.27817755	-122.47130211
DM-33	11/16/2022	10:42	A	47.27836089	-122.47133545
DM-33	11/16/2022	10:43	B	47.27836089	-122.47130211
DM-33	11/16/2022	10:45	C	47.27836089	-122.47128545
DM-34	11/16/2022	10:53	A	47.27837755	-122.47143545
DM-34	11/16/2022	10:54	B	47.27839422	-122.47143545
DM-34	11/16/2022	10:56	C	47.27836089	-122.47141878
DM-35	11/16/2022	12:03	A	47.27857755	-122.47160211
DM-35	11/16/2022	12:04	B	47.27859422	-122.47161878
DM-35	11/16/2022	12:06	C	47.27861089	-122.47161878
DM-36	11/16/2022	12:46	A	47.27871089	-122.47160211
DM-36	11/16/2022	12:48	B	47.27871089	-122.47161878
DM-36	11/16/2022	12:49	C	47.27872755	-122.47161878
DM-37	11/16/2022	13:07	A	47.27881089	-122.47165211
DM-37	11/16/2022	13:09	B	47.27879422	-122.47165211
DM-37	11/16/2022	13:10	C	47.27879422	-122.47166878
DM-37	11/16/2022	13:12	D	47.27877755	-122.47165211
DM-38	11/16/2022	13:39	A	47.27864422	-122.47126878
DM-38	11/16/2022	13:41	B	47.27866089	-122.47126878
DM-38	11/16/2022	13:50	C	47.27866089	-122.47128545
DM-39	11/16/2022	14:40	A	47.27866089	-122.47171878
DM-39	11/16/2022	14:41	B	47.27867755	-122.47170211
DM-39	11/16/2022	14:43	C	47.27867755	-122.47166878
DM-40	11/16/2022	14:53	A	47.27834422	-122.47096878
DM-40	11/16/2022	14:54	B	47.27834422	-122.47098545
DM-40	11/16/2022	14:56	C	47.27834422	-122.47100211
DM-41	11/16/2022	15:10	A	47.27821089	-122.47103545
DM-41	11/16/2022	15:13	B	47.27822755	-122.47101878
DM-41	11/16/2022	15:14	C	47.27821089	-122.47106878

Station ID	Date	Local Time	Sample Rep	Coordinates (NAD83)	
				Latitude N	Longitude W
Sediment Grab Samples					
DM-01	11/20/2022	14:23	1	47.27743792	-122.46867854
DM-01	11/20/2022	14:28	2	47.27740738	-122.46866127
DM-01	11/20/2022	14:30	3	47.27742175	-122.46864008
DM-01	11/20/2022	14:33	4	47.27741157	-122.46863094
DM-01	11/20/2022	14:35	5	47.27743619	-122.46866563
DM-03	11/20/2022	13:57	1	47.27766671	-122.46933693
DM-03	11/20/2022	13:59	2	47.27769443	-122.46932768
DM-07	11/20/2022	13:17	1	47.27814704	-122.46962923
DM-07	11/20/2022	13:35	2	47.27813909	-122.46966101
DM-10	11/20/2022	12:27	1	47.27818525	-122.47040863
DM-10	11/20/2022	12:52	2	47.27819345	-122.47042529
DM-10	11/20/2022	12:55	3	47.27820638	-122.47043036
DM-15	11/20/2022	11:28	1	47.27870872	-122.47099164
DM-15	11/20/2022	11:48	2	47.27870930	-122.47098734
DM-15	11/20/2022	11:52	3	47.27869874	-122.47097976
DM-18	11/20/2022	15:02	1	47.27817197	-122.47137673
DM-18	11/20/2022	15:03	2	47.27815000	-122.47136955
DM-18	11/20/2022	15:05	3	47.27813854	-122.47139595
DM-18	11/20/2022	15:07	4	47.27815798	-122.47133156
DM-18	11/20/2022	15:11	5	47.27817039	-122.47133224
DM-18	11/20/2022	15:14	6	47.27813612	-122.47134349
DM-18	11/20/2022	15:16	7	47.27811942	-122.47134708
DM-18	11/20/2022	15:18	8	47.27812139	-122.47130000
DM-18	11/20/2022	15:20	9	47.27808950	-122.47126395
DM-18	11/20/2022	15:23	10	47.27810662	-122.47128447
DM-19	11/20/2022	10:02	1	47.27890629	-122.47141320
DM-19	11/20/2022	10:33	2	47.27890955	-122.47141169
DM-21	11/19/2022	13:15	1	47.27845422	-122.4715955
DM-22	11/20/2022	8:12	1	47.27846061	-122.47206836
DM-22	11/20/2022	8:15	2	47.27845898	-122.47207729
DM-23	11/20/2022	9:14	1	47.27862328	-122.47204714
DM-23	11/20/2022	9:17	2	47.27862557	-122.47205003
DM-23	11/20/2022	9:19	3	47.27861645	-122.47206425
Sediment Core Samples					
DM-04	11/18/2022	14:13	1	47.27788854	-122.46928987

Station ID	Date	Local Time	Sample Rep	Coordinates (NAD83)	
				Latitude N	Longitude W
DM-06	11/19/2022	8:44	1	47.27787830	-122.46979102
DM-06	11/19/2022	8:59	2	47.27789966	-122.46980245
DM-08	11/18/2022	13:29	1	47.27812375	-122.47003308
DM-11	11/18/2022	11:00	1	47.27833918	-122.47058142
DM-11	11/18/2022	11:21	2	47.27834149	-122.47057726
DM-12	11/18/2022	8:58	1	47.27879875	-122.47051541
DM-13	11/18/2022	12:00	1	47.27813971	-122.47093802
DM-13	11/18/2022	12:21	2	47.27814057	-122.47093011
DM-17	11/19/2022	10:30	1	47.27850422	-122.4712955
DM-17	11/19/2022	11:30	2	47.27848422	-122.4713155
DM-20	11/17/2022	8:54	1	47.27828469	-122.47166827
DM-20	11/17/2022	9:25	2	47.27827659	-122.47168618
DM-24	11/18/2022	9:54	1	47.27890076	-122.47193869
DM-24	11/18/2022	10:20	2	47.27889830	-122.47197234
Intertidal Beach Samples					
DM-C1	11/20/2022	20:06	1	47.27778422	-122.47084545
DM-C1	11/20/2022	20:36	2	47.27778422	-122.47084545
DM-C2	11/20/2022	18:13	1	47.27776422	-122.47111545
DM-C2	11/20/2022	18:23	2	47.27776422	-122.47111545
DM-C3	11/20/2022	18:49	1	47.27786422	-122.47135545
DM-C3	11/20/2022	19:04	2	47.27786422	-122.47135545
DM-C4	11/20/2022	19:24	1	47.27794422	-122.47153545
DM-C4	11/20/2022	19:46	2	47.27794422	-122.47153545

Table 2. 2022 Dickman Mill Sediment Samples and Analyses

Sample ID	Sample Type	Sediment Depth Interval	Conventionals	Metals	PAHs Only	All SVOCs[a]	Dioxin/Furan Congeners	Chemistry Archive	Bioassays
Laboratory			**ARI**	**ARI**	**ARI**	**ARI**	**ARI**	**ARI**	**EcoAnalysts**
DM-01-S	Grab	0–10 cm	✓	✓	✓		(A)	(A)	(A)
DM-03-S	Grab	0–10 cm	✓	✓	✓		(A)	(A)	(A)
DM-07-S	Grab	0–10 cm	✓		✓		(A)	(A)	(A)
DM-10-S	Grab	0–10 cm	✓	✓	✓		(A)	(A)	(A)
DM-15-S	Grab	0–10 cm	✓			✓	✓	(A)	(A)
DM-18-S	Grab	0–10 cm	(NA)	(NA)	(NA)	(NA)	(NA)	(NA)	(NA)
DM-19-S	Grab	0–10 cm	✓	✓	✓		✓	(A)	✓
DM-21-S	Grab	0–10 cm	✓			✓	(A)	(A)	(A)
DM-22-S	Grab	0–10 cm	✓		✓		(A)	(A)	(A)
DM-23-S	Grab	0–10 cm	✓		✓		(A)	(A)	(A)
CARR-REF-7	Grab	0–10 cm	(✓)						(✓)
DM-04-C-0-1	Vibracore	0-1 ft	✓		✓		✓	(A)	
DM-04-C-1-3	Vibracore	1-3 ft	✓		✓		✓	(A)	
DM-06-C-0-1	Vibracore	0-1 ft	✓	✓		✓	✓	(A)	
DM-06-C-1-3	Vibracore	1-3 ft	✓	✓		✓	✓	(A)	
DM-06-C-3-5	Vibracore	3-5 ft				✓	✓	(A)	
DM-08-C-0-1	Vibracore	0-1 ft	✓	✓	✓		✓	(A)	
DM-08-C-1-3	Vibracore	1-3 ft	✓	✓	✓		✓	(A)	
DM-08-C-3-5	Vibracore	3-5 ft					(A)	(A)	
DM-11-C-0-1	Vibracore	0-1 ft	✓			✓	✓	(A)	
DM-11-C-1-3	Vibracore	1-3 ft	✓			✓	✓	(A)	
DM-11-C-3-5	Vibracore	3-5 ft	✓			✓	✓	(A)	
DM-12-C-0-1	Vibracore	0-1 ft	✓	✓	✓		✓	(A)	
DM-12-C-1-3	Vibracore	1-3 ft	✓	✓	✓		✓	(A)	
DM-12-C-3-5	Vibracore	3-5 ft					(A)	(A)	
DM-13-C-0-1	Vibracore	0-1 ft	✓			✓	✓	(A)	
DM-13-C-1-3	Vibracore	1-3 ft	✓		✓		✓	(A)	
DM-17-C-0-1	Vibracore	0-1 ft	✓			✓	✓	(A)	
DM-17-C-1-3	Vibracore	1-3 ft	✓			✓	✓	(A)	
DM-20-C-0-1	Vibracore	0-1 ft	✓		✓		(A)	(A)	
DM-20-C-1-3	Vibracore	1-3 ft	✓		✓		(A)	(A)	
DM-24-C-0-1	Vibracore	0-1 ft	✓		✓		✓	(A)	
DM-24-C-1-3	Vibracore	1-3 ft	✓		✓		✓	(A)	
DM-24-C-3-5	Vibracore	3-5 ft	✓				✓	(A)	
DM-24-C-5-7	Vibracore	5-7 ft					(A)	(A)	
DM-C1	Hand Core	0-1 ft[c]	✓	✓	✓		(A)	(A)	
DM-C2	Hand Core	0-1 ft[c]	✓	✓	✓		(A)	(A)	
DM-C3	Hand Core	0-1 ft[c]	✓	✓	✓		(A)	(A)	
DM-C4	Hand Core	0-1 ft[c]	✓	✓	✓		(A)	(A)	
Field QC Samples									
DM-15-S-DUP	Field Duplicate		✓			✓			

Sample ID	Sample Type	Sediment Depth Interval	Conventionals	Metals	PAHs Only	All SVOCs[a]	Dioxin/Furan Congeners	Chemistry Archive	Bioassays
DM-19-S-DUP	Field Duplicate		✓	✓	✓				
DM-15-S-TRIP	Field Triplicate		✓						
DM-19-S-TRIP	Field Triplicate		✓						
DM-ER-1	Equipment Rinsate			✓		✓			
DM-ER-2	Equipment Rinsate				✓				
DM-RB-1	Rinsate Blank			✓		✓			
	PS-SRM						✓		
Samples Submitted for Analysis			**38**	**17**	**24**	**14**	**22**		
Sample Archives							**38**	**37**	**1**

a. SVOCs include all other semi-volatile compounds in addition to PAHs (chlorinated hydrocarbons, phthalates, phenols, miscellaneous extractables)

b. Carr Inlet reference sample

c. Hand Core samples were anticipated to be collected below the beach gravel (1-foot cap thickness was targeted at construction), however the cap material was mixed vertically into the beach sand and the 0-1 ft depth interval was collected.

PS-SRM	Puget Sound Sediment Reference Material
(A)	Archived
(✓)	Analyzed
(NA)	Not Applicable; sample was not collected
CR	Carr Inlet

Table 3. Dickman Mill SPI Prism Penetration, Boundary Roughness, and Apparent RPD Summaries

Study Area Zone	n	Prism Penetration (cm)				Boundary Roughness (cm)				Apparent RPD (cm)			
		Min	Max	Mean	Stdev	Min	Max	Mean	Stdev	Min	Max	Mean	Stdev
Up/Down Stream	6	0.00	10.68	5.53	3.04	0.00	5.11	2.37	1.38	0.56	3.44	1.88	1.15
Eastern Pile Field	33	0.00	17.65	10.54	5.55	0.00	10.03	2.04	1.80	0.30	6.00	1.87	1.52
Dense Pile Field	25	0.00	18.38	5.76	4.62	0.00	5.68	1.69	1.31	0.00	5.19	1.86	1.02
Outside Pile Area	12	0.00	19.53	10.48	6.30	0.00	3.17	1.13	0.93	1.26	3.86	2.49	0.78

n = number of SPI images
Min = minimum
Max = maximum
Stdev = standard deviation

Table 4. Dioxin/Furan Toxic Equivalency Factors (TEFs)

Congener	Abbreviation	TEF
Dioxins		
2,3,7,8-tetrachlorodibenzo-p-dioxin	2,3,7,8-TCDD	1
1,2,3,7,8-pentachlorodibenzo-p-dioxin	1,2,3,7,8-PeCDD	1
1,2,3,4,7,8-hexachlorodibenzo-p-dioxin	1,2,3,4,7,8-HxCDD	0.1
1,2,3,6,7,8-hexachlorodibenzo-p-dioxin	1,2,3,6,7,8-HxCDD	0.1
1,2,3,7,8,9-hexachlorodibenzo-p-dioxin	1,2,3,7,8,9-HxCDD	0.1
1,2,3,4,6,7,8-heptachlorodibenzo-p-dioxin	1,2,3,4,6,7,8-HpCDD	0.01
Octachlorodibenzo-p-dioxin	OCDD	0.0003
Furans		
2,3,7,8-tetrachlorodibenzofuran	2,3,7,8-TCDF	0.1
1,2,3,7,8-pentachlorodibenzofuran	1,2,3,7,8-PeCDF	0.03
2,3,4,7,8-pentachlorodibenzofuran	2,3,4,7,8-PeCDF	0.3
1,2,3,4,7,8-hexachlorodibenzofuran	1,2,3,4,7,8-HxCDF	0.1
1,2,3,6,7,8-hexachlorodibenzofuran	1,2,3,6,7,8-HxCDF	0.1
1,2,3,7,8,9-hexachlorodibenzofuran	1,2,3,7,8,9-HxCDF	0.1
2,3,4,6,7,8-hexachlorodibenzofuran	2,3,4,6,7,8-HxCDF	0.1
1,2,3,4,6,7,8-heptachlorodibenzofuran	1,2,3,4,6,7,8-HpCDF	0.01
1,2,3,4,7,8,9-heptachlorodibenzofuran	1,2,3,4,7,8,9-HpCDF	0.01
Octachlorodibenzofuran	OCDF	0.0003

Table 5. 2022 Dickman Mill Sediment Chemistry Results

	Collection Method	Sediment Cores																													
	Sample ID	DM-04-C				DM-06-C						DM-08-C				DM-11-C						DM-12-C				DM-13-C				DM-17-C	
Analyte	Interval	0-1 ft	Q	1-3 ft	Q	0-1 ft	Q	1-3 ft	Q	3-5 ft	Q	0-1 ft	Q	1-3 ft	Q	0-1 ft	Q	1-3 ft	Q	3-5 ft	Q	0-1 ft	Q	1-3 ft	Q	0-1 ft	Q	1-3 ft	Q	0-1 ft	Q
Grain Size (%)	**SQS DW**																														
Gravel	-	17		21		4.3		9.2		-		20.6		17.4		21.8		42.6		-		3.6		5		12.6		2.7		14.1	
Sand	-	53.7		52.4		75.8		68.3		-		45.3		53.7		34.4		31.9		-		71		81.9		72.4		48.8		66.7	
Silt	-	20.6		16.6		12.4		11.1		-		19.1		13.2		24.5		11.7		-		12.7		6.1		7.7		33.2		9.5	
Clay	-	8.7		10.1		7.5		11.3		-		15		15.6		19.3		13.7		-		12.7		7		7.3		15.3		9.9	
Conventionals (%)	**SQS DW**																														
Total Solids	-	35.17		31.6		54.23		31.28		31.8		34.74		29.1		33.56		42.68		21.4		62.06		74.14		57.76		52.99		61.25	
Total Volatile Solids	-	41.24		43.26		16.65		62.52		56.15		45.22		61.05		26.09		25.3		73.73		6.72		4.04		7.8		11.91		7.85	
Total Organic Carbon	-	23.6		29.6		9.01		39.1		31.8		21.8		38.7		14.5		13.9		41.1		2.84		1.04		6.63		5.13		4.19	
Total Sulfides (mg/kg)	-	359	J	38.3	J	42.3	U	5.12	J	-		843	J	422	J	844	J	154	J	-		102	J	5.09	J	122	J	365	J	820	J
Ammonia - N (mg/kg NH3-N DW)	-	2.49		2.7		5.04		13.3		-		1.89		19.4		15.8		4.71		-		5.96		1.12		4.55		7.25		5.64	
Metals (mg/kg DW)	**SQS DW**																														
Arsenic	57	-		-		15.6		9.55		-		19		9.11		-		-		-		14.4		7.06		-		-		-	
Cadmium	51	-		-		1.19		1.2		-		1.04		0.89		-		-		-		0.46		0.28		-		-		-	
Chromium	260	-		-		22.8		15.6		-		19.2		11.3		-		-		-		20.2		16		-		-		-	
Copper	390	-		-		133	J	83.2	J	-		104	J	62.4	J	-		-		-		82.6	J	22.7	J	-		-		-	
Lead	450	-		-		77.4		108		-		82.5		59.5		-		-		-		69.5		59.2		-		-		-	
Mercury	0.41	-		-		0.353		**0.527**		-		**0.418**		0.399		-		-		-		0.166		0.0256		-		-		-	
Silver	6.1	-		-		0.36	J	0.7		-		0.52	J	0.61	J	-		-		-		0.35		0.16	J	-		-		-	
Zinc	410	-		-		132		152		-		135		77.6		-		-		-		78.8		39.2		-		-		-	
SVOCs (µg/kg DW)	**AET DW (SCUM)**																														
Naphthalene	2,100	27.9		49.2		221		551		662	J	246		628		40.1		248		351		115		88.2		109		180		173	
Acenaphthylene	1,300	41		37.3		43.7	J	65.1	J	35.1		54.9		146		56.3		101		27.2	J	34.1		15.1	J	20.4		33.2	J	55.8	
Acenaphthene	500	30.7		33.9		184		280		**502**		138		435		45.5		258		149		32.5		16.1	J	59.9		113		133	
Fluorene	540	57.1		58.9		246		430		518		163		512		54.6		386		189		48.9		22.9		79.5		159		177	
Phenanthrene	1,500	547		280		973		1,030		1,260		571		1,100		422		941	J	471		203		91.3		192		406		810	
Anthracene	960	130		188		325		308		414	J	245		865		160		591		256	J	85.9		29.7		89.9		139		310	
Fluoranthene	1,700	1,420		813		**1,930**		986		1,920		1,250		**5,690**		879		**13,700**		1,100		469		108		281	J	459		1,060	J
Pyrene	2,600	1,060		706		1,530		618		1,320		1,320		4,490		999		**16,300**		1,640		494		146		387	J	351		1,220	J
Benzo(a)anthracene	1,300	354		506		505		229		243		431		824		366		**1,730**	J	253		169		41.2		107		117		489	
Chrysene	1,400	643		1,050		744		339		277		691		**2,360**		667		**2,980**	J	285		208		50		148		167		774	
Benzofluoranthenes, Total	3,200	709		1,190		40	U	382		457	J	905		1,820		852		2,380		578		336		83.4		197		204		921	
Benzo(a)pyrene	1,600	287		577		430		189		227		433		497		391		1,000		232		179		43.3		112		114		479	
Indeno(1,2,3-cd)pyrene	600	90.3	J	183	J	20	UJ	20	UJ	54.5	J	20	UJ	20	UJ	119	J	242		37	J	81.2		21.3		49.1		20	UJ	174	
Dibenzo(a,h)anthracene	230	20	UJ	20	UJ	20	UJ	20	UJ	19.4	J	20	UJ	20	UJ	20	UJ	100		48.3	UJ	20	U	20	U	18.3	J	20	UJ	67.4	
Benzo(g,h,i)perylene	670	78.6	J	166	J	20	UJ	20	UJ	63.3	J	20	UJ	20	UJ	20	UJ	225	J	47.3	J	77.9		22.6		48.6		20	UJ	165	
Total LPAH	5,200	833.7		647.3		1,992.7	J	2,664.1	J	3,391.1	J	1,418		3,686		778.5		2,525.0	J	1,443.2	J	519.4		263.3	J	550.7		1,030.2	J	1,659	
Total HPAH	12,000	4,641.9	J	5,191	J	5,139		2,743		4,581.2	J	5,030		**15,681**		4,273	J	**38,657**	J	4,172.3	J	2,014.1		515.8		1,348	J	1,412		5,349.4	J
Total 16 PAH	-	5,476	J	5,838.3	J	7,131.7	J	5,407.1	J	7,972.3	J	6,448		19,367		5,051.5	J	41,182.0	J	5,615.5	J	2,533.5		779.1	J	1,898.7	J	2,442.2	J	7,008.2	J
2-Methylnaphthalene	670	12.4	J	20.8		90.2		218		364		66.1		208		18.6	J	60.9		106.0		37.4		22.4		39.6		62.6		76.2	
Dibenzofuran	540	-		-		92.2		129.0		425		-		-		43.1		248.0		207		-		-		66.5		-		112	
Di-n-Butylphthalate	1,400	-		-		19.8	U	19.6	U	19.9	U	-		-		20.0	U	19.8	U	48.3	U	-		-		20	U	-		19.8	J
bis(2-Ethylhexyl)phthalate	1,300	-		-		238.0		48.9	U	49.8	U	-		-		285.0	D	234.0		121	U	-		-		38.6	J	-		343	
Di-n-Octylphthalate	6,200	-		-		19.8	U	19.6	U	19.9	U	-		-		20.0	U	19.8	U	48.3	U	-		-		20	U	-		20	U

	Collection Method	Sediment Cores																													
	Sample ID	DM-04-C				DM-06-C						DM-08-C				DM-11-C						DM-12-C				DM-13-C				DM-17-C	
Analyte	Interval	0-1 ft	Q	1-3 ft	Q	0-1 ft	Q	1-3 ft	Q	3-5 ft	Q	0-1 ft	Q	1-3 ft	Q	0-1 ft	Q	1-3 ft	Q	3-5 ft	Q	0-1 ft	Q	1-3 ft	Q	0-1 ft	Q	1-3 ft	Q	0-1 ft	Q
SVOCs (µg/kg DW)	**AET DW (SCUM)**																														
1,4-Dichlorobenzene	110	-		-		4.2	J	1.8	J	0.7	J	-		-		4.1	J	4.5	J	1.9	J	-		-		6.1		-		6.2	
1,2-Dichlorobenzene	35	-		-		1.3	J	4.9	U	5	U	-		-		2.0	J	5.0	U	12.1	U	-		-		0.8	J	-		0.9	J
1,2,4-Trichlorobenzene	31	-		-		4.9	U	4.9	U	5	U	-		-		5.0	U	5.0	U	12.1	U	-		-		5	U	-		5	U
Hexachlorobutadiene	11	-		-		4.9	U	4.9	U	5	U	-		-		1.7	J	5.0	U	12.1	U	-		-		5	U	-		5	U
Dimethylphthalate	71	-		-		4.9	U	4.9	U	5	U	-		-		4.3	J	5.0	U	12.1	U	-		-		5	U	-		3.2	J
Diethyl phthalate	200	-		-		17.8	U	22.3		20.1		-		-		26.8	U	17.8	U	38.3	U	-		-		72.1	U	-		47.1	U
N-Nitrosodiphenylamine	28	-		-		4.9	U	4.9	U	5	U	-		-		5.0	UJ	5.0	U	12.1	U	-		-		5	U	-		5	U
Hexachlorobenzene	22	-		-		4.9	U	4.9	U	5	U	-		-		0.9	J	5.0	U	12.1	U	-		-		5	U	-		5	U
Butylbenzylphthalate	63	-		-		125.0		4.9	U	5	U	-		-		39.0		5.0	U	12.1	U	-		-		34.1	J	-		37.7	J
SVOCs (µg/kg OC)	**SQS OC***																														
Naphthalene	99,000	-		-		-		-		-		-		-		-		-		-		4,049		8,481		-		-		-	
Acenaphthylene	66,000	-		-		-		-		-		-		-		-		-		-		1,201		1,452	J	-		-		-	
Acenaphthene	16,000	-		-		-		-		-		-		-		-		-		-		1,144		1,548	J	-		-		-	
Fluorene	23,000	-		-		-		-		-		-		-		-		-		-		1,722		2,202		-		-		-	
Phenanthrene	100,000	-		-		-		-		-		-		-		-		-		-		7,148		8,779		-		-		-	
Anthracene	220,000	-		-		-		-		-		-		-		-		-		-		3,025		2,856		-		-		-	
Fluoranthene	160,000	-		-		-		-		-		-		-		-		-		-		16,514		10,385		-		-		-	
Pyrene	1,000,000	-		-		-		-		-		-		-		-		-		-		17,394		14,038		-		-		-	
Benzo(a)anthracene	110,000	-		-		-		-		-		-		-		-		-		-		5,951		3,962		-		-		-	
Chrysene	110,000	-		-		-		-		-		-		-		-		-		-		7,324		4,808		-		-		-	
Benzofluoranthenes, Total	230,000	-		-		-		-		-		-		-		-		-		-		11,831		8,019		-		-		-	
Benzo(a)pyrene	99,000	-		-		-		-		-		-		-		-		-		-		6,303		4,163		-		-		-	
Indeno(1,2,3-cd)pyrene	34,000	-		-		-		-		-		-		-		-		-		-		2,859		2,048		-		-		-	
Dibenzo(a,h)anthracene	12,000	-		-		-		-		-		-		-		-		-		-		704	U	1,923	U	-		-		-	
Benzo(g,h,i)perylene	31,000	-		-		-		-		-		-		-		-		-		-		2,743		2,173		-		-		-	
Total LPAH	370,000	-		-		-		-		-		-		-		-		-		-		18,289		25,317	J	-		-		-	
Total HPAH	960,000	-		-		-		-		-		-		-		-		-		-		70,919		49,596		-		-		-	
Total 16 PAH	-	-		-		-		-		-		-		-		-		-		-		89,208		74,913	J	-		-		-	
2-Methylnaphthalene	38,000	-		-		-		-		-		-		-		-		-		-		1,317		2,154		-		-		-	
Dibenzofuran	15,000	-		-		-		-		-		-		-		-		-		-		-		-		-		-		-	
Di-n-Butylphthalate	220,000	-		-		-		-		-		-		-		-		-		-		-		-		-		-		-	
bis(2-Ethylhexyl)phthalate	47,000	-		-		-		-		-		-		-		-		-		-		-		-		-		-		-	
Di-n-Octylphthalate	58,000	-		-		-		-		-		-		-		-		-		-		-		-		-		-		-	
1,4-Dichlorobenzene	3,100	-		-		-		-		-		-		-		-		-		-		-		-		-		-		-	
1,2-Dichlorobenzene	2,300	-		-		-		-		-		-		-		-		-		-		-		-		-		-		-	
1,2,4-Trichlorobenzene	810	-		-		-		-		-		-		-		-		-		-		-		-		-		-		-	
Hexachlorobutadiene	3,900	-		-		-		-		-		-		-		-		-		-		-		-		-		-		-	
Dimethylphthalate	53,000	-		-		-		-		-		-		-		-		-		-		-		-		-		-		-	
Diethyl phthalate	61,000	-		-		-		-		-		-		-		-		-		-		-		-		-		-		-	
N-Nitrosodiphenylamine	11,000	-		-		-		-		-		-		-		-		-		-		-		-		-		-		-	
Hexachlorobenzene	380	-		-		-		-		-		-		-		-		-		-		-		-		-		-		-	
Butylbenzylphthalate	4,900	-		-		-		-		-		-		-		-		-		-		-		-		-		-		-	

	Collection Method	Sediment Cores																													
	Sample ID	DM-04-C				DM-06-C						DM-08-C				DM-11-C						DM-12-C				DM-13-C				DM-17-C	
Analyte	Interval	0-1 ft	Q	1-3 ft	Q	0-1 ft	Q	1-3 ft	Q	3-5 ft	Q	0-1 ft	Q	1-3 ft	Q	0-1 ft	Q	1-3 ft	Q	3-5 ft	Q	0-1 ft	Q	1-3 ft	Q	0-1 ft	Q	1-3 ft	Q	0-1 ft	Q
Phenols (µg/kg DW)	**SQS DW**																														
Phenol	420	-		-		57.1		149		219		-		-		223		41.3		122		-		-		58.9		-		29.1	
2-Methylphenol (o-Cresol)	63	-		-		14.7		73.7		155		-		-		6.6		5.9		59.7		-		-		6.2		-		4.7	J
4-Methylphenol (p-Cresol)	670	-		-		118		443		768		-		-		52.5		61.4		515		-		-		84.2		-		55.8	
2,4-Dimethylphenol	29	-		-		21.5	J	88.5	J	203	J	-		-		9.7	J	12.9	J	96	J	-		-		8.1	J	-		7.1	J
Pentachlorophenol	360	-		-		12.5	UJ	19.6	UJ	19.9	UJ	-		-		24.4	UJ	19.8	UJ	48.3	UJ	-		-		12.2	J	-		51.8	
Benzyl Alcohol	57	-		-		19.8	U	19.6	U	19.9	U	-		-		44.9	U	19.8	U	48.3	U	-		-		20	U	-		20	U
Benzoic Acid	650	-		-		123	J	100	J	148	J	-		-		345	J	28.2	J	119	J	-		-		100	UJ	-		100	UJ
Dioxin/Furans (ng/kg DW)	**SQS DW**																														
2,3,7,8-TCDF	-	3.78	J	4.99	J	4.82	J	6.46		10.4		6.8	J	11.9	J	9.07	J	7.12	J	3.76		3.38	J	0.908	UJ	2.6	J	1.78	U	5.61	J
2,3,7,8-TCDD	-	0.874	J	1.22		1.13	U	0.756	U	1.8		1.18		1.45		1.54	U	1.32		1	U	0.555	U	0.298	U	0.707	U	0.426	U	1.37	
1,2,3,7,8-PeCDF	-	2.21		2.82		2.86		3.57		5.57		4.17		4.17		8.22		5.45		2.57		1.97		0.582	J	1.72	U	1.05		4.89	
2,3,4,7,8-PeCDF	-	2.93		3.7		2.9		3.38		5.12		4.64		4.55		6.77		4.67		1.78		2.23		0.589	U	1.99		0.74	U	4.35	
1,2,3,7,8-PeCDD	-	5.7		4.57		5.78		3.11		6.78		7.78		4.9		14.7		9.55		2.17		3.51		0.749	U	3.55		1.4		10.7	
1,2,3,4,7,8-HxCDF	-	7.81		4.35		4.82	J	3.14	J	4.98	J	9.26		3.54		23.8	J	14		1.44	J	6.46		1.05		4.89		0.724	J	13.8	
1,2,3,6,7,8-HxCDF	-	4.95		4.15		4.06		2.74		4.16		6.48		3.96		16.9		11.7		1.35	U	3.93		0.737	J	3.33		0.657	J	13.1	
2,3,4,6,7,8-HxCDF	-	7.21		3.76		3.65		3.35		4.06		9.61		5.11		13.7		9.57		1.53		5.25		1.12		3.5	U	0.57	J	17.6	
1,2,3,7,8,9-HxCDF	-	1.4		0.988	J	1.24	J	1.05	J	0.895	UJ	2.81		0.96	U	10.9	J	3.4	UJ	1	UJ	1.48		0.286	U	0.829	J	0.141	U	4.89	
1,2,3,4,7,8-HxCDD	-	3.69		3.09		3.87		1.65		3.39		4.02		2.11		12.3		6.27		1.34		1.64	U	0.397	J	2.07		1.15		7.14	
1,2,3,6,7,8-HxCDD	-	30.5		14.1		20		3.55		5.83		32.7		5.81		127		67.1		3.77		15.2		3.73		15.7		2.16		73.4	
1,2,3,7,8,9-HxCDD	-	11.6		9.11		8.48		2.5		5.58		11.4		3.66		43.6		19.9		2.77		6.61		1.88		4.23		1.17		22.3	
1,2,3,4,6,7,8-HpCDF	-	285		81.1		101		13.9		10.5		159		21.7		497		431		11.3		72.3		12.8		104		5.03		312	
1,2,3,4,7,8,9-HpCDF	-	7.87		1.93		4.31		1.06	U	0.973	J	5.93		0.746	U	20.1		12.3		1	U	5.7		0.73	J	4.79		0.266	U	16.7	
1,2,3,4,6,7,8-HpCDD	-	438		171		292		33.8		24.6		516		40.7		2030		696		29.5		190		34		204		12.7		1000	
OCDF	-	346		85.7		90.6		10.9		3.38		148		13.6		487		464		9.04		73.1		17.2		113		4.85		417	
OCDD	-	2860		1240		11400	J	195		27.5		3860		195		13000	J	3590		120		1630		272		1430		87.9		6220	J
Total TEQ (ND = 1/2 DL)	-	**22.8838**		**14.37641**		**19.81508**		**7.59717**		**14.53784**		**26.7968**		**12.18741**		**72.9917**		**38.7797**		**5.311312**		**12.01953**		**2.14247**		**11.657**		**2.701105**		**44.5838**	
Total TCDF	-	47.9		111		76.2		111		163		107		177		113		84.6		70		41.6		9.33		45		18.4		84	
Total TCDD	-	61.7		86.4		104		72.8		252		120		183		109		111		82.5		50.8		8.27		47.6		63.9		146	
Total PeCDF	-	99.9		160		96.4		52.1		77.5		175		165		227		151		16.8		80.9		15.5		64.3		8.53		197	
Total PeCDD	-	49.3		52.7		62.4		35		156		85.4		90.6		119		96.8		45.5		22.5		6.16		32.4		29.5		121	
Total HxCDF	-	304		132		176		46.1		34.8		281		70.9		805		483		10.6		131		22.4		135		11.4		538	
Total HxCDD	-	350		159		180		61.7		178		330		107		1080		441		113		119		30.4		150		46.9		494	
Total HpCDF	-	830		165		253		26.8		13		413		41.6		1270		999		21.5		196		35.5		280		12.2		1020	
Total HpCDD	-	1130		407		820		94.2		44		1720		80.1		7720		1520		56.1		471		85.6		477		29.7		2020	

	Collection Method	Sediment Cores												Grab Samples																	
	Sample ID	DM-17-C		DM-20-C				DM-24-C						DM-01-S		DM-03-S		DM-07-S		DM-10-S		DM-15-S		DM-15-S-DUP		DM-15-S-TRIP		DM-19-S		DM-19-S-DUP	
Analyte	Interval	1-3 ft	Q	0-1 ft	Q	1-3 ft	Q	0-1 ft	Q	1-3 ft	Q	3-5 ft	Q	0-10 cm	Q	0-10 cm	Q	0-10 cm	Q	0-10 cm	Q	0-10 cm	Q	0-10 cm	Q	0-10 cm	Q	0-10 cm	Q	0-10 cm	Q
Grain Size (%)	**SQS DW**																														
Gravel	-	21.5		9.3		8.3		32.4		22.1		-		13.8		1.4		12.9		4.4		35		26.7		30.5		12.4		12.2	
Sand	-	41.5		60.3		83.4		37.6		33.4		-		72.6		92.3		54.7		76.4		47.4		51.1		49.4		61.8		59.3	
Silt	-	21.3		23		5.8		16.1		23.5		-		10.2		3.2		22.6		12.6		7.3		15.2		13.9		12.9		12.6	
Clay	-	15.7		7.5		2.6		13.9		21.1		-		3.4		3.1		9.9		6.5		10		6.9		6.2		12.8		16	
Conventionals (%)	**SQS DW**																														
Total Solids	-	43.3		45.29		64.35		55.47		38.7		35.05		58.92		68.12		38.28		53.01		56.55		54.97		54.46		50.55		50.1	
Total Volatile Solids	-	20.2		24.48		7.18		6.46		19.67		29.84		9.73		4.03		29.7		10.77		4.75		4.66		4.83		10.01		10.53	
Total Organic Carbon	-	13.6		14.2		3.12		3.05		12.8		17.7		4.48		1.65		16.8		6.35		1.35		2.63		1.82		5.07		6.58	
Total Sulfides (mg/kg)	-	479	J	144	J	152	J	530	J	392	J	-		69.4	J	473	J	831	J	1070	J	332	J	389	J	434	J	450	J	526	J
Ammonia - N (mg/kg NH3-N DW)	-	12.1		5.74		4.14		7.67		10.9		-		1.71		3.4		9.32		7		7.51		7.4		8.25		6.55		7.37	
Metals (mg/kg DW)	**SQS DW**																														
Arsenic	57	-		-		-		-		-		-		4.22		6.25		-		19.7		-		-		-		31.4		29.8	
Cadmium	51	-		-		-		-		-		-		0.46		0.39		-		0.97		-		-		-		0.6		0.7	
Chromium	260	-		-		-		-		-		-		16.4		19.2		-		26.4		-		-		-		17.2		21.2	
Copper	390	-		-		-		-		-		-		34.7	J	40		-		89.7	J	-		-		-		197	J	219	J
Lead	450	-		-		-		-		-		-		47.3		34.3		-		64.6		-		-		-		79.1		102	
Mercury	0.41	-		-		-		-		-		-		0.0198	J	0.0221	J	-		0.366		-		-		-		**0.432**		0.346	
Silver	6.1	-		-		-		-		-		-		0.1	J	0.1	J	-		0.22	J	-		-		-		0.73		0.68	
Zinc	410	-		-		-		-		-		-		127		71.9		-		144		-		-		-		106		112	
SVOCs (µg/kg DW)	**AET DW (SCUM)**																														
Naphthalene	2,100	339		180		51.8		93.1		283		-		24.7	J	44.4		63.6		113		24.2	J	95.9	J	-		184	J	95.5	J
Acenaphthylene	1,300	73.8		158		43.6		36.2		80.1		-		20	U	36.7	J	60.4		77.5		23.3		53		-		181	J	33.8	J
Acenaphthene	500	**510**		168		58.3		57.2		417		-		21.4	J	106		67.3		91.6		21.1		37.7		-		89.5	J	61.9	
Fluorene	540	209		**544**		92.2		69.4		431		-		20	U	156		92.1		127		24.3		55.2		-		151	J	78.1	J
Phenanthrene	1,500	540		**3,360**		512		245		994		-		197		1,390		812		1,020		243	J	777	J	-		758	J	258	J
Anthracene	960	335		**19,500**		158		119		439		-		44.7	J	383		219		268		49.5	J	105	J	-		**1,380**	J	121	J
Fluoranthene	1,700	1,250	J	**3,670**		747		429		**2,080**		-		496		**2,410**		1,690		1,570		598	J	**2,850**	J	-		**7,580**	J	404	J
Pyrene	2,600	1,350	J	1,690		777		896		2,320		-		643		1,950		1,240		1,040		498	J	1,330	J	-		**4,890**	J	526	J
Benzo(a)anthracene	1,300	462		**4,140**		308		205		488		-		154		880		523		707		107	J	198	J	-		**3,910**	J	203	J
Chrysene	1,400	668		**6,680**		356		400		744		-		372		1,090		1,110		1,060		244	J	585	J	-		**4,850**	J	370	J
Benzofluoranthenes, Total	3,200	843		2,360		489		599		780		-		40	U	1,650		1,080		1,320		275		442		-		**3,700**	J	390	J
Benzo(a)pyrene	1,600	451		1,180		280		281		376		-		20	U	889		463		698		120		175		-		**1,720**	J	209	J
Indeno(1,2,3-cd)pyrene	600	157		296	J	83.7	J	113		163		-		20	UJ	347	J	167	J	245	J	59.5		81.4		-		**642**	J	104	J
Dibenzo(a,h)anthracene	230	58.6		20	UJ	20	UJ	44.4		71.5		-		20	UJ	20	UJ	20	UJ	20	UJ	22.7		20	U	-		20	UJ	41.3	J
Benzo(g,h,i)perylene	670	141		20	UJ	86.5	J	115		175		-		20	UJ	299	J	163	J	233	J	56.5		76.2		-		495	J	104	J
Total LPAH	5,200	2,006.8		**23,910.0**		915.9		619.9		2,644.1		-		287.8	J	2,116	J	1,314.4		1,697.1		385.4	J	1,123.8	J	-		2,743.5	J	648.3	J
Total HPAH	12,000	5,380.6	J	**20,016**	J	3,127.2	J	3,082.4		7,197.5		-		1,665		9,515	J	6,436	J	6,873	J	1,980.7	J	5,737.6	J	-		**27,787**	J	2,351.3	J
Total 16 PAH	-	7,387.4	J	43,926.0	J	4,043	J	3,702.3		9,841.6		-		1,952.8	J	11,631	J	7,750.4	J	8,570.1	J	2,366.1	J	6,861.4	J	-		30,530.5	J	2,999.6	J
2-Methylnaphthalene	670	112		89.5		22.9		35.2		92.7		-		20	U	21.9	J	31.9		50.7		12.5	J	40.1		-		50.1	J	33.6	
Dibenzofuran	540	269		-		-		-		-		-		-		-		-		-		19.7	J	26.5		-		-		-	
Di-n-Butylphthalate	1,400	6.2	J	-		-		-		-		-		-		-		-		-		20	U	20	U	-		-		-	
bis(2-Ethylhexyl)phthalate	1,300	233		-		-		-		-		-		-		-		-		-		99.3	J	565	J	-		-		-	
Di-n-Octylphthalate	6,200	20	U	-		-		-		-		-		-		-		-		-		20	U	20	U	-		-		-	

	Collection Method	Sediment Cores												Grab Samples																	
	Sample ID	DM-17-C		DM-20-C				DM-24-C						DM-01-S		DM-03-S		DM-07-S		DM-10-S		DM-15-S		DM-15-S-DUP		DM-15-S-TRIP		DM-19-S		DM-19-S-DUP	
Analyte	Interval	1-3 ft	Q	0-1 ft	Q	1-3 ft	Q	0-1 ft	Q	1-3 ft	Q	3-5 ft	Q	0-10 cm	Q	0-10 cm	Q	0-10 cm	Q	0-10 cm	Q	0-10 cm	Q	0-10 cm	Q	0-10 cm	Q	0-10 cm	Q	0-10 cm	Q
SVOCs (µg/kg DW)	**AET DW (SCUM)**																														
1,4-Dichlorobenzene	110	6.8		-		-		-		-		-		-		-		-		-		1.2	J	1.4	J	-		-		-	
1,2-Dichlorobenzene	35	1.6	J	-		-		-		-		-		-		-		-		-		5	U	5	U	-		-		-	
1,2,4-Trichlorobenzene	31	5	U	-		-		-		-		-		-		-		-		-		5	U	5	U	-		-		-	
Hexachlorobutadiene	11	5	U	-		-		-		-		-		-		-		-		-		5	U	5	U	-		-		-	
Dimethylphthalate	71	5	U	-		-		-		-		-		-		-		-		-		9.2		5	U	-		-		-	
Diethyl phthalate	200	55.6	U	-		-		-		-		-		-		-		-		-		50.8	U	42.1	U	-		-		-	
N-Nitrosodiphenylamine	28	5	U	-		-		-		-		-		-		-		-		-		5	U	5	U	-		-		-	
Hexachlorobenzene	22	5	U	-		-		-		-		-		-		-		-		-		0.8	J	5	U	-		-		-	
Butylbenzylphthalate	63	40.3	J	-		-		-		-		-		-		-		-		-		16.6	J	8.1	J	-		-		-	
SVOCs (µg/kg OC)	**SQS OC***																														
Naphthalene	99,000	-		-		1,660		3,052		-		-		-		2,691		-		-		1,793		3,646		-		-		-	
Acenaphthylene	66,000	-		-		1,397		1,187		-		-		-		2,224	J	-		-		1,726		2,015		-		-		-	
Acenaphthene	16,000	-		-		1,869		1,875		-		-		-		6,424		-		-		1,563		1,433		-		-		-	
Fluorene	23,000	-		-		2,955		2,275		-		-		-		9,455		-		-		1,800		2,099		-		-		-	
Phenanthrene	100,000	-		-		16,410		8,033		-		-		-		84,242		-		-		18,000		29,544		-		-		-	
Anthracene	220,000	-		-		5,064		3,902		-		-		-		23,212		-		-		3,667		3,992		-		-		-	
Fluoranthene	160,000	-		-		23,942		14,066		-		-		-		146,061		-		-		44,296		108,365		-		-		-	
Pyrene	1,000,000	-		-		24,904		29,377		-		-		-		118,182		-		-		36,889		50,570		-		-		-	
Benzo(a)anthracene	110,000	-		-		9,872		6,721		-		-		-		53,333		-		-		7,926		7,529		-		-		-	
Chrysene	110,000	-		-		11,410		13,115		-		-		-		66,061		-		-		18,074		22,243		-		-		-	
Benzofluoranthenes, Total	230,000	-		-		15,673		19,639		-		-		-		100,000		-		-		20,370		16,806		-		-		-	
Benzo(a)pyrene	99,000	-		-		8,974		9,213		-		-		-		53,879		-		-		8,889		6,654		-		-		-	
Indeno(1,2,3-cd)pyrene	34,000	-		-		2,683	J	3,705		-		-		-		21,030		-		-		4,407		3,095		-		-		-	
Dibenzo(a,h)anthracene	12,000	-		-		641	UJ	1,456		-		-		-		1,212	U	-		-		1,681		760	U	-		-		-	
Benzo(g,h,i)perylene	31,000	-		-		2,772	J	3,770		-		-		-		18,121		-		-		4,185		2,897		-		-		-	
Total LPAH	370,000	-		-		29,356		20,325		-		-		-		128,248	J	-		-		28,548		42,730		-		-		-	
Total HPAH	960,000	-		-		100,231	J	101,062		-		-		-		576,667		-		-		146,719		218,160		-		-		-	
Total 16 PAH	-	-		-		129,587	J	121,387		-		-		-		704,915	J	-		-		175,267		260,890		-		-		-	
2-Methylnaphthalene	38,000	-		-		734		1,154		-		-		-		1,327	J	-		-		926	J	1,525		-		-		-	
Dibenzofuran	15,000	-		-		-		-		-		-		-		-		-		-		1,459	J	1,008		-		-		-	
Di-n-Butylphthalate	220,000	-		-		-		-		-		-		-		-		-		-		1,481	U	760	U	-		-		-	
bis(2-Ethylhexyl)phthalate	47,000	-		-		-		-		-		-		-		-		-		-		7,356		21,483		-		-		-	
Di-n-Octylphthalate	58,000	-		-		-		-		-		-		-		-		-		-		1,481	U	760	U	-		-		-	
1,4-Dichlorobenzene	3,100	-		-		-		-		-		-		-		-		-		-		89	J	53	J	-		-		-	
1,2-Dichlorobenzene	2,300	-		-		-		-		-		-		-		-		-		-		370	U	190	U	-		-		-	
1,2,4-Trichlorobenzene	810	-		-		-		-		-		-		-		-		-		-		370	U	190	U	-		-		-	
Hexachlorobutadiene	3,900	-		-		-		-		-		-		-		-		-		-		370	U	190	U	-		-		-	
Dimethylphthalate	53,000	-		-		-		-		-		-		-		-		-		-		681		190	U	-		-		-	
Diethyl phthalate	61,000	-		-		-		-		-		-		-		-		-		-		3,763		1,601		-		-		-	
N-Nitrosodiphenylamine	11,000	-		-		-		-		-		-		-		-		-		-		370	U	190	U	-		-		-	
Hexachlorobenzene	380	-		-		-		-		-		-		-		-		-		-		59	J	190	U	-		-		-	
Butylbenzylphthalate	4,900	-		-		-		-		-		-		-		-		-		-		1,230		308		-		-		-	

	Collection Method	Sediment Cores												Grab Samples																	
	Sample ID	DM-17-C		DM-20-C				DM-24-C						DM-01-S		DM-03-S		DM-07-S		DM-10-S		DM-15-S		DM-15-S-DUP		DM-15-S-TRIP		DM-19-S		DM-19-S-DUP	
Analyte	Interval	1-3 ft	Q	0-1 ft	Q	1-3 ft	Q	0-1 ft	Q	1-3 ft	Q	3-5 ft	Q	0-10 cm	Q	0-10 cm	Q	0-10 cm	Q	0-10 cm	Q	0-10 cm	Q	0-10 cm	Q	0-10 cm	Q	0-10 cm	Q	0-10 cm	Q
Phenols (µg/kg DW)	**SQS DW**																														
Phenol	420	53.5		-		-		-		-		-		-		-		-		-		33.4	J	19.7	J	-		-		-	
2-Methylphenol (o-Cresol)	63	17.4		-		-		-		-		-		-		-		-		-		1.5	J	2.2	J	-		-		-	
4-Methylphenol (p-Cresol)	670	105		-		-		-		-		-		-		-		-		-		7.4		22.4		-		-		-	
2,4-Dimethylphenol	29	19.7	J	-		-		-		-		-		-		-		-		-		2.4	J	3.2	J	-		-		-	
Pentachlorophenol	360	171		-		-		-		-		-		-		-		-		-		8	J	2.5	J	-		-		-	
Benzyl Alcohol	57	20	U	-		-		-		-		-		-		-		-		-		20	U	20	U	-		-		-	
Benzoic Acid	650	100	UJ	-		-		-		-		-		-		-		-		-		100	UJ	100	UJ	-		-		-	
Dioxin/Furans (ng/kg DW)	**SQS DW**																														
2,3,7,8-TCDF	-	8.65	J	6.66	J	2.35	J	3.33	J	8.3	J	4.97		-		-		-		-		1.14		-		-		2.94	J	-	
2,3,7,8-TCDD	-	1.81		1.99		0.583	U	0.772	J	1.52		0.873	U	-		-		-		-		1	U	-		-		0.504	J	-	
1,2,3,7,8-PeCDF	-	6.79		4.67		1.75		2.03		4.23		2.57		-		-		-		-		0.807	J	-		-		1.64		-	
2,3,4,7,8-PeCDF	-	8.11		5.66		2.19		2.06		5.04		2.1		-		-		-		-		0.666	J	-		-		1.9		-	
1,2,3,7,8-PeCDD	-	15.2		21.5		3.87		5.72		6.08		2.65		-		-		-		-		1.81		-		-		4.04		-	
1,2,3,4,7,8-HxCDF	-	31.5		9.81		7.79		5.13		7.21		1.56	J	-		-		-		-		1.62		-		-		4.22		-	
1,2,3,6,7,8-HxCDF	-	27.9		9.49		11.2		3.92		6.55		1.89		-		-		-		-		1.33	U	-		-		3.38		-	
2,3,4,6,7,8-HxCDF	-	35.7		11.5		9.13		5.15		9.67		1.44		-		-		-		-		1.08		-		-		4.63		-	
1,2,3,7,8,9-HxCDF	-	7.59	U	1.54		1.41		1.6		1.71		0.999	UJ	-		-		-		-		0.634	J	-		-		1.16	U	-	
1,2,3,4,7,8-HxCDD	-	12.1		14.8		4.28		2.71		3.31		1.3		-		-		-		-		1.14		-		-		1.81	J	-	
1,2,3,6,7,8-HxCDD	-	168		45.7		22.2		23.7		20.6		1.92		-		-		-		-		7.22		-		-		13.5	J	-	
1,2,3,7,8,9-HxCDD	-	36.3		31.7		10.2		11.1		9.2		1.89		-		-		-		-		2.87		-		-		5.01	J	-	
1,2,3,4,6,7,8-HpCDF	-	785		179		196		81.5		163		3.52		-		-		-		-		28.8		-		-		81.2		-	
1,2,3,4,7,8,9-HpCDF	-	45.1		8.94		10.7		4.95		4.71		0.999	U	-		-		-		-		1.94		-		-		4.82		-	
1,2,3,4,6,7,8-HpCDD	-	2150		467		581		248		186		7.83	J	-		-		-		-		137		-		-		242		-	
OCDF	-	1030		255		208		114		204		1.33	J	-		-		-		-		47.2		-		-		180	J	-	
OCDD	-	12700	J	1860		5150	J	1940		1020		15.9		-		-		-		-		1080		-		-		1660		-	
Total TEQ (ND = 1/2 DL)	-	**85.9612**		**45.632**		**21.2114**		**16.7956**		**19.7982**		**5.464214**		-		-		-		-		**6.18647**		-		-		**12.6024**		-	
Total TCDF	-	145		147		48.6		40.5		160		75.9		-		-		-		-		14.9		-		-		46.5		-	
Total TCDD	-	254		138		24.4		55.1		117		77.6		-		-		-		-		29.1		-		-		27.3	J	-	
Total PeCDF	-	355		169		78.8		73.6		224		26.2		-		-		-		-		16.4		-		-		64.9		-	
Total PeCDD	-	192		113		26		49.4		77.6		40.7		-		-		-		-		22.3		-		-		27.9	J	-	
Total HxCDF	-	1170		282		222		137		212		13.2		-		-		-		-		43.3		-		-		106		-	
Total HxCDD	-	1040		338		150		200		220		67		-		-		-		-		70.5		-		-		133	J	-	
Total HpCDF	-	2490		496		453		241		419		3.52		-		-		-		-		91.3		-		-		248		-	
Total HpCDD	-	4420		895		1110		756		383		13.7		-		-		-		-		478		-		-		635		-	

	Collection Method	Grab Samples								Hammer Core							
	Sample ID	DM-19-S-TRIP		DM-21-S		DM-22-S		DM-23-S		DM-C1		DM-C2		DM-C3		DM-C4	
Analyte	Interval	0-10 cm	Q	0-10 cm	Q	0-10 cm	Q	0-10 cm	Q	1-2 ft	Q	1-2 ft	Q	1-2 ft	Q	1-2 ft	Q
Grain Size (%)	**SQS DW**																
Gravel	-	15.1		10.9		2.3		1.7		45.6		50.9		48		59.9	
Sand	-	59.5		78.5		90.9		93.3		51.1		46.2		49		37.4	
Silt	-	13.5		3.4		2.1		1.1		1.6		1.3		0.9		1.1	
Clay	-	12		7.3		4.6		3.8		1.7		1.7		2.2		1.7	
Conventionals (%)	**SQS DW**																
Total Solids	-	52.69		70.84		77.35		76.94		79.99		88.16		87.69		89.97	
Total Volatile Solids	-	8.54		2.3		1.13		0.97		0.94		0.94		0.83		0.84	
Total Organic Carbon	-	4.41		0.78		0.26		0.18		0.12		0.16		0.17		0.14	
Total Sulfides (mg/kg)	-	358	J	340	J	91.6	J	150	J	30.7	J	4.66	J	6.58	J	3.6	J
Ammonia - N (mg/kg NH3-N DW)	-	5.65		8.37		1.29		1.54		0.48		0.4	U	0.4	U	0.4	U
Metals (mg/kg DW)	**SQS DW**																
Arsenic	57	-		-		-		-		**151**		**89.7**		**141**		**113**	
Cadmium	51	-		-		-		-		0.2		0.15		0.14		0.15	
Chromium	260	-		-		-		-		14.7		14.5		15.7		9.7	
Copper	390	-		-		-		-		72.7	J	51.2	J	63.1	J	56.6	J
Lead	450	-		-		-		-		126		78.5		111		80.7	
Mercury	0.41	-		-		-		-		0.025	U	0.025	U	0.025	U	0.025	U
Silver	6.1	-		-		-		-		0.15	J	0.13	J	0.16	J, D	0.13	J
Zinc	410	-		-		-		-		401	D	222		334	D	238	
SVOCs (µg/kg DW)	**AET DW (SCUM)**																
Naphthalene	2,100	-		42.2		9.2	J	20	U	20	U	20	U	20	U	20	U
Acenaphthylene	1,300	-		16.6	J	11.3	J	20	U	20	U	20	U	20	U	20	U
Acenaphthene	500	-		92		8.9	J	5.5	J	20	U	20	U	20	U	20	U
Fluorene	540	-		83.8		23.6		20	U	20	U	20	U	20	U	20	U
Phenanthrene	1,500	-		322	J	160		55.9		20	U	72.7		22.4		13.7	J
Anthracene	960	-		98.9		38.7		17.6	J	20	U	15.3	J	20	U	20	U
Fluoranthene	1,700	-		569	J	215		88		17.2	J	79.6		45.5		21.2	
Pyrene	2,600	-		672	J	241	J	111		16.4	J	77.6		40.3		18.9	J
Benzo(a)anthracene	1,300	-		235		102		34.6		20	U	27.7		17.2	J	7.4	J
Chrysene	1,400	-		275		107		41.5		9.9	J	32		19.3	J	10.7	J
Benzofluoranthenes, Total	3,200	-		352		162		65.6		40	U	44.1		33.9	J	40	U
Benzo(a)pyrene	1,600	-		175		92.4		37.1		20	U	25.6		13.0	J	9.9	J
Indeno(1,2,3-cd)pyrene	600	-		83.7		54.1	J	20	UJ	20	U	20	U	20	U	20	U
Dibenzo(a,h)anthracene	230	-		35.5		20	UJ	20	UJ	20	U	20	U	20	U	20	U
Benzo(g,h,i)perylene	670	-		82.8		59.6	J	26	J	20	U	20	U	20	U	20	U
Total LPAH	5,200	-		655.5	J	251.7	J	79	J	20	U	88	J	22.4		13.7	J
Total HPAH	12,000	-		2,480	J	1,033.1	J	403.8	J	43.5	J	286.6		169.2	J	68.1	J
Total 16 PAH	-	-		3,135.5	J	1,285	J	482.8	J	43.5	J	374.6	J	191.6	J	81.8	J
2-Methylnaphthalene	670	-		27.3		5.2	J	20	U	20	U	20	U	20	U	20	U
Dibenzofuran	540	-		63.6		-		-		-		-		-		-	
Di-n-Butylphthalate	1,400	-		21.1		-		-		-		-		-		-	
bis(2-Ethylhexyl)phthalate	1,300	-		81.6		-		-		-		-		-		-	
Di-n-Octylphthalate	6,200	-		20	U	-		-		-		-		-		-	

	Collection Method	Grab Samples								Hammer Core							
	Sample ID	DM-19-S-TRIP		DM-21-S		DM-22-S		DM-23-S		DM-C1		DM-C2		DM-C3		DM-C4	
Analyte	Interval	0-10 cm	Q	0-10 cm	Q	0-10 cm	Q	0-10 cm	Q	1-2 ft	Q	1-2 ft	Q	1-2 ft	Q	1-2 ft	Q
SVOCs (µg/kg DW)	**AET DW (SCUM)**																
1,4-Dichlorobenzene	110	-		1.6	J	-		-		-		-		-		-	
1,2-Dichlorobenzene	35	-		5	U	-		-		-		-		-		-	
1,2,4-Trichlorobenzene	31	-		5	U	-		-		-		-		-		-	
Hexachlorobutadiene	11	-		5	U	-		-		-		-		-		-	
Dimethylphthalate	71	-		5	U	-		-		-		-		-		-	
Diethyl phthalate	200	-		49.6	U	-		-		-		-		-		-	
N-Nitrosodiphenylamine	28	-		5	U	-		-		-		-		-		-	
Hexachlorobenzene	22	-		5	U	-		-		-		-		-		-	
Butylbenzylphthalate	63	-		2.7	J	-		-		-		-		-		-	
SVOCs (µg/kg OC)	**SQS OC***																
Naphthalene	99,000	-		5,410		-		-		-		-		-		-	
Acenaphthylene	66,000	-		2,128	J	-		-		-		-		-		-	
Acenaphthene	16,000	-		11,795		-		-		-		-		-		-	
Fluorene	23,000	-		10,744		-		-		-		-		-		-	
Phenanthrene	100,000	-		41,282		-		-		-		-		-		-	
Anthracene	220,000	-		12,679		-		-		-		-		-		-	
Fluoranthene	160,000	-		72,949		-		-		-		-		-		-	
Pyrene	1,000,000	-		86,154		-		-		-		-		-		-	
Benzo(a)anthracene	110,000	-		30,128		-		-		-		-		-		-	
Chrysene	110,000	-		35,256		-		-		-		-		-		-	
Benzofluoranthenes, Total	230,000	-		45,128		-		-		-		-		-		-	
Benzo(a)pyrene	99,000	-		22,436		-		-		-		-		-		-	
Indeno(1,2,3-cd)pyrene	34,000	-		10,731		-		-		-		-		-		-	
Dibenzo(a,h)anthracene	12,000	-		4,551		-		-		-		-		-		-	
Benzo(g,h,i)perylene	31,000	-		10,615		-		-		-		-		-		-	
Total LPAH	370,000	-		84,038	J	-		-		-		-		-		-	
Total HPAH	960,000	-		317,949		-		-		-		-		-		-	
Total 16 PAH	-	-		401,987	J	-		-		-		-		-		-	
2-Methylnaphthalene	38,000	-		3,500		-		-		-		-		-		-	
Dibenzofuran	15,000	-		8,154		-		-		-		-		-		-	
Di-n-Butylphthalate	220,000	-		2,705		-		-		-		-		-		-	
bis(2-Ethylhexyl)phthalate	47,000	-		10,462		-		-		-		-		-		-	
Di-n-Octylphthalate	58,000	-		2,564	U	-		-		-		-		-		-	
1,4-Dichlorobenzene	3,100	-		205	J	-		-		-		-		-		-	
1,2-Dichlorobenzene	2,300	-		641	U	-		-		-		-		-		-	
1,2,4-Trichlorobenzene	810	-		641	U	-		-		-		-		-		-	
Hexachlorobutadiene	3,900	-		641	U	-		-		-		-		-		-	
Dimethylphthalate	53,000	-		641	U	-		-		-		-		-		-	
Diethyl phthalate	61,000	-		6,359		-		-		-		-		-		-	
N-Nitrosodiphenylamine	11,000	-		641	U	-		-		-		-		-		-	
Hexachlorobenzene	380	-		641	U	-		-		-		-		-		-	
Butylbenzylphthalate	4,900	-		346	J	-		-		-		-		-		-	

	Collection Method	Grab Samples								Hammer Core							
	Sample ID	DM-19-S-TRIP		DM-21-S		DM-22-S		DM-23-S		DM-C1		DM-C2		DM-C3		DM-C4	
Analyte	Interval	0-10 cm	Q	0-10 cm	Q	0-10 cm	Q	0-10 cm	Q	1-2 ft	Q	1-2 ft	Q	1-2 ft	Q	1-2 ft	Q
Phenols (µg/kg DW)	**SQS DW**																
Phenol	420	-		20.6		-		-		-		-		-		-	
2-Methylphenol (o-Cresol)	63	-		1.5	J	-		-		-		-		-		-	
4-Methylphenol (p-Cresol)	670	-		34.8		-		-		-		-		-		-	
2,4-Dimethylphenol	29	-		20	UJ	-		-		-		-		-		-	
Pentachlorophenol	360	-		5.4	J	-		-		-		-		-		-	
Benzyl Alcohol	57	-		20	U	-		-		-		-		-		-	
Benzoic Acid	650	-		37.3	J	-		-		-		-		-		-	
Dioxin/Furans (ng/kg DW)	**SQS DW**																
2,3,7,8-TCDF	-	-		-		-		-		-		-		-		-	
2,3,7,8-TCDD	-	-		-		-		-		-		-		-		-	
1,2,3,7,8-PeCDF	-	-		-		-		-		-		-		-		-	
2,3,4,7,8-PeCDF	-	-		-		-		-		-		-		-		-	
1,2,3,7,8-PeCDD	-	-		-		-		-		-		-		-		-	
1,2,3,4,7,8-HxCDF	-	-		-		-		-		-		-		-		-	
1,2,3,6,7,8-HxCDF	-	-		-		-		-		-		-		-		-	
2,3,4,6,7,8-HxCDF	-	-		-		-		-		-		-		-		-	
1,2,3,7,8,9-HxCDF	-	-		-		-		-		-		-		-		-	
1,2,3,4,7,8-HxCDD	-	-		-		-		-		-		-		-		-	
1,2,3,6,7,8-HxCDD	-	-		-		-		-		-		-		-		-	
Dioxin/Furans (ng/kg DW)	**SQS DW**																
1,2,3,7,8,9-HxCDD	-	-		-		-		-		-		-		-		-	
1,2,3,4,6,7,8-HpCDF	-	-		-		-		-		-		-		-		-	
1,2,3,4,7,8,9-HpCDF	-	-		-		-		-		-		-		-		-	
1,2,3,4,6,7,8-HpCDD	-	-		-		-		-		-		-		-		-	
OCDF	-	-		-		-		-		-		-		-		-	
OCDD	-	-		-		-		-		-		-		-		-	
Total TEQ (ND = 0)	-	-		-		-		-		-		-		-		-	
Total TEQ (ND = 1/2 DL)	-	-		-		-		-		-		-		-		-	
Total TCDF	-	-		-		-		-		-		-		-		-	
Total TCDD	-	-		-		-		-		-		-		-		-	
Total PeCDF	-	-		-		-		-		-		-		-		-	
Total PeCDD	-	-		-		-		-		-		-		-		-	
Total HxCDF	-	-		-		-		-		-		-		-		-	
Total HxCDD	-	-		-		-		-		-		-		-		-	
Total HpCDF	-	-		-		-		-		-		-		-		-	
Total HpCDD	-	-		-		-		-		-		-		-		-	

Notes:
Total LPAH = sum(non-U-qualifiers(naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene))
Total HPAH = sum(non-U-qualifiers(fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(a)pyrene, dibenzo(a,h)anthracene, benzo(g,h,i)perylene, indeno(1,2,3-c,d)pyrene, total benzofluoranthenes))
Exceeds SQS/AET DW Criteria
OC* TOC Normalized when TOC = 0.5%–3.5%. When TOC outside of 0.5%–3.5%, DW values compared to DW AET.

Qualifiers
U: this analyte is not detected above the reporting limit (RL) or, if noted, not detected above the limit of detection (LOD)
J: concentration less than limit of quantification
UJ: identified a compound that was not detected

Table 6. Puget Sound Sediment Reference Material Results

Analyte	TRUE (ng/kg wet)	FOUND (ng/kg wet)	MDL	MRL	Q	PS-SRM % REC.	QC LIMITS % REC.
***Dioxins/Furans* (PSRM0170) (ARI SDG: 22K0399)**							
2,3,7,8-TCDD	1.050	0.836	0.156	0.999	EMPC, J	79.6	50 - 150
1,2,3,7,8-PeCDD	1.080	1.10	0.255	0.999	EMPC	118.8	50 – 150
1,2,3,4,7,8-HxCDD	1.590	1.42	0.259	0.999		89.3	50 – 150
1,2,3,6,7,8-HxCDD	3.880	3.89	0.254	0.999		100.2	50 – 150
1,2,3,7,8,9-HxCDD	3.040	2.96	0.277	0.999	EMPC	97.4	50 – 150
1,2,3,4,6,7,8-HpCDD	90.60	96.0	0.587	2.50	B	106	50 – 150
OCDD	811.00	819	0.684	9.99	B	101	50 – 150
2,3,7,8-TCDF	1.110	0.759	0.164	0.999	EMPC, J	68.4	50 – 150
1,2,3,7,8-PeCDF	1.230	1.030	0.247	0.999		83.7	50 – 150
2,3,4,7,8-PeCDF	1.070	0.818	0.218	0.999	J	76.4	50 – 150
1,2,3,4,7,8-HxCDF	3.020	2.93	0.151	0.999		97.0	50 – 150
1,2,3,6,7,8-HxCDF	1.090	1.05	0.146	0.999		96.3	50 – 150
1,2,3,7,8,9-HxCDF	0.511	0.604	0.154	0.999	J	118.2	50 – 150
2,3,4,6,7,8-HxCDF	1.830	1.62	0.151	0.999		88.5	50 – 150
1,2,3,4,6,7,8-HpCDF	18.700	19.5	0.187	0.999	B	104.3	50 – 150
1,2,3,4,7,8,9-HpCDF	1.630	1.50	0.259	0.999		92.0	50 – 150
OCDF	58.40	56.1	0.301	2.50	B	96.1	50 – 150
***Dioxins/Furans* (PSRM0172) (ARI SDG: 23B0054)**							
2,3,7,8-TCDD	1.050	0.816	0.100	0.998	EMPC, J	77.7	50 – 150
1,2,3,7,8-PeCDD	1.080	1.11	0.180	0.998		102.8	50 – 150
1,2,3,4,7,8-HxCDD	1.590	1.59	0.145	0.998		100.0	50 – 150
1,2,3,6,7,8-HxCDD	3.880	3.36	0.147	0.998		86.6	50 – 150
1,2,3,7,8,9-HxCDD	3.040	2.80	0.161	0.998		92.1	50 – 150
1,2,3,4,6,7,8-HpCDD	90.600	96.6	0.431	2.50	B	106.6	50 – 150
OCDD	811.00	771	0.537	9.98	B	95.1	50 – 150
2,3,7,8-TCDF	1.110	0.786	0.244	0.998	J	70.8	50 – 150
1,2,3,7,8-PeCDF	1.230	1.11	0.199	0.988		90.2	50 – 150
2,3,4,7,8-PeCDF	1.070	0.908	0.179	0.998	J	84.8	50 – 150
1,2,3,4,7,8-HxCDF	3.020	2.62	0.103	0.998		86.8	50 – 150
1,2,3,6,7,8-HxCDF	1.090	1.02	0.104	0.998		93.6	50 – 150
1,2,3,7,8,9-HxCDF	0.511	0.830	0.124	0.998	*, J	162.4*	50 – 150
2,3,4,6,7,8-HxCDF	1.830	1.94	0.114	0.998		106.0	50 – 150
1,2,3,4,6,7,8-HpCDF	18.700	17.6	0.157	0.998		94.1	50 – 150
1,2,3,4,7,8,9-HpCDF	1.630	1.68	0.224	0.998		103.1	50 – 150
OCDF	58.400	53.4	0.298	2.50		109.4	50 – 150

Q = qualifier
* Values outside of QC limits

Table 7. Water Quality Test Results Compared to Test Control Limits.

Test (Species)	Control Limits/Test Results	Temperature (°C)	Salinity (ppt)	DO	pH
Larval Development (*Mytillus sp.*)	Control Limits	16 ± 1	28 ± 1	≥ 5.0 mg/L	7.5 - 9
	Test Results[1]	15.5 to 17.0	28	8.0 – 8.1 mg/L	7.9 – 8.0
Amphipod Mortality (*E. estuarius*)	Control Limits	15 ± 1	28 ± 1	≥ 5.1 mg/L	7-9
	Test Results[1]	15.4 - 16.1	28 – 29 ppt	8.0-8.4	7.9 -8.2
Juvenile Polychaete Growth (*N. arenaceodentata*)	Control Limits	20 ± 1	28 ± 2	≥ 4.6 mg/L	7-9
	Test Results[1]	19.4 to 20.9	28 – 29 ppt	6.3– 7.6 mg/L	7.7 – 8.2

Notes:

°C = degrees Celsius; ppt = parts per thousand; DO =dissolved oxygen

1. Water quality test results are for reference and test sediment parameters only; does not include negative control results.

Table 8. Water Quality Measurements of Total Ammonia and Sulfides.

Test (Test Species)	Total Ammonia (mg/L)	Unionized Ammonia – Total NH_3 (mg/L)	Total Sulfides (mg/L)	Hydrogen Sulfide (mg/L)
Larval Development (*M. galloprovincialis*)	0.108-0.501[1]	<0.5[2]	ND	ND[2]
Amphipod Mortality (*E. estuarius*)	0.444 – 5.95[1]	0.015 – 0.047[2,3]	ND-0.031	ND-0.0055[2,4]
Juvenile Polychaete Growth (*N. arenaceodentata*)	1.64 -6.31[5]	0.063 – 0.78[2,6]	0.004 – 0.074	ND – 0.011[7]

Notes:

ND = Non-detect

1. NOEC = 6.26 mg/L total ammonia for larval development; = 157 mg/L total ammonia for amphipod mortality.
2. Inouye et. al. 2015
3. NOEC = 2.08 mg/L unionized ammonia for amphipod mortality; trigger value for purging = 0.8 mg/L
4. Trigger value for purging = 0.122 mg/L
5. NOEC = 115 mg/L total ammonia for juvenile polychaete growth
6. NOEC = 2.05 mg/L unionized ammonia for juvenile polychaete growth
7. Trigger value for purging = 3.4 mg/L

Table 9. Negative Control Performance Standards and Test Results

Test (Species)	Negative Control Performance Standard	Negative Control Results	Reference Sediment Performance Standard	Reference Sediment Results
Larval Development (*Mytilus sp.*)	$N_C \div I \geq 0.70$	0.97, Pass	$N_R \div N_C \geq 65\%$	0.81, Pass
Amphipod Mortality (*E. estuarius*)	$M_C \leq 10\%$	0%, Pass	$M_R \leq 10\%$	5%, Pass
Juvenile Polychaete Growth (*N. arenaceodentata*)	$M_C \leq 10\%$ and $MIG_C \geq 0.38$[1]	0% and 1.047 MIG, Pass	$MIG_R \div MIG_C \geq 0.80$	1.17 MIG dw, Pass

Notes:

N = mean normal development survival in seawater control.
I = initial count
M = mean mortality.
MIG = mean individual growth rate (mg/individual/day)
Subscripts: R = reference; C = negative control

1. Target MIGc is 0.72 mg/individual/day; the test is considered to be failed if the Control MIG is less than 0.38 mg/individual/day.

Table 10. Reference Toxicant Results

Test (Species)	Reference Toxicant	Endpoint	LC_{50}	Laboratory Historical Range (mean ± 2 SD)
Larval Development (*Mytilus sp.*)	Ammonia (unionized)	normality	0.117 mg NH_3/L	0.057 – 0.319 mg NH_3/L
Amphipod Mortality (*E. estuarius*)	Ammonia (total)	mortality	192.4 mg/L	98.2 – 254 mg/L
Juvenile Polychaete Growth (*N. arenaceodentata*)	Ammonia (total)	96-hour survival	159.7 mg NH_3/L	137 – 273 mg NH_3/L

LC_{50}: Lethal concentration to 50 percent of organisms

Table 11. Larval Development Bioassay (*Mytilus galloprovincialis.*) Results

Sample ID	Normal Survival[1]	Mean Normal Survival[2]	Comparison to Reference[3]		SCO	CSL
			$N_T \div N_R$	N_T vs N_R SD; $p = 0.10$: significant? (test)	N_T vs N_R SD ($p = 0.10$); $N_T \div N_R < 0.85$; Pass/ Fail	N_T vs N_R SD ($p = 0.10$); $N_T \div N_R < 0.70$; Pass/ Fail
Sea Water Control	275 264 236 273 243	258.2 ± 17.7	n/a	n/a	n/a	n/a
CARR-REF 7	178 199 232 247 196	210.4 ± 28.3	n/a	n/a	n/a	n/a
DM-19-S	166 189 179 162 199	179.0 ± 15.5	85.1%	No; (Approximate t-test)	Pass	Pass

Notes:

N = normal development; SD = statistically different

SCO = sediment cleanup objective; CSL = cleanup screening level; n/a = not applicable

Subscripts: R = reference; T = test sediment

1. Normal survivors observed in individual replicates.
2. Mean percent normal survivors ± standard deviation.
3. Comparison to reference includes the numeric result for the comparative criteria, the result of the statistical test, and the statistical test used. All statistics were conducted using BioStat (DMMP/SMS Bioassay Statistics Program).

Table 12. Amphipod Mortality Bioassay (*Eohauastorius estuarius*) Results

Sample ID	Percent Survival (1)	Mean Percent Mortality[2]	Comparison to Reference[4,5]		SCO	CSL
			$M_T - M_R$ (%)	M_T vs M_R SD; $p = 0.05$: significant? (test)	$M_T > 25\%$; Pass/ Fail	$M_T > 30\%$; Pass/ Fail
Control	100 100 100 100 100	0 ± 0.0	n/a	n/a	n/a	n/a
CARR-REF 7	100 100 90 85 100	5.0 ± 7.1	n/a	n/a	n/a	n/a
DM-19-S	95 75 90 90 95	11.0 ± 8.2	6.0	No; (Approximate t-test)	Pass	Pass

Notes:

M = percent mortality; SD = statistically different

SCO = sediment cleanup objective; CSL = cleanup screening level; n/a = not applicable

Subscripts: R = reference; T = test sediment

1. Survival observed in individual replicates.
2. Mean mortality ± standard deviation.
4. Comparison to reference includes the numeric result for the comparative criteria, the result of the statistical test, and the statistical test used. All statistics were conducted using BioStat (DMMP/SMS Bioassay Statistics Program).

Table 13. Juvenile Polychaete Growth Bioassay (*N. arenaceodentata*) Results.

Sample ID	MIG [1]	Mean MIG[2]	Comparison to Reference[3]		SCO	CSL
			MIG_T/MIG_R	MIG_T vs MIG_R SD; $p = 0.05$: significant?; (test)	MIG_T vs MIG_R SD ($p = 0.05$); $MIG_T/MIG_R < 0.70$ Pass/ Fail	MIG_T vs MIG_R SD ($p = 0.05$); $MIG_T/MIG_R < 0.50$ Pass/ Fail
Negative Control	0.710 1.056 1.193 1.058 1.217	1.047 ± 0.203	n/a	n/a	n/a	n/a
CARR-REF 7	1.447 1.207 1.070 1.182 1.462	1.274 ± 0.173	n/a	n/a	n/a	n/a
DM-19-S	0.600 0.692 1.049 1.700 0.444	0.897 ± 0.501	0.704	No; (Student's t-test)	Pass	Pass

Notes:
MIG = mean individual growth rate (mg/individual/day)
SD = statistically different
SCO = sediment cleanup objective; CSL = cleanup screening level; n/a = not applicable
Subscripts: R = reference; T = test sediment
1. Mean individual growth per replicate (mg/individual/day) ash-free dry weight.
2. Mean individual growth ± standard deviation for sample (mg/individual/day).
3. Comparison to reference includes the numeric result for the comparative criteria, the result of the statistical test, and the statistical test used. All statistics were conducted using BioStat (DMMP/SMS Bioassay Statistics Program).

Table 14. Dickman Mill Total Dioxin/Furan TEQs Compared to Puget Sound and Regional Background Threshold Values

Puget Sound Regions	Average Dioxin/Furan Total TEQ (ng/kg)
Dickman Mill *(this investigation)*	22.5
Puget Sound Natural Background[a]	4.0
Bellingham Bay Regional Background[b]	15
North Olympic Peninsula Regional Background[c]	5.0
South Sound Regional Background[d]	19

a. Value from Ecology 2021
b. Value from Ecology 2015
c. Value from Ecology 2016
d. Value from Ecology 2018a

Table 15. Dickman Mill Piling Removal Cost Estimate

Task/Activity	Unit	No. of Units	Unit Cost	Cost
1. Consultant Engineer				
Bid Package	Hour	150	$ 200	$ 30,000
Oversight/Monitoring Labor	Day	40	$ 2,500	$ 100,000
Monitoring Equipment/Travel	Day	40	$ 250	$ 10,000
Laboratory Expense	Sample	20	$ 500	$ 10,000
Reporting	Hour	100	$ 200	$ 20,000
Project Management	Hour	85	$ 200	$ 17,000
Consultant Total			**$ 3,850**	**$ 187,000**
2. Contractor				
Mobilization/Demobilization	LS	1	$ 90,000	$ 90,000
Pulling of Pilings	Piling	1000	$ 420	$ 420,000
Offload/Disposal of Pilings	Piling	1000	$ 400	$ 400,000
Subtotal				$ 910,000
Contingency at 30%				$ 273,000
Sales Tax at 10.3%				$ 121,849
Contractor Total				**$ 1,304,849**
Project Total				**$ 1,491,849**

Table 16. Dickman Mill Sediment Samples Proposed for Remedial Investigation

Station ID	Sample Type	Sediment Depth Intervals	Conventionals	PAHs	Dioxin/Furan Congeners	Bioassays	Bioaccumulation Testing
On-Site Samples							
DM-11 (100 ft SE)	Grab	0–10 cm	✓	✓ (Low)	✓ (Low)	✓	✓
DM-17 (100 ft SE)	Grab	0–10 cm	✓	✓ (Low)	✓ (High)		✓
DM-19 (100 ft SE)	Grab	0–10 cm	✓	✓ (High)	✓ (Low)	✓	
DM-20 (100 ft SE)	Grab	0–10 cm	✓	✓ (High)	✓ (High)	✓	✓
Off-Site Samples							
Offsite-NW1	Grab	0–10 cm			✓		
Offsite-NW2	Grab	0–10 cm			✓		
Offsite-NW3	Grab	0–10 cm			✓		
Offsite-SE1	Grab	0–10 cm			✓		
Offsite-SE2	Grab	0–10 cm			✓		
Offsite-SE3	Grab	0–10 cm			✓		
Reference	Grab	0–10 cm	✓			✓	✓
Quality Control Samples							
DM-XX-DUP	Field Duplicate			✓	✓		
DM-XX-TRIP	Field Triplicate		✓				
DM-ER	Equipment Rinsate			✓			
PS-SRM	Reference Material				✓		
Samples Submitted for Analysis			**8**	**6**	**12**	**4**	**4**

✓ Analyze (relative concentration observed in surface sediments at station in the 2022 sediment investigation).

Table 17. Dickman Mill RI/FS Planning Level Cost Estimate

Task/Activity	Labor (Hours)	Expenses	Cost ($180/hr)
1. Work Plan Preparation			
Site Background	40	$ -	$ 7,200
Conceptual Site Model	30	$ -	$ 5,400
Sampling and Analysis Plan	100	$ -	$ 18,000
Health and Safety Plan	20	$ -	$ 3,600
Draft Work Plan	60	$ -	$ 10,800
Final Work Plan	30	$ -	$ 5,400
Task Total	280	$ -	**$ 50,400**
2. Sampling and Analysis			
Sample Collection/Process	60	$ 200	$ 11,000
Vessel Operation	0	$ 11,000	$ 11,000
Sample Analysis	0	$ 115,000	$ 115,000
Data Review/Management	40	$ -	$ 7,200
Task Total	100	$ 126,200	**$ 144,200**
3. RI/FS Report and Cleanup Plan			
Data Analysis	80	$ -	$ 14,400
Conceptual Site Model	20	$ -	$ 3,600
Alternatives Evaluation	60	$ -	$ 10,800
Disproportionate Cost Analysis	60	$ -	$ 10,800
Feasibility Study	80	$ -	$ 14,400
Cleanup Action Plan	100	$ -	$ 18,000
Plans and Specifications	120	$ -	$ 21,600
Pre-Draft Report	140	$ -	$ 25,200
Draft Report	50	$ -	$ 9,000
Final Report	35	$ -	$ 6,300
Task Total	745	$ -	**$ 134,100**
4. Stakeholder Involvement			
Agency Meetings	50	$ -	$ 9,000
Public Meetings	50	$ -	$ 9,000
Website/Factsheets	50	$ -	$ 9,000
Task Total	150	$ -	**$ 27,000**
5. Project Management			
Project Team Meetings	60	$ -	$ 10,800
Schedule/Budget	40	$ -	$ 7,200
Progress Reports/Invoices	60	$ -	$ 10,800
Task Total	160	$ -	**$ 28,800**
Project Total	**1,435**	**$ 126,200**	**$ 384,500**

APPENDIX A

Sampling and Analysis Plan

(Electronic Copy Only)

Sampling and Analysis Plan

2022 Dickman Mill Sediment Investigation
Tacoma, Washington

Final

November 7, 2022

Submitted to:

Washington State Department of Natural Resources
Aquatic Resources Division
Olympia, Washington 98504

Submitted by:

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115 2nd Avenue N, Suite 100
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SIGNATURE PAGE PROJECT TEAM

Approval signatures indicate that each member of the project team has reviewed this Sampling and Analysis Plan (SAP) and agree to follow the methods and quality assurance (QA) procedures contained herein. NewFields, and Herrera have prepared this SAP on behalf of the Washington State Department of Natural Resources (DNR), Olympia, Washington.

____ Date: ____________________
Tim Goodman, Environmental Engineer – Sediment Quality Unit
DNR

____ Date: ____________________
John Nakayama, Project Manager
NewFields

____ Date: ____________________
Tim Hammermeister, QA/QC Manager
NewFields

____ Date: ____________________
Rob Zisette, Senior Technical Advisor
Herrera

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LIST OF ACRONYMS AND ABBREVIATIONS

ARI	Analytical Resources, Inc.
aRPD	apparent redox potential discontinuity
CAB	cellulose acetate butyrate
CFR	Code of Federal Regulations
cPAH	carcinogenic polycyclic aromatic hydrocarbon
COC	chemical of concern
CRM	Certified Reference Material
CSL	Cleanup Screening Level
CVAA	cold vapor atomic absorption
DGPS	differential Global Positioning System
DNR	Washington State Department of Natural Resources
DW	dry weight
DUP	duplicate
Ecology	Washington Department of Ecology
EIM	Environmental Information Management
FOA	frequency of analysis
GC/MS	gas chromatography/mass spectrophotometry
GIS	Geographic Information System
HDPE	high-density polyethylene
HPAH	high molecular weight polycyclic aromatic hydrocarbon
ICP	inductively coupled plasma
LCS/LCSD	laboratory control sample/laboratory control sample duplicate
LPAH	low molecular weight polycyclic aromatic hydrocarbon
MDL	method detection limit
MLLW	mean lower low water
MS/MSD	matrix spike/matrix spike duplicate
NAD83	North American Datum 1983
NOAA	National Oceanic and Atmospheric Association
OC	organic carbon
PAH	polycyclic aromatic hydrocarbon
Parks	Metropolitan Parks District of Tacoma
PCB	polychlorinated biphenyl
PPE	personal protective equipment
PSEP	Puget Sound Estuary Program
PS-SRM	Puget Sound Sediment Reference Material

PV	plan view
QA	quality assurance
QA1	USEPA Stage 2b Data Validation
QAPP	Quality Assurance Project Plan
QC	quality control
RI/FS	Remedial Investigation/Feasibility Study
RL	reporting limit
RM	reference material
RPD	relative percent difference
R/V	research vessel
SAP	Sampling and Analysis Plan
SVOC	semi-volatile organic compound
SMARM	Sediment Management Annual Review Meeting
SMS	Sediment Management Standards
SOD	sediment oxygen demand
SOP	standard operating procedure
SPI	sediment profile imaging
SQS	Sediment Quality Standards
TEQ	toxic equivalency quotient
TPH	total petroleum hydrocarbons
TOC	total organic carbon
TRIP	triplicate
TVS	total volatile solids
USEPA	U.S. Environmental Protection Agency

1.0 INTRODUCTION

The Washington State Department of Natural Resources (DNR) is working toward full environmental restoration of the Dickman Mill sediment area in Tacoma, WA, which is expected to include the removal of creosote pilings, removal of all debris impacting benthic habitat health, and sediment remediation (Figure 1). Based on studies to date, DNR and the Washington Department of Ecology (Ecology) have determined that additional sediment characterization is warranted with a focus on the vertical extent of contamination and the possible impacts of wood waste. Polycyclic aromatic hydrocarbons (PAHs) and dioxins/furans are the primary contaminants of concern (Mott MacDonald 2020, 2021). A brief history of the Dickman Mill site and summaries of prior investigations are provided in Sections 1.1 through 1.3. Additional site details can be found in the 2017 Dickman Mill Periodic Review Report (Ecology 2017).

This Sampling and Analysis Plan (SAP), prepared by NewFields and Herrera, describes the methods and procedures for completing the Dickman Mill sediment investigation which will characterize the nature and extent of contaminants (vertical and horizontal) as well as potential impacts of wood waste on the benthic habitat. The sampling design in this SAP was informed by previous sediment investigations at the site (Section 1.3). The results of this investigation will be used to inform the development of a Remedial Investigation/Feasibility Study (RI/FS) that will be conducted for the removal of the creosote pilings and debris impacting benthic habitat quality.

To characterize the nature and extent of contaminants, sampling activities will include sediment core sampling and surface sediment sampling. Analysis of sediment samples will include physical and chemical parameters, and tiered bioassay testing, if needed (Section 3.3). Sediment profile imaging (SPI) and plan view (PV) imaging will be used to evaluate benthic habitat quality and assess potential impacts from wood debris in surface sediments.

The project team and tentative schedule for the Dickman Mill sediment investigation are presented in Section 2.0. The sediment sampling rationale, design, and station locations are presented in Section 3.0. Field methods and analytical methods are summarized in Sections 4.0 and 5.0, respectively. The Quality Assurance Project Plan (QAPP) is provided in Section 6.0. Section 7.0 summarizes the data interpretation and reporting requirements, and references are provided in Section 8.0. Safety procedures to be followed during this investigation are provided in the Project Health and Safety Plan (Appendix A).

1.1 Site History

The Dickman Mill Property (Site) was the location of a lumber mill operated continuously from 1889 until its decommissioning in 1977. The mill facility was built upon land created by fill placed into the tide flat of Commencement Bay. Structures on the property included a large overwater wharf at the west end of the Site, a boiler house, a sawmill building, office building, machine shop, auto shed, concrete water tank, decked area above tidelands at the east end of the Site, sawdust burner, and pier. The mill was initially powered by steam and converted to electric power generated by burning hog fuel in the sawdust burner between 1926 and 1927. The mill buildings were partially destroyed by fire in 1978.

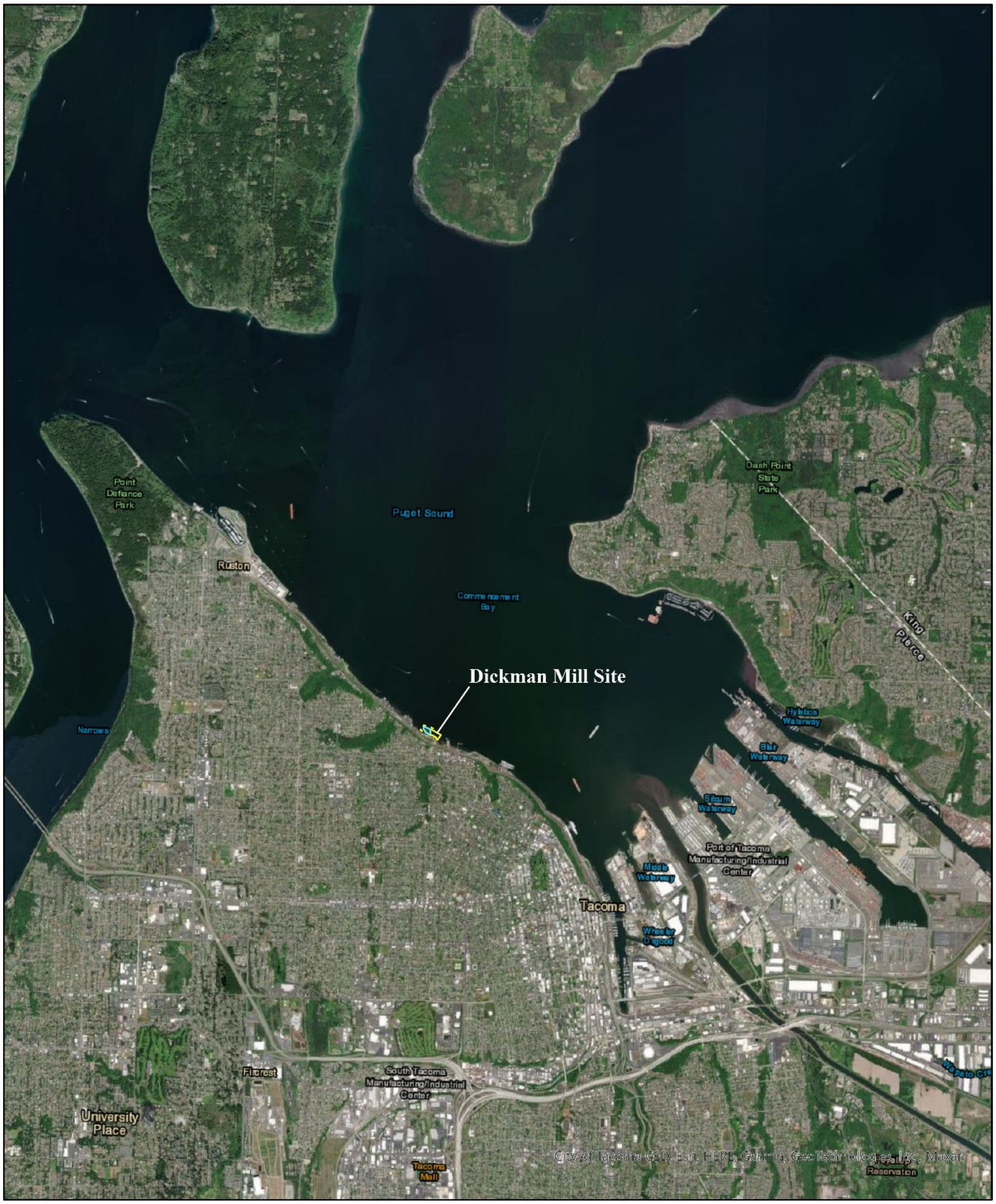

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Figure 1: Dickman Mill Site Location

0 0.5 1 2 Miles

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The Metropolitan Parks District of Tacoma (Parks) purchased the eastern portion of the property in 1991 and the western portion in 1993. Remaining remnants of the original sawmill buildings were demolished and removed from the Site in 1998 by Parks in preparation for developing the Site into a public park. Remnant creosote-treated pilings that once supported the overwater wharf, decked area, and pier remain today.

1.2 Prior Investigations – Upland

Environmental investigations conducted since 1985 have mapped the contamination of intertidal sediments and soils with metals (copper, lead, mercury, arsenic), individual PAH compounds, and carcinogenic PAH (cPAH) in excess of the Sediment Quality Standards (SQS). Additionally, oil residues and sulfur oxidizing bacterial mats have been observed on upland and intertidal substrates (Ecology 2017). In 1999, Parks entered into an Agreed Order with Ecology to conduct remedial actions at the Site in support of future upland development (Ecology 1999).

Upland remedial activities were conducted at the Site in 2000 and 2001. The upper 1 foot of sediment containing concrete rubble and wood debris was excavated from the northwest beach and replaced with 1 foot of pea gravel to improve the habitat quality of the substrate. Confirmatory testing of the remaining sediment below the emplaced gravel showed no elevated chemicals of concern (COCs) (Hart Crowser 2001). A minimum of 2 feet of soil cover was placed in upland areas consisting of 1 foot of structural fill covered by 1 foot of topsoil. An estimated 1,675 cubic yards of contaminated materials, including shredded creosote timber, lead, and petroleum, were excavated from the tidal channel as part of the cleanup action (Hart Crowser 2001). Ultimately, complete removal of oily materials was unachievable within the tidal channel due to constraints of the tide, equipment, and stability of the excavation, and the tidal channel was capped with at least 2 feet of clean cap material. Two years of post-construction confirmational groundwater monitoring showed that construction activities did not appear to have significantly impacted groundwater quality at the Site and groundwater monitoring was discontinued (Ecology 2017). Post-construction sediment cap monitoring was conducted from 2003 through 2005 to determine erosion and stability of the cap. Ecology concluded there was no evidence of significant cap erosion and approved the discontinuation of post-construction cap monitoring (Ecology 2017).

Following remedial activities, Parks and Ecology entered into a Restrictive Covenant regarding the Dickman Mill property on February 1, 2007. The Restrictive Covenant was required as a result of decisions made during Remedial Action to leave residual concentrations of PAHs underneath the sediment cap in the tidal channel. The Restrictive Covenant dictates the limitations, restrictions, and uses of the property to ensure long-term protection for the cleanup completed at the Site (Ecology 2007).

1.3 Prior Investigations – In-water

Few studies have characterized contamination within the offshore sediments of the Site. Of the limited data available, two sediment surface samples (S-4 and S-3) collected by Hart Crowser in 1998 within the intertidal area just offshore of the former boiler building contained high concentrations of copper, lead, and mercury above SQS criteria (Ecology 2017) (Appendix B[1]). Hart Crowser representatives also observed sulfur oxidizing bacteria within the vicinity of sample S-3 indicating localized anoxic conditions (Ecology 2017). This intertidal region remains an area of unaddressed contamination with unknown spatial delineation.

In 2015, the DNR collected ten surface sediment samples within and surrounding the remnant piling fields adjacent to the Site (Mott MacDonald 2020) (see Appendix B). Each sample was analyzed for metals, semi-volatile organic compounds (SVOCs) including PAHs, total petroleum hydrocarbons (TPH), polychlorinated biphenyls (PCBs), total organic carbon (TOC), sulfide, ammonia, total volatile solids (TVS), total solids, and grain size. Five samples were additionally analyzed for dioxins/furans. A slight sheen was observed in two samples within the northeast and southeast quadrants of the northwest pile field and two samples immediately adjacent to the seaward end of the relict pier. Heavy sheen was observed in one sample within the center of the northwest piling field. The cPAH concentration exceeded screening criteria in all samples and the dioxin concentration exceeded screening criteria in three of the five samples for which the analysis was conducted. In addition, one sample within the piling field (DMPR2015-D02) had detected concentrations of 1,2,4-trichlorobenzene, 1,2-dichlorobenzene, 1,4-dichlorobenzene, butyl benzyl phthalate, 2,4-dimethylphenol, 2 methylphenol, and pentachlorophenol that exceeded SQS or Cleanup Screening Level (CSL) criteria. Screening criteria were not exceeded in any of the ten surface sediment samples for TPH or PCBs. Of the metals, mercury exceeded the SQS of 0.41 mg/kg for two locations (DMPR2015-03 = 0.51 mg/kg and DMPR2015-05 = 0.43 mg/kg). Subsurface sediments remain uncharacterized for potential contaminants of concern.

1.3.1 Dickman Mill Sediment Transport Study

The approximately 1,000 remaining creosote-treated timber pilings remaining in the intertidal and nearshore areas of the Site remain a suspected ongoing source of environmental contamination. In preparation for the removal of these pilings, DNR contracted with Mott MacDonald to evaluate the risk of releasing additional contaminants of concern and potential effects on nearby properties due to the removal of the pilings.

Mott MacDonald observed that the northwest beach displays a convex shape indicating the northeast pile field may be providing wave attenuation in the nearshore (Mott MacDonald 2020). Results of modeling the adjustment of the beach profile after large storms (e.g., a 50-year storm) indicate localized areas of the beach could lower in elevation by approximately 4–8 inches after piling removal, potentially exposing material underneath the gravel cap (Mott MacDonald 2021).

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[1] Relevant figures from previous investigations showing sampling locations and chemical concentrations at the Site have been included in Appendix B. References include Ecology (2017) and Mott MacDonald (2020).

Limited sampling[2] during construction indicates that COCs were not present at the base of the cap, though dioxins/furans were never analyzed (Hart Crowser 2001, Ecology 2017). Contaminants left in place below cap material within the tidal channel, located above the mean higher high water level, are not anticipated to be impacted by piling removal (Mott MacDonald 2021).

Modeling of sediment erosion within the piling field after piling removal demonstrated that a typical 2-year storm event would induce minimal erosion of sediments within the piling field and a more energetic 50-year storm would cause relatively mild erosion (Mott MacDonald 2021). Gravel and coarse sands are not anticipated to be significantly mobilized while finer sediment size fractions (e.g., clay, silt, and remnant sawdust) are anticipated to be transported to the southeast into deeper water within Commencement Bay.

1.3.2 2022 Diver Survey

A subsampling of existing pilings within the northwest piling field were recently surveyed by DNR divers in support of characterizing the sediment, condition of pilings, and presence of eelgrass and benthic vegetation as well as any debris. More than 90 percent of the 42 pilings surveyed were observed to be intact and in good condition with minimal degradation (DNR 2022). The sediment type within the piling field was predominantly shell hash on either mud or sand substrate. Finer muds were predominant in the western portion of the piling field while the eastern portion was characterized by coarser sands with observations of a mixture of cobbles and shell hash in the shoreward edge of the piling field. Debris in the piling field included wood, metal rebar, and wood pieces with attached metal. Wood debris ranged in size from short stumps to whole pilings, with some large pieces silted in place on the sediment bed. Debris was present throughout the piling field but became more abundant proceeding southeastward across the field. The area to the west of the piling field was characterized by a healthy bed of eelgrass. Very little eelgrass was observed within the piling field.

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[2] One (1) four-point composite verification sediment sample was collected within northwest intertidal beach area as part of the 2000/2001 Cleanup Action. The four-point composite verification sediment sample (Sed-3) targeted a limited 20 ft-by-20 ft area of the beach where over-excavation of material was necessary to remove arsenic at concentrations exceeding SQS criteria. After careful review of available and relevant Site documents, there is no evidence of additional sediment chemistry data available for the material below the cap within the intertidal beach.

2.0 PROJECT TEAM AND SCHEDULE

2.1 Project Planning and Coordination

This project is funded by the DNR, and the sediment investigation will be implemented in coordination with Ecology and the Metropolitan Parks District of Tacoma. Tim Goodman is the DNR Project Manager and will oversee the implementation of this investigation.

DNR Project Manager
Tim Goodman, PE
Department of Natural Resources
Aquatics Division
1111 Washington Street SE
Olympia, WA 98504-7027
360-995-2500
Tim.Goodman@dnr.wa.gov

John Nakayama will serve as the Project Manager for NewFields and will be responsible for coordinating project activities with the DNR Project Manager. NewFields will be responsible for SAP preparation, field sampling, laboratory coordination, data evaluation, and reporting. Any significant deviation from the approved SAP will be coordinated with the DNR. Rob Zisette will serve as the Project Manager for Herrera and provide technical review and input for project planning and provide senior review of project deliverables. Herrera will be responsible for permitting of proposed sediment sampling activities, field sampling support, sediment transport evaluation, and engineering and cost estimation.

NewFields Project Manager
John Nakayama
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Herrera Project Manager
Rob Zisette
Herrera
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206-787-8262
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2.2 Field Sample Collection

Leon Delwiche of NewFields will serve as the field manager for proposed sampling activities at the Dickman Mill site. NewFields, with support from Herrera, will conduct SPI and PV imaging, vibracore sampling, powered grab sampling, and hand beach coring. NewFields will provide the SPI and PV imaging system, coordinate vessel and equipment logistics, assure conformance to the sampling and handling requirements, maintain the field documentation, and schedule personnel and subcontractor services. Mr. Delwiche will also serve as the Site Safety Officer (the Health and Safety Plan is provided as Appendix A). Shawn Hinz of Gravity Environmental will provide the proposed sampling vessel (Research Vessel [R/V] *Tieton*), remotely controlled float frame, vibracore system, and power grab sampler for the sediment investigation.

Field and Health and Safety Manager
Leon Delwiche
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Vessel Provider
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Gravity Environmental
32617 SE 44th St.
Fall City, WA 98024
425-281-1471
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2.3 Laboratory Analyses

Sue Dunnihoo of Analytical Resources, Inc. (ARI), Tukwila, WA, will serve as the analytical laboratory project manager for the testing and reporting of sediment chemistry analytical results. Mr. Brian Hester of EcoAnalysts, Port Gamble, WA, will serve as the biological laboratory project manager and will be responsible for the bioassay testing and reporting, if required.

ARI Laboratory Project Manager
Sue Dunnihoo
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Biological Laboratory Project Manager
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bhester@ecoanalysts.com

2.4 QA/QC Management

Tim Hammermeister will be responsible for quality assurance/quality control (QA/QC) management of the field sampling, sample processing, and reporting elements of the Dickman Mill sediment investigation. The DNR will be notified immediately of any activities that vary from the written SAP. NewFields will provide laboratory coordination, QA/QC oversight of both analytical and biological laboratory procedures, data review and management coordination, and assurance that reported data are valid and usable to meet project requirements. Christine Ransom of EcoChem, Inc. will serve as the Data Quality Reviewer to conduct independent data quality review and Level 2B validation of all chemistry results.

QA/QC Manager
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thammermeister@newfields.com

Data Quality Reviewer
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EcoChem, Inc.
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2.5 Schedule

The tentative project schedule is outlined below. Field sampling at the Dickman Mill site is targeted for the second and third weeks of November 2022.

• Draft SAP	October 18, 2022
• Agency Review and Comments on Draft SAP	October 28, 2022
• Final SAP	November 7, 2022
• Dickman Mill Field Sampling	November 14-22, 2022
• Initiate Laboratory Analyses	November 22, 2022
• Laboratory Sediment Chemistry Results	December 29, 2022[3]
• Bioassay Testing Initiated (if needed)	January 11, 2023
• Initiate Laboratory Analysis of Sample Archives (if needed)	January 11, 2023
• Laboratory Sediment Chemistry Results for Archives	February 24, 2023
• Data Validation Completed	March 24, 2023
• Draft Technical Report and Recommendations	April 28, 2023
• Agency Comments on Draft Technical Report	May 26, 2023
• Final Technical Report, Environmental Information Management (EIM) Submittal, Laboratory Data Package	June 23, 2023

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[3] If bioassays are triggered, reference sediment(s) would be collected in early January and testing initiated before the 8-week holding time expires, which is estimated to be January 11, 2023.

3.0 SEDIMENT SAMPLING DESIGN

3.1 Sediment Study Area

The Dickman Mill sediment area was divided into four general study areas (Figure 2) based on site conditions and the sampling rationale described in Section 3.2:

1. Dense Pile Field
2. Eastern Pile Area
3. Area Surrounding Dense Pile Field
4. Intertidal Beach

The Dense Pile Field requires a unique sampling approach that is dictated by ease of access to sampling locations and potential barriers to sediment sampling posed by metal and wood debris observed during the 2022 DNR diver survey. The areas east of the Dense Pile Field and surrounding the Dense Pile Field are anticipated to pose fewer obstacles to successful sediment sampling. Finally, the Intertidal Beach study area, located above the mean lower low water (MLLW) level, necessitates the use of sub-aerial sampling equipment as opposed to in-water equipment. Sampling within the Intertidal Beach study area will occur at low tide to allow access to sampling locations without overlying water.

3.2 Study Objectives and Sampling Approach

The study objectives for the Dickman Mill sediment investigation are as follows:

1. Determine the nature and extent (vertical and horizontal) of contamination within the offshore areas of Dickman Mill, with a focus on PAHs and dioxins/furans
2. Assess the potential impacts of wood debris to the benthic habitat
3. Evaluate the toxicity of contaminants and wood debris in offshore sediment areas using bioassays

These objectives will be addressed using SPI and PV imaging, and sediment sampling using a vibracorer, hand hammer corer, and power grab sampler as described below. A total of thirty (30) sampling locations are proposed within the four (4) study areas (Figure 2). Geographic coordinates and sampling requirements for the locations are listed in Table 1. The rationale for the numbers and types of sampling is described in Section 3.2.

- **SPI and PV (surface) imaging** will be conducted as the first element of the study, to provide near real-time surface sediment/benthic habitat evaluation, including identification of wood and other debris and habitat impacts (Figure 3). Up to three field days are planned for SPI and PV imaging in the dense pile field, eastern pile area, and areas surrounding the dense pile field. SPI and PV imaging will be reviewed following each field day and observations may be used to add SPI and PV imaging locations and inform or modify the targeted sediment sampling locations, in coordination with DNR. Specifically, locations in the Dense Pile Field with SPI imaging that show benthic habitat impacts from wood debris accumulation (low or absent apparent redox potential discontinuity [aRPD] depths, anoxic or low dissolved oxygen conditions, presence of methane bubbles) may be selected for sediment sampling instead of targeted sediment sampling locations that do not show evidence of wood debris impacts. A remotely controlled float frame (equipped with outboard motor, a-frame, and cable pulley) deployed from a primary sampling vessel will be used to deploy the SPI system within the dense pile field.

- **Vibracore sediment sampling** will be conducted at selected locations within and outside the dense pile field to evaluate subsurface sediment conditions (chemicals of concern, physical parameters, and wood debris abundance) (Figure 4). Cores up to 8 feet in length will be collected, and samples for each core will consist of the top 1 foot (0-1 ft) and 2-foot intervals until the bottom of the core is sampled (1-3 ft, 3-5 ft, 5-7 ft) (Section 4.4). Up to three field days are anticipated to collect vibracore samples in the Dense Pile Field, Eastern Pile Area, and the Area Surrounding Dense Pile Field. A remotely controlled float frame will be used to deploy the vibracore within the Dense Pile Field.

- **Hand hammer core sampling** is planned in the Intertidal Beach to evaluate current sand/gravel cap conditions (placed in 2000) and evaluate subsurface sediment conditions (metals and PAHs) (Section 3.2) (Figure 4). Two-foot cores will be collected and the sample for each core will consist of the bottom foot (approximately 1-2 ft) underlying the sand/gravel cap. The exact depths of the sample interval will be adjusted based on thickness of the existing sand/gravel cap (Section 4.5).

- **Power grab sampling** will collect surface sediments at selected locations within and outside of the dense pile field to evaluate surface sediment conditions, including verification of previously measured COCs, determine grain size and contaminant load in areas of potential erosion (e.g., low tide terrace), and toxicity (bioassay) testing of sediments with contaminants and/or wood debris (tiered testing) (Figure 4). Two field days are dedicated to surface sediment sampling in the dense pile field, eastern pile area, and areas surrounding the dense pile field. A remotely controlled float frame will be used to deploy the power grab within the dense pile field.

3.3 Rationale for Station Locations

As described in Section 3.1, the sampling strategy at the Site is designed to collect data at 30 sampling locations spanning the four (4) study area regions that will characterize the vertical and horizontal extent of sediment contamination and provide a baseline for benthic conditions and sediment chemistry within and proximal to the Site prior to pile removal. Six (6) sampling locations within the four study areas reoccupy locations sampled by DNR in 2015 where exceedances of metals, PAHs, dioxins/furans, or detections of sheen were observed.

The rationale for the numbers and types of sampling to occur in each general study area is summarized in Table 2 and discussed below.

3.3.1 Dense Pile Field

Eight (8) primary sediment sampling locations are targeted within the Dense Pile Field to delineate the horizontal and vertical extent of wood debris, PAHs, and dioxins/furans associated with the creosote-treated pilings. In addition, SVOCs (including PAHs) will be evaluated at four (4) locations to evaluate exceedances observed in the DNR 2015 study data. Locations were chosen to provide comprehensive spatial coverage within the Dense Pile Field. Two (2) secondary sediment coring locations within the Dense Pile Field serve as alternative locations if physical access to primary locations is impeded. Four (4) SPI transects will bisect the Dense Pile Field to assess the benthic conditions within the area and inform near real-time adjustments that may need to be made to targeted sediment sampling locations. SPI and PV imaging will be collected at one or more locations along each transect as accessibility and bottom conditions allow.

3.3.2 Eastern Pile Area

East of the Dense Pile Area, seven (7) sampling locations will serve to delineate the vertical and horizontal extent of wood debris, metals, PAHs, and dioxins/furans. Sampling locations were chosen to provide comprehensive spatial coverage of the area adjacent to the former hog fuel burner and the 1978 fire where dioxin/furan and PAH impacts are expected. Two (2) secondary coring locations were identified as alternative locations if coring is unsuccessful at primary locations.

3.3.3 Area Surrounding Dense Pile Field

The area surrounding the Dense Pile Field to the north, west, and south includes three (3) sampling locations to delineate the horizontal extent of wood debris, PAHs, and dioxins/furans. Two (2) locations to the north of the Dense Pile Field (DM-12 and DM-19) reoccupy locations sampled by DNR in 2015 with metals and PAH sediment impacts.

3.3.4 Intertidal Beach

Four (4) sampling locations positioned between +1 and +5 feet MLLW will target the Intertidal Beach proximal to the Dense Pile Field where erosion post-pile removal is modeled to be greatest (Mott MacDonald 2021). These sampling locations were selected to evaluate the quality and thickness of gravel cap material remaining after initial deposition in 2000 and 2001. Data from these locations will serve as a baseline for intertidal beach conditions in anticipation of enhanced erosion following removal of the dense pile field (Mott MacDonald 2021). Additionally, sediment recovered beneath the gravel cap will be evaluated for metals due to the proximity near the former boiler building, and PAH concentrations in light of observations made during a recent Site visit by representatives from Mott MacDonald and GeoEngineers indicating that material beneath the thinning gravel cap may contain a high concentration of remnant sawdust and wood waste.[4]

3.3.5 Additional Locations

Two additional sample locations are targeted outside of the four study areas. One sampling location, DM-01, is located to the southeast of the four study areas where sediment from within the dense piling area is anticipated to migrate post-removal (Mott MacDonald 2021). Characterization of the substrate and surface chemistry at this location will serve as a baseline for future sediment impacts following piling removal. A final sampling location, DM-26, is located to the northwest of the dense pile area to bound the horizontal extent of wood debris and assess current benthic habitat.

3.4 Tiered Bioassay Testing

Surface sediment from ten sampling locations at the Site will be collected and archived for potential toxicity (bioassay) testing. Up to four of the ten surface sediment samples will undergo bioassay testing. Selection of samples will be based on sediment chemical concentrations exceeding SQS criteria and/or elevated conventional parameter results (total organic carbon, total volatile solids, ammonia, total sulfides) suggesting habitat impacts from wood debris accumulation (Ecology 2013, 2021). Observations from SPI images that suggest benthic habitat impacts from wood debris (low or absent aRPD depths, anoxic or low dissolved oxygen conditions, presence of methane bubbles) will also inform selection of sediment samples for bioassay testing. If more than four surface sediment samples are identified for bioassay testing, four samples will be selected to provide a range of chemical concentrations that exceed SQS criteria and/or a range of elevated conventional parameters and SPI parameters that suggest benthic habitat impacts from wood debris.

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[4] Hart Crowser's Final Cleanup Completion Report (2001) notes that only the upper one foot of sediment, containing "abundant concrete rubble and wood", was excavated from the Northwest Beach ("Intertidal Beach Area") and replaced with one foot of imported pea gravel. In 2020, representatives from Mott MacDonald and GeoEngineers observed thinning of the gravel cap and the presence of sawdust and wood waste within the upper foot of the beach face at approximately +4 feet MLLW (Mott MacDonald 2020, Appendix D).

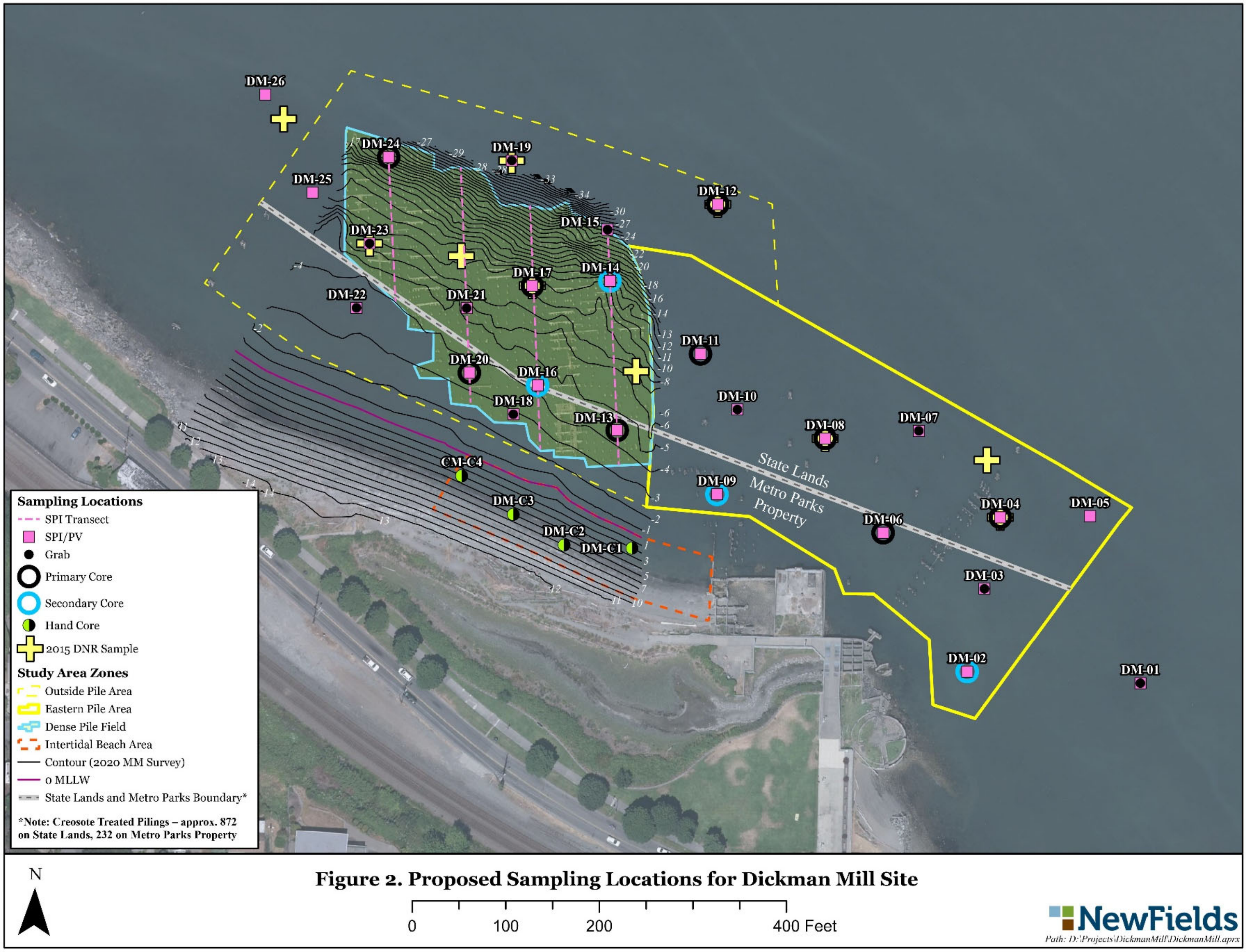

Figure 2. Proposed Sampling Locations for Dickman Mill Site

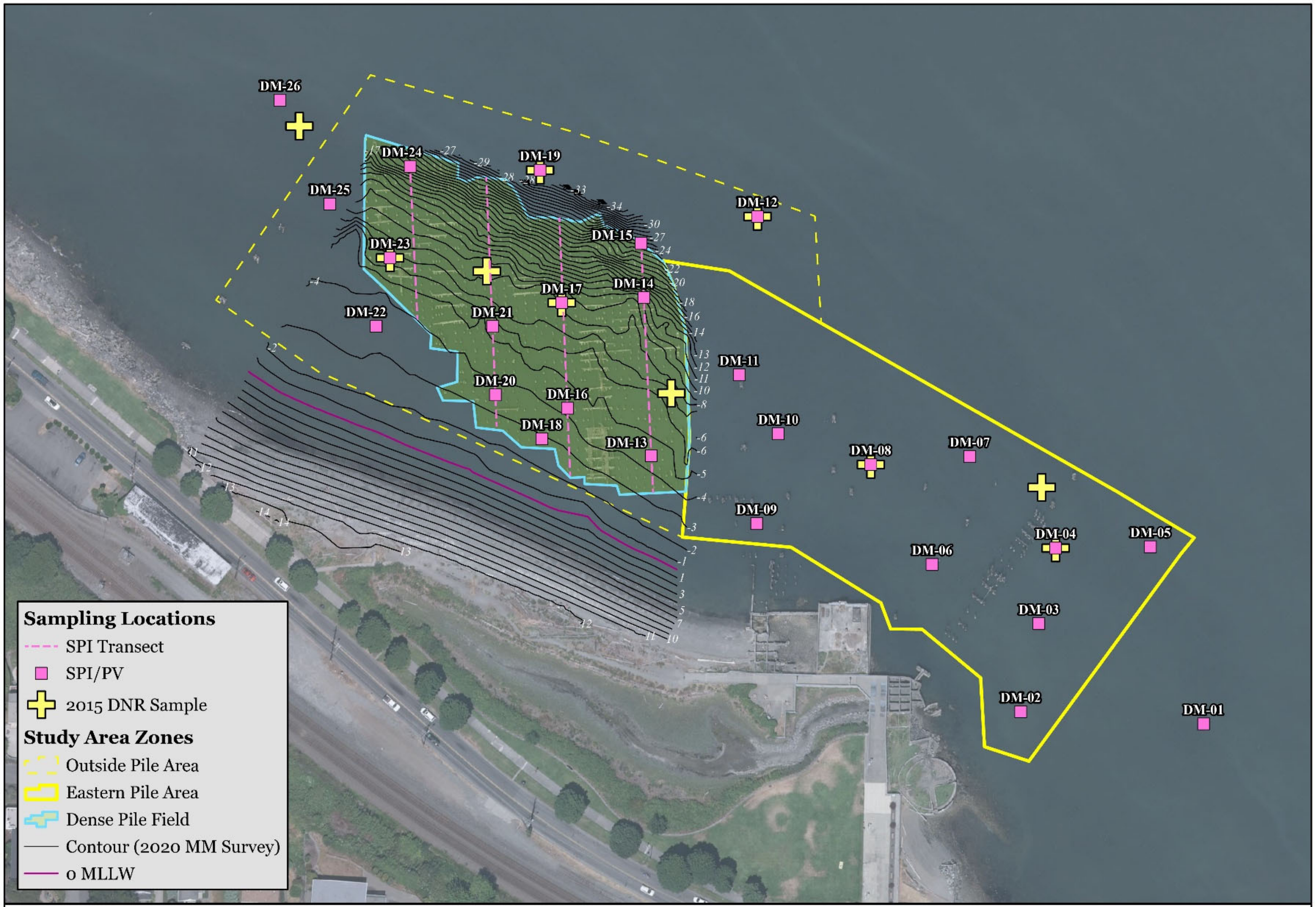

Figure 3. Proposed SPI Sampling Locations

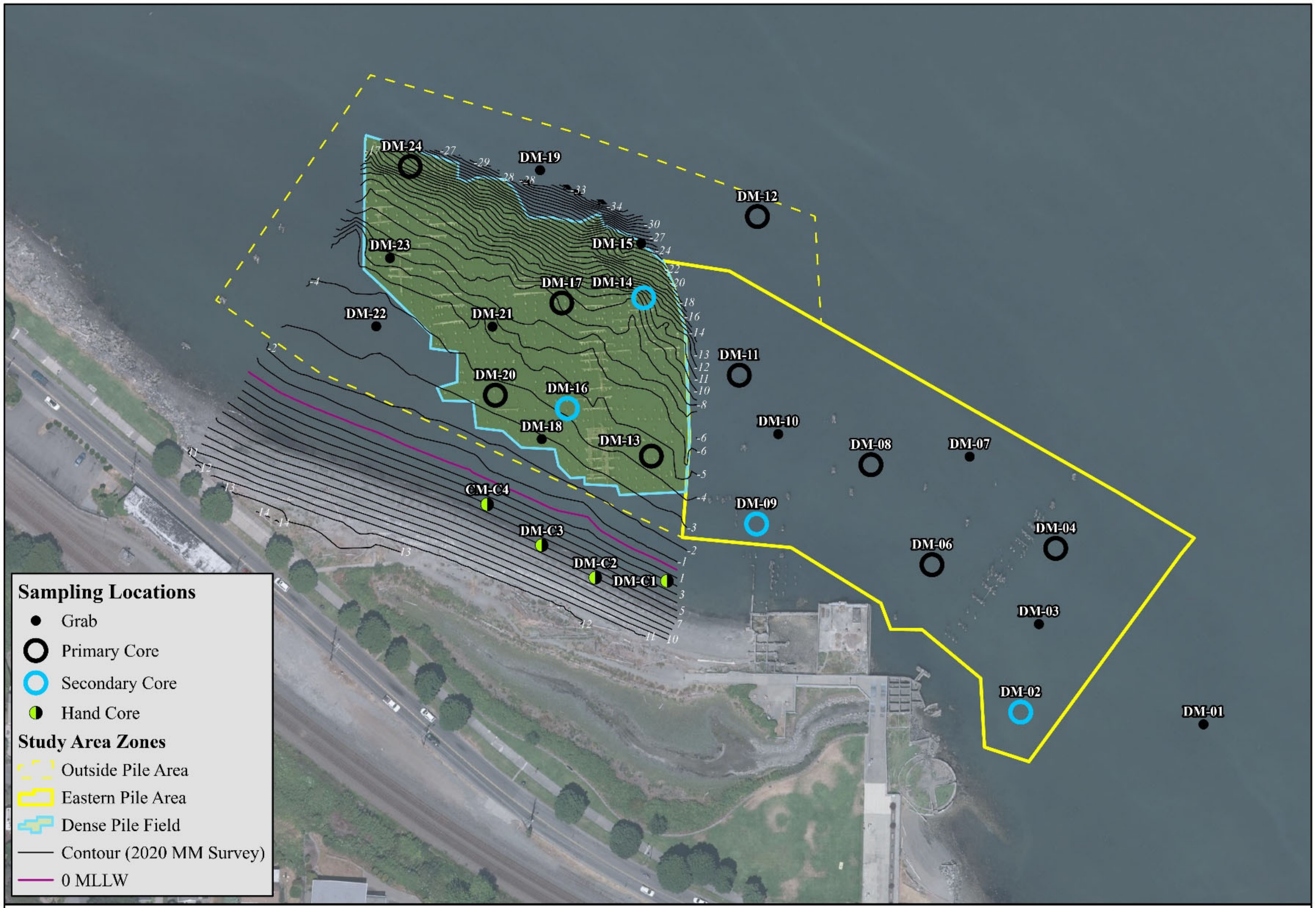

Figure 4. Proposed Subsurface Sediment Core and Sediment Grab Locations

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Table 1. Dickman Mill Site Sampling Location Coordinates and Proposed Sample Types

Location	Decimal Degrees (NAD-83)*		State Plane WA S HARN CS – NAD83 (ft)*		Depth (ft MLLW)	SPI	Sediment Core	Grab
	Latitude N	Longitude W	X SPWAS NAD83	Y SPWAS NAD83				
DM-01	47.277418	-122.468652	1151789.82	715064.77	-2.4	X		X
DM-02	47.277439	-122.469399	1151604.71	715077.14	-1.4	X	S	
DM-03	47.277683	-122.469334	1151623.14	715165.95	-5.6	X		X
DM-04	47.277894	-122.469273	1151640.14	715242.36	-10.8	X	X	
DM-05	47.277904	-122.468887	1151736.10	715243.72	-21.7	X		
DM-06	47.27784	-122.469776	1151514.88	715225.89	-5.1	X	X	
DM-07	47.278141	-122.469633	1151553.02	715334.72	-13.1	X		X
DM-08	47.278112	-122.470035	1151453.03	715326.57	-8.7	X	X	
DM-09	47.277941	-122.470495	1151337.32	715267.00	-3.6	X	S	
DM-10	47.27819	-122.470416	1151359.19	715357.46	-7.8	X		X
DM-11	47.278351	-122.470581	1151319.76	715416.95	-11.7	X	X	
DM-12	47.27879	-122.470523	1151338.12	715576.82	-42.2	X	X	
DM-13	47.278121	-122.470931	1151230.71	715335.26	-4.5	X	X	
DM-14	47.278558	-122.470978	1151223.01	715495.04	-11.5	X	S	
DM-15	47.278708	-122.470994	1151220.38	715549.76	-24.4	X		X
DM-16	47.278247	-122.471278	1151145.72	715383.33	-4.3	X	S	
DM-17	47.278538	-122.471312	1151140.03	715489.83	-8.3	X	X	
DM-18	47.27816	-122.47138	1151119.71	715352.42	-2.9	X		X
DM-19	47.278903	-122.471414	1151118.05	715623.55	-33.9	X		X
DM-20	47.278278	-122.471574	1151072.77	715396.76	-3.6	X	X	
DM-21	47.278468	-122.471592	1151069.86	715465.90	-5.7	X		X
DM-22	47.27846	-122.472066	1150952.19	715466.23	-3.4	X		X
DM-23	47.27865	-122.472017	1150966.11	715535.04	-6.4	X		X
DM-24	47.278904	-122.471944	1150986.55	715627.34	-19.3	X	X	
DM-25	47.278795	-122.472268	1150905.08	715589.41	-7.8	X		
DM-26	47.279079	-122.472482	1150854.69	715694.26	-14.9	X		
DM-C1	47.277777	-122.470855	1151246.55	715209.42	2.0		HC	
DM-C2	47.277781	-122.471147	1151174.05	715212.78	5.0		HC	
DM-C3	47.277867	-122.471369	1151119.78	715245.47	4.0		HC	
DM-C4	47.277976	-122.471596	1151064.50	715286.66	3.0		HC	

* Coordinates are based on the NAD-83 Datum with X and Y coordinates given in feet using the State Plane Washington South coordinate system.
X = Sample type proposed.
S = Secondary coring locations if a primary location is not accessible, or if time allows for additional sampling.
HC = Hand hammer core used to collect intertidal sediment sample.

Table 2. Dickman Mill Sediment Investigation Sampling Rationale

Location	SPI	Sediment Core	Grab	Rationale
DM-01	X		X	Bound horizontal extent of debris, metals, PAHs.
DM-02	X	S		Bound horizontal extent of debris.
DM-03	X		X	Horizontal extent of metals and PAHs. Near historical copper exceedance. Bound DM-04.
DM-04	X	X		Reoccupation of 2015 DNR investigation. Vertical extent of PAHs, dioxins/furans.
DM-05	X			Bound DM-04 and extent of debris.
DM-06	X	X		Vertical extent of metals and PAHs near historical boiler house.
DM-07	X		X	Horizontal extent of PAHs.
DM-08	X	X		Reoccupation of 2015 DNR investigation. Horizontal and vertical extent of metals, PAHs, dioxins/furans.
DM-09	X	S		Bound horizontal extent of debris. Analyze metals, PAHs, dioxins/furans.
DM-10	X		X	Horizontal extent of metals, PAHs.
DM-11	X	X		Horizontal and vertical extent of PAHs.
DM-12	X	X		Reoccupation of 2015 DNR investigation. Horizontal and vertical extent of metals, PAHs, dioxins/furans.
DM-13	X	X		Vertical extent of SVOCs including PAHs, dioxins/furans.
DM-14	X	S		Vertical extent of PAHs, dioxins/furans.
DM-15	X		X	Horizontal extent of SVOCs including PAHs.
DM-16	X	S		Vertical extent of PAHs, dioxins/furans.
DM-17	X	X		Reoccupation of 2015 DNR investigation. Horizontal and vertical extent of SVOCs including PAHs, dioxins/furans.
DM-18	X		X	Horizontal extent of PAHs.
DM-19	X		X	Reoccupation of 2015 DNR investigation. Horizontal and vertical extent of metals, PAHs.
DM-20	X	X		Vertical extent of PAHs.
DM-21	X		X	Horizontal extent of SVOCs including PAHs.
DM-22	X		X	Horizontal extent of debris, PAHs.
DM-23	X		X	Reoccupation of 2015 DNR investigation. Horizontal extent of PAHs.
DM-24	X	X		Vertical extent of PAHs, dioxins/furans.
DM-25	X			Bound horizontal extent of debris.
DM-26	X			Bound horizontal extent of debris.
DM-C1		HC		Baseline depth of constructed cap. Characterize metals and PAHs in underlying substrate.
DM-C2		HC		Baseline depth of constructed cap. Characterize metals and PAHs in underlying substrate.

Location	SPI	Sediment Core	Grab	Rationale
DM-C3		HC		Baseline depth of constructed cap. Characterize metals and PAHs in underlying substrate.
DM-C4		HC		Baseline depth of constructed cap. Characterize metals and PAHs in underlying substrate.

X = Sample type proposed.
S = Secondary coring locations if a primary location is not accessible, or if time allows for additional sampling.
HC = Hand hammer core used to collect intertidal sediment sample.

4.0 FIELD METHODS

4.1 Sampling Vessel and Float Frame

The R/V *Tieton*, owned and operated by Gravity Environmental, will be used for SPI and PV imaging, vibracore sampling, and power grab sampling at the Dickman Mill site. The R/V *Tieton* is a 34-foot-long landing craft vessel with a bow A-frame for sampler deployment and recovery. Gravity will also provide a custom float frame, which will be used to deploy the samplers within the dense pile field (Figure 5). Gravity's standard operating procedure (SOP) for utilizing the custom float frame with a vibracorer is provided in Appendix C. The deployment and recovery of the SPI and PV system and power grab from the custom float frame will follow the same procedures as the vibracorer.

4.2 Navigation and Positioning

Geographic station positioning will be accomplished using an onboard Differential Global Positioning System (DGPS). A satellite-based differential correction signal will be utilized to obtain a minimum accuracy of ± 1 meters. The antenna for the onboard DGPS receiver will be mounted above the sampler deployment boom to minimize separation between the sampler and the recorded position. Station coordinates will be recorded in latitude and longitude as decimal degrees with a minimum precision of six decimal places and shall be based on the North American Datum of 1983 (NAD83).

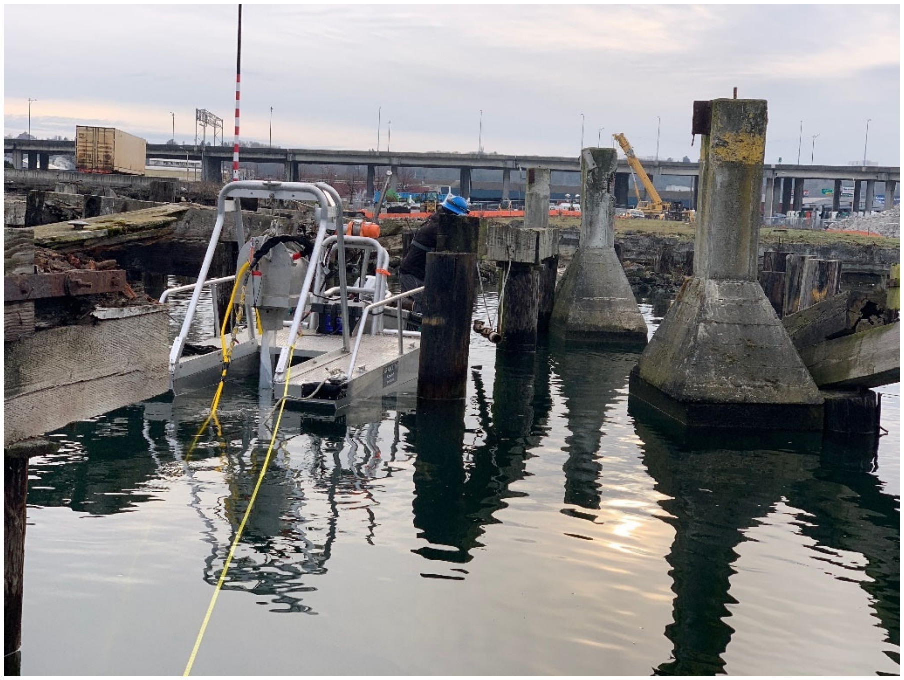
The mudline elevation at the sampling locations will be determined using a fathometer or lead line. The water level will be corrected to MLLW using the real-time local tide gauge data from the nearby Tacoma, WA, National Oceanic and Atmospheric Administration (NOAA) tide station (#9446484). Vertical accuracy of less than 0.5 feet will be achieved.

4.3 SPI and PV Image Collection

4.3.1 Sediment Profile Imaging

SPI will be collected using an Ocean Imaging Systems model 3731 digital sediment-profile camera (Rhoads and Germano 1982, 1986) (Figure 6). The sediment-profile camera consists of a wedge-shaped prism with a Plexiglass face plate and a back mirror mounted at a 45-degree angle. Light is provided by an internal strobe. The mirror reflects the image of the profile of the sediment-water interface up to a digital camera that is mounted horizontally on top of the prism. The camera can obtain images of up to 20 cm of the upper sediment column in profile. The camera prism is mounted on an assembly that can be moved up and down within a stainless-steel frame by allowing tension or slack on the winch wire. As the camera is lowered, tension on the winch wire keeps the prism in the up position. Once the camera frame touches the bottom, slack on the winch wire allows the prism to vertically intersect the seafloor. The rate of fall of the prism (6 cm/second) is controlled by an adjustable passive hydraulic piston, which minimizes the disturbance of the sediment-water interface.

R/V Tieton



Float Frame for Deployment in the Pile Field

Figure 5. R/V *Tieton* (top) and Float Frame (bottom) Sampling Platforms

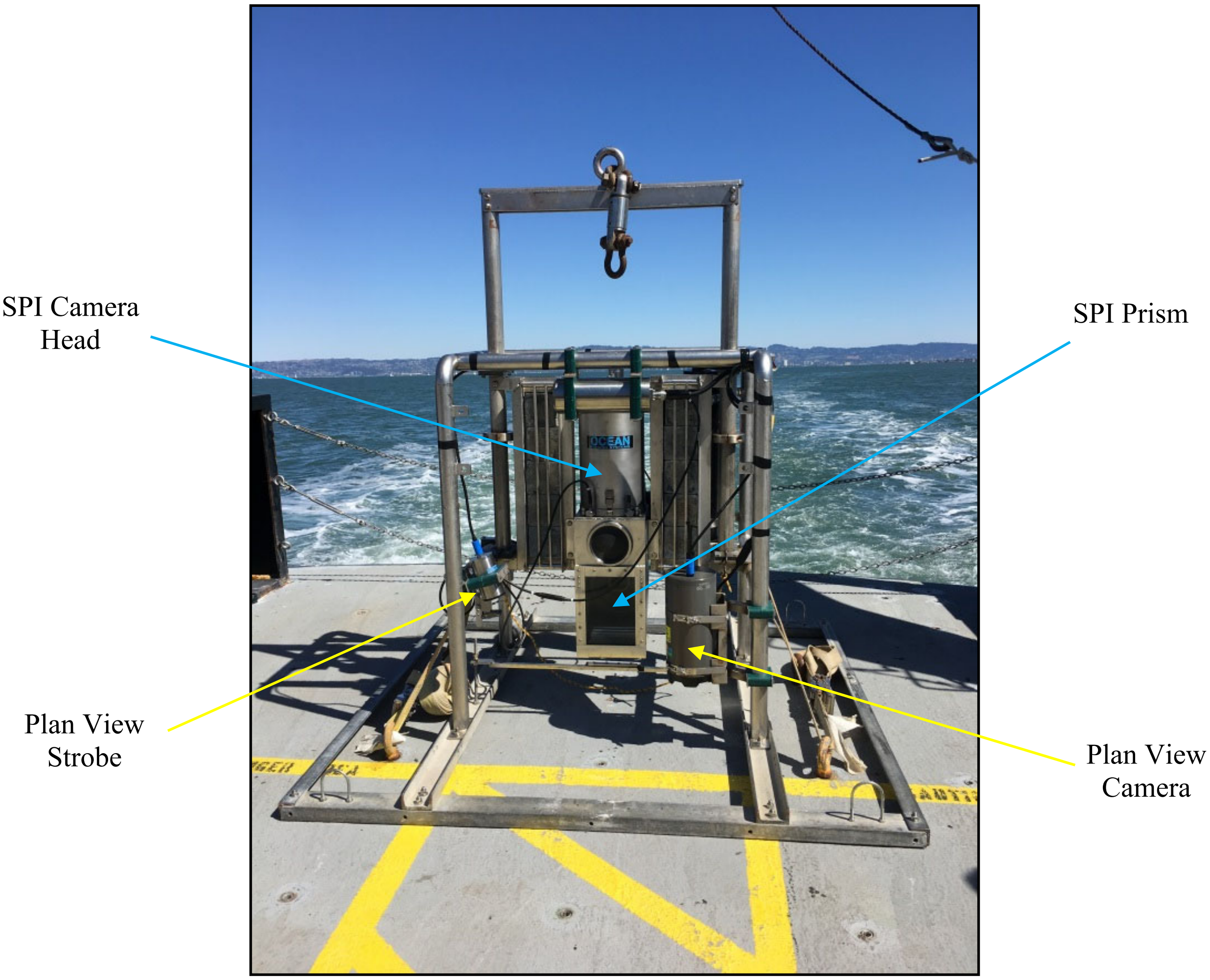


Figure 6. Ocean Imaging Systems Model 3731 Sediment-Profile Camera with Chimaera MKII Plan View Camera

A trigger is tripped on impact with the bottom, activating a 13 second time-delay on the shutter release; this gives the prism a chance to obtain maximum penetration before an image is collected. After an image is collected, the camera is raised from the bottom, a wiper blade automatically cleans off any sediment adhering to the prism faceplate, and the strobes are recharged. The camera can then be lowered to collect another replicate image.

When the camera is brought to the surface, optical prism penetration is measured from a penetration indicator, which measures the distance the prism falls relative to the camera base. Two weight racks, each capable of holding 125 lb. of lead (in 25 lb. increments) can be loaded to increase penetration. If penetration is too great, adjustable stops, which control the distance the prism can descend, can be lowered, and “mud” doors can be attached to each side of the frame to increase the bearing surface of the entire unit.

The SPI camera will be lifted and dropped at each discrete sampling location a minimum of three times to attempt collection of three interpretable SPI images. Given the potential for compact sands and gravels and wood and other debris on the seafloor, a minimum of one interpretable SPI image will be targeted for each location. Within the dense pile field, the SPI camera system will be deployed using the float frame (see Section 4.1). Approximate transect locations for SPI collection within the Dense Pile Field are shown in Figures 2 and 3. The actual transects and locations where SPI images are collected will be determined in the field based on where the float frame is able to access the Dense Pile Field. The SPI sampling locations and number of SPI images collected along each transect cannot be reliably predicted and will be based on best effort.

4.3.2 Plan View Imaging

Plan view (seafloor surface) images will be captured using either a downward-facing underwater video camera, manufactured by GoPro, or an underwater Chimaera MKII camera with external flash, manufactured by SubC Control, Newfoundland, Canada (Figure 6). The GoPro or Chimaera camera systems will be mounted on the frame of the SPI camera in a downward-looking orientation. The GoPro will record continuous video during the SPI deployment. The Chimaera collects plan view images just before the SPI camera touches the seafloor, using a lead ball and cable attached to a bounce trigger. When the SPI camera is raised from the bottom, the bounce trigger is reset, and the Chimaera plan view camera is ready to take another image. The total surface area captured in the plan view camera field of view can increase or decrease depending on water clarity at the site. The Chimaera MKII is equipped with dual lasers located 62.5 mm apart allowing an accurate scale to be applied to each image. Lasers are not included with the GoPro camera, but the base frame of the SPI system will be within view of the camera and provide a relative scale.

4.4 Vibracore Sediment Samples

Core samples at the Dickman Mill site will be collected using Gravity’s vibracorer equipped with 8-foot-long pre-cleaned Lexan or metal core barrels with a cellulose acetate butyrate (CAB) liner. The end of the sediment core barrel (4-inch diameter) is equipped with an “eggshell” core catcher to retain sediments that enter the barrel. A check-valve is used in the tube adapter clamp to prevent suction caused from pulling the core out of the mud and backflow of sample out of the vibracorer tube.

The vibracorer is mechanically lowered into position on the seafloor, activated, and allowed to penetrate to the full length of the core or refusal. An integrated measurement line is used to monitor real-time depth penetration of the corer head. Once sampling is complete, the vibracorer is retrieved and sediment recovery verified. The core barrel will then be removed and the condition and quantity of material within the core will then be inspected to determine acceptability.

To verify whether an acceptable core sample has been collected, the following criteria must be met:

- Target penetration depth was achieved or hit refusal due to presence of native sediment.
- Sample appears undisturbed and intact without any evidence of obstruction or blocking within the core tube or core catcher.
- The core sediment recovery guideline is a minimum of 75 percent of the penetration depth. The percent sediment recovery is determined by dividing the length of material recovered by the depth of core penetration below the mudline. Cores with recovery less than 75 percent may be considered acceptable if sediment stratigraphy appears intact and native sediment is present in the bottom of the core barrel.

If the sample is deemed acceptable, overlying water will be carefully poured off by tipping the core barrel, the CAB liner will be removed from the core barrel, and each end of the CAB liner will be sealed closed with caps. All cores will be labeled with the sampling location, core number, date and time of collection, depth, and direction arrows indicating the top end. The sampling location, core number, station coordinates, date and time of collection, field crew, and weather conditions will be recorded in the field log. The coring log will include penetration depth, length of core recovered, calculated recovery, measured water depth, tidal height at the time of sampling, and the calculated mudline elevation. The cores will be processed at a laboratory facility or a shore-based location adjacent to the project area.

4.4.1 Core Processing

At the core processing location, the core liner will be placed on a core processing tray. After removal of any remaining overlying water, the core liner will be cut along the axis using electric shears or a utility knife. The sediment will then be split along this axis using a pre-cleaned spatula. Once a core liner is opened, the sediment will be inspected, described, and photographed. Following visual classification, individual sediment samples will be collected as follows:

- Once the core has been split, sampling depth intervals will be delineated in the sediment using a pre-cleaned stainless-steel spoon. The depth intervals will not be adjusted to account for compaction. Samples for each core will consist of the top 1 foot (0-1 ft) and 2-foot intervals until the bottom of the core is sampled (1-3 ft, 3-5 ft, 5-7 ft).
- Each sediment core interval will be placed in a decontaminated stainless-steel container. Sediment coming in direct contact with the sampling equipment will be avoided, if possible.

- Sediment aliquots for total sulfides analysis will be collected directly from the core intervals and placed in a pre-cleaned, labeled sample containers (Table 3). Zinc acetate preservative (2 mL) will be added to each jar, lid fastened, and shaken until mixed.
- The sample will be homogenized with a pre-cleaned stainless-steel spoon until a consistent color and texture is achieved.
- Aliquots of the homogenized sediment will be placed in the appropriate pre-cleaned containers for conventional and chemical testing. An archive sample (16-oz) will be collected from each individual core interval.

All sample handling, subsampling, judgment of sample acceptability, gear and utensil decontamination, compositing, storage, and chain-of-custody procedures will follow Puget Sound Estuary Program (PSEP) guidelines (PSEP 1997a,b,c,d, 1998).

4.5 Hand Hammer Core Samples

Core samples at the north beach intertidal locations will be collected using a hand hammer corer manufactured by Aquatic Research Instruments and referred to as universal percussion corer. The head of the corer will be fitted with a 2-foot-long, 2 5/8-inch diameter, clear polycarbonate core tube. The corer includes a 3-kilogram slide hammer weight for driving the core tube into the sediment and a check valve to retain sediment in the core tube without a need for a core catcher.

The hand core locations are located between +2 and +5 feet MLLW (see Figure 4) and will be accessed by land during low tide. Prior to core collection, the entire beach area will be inspected and photographed to log the type of surface materials present. Targeted core locations may be modified based on the inspection to sample a wide range of conditions observed.

The hand corer will be placed in position and pushed into the sediment by raising and lowering the core hammer. The core will be hammer driven the full 2-foot length of the core tube, pushed side to side to reduce suction, and then pulled up to the sediment surface for immediate capping of the core bottom. The core head will be removed from the core tube and capped, and the condition and quantity of material within the core will then be inspected to determine acceptability and recovery.

If the sample is deemed acceptable and exhibits at least 75 percent recovery, both caps will be sealed with tape. All cores will be labeled with the sampling location, core number, date and time of collection, depth, and direction arrows indicating the top end. The sampling location, core number, station coordinates, date and time of collection, field crew, and weather conditions will be recorded in the field log. The coring log will include penetration depth, length of core recovered, calculated recovery, tidal height at the time of sampling, and estimated mudline elevation. In addition, the surface sediment conditions at the core location and the general vicinity will be noted. The cores will be processed at a laboratory facility or a shore-based location adjacent to the project area.

4.5.1 Core Processing

At the core processing location, the core tube caps will be removed, and the core tube will be placed in a vertical core extruding apparatus. The plunger will be inserted in the bottom of the core tube and pushed up until the sediment surface reaches the base of the extrusion plate. The core tube will be processed as follows:

- The upper 1 foot of sediment will be plunged into the extrusion plate as the material is inspected and physical conditions are logged in 0.1-foot increments.
- The lower 1 foot of sediment will plunged, inspected, logged, and placed in a decontaminated stainless steel container. The exact break between the upper and lower 1-foot intervals will be adjusted based on observations of physical conditions where the upper core interval will be comprised of clean cap materials (e.g., grey/brown sand and gravel) and the lower core interval will be primarily comprised of historical sediment (e.g., sand/silt without gravel, possible wood debris, and petroleum sheen/odor).
- Sediment aliquots for total sulfides analysis will be collected directly from near the center of the lower core interval and placed in pre-cleaned, labeled sample containers (Table 3). Zinc acetate preservative (2 mL) will be added to each jar, lid fastened, and shaken until mixed.
- The sample will be homogenized with a pre-cleaned stainless-steel spoon until a consistent color and texture is achieved.
- Aliquots of the homogenized sediment from the lower core interval will be placed in the appropriate pre-cleaned containers for conventional and chemical testing. An archive sample (16-oz) will be collected from each individual core interval.

All sample handling, subsampling, judgment of sample acceptability, gear and utensil decontamination, compositing, storage, and chain-of-custody procedures will follow PSEP guidelines (PSEP 1997a,b,c,d, 1998).

4.6 Surface Grab Sampling

A 0.15-m^2 stainless steel powered grab sampler will be used for the collection of surface sediment samples at the Dickman Mill site. Established deployment and recovery procedures for the grab sampling gear, described in PSEP, will be followed to ensure recovery of the best possible samples and minimize risks to personnel and equipment (PSEP 1997a). Once a grab sample is retrieved, the overlying water will be carefully siphoned off one side of the sampler. If the sample is judged to be acceptable according to PSEP specifications, the penetration depth will be measured with a decontaminated stainless-steel ruler, and sample quality, color, odor, and texture will be described in the sample log (Appendix D).

If needed, multiple grab samples will be collected and composited for each sampling location to provide sufficient volume for chemical and potential bioassay analysis. The general procedure for collecting sediment using a grab sampler is as follows:

1. Make logbook and field form entries as necessary throughout the sampling process to ensure accurate and thorough record-keeping.
2. Position the sampling vessel at the targeted sampling location.
3. Set the sampler jaws in the open position, place the sampler over the edge of the boat, and lower the sampler to the bottom.
4. Record the location using the DGPS; measure and record the water depth.

5. Retrieve the sampler and place it securely in the sampling vessel.
6. Examine the sample for the following sample acceptance criteria:
    a. The sampler is not overfilled with sample so that the sediment surface is pressing against the top of the sampler.
    b. The sample does not contain large foreign objects (i.e., trash or debris). A sample that is rock/gravel fill will be rejected in favor of depositional material (i.e., sand/silt/clay).
    c. Overlying water is present, indicating minimal leakage.
    d. Overlying water is not excessively turbid, indicating minimal sample disturbance.
    e. Sediment surface is relatively flat and/or intact without any indications of disturbance or winnowing.
    f. A penetration depth has been achieved that allows the collection of the upper 10 cm of sediment whenever feasible. In instances where 10 cm penetration is not possible due to sandy sediments, the maximum penetration depth will be recorded.
    g. If sample acceptance criteria are not achieved, the sample will be rejected, and another sample collection attempt will be made.
    h. If multiple attempts within 50 feet of a given target location do not produce an acceptable sample, the sampling location will be relocated.
7. Siphon off any overlying surface water.
8. Collect a digital image of the sediment surface, including the location, date, and time when the grab was collected (wipe board).
9. Collect samples for total sulfides analysis directly from the grab sampler and place the sediment aliquots in appropriate, pre-cleaned, labeled sample containers (Table 3). Add approximately 2 mL of zinc acetate preservative to the jar, fasten the lid, and shake until mixed.
10. Measure and collect the top 10 cm with a stainless-steel spoon, avoiding any sediment that is in contact with the inside surface of the grab sampler, and then place the sediment into a stainless-steel bowl and cover with aluminum foil.
11. Record the following observations of sediment sample characteristics on the field form (Appendix D); repeat steps 4 through 11 if more sample volume is required.
    a. Texture
    b. Color
    c. Biological organisms or structures (i.e., shells)
    d. Presence of debris (i.e., natural or anthropogenic objects); estimated percentage of wood debris
    e. Presence of oily sheen or obvious contamination
    f. Odor (e.g., hydrogen sulfide, petroleum)
12. Wash excess sediment back into the water away from any areas remaining to be sampled.
13. Once sufficient sediment volume has been collected and homogenized to a consistent texture, samples will be placed in the appropriate, pre-cleaned, labeled sample containers, placed in a cooler maintained at 4ºC, and prepared for shipment to the analytical laboratory.
14. Confirm all relevant documentation has been completed, entries are accurate, and paperwork has been signed.

15. Decontaminate all sampling equipment before proceeding to the next sampling location.

4.6.1 Carr Inlet Reference Sediment (if bioassay testing is required)

If required, reference sediment will be collected for bioassay testing of Dickman Mill site sediments (Section 3.4). The reference location(s) in Carr Inlet, WA, will be determined based on the Dickman Mill site sediment grain sizes determined by wet sieving (Section 4.6.2). The reference sediment should have a similar (within 20 percent) grain size percent fines with the test sediments. An adequate volume of sediment will be collected at the reference station(s) to perform conventional analyses and bioassays (Table 3). Sediment collection will follow the same procedures as at the Dickman Mill site. Surface sediment (top 10 cm) from the Carr Inlet reference station will be mixed until homogeneous in color and texture and placed into appropriate pre-cleaned containers provided by the analytical laboratory. Sediment for bioassay testing will be placed in a labeled polyethylene bag and sealed with no headspace. All sample containers will be stored in coolers at 4±2 ºC in darkness until delivery to the analytical laboratories.

4.6.2 Wet Sieving Procedures

The silt and clay (fines) content of the Dickman Mill and Carr Inlet reference samples will be determined in the field using the following wet-sieving procedure:

1) Measure and record the exact volume of a small (100-ml) flat-topped beaker. (Note: the 100-ml gradation is generally located slightly below the rim of the beaker; hence, the actual beaker volume is greater than 100 ml).

2) Completely fill the beaker to the rim with an aliquot of homogenized sediment. Lightly tap the beaker on a hard surface to remove any air bubbles, and level the surface.

3) Rinse the entire contents of the beaker through a 63-micron (#230, 4 phi) sieve. Aggregates of material should be gently broken to facilitate sieving. Continue sieving until clear rinse water passes through the sieve.

4) Carefully transfer and rinse the coarse-grained material from the sieve into a 100-ml graduated cylinder.

5) Divide the amount of material measured in the bottom of the graduated cylinder by the capacity of the beaker to determine the decimal percentage of coarse-grained material. Subtract the decimal percentage of coarse-grained material from 1 to determine the decimal percentage of fines (silt and clay).

4.7 Sample Identification

Samples will be identified based on the site, sampling location, sample type, and replicate (when required for laboratory replication). Examples of the sample identification scheme are provided in Table 4, and definitions are provided below:

- Site:
  - DM = Dickman Mill site
  - CR = Carr Inlet
- Location Number:
  - XX = Dickman Mill or Carr Inlet Station Number
- Sample Type (indicated by one or two character):
  - C = core sample
  - S = sediment grab
  - ER = equipment rinsate
  - RB = rinsate blank
- Core Interval or Replicate: core depth interval in feet (e.g., 0-1), field replicates [duplicate (DUP), triplicate (TRIP)], rinsate number (1, 2)

Sample labels will be self-adhering and of waterproof material. Indelible ink will be used to fill out each label. Each sample label will contain the project name (2022 Dickman Mill Sediment Investigation), sample identification, date and time of collection, analyses, preservative (as applicable), and the initials of the person preparing the sample. In addition, a unique, sequentially numbered jar tag label will be placed on each sample container for tracking purposes. Jar tag label numbers will be recorded in a Sample Container Logbook (Appendix C). Sample labels and jar tag labels will be protected by packaging tape wrapped around the entire jar to prevent loss or damage of the labels during handling and storage.

4.8 Sample Storage, Holding Times, and Delivery

All sediment samples will be stored in insulated coolers and preserved by cooling with ice or frozen gel-packs to a temperature of 4±2 °C. The required sample containers and holding times are provided in Table 3. The sediment sample types and analyses are summarized in Table 5.

Preparation of sample containers for shipment will be performed in the following manner:

- Place individual sample containers in plastic bubble-pack bags or in zip-lock bags wrapped in bubble pack and secured with packaging tape. Polyethylene bags with sediment will not require bubble pack.
- Prepare an empty insulated cooler by placing three to four ice packs at the bottom of the cooler. Place sample containers in a garbage bag and fill with the sample bottles. Add additional ice packs as needed to surround the bag containing the samples.
- Include a temperature blank in the cooler.
- Seal the cooler with strapping tape and a custody seal.

Samples for chemical analysis and biological testing will be hand-carried or shipped via overnight courier to the laboratories accompanied by the chain-of-custody record, which identifies the shipment contents. The chain-of-custody form will be signed by the individual relinquishing samples to the laboratory. Samples will be packaged and shipped in accordance with U.S. Department of Transportation regulations as specified in 49 Code of Federal Regulations (CFR) 173.6 and 49 CFR 173.24. NewFields field personnel will be responsible for the following:

- Packaging the samples
- Ensuring the signed chain-of-custody forms are enclosed in a plastic bag and taped to the inside lid of the cooler
- Applying a shipping label, a waybill, a custody seal, and strapping tape to the cooler
- Shipping the samples in accordance with the maximum holding time allowed for the analyses to be performed.

The samples will remain in the custody of the field staff until offloaded from the vessel at the end of the day and transported to a secure storage facility. The samples will be delivered to the respective analytical and biological laboratories, with deliveries made within sample holding times. Cooler temperatures will be monitored, and ice will be added daily to ensure proper sample preservation.

4.9 Equipment Decontamination Procedures

Sample collection and processing equipment (i.e., stainless-steel power grab sampler and stainless-steel spoons and bowls) will be washed with a laboratory-grade detergent (e.g., Liquinox) and water solution and then rinsed with distilled water prior to field operations. Decontaminated equipment will be wrapped or covered with aluminum foil. Subsampling and processing equipment will be decontaminated before use at each location to prevent cross contamination of samples. Any deviations from these procedures will be documented in the field notebook.

Personal non-disposable field equipment (e.g., boots and waterproof gloves and garments) will be rinsed with water and brushed clean prior to leaving the immediate vicinity of the sample collection area. Special attention will be given to removing mud and sediments that may adhere to boot treads.

4.10 Waste Disposal

Two types of investigation-derived waste will be generated during the activities described in this work plan:

- Sediment not submitted to the laboratories
- Disposable protective clothing and supplies

Excess sediment from grab sampling will be returned to the site at the time of collection. Excess sediment remaining after completion of core processing will be returned to the collection site. Used personal protective equipment (PPE) such as disposable gloves and supplies (e.g., paper towels and packaging) will be placed in plastic storage bags and disposed of as municipal waste. Recyclable waste material (e.g., cardboard, aluminum) will be recycled as feasible.

4.11 Field Documentation

A complete record of field activities will be maintained. Documentation necessary to meet QA objectives for this project include a field logbook, field forms (Appendix D), sample container labels, sample container logbook, and chain-of-custody forms. The field documentation will provide descriptions of all sampling activities, sampling personnel, sample descriptions, and weather conditions, and will record all modifications, decisions, and/or corrective actions to the study design and procedures.

Table 3. Sample Container Requirements and Holding Times

Sample Type	Sample Size[1]	Preservation[2]	Holding Time	Container[3]
Sediment Conventionals				
Grain size	100-200 g	4±2°C	6 months	16 oz. glass or HDPE
Total solids	125 g	4±2°C/-18±2°C	14 days/6 months	8 oz. glass
Total volatile solids	125 g	4±2°C/-18±2°C	14 days/6 months	
Total organic carbon	125 g	4±2°C/-18±2°C	14 days/6 months	
Ammonia	25 g	4±2°C	7 days	
Total sulfides	50 g	4±2°C, 2N Zn acetate	7 days	2 oz. glass
Chemistry				
Metals (except mercury)	50 g	4±2°C/-18±2°C	6 months/2 years	4 oz. glass
Mercury	50 g	≤6°C	28 days	
SVOCs including PAHs	150 g	4±2°C/-18±2°C	14 days/1 year	16 oz. glass
Dioxin/furan congeners	100 g	4±2°C/-18±2°C	30 days/1 year	8 oz. amber glass
Bioassay Testing				
Amphipod mortality	1.5 L	4±2°C, nitrogen atmosphere[4]	8 weeks	polyethylene bags
Larval development	0.5 L	4±2°C, nitrogen atmosphere[4]	8 weeks	
Juvenile polychaete growth	1.5 L	4±2°C, nitrogen atmosphere[4]	8 weeks	
Archival				
Sample archive[5]	variable	-18±2°C	variable	16 oz. glass

Notes:

1. Recommended minimum field sample sizes for one laboratory analysis. Actual volumes to be collected have been increased to provide a margin of error and allow for retests.
2. During transport to the lab, samples will be stored on ice. Archived samples will be frozen immediately upon receipt at the lab.
3. All sample containers will have Teflon-lined lids.
4. If headspace is present, purge with nitrogen at laboratory.
5. One 16 oz. container for each sample will be archived for potential analysis/re-analysis.

Table 4. Sample Identification Scheme Examples

Sample ID	Site	Sampling Location	Sample Type	Interval (ft)	Description
DM-02-S	DM	02	S		Surface sediment (0-10 cm) sample from DM-02
DM-07-C-0-1	DM	07	C	0-1	Core interval 0-1 ft sample from DM-07
DM-C1-C-1-2	DM	C1	C	1-2	Hand hammer core interval 1-2 ft sample from DM-C1
DM-02-S-DUP	DM	02	S	DUP	Field duplicate surface sample collected from DM-02
DM-ER-1	DM	--	ER	1	First equipment rinsate collected
CR-04-S	CR	04	S		Surface sediment (0-10 cm) sample from Carr Inlet station CR-04

Table 5. Dickman Mill Sediment Samples

Sample ID	Sample Type	Sediment Depth Interval[a]	Conventionals	Metals	PAHs Only	All SVOCs[b]	Dioxin/Furan Congeners	Chemistry Archive	Bioassays
Laboratory			**ARI**	**ARI**	**ARI**	**ARI**	**ARI**	**ARI**	**EcoAnalysts**
DM-01-S	Grab	0–10 cm	✓	✓	✓		(A)	(A)	(A)
DM-03-S	Grab	0–10 cm	✓	✓	✓		(A)	(A)	(A)
DM-07-S	Grab	0–10 cm	✓		✓		(A)	(A)	(A)
DM-10-S	Grab	0–10 cm	✓	✓	✓		(A)	(A)	(A)
DM-15-S	Grab	0–10 cm	✓			✓	(A)	(A)	(A)
DM-18-S	Grab	0–10 cm	✓		✓		(A)	(A)	(A)
DM-19-S	Grab	0–10 cm	✓	✓	✓		(A)	(A)	(A)
DM-21-S	Grab	0–10 cm	✓			✓	(A)	(A)	(A)
DM-22-S	Grab	0–10 cm	✓		✓		(A)	(A)	(A)
DM-23-S	Grab	0–10 cm	✓		✓		(A)	(A)	(A)
CR-XX-S[c]	Grab	0–10 cm	(✓)						(✓)
DM-04-C-0-1	Vibracore	0-1 ft	✓		✓		✓	(A)	
DM-04-C-1-3	Vibracore	1-3 ft	✓		✓		✓	(A)	
DM-04-C-3-5	Vibracore	3-5 ft					(A)	(A)	
DM-04-C-5-7	Vibracore	5-7 ft					(A)	(A)	
DM-06-C-0-1	Vibracore	0-1 ft	✓	✓	✓		(A)	(A)	
DM-06-C-1-3	Vibracore	1-3 ft	✓	✓	✓		(A)	(A)	
DM-06-C-3-5	Vibracore	3-5 ft					(A)	(A)	
DM-06-C-5-7	Vibracore	5-7 ft					(A)	(A)	
DM-08-C-0-1	Vibracore	0-1 ft	✓	✓	✓		✓	(A)	
DM-08-C-1-3	Vibracore	1-3 ft	✓	✓	✓		✓	(A)	
DM-08-C-3-5	Vibracore	3-5 ft					(A)	(A)	
DM-08-C-5-7	Vibracore	5-7 ft					(A)	(A)	
DM-11-C-0-1	Vibracore	0-1 ft	✓		✓		(A)	(A)	
DM-11-C-1-3	Vibracore	1-3 ft	✓		✓		(A)	(A)	
DM-11-C-3-5	Vibracore	3-5 ft					(A)	(A)	
DM-11-C-5-7	Vibracore	5-7 ft					(A)	(A)	
DM-12-C-0-1	Vibracore	0-1 ft	✓	✓	✓		✓	(A)	
DM-12-C-1-3	Vibracore	1-3 ft	✓	✓	✓		✓	(A)	
DM-12-C-3-5	Vibracore	3-5 ft					(A)	(A)	
DM-12-C-5-7	Vibracore	5-7 ft					(A)	(A)	
DM-13-C-0-1	Vibracore	0-1 ft	✓			✓	✓	(A)	
DM-13-C-1-3	Vibracore	1-3 ft	✓		✓		✓	(A)	
DM-13-C-3-5	Vibracore	3-5 ft					(A)	(A)	
DM-13-C-5-7	Vibracore	5-7 ft					(A)	(A)	
DM-17-C-0-1	Vibracore	0-1 ft	✓			✓	✓	(A)	
DM-17-C-1-3	Vibracore	1-3 ft	✓			✓	✓	(A)	
DM-17-C-3-5	Vibracore	3-5 ft					(A)	(A)	
DM-17-C-5-7	Vibracore	5-7 ft					(A)	(A)	
DM-20-C-0-1	Vibracore	0-1 ft	✓		✓		(A)	(A)	
DM-20-C-1-3	Vibracore	1-3 ft	✓		✓		(A)	(A)	
DM-20-C-3-5	Vibracore	3-5 ft					(A)	(A)	
DM-20-C-5-7	Vibracore	5-7 ft					(A)	(A)	

Sample ID	Sample Type	Sediment Depth Interval[a]	Conventionals	Metals	PAHs Only	All SVOCs[b]	Dioxin/Furan Congeners	Chemistry Archive	Bioassays
DM-24-C-0-1	Vibracore	0-1 ft	✓		✓		✓	(A)	
DM-24-C-1-3	Vibracore	1-3 ft	✓		✓		✓	(A)	
DM-24-C-3-5	Vibracore	3-5 ft					(A)	(A)	
DM-24-C-5-7	Vibracore	5-7 ft					(A)	(A)	
DM-C1	Hand Core	1-2 ft[d]	✓	✓	✓		(A)	(A)	
DM-C2	Hand Core	1-2 ft[d]	✓	✓	✓		(A)	(A)	
DM-C3	Hand Core	1-2 ft[d]	✓	✓	✓		(A)	(A)	
DM-C4	Hand Core	1-2 ft[d]	✓	✓	✓		(A)	(A)	
Field QC Samples									
DM-XX-S-DUP	Field Duplicate		✓	✓		✓			
DM-YY-S-DUP	Field Duplicate		✓		✓				
DM-XX-S-TRIP	Field Triplicate		✓						
DM-YY-S-TRIP	Field Triplicate		✓						
DM-ER-1	Equipment Rinsate			✓		✓			
DM-ER-2	Equipment Rinsate				✓				
DM-RB-1	Rinsate Blank			✓		✓			
	PS-SRM						✓		
Samples Submitted for Analysis			**34**	**17**	**29**	**8**	**13**		
Sample Archives							**38**	**50**	**10**

a. Vibracore penetration is dependent on substrate and sampling will be best effort. All subsurface core sections may not be obtained.
b. SVOCs include all other semi-volatile compounds in addition to PAHs (chlorinated hydrocarbons, phthalates, phenols, miscellaneous extractables)
c. Carr Inlet reference sample(s) will be collected only if bioassays are triggered
d. Hand Core samples will be collected below the beach gravel (1-foot cap thickness was targeted at construction)
PS-SRM Puget Sound Sediment Reference Material
(A) Archive
(✓) Analyzed if collected
CR Carr Inlet

5.0 ANALYTICAL METHODS

5.1 SPI Image Analysis

Computer image analysis of SPI images follows a formal and standardized technique developed by Rhoads and Germano (1982, 1986). Physical and biological parameters are measured directly from the digital SPI images by an SPI analyst using a Geographic Information System (GIS) – based image analysis system. At a minimum the image analysis parameters for this project will include:

- Camera prism penetration depth (cm)
- Grain size major mode and range in phi sizes
- Presence of wood and other debris (estimate of percent coverage)
- Surface boundary roughness
- Depth of the apparent redox potential discontinuity (aRPD) (cm)
- Infaunal successional stage
- Presence of methane
- Evidence of excessive organic loading and high sediment oxygen demand (SOD)
- Distribution of sulfate-reducing bacterial mats (e.g., *Beggiatoa*)

The measurement techniques and interpretive criteria for each parameter are provided in Appendix E.

5.2 Plan View Image Analysis

Image analysis of the plan view images will, at a minimum, consist of evaluating the images for evidence of physical disturbance (e.g., ripples, scour features), biological features (e.g., burrows, feeding structures), classification of surface type and grain size characteristics, presence of wood or man-made debris, and identification and enumeration of flora and fauna visible on the seafloor.

5.3 Sediment Analyses

Chemical analytical procedures will be performed in accordance with PSEP guidelines (PSEP 1997a,b,c,d) with appropriate modifications as specified during the annual Sediment Management Annual Review Meeting (SMARM) process (Ecology 2021), and current laboratory recommendations. Each laboratory participating in this program has instituted internal QA/QC plans. Analyses will be required to conform to accepted standard methods and internal QA/QC checks prior to final approval.

ARI will conduct the chemical analysis. Table 6 presents the sample preparation methods, analytical methods, method detection limits (MDLs), reporting limits (RLs), and SQS criteria for the target conventionals, metals, PAHs, and dioxin/furan congeners. Laboratory QA/QC requirements are listed in Table 7.

5.4 Toxicity Testing

If triggered, the recommended suite of bioassays (10-Day amphipod acute test, sediment larval development test, and 20-day *Neanthes* polychaete growth test) will be conducted in compliance with *Recommended Protocols for Conducting Laboratory Bioassays on Puget Sound sediments (PSEP)*, July 1995, with appropriate modifications as specified during the annual SMARM process. Two potential modifications described in Ecology (2021) may be relevant for the Dickman Mill sediment investigation:

1. If sediments have flocculent material such as wood fiber, a re-suspension protocol for the larval test has been developed to address this issue as presented during the 2013 SMARM.
2. Sediments that contain PAHs can result in toxicity increases when exposed to UV light (Ahrens and Hickey 2002). Toxicity tests for sediment collected in shallow water or the intertidal area that contain PAHs should follow the recommendations in Appendix C of Ecology (2021). Dickman Mill test sediments will be evaluated for these conditions and test modifications applied, if needed.

Reference sediment samples will be collected from Carr Inlet as soon as possible once bioassay testing is determined necessary for any Dickman Mill sediment samples. The number of reference sediments will be dependent upon the grain size of the Dickman Mill samples selected for testing. Adequate volumes of reference materials will be collected to allow two complete runs of the bioassay suite. Reference sediment subsamples will be submitted for conventional parameter analysis (see Tables 3 and 5).

Table 6. Target analytes, methods, MDLs, RLs, and SQS criteria

Parameter	Prep Method	Analysis Method	Sediment		SQS[1]
			MDL[1]	RL[1]	mg/kg DW
Conventionals					
Total Solids (%)	---	PSEP	---	0.1	---
Total Volatile Solids (%)	---	PSEP	---	0.1	---
Total Organic Carbon (%)	---	9060(modified)	0.0200	0.0200	---
Total Sulfides (mg/kg)	---	PSEP	5.63	10	---
Ammonia (mg/kg)	---	SM4500[2]	0.400	0.400	---
Grain Size (%)	---	ASTM D422(Subc)	---	0.1	---
Metals (mg/kg DW)					
Arsenic	3050B[3]	6020B[4]	0.0380	0.200	57
Cadmium	3050B[3]	6020B[4]	0.0400	0.100	51
Chromium	3050B[3]	6020B[4]	0.260	0.500	260
Copper	3050B[3]	6020B[4]	0.350	0.500	390
Lead	3050B[3]	6020B[4]	0.0520	0.100	450
Mercury	7471B[5]	7471B[5]	0.00525	0.0250	0.41
Silver	3050B[3]	6020B[4]	0.0220	0.200	6.1
Zinc	3050B[3]	6020B[4]	2.92	6.00	410
Parameter	**Prep Method**	**Analysis Method**	**Sediment**		**SQS[1]**
			MDL[1]	**RL[1]**	**mg/kg OC**
Organics (µg/kg DW)					
Low Molecular Polycyclic Aromatic Hydrocarbons (LPAH)					
Naphthalene	3550E[6]	8270E[7]	4.24	20	99
Acenaphthylene	3550E[6]	8270E[7]	6.24	20	66
Acenaphthene	3550E[6]	8270E[7]	5.22	20	16
Fluorene	3550E[6]	8270E[7]	14.6	20	23
Phenanthrene	3550E[6]	8270E[7]	8.72	20	100
Anthracene	3550E[6]	8270E[7]	7.19	20	220
2-Methylnaphthalene	3550E[6]	8270E[7]	4.51	20	38
Total LPAH	3550E[6]	8270E[7]	---	---	370
High Molecular Polycyclic Aromatic Hydrocarbons (HPAH)					
Fluoranthene	3550E[6]	8270E[7]	6.09	20	160
Pyrene	3550E[6]	8270E[7]	5.68	20	1000
Benzo(a)anthracene	3550E[6]	8270E[7]	5.96	20	110
Chrysene	3550E[6]	8270E[7]	6.06	20	110
Benzofluoranthenes	3550E[6]	8270E[7]	10.0	40	230
Benzo(a)pyrene	3550E[6]	8270E[7]	4.23	20	99
Indeno(1,2,3-c,d)pyrene	3550E[6]	8270E[7]	14.6	20	34
Dibenzo(a,h)anthracene	3550E[6]	8270E[7]	17.2	20	12
Benzo(g,h,i)perylene	3550E[6]	8270E[7]	13.6	20	31

Parameter	Prep Method	Analysis Method	Sediment		SQS[1]
			MDL[1]	RL[1]	mg/kg OC
Total HPAH	3550E[6]	8270E[7]	---	---	960
Chlorinated Hydrocarbons					
1,4-Dichlorobenzene	3550E[6]	8270E SIM[7]	0.6	5	3.1
1,2-Dichlorobenzene	3550E[6]	8270E SIM[7]	0.7	5	2.3
1,2,4-Trichlorobenzene	3550E[6]	8270E SIM[7]	2.7	5	0.81
Hexachlorobenzene	3550E[6]	8270E SIM[7]	0.7	5	0.38
Phthalates					
Dimethyl phthalate	3550E[6]	8270E SIM[7]	1	5	53
Diethyl phthalate	3550E[6]	8270E SIM[7]	4.8	20	61
Di-n-butyl phthalate	3550E[6]	8270E[7]	5.6	20	220
Butyl benzyl phthalate	3550E[6]	8270E SIM[7]	0.7	2.5	4.9
Bis(2-ethylhexyl)phthalate	3550E[6]	8270E[7]	5.5	50	47
Di-n-octyl phthalate	3550E[6]	8270E[7]	4.4	20	58
Miscellaneous Extractables					
Dibenzofuran	3550E[6]	8270E[7]	14.1	20	15
Hexachlorobutadiene	3550E[6]	8270E SIM[7]	0.7	5	3.9
N-Nitrosodiphenylamine	3550E[6]	8270E SIM[7]	1.3	5	11
Parameter	**Prep Method**	**Analysis Method**	**Sediment**		**SQS[1]**
			MDL[1]	**RL[1]**	**mg/kg DW**
Phenols					
Phenol	3550E[6]	8270E SIM[7]	2.2	5	420
2 Methylphenol	3550E[6]	8270E SIM[7]	1.1	5	63
4 Methylphenol	3550E[6]	8270E SIM[7]	0.9	5	670
2,4-Dimethylphenol	3550E[6]	8270E SIM[7]	2.2	20	29
Pentachlorophenol	3550E[6]	8270E SIM[7]	2.1	20	360
Benzyl alcohol	3550E[6]	8270E SIM[7]	2.5	20	57
Benzoic acid	3550E[6]	8270E SIM[7]	13.4	100	650
Dioxin/Furan Congeners (ng/kg)					
2,3,7,8-TCDD[10]	---	1613B	0.150	1.00	---
1,2,3,7,8-PeCDD[10]	---	1613B	0.170	1.00	---
1,2,3,4,7,8-HxCDD[10]	---	1613B	0.170	1.00	---
1,2,3,6,7,8-HxCDD[10]	---	1613B	0.180	1.00	---
1,2,3,7,8,9-HxCDD[10]	---	1613B	0.220	1.00	---
1,2,3,4,6,7,8-HpCDD[10]	---	1613B	0.560	2.50	---
OCDD[10]	---	1613B	4.60	10.0	---
2,3,7,8-TCDF[10]	---	1613B	0.0580	1.00	---
1,2,3,7,8-PeCDF[10]	---	1613B	0.240	1.00	---
2,3,4,7,8-PeCDF[10]	---	1613B	0.220	1.00	---
1,2,3,4,7,8-HxCDF[10]	---	1613B	0.280	1.00	---
1,2,3,6,7,8-HxCDF[10]	---	1613B	0.200	1.00	---
1,2,3,7,8,9-HxCDF[10]	---	1613B	0.170	1.00	---

Parameter	Prep Method	Analysis Method	Sediment		SQS[1]
			MDL[1]	RL[1]	mg/kg DW
2,3,4,6,7,8-HxCDF[10]	---	1613B	0.190	1.00	---
1,2,3,4,6,7,8-HpCDF[10]	---	1613B	0.210	1.00	---
1,2,3,6,7,8,9-HpCDF[10]	---	1613B	0.240	1.00	---
OCDF[10]	---	1613B	1.10	2.50	---
Total TEQ[11]	---	1613B	---	---	---

Table 6 Notes:

1. MDLs and RLs are on a dry weight (DW) basis. SQS is dry weight or organic carbon (OC)-normalized depending on the parameter.
2. Procedures for Handling and Chemical Analysis of Sediment and Water Samples, Russell H. Plumb, Jr., EPA/Corps of Engineers, May 1981.
3. Recommended Protocols for Measuring Metals in Puget Sound Water, Sediment and Tissue Samples, Puget Sound Estuary Program, April 1997.
4. Inductively Coupled Plasma (ICP) Emission Spectrometry - SW-846, Test Methods for Evaluating Solid Waste Physical/Chemical Methods, EPA 1986 and updates.
5. Mercury Digestion and Cold Vapor Atomic Absorption (CVAA) Spectrometry - Method 747I, SW-846, Test Methods for Evaluating Solid Waste Physical/Chemical Methods, EPA 1986 and updates.
6. Ultrasonic Extraction - Method 3550C, SW-846, Test Methods for Evaluating Solid Waste Physical/Chemical Methods, EPA 1986 and updates.
7. Gas Chromatography/Mass Spectrophotometry (GC/MS) Capillary Column - Method 8270 low level, SW-846, Test Methods for Evaluating Solid Waste Physical/Chemical Methods, EPA 1986 and updates.
8. Sulfuric acid/permanganate cleanup (method 3665A) or ultrasonic extraction (3550C) methods, Test Methods for Evaluating Solid Waste Physical/Chemical Methods, EPA 1994 and updates.
9. PCBs as Aroclors by Gas Chromatography and Capillary Column Technique, Method 8081/8082. Test Methods for Evaluating Solid Waste Physical/Chemical Methods, EPA 1994 & updates.
10. Lower RLs will be achieved by extracting 20 grams of sediment instead of the standard 10 grams.
11. Toxic Equivalency Quotients (TEQs) will be calculated by substituting the MDL (or estimated detection limit for dioxin/furan congeners) in place of non-detects at ½ the MDL.

Table 7. Laboratory QA/QC Requirements

Analysis Type	Method Blanks[1]	Replicates[1]	Triplicates[1]	CRM/RM	MS/MSD[1]	Surrogates[2]
Total solids			X			
Total volatile solids			X			
Total organic carbon	X		X	X		
Total sulfides	X		X			
Ammonia	X		X			
Grain size			X			
Metals	X	X		X	X	
PAHs only [3,4]	X[5]	X[6]		X	X	X
SVOCs[3,4]	X[5]	X[6]		X	X	X
Dioxins/Furans	X[5]	X		X[7]	X[8]	

Notes:

CRM = certified reference material
RM = reference material
MS/MSD = matrix spike/matrix spike duplicate

1. Frequency of Analysis (FOA) = 5 percent or one per batch, whichever is more frequent.
2. Surrogate spikes required for every sample, including matrix spiked samples, blanks, and reference materials.
3. Initial calibrations required before any samples are analyzed, after each major disruption of equipment, and when ongoing calibration fails to meet criteria.
4. Ongoing calibration required at the beginning of each work shift, every 10 to 12 samples or every 12 hours (whichever is more frequent), and at the end of each shift.
5. FOA = one per extraction batch.
6. Matrix spike duplicate may be used.
7. The Puget Sound Sediment Reference Material will be used.
8. Stable-isotope-labeled compounds.

6.0 QUALITY ASSURANCE PROJECT PLAN

The purpose of the project QA/QC is to provide confidence in the project data results through a system of quality control performance checks with respect to data collection methods, laboratory analysis, data reporting, and appropriate corrective actions to achieve compliance with established performance and data quality criteria. This section presents the QA/QC procedures to ensure that the investigation data results are defensible and usable for their intended purpose.

6.1 Measurements of Data Quality

Measurement performance criteria are quantitative statistics that are used to interpret the degree of acceptability or utility of the data to the user. These criteria include precision, accuracy, representativeness, completeness, and comparability.

Precision is a measure of mutual agreement among individual measurements of the same property under prescribed conditions. Precision will be assessed by the analysis of matrix spike/matrix spike duplicates (MS/MSDs), field duplicate and triplicates, and laboratory control sample/laboratory control sample duplicates (LCS/LCSD). The calculated relative percent differences (RPDs) for field duplicates and triplicates and MS/MSD pairs will provide information on the precision of sampling and analytical procedures, and the RPDs for LCS/LCSD pairs will provide information on precision of the analytical procedures.

Accuracy is the degree to which an observed measurement agrees with an accepted reference or true value. Accuracy is a measure of the bias in the system and is expressed as the percent recoveries of spiked analytes in MS/MSD and LCS/LCSD samples. Accuracy will also be evaluated through the surrogate spikes in each sample. The laboratory control limits for surrogates will be used for the project. SPI is a semi-quantitative sampling technique and no specific reference materials, or standards exist that can be used to directly evaluate the accuracy of the collected data.

Representativeness expresses the degree to which data accurately and precisely represent an actual condition or characteristic at a particular sampling point. Representativeness is achieved by collecting samples representative of the matrix at the time of collection. Representativeness can be evaluated using replicate samples, additional sampling locations, and blanks. For SPI, up to three replicate profile images will be collected and analyzed at each station.

Completeness refers to the amount of measurement data collected relative to that needed to assess the project's technical objectives. It is calculated as the number of valid data points achieved divided by the total number of data points requested by virtue of the study design. For this project, completeness objectives have been established at 90 percent.

Comparability is based on the use of established U.S. Environmental Protection Agency (USEPA)-approved methods for the analysis of the selected physical and chemical parameters. The quantification of the analytical parameters is based on published methods, supplemented with well-documented procedures used in the laboratory to ensure reproducibility of the data. Use of standard operating procedures for SPI and plan view image acquisition, analysis, and reporting ensures comparability and reproducibility of the data.

6.2 Sediment Profile Imaging QA/QC Methods

Up to three replicate SPI images will be obtained at each station, and an average or median value will be calculated for each of the measured parameters (e.g., apparent redox potential discontinuity (aRPD) depth, camera penetration depth, small-scale surface roughness). It is not possible to specify acceptance criteria for precision or agreement among the values measured for the three replicate images; these values will reflect the small-scale (i.e., on the order of a few feet between individual drops of the camera onto the seafloor at each station) spatial heterogeneity or homogeneity, which is naturally present at a given location.

A scientist trained in SPI image analysis will operate the GIS-based image analysis system and generate a series of measurements for each SPI image. The data for each image are stored in the GIS, pending a review (QA check) by a senior-level SPI scientist. Upon completion of the initial analysis by the operator, the senior scientist uses the image analysis system to review all measurements performed on each image. Any changes or corrections made by the senior scientist are automatically flagged within the GIS. The operator responsible for the initial analysis will review and accept any changes made by the senior scientist. Upon accepting the changes, the data are finalized in the GIS, eliminating the need to export the data for mapping purposes.

6.3 Chemical Analysis QA/QC Methods

Field and laboratory QA/QC samples will be used to evaluate the data precision, accuracy, representativeness, and comparability of the analytical results.

6.3.1 Field QA/QC for Sediment Chemistry

Field QC samples will be collected during sampling to quantitatively measure and ensure the quality of the sampling effort and the analytical data. Field QC samples include field duplicates, equipment rinsate, and rinsate blanks. QC samples are to be handled in the same manner as the environmental samples collected. Brief descriptions of the field QC samples are provided below.

Field Duplicates and Triplicates

Field duplicates and triplicates are collected at the same time as the original sample using identical sampling techniques. Field duplicate sample results (triplicates for sediment conventional parameters) are used to assess the precision of the sample collection process and to help determine the representativeness of the sample. Field duplicates/triplicates will be collected at a five percent frequency. The duplicates/triplicates will be designated for the same analysis as the original samples. The field duplicates/triplicates will be collected from the same homogenate as the original sample.

Equipment Rinsate and Rinsate Blanks

The equipment rinsate blank and decontamination water (rinsate) blank provide a quality control check on the potential for cross contamination by measuring the effectiveness of the sampling and processing decontamination procedures. The equipment rinsate sample consists of de-ionized water rinsed across sample collection and processing equipment after they have been used to collect a sample and have been decontaminated for use at the next sampling location. Equipment rinsate samples will be collected at a five percent frequency. The decontamination water blank is an unadulterated sample of the de-ionized water used to create the rinsate blank, analyzed to ensure no contaminants were present in the rinse water. Equipment blank samples will not be required when using disposable sample equipment. A single rinsate blank will be collected for this sediment characterization.

6.3.2 Laboratory QA/QC for Sediment Chemistry

One laboratory matrix spike and matrix spike duplicate will be analyzed for every 20 samples submitted or for each analytical batch of samples (if less than 20 submitted). The combination of these spiked samples will provide information on the accuracy and precision of the chemical analysis and verify that the extraction and measured concentrations are acceptable. The MS/MSDs will be analyzed in accordance with USEPA methods for each respective analyte.

One laboratory replicate will be analyzed for all constituents (except dioxins/furans) for every 20 samples submitted or for each analytical batch of samples (if less than 20 submitted). Laboratory triplicates will be analyzed for grain size, total solids, TVS, TOC, total sulfides, and ammonia. These QA/QC samples will be analyzed in accordance with the respective USEPA method and will be used to evaluate the precision of the analytical method.

One laboratory method blank and LCS will be analyzed for all constituents (except grain size, total solids, and TVS) for each analytical batch of 20 samples to assess potential laboratory contamination and accuracy. An LCSD will be analyzed if required by the method or if the laboratory does not have enough sample volume to prepare an MS/MSD.

Laboratory control samples, ongoing precision and recovery samples, and surrogate spikes will be used as defined by the analytical methods and equipment calibration requirements. The Puget Sound specific reference material will be analyzed for dioxin/furan congeners.

6.4 Data Validation

The chemical and biological laboratories participating in this program will provide data reports that will include a cover letter describing any problems or deviations from standard protocols, analytical results, associated QA/QC materials, and a comprehensive laboratory data package sufficient to conduct a Stage 4 data validation as needed.

Chemistry and conventionals results will undergo an independent quality assurance review and data validation by EcoChem, Inc. Validation shall include USEPA Stage 2b (QA1) data validation for all chemical data (USEPA 2009). If data quality concerns are noted, the laboratory will be contacted, and the data will be reanalyzed, qualified, and/or discussed in a data validation report. The results of the data validation will be summarized in the data validation report, which will be included as an appendix to the data report.

Bioassay results will be evaluated for completeness, format, holding conditions, performance standards for negative and positive controls, and water quality control limits (PTI 1989). Bioassay

QA1 review checklists will be prepared and submitted with the data validation report. Where data fail criteria provided in the QA1 review, the laboratory will be contacted and the data will be (a) reanalyzed, (b) qualified, or (c) unqualified with an explanation.

7.0 DATA EVALUATION AND REPORTING

7.1 Data Compilation and Interpretation

The results from the Dickman Mill sediment investigation will be compiled and interpreted based on the following objectives:

- Chemistry results for the Dickman Mill sediment investigation will be compiled, summarized, and evaluated relative to Sediment Management Standards (SMS) criteria to evaluate the vertical and horizontal extent of sediment contaminants and wood debris.
- SPI and PV imaging results will be used to evaluate benthic habitat quality and assess potential impacts from wood debris in surface sediments.
- Bioassays will be used to evaluate toxicity of surface sediments impacted by contaminants and/or wood debris.
- The physical and chemical data collected within the dense pile field and north beach, as well as information from previous studies will be used to evaluate the potential impacts of pile removal on offsite sediment transport and erosion of the adjacent shoreline and intertidal sediments.
- The evaluation of the Dickman Mill sediment investigation results will include recommendations, proposed planning, and initial cost estimation for a RI/FS in support of the pile removal.

7.2 Reporting

The written data report documenting all activities associated with SPI and PV imaging, vibracoring, hand coring, and power grab sediment collection, and evaluation of the Dickman Mill sediment investigation results will include the following:

- A summary of the purpose of the investigation
- Description of sampling and analysis activities
- Protocols used during sampling and testing, and an explanation of any deviations from the sampling plan protocols or the approved work plan
- Methods used for station positioning and sample collection locations reported in latitude and longitude to the nearest tenth of a second (NAD83)
- Maps showing actual locations of sampling stations
- Maps and data tables of the SPI and PV imaging results
- Maps and data tables of sediment chemistry data (results in mg/kg organic carbon, and dry weight)
- Chemical data interpretation and comparison to SMS criteria
- Summary and interpretation of bioassay results (if bioassays are performed)
- Evaluation of potential sediment transport impacts from pile removal
- Recommendations and initial cost estimation for a RI/FS

Appendices to the written data report will include the chain-of-custody records, analytical and biological laboratory reports, copies of field and sampling logs, and data validation reports.

Project information and validated analytical data will be formatted for Ecology’s EIM database and included as part of the written data report submittal.

8.0 REFERENCES

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APPENDIX A

HEALTH AND SAFETY PLAN

APPENDIX B

Sample Locations and Data from Previous Sediment Investigations

APPENDIX C

SOPs

APPENDIX D

Field Forms

APPENDIX E

SPI Analysis Parameters

APPENDIX B

SPI and Plan View Results

(Electronic Copy Only)

Project: Dickman Mill Sediment Investigation 2022

Station	Rep	Image ID	Pen Min (cm)	Pen Max (cm)	Pen Ave (cm)	aRPD Depth Mean (cm)	Surface Relief (cm)	Roughness	Grain Size Major Mode	Succ. Stage	Fecal Pellets Present	Benthic Habitat Class
DM01	A	DM01-A	0.0	0.0	0.0	Indet.	0.0	Indet.	Indet.	Indet.	Indet.	Indet.
DM01	C	DM01-C	0.3	1.8	0.9	Indet.	1.5	Physical	2 to 1 phi	Indet.	No	SA.M
DM02	A	DM02-A	4.8	6.7	5.5	>6.7	1.9	Physical	1 to 0 phi	Stage I	No	SA.M
DM02	B	DM02-B	5.8	6.5	6.0	>6.5	0.7	Physical	1 to 0 phi	Stage I	No	SA.M
DM02	C	DM02-C	5.0	7.3	6.5	5.6	2.3	Physical	1 to 0 phi	Stage I	No	SA.M
DM03	A	DM03-A	1.8	3.4	2.7	1.4	1.6	Biological	3 to 2 phi	Stage II	No	SA.F
DM03	B	DM03-B	0.9	2.4	1.6	1.3	1.4	Physical	3 to 2 phi	Stage I	No	SA.F
DM03	D	DM03-D	0.0	0.0	0.0	Indet.	0.0	Indet.	Indet.	Indet.	Indet.	Indet.
DM04	A	DM04-A	15.1	16.5	15.6	2.0	1.4	Physical	4 to 3 phi	Stage III	No	SA.F
DM04	B	DM04-B	15.8	18.9	17.5	3.3	3.0	Physical	3 to 2 phi	Stage III	No	SA.F
DM04	C	DM04-C	16.6	18.4	17.5	4.2	1.8	Physical	4 to 3 phi	Stage III	No	SA.F
DM05	A	DM05-A	14.5	16.5	15.4	6.4	2.0	Physical	3 to 2 phi	Stage III	No	SA.F
DM05	B	DM05-B	17.2	18.1	17.7	4.2	0.9	Physical	3 to 2 phi	Stage III	No	SA.F

Station	Rep	Image ID	Pen Min (cm)	Pen Max (cm)	Pen Ave (cm)	aRPD Depth Mean (cm)	Surface Relief (cm)	Roughness	Grain Size Major Mode	Succ. Stage	Fecal Pellets Present	Benthic Habitat Class
DM05	C	DM05-C	11.5	14.6	12.6	4.1	3.1	Physical	3 to 2 phi	Stage III	No	SA.F
DM06	H	DM06-H	9.4	11.1	10.0	2.3	1.7	Physical	3 to 2 phi	Stage III	No	SA.F
DM06	I	DM06-I	7.4	8.7	8.0	3.0	1.3	Physical	3 to 2 phi	Stage I	No	SA.F
DM06	J	DM06-J	8.6	9.3	9.0	2.0	0.7	Physical	3 to 2 phi	Stage I	No	SA.F
DM07	A	DM07-A	8.8	11.5	10.1	4.4	2.7	Physical	4 to 3 phi	Stage I	No	SA.F
DM07	B	DM07-B	15.9	18.2	17.3	7.1	2.3	Physical	3 to 2 phi	Stage III	No	UN.SS
DM07	C	DM07-C	12.1	14.8	13.3	2.4	2.7	Physical	3 to 2 phi	Stage III	No	SA.F
DM08	A	DM08-A	14.4	15.2	14.8	2.7	0.7	Physical	3 to 2 phi	Stage III	No	SA.F
DM08	B	DM08-B	13.6	15.1	14.3	2.5	1.4	Physical	3 to 2 phi	Stage III	No	SA.F
DM08	C	DM08-C	12.4	13.2	12.8	2.2	0.8	Physical	3 to 2 phi	Stage III	No	SA.F
DM09	A	DM09-A	3.0	3.4	3.2	1.7	0.4	Physical	3 to 2 phi	Stage I	No	SA.F
DM09	B	DM09-B	2.5	4.1	3.3	2.9	1.6	Physical	3 to 2 phi	Stage II	No	SA.F
DM09	C	DM09-C	0.0	0.0	0.0	Indet.	0.0	Indet.	Indet.	Indet.	Indet.	Indet.

Station	Rep	Image ID	Pen Min (cm)	Pen Max (cm)	Pen Ave (cm)	aRPD Depth Mean (cm)	Surface Relief (cm)	Roughness	Grain Size Major Mode	Succ. Stage	Fecal Pellets Present	Benthic Habitat Class
DM10	A	DM10-A	13.2	14.6	13.9	3.4	1.3	Physical	3 to 2 phi	Stage III	No	SA.F
DM10	B	DM10-B	12.3	13.8	13.3	3.7	1.5	Physical	4 to 3 phi	Stage II	No	SA.F
DM10	C	DM10-C	10.1	11.9	11.4	1.7	1.8	Physical	3 to 2 phi	Stage III	No	SA.F
DM11	A	DM11-A	13.9	16.3	15.2	2.6	2.4	Physical	3 to 2 phi	Stage III	No	SH.SA
DM11	B	DM11-B	10.5	15.3	12.4	4.7	4.8	Physical	3 to 2 phi	Stage III	No	SH.SA
DM11	C	DM11-C	14.6	15.8	15.0	3.0	1.2	Physical	3 to 2 phi	Stage III	No	SH.SA
DM12	A	DM12-A	19.1	19.9	19.5	5.2	0.8	Physical	3 to 2 phi	Stage III	No	UN.SS
DM12	B	DM12-B	15.3	16.5	15.9	3.3	1.2	Physical	4 to 3 phi	Stage III	No	UN.SS
DM12	C	DM12-C	19.1	19.6	19.4	3.9	0.5	Physical	4 to 3 phi	Stage I on III	No	UN.SS
DM13	C	DM13-C	3.7	5.0	4.2	2.6	1.2	Physical	3 to 2 phi	Stage I	No	SA.M
DM14	A	DM14-A	4.4	6.4	5.4	0.0	2.0	Physical	3 to 2 phi	Stage II	No	SH.SA
DM14	B	DM14-B	1.7	3.0	2.3	2.6	1.3	Physical	3 to 2 phi	Stage I	No	SH.SA
DM14	C	DM14-C	2.9	5.1	4.2	4.4	2.2	Physical	4 to 3 phi	Stage II	No	SA.F

Station	Rep	Image ID	Pen Min (cm)	Pen Max (cm)	Pen Ave (cm)	aRPD Depth Mean (cm)	Surface Relief (cm)	Roughness	Grain Size Major Mode	Succ. Stage	Fecal Pellets Present	Benthic Habitat Class
DM15	C	DM15-C	2.1	4.1	2.8	4.1	2.0	Physical	0 to -1 phi	Stage I	No	SH.SA
DM15	D	DM15-D	4.1	6.3	5.2	6.3	2.2	Physical	1 to 0 phi	Stage III	No	SH.SA
DM15	E	DM15-E	0.2	1.4	0.5	Indet.	1.2	Physical	0 to -1 phi	Indet.	No	SH.SA
DM17	A	DM17-A	5.2	5.6	5.5	3.9	0.4	Physical	3 to 2 phi	Stage III	No	SH.SA
DM17	B	DM17-B	3.3	7.5	5.4	2.9	4.3	Physical	3 to 2 phi	Stage III	No	SA.F
DM17	C	DM17-C	8.6	9.8	9.2	2.3	1.2	Physical	4 to 3 phi	Stage III	No	SA.F
DM19	A	DM19-A	11.5	14.6	13.4	4.0	3.2	Physical	3 to 2 phi	Stage III	No	UN.SS
DM19	B	DM19-B	11.4	12.3	11.8	3.3	1.0	Physical	4 to 3 phi	Stage III	No	UN.SS
DM19	C	DM19-C	0.0	0.0	0.0	Indet.	0.0	Indet.	Indet.	Indet.	Indet.	Indet.
DM24	A	DM24-A	8.2	11.7	10.1	4.3	3.5	Physical	4 to 3 phi	Stage II	No	SA.F
DM24	B	DM24-B	0.0	0.0	0.0	Indet.	0.0	Indet.	Indet.	Indet.	Indet.	Indet.
DM24	C	DM24-C	0.0	0.0	0.0	Indet.	0.0	Indet.	Indet.	Indet.	Indet.	Indet.
DM25	A	DM25-A	7.2	8.1	7.6	2.1	0.9	Physical	3 to 2 phi	Stage II	No	SH.SA

Station	Rep	Image ID	Pen Min (cm)	Pen Max (cm)	Pen Ave (cm)	aRPD Depth Mean (cm)	Surface Relief (cm)	Roughness	Grain Size Major Mode	Succ. Stage	Fecal Pellets Present	Benthic Habitat Class
DM25	B	DM25-B	5.9	7.1	6.6	2.5	1.3	Physical	3 to 2 phi	Stage II	No	SA.F
DM25	C	DM25-C	6.4	7.5	6.9	2.1	1.1	Physical	3 to 2 phi	Stage II	No	SA.F
DM26	A	DM26-A	4.3	7.5	5.9	2.9	3.3	Physical	4 to 3 phi	Stage III	No	SA.F
DM26	B	DM26-B	1.1	4.7	3.6	3.6	3.6	Physical	2 to 1 phi	Stage III	No	SH.SA
DM26	C	DM26-C	7.6	9.7	8.5	2.5	2.1	Physical	4 to 3 phi	Stage I	No	SA.F
DM27	A	DM27-A	9.5	11.6	10.4	4.8	2.2	Physical	4 to 3 phi	Stage III	No	SA.F
DM27	C	DM27-C	2.1	7.2	4.4	3.3	5.1	Physical	3 to 2 phi	Stage III	No	SA.F
DM27	E	DM27-E	10.0	11.2	10.7	3.3	1.2	Physical	4 to 3 phi	Stage III	No	SA.F
DM28	A	DM28-A	8.8	11.7	10.2	3.9	2.9	Physical	4 to 3 phi	Stage III	No	UN.SS
DM28	C	DM28-C	17.7	18.1	17.9	4.3	0.4	Physical	4 to 3 phi	Stage III	No	UN.SS
DM29	A	DM29-A	7.0	8.7	8.1	4.5	1.7	Physical	4 to 3 phi	Stage III	No	SA.F
DM29	B	DM29-B	9.1	9.9	9.5	4.7	0.9	Physical	4 to 3 phi	Stage III	No	UN.SS
DM29	C	DM29-C	0.0	0.0	0.0	Indet.	0.0	Indet.	Indet.	Indet.	Indet.	Indet.

Station	Rep	Image ID	Pen Min (cm)	Pen Max (cm)	Pen Ave (cm)	aRPD Depth Mean (cm)	Surface Relief (cm)	Roughness	Grain Size Major Mode	Succ. Stage	Fecal Pellets Present	Benthic Habitat Class
DM30	A	DM30-A	14.0	16.9	15.3	2.2	2.9	Physical	4 to 3 phi	Stage III	No	UN.SS
DM30	C	DM30-C	7.7	17.7	12.9	7.5	10.0	Physical	3 to 2 phi	Stage III	No	UN.SS
DM30	D	DM30-D	12.8	15.9	14.7	3.8	3.1	Physical	4 to 3 phi	Stage III	No	UN.SS
DM31	A	DM31-A	0.0	0.0	0.0	Indet.	0.0	Indet.	Indet.	Indet.	Indet.	Indet.
DM31	B	DM31-B	4.4	9.7	6.8	2.2	5.3	Physical	3 to 2 phi	Indeterminate	No	SA.M
DM31	C	DM31-C	12.4	14.8	13.5	5.3	2.4	Physical	3 to 2 phi	Stage III	No	UN.SS
DM32	A	DM32-A	0.0	0.0	0.0	Indet.	0.0	Indet.	Indet.	Indet.	Indet.	Indet.
DM32	B	DM32-B	0.2	2.5	1.2	Indet.	2.3	Physical	3 to 2 phi	Indet.	No	SA.F
DM35	B	DM35-B	5.5	6.4	5.9	2.1	0.9	Physical	4 to 3 phi	Stage I	No	SA.F
DM35	C	DM35-C	6.0	7.0	6.5	2.4	1.0	Physical	3 to 2 phi	Stage III	No	SA.F
DM36	A	DM36-A	1.5	5.7	3.6	5.1	4.2	Physical	3 to 2 phi	Stage I	No	SH.SA
DM36	B	DM36-B	2.8	8.5	5.1	3.8	5.7	Physical	4 to 3 phi	Stage II	No	SA.F
DM36	C	DM36-C	0.0	0.0	0.0	Indet.	0.0	Indet.	Indet.	Indet.	Indet.	Indet.

Station	Rep	Image ID	Pen Min (cm)	Pen Max (cm)	Pen Ave (cm)	aRPD Depth Mean (cm)	Surface Relief (cm)	Roughness	Grain Size Major Mode	Succ. Stage	Fecal Pellets Present	Benthic Habitat Class
DM37	A	DM37-A	1.3	2.8	2.1	2.3	1.6	Physical	3 to 2 phi	Stage III	No	SA.M
DM37	B	DM37-B	17.4	18.8	18.4	4.5	1.4	Physical	4 to 3 phi	Stage III	No	UN.SS
DM37	C	DM37-C	13.8	15.4	14.7	6.7	1.5	Physical	4 to 3 phi	Stage II	No	UN.SS
DM38	A	DM38-A	9.5	11.0	10.2	5.1	1.5	Physical	3 to 2 phi	Stage III	No	SA.F
DM38	B	DM38-B	11.4	13.7	12.5	4.7	2.3	Physical	4 to 3 phi	Stage III	No	SA.F
DM38	C	DM38-C	13.1	14.6	13.8	4.2	1.4	Physical	4 to 3 phi	Stage III	No	SA.F
DM39	A	DM39-A	2.7	5.5	4.1	3.2	2.8	Physical	0 to -1 phi	Stage III	No	SH.SA
DM39	B	DM39-B	3.2	4.4	4.0	4.3	1.2	Physical	4 to 3 phi	Stage II	No	SH.SA
DM39	C	DM39-C	6.0	7.3	6.6	3.1	1.3	Physical	0 to -1 phi	Stage II	No	SH.SA
DM40	B	DM40-B	8.3	9.3	9.0	3.8	1.0	Physical	3 to 2 phi	Stage III	No	SH.SA
DM41	B	DM41-B	5.9	6.8	6.3	3.2	0.9	Physical	4 to 3 phi	Stage I	No	SA.F

Station	Rep	Mud Clast Count	Debris (%)*	OSI	Comments
DM01	A	-	Indet.	Indet.	No penetration.
DM01	C	-	Indet.	Indet.	Under penetration. Disturbed surface. Dark grey/black sands. Acorn barnacles present
DM02	A	-	-	Indet.	Under penetration. [Dark] grey medium/coarse sands with cluster of black sediment in bottom righthand corner. Trace red sand granules visible. Sea lettuce visible scattered on surface.
DM02	B	-	-	Indet.	Under penetration. Dark grey medium/coarse sands. Trace red sand granules. Sea lettuce scattered on the surface
DM02	C	-	-	7	Under penetration. [Dark] grey medium/coarse sands with trace very fine gravel. Trace red sand granules and calcareous fragments present. Sea lettuce scattered on surface.
DM03	A	-	Indet.	5	Under penetration. [Dark] grey medium/fine sand with calcareous shell fragments. 4cm structure covered with barnacles. Cluster of Chlorophyta and filamentous plants. Large piling visible in background.
DM03	B	-	-	2	Under penetration. Disturbed surface. Dark grey medium/fine sand and silt. Eelgrass and filamentous plants. Barnacles visible in background. 6cm silver/grey object - screw?
DM03	D	-	Indet.	Indet.	No penetration.
DM04	A	-	30	6	[Dark] grey medium/fine sand and silt with woody debris and calcareous shell fragments. Sea lettuce visible on surface. Large pits with woody debris visible.
DM04	B	-	10	7	[Dark] grey medium/fine sand and silt with woody debris and calcareous shell fragments. Sea lettuce, barnacles, bivalve shells, and large wood fragments visible on surface. Voids visible at depth.
DM04	C	-	20	8	[Dark] grey medium/fine sand and silt with woody debris and calcareous shell fragments. Sea lettuce, shells, and large wood fragments visible on surface. Voids visible at depth.
DM05	A	-	50	11	[Dark] grey medium/fine sand and silt with woody debris and trace calcareous shell fragments. Sea lettuce, barnacles, shells, large wood fragments, and voids visible. Air bubble artifacts inside prism.
DM05	B	-	10	9	Tan/[Dark] grey medium/fine sand and silt with woody debris and trace calcareous shell fragments. Sea lettuce and surface burrow leading to voids. Crab on surface. Air bubble artifacts inside prism.

Station	Rep	Mud Clast Count	Debris (%)*	OSI	Comments
DM05	C	-	5	7	Tan/[dark] grey medium/fine sand and silt. Woody debris and trace coarse sand and calcareous shells/fragments. Voids visible at depth. Air bubble artifacts inside prism.
DM06	H	-	-	7	Dark tan over dark grey/black medium/fine sand and silt with trace calcareous shell fragments. Sea lettuce, filamentous algae, and bivalve shells. Polychaete and void visible at depth.
DM06	I	-	-	4	Under penetration. Dark tan medium/fine sand with pebbles over dark grey/black medium/fine sand and trace calcareous shell fragments. Eelgrass and algae on surface and in background.
DM06	J	-	-	3	Under penetration. Dark tan medium/fine sand with pebbles over dark grey/black medium/fine sand and trace calcareous shell fragments. Eelgrass and unknown structure surface.
DM07	A	-	50	4	Dark grey fine sand and silt with dense woody debris/dust throughout the top 5cm. Light grey fine sand silt/clay at depth. Surface covered in woody debris, sea lettuce and possible surface tubes visible.
DM07	B	-	50	9	Dark grey fine sand and silt with dense woody debris/dust throughout the top 4cm. Light grey fine sand silt/clay at depth. Surface covered in woody debris and large (15+ cm) wood plank drag down, sea lettuce. Polychaete and voids visible at depth.
DM07	C	-	30	6	Disturbed surface. grey medium/fine sand and silt with woody debris/dust throughout. Surface covered in large woody debris, sea lettuce, and bivalve shell fragments. Possible polychaete and voids visible.
DM08	A	-	5	2	Dark tan medium/fine sand with trace coarse sand over dark grey /black medium/fine sand with calcareous shell fragments and trace woody debris throughout. Algae on surface with large wood chunks. Voids and methane bubble at depth.
DM08	B	-	5	6	Dark tan medium/fine sand with trace coarse sand over dark grey /black medium/fine sand with calcareous shell fragments and trace woody debris throughout. Algae on surface with large wood chunks and bivalve shells. Voids at depth.
DM08	C	-	5	7	Dark grey/black medium/fine sand with calcareous shell fragments and trace woody debris throughout. Large wood chunks on surface with bivalve shells. Voids at depth.
DM09	A	-	-	2	Under penetration. Tan over grey medium/fine sand with calcareous shell fragments. Surface covered with sea lettuce and eelgrass visible.
DM09	B	-	-	4	Under penetration. Tan/grey medium/fine sand with calcareous shell fragments. Surface covered with sea lettuce. Polychaete visible.
DM09	C	-	Indet.	Indet.	No penetration. Sea lettuce and piling visible.

Station	Rep	Mud Clast Count	Debris (%)*	OSI	Comments
DM10	A	-	5	7	Dark tan medium/fine sand over dark grey/black medium/fine sand with calcareous shell fragments and trace woody debris throughout. Sea lettuce and eelgrass on surface with large wood pieces. Voids and possible polychaetes at depth.
DM10	B	-	2	4	Dark tan/light grey medium/fine sand over dark grey medium/fine sand with trace coarse sand and calcareous shell fragments. Wood debris on surface. Drag down of surface flora. Anthropogenic plastic pollution.
DM10	C	-	2	6	Dark tan/light grey medium/fine sand with trace coarse sand over dark grey medium/fine sand and trace calcareous shell fragments. Drag down of surface flora and woody debris. Polychaete and small void visible.
DM11	A	-	-	8	Shell hash with dark tan/grey fine sand/silt over dark grey medium/fine sand with shell fragments. Large void visible. Sea lettuce on surface
DM11	B	-	-	9	Shell hash with dark tan/grey fine sand/silt over dark grey medium/fine sand/silt with shell fragments. Voids and burrows visible at depth. Sea lettuce on surface
DM11	C	-	-	8	Shell hash with dark tan/grey fine sand/silt over dark grey medium/fine sand/silt with shell fragments. Voids and burrows visible at depth. Sea lettuce and algae on surface
DM12	A	-	15	11	Tan fine sand/silt with calcareous shell fragments over grey/dark grey sandy silt. Woody debris throughout. Polychaete and voids visible. Possible wood chunk on surface.
DM12	B	-	15	9	Tan coarse/medium/fine sand with calcareous shell fragments over grey/dark grey sandy silt. Woody debris throughout. Polychaete and small voids visible.
DM12	C	-	15	9	Tan coarse/medium/fine sand with calcareous shell fragments over grey/dark grey sandy silt. Woody debris throughout and large wood chunks on surface. Surface tubes. Polychaete and small voids visible.
DM13	C	-	-	3	Under penetration. Dark tan/grey medium/fine sand over grey/black fine sand/silt with large fragments of calcareous shell fragments. Minor shell hash and sea lettuce on surface.
DM14	A	-	5	Indet.	Under penetration. Shell hash over dark grey/black silty sand with trace woody debris. Filamentous algae present on surface.
DM14	B	-	5	3	Under penetration. Shell hash over dark grey/black silty sand with trace woody debris.
DM14	C	-	-	7	Under penetration. Dark grey/black silty fine sand with calcareous shells and trace woody debris. Sea lettuce and 3cm shell present on surface.

Station	Rep	Mud Clast Count	Debris (%)*	OSI	Comments
DM15	C	-	-	5	Under penetration. Shell hash with trace dark grey/black coarse/medium sand.
DM15	D	-	5	11	Under penetration. Shell hash with dark tan/grey coarse/medium sand and trace woody debris.
DM15	E	-	-	Indet.	Under penetration. Shell hash with trace dark grey coarse/medium sand. Shell hash ridges visible in background.
DM17	A	-	10	8	Under penetration. Shell hash with woody debris and dark tan/black silty sand. Large voids visible at depth. Filamentous algae visible on surface.
DM17	B	-	10	7	Under penetration. Dark tan/black silty sand with calcareous shell fragments and woody debris. Voids visible at depth. Possible holothurian on surface.
DM17	C	-	5	7	Under penetration. Dark tan/black silty sand with calcareous shell fragments and trace woody debris. Voids visible at depth. Various algae, woody debris, and shell hash on surface.
DM19	A	-	10	9	Dark tan/grey silty sand with trace woody debris and calcareous shell fragments. Large wood chunks and organism tubes on surface. Polychaete and voids visible at depth.
DM19	B	-	5	8	Dark tan/dark grey silty sand with trace woody debris and calcareous shell fragments. Large wood chunks and surface burrow. Voids visible at depth.
DM19	C	-	Indet.	Indet.	No penetration.
DM24	A	-	-	7	Dark tan/grey medium/fine sand with shell fragments over grey silty sand. Polychaetes and surface burrows visible. Surface with shell hash, sea lettuce, and crab in background.
DM24	B	-	Indet.	Indet.	No penetration.
DM24	C	-	Indet.	Indet.	No penetration.
DM25	A	-	-	5	Under penetration. Dark tan medium/fine sand over dark grey fine sand with trace calcareous shell fragments. Drag down of surface flora. Eelgrass and kelp visible on surface.

Station	Rep	Mud Clast Count	Debris (%)*	OSI	Comments
DM25	B	-	-	6	Under penetration. Dark tan medium/fine sand over dark grey fine sand with trace calcareous shell fragments. Eelgrass and bivalve shells visible on surface.
DM25	C	-	-	5	Under penetration. Dark tan medium/fine sand over dark grey fine sand with trace calcareous shell fragments. Surface flora drag down. Eelgrass and bivalve shells visible on surface.
DM26	A	-	5	6	Under penetration. Dark tan/black silty sand with calcareous shell fragments and trace woody debris. Voids visible at depth. Algae and shells on surface and in background.
DM26	B	-	50	9	Under penetration. Surface layer of woody debris/dust over shell hash with dark tan/black silty sand. Voids visible at depth. Large wooden structures visible surface and in background.
DM26	C	-	1	2	Under penetration. Dark tan/black silty sand with calcareous shell fragments and trace woody debris. Surface tubes, large 7cm shell on surface, pilings visible in background.
DM27	A	-	30	10	Tan medium/fine sand/silt with woody debris and calcareous shell fragments over grey silty sand. Voids visible throughout. Various algae visible in background and surface covered with woody debris.
DM27	C	-	25	8	Under penetration. Dark tan coarse/medium sand with woody debris over dark grey silty sand. Disturbed surface. Large calcareous shell and wood chunks visible on surface. Voids visible.
DM27	E	-	15	9	Dark tan coarse/medium sand with woody debris over dark grey silty sand. Large calcareous shells and wood visible on surface. Voids visible at depth.
DM28	A	-	25	9	Dark tan medium/fine sand with woody debris and trace shell fragments over grey silty sand. Large wood chunks on surface. Polychaete and voids visible.
DM28	C	-	30	9	Tan fine sand/silt with woody debris/dust over grey fine sand and silt. Polychaete and voids visible. Wood chunks on surface.
DM29	A	-	5	10	Under penetration. Dark tan/grey medium/fine sand with trace calcareous shell fragments over dark grey/black silty fine sand. Large wood chunk on surface, organism tubes, and hard structure with barnacles in background. Polychaete and voids visible.
DM29	B	-	5	9	Under penetration. Dark tan/grey fine sand with trace calcareous shell fragments over dark grey/black silty fine sand. Surface layer of grey coarse sand. Trace woody debris. Polychaetes and voids visible.
DM29	C	-	Indet.	Indet.	No penetration.

Station	Rep	Mud Clast Count	Debris (%)*	OSI	Comments
DM30	A	-	-	6	Disturbed surface. Dark tan/dark grey silty sand with trace calcareous shell fragments, coarse granules well mixed at surface. Surface flora drag down. Polychaetes and voids visible.
DM30	C	-	5	10	disturbed surface. Dark tan/dark grey silty sand with trace woody debris and calcareous shell fragments, coarse granules well mixed at surface. Surface flora drag down. Large surface pit and voids visible.
DM30	D	-	2	8	disturbed surface. Dark tan/dark grey silty sand with trace woody debris, coarse granules well mixed at surface. Surface flora drag down. Polychaetes and voids visible.
DM31	A	-	Indet.	Indet.	No penetration.
DM31	B	-	75	Indet.	Under penetration. Disturbed surface. Grey medium/fine sand dominated with woody debris/dust. Sea lettuce visible.
DM31	C	-	30	10	Dark tan sand/silt with trace calcareous shell fragments over grey medium/fine sand with woody debris/dust throughout. Crab, sea lettuce, and algae visible on surface. Burrows and voids visible.
DM32	A	-	Indet.	Indet.	No penetration.
DM32	B	-	-	Indet.	Under penetration. Dark grey sands with trace calcareous shell fragments. Cluster of blue shards on surface, possible broken mussel shell. Sea lettuce and large piling visible in the background.
DM35	B	-	-	3	Under penetration. Dark tan sand/silt over dark grey/black silty sand. Calcareous shell fragments throughout profile. Surface tubes present, possible Beggiatoa.
DM35	C	-	-	8	Under penetration. Dark tan sand/silt over dark grey/black silty sand. Calcareous shell fragments throughout profile. Surface tubes present, large unknown black debris chunks on surface. Burrows and voids visible.
DM36	A	-	-	3	Under penetration. Shell hash over dark grey /black silty sand. Sea lettuce cluster.
DM36	B	-	-	6	Under penetration. Dark tan/black silty sand with calcareous shell fragments. Algae and shells on surface and in background.
DM36	C	-	Indet.	Indet.	No penetration. Downed pile in background. Shells visible on surface.

Station	Rep	Mud Clast Count	Debris (%)*	OSI	Comments
DM37	A	-	1	7	Under penetration. Dark tan/black silty sand with calcareous shell fragments and trace woody debris. Surface tubes, woody debris, and shells visible on surface.
DM37	B	-	5	10	Dark tan/dark grey silty sand with calcareous shell fragments and trace woody debris. Woody debris and shells visible on surface. Polychaetes and voids visible at depth.
DM37	C	-	5	5	Dark tan/black silty sand with calcareous shell fragments and trace woody debris. Various algae, woody debris, and shells visible on surface. Polychaete and possible decapod visible.
DM38	A	-	10	8	Dark tan/dark grey silty sand with calcareous shell fragments and woody debris. Sea lettuce visible on surface. Large voids visible at depth. Piling in background.
DM38	B	-	15	8	Dark tan/dark grey/black silty sand with calcareous shell fragments and woody debris. Various algae, woody debris, and shell hash on surface. Burrow and voids visible at depth.
DM38	C	-	15	7	Dark tan/dark grey/black silty sand with calcareous shell fragments and woody debris. Various algae, large woody debris, Beggiatoa clusters, and shell hash on surface. Burrow and voids visible at depth.
DM39	A	-	30	7	Under penetration. Shell hash with dark tan silty sand. Various algae, possibly trace woody debris, and shell hash visible on surface. Voids visible.
DM39	B	-	30	7	Under penetration. Shell hash and woody debris with dark tan/black silty sand. Various algae and shell hash visible on surface. Voids visible.
DM39	C	-	30	6	Under penetration. Shell hash and woody debris with dark tan /black silty sand. Various algae, woody debris, shell hash visible on surface. Voids visible.
DM40	B	-	5	9	Under penetration. Shell hash with woody debris over dark grey/black silty sand. Large voids visible. Sea lettuce and algae on surface
DM41	B	-	1	4	Under penetration. Tan coarse/medium/fine sand over light/dark grey medium/fine sand with calcareous shell fragments. Trace woody debris present on surface. Patch of orange sediment (iron rich?). Anthropogenic object(?) and algae in background.

Notes:

* Debris percentage includes woody debris (planks and chips/dust) and man-made debris (plastics, metals, etc.).

Image ID	Station	Rep	Sediment Class	Flora and Fauna	Lebensspuren Present	Bedforms/ Ripples Present	Woody Debris Present[1]	Man Made Debris Present[2,3]	Beggiatoa Present	Shell Hash Present	Mudclasts Present	Feeding Burrows/ Mounds Present	Turbidity	Tube worms/ dwelling Count	Sea Anemone Count	Barnacles Count	Sea star Count	Shrimp Count	Crab Count	Others	Comments
DM01-A.PNG	1	A	sand	sea lettuce, tube worms, barnacles	no	yes	no	no	no	no	no	no	none	15	0	4	0	0	0	Algae (sea lettuce)	fine sand with physical sand ripples. Few species present.
DM01-B.PNG	1	B	sand and pebbles	sea lettuce, tube worms, barnacles	no	yes	no	no	no	no	no	no	low	7	0	30	0	0	0	Algae (sea lettuce)	fine sand and pebbles with physical sand ripples. Few species present.
DM01-C.PNG	1	C	sand and pebbles	sea lettuce, tube worms, barnacles	no	no	no	no	no	no	no	no	none	2	0	25	0	0	0	Algae (sea lettuce)	fine sand and pebbles. Few species present.
DM02-A.PNG	2	A	sand and pebbles	sea lettuce, tube worms, barnacles	yes	yes	no	no	no	no	yes	yes	none	18	0	20	0	0	0	Algae (sea lettuce)	fine sand and pebbles with physical sand ripples. Few species present.
DM02-B.PNG	2	B	sand and pebbles	sea lettuce, barnacles	yes	yes	no	no	no	no	yes	no	none	0	0	15	0	0	0	Algae (sea lettuce)	fine sand and pebbles with physical sand ripples. Few species present.
DM02-C.PNG	2	C	sand and pebbles	sea lettuce, barnacles	yes	no	no	no	no	no	no	no	none	0	0	32	0	0	0	Algae (sea lettuce)	fine sand and pebbles with physical sand ripples. Few species present.
DM03-A.PNG	3	A	sand and shells	sea lettuce, kelp, barnacles, tube worms	no	no	no	no	no	yes	no	no	none	14	0	10	0	0	0	Algae (sea lettuce, kelp)	sea lettuce mat, fine sand and shells. Few species present.
DM03-B.PNG	3	B	sand and pebbles	sea lettuce, eelgrass, barnacles	no	no	no	no	no	no	yes	no	low	0	0	100	0	0	0	Algae (sea lettuce, eelgrass)	fine sand with pebbles and shells. Few species present.
DM03-C.PNG	3	C	sand and pebbles	sea lettuce, barnacles	yes	no	no	no	no	no	yes	no	moderate	0	0	3	0	0	0	Algae (sea lettuce)	fine sand with pebbles and shells. Few species present. Sediment cloud.
DM04-A.PNG	4	A	silty sand	sea lettuce, kelp, barnacles, tube worms	no	no	yes	yes	no	no	yes	no	none	29	0	15	0	0	0	Algae (sea lettuce, kelp)	fine sand with woody debris. Few species present.
DM04-B.PNG	4	B	silty sand	sea lettuce	yes	no	yes	yes	no	no	no	no	low	0	0	0	0	0	0	Algae (sea lettuce)	fine sand with woody debris and trace shell fragments. Few species present, additional anthropogenic material.
DM04-C.PNG	4	C	silty sand	sea lettuce, brown algae, small shrimp (unknown sp.)	no	no	yes	yes	no	no	no	no	low	0	0	0	0	1	0	Algae (sea lettuce, Phaeophyceae)	fine sand with woody debris and trace shell fragments, crab carapace. Few species present.
DM05-A.PNG	5	A	sand	sea lettuce, red algae	no	no	yes	yes	no	no	yes	no	low	0	0	0	0	0	0	Algae (sea lettuce, Rhodophyta)	fine sand with woody debris. Few species present.
DM06-A.PNG	6	A	sand	sea lettuce, eelgrass, barnacles, small crab (*Metacarcinus gracilis*), Beggiatoa	yes	no	yes	yes	yes	no	no	no	none	0	0	10	0	0	1	Algae (sea lettuce, eelgrass)	fine sand with shell fragments and chunk of woody debris under frame. Beggiatoa mat visible. Few species present.
DM06-B.PNG	6	B	sand	sea lettuce, eelgrass, small crab (*M. gracilis*)	no	no	no	no	no	no	no	no	none	0	0	0	0	0	0	Algae (sea lettuce, eelgrass)	fine sand with shell fragments. Few species present.
DM06-C.PNG	6	C	sand	sea lettuce, eelgrass, Beggiatoa	no	no	no	no	yes	no	no	no	none	0	0	0	0	0	0	Algae (sea lettuce, eelgrass)	fine sand with shell fragments. Beggiatoa mats visible. Few species present.
DM06-D.PNG	6	D	sand	sea lettuce, kelp, Beggiatoa, barnacles	yes	no	no	no	yes	no	yes	yes	none	0	0	6	0	0	0	Algae (sea lettuce, kelp)	fine sand with shell fragments and hard rock structure, crab carapace. Beggiatoa mats visible. Few species present.
DM06-E.PNG	6	E	sand	sea lettuce, Beggiatoa	yes	yes	no	no	yes	no	yes	yes	none	0	0	0	0	0	0	Algae (sea lettuce)	fine sand with trace shell fragments and cluster of mudclasts(?) or fecal clasts(?). Beggiatoa mats visible. Few species present.
DM06-F.PNG	6	F	silty sand	sea lettuce, eelgrass, Beggiatoa	no	yes	no	no	yes	no	no	no	none	0	0	0	0	0	0	Algae (sea lettuce, eelgrass)	fine sand with small Beggiatoa mats, crab carapace. Few species present.
DM06-G.PNG	6	G	silty sand	sea lettuce, eelgrass, kelp, Beggiatoa, barnacles	yes	no	yes	yes	yes	no	no	no	none	0	0	100	0	0	0	Algae (sea lettuce, eelgrass, kelp)	fine sand with shell fragments and chunk of woody debris near frame. Beggiatoa mat visible. Few species present.
DM06-H.PNG	6	H	silty sand	sea lettuce, eelgrass, kelp, Beggiatoa	yes	yes	yes	yes	yes	no	no	no	none	0	0	0	0	0	0	Algae (sea lettuce, eelgrass, kelp)	fine sand with chunks of woody debris and trace shell fragments. Beggiatoa mats visible. Few species present.
DM06-I.PNG	6	I	silty sand	sea lettuce, eelgrass, kelp, Beggiatoa, barnacles	yes	no	no	no	yes	no	no	no	none	0	0	75	0	0	0	Algae (sea lettuce, eelgrass, kelp)	fine sand with trace shell fragments. Beggiatoa mats visible. Few species present.
DM07-A.PNG	7	A	sand	sea lettuce, eelgrass, kelp	no	no	yes	yes	no	no	no	no	none	0	0	0	0	0	0	Algae (sea lettuce, eelgrass, kelp)	fine sand with woody debris and trace shell fragments. Few species present.
DM07-C.PNG	7	C	silty sand	sea lettuce, eelgrass, barnacles	no	no	yes	yes	no	no	no	no	moderate	0	0	1	0	0	0	Algae (sea lettuce, eelgrass)	fine sand with woody debris and trace shell fragments. Few species present.
DM08-A.PNG	8	A	sand	sea lettuce, eelgrass, Beggiatoa	no	no	yes	yes	yes	no	no	no	none	0	0	0	0	0	0	Algae (sea lettuce, eelgrass)	fine sand with small patch of Beggiatoa, shell fragments, and woody debris. Few species present.
DM08-B.PNG	8	B	sand	sea lettuce, eelgrass	no	no	yes	yes	no	no	no	no	none	0	0	0	0	0	0	Algae (sea lettuce, eelgrass)	fine sand with shell fragments and woody debris. Few species present.

Image ID	Station	Rep	Sediment Class	Flora and Fauna	Lebensspuren Present	Bedforms/ Ripples Present	Woody Debris Present[1]	Man Made Debris Present[2,3]	Beggiatoa Present	Shell Hash Present	Mudclasts Present	Feeding Burrows/ Mounds Present	Turbidity	Tube worms/ dwelling Count	Sea Anemone Count	Barnacles Count	Sea star Count	Shrimp Count	Crab Count	Others	Comments
DM08-C.PNG	8	C	sand and shell hash	sea lettuce, small crabs (*M. gracilis*)	no	no	yes	yes	no	yes	no	no	moderate	0	0	0	0	0	2	Algae (sea lettuce)	fine sand with shell fragments and woody debris. Few species present.
DM09-A.PNG	9	A	sand	sea lettuce, eelgrass	no	no	no	no	no	no	no	no	none	0	0	0	0	0	0	Algae (sea lettuce, eelgrass)	sand with sea lettuce mat and trace shell fragments. Few species present
DM09-B.PNG	9	B	sand	sea lettuce, terrestrial leaves	no	no	no	no	no	no	no	no	none	0	0	0	0	0	0	Algae (sea lettuce)	sand with sea lettuce mat. Few species present
DM09-C.PNG	9	C	sand	sea lettuce, crab (*M. gracilis*), barnacles	no	no	no	yes	no	no	no	no	none	0	0	26	0	0	1	Algae (sea lettuce)	fine sand with shell fragments and hard rock structures, anthropogenic plastic spoon. Few species visible
DM09-D.PNG	9	D	na	sea lettuce, terrestrial leaves, driftwood	no	no	yes	no	no	no	no	no	none	0	0	0	0	0	0	Algae (sea lettuce)	sediment surface masked by sea lettuce mat.
DM09-E.PNG	9	E	sand	sea lettuce	no	no	no	no	no	no	no	no	none	0	0	0	0	0	0	Algae (sea lettuce)	sand with shell fragments, majority of sediment surface masked by sea lettuce mat.
DM09-F.PNG	9	F	sand	sea lettuce, terrestrial leaves, barnacles	no	no	no	no	no	no	no	no	none	0	0	0	0	0	0	Algae (sea lettuce)	sand with shell fragments, majority of sediment surface masked by sea lettuce mat. Piling visible in background covered in barnacles.
DM10-A.PNG	10	A	silty sand	sea lettuce, eelgrass, kelp, Rhodophyta, kelp crab, barnacles	no	no	yes	yes	no	no	no	no	none	0	0	36	0	0	1	Algae (sea lettuce, eelgrass, kelp, Rhodophyta)	silty sand with shells, woody debris, and hard rock structures. Few species present.
DM10-B.PNG	10	B	silty sand	eelgrass	na	na	na	na	na	na	na	na	high	0	0	0	0	0	0	Algae (sea lettuce, eelgrass)	sediment surface masked by turbidity and sea lettuce
DM10-C.PNG	10	C	silty sand	sea lettuce, eelgrass, potential crabs, terrestrial leaves	no	no	yes	yes	no	no	no	no	none	0	0	0	0	0	3	Algae (sea lettuce, eelgrass)	silty sand with trace pebbles and woody debris. Few species present.
DM11-A.PNG	11	A	silty sand and shell hash	sea lettuce, crab (*M. gracilis*), Beggiatoa	no	no	yes	yes	yes	yes	no	no	none	0	0	0	0	0	2	Algae (sea lettuce)	shell hash and woody debris. Small patch of Beggiatoa. Few species present.
DM11-B.PNG	11	B	silty sand and shell hash	sea lettuce	no	no	yes	yes	no	yes	no	no	moderate	0	0	0	0	0	0	Algae (sea lettuce)	out of focus, masking surface. shell hash and woody debris. Few species present.
DM11-C.PNG	11	C	silty sand and shell hash	sea lettuce, crab (*M. gracilis*)	no	no	yes	yes	no	yes	no	no	moderate	0	0	0	0	0	2	Algae (sea lettuce)	turbidity masking surface. shell hash and woody debris. Few species present.
DM12-A.PNG	12	A	silt	none	no	no	yes	yes	no	no	no	no	none	0	0	0	0	0	0		silt with woody debris.
DM12-C.PNG	12	C	silt	none	no	no	yes	yes	no	no	no	no	none	0	0	0	0	0	0		silt with woody debris.
DM13-A.PNG	13	A	silt and shells	sea lettuce, Rhodophyta, barnacles	yes	yes	no	no	no	no	no	no	none	0	0	25	0	0	0	Algae (sea lettuce, Rhodophyta)	silt and shell hash with physical sand ripples. Few species present.
DM13-B.PNG	13	B	silt and shells	sea lettuce, Rhodophyta, barnacles	no	yes	no	no	no	no	no	no	none	0	0	10	0	0	0	Algae (sea lettuce, Rhodophyta)	silt and shell hash with physical sand ripples. Few species present.
DM13-C.PNG	13	C	silty sand and shell hash	sea lettuce, Rhodophyta	no	yes	no	no	no	yes	no	no	none	0	0	0	0	0	0	Algae (sea lettuce, Rhodophyta)	silt and shell hash with physical sand ripples, piling visible. Few species present.
DM14-A.PNG	14	A	silt and shell hash	sea lettuce	no	no	yes	yes	no	yes	no	no	none	0	0	0	0	0	0	Algae (sea lettuce)	silt and shell hash. Potentially woody debris, could just be shells. Few species present.
DM14-C.PNG	14	C	shell hash	sea lettuce, Rhodophyta	no	no	no	no	no	yes	no	no	moderate	0	0	0	0	0	0	Algae (sea lettuce, Rhodophyta)	shell hash, turbidity masking half of surface. Few species visible.
DM15-A.PNG	15	A	shell hash	sea lettuce, Rhodophyta	no	no	no	no	no	yes	no	no	none	0	0	0	0	0	0	Algae (sea lettuce, Rhodophyta)	shell hash with clusters of algae visible.
DM15-B.PNG	15	B	shell hash	sea lettuce, crabs (*Cancer productus*)	no	no	no	no	no	yes	no	no	none	0	0	0	0	0	2	Algae (sea lettuce)	shell hash with clusters of algae visible. Multiple crabs visible.
DM15-C.PNG	15	C	shell hash	none	yes	no	no	no	no	yes	no	no	moderate	0	0	0	0	0	0		shell hash
DM16-A.PNG	16	A	sand	sea lettuce, kelp, barnacles, tube worms	yes	no	no	no	no	no	no	yes	none	125	0	1000	0	0	0	Algae (sea lettuce, kelp)	silty sand with algal mat, crab carapace on surface. Piling visible in background covered in barnacles. Few species present.
DM16-B.PNG	16	B	sand	sea lettuce, barnacles, tube worms	yes	yes	no	no	no	no	no	yes	none	150	0	500	0	0	0	Algae (sea lettuce)	silty sand with surface ripples and feeding burrows. Piling visible in background covered in barnacles. Few species present.

Image ID	Station	Rep	Sediment Class	Flora and Fauna	Lebensspuren Present	Bedforms/ Ripples Present	Woody Debris Present[1]	Man Made Debris Present[2,3]	Beggiatoa Present	Shell Hash Present	Mudclasts Present	Feeding Burrows/ Mounds Present	Turbidity	Tube worms/ dwelling Count	Sea Anemone Count	Barnacles Count	Sea star Count	Shrimp Count	Crab Count	Others	Comments
DM16-C.PNG	16	C	sand	sea lettuce, crab (*C. productus*), tube worms	yes	yes	no	no	no	no	no	yes	none	75	0	0	0	0	1	Algae (sea lettuce)	silty sand with surface ripples and feeding burrows. Piling visible in background. Few species present.
DM17-A.PNG	17	A	shell hash	sea lettuce, barnacles, Phaeophyceae	no	no	yes	yes	yes	yes	no	no	none	0	0	100	0	0	0	Algae (sea lettuce, Phaeophyceae)	shell hash with woody debris. Piling visible in background. Few species present.
DM17-B.PNG	17	B	silt and shell hash	sea lettuce, barnacles, kelp, Rhodophyta	no	no	yes	yes	no	yes	no	no	low	0	0	0	0	0	0	Algae (sea lettuce, kelp, Rhodophyta)	shell hash with woody debris. Few species present.
DM17-C.PNG	17	C	silt and shell hash	sea lettuce, crab (*C. productus*), barnacles, kelp, Rhodophyta	yes	no	yes	yes	no	yes	no	no	none	0	0	100	0	0	1	Algae (sea lettuce, kelp, Rhodophyta)	shell hash with woody debris and piece of driftwood. Piling visible in background. Few species present.
DM18-A.PNG	18	A	sand	sea lettuce, barnacles, Rhodophyta	yes	yes	no	no	no	no	no	yes	none	0	0	250	0	0	0	Algae (sea lettuce, Rhodophyta)	sand with physical sand ripples, fecal clasts. Piling visible in background. Few species present.
DM18-B.PNG	18	B	sand	sea lettuce, barnacles, Rhodophyta	yes	yes	no	no	no	no	no	yes	none	0	0	100	0	0	0	Algae (sea lettuce, Rhodophyta)	sand with physical sand ripples. Piling shadow visible in background. Few species present.
DM18-C.PNG	18	C	silty sand	sea lettuce, barnacles, Rhodophyta, juvenile sea anemone (*Metridium* sp.)	no	yes	no	no	no	no	yes	no	none	0	3	75	0	0	0	Algae (sea lettuce, Rhodophyta)	silty sand with physical sand ripples. Piling visible in background. Few species present.
DM19-A.PNG	19	A	sandy silt	sea anemones, sea star, barnacles, kelp, tube worms	no	no	yes	yes	no	yes	yes	yes	none	25	7	160	1	0	0	Algae (sea lettuce, kelp)	sandy silt with shell hash and trace woody debris. Fallen piling with sea anemones, barnacles, and sea star visible.
DM19-B.PNG	19	B	sandy silt	na	na	na	na	na	na	no	yes	na	high	0	0	0	0	0	0		majority of surface masked/out of focus.
DM20-A.PNG	20	A	sand	sea lettuce, Rhodophyta, kelp, barnacles, tube worms, Beggiatoa	yes	yes	no	no	yes	no	yes	yes	none	50	0	50	0	0	0	Algae (sea lettuce, kelp, Rhodophyta)	sand with physical sand ripples. Piling shadow visible in background. Few species present.
DM20-B.PNG	20	B	sand	sea lettuce, Rhodophyta, kelp, barnacles, tube worms	yes	yes	no	no	no	no	no	yes	low	20	0	15	0	0	0	Algae (sea lettuce, kelp, Rhodophyta)	sand with physical sand ripples. Piling shadow visible in background. Few species present.
DM20-C.PNG	20	C	sand	sea lettuce, Rhodophyta, kelp, barnacles, tube worms	yes	yes	no	no	no	no	no	yes	low	35	0	75	0	0	0	Algae (sea lettuce, kelp, Rhodophyta)	sand with physical sand ripples. Fallen piling visible in background. Few species present.
DM21-A.PNG	21	A	sand	sea lettuce, Rhodophyta mat, crab (*M. gracilis*)	yes	no	no	no	no	no	no	yes	none	0	0	0	0	0	2	Algae (sea lettuce, Rhodophyta)	sand with shell fragments and algal mat. Few species present.
DM21-B.PNG	21	B	sand	sea lettuce, Rhodophyta mat, barnacles	yes	no	no	no	no	no	yes	yes	none	0	0	100	0	0	0	Algae (sea lettuce, Rhodophyta)	sand with shell fragments and algal mat. Piling visible in background. Few species present.
DM21-C.PNG	21	C	silty sand	sea lettuce, eelgrass, Rhodophyta, barnacles, potential juvenile sea anemone (*Metridium* sp.)	yes	yes	no	no	no	no	no	yes	none	0	61	150	0	0	0	Algae (sea lettuce, eelgrass, Rhodophyta)	sand with shell fragments and algal mat. Piling visible in background. Few species present.
DM22-A.PNG	22	A	silty sand	sea lettuce, Rhodophyta mat, tube worms, crab (*M. gracilis*)	yes	yes	no	no	no	no	yes	yes	none	250	0	0	0	0	1	Algae (sea lettuce, Rhodophyta)	sand with physical sand ripples, shell fragments, and algal mat. Few species present.
DM22-B.PNG	22	B	sand	sea lettuce, tube worms	yes	yes	no	no	no	no	no	yes	none	125	0	0	0	0	0	Algae (sea lettuce)	sand with physical sand ripples and algal mat. Few species present.
DM22-C.PNG	22	C	sand	sea lettuce, kelp, Rhodophyta, tube worms, crab (*C. productus*)	yes	yes	no	no	no	no	no	yes	none	150	0	0	0	0	2	Algae (sea lettuce, kelp, Rhodophyta)	sand with physical sand ripples. Few species present.
DM23-A.PNG	23	A	sand	sea lettuce, eelgrass, anemone (*Metridium farcimen*), Beggiatoa, tube worms	yes	no	no	no	yes	no	no	yes	none	200	1	0	0	0	0	Algae (sea lettuce, eelgrass, Rhodophyta)	sand with shell fragments and algal mat. Few species present.
DM23-B.PNG	23	B	sand	sea lettuce, eelgrass	no	no	no	no	no	no	no	no	low	0	0	0	0	0	0	Algae (sea lettuce, eelgrass)	sand with shell fragments, small turbidity cloud. Few species present.
DM23-C.PNG	23	C	sand	eelgrass, Beggiatoa	na	na	na	na	yes	na	na	na	high	0	0	0	0	0	0	Algae (eelgrass)	majority of surface masked from turbidity. Eelgrass and Beggiatoa visible.
DM23-C1.PNG	23	C1	sand	eelgrass, Beggiatoa	na	na	na	na	yes	na	na	na	high	0	0	0	0	0	0	Algae (eelgrass)	majority of surface masked from turbidity. Eelgrass and Beggiatoa visible.

Image ID	Station	Rep	Sediment Class	Flora and Fauna	Lebensspuren Present	Bedforms/ Ripples Present	Woody Debris Present[1]	Man Made Debris Present[2,3]	Beggiatoa Present	Shell Hash Present	Mudclasts Present	Feeding Burrows/ Mounds Present	Turbidity	Tube worms/ dwelling Count	Sea Anemone Count	Barnacles Count	Sea star Count	Shrimp Count	Crab Count	Others	Comments
DM24-A.PNG	24	A	sand	sea lettuce, Rhodophyta, crab (*C. productus*)	no	no	no	no	no	no	no	yes	none	0	0	0	0	0	1	Algae (sea lettuce, Rhodophyta)	sand with shell fragments, small trench in top right corner. Few species visible.
DM24-C.PNG	24	C	shell hash	sea lettuce	no	no	yes	yes	no	yes	no	no	moderate	0	0	0	0	0	0	Algae (sea lettuce)	tip over. Shell hash potentially with woody debris.
DM25-A.PNG	25	A	sand	eelgrass, kelp crab	no	no	no	no	no	no	no	no	none	0	0	0	0	0	2	Algae (eelgrass)	sand with eelgrass bed and trace bivalve shells. Few species present
DM25-B.PNG	25	B	sand	eelgrass, kelp crab	no	no	no	no	no	no	no	no	low	0	0	0	0	0	2	Algae (eelgrass)	sand with eelgrass bed and trace bivalve shells. Few species present
DM25-C.PNG	25	C	sand	eelgrass, kelp	na	na	na	na	na	na	na	na	high	0	0	0	0	0	0	Algae (eelgrass, kelp)	majority of surface masked from turbidity. Eelgrass and kelp visible.
DM26-A1.PNG	26	A1	silty sand and shell hash	sea lettuce, kelp, barnacles	no	no	yes	yes	no	yes	no	no	none	0	0	75	0	0	0	Algae (sea lettuce, kelp)	silty sand and shell hash with woody debris. Large kelp visible on surface.
DM26-B.PNG	26	B	shell hash	sea anemone (*M. farcimen*), kelp, barnacles	no	no	yes	yes	no	yes	no	no	low	0	3	25	0	0	0	Algae (kelp)	shell hash with large woody debris, turbidity cloud in upper lefthand corner. Few species visible.
DM26-C.PNG	26	C	silty sand and shell hash	kelp, barnacles	no	no	yes	yes	no	yes	no	no	none	0	0	10	0	0	0	Algae (kelp)	majority of surface masked by kelp and other organic material. Few species present.
DM27-A.PNG	27	A	sandy silt	eelgrass, kelp	no	no	yes	yes	no	no	no	no	none	0	0	0	0	0	0	Algae (eelgrass, kelp)	sandy silt with fine woody debris and other organic material. Large kelp blade visible.
DM27-C.PNG	27	C	sandy silt	sea lettuce, kelp	no	no	yes	yes	no	no	no	no	none	0	0	0	0	0	0	Algae (sea lettuce, kelp)	sandy silt with fine woody debris and other organic material. Large kelp blade visible.
DM27-D.PNG	27	D	sandy silt	eelgrass, kelp, barnacles	no	no	yes	yes	no	no	yes	no	none	0	0	25	0	0	0	Algae (eelgrass, kelp)	sandy silt with fine woody debris and other organic material. Large kelp blade visible.
DM27-E.PNG	27	E	sandy silt	sea lettuce, eelgrass, kelp	no	no	yes	yes	no	no	yes	no	none	0	0	10	0	0	0	Algae (sea lettuce, eelgrass, kelp)	sandy silt with fine woody debris and other organic material.
DM28-A.PNG	28	A	silt	sea lettuce, sea anemone (*M. farcimen*), barnacles	no	no	yes	yes	no	no	yes	no	none	0	1	20	0	0	0	Algae (sea lettuce)	silt with woody debris. Few species present.
DM28-B.PNG	28	B	silt	sea lettuce, barnacles	no	no	yes	yes	no	no	yes	no	none	0	0	30	0	0	0	Algae (sea lettuce)	silt with woody debris. Few species present.
DM28-C.PNG	28	C	na	na	na	na	na	na	na	na	na	na	high	0	0	0	0	0	0		surface masked by turbidity cloud
DM29-A.PNG	29	A	silt	sea anemone (*M. farcimen*)	no	no	yes	yes	no	no	yes	no	none	0	1	0	0	0	0		camera sitting on fallen pile. Barren surface
DM29-A1.PNG	29	A1	silt	sea anemones (*Metridium* sp.), sea star (*Pisaster ochraceus*), barnacles	na	na	yes	yes	na	na	na	na	moderate	0	7	30	1	0	0		water shot; sediment surface not visible. Biota visible on fallen piling.
DM29-B.PNG	29	B	silt	sea lettuce	no	no	yes	yes	no	no	yes	no	none	0	1	0	0	0	0	Algae (sea lettuce)	camera sitting on fallen pile. Barren surface
DM29-C.PNG	29	C	silt	sea anemones (*Metridium* sp.), sea star (*P. ochraceus*), barnacles	no	no	yes	yes	no	no	yes	no	moderate	0	4	100	1	0	0		camera sitting on fallen pile. Biota visible on fallen piling.
DM29-D.PNG	29	D	silt	barnacles	no	no	yes	yes	no	no	yes	no	none	0	0	15	0	0	0		camera sitting on fallen pile. Barren surface
DM29-E.PNG	29	E	silt	none	no	no	yes	yes	no	no	no	no	moderate	0	0	5	0	0	0		silt with woody debris, turbidity cloud masking part of surface. Barren surface.
DM30-A.PNG	30	A	na	sea lettuce, Rhodophyta, terrestrial leaves	na	na	yes	yes	na	na	na	na	none	0	0	0	0	0	0	Algae (sea lettuce, Rhodophyta)	sediment surface masked by sea lettuce mat. Woody debris visible.
DM30-B.PNG	30	B	na	sea lettuce, Rhodophyta, kelp, terrestrial leaves	na	na	yes	yes	na	na	na	na	none	0	0	0	0	0	0	Algae (sea lettuce, Rhodophyta, kelp)	sediment surface masked by sea lettuce mat. Woody debris visible.
DM30-C.PNG	30	C	na	sea lettuce, Phaeophyceae, terrestrial leaves	na	na	yes	yes	na	na	na	na	none	0	0	0	0	0	0	Algae (sea lettuce, Phaeophyceae)	sediment surface masked by sea lettuce mat. Woody debris visible.
DM30-D.PNG	30	D	na	sea lettuce, terrestrial leaves	na	na	yes	yes	na	na	na	na	high	0	0	0	0	0	0	Algae (sea lettuce, Phaeophyceae)	sediment surface masked by turbidity cloud and sea lettuce mat. Potential woody debris.
DM30-E.PNG	30	E	na	sea lettuce, Phaeophyceae, terrestrial leaves	na	na	yes	yes	na	na	na	na	moderate	0	0	0	0	0	0	Algae (sea lettuce, Phaeophyceae)	sediment surface masked by turbidity cloud and sea lettuce mat. Potential woody debris.
DM31-A.PNG	31	A	sandy silt	sea lettuce, Beggiatoa	no	no	yes	yes	yes	no	no	yes	none	0	0	0	0	0	0	Algae (sea lettuce)	sediment surface covered in fine woody debris and shell fragments. Few species present.
DM31-C.PNG	31	C	silt	sea lettuce, Rhodophyta	na	na	yes	yes	na	na	na	na	high	0	0	0	0	0	0	Algae (sea lettuce)	majority of sediment surface masked by turbidity cloud. Woody debris likely and shell fragments visible.

Image ID	Station	Rep	Sediment Class	Flora and Fauna	Lebensspuren Present	Bedforms/ Ripples Present	Woody Debris Present[1]	Man Made Debris Present[2,3]	Beggiatoa Present	Shell Hash Present	Mudclasts Present	Feeding Burrows/ Mounds Present	Turbidity	Tube worms/ dwelling Count	Sea Anemone Count	Barnacles Count	Sea star Count	Shrimp Count	Crab Count	Others	Comments
DM32-A.PNG	32	A	sand	sea lettuce, barnacles, potential juvenile sea anemone (*Metridium* sp.), Rhodophyta mat	yes	yes	yes	yes	no	no	yes	yes	none	0	9	500	0	0	0	Algae (sea lettuce, Rhodophyta)	sand with physical sand ripples and algal mat. Piling in background covered with barnacles, chunk of wood at base of piling. Few species present.
DM32-B.PNG	32	B	sand	sea lettuce, barnacles, potential juvenile sea anemone (*Metridium* sp.), crab (*C. productus*)	yes	yes	no	no	no	no	yes	yes	none	0	9	750	0	0	1	Algae (sea lettuce)	sand with physical sand ripples and algal mat. Piling in background covered with barnacles. Footprint of previous drop visible. Few species present.
DM32-C.PNG	32	C	sand	sea lettuce, terrestrial leaves	yes	yes	no	no	no	no	yes	yes	none	0	0	0	0	0	0	Algae (sea lettuce)	sand with physical sand ripples. Few species present.
DM33-A.PNG	33	A	silty sand	sea lettuce, Beggiatoa, crab (*C. productus*?)	yes	yes	no	no	yes	no	yes	yes	none	0	0	0	0	0	1	Algae (sea lettuce)	sand with shell fragments and physical sand ripples. Surface algal mat. Few species present.
DM33-B.PNG	33	B	silty sand	sea lettuce, kelp, Rhodophyta, barnacles, Beggiatoa, potential juvenile sea anemone (*Metridium* sp.)	yes	yes	yes	no	yes	no	yes	yes	none	0	0	750	0	0	0	Algae (sea lettuce, Rhodophyta, kelp)	sand with shell fragments and physical sand ripples. Surface algal mat. Piling visible in background, driftwood present. Few species present.
DM33-C.PNG	33	C	silty sand	sea lettuce, kelp, Rhodophyta, crab (*C. productus*)	yes	yes	no	no	no	no	yes	yes	none	0	0	0	0	0	1	Algae (sea lettuce, Rhodophyta, kelp)	sand with shell fragments and physical sand ripples. Surface algal mat. Few species present.
DM34-A.PNG	34	A	silty sand	sea lettuce, Rhodophyta	yes	yes	no	no	yes	no	yes	yes	none	0	0	0	0	0	0	Algae (sea lettuce, Rhodophyta)	sand with faint physical sand ripples. Surface algal mat, crab carapace. Few species present.
DM34-B.PNG	34	B	silty sand	sea lettuce, Rhodophyta, sea star (unknown sp.)	yes	yes	no	no	yes	no	yes	yes	none	0	0	0	1	0	0	Algae (sea lettuce, Rhodophyta)	sand with faint physical sand ripples. Surface algal mat and piling visible in background. Few species present.
DM34-C.PNG	34	C	silty sand	sea lettuce, Rhodophyta, crab (unknown sp.)	yes	yes	no	no	yes	no	yes	yes	none	0	0	0	0	0	1	Algae (sea lettuce, Rhodophyta)	sand with faint physical sand ripples. Surface algal mat and piling visible in background. Few species present.
DM35-A.PNG	35	A	shell hash	sea lettuce, Rhodophyta, kelp, terrestrial leaves	no	no	yes	yes	no	yes	no	yes	none	0	0	0	0	0	0	Algae (sea lettuce, Rhodophyta, kelp)	shell hash with potential woody debris. Few species visible.
DM35-B.PNG	35	B	shell hash	sea lettuce, Rhodophyta, kelp, terrestrial leaves	no	no	yes	yes	no	yes	no	yes	none	0	0	0	0	0	0	Algae (sea lettuce, Rhodophyta, kelp)	shell hash with potential woody debris. Few species visible.
DM35-C.PNG	35	C	shell hash	sea lettuce, Rhodophyta	no	no	yes	yes	no	yes	no	yes	none	0	0	0	0	0	0	Algae (sea lettuce, Rhodophyta, kelp)	shell hash with potential woody debris. Few species visible.
DM36-A1.PNG	36	A1	shell hash	sea lettuce, Rhodophyta, barnacles	no	no	yes	yes	no	yes	no	yes	none	0	0	50	0	0	0	Algae (sea lettuce, Rhodophyta)	shell hash with fallen piling visible. Few species visible.
DM36-A2.PNG	36	A2	shell hash	sea lettuce, Rhodophyta, barnacles, sea stars (*P. ochraceus*, unknown sp.)	no	no	yes	yes	no	yes	no	no	low	0	0	300	2	0	0	Algae (sea lettuce, Rhodophyta)	shell hash with [fallen] piling(s) visible. Few species visible.
DM36-B.PNG	36	B	shell hash	sea lettuce, Rhodophyta, barnacles, Beggiatoa	no	no	yes	yes	yes	yes	no	no	none	0	0	400	0	0	0	Algae (sea lettuce, Rhodophyta)	shell hash with woody debris. Bacterial (Beggiatoa) growth present at base of piling. Few species present.
DM36-C.PNG	36	C	shell hash	sea lettuce, kelp, Rhodophyta, barnacles, sea stars (*P. ochraceus*, unknown sp.)	no	no	yes	yes	no	yes	no	no	moderate	0	0	1000	2	0	0	Algae (sea lettuce, kelp, Rhodophyta)	shell hash with multiple [fallen] pilings visible. Few species present.
DM37-B.PNG	37	B	shell hash	sea lettuce, Rhodophyta	no	no	yes	yes	no	yes	no	no	low	0	0	0	0	0	0	Algae (sea lettuce, Rhodophyta)	shell hash with potential woody debris. Few species visible.
DM37-C.PNG	37	C	shell hash	sea lettuce, Rhodophyta	no	no	yes	yes	no	yes	no	no	moderate	0	0	0	0	0	0	Algae (sea lettuce, Rhodophyta)	shell hash with potential woody debris. Footprint from previous drop visible. Turbidity cloud masking half of surface. Few species visible.
DM37-D.PNG	37	D	shell hash	sea lettuce, Rhodophyta	no	no	yes	yes	no	yes	no	no	low	0	0	0	0	0	0	Algae (sea lettuce, Rhodophyta)	shell hash with potential woody debris. Few species visible.
DM38-A.PNG	38	A	silty shell hash	sea lettuce, Rhodophyta, barnacles, Beggiatoa, crab (*C. productus*)	no	no	yes	yes	yes	yes	no	no	none	0	0	350	0	0	1	Algae (sea lettuce, Rhodophyta)	shell hash with woody debris. Bacterial (Beggiatoa) growth present at base of piling. Few species present.
DM38-B.PNG	38	B	silty shell hash	sea lettuce, Rhodophyta, barnacles	no	no	yes	yes	no	yes	no	no	none	0	0	0	0	0	0	Algae (sea lettuce, Rhodophyta)	shell hash with woody debris, large chunk visible in background. Few species visible.
DM38-C.PNG	38	C	silty shell hash	sea lettuce, Rhodophyta, crab (*C. productus*), potential eelgrass?	no	no	yes	yes	no	yes	no	no	none	0	0	0	0	0	2	Algae (sea lettuce, Rhodophyta, eelgrass?)	shell hash with woody debris. Few species present.

Image ID	Station	Rep	Sediment Class	Flora and Fauna	Lebensspuren Present	Bedforms/ Ripples Present	Woody Debris Present[1]	Man Made Debris Present[2,3]	Beggiatoa Present	Shell Hash Present	Mudclasts Present	Feeding Burrows/ Mounds Present	Turbidity	Tube worms/ dwelling Count	Sea Anemone Count	Barnacles Count	Sea star Count	Shrimp Count	Crab Count	Others	Comments
DM39-A.PNG	39	A	silty shell hash	sea lettuce, Rhodophyta, eelgrass	no	no	yes	yes	no	yes	no	no	none	0	0	0	0	0	0	Algae (sea lettuce, Rhodophyta, eelgrass)	shell hash with woody debris. Piling visible in background. Few species present.
DM39-B.PNG	39	B	silty shell hash	sea lettuce, sea anemone (*M. farcimen*)	no	no	yes	yes	no	yes	no	no	moderate	0	1	0	0	0	0	Algae (sea lettuce)	shell hash with woody debris. Turbidity cloud masking part of profile. Piling visible in background. Few species present.
DM39-C.PNG	39	C	shell hash	sea lettuce, Rhodophyta, kelp, terrestrial leaves	no	no	yes	yes	no	yes	no	no	none	0	0	0	0	0	0	Algae (sea lettuce, Rhodophyta, kelp)	shell hash with woody debris. Piling visible in background. Few species present.
DM40-A.PNG	40	A	silty shell hash	sea lettuce, Rhodophyta	yes	no	yes	yes	no	yes	no	no	none	0	0	0	0	0	0	Algae (sea lettuce, Rhodophyta)	shell hash with woody debris. Small plastic object visible. Few species present.
DM40-B.PNG	40	B	silty shell hash	sea lettuce, Rhodophyta, terrestrial leaves	no	no	yes	yes	no	yes	no	no	none	0	0	0	0	0	0	Algae (sea lettuce, Rhodophyta)	shell hash with woody debris. Piling in background visible. Few species present.
DM40-C.PNG	40	C	silty shell hash	sea lettuce, Rhodophyta, terrestrial leaves	yes	no	yes	yes	no	yes	no	no	low	0	0	0	0	0	0	Algae (sea lettuce, Rhodophyta)	shell hash with woody debris. Turbidity cloud masking part of profile. Few species present.
DM41-A.PNG	41	A	sand	sea lettuce, kelp, Rhodophyta mat	no	no	no	no	no	no	no	no	none	0	0	0	0	0	0	Algae (sea lettuce, Rhodophyta, kelp)	sand with shell fragments and algal mats. Piling visible in background. Few species present.
DM41-B.PNG	41	B	sand	sea lettuce, kelp, Rhodophyta mat, sea anemone (*M. farcimen*)	yes	no	no	no	no	no	no	no	none	0	1	0	0	0	0	Algae (sea lettuce, Rhodophyta, kelp)	sand with shell fragments and algal mats. Piling visible in background. Few species present.
DM41-C.PNG	41	C	sand	sea lettuce, Rhodophyta mat, sea anemone (*M. farcimen*), crab (*M. gracilis*)	no	no	no	no	no	no	no	no	none	0	1	0	0	0	2	Algae (sea lettuce, Rhodophyta)	sand with shell fragments and algal mats. Cluster of dark sediment on surface. Few species present.

Notes:

1. Woody debris = planks, chips/dust, fallen pilings, driftwood
2. Man-made debris = plastics, woody debris from the mill
3. ‘Intact’ vertical structural pilings noted in comments but not classified as woody or man-made debris.

APPENDIX C

Field Forms and Photos

(Electronic Copy Only)

APPENDIX D

Laboratory Data Reports

(Electronic Copy Only)

APPENDIX E

Data Validation Reports

(Electronic Copy Only)

APPENDIX F

EIM Data Files

(Electronic Copy Only)

APPENDIX G

EcoAnalysts Bioassay Testing Report

(Electronic Copy Only)

APPENDIX H

Dickman Mill Geomorphic Assessment

(Electronic Copy Only)

Dickman Mill Geomorphic Assessment

Tacoma, Washington

Prepared for
NewFields

Prepared by
Herrera Environmental Consultants, Inc.

HERRERA
Science + Planning + Design

Dickman Mill Geomorphic Assessment
Tacoma, Washington

Prepared for
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June 5, 2023

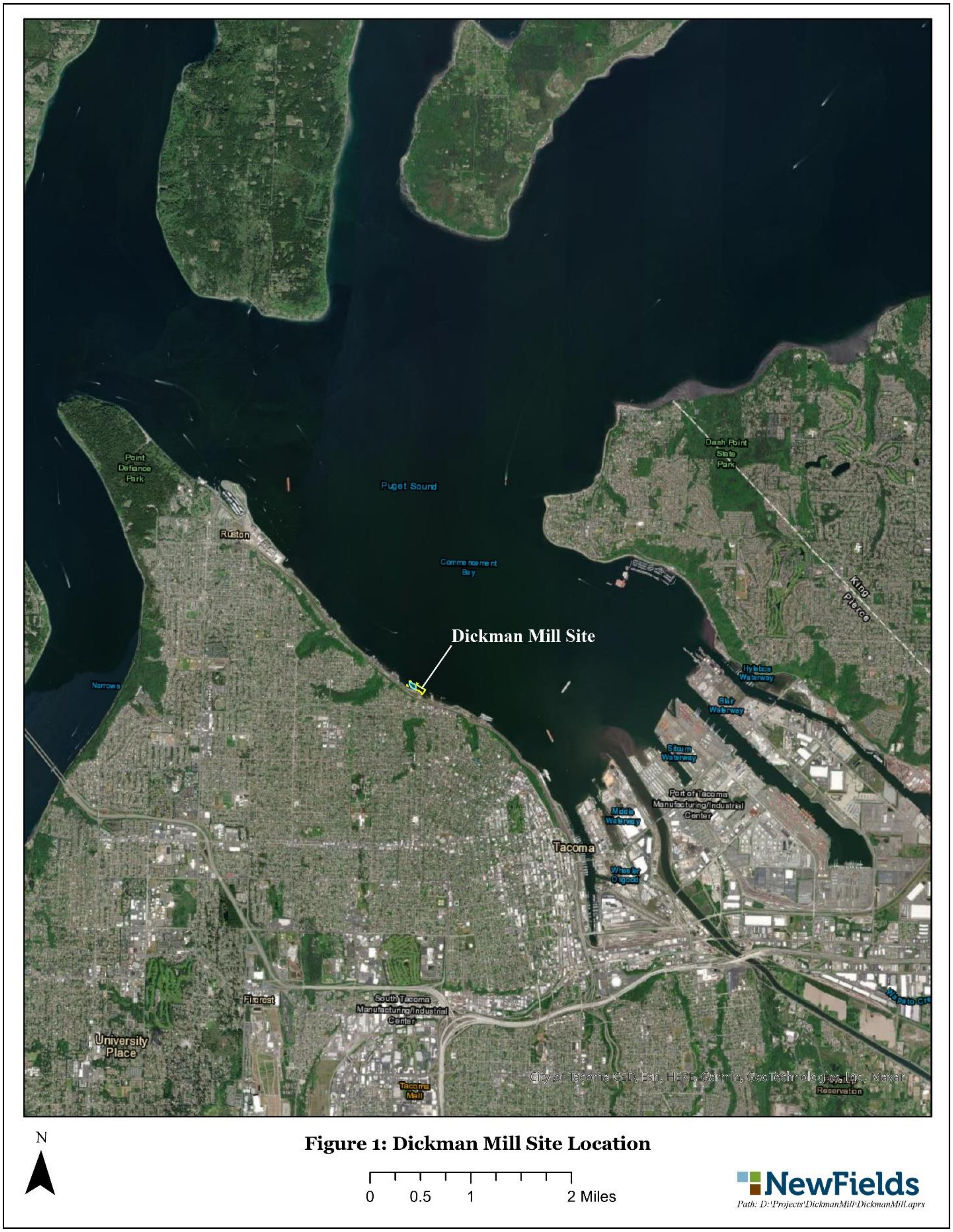
Contents

Introduction

Dickman Mill is located along Ruston Way in Tacoma, Washington, on Commencement Bay in Puget Sound. It is currently a park within the City of Tacoma, Washington. The original mill operated from 1889 to 1977 and was located on a large wharf built over the water. The mill site (the site) was decommissioned in 2000. As part of the decommissioning of the mill and conversion to a city park, contaminated intertidal sediments were capped with a 1-foot-thick layer of gravel to lower elevation boundary of approximately 0 feet mean lower low water (MLLW) (Hart Crowser 2000). There is interest in removing the remaining creosote-treated pile field in the near-subtidal part of the park, as it is an ongoing source of contamination. Prior to removing the pile field, NewFields requested a qualitative geomorphic assessment be performed to assess the risk of endangering the sediment cap (the cap) that was placed in 2000 to isolate underlying contaminated sediments.

Earlier work included hydrodynamic modeling of the site with an emphasis on the mobility of the sediments within the pile field itself and the impacts to adjacent properties. It also included a beach profile analysis. This report has a slightly different emphasis and approach. In this report, the mobility of the intertidal cap is examined in detail and how it may be affected by removal of the piles, using direct observations of past geomorphic activity in intertidal areas.

Figure 1. Vicinity Map for Dickman Mill Park, Tacoma Washington.



Methods

There were two components of the assessment. The first component was an analysis of existing modeling and documentation of the wave conditions at the site. The principal modeling resource analyzed were two studies performed of this site by Mott Macdonald (2020, 2021) that focused on effects of strong northerly onshore winds. Finlayson (2006) has documented that the dominant wind forcing in the main basin of Puget Sound, of which Commencement Bay is a part, is generally limited to northerlies and southerlies. These directions are seasonally dependent, with strong southerlies dominating in the winter and weak northerlies dominating the summer. However, strong northerlies occasionally occur in the winter.

The second component of the analysis, similar to the work of Mott Macdonald (2020, 2021), was to analyze past geomorphic change at the site and use that to determine the relative risk of cap loss and erosion. This was accomplished primarily through visiting and potholing the site during a low tide to identify the current integrity of the cap and adjacent areas within the park. It also considered the model MIKE21 results of Mott Macdonald (2021), despite that this tool was developed for sediment movement by waves and not specifically for beach erosion. Mott Macdonald (2021) also used the model Xbeach-G to estimate beach profile change that it is designed to do. The field assessment also characterized the near-surface stratigraphy at a coarse resolution to determine the response of the cap and adjacent areas in the park from environmental forcing over the past 23 years.

Assessment of Previous Work Applied to the Cap

Mott Macdonald (2020) used an analysis of the bathymetric profiles to suggest that the pile field influenced the geomorphic character in its vicinity. They demonstrated that the offshore profile (i.e., the low tide terrace of shallow subtidal sediments) was convex in shape. They likened the convexity to accumulated sediments found adjacent to breakwaters elsewhere in Puget Sound. However, there could be other explanations for the difference in bathymetric profile in the pile field versus other adjacent areas, owing to past fill or other activities associated with the construction and operation of the mill. Further, they suggested that removing the piles could increase the size of waves through the pile field enough to increase erosion of sediments within the pile field and of cap materials present in the adjacent intertidal beach area. However, this was a supposition and they did not model future geometry of the beach materials or offshore sediments. Therefore, it is unclear how this change in geomorphic process would occur, particularly if the pile field only slightly modifies the incident wave energy, as will be shown below.

The hydrodynamic modeling performed by Mott Macdonald (2021) used MIKE21, a proprietary three-dimensional hydrodynamic model, capable of simulating stratified, tidally influenced flow. Of particular emphasis here, is the wave-model component of the model, SWAN. SWAN is a publicly available two-dimensional wave model, widely considered the best model in the world for simulating a wide range of wave conditions. However, SWAN cannot accurately simulate closely spaced pile groups. To estimate the effects of the piles, Mott Macdonald (2021) used an empirical model of transmission through the pile field

(Truitt and Herbich 1986). This approach was further based on a quasi-analytical model developed by Hayashi et al. (1966). In sum, the pile field was assumed to transmit 75 percent of the wave energy based on the empirical relationship developed by Truitt and Herbich (1986). This assumed the condition of the pile field at the time that the study was performed (2020). For the stated purposes of the study and the general consideration of effects at the site, their model is adequate. However, the wave field within the pile field and further onshore is highly simplified, especially considering the pile field is in a constant state of decay and the assumptions made to arrive at the transmission efficiency will be invalidated beyond the time the study was performed (i.e., 2020). In addition, the model may have difficulty accurately capturing the mobility of the sediment in the pile field based on the limited sediment data available in this area at the time the model was developed.

SWAN also cannot simulate swash, the movement of waves up a beach and the dominant mechanism for sediment transport on Puget Sound intertidal beaches (Finlayson 2006). In fact, there is currently no sediment transport model that has been proven to accurately model sediment transport rates. Therefore, the approach to estimate mobility of the cap in this study is largely observational. Fortunately, the long period since the cap was placed provides sufficient time to assess the long-term mobility of the cap.

In addition to the MIKE21 modeling, Mott Macdonald (2021) also used Xbeach-G to simulate the response of the beach foreshore. Xbeach-G is a publicly available, two-dimensional hydrodynamic model that examines profile dynamics with wave input from SWAN. The details of the inputs of the model were not well documented, but it is suspected, given the lack of coring performed by Mott Macdonald (2021), standard inputs of bed material were used (i.e., a fixed median diameter only). Finalyson (2006) found from geomorphic inference that the grain-size distribution is an important parameter for sediment transport rates on Puget Sound beaches. The physical processes associated with sediment transport when coarser material is present are largely missing from Xbeach-G, and therefore the applicability of Xbeach-G to gravel beaches is limited (McCall et al. 2016). Regardless, the model results of Mott Macdonald (2021) indicated that up to 8 inches of erosion could be possible in the largest events, though they also state that "the increase in risk of exposing wood waste material under the gravel/sand beach due to pile removal is minimal" for ordinary storm events.

Site Observations

The site was visited on February 14, 2023 at 7 pm. The time of the visit occurred just after a low tide and a small winter storm event. The low tide was recorded as –2.64 feet MLLW at 5:30 pm local time at the NOAA Tacoma gage (Gage #9446484: NOAA 2023). This means that the water line was only a few feet landward of the nearshore edge of the pile field (Figure 2) and was at 0.5 feet MLLW at the start of the site visit. Sustained winds preceding the visit were out of the north at between 4 and 8 miles per hour, with gusts exceeding 10 miles per hour, according to a local weather station (Weather Underground 2023). This fortuitously produced 6-inch chop in Commencement Bay. The chop was only marginally affected by the pile field (Figure 2). There was significant swash at the water line, even in areas "protected" by the piles.

Although wave measurements were not made, wave transmission through the piles was estimated to exceed 75 percent. It is unclear what the impact of the piles would have on larger wind events, but it is difficult to imagine that the protection of the piles would increase much, if any, with increasing wave height. A lack of relationship between wave transmission and height is consistent with Mott Macdonald (2021), which assumed a fixed transmission percentage for all their model runs.

Four test pits were excavated throughout the park at elevations approximately 1-2 feet above the water line (i.e., at +2 feet MLLW). Test-pit spacing was less than a wavelength (less than 150 feet in the alongshore direction) of the largest wave events, meaning that the pits should have captured the full range of geomorphic processes at the beach. According to maps of the nearshore sediment cap in the cleanup action plan (Hart Crowser 2000), the elevation of the test pits would put them well above the lower cap boundary reported at 0 feet MLLW. The pits were roughly equidistant from one other in an alongshore direction, spanning the entire beach between the mill in the southeast and the revetment in the northwest. The eastern three pits were in areas marked in the as-builts as having had a cap. The westernmost pit was outside (west) of the cap. Excavation was only possible to about 1-2 feet due to infiltration of groundwater.

Figure 2. Wave Conditions During Low Tide Site Visit on February 14, 2023.

Cap material was not generally apparent from the surface, though some patches could be seen (see upper left corner in Figure 3). The surface was dominated by sand in most areas, though some of the gravel/cobble on the surface in coarser patches may have been from the cap. But at the central two pits, cap material was obvious less than a few inches below the surface. The cap material at both these locations was mixed with beach sand and shell hash (Figure 4), indicating that the cap material is at least occasionally marginally mobile during large storm events. The bottom of the cap was not reached at either of these pits (i.e., cap material was present at the bottom of the pits), despite that Mott Macdonald (2020) suggest that the thickness was only 6 inches at its lower end. The disturbance found is consistent with the modeling of Mott Macdonald (2021), which showed that the largest events were sufficient to mobilize the cap material. However, wholesale erosion has not occurred in the 23 years since the cap was placed. It is important to note that there was a 38 percent chance of a 50-year event occurring during this period. Further, the Xbeach model was developed for sandy coastal sediments exposed to swell, where profile changes happen much more quickly than they do on coarse sediment along Puget Sound shorelines. The modeling results suggest that future disturbance of the cap is likely, but wholesale erosion would only be possible by events significantly larger than the 50-year event. The protection of the pile field is also modest, particularly since an event of this magnitude is likely to destroy many of the piles in the process of the event.

Figure 3. Beach Conditions at a Central Test Pit on the Site Visit.

Figure 4. Cap Material Found in One of the Central Test Pits.

At the east end pit, anoxic sediment was found to the depth of the pit and no cap material was encountered. It is likely that the cap material was deeper than the bottom of the pit since this location was more protected than the other two sites and appeared to be generally finer grained than other locations. The west end pit contained a mix of debris (bricks), sand, and shell hash, but there was less shell hash at this site than the two central pits (Figure 5). The presence of shell hash indicates that the cap represents an erosional surface (i.e., the cap arrested erosion of the material from underneath it), whereas the west pit was primarily depositional. An erosional surface at the west pit, if there was one, was below the bottom of the pit.

Figure 5. Westernmost Test Pit Outside of Cap

Based on our observations, wave heights were not significantly reduced by the pilings, partly because the fetch (nearly the maximum fetch, in this case) is aligned with the rows of piles. It is also important to mention that Google Earth images show that the beach has not significantly changed position since the regrading of the site and the placement of the cap 23 years ago. This is true both where the cap exists and west of the cap.

Conclusion

The long duration of no significant erosion, the continued presence of the cap, and the likely minimal protection the pile field provides, would suggest the piles can be safely removed with causing significant erosion of the cap or other parts of the shoreline. It is also important to note that the wave-protection function provided by the pile field is being lost over time and will likely be lost entirely prior to 2050 at its current rate of loss. If the creosote-treated piles are not deliberately removed, much of the creosote-treated material from the pile field will remain in the surrounding area. With regards to the protection of the accumulated sediment from wave suppression by the dense pilings as suggested by Mott Macdonald (2020), it is unlikely that geomorphic processes affecting those offshore sediments without the pilings during extreme storm events in the future would be significantly different greater than the past variability in wave conditions that have occurred over the last 23 years.

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APPENDIX I

Puget Sound Sediment Reference Material Submittal

(Electronic Copy Only)