United States Department of Commerce
National Marine Fisheries Service
United States Department of the Interior
Fish and Wildlife Service

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7600 Sand Point Way N.E.
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U.S. Fish and Wildlife Service
Pacific Region
911 N.E. 11th Avenue
Portland, Oregon 97232-4181

Reply to:
NMFS Tracking No.: 2012-9473
FWS Ref No.: 01EWFW00-2013-F-0063

Michelle Walker
Corps of Engineers, Seattle District
Regulatory Branch CENWS-OD-RG
Post Office Box 3755
Seattle, Washington 98124-3755

Re: Endangered Species Act Section 7 Formal Consultation and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation for the proposed Elliott Bay Seawall Project, City of Seattle, King County, Washington. Fifth Field HUC 1711001904, Puget Sound/East Passage. (COE No. NWS-2011-778-WRD).

Dear Ms. Walker:

The enclosed document contains the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service's (USFWS) joint (the Services) biological opinion (Opinion) pursuant to Section 7(a)(2) of the Endangered Species Act (ESA). It analyzes the effects of both the U.S. Army Corps of Engineers (COE) proposal to issue a permit to the City of Seattle and NMFS' issuance of a Letter of Authorization (LOA) under Section 101 (a)(5)(D) of the Marine Mammal Protection Act (MMPA) associated with the proposed replacement of the Elliott Bay Seawall project, in King County, Washington.

In this Opinion, the Services conclude that the actions, as proposed, are not likely to jeopardize the continued existence of the following species and will not result in the destruction or adverse modification of the following designated critical habitat:

NMFS species:

- Puget Sound Chinook salmon (*Oncorhynchus tshawytscha*)
- Puget Sound Chinook salmon critical habitat
- Southern Resident killer whale (*Orcinus orca*)
- Steller sea lion (*Eumetopias jubatus*)
- Humpback whale (*Megaptera novaeangliae*)
- Bocaccio (*Sebastes paucispinis*)
- Canary rockfish (*S. pinniger*)
- Yelloweye rockfish (*S. ruberrimus*)

FWS species:

- Coastal-Puget Sound bull trout (*Salvelinus confluentus*)
- Coastal-Puget Sound bull trout critical habitat

The Services have also concluded that the proposed actions may affect, but are not likely to adversely affect the following species and designated critical habitat:

NMFS species:

- Puget Sound steelhead (*O. mykiss*)
- Southern Resident killer whale critical habitat

FWS species:

- Marbled murrelet (*Brachyramphus marmoratus*)

As required under Section 7 of the ESA, the Services provided an incidental take statement (ITS) with the Opinion. The ITS describes reasonable and prudent measures the Services consider necessary or appropriate to minimize incidental take associated with these actions. The take statement sets forth nondiscretionary terms and conditions, including reporting requirements, that the Federal agency and any person who performs the action must comply with to carry out the reasonable and prudent measures. Incidental take from actions that meet these terms and conditions will be exempt from the ESA take prohibition. The LOA Terms and Conditions are appended to this document.

This document also includes the results of our analysis of the action's likely effects on essential fish habitat (EFH) pursuant to Section 305(b) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA). It includes four conservation recommendations that are not identified in whole or in part in the ESA section of the document.

This document is based on information provided in the November 2012 Biological Assessment (received by the Services on November 28, 2012), various emails, phone calls, and meetings with

the COE and the Seattle Department of Transportation held to discuss the project and potential effects of the project.

A complete record of this consultation is on file at both NMFS's Washington State Habitat Office and the USFWS's Washington Fish and Wildlife Office in Lacey, Washington. If you have any questions, please contact Jim Muck at (206) 526-4740, email Jim.Muck@noaa.gov, Martha Jensen (USFWS) at (360) 753-9000, email Martha_L_Jensen@fws.gov, Tom Sibley (NMFS) at (206) 526-4446, email Thomas.Sibley@noaa.gov, or by mail at the letterhead addresses.

Sincerely,

for William W. Stelle, Jr.
Regional Administrator
NOAA Fisheries

for Ken S. Berg, Manager
Washington Fish and Wildlife Service
U.S. Fish and Wildlife Service

cc J. Printz, COE

Endangered Species Act – Section 7(a)(2)

Biological Opinion

And

Magnuson-Stevens Fisheries Conservation and Management Act Essential Fish Habitat Consultation

Elliott Bay Seawall Project
King County, Washington
Fifth Field HUC 1711001904, Puget Sound/East Passage

NMFS Consultation Number: 2012-9473
FWS Reference Number: 01EWFW00-2013F-0063

Action Agencies: U.S. Army Corps of Engineers

Consultation Conducted By: National Marine Fisheries Service
Northwest Region
And
U.S. Fish and Wildlife Service
Washington Fish and Wildlife Office

Issued By: Michael Tehan (signature) — Septrmber 30, 2013
for William W. Stelle, Jr.
Regional Administrator
National Marine Fisheries Service

Issued By: (signature) — September 30, 2013
FOR Ken Berg, Manager
Washington Fish and Wildlife Service
U.S. Fish and Wildlife Service

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ABBREVIATIONS AND ACRONYMS

Abbreviation or Acronym	Agency or Meaning
AHD	Acoustic harassment device
BA	Biological assessment
BMP	Best management practice
CFR	Code of Federal Regulations
CHU	Critical Habitat Unit
City	City of Seattle
COC	Chemicals of concern
COE	U.S. Army Corps of Engineers
CSO	Combined sewer overflow
CUL	Clean-up level
DO	Dissolved oxygen
DPS	Distinct Population Segment
Ecology	Washington Department of Ecology
ESCA	Endangered Species Conservation Act
EFH	Essential fish habitat
ESA	Endangered Species Act
ESU	Evolutionarily Significant Unit
FHWA	Federal Highway Administration
FMO	Foraging, migration, and overwintering
HAPC	Habitat areas of particular concern
HCP	Habitat conservation plan
IGDO	Inter-gravel dissolved oxygen
ILL	Incipient Lethal Level
ITS	Incidental take statement
km^2	Square kilometers
LOA	Letter of Authorization
LPS	Light penetrating surface
mi^2	Square miles
MHHW	Mean higher high water
MLLW	Mean lower low water
MMPA	Marine Mammal Protection Act
MSA	Magnuson-Stevens Fishery Conservation and Management Act
MTCA	Model Toxics Control Act
NAVD88	North American Vertical Datum 1988
NMFS	National Marine Fisheries Service
Opinion	Biological opinion
PAH	Polycyclic aromatic hydrocarbons
PAR	Photosynthetically Active Radiation
PCB	Polychlorinated biphenyls
PCE	Primary constituent element
PGIS	Pollution generating impervious surface
PS	Puget Sound

PSTRT	Puget Sound Technical Recovery Team
PTS	Permanent hearing impairment
ROY	Remotely operated vehicle
RMS	Root mean square
SDOT	Seattle Department of Transportation
SEL	Sound exposure level
Seattle	City of Seattle
Service	National Marine Fisheries Service and U.S. Fish and Wildlife Service
SMC	Seattle Municipal Code
SPL	Sound pressure level
SR	Southern Resident
TL	Transmission loss
TTS	Temporary threshold shift
USFWS	U.S. Fish and Wildlife Service
WDFW	Washington Department of Fish and Wildlife
WSDNR	Washington State Department of Natural Resources
WSDOT	Washington Department of Transportation
yd^3	Cubic yards

INTRODUCTION

This document prepared by the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS; jointly the Services) contains a biological opinion (Opinion) and incidental take statement (ITS) prepared in accordance with section 7(b) of the Endangered Species Act (ESA) of 1973, as amended (16 USC 1531, et seq.), and implementing regulations at 50 CFR 402. The essential fish habitat (EFH) consultation element of this document was conducted in accordance with Section 305(b)(2) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA) (16 U.S.C. 1801 et seq.) and implementing regulations at 50 CFR 600. The Opinion complies with the Data Quality Act (DQA) (44 U.S.C. 3504(d)(1) and 3516), and underwent pre-dissemination review. A complete record of this consultation is on file at both NMFS's Washington State Habitat Office and the USFWS's Washington Fish and Wildlife Office in Lacey, Washington.

1.1 Consultation History

The U.S. Army Corps of Engineers (COE) proposes to issue a permit and NMFS' proposes to issuance of a Letter of Authorization (LOA) under Section 101 (a)(5)(D) of the Marine Mammal Protection Act (MMPA) to the City of Seattle (City or Seattle) for certain construction activities for the proposed replacement of the Elliott Bay Seawall project. The Services have been coordinating on the proposed project for almost 10 years when it was part of the Alaskan Way Viaduct and Seawall Replacement Project. At that time the project was being developed by the Federal Highway Administration (FHWA), Washington State Department of Transportation (WSDOT), and the City of Seattle.

In 2009, FHWA, WSDOT, and the City of Seattle began pursuing the bored tunnel option for replacing the Alaskan Way Viaduct. The alignment for the bored tunnel alternative resulted in eliminating the need to replace the seawall as part of the project. Therefore, the City of Seattle and the COE began development of the Elliott Bay Seawall Project.

The project is a cost-shared project between the Seattle Department of Transportation (SDOT) and the COE. In 2009, the COE funded the USFWS under the Fish and Wildlife Coordination Act to prepare a Planning Aid Letter on the project. The Planning Aid Letter was prepared in 2010, in cooperation with NMFS, and included recommendations to help SDOT and the COE to evaluate alternatives and move forward with the design of the project.

Beginning in January, 2011, the COE Environmental Department, held a series of meetings as part of their environmental benefits analysis to rank or score different habitat measures proposed for the seawall project. Agencies involved in the meetings included the COE and their consultants, SDOT, Muckleshoot Indian Tribe, Suquamish Tribe, University of Washington, WSDOT, and the Services. The scores were to be used in a cost effectiveness and incremental cost analysis to determine the best habitat measures to be included in the project.

The SDOT holds interagency and tribal meetings to provide an overview, status, schedule, and update on the project. Six meetings have been held to date. Attendees at these meetings include SDOT, Seattle Department of Planning and Development, WSDOT, Washington Department of Fish

and Wildlife (WDFW), Washington Department of Ecology (Ecology), Washington Department of Natural Resources, King County, Port of Seattle, Muckleshoot Indian Tribe, Suquamish Tribe, Washington State Ferries, Environmental Protection Agency, and the Services.

The SDOT has been coordinating on a monthly basis with the Services since August 2011 to discuss key elements of the project, including the project description, environmental baseline, and potential effects on listed species.

The Services reviewed and provided comments on two drafts of the biological assessment (BA) for the project. Comments were provided on August 20 and October 24, 2011. The COE requested consultation on November 27, 2012.

On April 24, 2013, the Services received a letter from NMFS' Office of Protected Resources initiating consultation on the LOA for the project.

Numerous emails, phone calls, and meetings were held between SDOT, COE, and the Services to further define the project and its effects. Key emails and meetings included the following:

- December 19, 2012 – Email from SDOT consultant transmitting December 10, 2012 – Memorandum for SDOT to Service responding to questions on the BA.
- January 3, 2013 – Email from SDOT consultant transmitting revised paragraph to Section 5.2.1.6 on number of combined sewer overflow outfalls and number of discharges per year.
- January 25, 2013 – Meeting with SDOT and COE to discuss project and consultation.
- January 31, 2013 – Email from SDOT consultant providing additional information requested at the January 25, 2013, meeting. Information provided on installation of the containment wall, sheet pile installation, and the light penetrating surfaces (LPS) to get light under the cantilevered sidewalk and onto the habitat bench.
- February 21, 2013 – First of two meetings to discuss habitat features, specifically the LPS, Zone 1 Habitat Beach, and Adaptive Management Plan. Attendees included the Services, COE, Muckleshoot Indian Tribe, Suquamish Tribe, University of Washington, and SDOT.
- February 22, 2013 – Email from SDOT on how to download supplemental information for revised JARPA.
- February 28, 2013 – Second meeting to discuss habitat features, specifically the LPS and Zone 1 Habitat Beach. Attendees included the Services, COE, Muckleshoot Indian Tribe, Suquamish Tribe, University of Washington, WDFW, Ecology, and SDOT.
- March 18, 2013 – Email from SDOT transmitting March 12, 2013 – Memorandum from SDOT to the Service responding to Services' emails sent on February 15, 22, and 26, requesting additional information on the differences between the draft Federal Register Notice for take associated with the MMPA LOA and the BA, total size of the project area, barge use, and the Post-construction Monitoring and Adaptive Management Plan.
- April 1, 2013 – Email from SDOT consultant on total number of piles to be installed, number of piles to be proofed, and time required to proof piles.
- April 16, 2013 – Email from COE forwarding SDOT email transmitting barging, Zone 1 beach analysis, Monitoring and Adaptive Management Plan, and LPS sensitivity analysis.
- April 25, 2013 – Email from SDOT responding to questions on barging, Zone 1 beach analysis, and Monitoring and Adaptive Management Plan.

- April 29, 2013 – Email from SDOT on updating barge activities. Complete consultation package received, initiated consultation.
- May 9, 2013 – Email from SDOT with clarifications on project description changed during their review.
- September 3, 2013 – Email from the Corps stating two proposed changes to the project. First that two temporary mooring buoys will be installed, one near Piers 62/63 and the second on south of Pier 69. Second, SDOT is no longer proposing the extended habitat bench north of Pier 69.
- September 5, 2013 – Email from SDOT responding to Services questions on monitoring.

1.2 Proposed Action

"Action" means all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by Federal agencies. Interrelated actions are those that are part of a larger action and depend on the larger action for their justification. Interdependent actions are those that have no independent utility apart from the action under consideration. No interrelated or interdependent actions are associated with the Elliott Bay Seawall project.

This biological opinion addresses two separate but related activities: (l) the COE's issuance of a permit to SDOT for the construction of the Elliott Bay Seawall project, and (2) NMFS' issuance of a LOA under Section 101 (a)(5)(D) of the MMPA for this activity. Each action is introduced below. For the rest of the document, the action or proposed action refers to both activities.

1.2.1 Seattle's Seawall Replacement Project

The SDOT proposes to replace the Elliott Bay seawall to reduce the risks of coastal storm and seismic damages and to protect public safety, critical infrastructure, and associated economic activities along Seattle's downtown waterfront. The project has features and design intended to improve the degraded ecosystem functions and processes of the Elliott Bay nearshore in the vicinity of the existing seawall.

The Elliott Bay Seawall Project includes three major elements:

1. Reconstruct/replace the seawall to provide coastal storm damage and seismic protection over a 75-year design life.

2. Install habitat features along the marine nearshore adjacent to the seawall to provide an improved migratory corridor for juvenile salmonids and enhanced ecosystem function.

3. Restore the Alaskan Way surface street, sidewalk, and bike trail to maintain existing function and capacity.

The proposed project is located along 7,112 feet (2,170 meters) of the downtown Seattle waterfront from S. Washington Street to Broad Street (Figure 1). The seawall is adjacent to land used for businesses, residences, transportation facilities (streets, ferries, cruise ships, etc.), public services (fire station, utilities), parks, and other recreational elements.

Figure 1 – Elliott Bay Seawall Project Vicinity Map

1.2.1.1 Construction

The project has been divided into two phases (Figure 2), encompassing six zones (Figures 3 and 4): four zones are in Phase 1, and two zones are in Phase 2. The project area is also divided into five segments - three segments of construction are within Phase 1 and two segments of construction are within Phase 2 (Figure 5). The two phases are based on the two primary areas of infrastructure along the seawall, with Phase 1 being the Central Seawall and Phase 2 being the North Seawall. The six zones are based on the different uses of the piers and adjacent upland areas. The five segments are associated with the timing of the construction seasons.

Figure 2 – Elliott Bay Seawall Project construction phases.

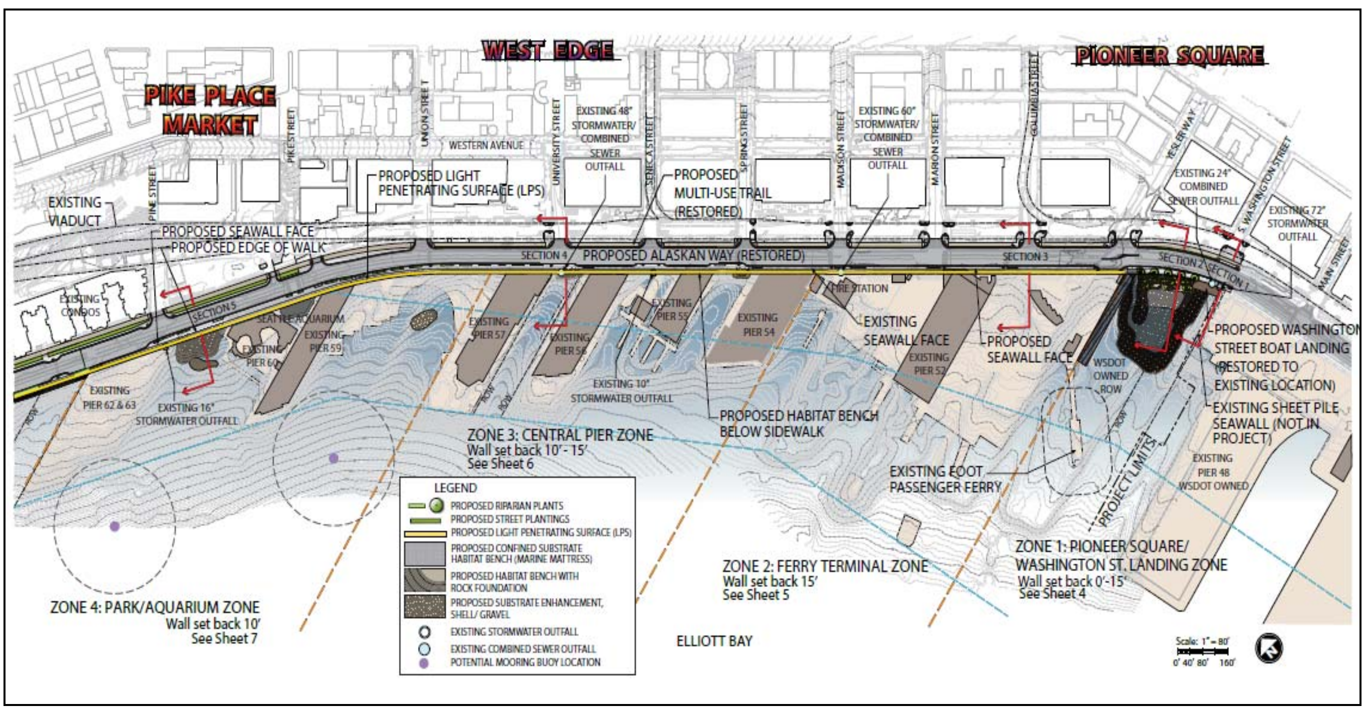

Figure 3 – Four zones located within Phase 1 of construction.

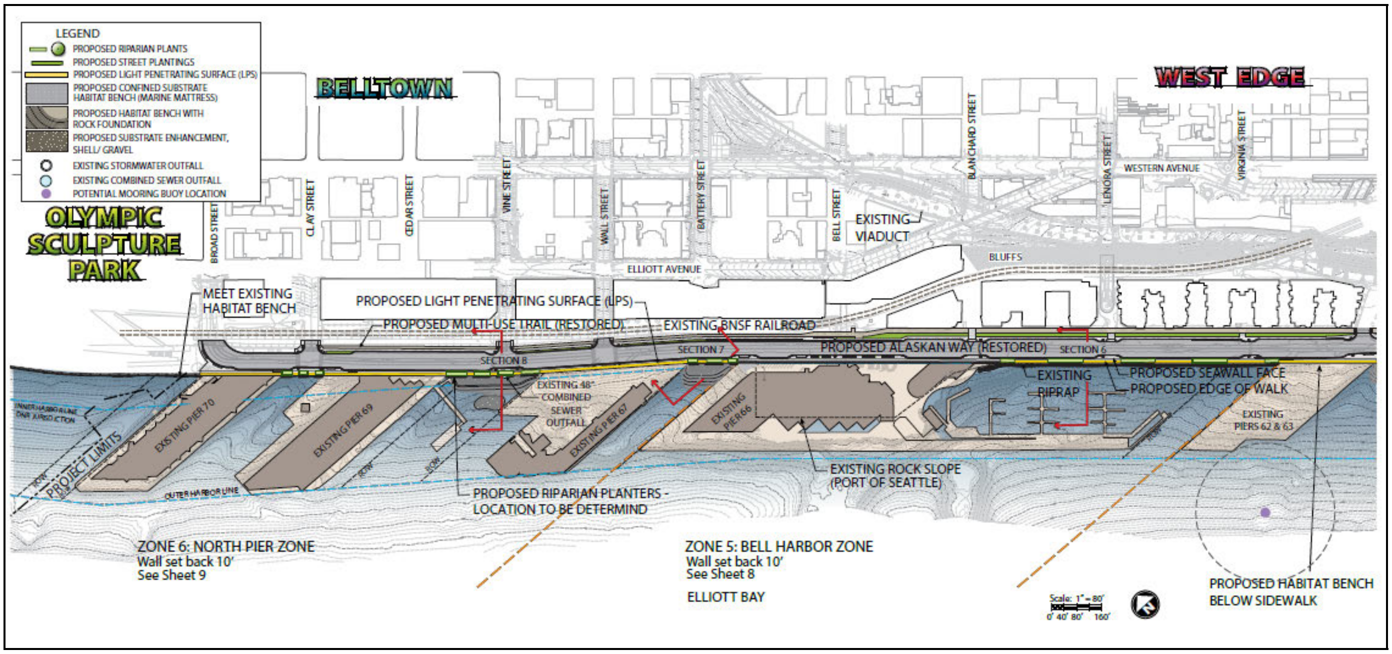

Figure 4 – Two zones located within Phase 2 of construction.

Figure 5 – Five construction segments within the project area. Three segments within Phase 1 and two segments within Phase 2. Each segment will be either 1 year of construction (Phase 1) or 2 years of construction (Phase 2).

The Alaskan Way Viaduct, which is currently being replaced by WSDOT with a bored tunnel, is part of Phase 1 (Central Seawall). The seawall in Phase 1 needs to be completed first, to allow for the demolition of the viaduct.

Phase 1 extends from S. Washington Street to Virginia Street, and is divided into four zones and three segments.

- Zone 1 (Pioneer Square/Washington Street Boat Landing Zone) extends from S. Washington Street to Yesler Way.

- Zone 2 (Ferry Terminal Zone) extends from Yesler Way to Madison Street and includes the Colman Dock Ferry Terminal and Fire Station No. 5.

- Zone 3 (Central Pier Zone) includes the historic waterfront piers (piers 54 to 57) and extends from Madison Street to just north of University Street.

- Zone 4 (Park/Aquarium Zone) includes Waterfront Park, the Seattle Aquarium, and Piers 62/63 and extends from north of University Street to approximately Virginia Street.

- Segment 1 – 1,200 feet (366 m) from Virginia Street to Union Street.

- Segment 2 – 1,200 feet (366 m) from Union Street to Madison Street.

- Segment 3 – 1,200 feet (366 m) from Madison Street to S Washington Street.

Phase 2 is the North Seawall, extending from Virginia Street to Broad Street and includes two zones and two segments.

- Zone 5 (Bell Harbor Zone) extends from Virginia Street to Battery Street and includes the Bell Harbor Conference Center, Bell Harbor Marina, and the Cruise Ship Terminal.

- Zone 6 (North Pier Zone) extends from Battery Street to Broad Street and includes the Edgewater Hotel, Port of Seattle offices, and Pier 70.

- Segment 1 – 1,700 feet (518 m) from Broad Street to Wall Street.

- Segment 2 – 1,700 feet (518 m) from Wall Street to Virginia Street.

The new seawall will be constructed behind the existing seawall face. The old seawall will be removed, and this will result in an increase of approximately 1.8 acres of aquatic habitat being restored due to the setback of the wall from its existing location. The approximate proposed location of the new seawall face relative to the existing seawall face is as follows:

- S. Washington Street to Madison Street – up to 15 feet (4.5 meters) landward;

- Madison Street to University Street – up to 10 to 15 feet (3 to 4.5 meters) landward; and

- University Street to Broad Street – up to 10 feet (3 meters) landward.

The existing seawall will be left in place during the beginning stages of construction as the new structure is built landward of the existing face. The existing seawall will be demolished behind the temporary containment wall.

The SDOT will stabilize soil as the primary structural, load-resisting seawall element (or "spine" element) of the project. The new seawall will achieve seismic stability by strengthening the fill material over a finite area to create an improved soil mass that restrains the landward unimproved liquefiable soil. Improved soil is formed by arranging the vertical or near-vertical soil-cement columns in a cellular pattern.

The northern portion of the seawall has a relieving platform, existing buried piles, utilities and other potential obstructions. The relieving platform is the wooden deck on top of all the vertical and battered (angled) piles behind the face of the existing seawall and forms an integral part of the seawall. The purpose of the relieving platform is to relieve the wall itself of the pressure of the live load and of any filling on top of the platform, and of a part of the horizontal pressure of the filling beneath. To contend with these potential obstructions, SDOT will use jet grouting in the northern portion of the project to stabilize the soil. Jet grouting creates circular columns of soil cement by inserting a hollow drill pipe a few inches in diameter into the soil to be stabilized or solidified. The contractor sprays grout through the rotating drill pipe, under high pressure, and through horizontal nozzles in the drill pipe into the surrounding soil. The high pressure grout cuts the existing soil and mixes the soil with the grout.

Soil stabilization will extend vertically from the bottom of the existing relieving platform down to the glacially overridden deposits. The grout columns may penetrate several feet into the glacially overridden deposits. Horizontal alignment will begin 10 to 15 feet upland of the existing seawall alignments and extend 35 to 40 feet further upland (40 to 55 feet from the existing Type A and Type B wall face). At the face of the seawall and at the eastern extent of soil stabilization area, the concreted soil mass will essentially be continuous; columns situated between the face and the back of the improved area will be spaced at approximately 12- to 16-foot intervals (Figure 6).

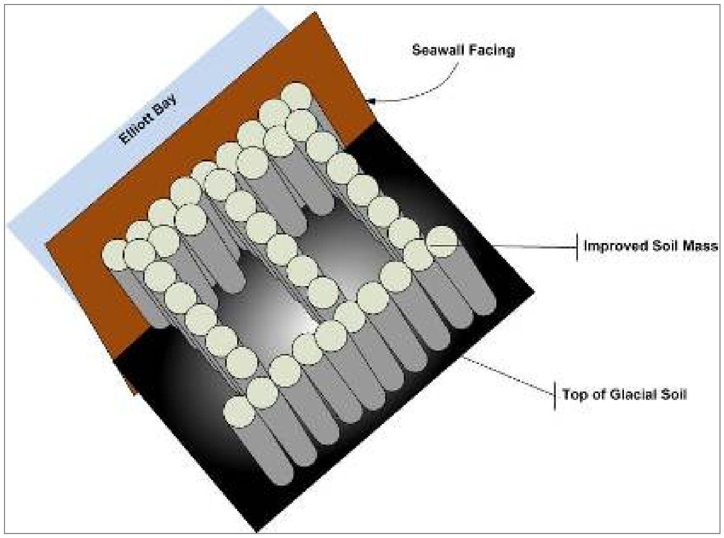

Figure 6 – Schematic of jet grouted columns.

In contrast to the northern portion of the seawall, the southern portion consists of gravity and pile-supported walls and has no relieving platform extending inland from the seawall face. Therefore, SDOT will use deep soil mixing methods to stabilize soil in that portion of the project. Deep soil mixing uses a large diameter auger system to mix cement with the soil. Deep soil mixing does not require high pressures during mixing which may reduce the risk of soil-cement finding its way into the bay, utilities, and other unintended locations. Deep soil mixing also provides a more certain geometry of individual columns. The absence of a relieving platform in the southern portion of the seawall facilitates excavation of obstructions prior to deep soil mixing.

1.2.1.2 Construction Schedule

The construction schedule will occur in segments. Each segment represents 1 to 2 years of construction (Table 1).

Table 2 – Anticipated Construction Schedule

Phase	**Segment**	**Year of Construction**
1 (Central Seawall)	1	Year 1 (Fall 2013–Spring 2014)
	2	Year 2 (Fall 2014–Spring 2015)
	3	Year 3 (Fall 2015–Spring 2016)
2 (North Seawall)	1	Years 4 & 5 (Fall 2016–Spring 2018)
	2	Years 6 & 7 (Fall 2018– Spring 2020)

During Phase 1, construction is expected to generally occur from north to south, starting at Virginia Street and moving toward the southern end of the project area. However, during the first construction season (Segment 1) the project might include some work at the southern end of the project to take advantage of the current closure of Alaskan Way for the bored tunnel south portal construction. During Phase 2, construction is expected to occur in a similar pattern, starting in the north at Broad Street and moving south.

Phase 1 will be constructed over three construction seasons with two summer shut-down periods that are scheduled to occur from Memorial Day weekend through Labor Day weekend to accommodate the primary tourist and business season (Table 1). The construction of the North Seawall phase (Phase 2) is anticipated to begin following completion of Phase 1. Phase 2 will be constructed over two 2-year construction seasons for a total of 4 years. As with Phase 1, summer shut-down periods will occur each year.

The following is a detailed discussion of each individual major construction action in the expected sequence for each segment.

Construct temporary roadway, bike trail, and sidewalk. During construction, Alaskan Way will be relocated eastward to accommodate the work zone and will be moved under the Alaskan Way Viaduct in Phase 1 and moved over the existing trolley tracks in Phase 2. The trolley tracks will be removed and paved over. The existing roadway is generally four lanes (two lanes in each direction), except in the vicinity of Colman Dock (Yesler Way to Spring Street) where there is one northbound lane and two southbound lanes with a left-turn lane into the ferry terminal.

With Alaskan Way temporarily shifted to the east, construction equipment and trucks will use the remaining space on Alaskan Way as a construction haul road through the Central Seawall area. A separated construction haul road will not be possible for the North Seawall area due to a lack of space. For the North Seawall construction, the temporary roadway will need to be accommodated within the available right-of-way along with the construction work zone. As three lanes will be required for the temporary roadway, the width of the construction work zone will be reduced in that location.

This action will occur in the upland area adjacent to the existing seawall. Construction of the temporary road will occur once for each construction phase and will be in place for 3 and 4 years, respectively.

1. **Removal of existing sidewalk and riprap.** Removal of the existing cantilevered sidewalk that runs along the waterfront will occur at the beginning of each of the five construction segments. In-water work will occur during the designated work window each year and require 1 to 2 weeks. Removal or displacement of riprap along the existing seawall will also occur in Elliott Bay after the removal of the existing cantilevered sidewalk to facilitate installation of the temporary containment wall to isolate the work area from Elliott Bay. Removal of the existing sidewalk will facilitate actions 3 and 4 (below). Contractors will move or remove an estimated that 1,000 to 1,500 yd^3 of material for each of the five segments, totaling an estimated 6,500 yd^3.

2. **Removal of existing timber pilings**. Following the removal of the cantilevered sidewalk, any old pilings that are in the way for the installation of the temporary containment wall will be removed. The work will occur within each segment and require 1 to 2 days each year. Contractors will remove as many as 74 to 80 existing timber/creosote-treated pilings at the Washington Street Boat Landing and possibly at others piers (approximately 10 to 20 pilings in each segment). The pilings will be removed using vibratory equipment or other extraction

means. If the timber pilings break during removal, they will be cut off two feet below the mudline.

3. **Install temporary sheet-pile containment wall.** Contractors will install a temporary sheet pile containment wall in Elliott Bay for each of the five construction segments before beginning soil stabilization, excavation, and demolition of the existing seawall. The work will require up to 20 days for installation in each segment. Contractors will install approximately 1,740 sheet-pile pairs. This estimate includes a 10 percent contingency consisting of approximately 1,023 pile pairs for the Central Seawall and approximately 717 pile pairs for the North Seawall). Each segment of the Central Seawall will have approximately 342 pairs of sheet piles and each segment of the North Seawall will have approximately 358 pairs. Each sheet pile pair is assumed to be 48 inches in width and will be driven 40 to 70 feet (12 to 21 meters) below ground to competent soils depending on soil conditions. Vibratory pile-driving equipment will be used to install the majority of sheet piles; however, it is estimated that some sets will need to be proofed with an impact hammer to provide some load bearing capability (i.e., at temporary access bridges such as at Colman Dock). SDOT estimates that up to twenty percent of the sheet pile pairs will need proofing (four pile pairs per day). Proofing will require approximately 5 minutes of impact pile driving (20 strikes per minute) for each pile pair of piles, for a total of 20 minutes a day.

4. **Fish handling and removal.** Fish will be salvaged and removed from behind the containment wall at the beginning of each of the five construction segments to reduce the likelihood of fish stranding and death. This work is expected to last for 2 days for each segment.

5. **Pre-drilling for soil stabilization**. This action will occur in the uplands. Prior to conducting any soil stabilization, approximately six-inch holes will be pre-drilled from the roadway surface down to the timber relieving platform to avoid the need to excavate the roadway for soil stabilization activities.

6. **Seawall installation and soil stabilization.** Contractors will conduct the soil stabilizing activities in the uplands, and behind the existing seawall and temporary containment wall. Jet-grouting nozzles will be placed in the pre-drilled holds (Step 6) to install the grouted columns. Initially, the void spaces around the relieving platform will be filled to the greatest extent practicable using low-pressure grout and then the columns will be installed. In the south end of the project area, deep soil mixing will be used instead of jet grouting and will involve excavating a trench in the uplands behind the seawall and mixing grout into the existing soils under ambient pressure. Soil stablization work will require approximately 4 months within each 9 month construction season (September through May) for each segment over the 7 years to the project.

7. **Excavate old seawall and provide setback area.** This action will occur behind the temporary containment wall and will last for 2 to 3 months. The majority of the excavation of the existing seawall face involves removal of concrete, steel, or timber with limited areas of soil disturbance. The material would be hauled away to an approved landfill or disposal site. As the material is excavated it would be periodically sampled to ensure it is sent to the

appropriate disposal location. Waterward of the existing seawall face, excavation in the pullback area could go down to approximately -8.3 feet North American Vertical Datum 1988 [NAVD88] (-6 feet mean lower low water [MLLW]). This is 6 feet below the proposed habitat bench elevation. The new surface left behind after excavation of the old seawall would be sampled for contaminants to ensure leaving a "clean" surface before placing the marine mattresses or foundation rock for the benches.

8. **Install new seawall face panels.** This action includes lifting and placing 8 foot-wide precast concrete face panels onto a leveling pad at the new face location (10 to 15 feet back from the existing seawall face). Approximately 850 face panels will be installed in total (490 in the Central Seawall and 357 in the North Seawall; note: no new wall will be constructed at Pier 66 because the wall was replaced with fill during the Pier 66 redevelopment). Installation of the face panels will require approximately 23 to 27 days. The face panels will be textured to support attachment of microalgae and invertebrates. Fins and shelves will be attached to the face panels after installation of the vertical panels (likely to be bolted by divers into precast locations) at intertidal elevations.

9. **Place habitat bench in setback area.** This action will occur behind the temporary containment wall at the end of each of the five construction segments and last for 2 to 3 weeks. Confined fill substrate (marine mattresses) will be installed to create a shallow nearshore intertidal migratory corridor in areas behind piers or where the existing bathymetry is very deep. These mattresses are comprised of a geogrid mattress structure filled with a cobble/gravel mix that can be stacked to an elevation just below MLLW (-2.5 feet NAVD88). The geogrid material is made of high-density plastic that is expected to last several decades in the marine environment. The remaining rock slope for the benches will need to be installed in-water after the temporary containment wall is removed.

10. **Rebuild outfalls with wall setback.** Stormwater outfalls will be consolidated to the greatest extent practicable. Flows from the small individual outfalls (scupper drains) will be routed into the existing larger outfalls at South Washington, Madison, Seneca, University, Pine, Pike, and Vine streets. This will reduce the total number of outfalls that discharge along the seawall from approximately 50 outfalls, to the seven major outfalls, with up to six individual outfalls retained where other infrastructure prevents consolidation of the pipes. At South Washington Street, the City will divert the existing combined sewer overflow (CSO) discharge pipe into the adjacent storm drain at a point between the CSO diversion structure and the new seawall. The existing 24-inch diameter CSO outfall, which is in poor condition, will be abandoned and buried in place under the habitat bench. Any CSO events, which occur only once every 4 to 5 years on average at this location, will discharge via the storm drain outfall. There will be no change in frequency or volume of CSOs as a result of this project.

    New stormwater conveyance pipes will be installed east of the new seawall to direct runoff into the larger or existing outfalls. Each of the existing outfalls, except Madison, will have a drop structure installed east of the new seawall to allow the outfall to be lowered to below -2.3 feet NAVD88 (0 feet MLLW). Stormwater treatment facilities will be installed to treat stormwater runoff from the project area pollution generating impervious surfaces (PGIS)

using technology to remove sediments and associated pollutants (as required by Seattle Municipal Code [SMC] 22.805.090(B)(2)). Given the location and limited space available for constructing runoff treatment facilities, a manufactured treatment system will be used. SDOT will use any one of several suitable commercial systems. This will improve the quality of stormwater discharging from the project area. This action will occur simultaneous with Steps 8 through 10 and will be completed behind the temporary containment wall at the end of each of the five construction segments.

Outfall lowering will require extensions of some outfalls in locations where the existing substrate elevation in Elliott Bay is higher than -2.3 feet NAVD88 (0 feet MLLW). In addition, outfalls will extend under the proposed new habitat bench and discharge beyond the top of the bench onto the confining rock slope. At Pine Street, the outfall will discharge in a lowered slot below the outer half of the bench. Outfall lowering will occur either behind the temporary containment wall (small outfalls) or a containment/sediment curtain (large outfalls), while outfall extension segments will be installed after removal of the temporary containment wall during the placement of the remaining habitat bench materials.

11. **Install pilings for the load bearing sidewalk segments.** Permanent concrete pilings will be installed to support certain segments of the sidewalk where loading is heavy (such as at Colman Dock). An estimated 190 permanent concrete pilings will be installed landward of the containment wall using impact-pile-driving equipment. The concrete pilings will be installed prior to removing the temporary containment wall. Approximately eight piles will be installed each day, requiring approximately 500 strikes per pile and 4 days per segment. Therefore, up to 200 minutes of impact pile driving will be required per day for the installation of the concrete piles.

12. **Remove temporary sheet-pile containment wall.** This action will occur in Elliott Bay near the end of each of the five construction segments and will require 2 to 3 weeks for each segment. The containment wall will be removed using vibratory equipment or other extraction equipment.

13. **Install new cantilevered or pile-supported sidewalk with LPS**. Contractors will reconstruct sidewalks extending from the restored Alaskan Way curb line to the western Alaskan Way right-of-way line (i.e., the western edge of the existing sidewalk at the pier faces). The new sidewalks will be from 15 to 20 feet wide and be cantilevered or pile supported over the seawall. The LPS will extend along the length of the restored sidewalk. The railing will be replaced along the length of the wall and planter boxes will be installed within the sidewalk width. This action will occur from the uplands or over Elliott Bay at the end of each of the five construction segments and last for three to four months. The new cantilevered sidewalk or pile-supported sidewalk will be pre-cast concrete and modular to incorporate LPS.

14. **Install pilings for Washington Street Boat Landing.** Washington Street Boat Landing will be restored and reinstalled within its existing footprint immediately adjacent to the new seawall face. This action will occur in Elliott Bay at the end of the Central Seawall construction phase (2016) and will last approximately one month. This work will involve the

installation of approximately 15 concrete pilings using impact pile-driving equipment and require up to 2 days for installation.

15. **Restore roadway.** Following seawall construction, SDOT will move Alaskan Way to the original roadway location, and the sidewalk, trail, and parking will be restored to their original function and capacity. This action will occur in the upland area adjacent to the new seawall and will occur once following each construction phase. Each element of the road restoration action is expected to last 2 months. This work will involve backfilling and paving to restore the roadway and include permanently adding the new northbound lane segment (Yesler Way to Spring Street). The design for the streetlights to be reinstalled along the sidewalk and roadway is intended to direct light away from the LPS or use light shields to further minimize light through the LPS or towards the water at night.

    An additional permanent northbound through lane will be added between S. King Street and Madison Street to achieve better traffic flow. A sidewalk of approximately the same width as the existing sidewalk will be provided on the west side of the street after construction. The mixed-use trail on the east side of Alaskan Way will be extended north from its existing terminus to Clay Street, where it would cross Alaskan Way and continue on the west side to the Olympic Sculpture Park and Myrtle Edwards Park. Parking and loading zones will be similar to what are currently present.

16. **Bike trail replacement.** This will occur in the upland area east of Alaskan Way and taking place following each construction phase. This work will be simultaneous with the restoration of the roadway, and place the bike trail back to its existing location.

17. **Intertidal habitat bench.** A continuous corridor of habitat bench or confined fill substrate bench will be installed along the new seawall face at an elevation just below MLLW (-2.5 feet NAVD88) and have a top width of approximately 10 to 30 feet to provide suitable intertidal depths for migrating juvenile salmonids along the shoreline. Zone 1 (Phase 1) will include an expanded area of intertidal bench (up to 200 feet wide) with a narrow beach bordered by backshore riparian plants, rocks, and drift logs. The one area where a bench will not be installed is an approximately 300-foot-long section at Pier 66 where there is no seawall. The pier is supported by fill that currently provides intertidal depths around the pier, and openings in the pier structure provide lighting below. The installation of the expanded habitat bench areas will occur twice, once at the end of each construction phase (February) and last for 2 to 4 weeks.

18. **Substrate enhancement (below 10 feet [3 m] NAVD88).** Additional substrate types will be added along the shoreline to improve nearshore ecosystem productivity and diversity along the waterward side of the new seawall. This action includes placing substrates (pea gravel and shell hash mix) at a -10 to -15-foot NAVD88 (-7.7 to -12.7 feet MLLW) to provide habitat for juvenile crabs and other invertebrate settlement. This action will occur in Elliott Bay at the end of each construction phase and last approximately 1 week (February).

19. **Riparian vegetation.** This will occur adjacent to Elliott Bay and will occur at the end of each construction segment when the sidewalk is reinstalled. This work involves the installation of vegetation along the sidewalk and at the backshore zone in Zone 1.

1.2.1.3 Barge Use

To reduce traffic congestion, fuel consumption, and the risk of accidents during project construction, the movement of large, heavy materials will be brought and stored at the project site on barges. Barges would be used for the following activities:

- Delivering precast components, such as superstructure foundation, sidewalk, and face panels
- Storing construction equipment and materials, such as marine mattresses, precast components, removed piles, and aquatic materials.
- Removing riprap and large debris waterward of the existing seawall
- Installing and removing temporary sheet piles and permanent piles
- Placing habitat components.

Four access points will be used along the seawall throughout construction for both phases of construction. The primary location where the barges will be moored for the longest time will be between Piers 62/63 and the Seattle Aquarium. Secondary locations for Phase 1 include Waterfront Park and between Colman Dock and Pier 48. For Phase 2, the secondary location is anticipated to be between Piers 69 and 70. The barge will be restricted to the primary location from March through May. Secondary moorage locations will be used throughout construction as needed. Use of the secondary locations will be restricted to September through February. Two buoys will be installed to provide short-term moorage of delivery barges. These buoys will be located in deeper water near the primary location between Piers 62/63 and the Seattle Aquarium and the secondary location near Waterfront Park (see Figure 3).

On average, two barges will be on site -- one derrick barge and one delivery barge -- to support construction activities. At times up to four barges could be used: two derrick barges and two delivery barges. Barges will be located at primary or secondary locations. The derrick barge will be anchored to the seafloor with two spud anchors, each 3 feet in diameter, and will remain in place during active periods of material deliveries. Delivery barges will be tied to the derrick barge for an average of 5 to 6 days at a time, and will be available to provide a continuous supply of construction material. No gangways or walkways will be used between the piers and barges.

The two buoys installed to provide short-term moorage of delivery barges will be anchored with a "dual-chained" anchoring system at a depth greater then 60 feet MLLW. The anchor will be selected based on the sediment type to reduce or eliminate drag. A considerable length of heavy chain will rest on the seafloor and will act as ballast for this system. The extra weight is intended to limit the movement (from tides, wakes, etc.) of the chains and bouy. A vertical chain will extend from the ballast to the buoy. The vertical chain will be sized to a length approximately 10 feet less

than the water depth at low tide. This will cause about 10 feet of the chain to lift up from the seafloor during high tide.

Construction of the habitat features waterward of the existing seawall face will require up to 2 weeks of barge moorage. Short-term barge moorage locations for Phase 1 will be between Piers 56 and 57 and between Piers 54 and 55. For Phase 2, short-term barge moorage locations are anticipated between Piers 67 and 69 and between Piers 66 and 67.

Barges of various sizes would be used during project construction. For construction work and material deliveries, the primary barge size is 55 feet by 180 feet. The draft on a delivery barge is approximately 3 feet when empty and 12.5 feet when fully loaded. A size of a derrick barge is approximately 70 feet by 200 feet. The draft on a derrick barge is approximately 6 feet when empty and 13 feet when fully loaded or handling materials. Tugboats would be used to move barges and marine equipment in shallower waters. The majority of the barges used for the project would be smaller delivery barges, which do not have any anchor gear and would need to be secured to the derrick barge.

The contractor will likely move delivery and derrick barges used during construction to the project site from the contractor's facility on the Duwamish River (located at 5209 East Marginal Way South), just east of Kellogg Island. However, these barges could be sourced from various sites around the Puget Sound if barges are supplied by a different contractor. Once the barges are put into service, they will primarily navigate between Elliott Bay and southern Puget Sound. Currently, the Port of Tacoma is identified as the potential primary source location for precast components and aquatic materials. Existing north Puget South commercial facilities could also serve as source points.

Preliminary construction estimates show that approximately 25 round-trips (50 one-way trips) will occur during each construction season. Approximately 75 total round-trips (150 one-way trips) will be made to the site over the 3-year construction period for Central Seawall and 100 round-trips (200 one-way trips) for construction of the North Seawall. Barges are moved by tugboats; therefore, tugboat traffic to and from the site is expected to equal that of the barge trips. The derrick barges will not leave the project site as frequently as delivery barges, as they will remain in place during active periods of loading and unloading. In extremely adverse weather conditions, barges may be moved from the project site to existing barge moorage near West Seattle, or to the contractor's facility in the Duwamish River as a safety precaution.

1.2.1.4 Habitat Features Installed in Elliott Bay

The following structures will be installed in Elliott Bay to improve aquatic habitat along the nearshore.

1) Expanded Zone 1 bench with narrow beach and riparian improvements – Between Colman Dock and Pier 48, an intertidal and shallow water bench would be constructed (Figure 7). The habitat enhancement feature would extend approximately 200 feet from the seawall and would measure approximately 250 feet at its widest point. The grade will range from -27.7 feet to +14.8 feet MLLW with slopes between 8H:1V and 12H:1V. The bench would

provide shallower water depths by approximately 15 feet to 26 feet from existing conditions. With the substrate enhancement, the MLLW level would be moved approximately 150 feet waterward from the existing seawall face. Riparian vegetation will be planted along the seawall. SDOT evaluated whether the size and extent of the Zone 1 habitat enhancement could be reduce without compromising the anticipated habitat benefits, especially the size and extent of the two rock arms. Four alternatives were developed and two were determined to provide the intended benefits (April 12, 2013, Memorandum from Mark Mazzola).

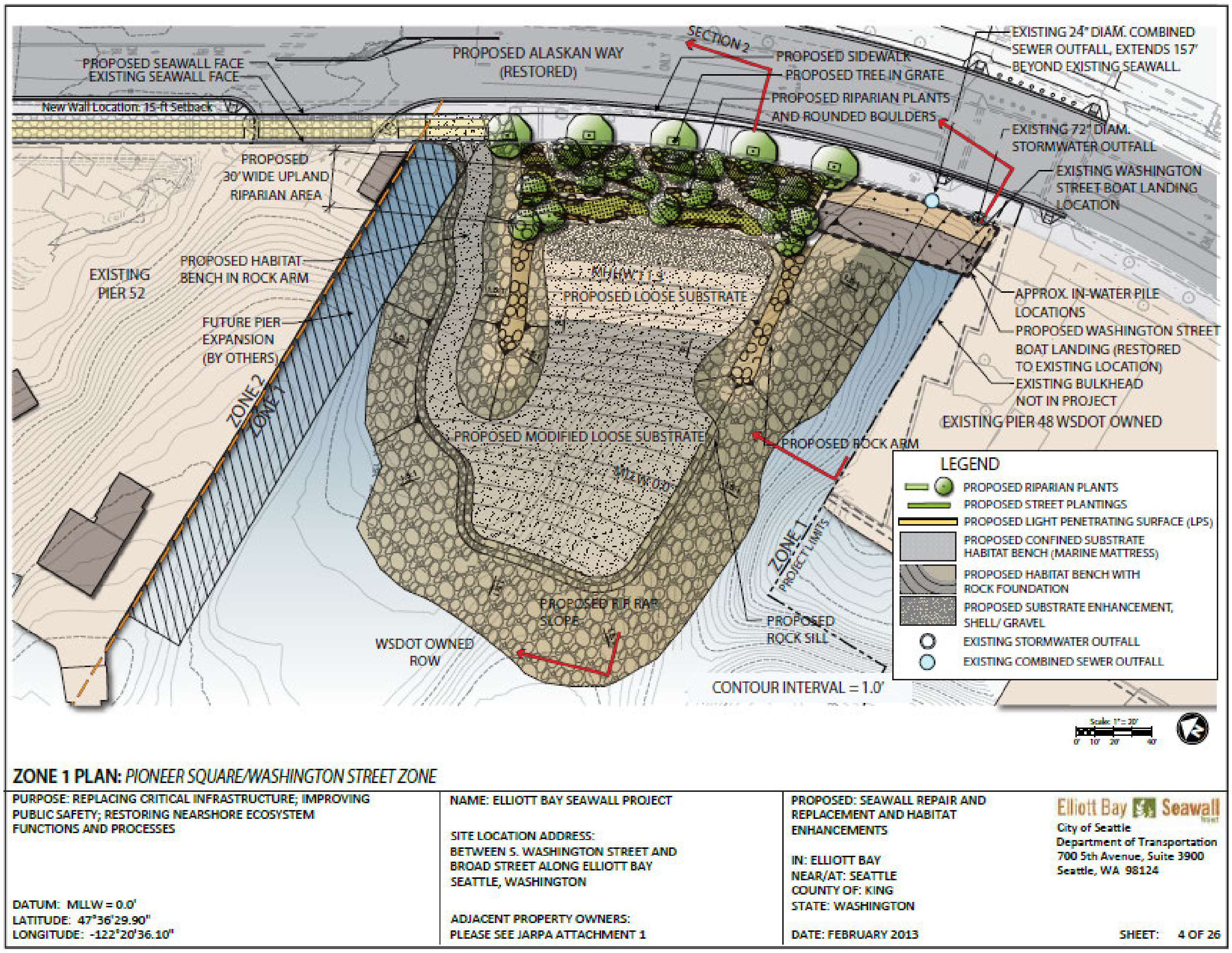

Figure 7 – Proposed intertidal and shallow water bench located in Zone 1.

2) Two enhanced habitat benches will be installed in Zone 3 (Figure 8). One at Spring Street between Piers 54 and 55 and a second at University Street between Piers 56 and 57. At Spring Street, the enhanced habitat area would extend approximately 25 feet from the new seawall face, and would create an intertidal habitat bench at 0.0 feet MLLW. The existing grade would be increased by placing a 2-foot layer of modified and loose substrate on top of a 3-foot to 5-foot base layer of loose substrate. This habitat bench is located in an area of steep bathymetry and would require a stack of marine mattresses to act as a containing sill and support for the habitat bench. Waterward of the stacked marine mattresses, the slope would drop quickly from about -0.2 feet MLLW down to the existing grade of the seafloor.

The average grade in this area ranges from -13.7 to -7.7 feet MLLW; the marine mattress stacks would bring grade up to approximately -1.7 feet MLLW, which reduces water depths by approximately 6 to 12 feet within 25 feet of the seawall face.

At University Street, the enhanced habitat area would extend approximately 35 feet from the new seawall face. Similar to the habitat bench at Spring Street, a 5- to 10-foot layer of modified and loose substrate would be placed to create an intertidal habitat bench at 0.0 feet MLLW. Confined marine mattresses would support the habitat bench. The edge of the habitat bench would slope quickly from about -0.2 feet MLLW down to existing grade. Average grade in this area ranges from -13.7 to -7.7 feet MLLW; the marine mattress stacks would bring grade up to approximately -1.7 feet MLLW, which reduces water depths by approximately 6 to 12 feet within 35 feet of the seawall face.

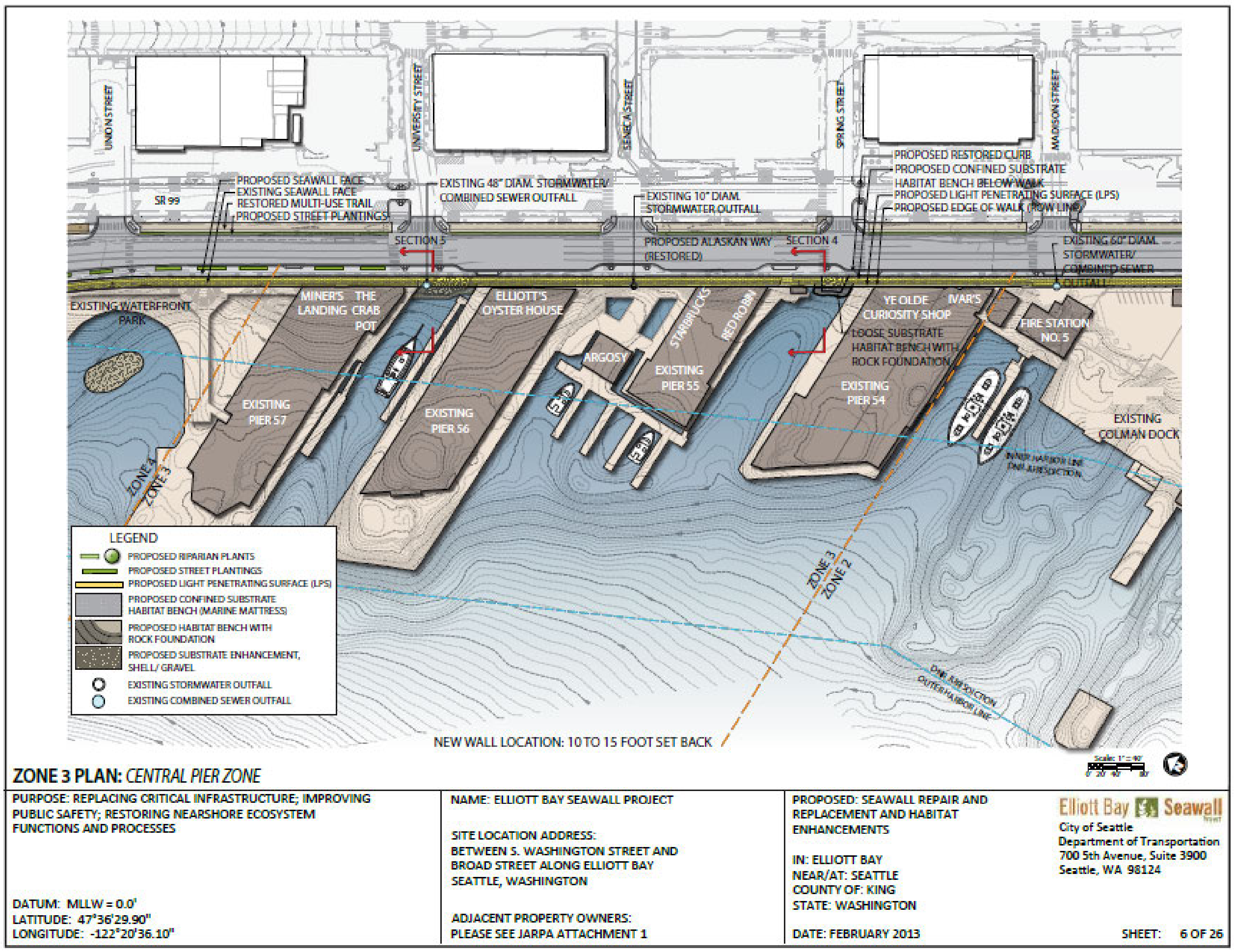

Figure 8 – Proposed habitat enhancement features in Zone 3.

3) Two enhanced habitat areas will be installed in Zone 4; west of Waterfront Park and north of Pier 60 between the Seattle Aquarium and Pier 62/63 (Figure 9). The substrate enhancement area west of Waterfront Park will consist of pea gravel and shell hash, placed at a thickness of approximately 1 foot to 2 feet at subtidal depths of between -9.7 and -17.7 feet MLLW. This enhancement is located approximately 40 to 60 feet west of Waterfront Park. Existing

water depths would be reduced by approximately 1 foot within this subtidal substrate enhancement area, which is approximately 30 feet in length.

The enhanced habitat bench located to the north of Pier 60, between the Seattle Aquarium and Piers 62/63 will extend approximately 85 feet waterward from the new seawall face, increasing the nearshore elevation by approximately 6 feet. The existing grade ranges from approximately 0.0 to -5.7 feet MLLW. The habitat bench would increase grade to 0.0 feet MLLW throughout this area, which causes a reduction in water depth of no more than 6 feet. Waterward of this enhanced habitat bench, the habitat materials would extend another 30 to 45 feet, through the placement of a layer of pea gravel and shell hash.

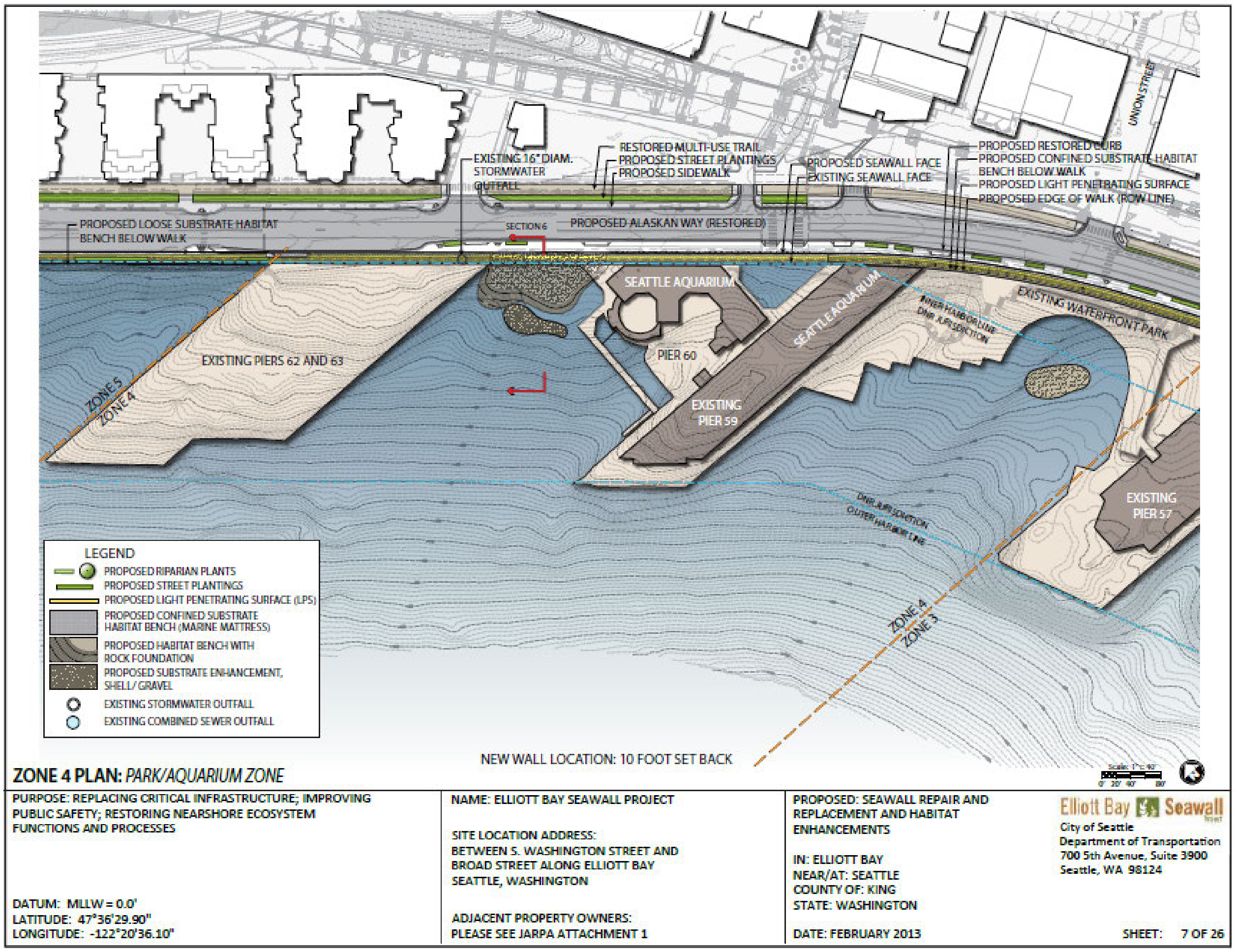

Figure 9 – Two habitat enhancement features proposed in Zone 4.

4) Within Zone 5, an existing riprap revetment extends out from the face of the existing seawall in the vicinity of the Bell Harbor Marina. The upper portion of the riprap would be removed and leveled-off at 1 foot to 2 feet below MLLW. Quarry spalls would be placed as a stabilizing under-layer along the reshaped riprap slope, and up to 2 feet of angular, crushed rock would be placed over the quarry spalls to enhance the substrate and bring the elevation up to 0.0 feet MLLW.

5) In Zone 6, two enhanced habitat benches will be constructed(Figure 10). The enhanced habitat bench located to the north of Pier 66 would extend approximately 100 feet waterward from the new seawall face. A layer of loose substrate and modified and loose substrate would increase the elevation to 0.0 feet MLLW changing the existing grade (and reducing water depth equally) by approximately 1 to 5 feet, for up to 60 feet from the new seawall face. A confining rock sill would be placed at the toe of the substrate enhancement. The confining rock sill represents the largest change to existing grade in this area; a maximum change of approximately 12 feet is expected.

   The enhanced habitat bench located to the south of Pier 69 would be located between the existing moorage and the seawall. The habitat bench will extend out approximately 125 feet from the new seawall face. Intertidal habitat at 0.0 feet MLLW will be created within 35 feet of the seawall with the placement of up to 5 feet of loose and modified loose substrate. The confining rock sill would then slope down to existing grade, over a width of approximately 40 feet. The maximum change to the elevation (and water depth) would be approximately 15 feet, where the confining rock sill would be constructed to contain the loose substrate. Waterward of this rock sill, the habitat materials would extend another 50 to 55 feet, through the placement of a layer of pea gravel and shell hash. This improvement would result in a very minor change to grade and water depth, with a difference of no more than 2 feet.

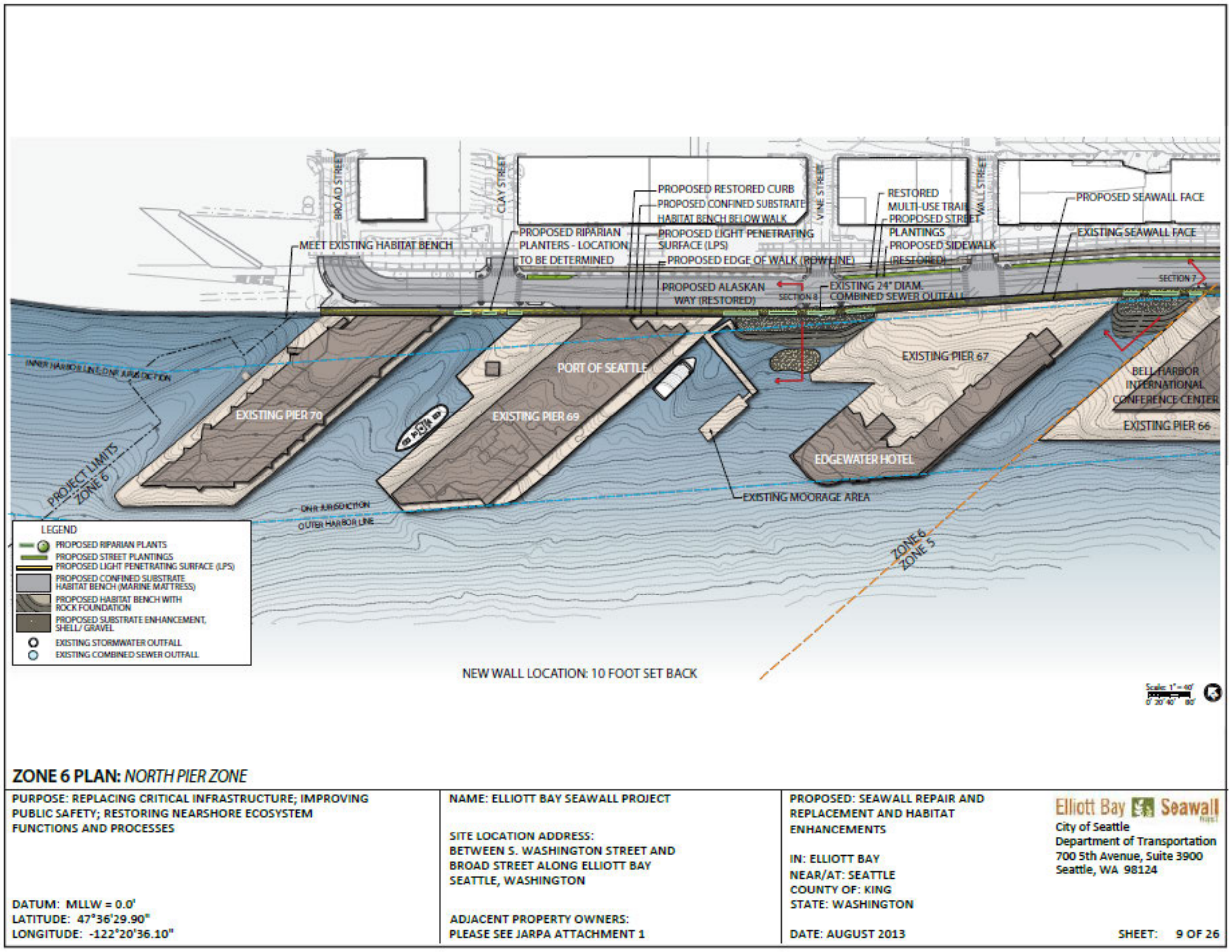

Figure 10 – Two enhanced habitat features proposed in Zone 6.

1.2.1.5 Operation and Maintenance

The habitat features included in the Seawall Project will likely require periodic maintenance to ensure their long-term functionality. The following maintenance measures will occur over the life of the project.

1. **Annual power washing of LPS to ensure maximum light penetration (2013-2023).** The City will monitor algae growth and accumulations of dirt or other materials on the LPS and periodically clean the top and/or bottom surfaces. Currently, it is estimated that power washing will occur once per year between July 16 and February 15, and comply with all applicable permits. Optimal timing to allow the most light penetration through the LPS will be immediately before Chinook salmon outmigration, in February, each year. If monitoring indicates algae growth or other materials substantially impair light penetration and accumulation/occlusion occurs much more quickly, the City will conduct power washing twice during the year.

2. **Nourishment of loose substrate on benches and at substrate enhancement locations.** It is predicted that the loose substrate on the habitat benches and substrate enhancement

material (pea gravel and shell hash), while sized to be optimum for salmonid prey species and juvenile crab settlement, will be scoured by wave and vessel propeller action along the seawall; thus, the material will require periodic re-nourishment. Currently, it is estimated that this re-nourishment will occur on a 10-year interval throughout the life of the project. It is estimated that up to 10,000 yd^3 of new replacement substrate material would need to be placed on the habitat benches and up to 300 yd^3 of pea gravel and shell hash on the substrate enhancement locations. The material placement will occur by barge between October 1 to February 15 and comply with all applicable permits.

1.2.1.6 Monitoring, Maintenance and Adaptive Management

A Post-Construction Monitoring and Adaptive Management Plan will be implemented to assess the success of the project's nearshore habitat enhancement features in meeting project objectives, inform future restoration project design, and identify if any adaptive management actions are warranted. The nearshore habitat enhancement is designed to create an effective intertidal migratory corridor for juvenile salmonids, and enhance the marine nearshore ecosystem quality and function.

Habitat improvement measures were incorporated into the project to address the current degraded condition of the nearshore ecosystem. The habitat measures will be monitored and changes may be needed to make sure they meet project objectives.

Monitoring and adaptive management measures will be incorporated into the project to meet the following objectives and restoration targets:

1) Create an effective intertidal migratory corridor for juvenile salmonids.

    a. Increase illumination behind piers and below cantilevered sidewalks to increase light levels within the proposed intertidal corridor during daylight hours, and diminish light/dark transitions.

    b. Create a continuous intertidal corridor at appropriate depth (approximately 0 feet MLLW) for juvenile salmon migration along the entire length of the project.

    c. Achieve colonization of the loose substrate habitat benches and Zone 1 bench/beach by salmonid prey species.

    d. Observe statistical increase in presence of juvenile salmonids within the intertidal migratory corridor.

2) Enhance the marine nearshore ecosystem of Elliott Bay.

    a. Increase invertebrate and algal density and diversity on the shelves and textured seawall face panels.

b. Provide sufficient illumination to allow macroalgae to grow underneath the cantilevered sidewalk and behind piers and also increase invertebrate diversity and density.

c. Provide suitable substrate for crab and other invertebrate colonization on the substrate enhancement sites.

d. Provide sustainable riparian zone on upper area of Zone 1 beach/bench.

e. Provide increased terrestrial insect input in areas of riparian vegetation.

f. Increase kelp distribution and density.

Monitoring methods include:

1) Light-level monitoring – Monitoring will occur monthly from February through October in Years 1, 2, and 3 following construction. Data will be collected by portable light sensors and continuous-recording loggers.

2) Corridor physical characteristics – Cross-section surveys and substrate sampling will occur to evaluate physical changes of the intertidal habitat bench corridor and the Zone 1 beach. Three cross-section elevation surveys will be conducted across the expanded benches. Surveys will be conducted monthly during the first year after construction to document frequent changes. In Years 3, 5, and 10 following construction, the surveys will be conducted once per year during August.

3) Invertebrate Colonization of Benches and Beach – Benthic and epibenthic invertebrate samples will be collected monthly from March through August in Years 1, 3, and 5 after construction.

4) Salmon Presence and Behavior – Land-based and water-based methods will be used in Years 1, 2, 3, 5, and 10 following construction to determine salmon presence and behavior. Snorkeling will be conducted three times per month and SCUBA once per month from February through October. Land-based visual surveys will be conducted twice per month from February through October.

5) Invertebrate/Algal Attachment on Seawall – Quadrat and epibenthic sampling will occur on the seawall shelves and fins. Sampling will occur once per month in April, June, and August in Years 1, 3, 5, and 10 following construction.

6) Macroalgae Growth Under Light Penetrating Surfaces – Quadrat sampling with visual scanning and identification of algae will be conducted once per month in April, June, and August in Years 1, 3, 5, and 10 following construction.

7) Invertebrate Colonization on Substrate Enhancement – Epibenthic sampling will be conducted in September during Years 1, 3, and 5 following construction.

8) Riparian Vegetation Density and Cover at Zone 1 Beach – Photos will be taken (at permanent photo points) during the peak growing season (estimated to be August) and sampling conducted in permanent circular plots in Years 1, 3, 5, and 10 following construction.

9) Terrestrial Insect Input from Riparian Vegetation – Fall-out traps will be installed twice monthly from February through October during Years 1, 3, and 5 following construction.

10) Kelp Distribution and Density – Visual observation of bull kelp distribution and density will be conducted via boat in August in Years 1, 3, and 5 following construction.

Monitoring will determine whether project goals and objectives are being met. Thresholds have been set that will trigger adaptive management actions to evaluate project design, operation and maintenance activities to determine whether additional actions should be undertaken to meet project thresholds. The following adaptive management thresholds have been developed:

1) Corridor Stability and Persistence – Habitat benches and the Zone 1 beach are expected to require periodic maintenance via the renourishment of the loose surface substrate (2.5 in minus crushed rock) material at least once every 10 years. If the evaluation of cross-sections on the benches and/or beach shows 2 feet of erosion at any sampling location within 5 years (and was not specifically due to a storm at or above the design storm event), the City will evaluate a change in material sizing and the potential need for reconfiguration of the bench (such as installation of a larger "lip" at the outer edge of the benches to retain material) or beach.

   The marine mattresses are expected to require periodic maintenance via repair of grid and installation of additional cobble material if elevation declines by more than 2 feet due to loss of material. If more than 2 feet of elevation change occurs within 10 years or other damage is compromising the stability of the mattresses, the City will evaluate repair options.

2) Salmon Migration at Piers - There is no light threshold known at this time to trigger or assist salmon in migrating under piers. The target for illumination is to substantially reduce light/dark transitions at pier margins and to encourage juvenile salmonids to migrate behind the piers and under the cantilevered sidewalk. If the light monitoring indicates that no substantial difference can be observed between salmon behavior at pier margins from the pre-construction condition and salmon are generally not observed behind the piers, it can be assumed that the LPS has not positively benefitted migration through and behind pier structures. Due to the width of most of the piers on the waterfront, it will be difficult to immediately determine if the pier width/structural characteristics or total number of piers is the primary issue or if insufficient illumination is the primary issue.

   The City will evaluate options to tease out details on pier width and structure versus total light levels by increasing monitoring at additional piers. The City will also consider options to increase illumination behind or under piers such as the installation of reflective materials under piers or sidewalk, grating or other LPS on pier decking in partnership with pier owners, or the potential for narrowing piers or opening up portals in the nearshore. If it is

ultimately determined that the pier structure or width and/or total number of piers along the waterfront are more correlated with fish behavior than light levels, the City will determine that illumination will not be successful in changing salmonid behavior and will evaluate the potential opportunities with pier owners for reducing pier widths or opening up portals in the nearshore area.

The City will also monitor artificial light issues due to street, pedestrian, and safety lighting above the LPS. Light levels and fish behavior will be monitored. If it is determined that artificial lighting is causing fish behavior issues, the City will determine if artificial lighting can be directed away from the LPS.

3) Invertebrate Colonization of Benches - The invertebrate species density and distribution will be compared to reference sites. If the invertebrate species density and distribution on the enhanced expanded bench areas (Zones 3, 4, and 6) are not statistically similar to the reference benches (i.e., Olympic Sculpture Park) within 5 years of construction, or if they are statistically different by approximately 30 percent of the reference benches under the cantilevered sidewalk, the City will evaluate options such as a change in material sizing, to promote better invertebrate colonization. Similarly, if the benthic invertebrate species density and distribution on the Zone 1 beach area are statistically lower to the reference beach at Olympic Sculpture Park within 5 years of construction, the City will identify the reasons for this potential difference, such as public use, stability of beach material, etc. to help formulate adaptive management actions.

4) Salmon Presence and Behavior (Non-pier Areas) - Salmon presence, distribution, and behavior between the piers and the expanded bench areas will be compared to reference sites and baseline monitoring from the seawall to determine if salmon are using the intertidal benches and feeding at similar or greater levels based on total numbers observed by location and total behavioral categories. If there is a statistical similarity in the presence or beneficial behaviors associated with the benches on average along the seawall as compared to the reference sites, this objective will have been met. If there is no difference in use or greater use offshore as compared to the reference sties, the City will evaluate the reasons why this could be occurring. Additional monitoring could be considered to determine if shading of the sidewalk is a factor, or if there are other factors contributing to greater offshore use. The City will implement adaptive management measures, which could include changing the elevation of the bench or the potential for increased illumination of the bench, as feasible.

5) Textured Seawall - Sampling of invertebrate and algal attachment to the textured wall and shelves/fins will be evaluated in comparison to pre-construction conditions and literature to identify if increased attachment/use is occurring. If the textured panels are statistically similar to the pre-construction conditions and literature, this objective will have been met. If there is no difference between textured and flat vertical seawalls, the City will consider adding additional features to the seawall to promote attachment.

6) Macroalgae Under LPS - The City intends to provide ongoing maintenance of the LPS to remove algal growth and dirt to allow light penetration. It is anticipated that this would occur annually immediately prior to the salmonid outmigration and start of the growing

season (i.e., early February) and be conducted via power-washing or similar effective methods. Based on the light-level monitoring, if it is determined that algal growth or other dirt accumulations beneath the LPS are occurring more quickly and light penetration is not effective all year, additional cleaning would occur, such as in July, to ensure that light is penetrating as designed. The macroalgae density will be compared to unshaded reference sites. If macroalgae density is at least 30 percent as dense under the cantilevered sidewalk (between piers) and 15 percent as dense behind piers, this objective will have been met. If macroalgae is less dense, the City will evaluate what factors are preventing growth, whether it is light penetration, substrate size, or other factors, and will consider appropriate adaptive management actions such as material sizing changes. Ultimately, if it is determined that the lack of growth is due to the lack of light penetration, the City will evaluate whether additional illumination can be provided or if it should be deemed impractical with current technology.

7) Invertebrate Colonization on Substrate Enhancement - It is anticipated that enhancement material will sink into the existing silty/shell hash substrate or be distributed via wave action and require periodic replacement approximately once every 10 years. The epibenthic species and density will be compared to adjacent reference sites, and if there is a statistically significant difference in species type or increased density on the substrate enhancement patches, this objective will have been met. If there is not a statistically significant difference, the City will determine whether it is appropriate to consider different-sized substrate. If the material appears to be eroding more quickly and distributed in less than 10 years due to wave action, the City will consider whether larger material would be appropriate.

8) Riparian Zone Cover - Riparian zone cover should be maintained at 80 percent cover (total for all strata) to provide a natural riparian zone and function. Within 3 years following construction, if 80 percent cover is not achieved, or if in subsequent monitoring years the 80 percent cover is reduced, the City will consider actions such as fencing or replantings to ensure that 80 percent cover is maintained.

9) Terrestrial Insect Input - If there is statistical similarity in insect taxa or total abundance at the Zone 1 beach after 5 years as compared to the reference site, this metric will have been met. If there is a statistical difference, the City will consider the potential for additional riparian vegetation.

10) Kelp Distribution and Density - If there is at least a 10 percent increase in kelp distribution and/or density along the entire seawall, this objective will have been met. If this increase is not met, the City will consider whether placement of additional substrate for kelp attachment is warranted, or if wave action or vessel action is inhibiting growth. Additionally, if kelp increase is so great that interference with navigation is identified, the City will consider removal of substrate in key areas

1.2.1.7 Minimization Measures and Best Management Practices

A variety of minimization measures and best management practices (BMPs) will be implemented prior to or during construction to avoid, reduce, or minimize the potential for direct and indirect

effects of the project. These measures are designed to reduce or eliminate disturbance, turbidity, resuspension of contaminants, removal of biota, noise, debris falling into the water, and fish stranding.

Measures and Practices that will be employed during construction include:

- Develop and implement a stormwater pollution and prevention plan during construction.

- Comply with water quality standards and monitoring requirements (such as from Water Quality Certification) for turbidity, pH, etc. Turbidity monitoring will occur at 50 and 150 feet.

- Confine in-water work activities to between September 1 through March 1. In-water work includes all activities exposed to the open water of Elliott Bay. It does not pertain to activities conducted landward of the temporary containment wall, even though water may be present.

- Install a temporary containment wall to isolate Elliott Bay from the construction work zone to reduce turbidity, re-suspension of contaminants, and reduce noise during impact pile driving of concrete pilings[1].

- Leave the final segment of the containment wall open to first allow the tide to recede naturally and encourage fish to swim out, then sweep with nets to push the majority of remaining fish out into Elliott Bay beyond the wall prior to fully closing to reduce fish stranding and reduce fish handling.

- Temporarily dewater behind containment wall as feasible (or conduct at low tide) to conduct fish salvage behind the containment wall and release fish out into Elliott Bay beyond the wall.

- Filling or plugging voids or holes in the existing seawall prior to beginning soil stabilization activities, as feasible.

- Directing jets away from the existing seawall during installation of the first row of jet grout columns (the furthest westward jet grout columns) to reduce the velocity of grout directed towards the wall face to minimize any leakage of grout.

- Visual monitoring of the area between the existing seawall and the containment wall for any releases during soil stabilization activities. If a release is identified, work would stop until the void/hole is filled.

[1] While the temporary containment wall may serve as an attenuation measure during the driving of the permanent concrete pilings; similar to results reported for coffer dams (Caltrans 2007, 2009); for the purposes of this consultation, all distances to thresholds are reported for unattenuated pile driving.

- Implement additional use of turbidity curtains to reduce impacts to water quality in Elliott Bay from release of contaminants and turbidity once the containment wall is constructed. The turbidity curtain will act as a second barrier if a complete seal cannot be maintained on the containment wall.

- Treat stormwater and process water runoff from the construction zones prior to discharge to either Elliott Bay or the King County sewer system.

- Minimize the removal of riprap to avoid removing associated biota, reduce turbidity, and avoid resuspension of contaminants.

- Employ vibratory pile-driving equipment to reduce sound levels to below fish-injury thresholds and use sound attenuation measures, as feasible, for impact driving of concrete piles.

- During all in-water pile-related activities, ramp-up techniques would be used at the beginning of each day's in-water pile-related activities or if pile driving has ceased for more than 1 hour.

- Monitor for the presence of marine mammals and follow MMPA authorization monitoring or other requirements for temporary shutdowns when any marine mammals enter the exclusion zone, or other measures.

- Install netting and/or tarping to catch any falling debris from entering the water from over-water activities (e.g., sidewalk removal and installation).

- Use only clean and coarse materials and place via bucket close to the substrate surface to minimize sediment resuspension where material will be placed in-water (e.g., habitat benches). Fill material quantities have been optimized during design to minimize fill while maximizing habitat area and function.

- The City will comply with all permit conditions issued by resource agencies for the project.

- Barge BMPs

    - Barges will be positioned at approximately -20 feet MLLW, which will minimize nearshore propeller wash and avoid impacts to macroalgae.

    - Barges will not be allowed to ground out during construction.

BMPs that will be employed for operation and maintenance activities include:

- Stormwater treatment facilities will be maintained throughout the life of the project. Maintenance includes inspecting at least annually and as needed after major storms or other events that may result in the stormwater treatment facility not operating as

designed. Cleaning, repair and filter changes will be completed as needed based on inspection results.

- Confine in-water work activities to the approved designated work window (October 1 through February 15).

- Placement of beach or bench nourishment material will be placed in the dry at low tides to the extent feasible.

- Placement of beach or bench nourishment below MLLW will use a sediment or turbidity curtain.

1.2.2 <u>NMFS Proposed Issuance of a Letter of Authorization</u>

The NMFS is proposing to issue a 5-year LOA under Section 101(a)(5)(A) of the MMPA for the above identified City project. In order to issue the LOA, NMFS proposed to set forth the permissible methods of taking pursuant to the activity, and other means of affecting the least adverse impact practicable on such species or stock, and its habitat. NMFS must also set forth requirements pertaining to the monitoring and reporting of such taking that will result in increased knowledge of the species and of the level of taking or impacts on populations of marine mammals that are expected to be present. The Federal Register published NMFS's Notice of intent to issue the LOA on April 12, 2013 (78 FR 22095). The notice included a description of proposed mitigation and monitoring measures as presented below:

a) Limited Impact Pile Driving – All sheet piles would be removed and installed using a vibratory driver, unless impact driving is required to install piles that encounter consolidated sediments or for proofing load bearing sections. Any impact driving used in conjunction with vibratory pile driving would employ attenuation measures such as a cushioning block, where applicable. Any attenuation measures that become available for vibratory pile driving would also be considered for the proposed project.

    1) Containment of Impact Pile Driving - The majority of permanent concrete piles would be driven behind the temporary containment wall that would function as a physical barrier to partially attenuate pile driving noise. Estimated noise-reduction values are not readily available for this attenuation type; however, it has been shown that the use of cofferdams, which are analogous to the temporary containment wall, is effective at reducing noise up to 10 dB (Caltrans, 2009).

    2) Additional Attenuation Measures - Other attenuation measures such as bubble curtains may be employed as necessary to reduce sound levels. While bubble curtains were considered, they are not being proposed due to the potential for resuspension of contaminated materials and/or existing sediment caps. However, in some locations they could be feasible for the concrete pile driving and would be considered if sound levels are measured higher than what is shown in the sound analysis. In the event that underwater sound monitoring shows that noise

generation from pile installation exceeds the levels originally expected, the implementation of additional attenuation devices would be re-evaluated.

3) Ramp-up - The objective of a ramp-up is to alert any animals close to the activity and allow them time to move away, which would expose fewer animals to loud sounds, including both underwater and above water sound. This procedure also ensures that any animals missed during monitoring within the exclusion zone would have the opportunity to move away from the activity and avoid injury. During all in-water pile-related activities, ramp-up would be used at the beginning of each day's in-water pile-related activities or if pile driving has ceased for more than 1 hour. If a vibratory driver is used, contractors would be required to initiate sound from vibratory hammers for 15 seconds at reduced energy followed by a 1-minute waiting period. The procedure would be repeated two additional time before full energy may be achieved. If a non-diesel impact hammer is used, contractors would be required to provide an initial set of strikes from the impact hammer at reduced energy, followed by a 1-minute waiting period, then two subsequent sets. The reduced energy of an individual hammer cannot be quantified because they vary by individual drivers. Also, the number of strikes would vary at reduced energy because raising the hammer at less than full power and then releasing it results in the hammer 'bouncing' as it strikes the pile, resulting in multiple strikes.

b) Marine Mammal Exclusion Zones – The purpose of an exclusion zone is to prevent the potential to injure all marine mammals (180 and 190 dB_{RMS}[2] [re: 1μPa] acoustic injury criteria for cetaceans and pinnipeds, respectively) and to reduce the potential to disturb a large whale by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering. Table 2 shows the established exclusion or shutdown zones.

Table 2 – Established exclusion zone thresholds in which all pile driving activities will stop if thresholds are exceeded.

Taxa[1]	**Threshold or Zone Location (radius distance from point-source pile-related noise)**	**Pile Work Type**	**Pile Type**

[2] RMS – Root mean square. Throughout this document, the reference value for dBrms pressure is 1 μPa.

Exclusion Zone Thresholds (stop-work order will be issued if threshold is crossed)			
Pinnipeds & small cetaceans	50 feet (15 meters)	Impact	Concrete
Pinnipeds & small cetaceans	200 feet (61 meters)	Impact	Steel sheet
Large cetaceans (Level B)	3,280 feet[1] (1,000 meters)	Impact	Steel sheet & concrete
Large cetaceans (Level B)	2.5 miles[2] (3,981 meters)	Vibratory	Steel sheet

1 Large cetaceans include killer whales and all balaenoptera whales; small cetaceans include all porpoises.

2 Distance represents both an exclusion threshold and Level B threshold for large cetaceans, but is not expected to represent a Level A injury threshold; this conservative exclusion threshold was established by NMFS to minimize behavioral “take” of large cetaceans to ensure each stock bears no more than a “negligible impact.”

Temporary buoys would be used, as feasible, to mark the distance to the exclusion zones. These zones are intended to provide a physical threshold for a stop-work order for in-water pile-related activities if a marine mammal nears the proposed work area. At the start of in-water pile-related construction each day, a minimum of one qualified protected species observer would be staged on land (or an adjacent pier) near the location of in-water activities to document any marine mammal that approaches the exclusion zones. Additional land-based observers would be deployed if needed to ensure the construction area is adequately monitored. Land-based monitoring would occur throughout each day of active pile-related activities.

If a marine mammal is sighted approaching the work area, protected species observers would immediately notify the construction personnel operating the pile-related equipment of the direction of travel and distance relative to the exclusion zones. A stop-work order would be triggered if any marine mammal enters an exclusion zone, regardless of observed behavior. SDOT’s proposed exclusion zones would minimize injurious impacts from increased sound exposures among all marine mammals, and would prevent take of large whales. The exclusion zones must not be obscured by fog or poor lighting conditions in order for in-water pile-related activities to begin/continue.

c) Shutdown and Delay Procedures - If a marine mammal is seen approaching or entering an exclusion zone, observers would immediately notify the construction personnel operating the pile-related equipment to shutdown pile-related activities. If a marine mammal is present within the applicable exclusion zone prior to in-water pile-related activities, pile driving/removal would be delayed until the animal has left the exclusion zone or until 15 minutes have elapsed without observing the animal.

d) Visual Monitoring - In addition to the mitigation monitoring described in the Marine Mammal Exclusion Zones section above (See Section 1.2.2, b), a minimum of two protected species observers would be positioned on land at the north and sound ends of Elliott Bay near the 2.5 mile exclusion zone to monitor for marine mammals during vibratory pile-related activities or any other construction activities that may pose a threat to marine mammals moving through the area. These observers would have no other responsibilities while on station. Observers would also be responsible for recording the location of all marine mammal sightings and logging information onto marine mammal sighting forms. Observers would use the naked eye, wide-angle binoculars with reticles, and spotting scopes to scan the area around their station. SDOT proposes to employ this monitoring every day during which vibratory pile driving occurs.

Each observer would work a maximum of 8 hours per day and would be relieved by a fresh observer if pile driving occurs over a longer day (i.e., 12 or 16 hours). The number of observers would be increased and/or positions changed to ensure full visibility of the area. All monitoring would begin at least 30 minutes prior to the start of in-water pile-related activities and continue during active construction. At a minimum, observers would record the following information:

- Date of observation period, monitoring type (land-based/boatbased), observer name and location, climate and weather conditions, and tidal conditions;
- Environmental conditions that could confound marine mammal detections and when/where they occurred;
- For each marine mammal sighting, the time of initial sighting and duration to the end of the sighting period;
- Observed species, number, group composition, distance to pile-related activities, and behavior of animals throughout the sighting;
- Discrete behavioral reactions, if apparent;
- Initial and final sighting locations marked on a grid map;
- Pile-related activities taking place during each sighting and if/why a shutdown was or was not triggered; and
- The number of takes (by species) of marine mammals, their locations, and behavior.

e) Acoustic Monitoring - SDOT would conduct acoustic monitoring during pile-related in-water work. The purpose of this monitoring would be to identify or confirm noise levels for pile-related work during in-water construction. Collection of acoustic data would be accomplished from both a drifting boat to reduce the effect of flow noise, and attached on or adjacent to piers located at 10 meters from the pile source. All acoustical recordings would be conducted 1 meter below the water surface and 1 meter above the sea floor. Background noise recordings (in the absence of pile driving) would also be made to provide a baseline background noise profile. The results and conclusions of the study would be summarized and presented to NMFS with recommendations for any modifications to the monitoring plan or exclusion zones.

Underwater hydrophones and an airborne microphone would be used for acoustic recordings. All sensors, signal conditioning equipment, and sampling equipment would be calibrated at the start of the monitoring period and rechecked at the start of each day. A stationary two-channel hydrophone recording system would be deployed to record a representative sample (subset of piles) during the monitoring period. Prior to monitoring, water depth measurements would be taken to ensure that hydrophones do not drag on the

bottom during tidal changes. One hydrophone would be placed at mid-depth and the other would be placed closer to the bottom (70 percent to 85 percent of the water depth). The depth with respect to the bottom may vary due to tidal changes and current effects since the hydrophones may be supported from a floating platform.

Appropriate measures would be taken to eliminate strumming of the hydroacoustic cable in the current and minimize flow noise over the hydrophones. There would be a direct line of acoustic transmission through the water column between the pile and the hydrophones in all cases, without any interposing structures, including other piles. At least one stationary land-based microphone would be deployed to record airborne sound levels produced during pile installation and removal. The microphone would measure far-field airborne sounds. A sound level meter with microphone would be located in the near-field if logistical and security constraints allow for the collection of near-field source level measurements. Near-field measurements would not be continuous and would be used to identify which sound sources are making significant contributions to the overall noise levels measured at the shoreline microphones. Specific locations would be determined by ease of access (terrain restrictions and presence of a road) and security permission. The microphone will be calibrated at the beginning of each day of monitoring activity.

To empirically verify the modeled behavioral disturbance zones, underwater and airborne acoustic monitoring would occur for the first five steel sheet pile and the first five concrete piles during the duration of pile driving. If a representative sample has not been achieved after the five piles have been monitored (e.g., if there is high variability of sound levels between pilings), acoustic monitoring would continue until a representative acoustic sample has been collected. Post-analysis of underwater sound level signals would include the following:

- RMS values (average, standard deviation/error, minimum, and maximum) for each recorded pile. The 10-second RMS averaged values will be used for determining the source value and extent of the 120 dB underwater isopleth;
- Frequency spectra for each functional hearing group; and
- Standardized underwater source levels to a reference distance of 10 meters (33 feet).

Post-analysis of airborne noise would be presented in an unweighted format and include:

- The unweighted RMS values (average, minimum, and maximum) for each recorded pile. The average values would be used for determining the extent of the airborne isopleths relative to species-specific criteria;
- Frequency spectra from 10 Hz to 20 kHz for representative pile-related activity; and

- Standardized airborne source levels to a reference distance of approximately 15 meters (50 feet).

It is intended that acoustic monitoring would be performed using a standardized method that would facilitate comparisons with other studies. Real-time monitoring of noise levels during in-water pile-related activities would ensure sound levels do not surpass analyzed estimated levels. In the event noise does surpass estimated levels for extended periods of time, construction would be stopped and NMFS would be contacted to discuss the cause and potential solutions.

f) Reporting - All marine mammal sightings would be documented by observers on a NMFS-approved sighting form. Takes of marine mammals would be recorded for any individual present within the area of potential effects. Marine mammal reporting would include all data described previously under Proposed Monitoring, including observation dates, times, and conditions, and any correlations of observed marine mammal behavior with activity type and received levels of sound, to the extent possible.

SDOT would also submit a report(s) concerning the results of all acoustic monitoring. This report(s) would include:

- Size and type of piles;
- A detailed description of any sound attenuation device used, including design specifications;
- The impact hammer energy rating used to drive the piles, make and model of the hammer(s), and description of the vibratory hammer;
- A description of the sound monitoring equipment;
- The distance between hydrophones and depth of water and the hydrophone locations;
- The depth of the hydrophones;
- The distance from the pile to the water's edge;
- The depth of water in which the pile was driven;
- The depth into the substrate that the pile was driven;
- The physical characteristics of the bottom substrate into which the pile were driven;
- The total number of strikes to drive each pile;

- The results of the hydroacoustic monitoring, including the frequency spectrum, ranges and means for the peak and RMS sound pressure levels, and an estimation of the distance at which RMS values reach the relevant marine mammal thresholds and background sound levels. Vibratory driving results would include the maximum and overall average RMS calculated from 30-s RMS values during the drive of the pile;

- A description of any observable marine mammal behavior in the immediate area and, if possible, correlation to underwater sound levels occurring at that time.

g) Annual Reports - The annual reports would summarize information presented in the weekly reports and include data collected for each distinct marine mammal species observed in the project area, including descriptions of marine mammal behavior, overall numbers of individuals observed, frequency of observation, and any behavioral changes and the context of the changes relative to activities would also be included in the annual reports. Additional information that would be recorded during activities and contained in the reports include: date and time of marine mammal detections, weather conditions, species identification, approximate distance from the source, and activity at the construction site when a marine mammal is sighted.

h) Comprehensive Final Report - SDOT would submit a draft comprehensive final report to NMFS 180 days prior to the expiration of the regulations. This comprehensive technical report would provide full documentation of methods, results, and interpretation of all monitoring during the first 4.5 years of the regulations. A revised final comprehensive technical report, including all monitoring results during the entire period of the regulations, would be due 90 days after the end of the period of effectiveness of the regulations.

i) Adaptive Management - The final regulations governing the take of marine mammals incidental to the specified activities at Elliott Bay would contain an adaptive management component. In accordance with 50 CFR 216.105(c), regulations for the proposed activity must be based on the best available information. As new information is developed, through monitoring, reporting, or research, the regulations may be modified, in whole or in part. The use of adaptive management would allow NMFS to consider new information from different sources to determine if mitigation or monitoring measures should be modified (including additions or deletions) if new data suggest that such modifications are appropriate. The following are some of the possible sources of applicable data:

    - Results from SDOT's monitoring from the previous year;

    - Results from general marine mammal and sound research; or

    - Any information which reveals that marine mammals may have been taken in a manner, extent, or number not authorized by these regulations or subsequent LOAs.

If, during the effective dates of the regulations, new information is presented from monitoring, reporting, or research, these regulations may be modified, in whole or in part, as allowed for in 50 CFR 216.105(c). In addition, LOAs would be withdrawn or suspended if, NMFS finds, among other things, that the regulations are not being substantially complied with or that the taking allowed is having more than a negligible impact on the species or stock, as allowed for in 50 CFR 216.106(e). That is, should substantial changes in marine mammal populations in the project area occur, or monitoring and reporting show that project actions are having more than a negligible impact on marine mammals, then NMFS reserves the right to modify the regulations and/or withdraw or suspend LOAs.

1.3 Action Area

The action area is defined as the geographical extent of project impacts and not merely the immediate area directly adjacent to the action. The action area includes the project footprint and all surrounding areas where project activities could potentially affect the environment. The extent of the action area encompasses direct and indirect effects, as well as any effects of interrelated or interdependent actions.

The action area was determined based on the anticipated sound pressure levels generated both above water and in-water during construction (impact and vibratory pile driving). The measures of the farthest-reaching effects are: 1) the distance that underwater sound generated by the action intersects with a land mass or where it attenuates to background levels, and 2) the areas that the above water sound attenuates to background levels (Figure 11). The Services assume that sound travels in a straight line and is absorbed by land and does not reflect or bend.

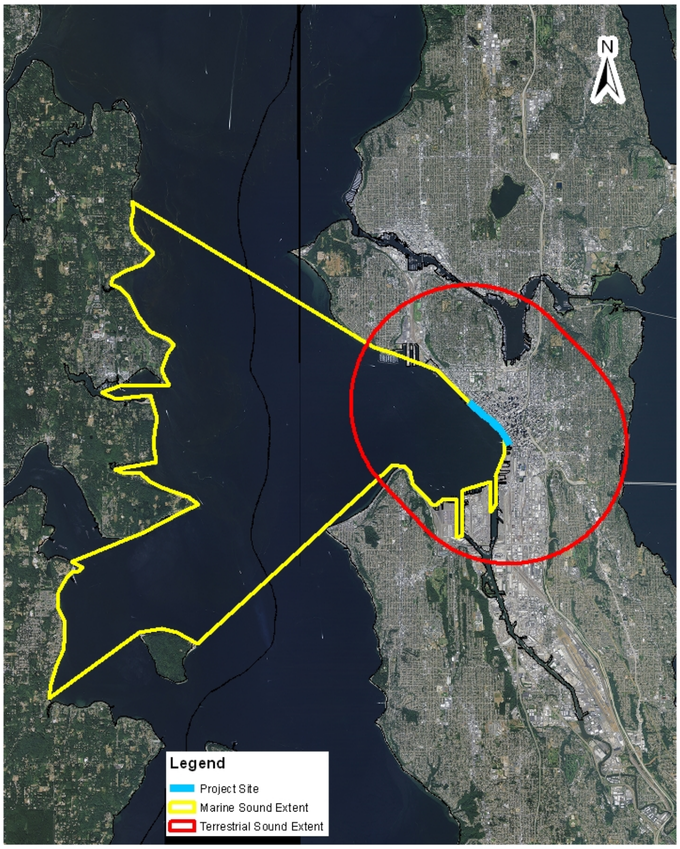

Figure 11 – Project action area.

Temporarily elevated sound pressure levels (SPLs) resulting from impact sheet pile installation are expected to have the farthest reaching effects in both the aquatic and terrestrial environment. To estimate the in-water geographic area in which measureable effects to listed species may occur, the distance at which transmission loss (TL) attenuates to sound pressures below specified thresholds are determined. Calculating TL is extremely complicated, and is influenced by site-specific conditions. A practical spreading model, as described by Davidson (2004, p. 2) [TL = 15*Log(R)] is used to estimate the distances at which injury and behavioral disruption to listed species are expected. This model assumes that underwater SPLs decrease at a rate of 4.5 dB per doubling distance.

The in-water action area is defined as the radius within which underwater sound levels generated by pile driving and removal exceed the marine mammal disturbance thresholds of 120 dB_{RMS} for vibratory pile driving. Using the practical spreading loss model for transmission, sound from vibratory driving and removal will not attenuate to 120 dB_{RMS} prior to the sound being absorbed by land at Bainbridge Island. The extent of the action area is therefore defined as the marine environments of Elliott Bay and Puget Sound east of Bainbridge Island from Skiff Point south to Blake Island. The extent of the action area is approximately 41 mi^2 (106.2 km^2).

Similarly, the above-water geographic area for the action area uses the spherical loss model which for a point source of noise is a 6 dB reduction per doubling of distance for hard sites (WSDOT 2013). Impact pile driving will result in the greatest noise levels during project construction. Impact pile drivers result in a 110 dB in-air noise level at 50 feet. The ambient sound levels measured along the seawall was 75 dB along the Central Seawall (Phase 1) and 65 dB along the North Seawall (Phase 2, SDOT 2012a). Project related in-air sound is expected to attenuate to ambient sound levels (65 dB) within approximately 12,800 feet (approximately 2.5 mi) across the water. However, the topography of the surrounding area, especially the downtown Seattle area, has steep hills and tall buildings that will greatly reduce the distance increased sound levels will travel landward of the project site.

The action area is within designated critical habitat for Puget Sound Chinook salmon. Juvenile Chinook salmon from mainly the Green/Duwamish River and the Skykomish River use the action area to forage and rear, both are considered Tier 2 populations. Southern Resident killer whale (*Orcinus orca*), Humpback whale, Steller sea lion, bull trout, and listed rockfishes also use portions of the action area.

2.0 ENDANGERED SPECIES ACT: BIOLOGICAL OPINION

Section 7(a)(2) of the ESA requires Federal agencies to consult with the Services to ensure that their actions are not likely to jeopardize the continued existence of endangered or threatened species or adversely modify or destroy their designated critical habitat. To jeopardize the continued existence of a listed species means to engage in an action that would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species (50 CFR 402.02). This Opinion does not rely on the regulatory definition of 'destruction or adverse modification' of critical habitat at 50 CFR 402.02. Instead, we have relied upon the statutory provisions of the ESA to complete the following analysis with respect to critical habitat (Hogarth 2005).

The Opinion included below records the results of the consultation. Section 7(b)(4) requires the provision of an ITS that specifies the impact of any incidental taking and includes reasonable and prudent measures to minimize such impacts. The ITS follows the Opinion in this document.

2.1 Analytical Approach

This Opinion presents the results of the Services' consultation with the COE regarding whether the proposed action will jeopardize listed species or adversely modify or destroy their designated critical habitat. For the jeopardy analysis, the Services reviewed the status of species, the environmental baseline in the action area, the effects of the action, and cumulative effects (50 CFR 402.14(g)). From this assessment, the Services discern whether effects on individual animals in the action area are meaningful enough, in view of existing risks, to appreciably reduce the likelihood of the survival and recovery of the affected listed species.

For the critical habitat analysis, the Services consider the status of critical habitat, the functional condition of critical habitat in the action area (environmental baseline), the likely effects of the

action on that level of function, and the cumulative effects. From this assessment, the Services discern whether any predicted change in the function of the PCEs of critical habitat in the action area would be enough, in view of existing risks, to appreciably reduce the conservation value of the critical habitat at the designation scale. This analysis does not employ the regulatory definition of "destruction or adverse modification" at 50 CFR 402.02. Instead, this analysis relies on statutory provisions of the ESA, including those in section 3 that define "critical habitat" and "conservation," in section 4 that describe the designation process, and in section 7 that set forth the substantive protections and procedural aspects of consultation, and on agency guidance for application of the "destruction or adverse modification" standard (Hogarth 2005).

2.2 Rangewide Status of the Species and Critical Habitat

This section describes the current status and limiting factors affecting the conservation of ESA-listed species occurring within the project action area. Those species facing a high risk of extinction are more vulnerable to the aggregate effects of existing degraded conditions, new effects imposed by a proposed action, and the cumulative effects of future local, state, and federal actions.

2.2.1 Status of the Species

2.2.1.1 Chinook Salmon

This Evolutionarily Significant Unit (ESU) was listed as a threatened species in1999; its threatened status was reaffirmed in 2005. The NMFS issued results of a five-year review on August 15, 2011 (76 FR 50448), and concluded that this species should remain listed as threatened.

The NMFS adopted the recovery plan for Puget Sound Chinook on January 19, 2007 (72 FR 2493). The recovery plan consists of two documents: the Puget Sound Salmon Recovery Plan prepared by the Shared Strategy for Puget Sound and NMFS' Final Supplement to the Shared Strategy Plan. The recovery plan adopts ESU and population level viability criteria recommended by the Puget Sound Technical Recovery Team (PSTRT) (Ruckelhaus et al. 2002). The PSTRT's Biological Recovery Criteria will be met when the following conditions are achieved:

1. All watersheds improve from current conditions, resulting in improved status for the species;

2. At least two to four Chinook salmon populations in each of the five biogeographical regions of Puget Sound attain a low risk status over the long-term;

3. At least one or more populations from major diversity groups historically present in each of the five Puget Sound regions attain a low risk status;

4. Tributaries to Puget Sound not identified as primary freshwater habitat for any of the 22 identified populations are functioning in a manner that is sufficient to support an ESU-wide recovery scenario;

5. Production of Chinook salmon from tributaries to Puget Sound not identified as primary freshwater habitat for any of the 22 identified populations occurs in a manner consistent with ESU recovery.

Spatial Structure and Diversity. The PSTRT determined that 22 historical populations currently contain Chinook salmon and grouped them into five major geographic regions, based on consideration of historical distribution, geographic isolation, dispersal rates, genetic data, life history information, population dynamics, and environmental and ecological diversity. Ruckelshaus et al. (2002) recommended for the recovery of Chinook salmon at least two viable populations per geographic region. Based on genetic and historical evidence reported in the literature, the PSTRT also determined that there were 16 additional spawning aggregations or populations in the Puget Sound Chinook Salmon ESU that are now putatively extinct[3] (Ruckelshaus et al. 2006). This ESU includes all naturally spawned populations of Chinook salmon from rivers and streams flowing into Puget Sound including the Straits of Juan De Fuca from the Elwha River, eastward, including rivers and streams flowing into Hood Canal, South Sound, North Sound and the Strait of Georgia in Washington, and progeny of 26 artificial propagation programs. Indices of spatial distribution and diversity have not been developed at the population level, though diversity at the ESU level is declining. Abundance is becoming more concentrated in fewer populations and regions within the ESU. Abundance has increased particularly within the Whidbey Basin Region (Ford 2011).

Abundance and Productivity. Most PS Chinook populations are well below escapement levels identified as required for recovery to low extinction risk. All populations are consistently below productivity goals identified in the recovery plan. Although trends vary for individual populations across the ESU, most populations have declined in total natural origin recruit (NOR) abundance (prior to harvest) since the last status review. However, most populations exhibit a stable or increasing growth rate in natural-origin escapement (after harvest). No clear patterns in trends in escapement or abundance are evident among the five major regions of Puget Sound. No trend was notable for total ESU escapements. Trends in growth rate of natural-origin escapement are generally higher than growth rate of natural-origin abundance indicating some stabilizing influence on escapement from past reductions in fishing-related mortality. Survival and recovery of the Puget Sound Chinook salmon ESU will depend, over the long term, on necessary actions in all "4 H" sectors (hatcheries, habitat, harvest and hydro). Many of the habitat and hatchery actions identified in the PS Chinook salmon recovery plan are likely to take years or decades to be implemented and to produce significant improvements in natural population attributes, and these trends are consistent with these expectations and reiterated in Ford (2011).

Limiting factors. Limiting factors described in SSPS (2007) and NMFS (2011a) include:

- Degraded nearshore and estuarine habitat: Residential and commercial development has reduced the amount of functioning nearshore and estuarine habitat available for salmon rearing and migration. The loss of mudflats, eelgrass meadows, and macroalgae further limits salmon foraging and rearing opportunities in nearshore and estuarine areas.

- Degraded freshwater habitat: Floodplain connectivity and function, channel structure and complexity, riparian areas and large wood supply, stream substrate, and water quality have been degraded for adult spawning, embryo incubation, and rearing as a result of cumulative impacts of agriculture, forestry, and development.

[3] It was not possible in most cases to determine whether these Chinook salmon spawning groups historically represented independent populations or were distinct spawning aggregations within larger populations.

- Anadromous salmonid hatchery programs: Salmon and steelhead (*O. mykiss*) released from Puget Sound hatcheries operated for harvest augmentation purposes pose ecological, genetic, and demographic risks to natural-origin Chinook salmon populations.Salmon harvest management: Total fishery exploitation rates have decreased 14 to 63 percent from rates in the 1980s, but weak natural-origin Chinook salmon populations in Puget Sound still require enhanced protective measures to reduce the risk of overharvest.

2.2.1.2 Southern Resident Killer Whale

The Southern Resident (SR) killer whale Distinct Population Segment (DPS) was listed as endangered under the ESA on November 18, 2005 (70 FR 69903). Southern Residents are designated as depleted and strategic under the Marine Mammal Protection Act (May 29, 2003, 68 FR 31980). NMFS issued the final recovery plan for SR killer whales in January 2008 (NMFS 2008a).

Southern Resident killer whales are a long-lived species, with late onset of sexual maturity (NMFS 2008a). Mothers and offspring maintain highly stable social bonds throughout their lives, which is the basis for the matrilineal social structure in the SR killer whale population (NMFS 2008a). Groups of related matrilines form pods. Three pods – J, K, and L – make up the SR killer whale DPS. All SR killer whales are individually identified by photo-identification based on uniquely shaped and scarred dorsal fins and saddle patches (The Center for Whale Research unpubl. data).

Vocal communication is advanced in killer whales and is important to their social structure, navigation and foraging (NMFS 2008a). Southern Resident killer whales consume a variety of fish and one species of squid, but salmon, and Chinook salmon in particular, are their primary prey (Ford and Ellis 2006, Hanson et al. 2010).

Spatial Distribution and Diversity. The SR killer whale DPS is composed of a single population that ranges as far south as central California and as far north as Southeast Alaska. From late spring to early autumn, SR killer whales spend considerable time in the Salish Sea, with concentrated activity around the San Juan Islands and then move south into Puget Sound in early autumn. Pods make frequent trips to the outer coast during this time. Although the entire SR killer whale DPS has the potential to occur along the outer coast at any time during the year, occurrence along the outer coast is more likely from late autumn to early spring.

The estimated effective size of the population (based on the number of breeding individuals under ideal genetic conditions) is very small <30 whales or about 1/3 of the current population size (Ford 2011). The small effective population size, the absence of gene flow from other populations, and documented breeding within pods may elevate the risk from inbreeding and other issues associated with genetic deterioration (Ford 2011). In addition, the small effective population size may contribute to the lower growth rate of the SR killer whale population in contrast to the Northern Resident population (Ford 2011, Ward et al. 2009).

Abundance and Productivity. As of December 31, 2012, there were 26 whales in J pod, 19 whales in K pod and 39 whales in L pod, for a total of 84 whales (Center for Whale Research 2013). The historical abundance of SR killer whales is estimated from 140 whales (based on public display

removals; Olesiuk et al. 1990) up to 400 whales as used in population viability assessment scenarios (Krahn et al. 2004). Over the last 28 years (1983-2010), population growth has been variable, with an average annual population growth rate of 0.3 percent and standard deviation of ± 3.2 percent (The Center for Whale Research unpubl. data).

A delisting criterion for the SR killer whale DPS is an average growth rate of 2.3 percent for 28 years (NMFS 2008a). In light of the recent average growth rate of 0.3 percent, this recovery criterion has not yet been met (NMFS 2011b) and the recent low population growth rate is not sufficient to achieve recovery. There are also several demographic factors of the SR killer whale population that are cause for concern, namely the small number of breeding males (particularly in J and K pods), reduced fecundity, decreased sub-adult survivorship in L pod, and the total number of individuals in the population (NMFS 2008a).

Limiting Factors. Several factors identified in the final recovery plan for SR killer whales may be limiting recovery. These are quantity and quality of prey (particularly their primary prey, Chinook salmon), exposure to toxic chemicals that accumulate in top predators, and disturbance from sound and vessels. Oil spills are also a risk factor. It is likely that multiple threats are acting in concert to impact the whales. Although it is not clear which threat or threats are most significant to the survival and recovery of SR killer whales, all of the threats identified are potential limiting factors in their population dynamics (NMFS 2008a).

2.2.1.3 Steller Sea Lion

Steller sea lions were listed as threatened under the ESA on November 26, 1990 (55 FR 49204) across their entire range. Continued declines in the western portion of the population led to listing the western stock as endangered on May 5, 1997 (62 FR 24345), however the eastern stock remained listed as threatened. Under the Marine Mammal Protection Act, all Steller sea lions are classified as strategic stocks and are considered depleted. NMFS issued the final revised recovery plan for Steller sea lions in March 2008 (NMFS 2008b). The final Steller sea lion recovery plan identified the need to initiate a status review for the eastern DPS of Steller sea lions and consider removing it from the Federal List of Endangered Wildlife and Plants (NMFS 2008b). On December 13, 2010, NMFS announced a decision to review the status of the eastern DPS in response to two petitions to delist the eastern DPS (75 FR 77602). On April 18, 2012, NMFS issued a proposed rule to remove the eastern DPS of Steller sea lions from the List of Endangered and Threatened Wildlife (77 FR 23209).

Steller sea lions are a long-lived species, and reproduction is somewhat delayed (until age 10 years; NMFS 2008b). Breeding occurs at rookeries where males compete for females by defending territories. Females bear at most a single pup each year from late May through early July, with peak numbers of births during the second or third week of June.

Steller sea lions are generalist predators, able to respond to changes in prey abundance. Their primary prey includes a variety of fishes and cephalopods. Some prey species are eaten seasonally when locally available or abundant, and other species are available and eaten year- round (NMFS 2008b). Pacific hake appears to be the primary prey item across the range of eastern Steller sea lion (NMFS 2008b). Other prey items include Pacific cod, walleye Pollock, salmon, and herring, among other species.

Spatial Distribution and Diversity. The eastern DPS of Steller sea lions is a single population that ranges from southeast Alaska to southern California, including inland waters of Washington State and British Columbia. Occurrence in inland waters of Washington is limited to primarily male and sub-adult Steller sea lions in fall, winter, and spring months. They breed on rookeries in southeast Alaska, British Columbia, Oregon, and California. No rookeries occur in Washington. Haulouts are located throughout their range (NMFS 2008b).

Steller sea lions are not known to migrate. They disperse from rookeries outside of the breeding season (late May – early July), and adult males and juveniles are wider ranging than adult females (Allen and Angliss 2012). Exchange of breeding animals appears low between rookeries (Allen and Angliss 2012). The breeding distribution of the eastern DPS has shifted north, with range contraction in southern California and new rookeries established in southeast Alaska (Pitcher et al. 2007).

Abundance and Productivity. The total population estimate is a range between 58,334 and 72,223 animals based on extrapolation from pup counts, and the estimate of minimum abundance of non-pup and pup counts from all rookeries is 52,847 animals (Allen and Angliss 2012). The minimum estimate is not corrected for animals that were at sea. The population has increased at a rate of 3.1% per year from the 1970s until 2002 (Pitcher et al. 2007). The greatest increases have occurred in southeast Alaska and British Columbia (together accounting for 82 percent of pup production), but performance has remained poor in California at the southern extent of their range (Allen and Angliss 2012). In Southeast Alaska, British Columbia and Oregon, the number of Steller sea lions has more than doubled since the 1970s. Historical abundance is not well known, because prior to 1970 count data were intermittently available and therefore not comparable with more recent count data (NMFS 2008b).

Limiting Factors. Given the long-term positive population growth, no threats to the continued recovery of the eastern DPS were identified in the final revised recovery plan (NMFS 2008b). There are, however, factors that affect or have the potential to affect population dynamics of the eastern DPS. Those factors are predation (from killer whales and sharks), harvests, killing and other human impacts, entanglement in debris, parasitism and disease, toxic substances, global climate change, reduced prey biomass and quality, and disturbance (NMFS 2008b).

2.2.1.4 Humpback Whale

Humpback whales were listed as endangered across their entire range under the Endangered Species Conservation Act (ESCA) in June 1970 (35 FR 18319). The ESA replaced the ESCA in 1973 and continued to list humpback whales as endangered. NMFS issued the final recovery plan for humpback whales in November 1991 (NMFS 1991).

Spatial Structure and Diversity. Humpback whales occur in all major oceans of the world. In the North Pacific, humpback whales feed in coastal waters from California to Russia, including in the Bering Sea. These humpback whales migrate south off Mexico, Central America, Hawaii, southern Japan, and the Philippines (Carretta et al. 2012). Significant levels of nuclear and mtDNA differences exist between the North Pacific humpback whale populations (Baker et al. 1998).

Currently, there are four separate stocks (defined based on feeding areas) in the North Pacific recognized in the U.S. MMPA Pacific stock assessment reports: the Central North Pacific Stock, the Western North Pacific Stock, the California/Oregon/Washington Stock, and the American Samoa Stock (Carretta et al. 2012). These stocks are defined based on feeding areas because maternally directed fidelity appears stronger in feeding areas than in wintering areas. The California/Oregon/Washington stock winters in coastal waters of Mexico and Central America and migrates to feeding areas ranging from the coast of California to southern British Columbia in summer/fall (Carretta et al. 2012).

Humpback whales forage on a variety of crustaceans, other invertebrates, and forage fish (reviewed in NMFS 1991). In their summer foraging areas, humpback whales tend to occupy shallow, coastal waters. In contrast, during their winter migrations humpback whales tend to occupy deeper waters further offshore, and are less likely to occupy shallow, coastal waters.

Abundance and Productivity. The abundance and population trends of humpback whales are difficult to estimate, but based on the available data, humpback whales appear to be increasing in abundance across much of their range (Carretta et al. 2012). Calambokidis et al. (2008) estimated that the current population of humpback whales in the North Pacific is approximately 18,000 to 20,000 whales, not counting calves. More recently, the abundance was estimated to be over 21,000 individuals (Barlow et al. 2011). The estimated growth rate for this stock is between seven percent and eight percent, annually (Calambokidis et al. 2009).

The best estimate of abundance for the California/Oregon/Washington stock is 2,043 (Calambokidis et al. 2009). Within this stock, regional abundance estimates vary among the feeding areas. Average abundance estimates ranged from 200 to 400 individuals for southern British Columbia/northern Washington, and 1,400 to 2,000 individuals for California/Oregon (Calambokidis et al. 2008, Barlow et al. 2011). There is a high degree of site fidelity in these feeding ranges with almost no interchange between these two feeding regions.

Limiting Factors. Several factors identified in the final recovery plan for humpback whales may be limiting recovery. These factors include entanglement in fishing gear, collision with ships, whale watch harassment, proposed harvest (i.e., Japan's proposal for scientific whaling) and subsistence hunting, and anthropogenic sound in the ocean that is a habitat concern for low- frequency sound specialists, such as humpback whales (NMFS 1991).

2.2.1.5 Yelloweye Rockfish, Canary Rockfish, and Bocaccio

The Puget Sound/Georgia Basin DPSs of yelloweye rockfish and canary rockfish were listed under the ESA as threatened, and bocaccio was listed as endangered on April 28, 2010 (75 FR 22276). These DPSs include all yelloweye rockfish, canary rockfish, and bocaccio found in waters of the Puget Sound, the Strait of Georgia, and the Strait of Juan de Fuca east of Victoria Sill. Unlike ESA-listed salmonids, NMFS has not identified biological populations of each species below the DPS level, and thus use the term "populations" to refer to groups of fish within a particular basin of the DPSs. Yelloweye rockfish, canary rockfish, and bocaccio are three of 28 species of rockfish in Puget Sound (Palsson et al 2009).

The life-histories of yelloweye rockfish, canary rockfish, and bocaccio include a larval/pelagic juvenile stage followed by a nearshore juvenile stage, and sub-adult and adult stages. Much of the life-history and habitat use for these three species is similar, with differences noted below. Rockfish fertilize their eggs internally, and the young are extruded as larvae. Yelloweye rockfish, canary rockfish, and bocaccio produce from several thousand to over a million eggs (Love et a1. 2002). Larvae can make small local movements to pursue food immediately after birth (Tagal et al. 2002), but are likely passively distributed with prevailing currents (NMFS 2003). Larvae are observed under free-floating algae, seagrass, and detached kelp (Love et al. 2002; Shaffer et al. 1995) but are also distributed throughout the water column (Weis 2004). Unique oceanographic conditions within Puget Sound proper likely result in most larvae staying within the basin where they are released (e.g., the South Sound) rather than being broadly dispersed (Drake et al. 2010).

When bocaccio and canary rockfish reach sizes of 1 to 3.5 in (3 to 9 cm) (approximately 3 to 6 months old), they settle onto shallow nearshore waters in rocky or cobble substrates with or without kelp (Love et a1. 1991, 2002). These habitat features offer a beneficial mix of warmer temperatures, food, and refuge from predators (Love et al. 1991). Areas with floating and submerged kelp species support the highest densities of most juvenile rockfish (Carr 1983; Halderson and Richards 1987; Hayden-Spear 2006; Matthews 1989). Unlike bocaccio and canary rockfish, juvenile yelloweye rockfish do not typically occupy intertidal waters (Love et al. 1991; Studebaker et al. 2009), but settle in 98 to 131 feet (30 to 40 meters) of water near the upper depth range of adults (Yamanaka and Lacko 2001).

Sub-adult and adult yelloweye rockfish, canary rockfish, and bocaccio typically utilize habitats with moderate to extreme steepness, complex bathymetry, and rock and boulder-cobble complexes (Love et al. 2002). Within Puget Sound proper, each species has been documented in areas of high relief rocky and non-rocky substrates such as sand, mud, and other unconsolidated sediments (Miller and Borton 1980; Washington 1977). Yelloweye rockfish remain near the bottom and have small home ranges, while some canary rockfish and bocaccio have larger home ranges, move long distances, and spend time suspended in the water column (Love et al. 2002). Adults of each species are most commonly found between 131 feet to 820 feet (40 to 250 m) (Love et a1. 2002; Orr et al. 2000).

Yelloweye rockfish are one of the longest lived of the rockfishes, with some individuals reaching more than 100 years of age. They reach 50 percent maturity at sizes around 16 to 20 in (40 to 50 cm) and ages of 15 to 20 years (Rosenthal et a1. 1982; Yamanaka and Kronlund 1997). Maximum age of canary rockfish is at least 84 years (Love et a1. 2002), although 60 to 75 years is more common (Caillet et a1. 2000). They reach 50 percent maturity at sizes around 16 in (40 cm) and ages of 7 to 9 years. The maximum age of bocaccio is unknown, but may exceed 50 years, and they are first reproductively mature near age six (FishBase 2010).

The timing of larval release for each species varies throughout the geographic range. In Puget Sound, there is some evidence that larvae are extruded in early spring to late summer for yelloweye rockfish (Washington et al. 1978). In British Columbia, parturition (larval birth) peaks in February for canary rockfish (Hart 1973; Westrheim and Harling 1975). Along the coast of Washington State, female bocaccio release larvae between January and April (Love et al. 2002).

Spatial Structure and Connectivity. Spatial structure consists of a population's geographical distribution and the processes that generate that distribution (McElhaney et al. 2000). A population's spatial structure depends on habitat quality, spatial configuration, and dynamics as well as dispersal characteristics of individuals within the population (McElhaney et al. 2000). Prior to contemporary fishery removals, each of the major basins in the range of the DPSs likely hosted relatively large populations of yelloweye rockfish, canary rockfish, and bocaccio (Moulton and Miller 1987; Washington 1977; Washington et al. 1978). This distribution allowed each species to utilize the full suite of available habitats to maximize their abundance and demographic characteristics, thereby enhancing their resilience (Hamilton 2008). This distribution also enabled each species to potentially exploit ephemerally good habitat conditions, or in turn receive protection from smaller-scale and negative environmental fluctuations. These types of fluctuations may change prey abundance for various life stages and/or may change environmental characteristics that influence the number of annual recruits. Spatial distribution also provides a measure of protection from larger scale anthropogenic changes that damage habitat suitability, such as oil spills or hypoxia that can occur within one basin, but not necessarily the other basins. Rockfish population resilience is sensitive to changes in connectivity among various groups of fish (Hamilton 2008). Hydrologic connectivity of the basins of the Puget Sound is naturally restricted by relatively shallow sills located at Deception Pass, Admiralty Inlet, the Tacoma Narrows, and in Hood Canal (Burns 1985). The Victoria Sill bisects the Strait of Juan de Fuca and runs from east of Port Angeles north to Victoria, and regulates water exchange (Drake et al. 2010). These sills regulate water exchange from one basin to the next, and thus likely moderate the movement of rockfish larvae (Drake et al. 2010). When localized depletion of rockfish occurs it can reduce stock resiliency (Hamilton 2008; Hilborn et al. 2003; Levin 1998). The effects of localized depletions of rockfish are likely exacerbated by the natural hydrologic constrictions within Puget Sound.

Yelloweye Rockfish Spatial Structure and Connectivity. Yelloweye rockfish spatial structure and connectivity is threatened by the reduction of fish within each of the basins of the DPS. This reduction is most acute within the basins of Puget Sound proper. The severe reduction of fish in these basins may eventually result in a contraction of the DPS' range (Drake et al. 2010). Yelloweye rockfish are probably most abundant within the San Juan Basin, but the likelihood of juvenile recruitment from this basin to the adjacent basins of Puget Sound proper is naturally low because of the generally retentive circulation patterns that occur within each of the major basins of Puget Sound proper. Combined with limited adult movement, yelloweye rockfish population viability may be highly influenced by the probable localized loss of populations within the DPS, which decreases spatial structure and connectivity.

Canary Rockfish Spatial Structure and Connectivity. Canary rockfish were present in each of the major basins of the DPS in the 1970s (Moulton and Miller 1987), yet were not detected in any WDFW trawl or drop camera survey in Puget Sound proper within the past several years. Several historically large populations in the canary rockfish DPS may be severely reduced, including an area of distribution in South Sound, which has declined because of harvest and perhaps because of low dissolved oxygen (DO) (Drake et al. 2010). The apparent steep reduction of fish in Puget Sound proper leads to concerns about the viability of these populations (Drake et al. 2010). The ability of adults to migrate hundreds of kilometers could allow the DPS to re-establish spatial structure and connectivity in the future under favorable conditions (Drake et al. 2010).

Bocaccio Spatial Structure and Connectivity. Most bocaccio within the DPS may have been historically spatially limited to several basins. They were historically most abundant in the Central and South Sound (Drake et al. 2010) with no documented occurrences in the San Juan Basin until 2008 (WDFW 2011a). Positive signs for spatial structure and connectivity come from the propensity of some adults and pelagic juveniles to migrate long distances, which could re-establish aggregations of fish in formerly occupied habitat (Drake et al. 2010). The apparent reduction of populations of bocaccio in the Main Basin and South Sound represents a further reduction in the historically spatially limited distribution of bocaccio, and adds significant risk to the viability of the DPS.

Diversity. Characteristics of diversity for rockfish include fecundity, timing of the release of larvae and their condition, morphology, age at reproductive maturity, physiology, and molecular genetic characteristics. In spatially and temporally varying environments, there are three general reasons why diversity is important for species and population viability: 1) diversity allows a species to use a wider array of environments; 2) it protects a species against short-term spatial and temporal changes in the environment; and 3) genetic diversity provides the raw material for surviving long-term environmental changes. Though there are no genetic data for the ESA-listed rockfish DPSs, the unique oceanographic features and relative isolation of some of its basins may have led to unique adaptations, such as timing of larval release (Drake et al. 2010).

Yelloweye Rockfish Diversity. Yelloweye rockfish size and age distributions have been truncated. Recreationally caught yelloweye rockfish in the 1970s spanned a broad range of sizes. By the 2000s, there was some evidence of fewer older fish in the population (Drake et al. 2010). However, overall numbers of fish in the database were also much lower, making it difficult to determine if clear size truncation occurred within the U.S. portion of the DPS. No adult yelloweye rockfish have been observed within the WDFW ROV surveys. As a result, the reproductive burden may be shifted to younger and smaller fish. This shift could alter the timing and condition of larval release, which may be mismatched with habitat conditions within the range of the DPS, potentially reducing the viability of offspring (Drake et al. 2010).

Canary Rockfish Diversity. Canary rockfish size and age distributions have been truncated (Drake et al. 2010). As a result, the reproductive burden may be shifted to younger and smaller fish. The population of canary rockfish in the 1970s exhibited a broad range of sizes. However, by the 2000s there were far fewer size classes represented and no fish greater than 21.65 in (55 cm) were recorded in the recreational data (Drake et al. 2010). Although some of this truncation may be a function of the overall lower number of sampled fish, the data in general suggest few older fish remain in the population. This shift could alter the timing and condition of larval release that may be mismatched with habitat conditions within the DPS, potentially reducing the viability of offspring (Drake et al. 2010).

Bocaccio Diversity. Size-frequency distributions for bocaccio in the 1970s indicate a wide range of sizes, with recreationally caught individuals from 9.8 to 33.5 in (25 to 85 cm). This broad size distribution suggests a spread of ages, with some successful recruitment over many years. A similar range of sizes is also evident in the 1980s catch data. The temporal trend in size distributions for bocaccio also suggests size truncation of the population, with larger fish becoming less common over time. By the decade of the 2000s, no size distribution data for bocaccio were available.

Bocaccio in the Puget Sound/Georgia Basin may have physiological or behavioral adaptations because of the unique habitat conditions in the range of the DPS. The potential loss of diversity in the bocaccio DPS, in combination with their relatively low productivity, may result in a mismatch with habitat conditions and further reduce population viability (Drake et al. 2010).

Abundance and Productivity. There is no single reliable historic or contemporary population estimate for yelloweye rockfish, canary rockfish, or bocaccio within the Puget Sound/Georgia Basin DPS (Drake et a1. 2010). Despite this limitation, there is clear evidence each species' abundance has declined dramatically (Drake et a1. 2010). The total rockfish population in the Puget Sound region is estimated to have declined around three percent per year for the past several decades, which corresponds to an approximate 70 percent decline from the 1965 to 2007 time period (Drake et a1. 2010). Catches of yelloweye rockfish, canary rockfish, and bocaccio have declined as a proportion of the overall rockfish catch (Drake et a1. 2010; Palsson et a1. 2009).

Present-day abundance of all three DPSs is influenced by bycatch from several commercial and recreational fisheries. Though rockfish may no longer be retained in these fisheries, released fish are often injured or killed by barotrauma. When rockfish are brought from depths of deeper than 60 feet (18.3 meters) the rapid decompression causes over-inflation and/or rupture of the swim bladder (termed barotrauma), which can result in multiple injuries (Jarvis and Lowe 2008; Palsson et a1. 2009; Parker et a1. 2006). These injuries cause various levels of disorientation among rockfish species, which result in fish remaining at the surface after they are released (Hannah and Matteson 2007). Rockfish at the surface are susceptible to predation by birds, sharks, or marine mammals, damage from solar radiation, and gas embolisms (Palsson et a1. 2009).

Fishery-independent estimates of population abundance come from spatially and temporally limited research trawls, drop camera surveys, and underwater remotely operated vehicle (ROY) surveys conducted by WDFW. The trawl surveys were conducted on the bottom to assess marine fish abundance for a variety of species. These trawls generally sample over non-rocky substrates where yelloweye rockfish, canary rockfish, and bocaccio are less likely to occur compared to steep-sloped, rocky habitat (Drake et al. 2010). The drop camera surveys sampled habitats less than 120 feet (36.6 meters), which is potential habitat for juveniles, but less likely habitat for adults of the three listed species. Similarly, because juvenile yelloweye rockfish are less dependent on rearing in shallow nearshore environments, the likelihood of documenting them with drop camera surveys in water shallower than 120 feet (36.6 meters) is less than for canary rockfish and bocaccio.

The WDFW ROY surveys were conducted exclusively within the rocky habitats of the San Juan Basin in 2008, and represent the best available abundance estimates for one basin of the DPS for each species to date because of their survey area, number of transects, and stratification methods. Rocky habitats have been mapped within the San Juan Basin, which allows a randomized survey of these areas to assess species assemblages and collect data for abundance estimates. WDFW conducted 200 transects and stratified each rocky habitat survey as either "shallower than" and "deeper than" 120 feet (36.6 meters). The total area surveyed within each stratum was calculated using the average transect width multiplied by the transect length. The mean density of yelloweye rockfish, canary rockfish, and bocaccio was calculated by dividing the species counts within each stratum by the area surveyed. Population estimates for each species were calculated by multiplying

the species density estimates by the total survey area within each stratum (WDFW unpublished data). Because WDFW did not survey non-rocky habitats of the San Juan Basin with the ROY, these estimates do not account for ESA-listed rockfish in non-rocky habitat in 2008.

Though the bottom trawl and drop camera surveys did not detect canary rockfish or bocaccio in Puget Sound proper, each species has been historically present there and each has been caught in recent recreational fisheries. The lack of detected canary rockfish and bocaccio from these sampling methods in Puget Sound proper is probably due to the following factors: 1) populations of each species are depleted; 2) the general lack of rocky benthic areas in Puget Sound proper may lead to densities of each species that are naturally less than the San Juan Basin; and 3) the study design or effort may not have been sufficiently powerful to detect each species. Though yelloweye rockfish were detected in Puget Sound proper with bottom trawl surveys, NMFS does not consider the WDFW estimate of 600 fish to be a complete estimate, for the same reasons given above.

Productivity is the measurement of a population's growth rate through all or a portion of its lifecycle. Life-history traits of yelloweye rockfish, canary rockfish, and bocaccio suggest generally low levels of inherent productivity because they are long-lived, mature slowly, and have sporadic episodes of successful reproduction (Drake et al. 2010; Tolimieri and Levin 2005). Historic over-fishing can have dramatic impacts on the size or age structure of the population, with effects that can influence ongoing productivity. When the size and age of females decline, there are negative impacts to reproductive success. These impacts, termed maternal effects, are evident in a number of traits. Larger and older females of various rockfish species have a higher weight-specific fecundity (number of larvae per unit of female weight) (Bobko and Berkeley 2004; Boehlert et al. 1982; Sogard et al. 2008). A consistent maternal effect in rockfishes relates to the timing of parturition. The timing of larval birth can be crucial in terms of corresponding with favorable oceanographic conditions because most larvae are released on only 1 day each year, with a few exceptions in southern coastal populations and in yelloweye rockfish in Puget Sound (Washington et al. 1978). Several studies of rockfish species have shown that larger or older females release larvae earlier in the season compared to smaller or younger females (Nichol and Pikitch 1994; Sogard et al. 2008). Larger or older females provide more nutrients to larvae by developing a larger oil globule released at parturition, which provides energy to the developing larvae (Berkeley et al. 2004; Fisher et al. 2007), and in black rockfish enhances early growth rates (Berkeley et al. 2004).

Yelloweye Rockfish Abundance and Productivity. Yelloweye rockfish within the Puget Sound/Georgia Basin (in U.S. waters) are very likely the most abundant within the San Juan Basin of the DPS, total abundance of this DPS has been declining. Yelloweye rockfish were 2.4 percent of the harvest in North Sound during the 1960s, occurred in 2.1 percent of the harvest during the 1980s, but then decreased to an average of one percent from 1996 to 2002 (Palsson et al. 2009). In Puget Sound proper, yelloweye rockfish were 4.4 percent of the harvest during the 1960s, only 0.4 percent during the 1980s, and 1.4 percent from 1996 to 2002 (Palsson et a1. 2009). Though there is a lack of a reliable population census (ROY or otherwise) within the basins of Puget Sound proper, the San Juan Basin has the most suitable rocky benthic habitat (Palsson et a1. 2009) and historically was the area of greatest numbers of angler catches (Moulton and Miller 1987; Olander 1991). Productivity for yelloweye rockfish is influenced by long generation times that reflect intrinsically low annual reproductive success. Natural mortality rates have been estimated from two to 4.6 percent (Wallace

2007; Yamanaka and Kronlund 1997). Productivity may also be particularly impacted by Allee effects, which occur as adults have been removed by fishing, and the density and proximity of mature fish has decreased. Adult yelloweye rockfish typically occupy relatively small ranges (Love et al. 2002) and may not move to find suitable mates.

Canary Rockfish Abundance and Productivity. Historically, the South Sound may have been a population stronghold within the DPS, but it appears to be greatly depleted (Drake et al. 2010). Canary rockfish occurred in 6.5 percent of the North Sound recreational harvests during the 1960s and then declined to 1.4 percent and to 0.6 percent during the subsequent two periods (Palsson et al. 2009). During the 1960s, canary rockfish were 3.1 percent of the Puget Sound proper rockfish harvest and then declined to one percent in the 1980s and 1.4 percent from 1996 to 2002 (Palsson et a1. 2009). Natural annual mortality ranges from six to nine percent (Methot and Stewart 2005; Stewart 2007). Life-history traits suggest intrinsically slow growth rate and low rates of productivity for canary rockfish, specifically its age at maturity, long generation time, and its maximum observed age (84 years) (Love et a1. 2002). Past commercial and recreational fishing may have depressed the DPS to a threshold beyond which optimal productivity is unattainable (Drake et a1. 2010).

Bocaccio Abundance and Productivity. Bocaccio in the Puget Sound/Georgia Basin were historically most common within the South Sound and Central Sound Basins (Drake et al. 2010). Bocaccio consisted of eight to nine percent of the overall rockfish catch in the late 1970s and declined in frequency, relative to other species of rockfish, from the 1970s to the 1990s (Drake et a1. 2010). From 1975 to 1979, bocaccio averaged 4.63 percent of the catch. From 1980 to 1989, they were 0.24 percent of the 8,430 rockfish identified (Palsson et a1. 2009). In the 1990s and early 2000s bocaccio were not observed by WDFW in the dockside surveys of the recreational catches (Drake et a1. 2010). In 2008 and 2009, some fish were reported by recreational anglers in the Central Sound (WDFW 201I).

Though bocaccio were never a predominant segment of the multi-species rockfish population within the Puget Sound/Georgia Basin (Drake et al. 2010), their present-day abundance is likely a fraction of their pre-contemporary fishery abundance. Bocaccio abundance may be very low in significant segments of the Puget Sound/Georgia Basin. From 1998 to 2008, fish were reported by anglers in only one basin of the DPS range. Productivity is driven by high fecundity and episodic recruitment events, largely correlated with environmental conditions. Thus, bocaccio populations do not follow consistent growth trajectories and sporadic recruitment drives population structure (Drake et al. 2010). Natural annual mortality is approximately eight percent (Palsson et. al 2009). Tolimieri and Levin (2005) found that the bocaccio population growth rate is around 1.01, indicating a very low intrinsic growth rate for this species. Demographically, this species demonstrates some of the highest recruitment variability among rockfish species, with many years of failed recruitment being the norm (Tolimieri and Levin 2005). Given their severely reduced abundance, Allee effects may be particularly acute for bocaccio, even considering the propensity of some individuals to move long distances and potentially find mates.

Limiting Factors. Contaminants such as polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers, and chlorinated pesticides appear in rockfish collected in urban areas (Palsson et al. 2009). While the highest levels of contamination occur in urban areas, toxins can be found in the tissues of fish throughout Puget Sound (West et al. 2001). Although few studies have investigated

the effects of toxins on rockfish ecology or physiology, other fish in the Puget Sound region that have been studied do show a substantial impact, including reproductive dysfunction of some sole species (Landahl et a1. 1997). Reproductive function of rockfish is also likely affected by contaminants (Palsson et al. 2009) and other life-history stages may be as well (Drake et a1. 2010).

Climate-induced changes to rockfish habitat could alter their productivity (Drake et a1. 2010). Harvey (2005) created a generic bioenergetic model for rockfish, showing that productivity of rockfish is highly influenced by climate conditions. For instance, EI Nino-like conditions generally lowered growth rates and increased generation time. The negative effect of the warm water conditions associated with El Nino appear to be common across rockfishes (Moser et a1. 2000). Recruitment of all species of rockfish appears to be correlated at large scales. Field and Ralston (2005) hypothesized that such synchrony was the result of large-scale climate forcing. Exactly how climate influences rockfish in Puget Sound is unknown; however, given the general importance of climate to rockfish recruitment, it is likely that climate strongly influences the dynamics of ESA-listed rockfish population viability (Drake et a1. 2010).

The yelloweye rockfish face several threats including bycatch in commercial and recreational harvest, non-native species introductions, and habitat degradation. NMFS has determined that this DPS is likely to be in danger of extinction in the foreseeable future throughout all of its range.

Several factors, both population- and habitat-related, have caused the DPS of canary rockfish to decline to the point that NMFS has listed them as threatened. The general outlook in terms of all five criteria (habitat, spatial structure, diversity, abundance, and productivity) is that the DPS is likely to become in danger of extinction in the foreseeable future throughout all of its range.

The bocaccio DPS exists at very low abundance, and observations are rare. Their low intrinsic productivity, combined with continuing threats from bycatch in commercial and recreational harvest, non-native species introductions, loss and degradation of habitat, and chemical contamination, increase the extinction risk. NMFS has determined that this DPS is currently in danger of extinction throughout all of its range.

2.2.1.6 Bull Trout

Listing Status. The coterminous United States population of the bull trout was listed as threatened on November 1, 1999 (64 FR 58910). The threatened bull trout generally occurs in the Klamath River Basin of south-central Oregon; the Jarbidge River in Nevada; the Willamette River Basin in Oregon; Pacific Coast drainages of Washington, including Puget Sound; major rivers in Idaho, Oregon, Washington, and Montana, within the Columbia River Basin; and the St. Mary-Belly River, east of the Continental Divide in northwestern Montana (Bond 1992, p. 2; Brewin and Brewin 1997, p. 215; Cavender 1978, pp. 165-166; Leary and Allendorf 1997, pp. 716-719).

Throughout its range, the bull trout are threatened by the combined effects of habitat degradation, fragmentation, and alterations associated with dewatering, road construction and maintenance, mining, grazing, the blockage of migratory corridors by dams or other diversion structures, poor water quality, entrainment (a process by which aquatic organisms are pulled through a diversion or other device) into diversion channels, and introduced non-native species (64 FR 58910 [November

1, 1999]). Although all salmonids are likely to be affected by climate change, bull trout are especially vulnerable given that spawning and rearing are constrained by their location in upper watersheds and the requirement for cold water temperatures (Battin et al. 2007, pp. 6672-6673; Rieman et al. 2007, p. 1552). Poaching and incidental mortality of bull trout during other targeted fisheries are additional threats.

The bull trout was initially listed as three separate Distinct Population Segments (DPSs) (63 FR 31647 [June 10, 1998]; 64 FR 17110 [April 8, 1999]). The preamble to the final listing rule for the United States coterminous population of the bull trout discusses the consolidation of these DPSs with the Columbia and Klamath population segments into one listed taxon and the application of the jeopardy standard under section 7 of the Act relative to this species (64 FR 58910 [November 1, 1999]):

> Although this rule consolidates the five bull trout DPSs into one listed taxon, based on conformance with the DPS policy for purposes of consultation under section 7 of the Act, we intend to retain recognition of each DPS in light of available scientific information relating to their uniqueness and significance. Under this approach, these DPSs will be treated as interim recovery units with respect to application of the jeopardy standard until an approved recovery plan is developed. Formal establishment of bull trout recovery units will occur during the recovery planning process.

Current Status and Conservation Needs. In recognition of available scientific information relating to their uniqueness and significance, five segments of the coterminous United States population of the bull trout are considered essential to the survival and recovery of this species and are identified as interim recovery units: 1) Jarbidge River, 2) Klamath River, 3) Columbia River, 4) Coastal-Puget Sound, and 5) St. Mary-Belly River (USFWS 2002a, pp. iv, 2, 7, 98; 2004a, Vol. 1 & 2, p. 1; 2004b, p. 1). Each of these interim recovery units is necessary to maintain the bull trout's distribution, as well as its genetic and phenotypic diversity, all of which are important to ensure the species' resilience to changing environmental conditions.

A summary of the current status and conservation needs of the bull trout within these interim recovery units is provided below and a comprehensive discussion is found in the Service's draft recovery plans for the bull trout (USFWS 2002a, pp. vi-viii; 2004a, Vol. 2 p. iii-x; 2004b, pp. iii-xii).

The conservation needs of bull trout are often generally expressed as the four "Cs": cold, clean, complex, and connected habitat. Cold stream temperatures, clean water quality that is relatively free of sediment and contaminants, complex channel characteristics (including abundant large wood and undercut banks), and large patches of such habitat that are well connected by unobstructed migratory pathways are all needed to promote conservation of bull trout at multiple scales ranging from the coterminous to local populations (a local population is a group of bull trout that spawn within a particular stream or portion of a stream system). The recovery planning process for bull trout (USFWS 2002a, pp. 49-50; 2004a, Vol 1 & 2 pp. 12-18; 2004b, pp. 60-86) has also identified the following conservation needs: 1) maintenance and restoration of multiple, interconnected populations in diverse habitats across the range of each interim recovery unit, 2) preservation of the diversity of life-history strategies, 3) maintenance of genetic and phenotypic diversity across the

range of each interim recovery unit, and 4) establishment of a positive population trend. Recently, it has also been recognized that bull trout populations need to be protected from catastrophic fires across the range of each interim recovery unit (Rieman et al. 2003).

Central to the survival and recovery of bull trout is the maintenance of viable core areas (USFWS 2002a, pp. 53-54; 2004a, Vol. 1 pp. 210-218, Vol 2. pp. 61-62; 2004b, pp. 15-30, 64-67). A core area is defined as a geographic area occupied by one or more local bull trout populations that overlap in their use of rearing, foraging, migratory, and overwintering habitat. Each of the interim recovery units listed above consists of one or more core areas. There are 121 core areas recognized across the coterminous range of the bull trout (USFWS 2002a, pp. 6, 48, 98; 2004a, Vol. 1 p. vi, Vol. 2 pp. 14, 134; 2004b, pp. iv, 2; 2005, p. ii).

Jarbidge River Interim Recovery Unit. This interim recovery unit currently contains a single core area with six local populations. Less than 500 resident and migratory adult bull trout, representing about 50 to 125 spawning adults, are estimated to occur in the core area. The current condition of the bull trout in this interim recovery unit is attributed to the effects of livestock grazing, roads, incidental mortalities of released bull trout from recreational angling, historic angler harvest, timber harvest, and the introduction of non-native fishes (USFWS 2004a). The draft bull trout recovery plan (USFWS 2004b) identifies the following conservation needs for this interim recovery unit: 1) maintain the current distribution of the bull trout within the core area, 2) maintain stable or increasing trends in abundance of both resident and migratory bull trout in the core area, 3) restore and maintain suitable habitat conditions for all life history stages and forms, and 4) conserve genetic diversity and increase natural opportunities for genetic exchange between resident and migratory forms of the bull trout. An estimated 270 to 1,000 spawning bull trout per year are needed to provide for the persistence and viability of the core area and to support both resident and migratory adult bull trout (USFWS 2004a).

Klamath River Interim Recovery Unit. This interim recovery unit currently contains three core areas and seven local populations. The current abundance, distribution, and range of the bull trout in the Klamath River Basin are greatly reduced from historical levels due to habitat loss and degradation caused by reduced water quality, timber harvest, livestock grazing, water diversions, roads, and the introduction of non-native fishes (USFWS 2002a). Bull trout populations in this interim recovery unit face a high risk of extirpation (USFWS 2002a). The draft Klamath River bull trout recovery plan (USFWS 2002a) identifies the following conservation needs for this interim recovery unit: 1) maintain the current distribution of bull trout and restore distribution in previously occupied areas, 2) maintain stable or increasing trends in bull trout abundance, 3) restore and maintain suitable habitat conditions for all life history stages and strategies, 4) conserve genetic diversity and provide the opportunity for genetic exchange among appropriate core area populations. Eight to 15 new local populations and an increase in population size from about 2,400 adults currently to 8,250 adults are needed to provide for the persistence and viability of the three core areas (USFWS 2002a).

Columbia River Interim Recovery Unit. The Columbia River interim recovery unit includes bull trout residing in portions of Oregon, Washington, Idaho, and Montana. Bull trout are estimated to have occupied about 60 percent of the Columbia River Basin, and presently occur in 45 percent of the estimated historical range (Quigley and Arbelbide 1997, p. 1177). This interim recovery unit currently contains 97 core areas and 527 local populations. About 65 percent of these core areas and

local populations occur in central Idaho and northwestern Montana. The Columbia River interim recovery unit has declined in overall range and numbers of fish (63 FR 31647 [June 10, 1998]). Although some strongholds still exist with migratory fish present, bull trout generally occur as isolated local populations in headwater lakes or tributaries where the migratory life history form has been lost. Though still widespread, there have been numerous local extirpations reported throughout the Columbia River basin. In Idaho, for example, bull trout have been extirpated from 119 reaches in 28 streams (IDFG, in litt. 1995). The draft Columbia River bull trout recovery plan (USFWS 2002c) identifies the following conservation needs for this interim recovery unit: 1) maintain or expand the current distribution of the bull trout within core areas, 2) maintain stable or increasing trends in bull trout abundance, 3) restore and maintain suitable habitat conditions for all bull trout life history stages and strategies, and 4) conserve genetic diversity and provide opportunities for genetic exchange.

This interim recovery unit currently contains 97 core areas and 527 local populations. About 65 percent of these core areas and local populations occur in Idaho and northwestern Montana. The condition of the bull trout within these core areas varies from poor to good. All core areas have been subject to the combined effects of habitat degradation and fragmentation caused by the following activities: dewatering; road construction and maintenance; mining; grazing; the blockage of migratory corridors by dams or other diversion structures; poor water quality; incidental angler harvest; entrainment into diversion channels; and introduced non-native species. The Service completed a core area conservation assessment for the 5-year status review and determined that, of the 97 core areas in this interim recovery unit, 38 are at high risk of extirpation, 35 are at risk, 20 are at potential risk, 2 are at low risk, and 2 are at unknown risk (USFWS 2005, pp. 2, Map A, pp. 73-83).

Coastal-Puget Sound Interim Recovery Unit, Bull trout in the Coastal-Puget Sound interim recovery unit exhibit anadromous, adfluvial, fluvial, and resident life history patterns. The anadromous life history form is unique to this interim recovery unit. This interim recovery unit currently contains 14 core areas and 67 local populations (USFWS 2004b). Bull trout are distributed throughout most of the large rivers and associated tributary systems within this interim recovery unit. Bull trout continue to be present in nearly all major watersheds where they likely occurred historically, although local extirpations have occurred throughout this interim recovery unit. Many remaining populations are isolated or fragmented and abundance has declined, especially in the southeastern portion of the interim recovery unit. The current condition of the bull trout in this interim recovery unit is attributed to the adverse effects of dams, forest management practices (e.g., timber harvest and associated road building activities), agricultural practices (e.g., diking, water control structures, draining of wetlands, channelization, and the removal of riparian vegetation), livestock grazing, roads, mining, urbanization, poaching, incidental mortality from other targeted fisheries, and the introduction of non-native species. The draft Coastal-Puget Sound bull trout recovery plan (USFWS 2004b) identifies the following conservation needs for this interim recovery unit: 1) maintain or expand the current distribution of bull trout within existing core areas, 2) increase bull trout abundance to about 16,500 adults across all core areas, and 3) maintain or increase connectivity between local populations within each core area.

St. Mary-Belly River Interim Recovery Unit. This interim recovery unit currently contains six core areas and nine local populations (USFWS 2002b). Currently, bull trout are widely distributed in the

St. Mary-Belly River drainage and occur in nearly all of the waters that it inhabited historically. Bull trout are found only in a 1.2-mile reach of the North Fork Belly River within the United States. Redd count surveys of the North Fork Belly River documented an increase from 27 redds in 1995 to 119 redds in 1999. This increase was attributed primarily to protection from angler harvest (USFWS 2002b). The current condition of the bull trout in this interim recovery unit is primarily attributed to the effects of dams, water diversions, roads, mining, and the introduction of non-native fishes (USFWS 2002b). The draft St. Mary-Belly River bull trout recovery plan (USFWS 2002b) identifies the following conservation needs for this interim recovery unit: 1) maintain the current distribution of the bull trout and restore distribution in previously occupied areas, 2) maintain stable or increasing trends in bull trout abundance, 3) restore and maintain suitable habitat conditions for all life history stages and forms, 4) conserve genetic diversity and provide the opportunity for genetic exchange, and 5) establish good working relations with Canadian interests because local bull trout populations in this interim recovery unit are comprised mostly of migratory fish, whose habitat is mostly in Canada.

Life History. Bull trout exhibit both resident and migratory life history strategies. Both resident and migratory forms may be found together, and either form may produce offspring exhibiting either resident or migratory behavior (Rieman and McIntyre 1993, pp. 1-18) . Resident bull trout complete their entire life cycle in the tributary (or nearby) streams in which they spawn and rear. The resident form tends to be smaller than the migratory form at maturity and also produces fewer eggs (Fraley and Shepard 1989, p. 1; Goetz 1989, pp. 15-16). Migratory bull trout spawn in tributary streams where juvenile fish rear 1 to 4 years before migrating to either a lake (adfluvial form), river (fluvial form) (Fraley and Shepard 1989, pp. 135-137; Goetz 1989, pp. 22-25), or saltwater (anadromous form) to rear as subadults and to live as adults (Cavender 1978, pp. 139, 165-68; McPhail and Baxter 1996, p. 14; WDFW et al. 1997, pp. 17-18, 22-26). Bull trout normally reach sexual maturity in 4 to 7 years and may live longer than 12 years. They are iteroparous (they spawn more than once in a lifetime). Repeat- and alternate-year spawning has been reported, although repeat-spawning frequency and post-spawning mortality are not well documented (Fraley and Shepard 1989, pp. 135-137; Leathe and Graham 1982, p. 95; Pratt 1992, p. 6; Rieman and McIntyre 1996, p. 133).

The iteroparous reproductive strategy of bull trout has important repercussions for the management of this species. Bull trout require passage both upstream and downstream, not only for repeat spawning but also for foraging. Most fish ladders, however, were designed specifically for anadromous semelparous salmonids (fishes that spawn once and then die, and require only one-way passage upstream). Therefore, even dams or other barriers with fish passage facilities may be a factor in isolating bull trout populations if they do not provide a downstream passage route. Additionally, in some core areas, bull trout that migrate to marine waters must pass both upstream and downstream through areas with net fisheries at river mouths. This can increase the likelihood of mortality to bull trout during these spawning and foraging migrations.

Growth varies depending upon life-history strategy. Resident adults range from 6 to 12 inches total length, and migratory adults commonly reach 24 inches or more (Goetz 1989, pp. 29-32; Pratt 1984, p. 13) The largest verified bull trout is a 32-pound specimen caught in Lake Pend Oreille, Idaho, in 1949 (Simpson and Wallace 1982).

Habitat Characteristics. Bull trout have more specific habitat requirements than most other salmonids (Rieman and McIntyre 1993, p. 7). Habitat components that influence bull trout distribution and abundance include water temperature, cover, channel form and stability, valley form, spawning and rearing substrate, and migratory corridors (Fraley and Shepard 1989, pp. 137, 141; Goetz 1989, pp. 19-26; Bond in Hoelscher and Bjornn 1989, p. 57; Howell and Buchanan 1992, p. 1; Pratt 1992, p. 6; Rich 1996, pp. 35-38; Rieman and McIntyre 1993, pp. 4-7; Rieman and McIntyre 1995, pp. 293-294; Sedell and Everest 1991, p. 1; Watson and Hillman 1997, pp. 246-250). Watson and Hillman (1997, pp. 247-249) concluded that watersheds must have specific physical characteristics to provide the habitat requirements necessary for bull trout to successfully spawn and rear and that these specific characteristics are not necessarily present throughout these watersheds. Because bull trout exhibit a patchy distribution, even in pristine habitats (Rieman and McIntyre 1993, p. 7), bull trout should not be expected to simultaneously occupy all available habitats (Rieman et al. 1997, p. 1560).

Migratory corridors link seasonal habitats for all bull trout life histories. The ability to migrate is important to the persistence of bull trout (Gilpin, in litt. 1997, pp. 4-5; Rieman and McIntyre 1993, p. 7; Rieman et al. 1997, p. 1114). Migrations facilitate gene flow among local populations when individuals from different local populations interbreed or stray to nonnatal streams. Local populations that are extirpated by catastrophic events may also become reestablished by bull trout migrants. However, it is important to note that the genetic structuring of bull trout indicates there is limited gene flow among bull trout populations, which may encourage local adaptation within individual populations, and that reestablishment of extirpated populations may take a long time (Rieman and McIntyre 1993, p. 7; Spruell et al. 1999, pp. 118-120). Migration also allows bull trout to access more abundant or larger prey, which facilitates growth and reproduction. Additional benefits of migration and its relationship to foraging are discussed below under "Diet."

Cold water temperatures play an important role in determining bull trout habitat quality, as these fish are primarily found in colder streams (below 15 °C or 59 °F), and spawning habitats are generally characterized by temperatures that drop below 9 °C (48 °F) in the fall (Fraley and Shepard 1989, p. 133; Pratt 1992, p. 6; Rieman and McIntyre 1993, p. 7).

Thermal requirements for bull trout appear to differ at different life stages. Spawning areas are often associated with cold-water springs, groundwater infiltration, and the coldest streams in a given watershed (Baxter et al. 1997, pp. 426-427; Pratt 1992, p. 6; Rieman and McIntyre 1993, p. 7; Rieman et al. 1997, p. 1117). Optimum incubation temperatures for bull trout eggs range from 2 °C to 6 °C (35 °F to 39 °F) whereas optimum water temperatures for rearing range from about 6 °C to 10 °C (46 °F to 50 °F) (Buchanan and Gregory 1997, pp. 121-122; Goetz 1989, pp. 22-24; McPhail and Murray 1979, pp. 41, 50, 53, 55). In Granite Creek, Idaho, Bonneau and Scarnecchia (1996) observed that juvenile bull trout selected the coldest water available in a plunge pool, 8 °C to 9 °C (46 °F to 48 °F), within a temperature gradient of 8 °C to 15 °C (4 °F to 60 °F). In a landscape study relating bull trout distribution to maximum water temperatures, Dunham et al. (2003) found that the probability of juvenile bull trout occurrence does not become high (i.e., greater than 0.75) until maximum temperatures decline to 11 °C to 12 °C (52 °F to 54 °F).

Although bull trout are found primarily in cold streams, occasionally these fish are found in larger, warmer river systems throughout the Columbia River basin (Buchanan and Gregory 1997, pp. 121-

122; Fraley and Shepard 1989, pp. 135-137; Rieman and McIntyre 1993, p. 2; Rieman and McIntyre 1995, p. 288; Rieman et al. 1997, p. 1114). Availability and proximity of cold water patches and food productivity can influence bull trout ability to survive in warmer rivers (Myrick et al. 2002). For example, in a study in the Little Lost River of Idaho where bull trout were found at temperatures ranging from 8 °C to 20 °C (46 °F to 68 °F), most sites that had high densities of bull trout were in areas where primary productivity in streams had increased following a fire (Gamett, pers. comm. 2002).

All life history stages of bull trout are associated with complex forms of cover, including large woody debris, undercut banks, boulders, and pools (Fraley and Shepard 1989, pp. 135-137; Goetz 1989, pp. 22-25; Hoelscher and Bjornn 1989, p. 54; Pratt 1992, p. 6; Rich 1996, pp. 35-38; Sedell and Everest 1991, p. 1; Sexauer and James 1997, pp. 367-369; Thomas 1992, pp. 4-5; Watson and Hillman 1997, pp. 247-249). Maintaining bull trout habitat requires stability of stream channels and maintenance of natural flow patterns (Rieman and McIntyre 1993, p. 7). Juvenile and adult bull trout frequently inhabit side channels, stream margins, and pools with suitable cover (Sexauer and James 1997, pp. 367-369). These areas are sensitive to activities that directly or indirectly affect stream channel stability and alter natural flow patterns. For example, altered stream flow in the fall may disrupt bull trout during the spawning period, and channel instability may decrease survival of eggs and young juveniles in the gravel from winter through spring (Fraley and Shepard 1989, pp. 135-137; Pratt 1992, p. 6; Pratt and Huston 1993, pp. 70-72). Pratt (1992, p. 6) indicated that increases in fine sediment reduce egg survival and emergence.

Bull trout typically spawn from August through November during periods of increasing flows and decreasing water temperatures. Preferred spawning habitat consists of low-gradient stream reaches with loose, clean gravel (Fraley and Shepard 1989, p. 135). Redds are often constructed in stream reaches fed by springs or near other sources of cold groundwater (Goetz 1989, p. 15; Pratt 1992, p. 8; Rieman and McIntyre 1996, p. 133). Depending on water temperature, incubation is normally 100 to 145 days (Pratt 1992, p. 8). After hatching, fry remain in the substrate, and time from egg deposition to emergence may surpass 200 days. Fry normally emerge from early April through May, depending on water temperatures and increasing stream flows (Ratliff and Howell 1992 in Howell and Buchanan 1992, pp. 10, 15; Pratt 1992, pp. 5-6).

Early life stages of fish, specifically the developing embryo, require the highest inter-gravel dissolved oxygen (IGDO) levels, and are the most sensitive life stage to reduced oxygen levels. The oxygen demand of embryos depends on temperature and on stage of development, with the greatest IGDO required just prior to hatching.

A literature review conducted by Ecology (WDOE 2002) indicates that adverse effects of lower oxygen concentrations on embryo survival are magnified as temperatures increase above optimal (for incubation). In a laboratory study conducted in Canada, researchers found that low oxygen levels retarded embryonic development in bull trout (Giles and Van der Zweep 1996, pp. 54-55). Normal oxygen levels seen in rivers used by bull trout during spawning ranged from 8 to 12 mg/L (in the gravel), with corresponding instream levels of 10 to 11.5 mg/L (Stewart et al. 2007). In addition, IGDO concentrations, water velocities in the water column, and especially the intergravel flow rate, are interrelated variables that affect the survival of incubating embryos (ODEQ 1995).

Due to a long incubation period of 220+ days, bull trout are particularly sensitive to adequate IGDO levels. An IGDO level below 8 mg/L is likely to result in mortality of eggs, embryos, and fry.

Migratory forms of bull trout may develop when habitat conditions allow movement between spawning and rearing streams and larger rivers, lakes or nearshore marine habitat where foraging opportunities may be enhanced (Brenkman and Corbett 2005, pp. 1073, 1079-1080; Frissell 1993, p. 350; Goetz et al. 2004, pp. 45, 55, 60, 68, 77, 113-114, 123, 125-126). For example, multiple life history forms (e.g., resident and fluvial) and multiple migration patterns have been noted in the Grande Ronde River (Baxter 2002). Parts of this river system have retained habitat conditions that allow free movement between spawning and rearing areas and the mainstem Snake River. Such multiple life history strategies help to maintain the stability and persistence of bull trout populations to environmental changes. Benefits to migratory bull trout include greater growth in the more productive waters of larger streams, lakes, and marine waters; greater fecundity resulting in increased reproductive potential; and dispersing the population across space and time so that spawning streams may be recolonized should local populations suffer a catastrophic loss (Frissell 1999, pp. 15-16; MBTSG 1998, pp. iv, 48-50; Rieman and McIntyre 1993, pp. 18-19; USFWS 2004b, Vol. 2, p. 63). In the absence of the migratory bull trout life form, isolated populations cannot be replenished when disturbances make local habitats temporarily unsuitable. Therefore, the range of the species is diminished, and the potential for a greater reproductive contribution from larger fish with higher fecundity is lost (Rieman and McIntyre 1993, pp. 1-18).

Diet. Bull trout are opportunistic feeders, with food habits primarily a function of size and life-history strategy. A single optimal foraging strategy is not necessarily a consistent feature in the life of a fish, because this strategy can change as the fish progresses from one life stage to another (i.e., juvenile to subadult). Fish growth depends on the quantity and quality of food that is eaten (Gerking 1994), and as fish grow, their foraging strategy changes as their food changes, in quantity, size, or other characteristics. Resident and juvenile migratory bull trout prey on terrestrial and aquatic insects, macrozooplankton, and small fish (Boag 1987, p. 58; Donald and Alger 1993, pp. 239-243; Goetz 1989, pp. 33-34). Subadult and adult migratory bull trout feed on various fish species (Brown 1994, p. 21; Donald and Alger 1993, p. 242; Fraley and Shepard 1989, p. 135; Leathe and Graham 1982, p. 95). Bull trout of all sizes other than fry have been found to eat fish up to half their length (Beauchamp and VanTassell 2001). In nearshore marine areas of western Washington, bull trout feed on Pacific herring (*Clupea pallasi*), Pacific sand lance (*Ammodytes hexapterus*), and surf smelt (*Hypomesus pretiosus*) (Goetz et al. 2004, p. 114; WDFW et al. 1997, p. 23).

Bull trout migration and life history strategies are closely related to their feeding and foraging strategies. Migration allows bull trout to access optimal foraging areas and exploit a wider variety of prey resources. Optimal foraging theory can be used to describe strategies fish use to choose between alternative sources of food by weighing the benefits and costs of capturing one source of food over another. For example, prey often occur in concentrated patches of abundance ("patch model") (Gerking 1994). As the predator feeds in one patch, the prey population is reduced, and it becomes more profitable for the predator to seek a new patch rather than continue feeding on the original one. This can be explained in terms of balancing energy acquired versus energy expended. For example, in the Skagit River system, anadromous bull trout make migrations as long as 121 miles between marine foraging areas in Puget Sound and headwater spawning grounds, foraging on salmon eggs and juvenile salmon along their migration route (WDFW et al. 1997). Anadromous

bull trout also use marine waters as migration corridors to reach seasonal habitats in non-natal watersheds to forage and possibly overwinter (Brenkman and Corbett 2005, p. 1079; Goetz et al. 2004, pp. 36, 60).

Changes in Status of the Coastal-Puget Sound Interim Recovery Unit. Although the status of bull trout in Coastal-Puget Sound interim recovery unit has been improved by certain actions, it continues to be degraded by other actions, and it is likely that the overall status of the bull trout in this population segment has not improved since its listing on November 1, 1999. Improvement has occurred largely through changes in fishing regulations and habitat-restoration projects. Fishing regulations enacted in 1994 either eliminated harvest of bull trout or restricted the amount of harvest allowed, and this likely has had a positive influence on the abundance of bull trout. Improvement in habitat has occurred following restoration projects intended to benefit either bull trout or salmon, although monitoring the effectiveness of these projects seldom occurs. On the other hand, the status of this population segment has been adversely affected by a number of Federal and non-Federal actions, some of which were addressed under section 7 of the Act. Most of these actions degraded the environmental baseline; all of those addressed through formal consultation under section 7 of the Act permitted the incidental take of bull trout.

Section 10(a)(1)(B) permits have been issued for Habitat Conservation Plans (HCP) completed in the Coastal-Puget Sound population segment. These include: 1) the City of Seattle's Cedar River Watershed HCP, 2) Simpson Timber HCP (now Green Diamond Resources), 3) Tacoma Public Utilities Green River HCP, 4) Plum Creek Cascades HCP, 5) Washington State Department of Natural Resources (WSDNR) State Trust Lands HCP, 6) West Fork Timber HCP, and 7) WSDNR Forest Practices HCP. These HCPs provide landscape-scale conservation for fish, including bull trout. Many of the covered activities associated with these HCPs will contribute to conserving bull trout over the long-term; however, some covered activities will result in short-term degradation of the baseline. All HCPs permit the incidental take of bull trout.

Changes in Status of the Columbia River Interim Recovery Unit. The overall status of the Columbia River interim recovery unit has not changed appreciably since its listing on June 10, 1998. Populations of bull trout and their habitat in this area have been affected by a number of actions addressed under section 7 of the Act. Most of these actions resulted in degradation of the environmental baseline of bull trout habitat, and all permitted or analyzed the potential for incidental take of bull trout. The Plum Creek Cascades HCP, Plum Creek Native Fish HCP, Storedahl Daybreak Mine HCP, and WSDNR Forest Practices HCP addressed portions of the Columbia River population segment of bull trout.

Changes in Status of the Klamath River Interim Recovery Unit. Improvements in the Threemile, Sun, and Long Creek local populations have occurred through efforts to remove or reduce competition and hybridization with non-native salmonids, changes in fishing regulations, and habitat-restoration projects. Population status in the remaining local populations (Boulder-Dixon, Deming, Brownsworth, and Leonard Creeks) remains relatively unchanged. Grazing within bull trout watersheds throughout the recovery unit has been curtailed. Efforts at removal of non-native species of salmonids appear to have stabilized the Threemile and positively influenced the Sun Creek local populations. The results of similar efforts in Long Creek are inconclusive. Mark and

recapture studies of bull trout in Long Creek indicate a larger migratory component than previously expected.

Although the status of specific local populations has been slightly improved by recovery actions, the overall status of Klamath River bull trout continues to be depressed. Factors considered threats to bull trout in the Klamath Basin at the time of listing – habitat loss and degradation caused by reduced water quality, past and present land use management practices, water diversions, roads, and non-native fishes – continue to be threats today.

Changes in Status of the Saint Mary-Belly River Interim Recovery Unit. The overall status of bull trout in the Saint Mary-Belly River interim recovery unit has not changed appreciably since its listing on November 1, 1999. Extensive research efforts have been conducted since listing, to better quantify populations of bull trout and their movement patterns. Limited efforts in the way of active recovery actions have occurred. Habitat occurs mostly on Federal and Tribal lands (Glacier National Park and the Blackfeet Nation). Known problems due to instream flow depletion, entrainment, and fish passage barriers resulting from operations of the U.S. Bureau of Reclamation's Milk River Irrigation Project (which transfers Saint Mary-Belly River water to the Missouri River Basin) and similar projects downstream in Canada constitute the primary threats to bull trout and to date they have not been adequately addressed under section 7 of the Act. Plans to upgrade the aging irrigation delivery system are being pursued, which has potential to mitigate some of these concerns but also the potential to intensify dewatering. A major fire in August 2006 severely burned the forested habitat in Red Eagle and Divide Creeks, potentially affecting three of nine local populations and degrading the baseline.

2.2.2 Status of Designated Critical Habitat

The action area falls within the designation of critical habitat for Puget Sound Chinook Salmon, and Bull Trout, and the project will both beneficially and adversely affect features of designated critical habitat.

2.2.2.1 Status of Puget Sound Chinook Critical Habitat

The NMFS designated critical habitat for Puget Sound Chinook salmon on September 2, 2005 (70 FR 52630). The specific geographic area includes portions of the Nooksack River, Skagit River, Sauk River, Stillaguamish River, Skykomish River, Snoqualmie River, Lake Washington, Green River, Puyallup River, White River, Nisqually River, Hamma Hamma River and other Hood Canal watersheds, the Dungeness/Elwha Watersheds, and nearshore marine areas of the Strait of Georgia, Puget Sound, Hood Canal, and the Strait of Juan de Fuca. This designation includes the stream channels within the designated stream reaches, and includes a lateral extent as defined by the ordinary high water line. In areas where the ordinary high water line is not defined the lateral extent is defined as the bank full elevation.

The designation for this ESU includes sites necessary to support one or more life stages. These areas are important for the species' overall conservation by protecting quality growth, reproduction, and feeding. The PCEs of PS Chinook salmon critical habitat are:

1) Freshwater spawning sites with water quantity and quality conditions and substrate that support spawning, incubation, and larval development;

2) Freshwater rearing sites with (1) water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility, (2) water quality and forage that support juvenile development, and (3) natural cover such as shade, submerged and overhanging large wood, logjams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks;

3) Freshwater migration corridors free of obstruction and excessive predation with water quantity and quality conditions and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels, and undercut banks that support juvenile and adult mobility and survival;

4) Estuarine areas free of obstruction and excessive predation with water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between fresh- and saltwater; natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels; and juvenile and adult forage, including aquatic invertebrates and fishes, supporting growth and maturation;

5) Nearshore marine areas free of obstruction and excessive predation with water quality and quantity conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation; and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels; and

6) Offshore marine areas with water quality conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation.

Of 49 subbasins reviewed in NMFS' assessment of critical habitat for the Puget Sound ESUs, nine subbasins were rated as having a medium conservation value, 12 were rated as low, and the remaining subbasins (40), where the bulk of Federal lands occur for this ESU, were rated as having a high conservation value to Puget Sound Chinook salmon. Factors contributing to the downward trends in this ESU are hydromorphological changes (such as diking, revetments, loss of secondary channels in floodplains, widespread blockages of streams, and changes in peak flows), degraded freshwater and marine habitat affected by agricultural activities and urbanization, and upper river tributaries widely affected by poor forest practices. Changes in habitat quantity, availability, diversity, flow, temperature, sediment load, and channel stability are common limiting factors in areas of critical habitat. The nearshore marine habitat has been extensively altered and armored by industrial and residential development near the mouths of many of Puget Sound's tributaries. A railroad runs along large portions of the eastern shoreline of Puget Sound, eliminating natural cover along the shore and natural recruitment of beach sand (SSPS 2007).

Habitat conditions that are limiting. Residential and commercial development has reduced the amount of functioning nearshore and estuarine habitat available for salmon rearing and migration (NMFS 2011c; SSPS 2007). The loss of mudflats, eelgrass meadows, and macroalgae further limits salmon foraging and rearing opportunities in nearshore and estuarine areas. Floodplain connectivity

and function, channel structure and complexity, riparian areas and large wood supply, stream substrate, and water quality have also been degraded for adult spawning, embryo incubation, and rearing as a result of cumulative impacts of agriculture, forestry, and development.

2.2.2.2 Status of Coastal-Puget Sound Bull Trout Critical Habitat

The USFWS published a final critical habitat designation for the coterminous United States population of the bull trout on October 18, 2010 (75 FR 63898). A justification document was also developed to support the rule and is available on the USFWS website (http://www.fws.gov/pacific/bulltrout). The scope of the designation involved the species' coterminous range, including six draft recovery units [Mid-Columbia, Saint Mary, Columbia Headwaters, Coastal, Klamath, and Upper Snake (75 FR 63927 [October 18, 2010]). The USFWS's 1999 coterminous listing rule identified five interim recovery units (50 CFR Part 17, pg. 58910), which includes the Jarbidge River, Klamath River, Columbia River, Coastal-Puget Sound, and Saint Mary-Belly River population segments (also considered as interim recovery units). The USFWS's 5-year review recommended re-evaluation of these units based on new information (USFWS 2008, p. 9). However, until the bull trout draft recovery plan is finalized, the current five interim recovery units will be used for purposes of section 7 jeopardy analyses and recovery planning. The adverse modification analysis in this Opinion does not rely on recovery units, relying instead on the listed critical habitat units and subunits.

Rangewide, the USFWS designated reservoirs/lakes and stream/shoreline miles as bull trout critical habitat (Table 3). Designated bull trout critical habitat is of two primary use types: 1) spawning and rearing, and 2) foraging, migration, and overwintering (FMO).

Table 3 – Stream/shoreline distance and reservoir/lake area designated as bull trout critical habitat by state.

State	Stream/Shoreline Miles	Stream/Shoreline Kilometers	Reservoir /Lake Acres	Reservoir/ Lake Hectares
Idaho	8,771.6	14,116.5	170,217.5	68,884.9
Montana	3,056.5	4,918.9	221,470.7	89,626.4
Nevada	71.8	115.6	-	-
Oregon	2,835.9	4,563.9	30,255.5	12,244.0
Oregon/Idaho	107.7	173.3	-	-
Washington	3,793.3	6,104.8	66,308.1	26,834.0
Washington (marine)	753.8	1,213.2	-	-
Washington/Idaho	37.2	59.9	-	-
Washington/Oregon	301.3	484.8	-	-
Total	19,729.0	31,750.8	488,251.7	197,589.2

The final rule identifies and designates as critical habitat approximately 1,323.7 km (822.5 miles) of streams/shorelines and 6,758.8 ha (16,701.3 acres) of lakes/reservoirs of unoccupied habitat to address bull trout conservation needs in specific geographic areas in several areas not occupied at the time of listing. These unoccupied areas were determined by the USFWS to be essential for restoring

functioning migratory bull trout populations based on currently available scientific information. These unoccupied areas often include lower main stem river environments that can provide seasonally important migration habitat for bull trout. This type of habitat is essential in areas where bull trout habitat and population loss over time necessitates reestablishing bull trout in currently unoccupied habitat areas to achieve recovery.

The final rule excludes some critical habitat segments based on a careful balancing of the benefits of inclusion versus the benefits of exclusion. Critical habitat does not include: 1) waters adjacent to non-Federal lands covered by legally operative incidental take permits for HCPs issued under section 10(a)(1)(B) of the ESA, in which bull trout is a covered species on or before the publication of this final rule; 2) waters within or adjacent to Tribal lands subject to certain commitments to conserve bull trout or a conservation program that provides aquatic resource protection and restoration through collaborative efforts, and where the Tribes indicated that inclusion would impair their relationship with the USFWS; or 3) waters where impacts to national security have been identified (75 FR 63898 [October 18, 2010]). Excluded areas are approximately 10 percent of the stream/shoreline miles and 4 percent of the lakes and reservoir acreage of designated critical habitat. Each excluded area is identified in the relevant Critical Habitat Unit (CHU) text, as identified in paragraphs (e)(8) through (e)(41) of the final rule. See Tables 4 and 5 for the list of excluded areas. It is important to note that the exclusion of water bodies from designated critical habitat does not negate or diminish their importance for bull trout conservation. Because exclusions reflect the often complex pattern of land ownership, designated critical habitat is often fragmented and interspersed with excluded stream segments.

Table 4 – Stream/shoreline distance excluded from bull trout critical habitat based on tribal ownership or other plan.

Ownership and/or Plan	Kilometers	Miles
Lewis River Hydro Conservation Easements	7.0	4.3
DOD – Dabob Bay Naval	23.9	14.8
HCP – Cedar River (City of Seattle)	25.8	16.0
HCP – Washington Forest Practices Lands	1,608.30	999.4
HCP – Green Diamond (Simpson)	104.2	64.7
HCP – Plum Creek Central Cascades (WA)	15.8	9.8
HCP – Plum Creek Native Fish (MT)	181.6	112.8
HCP–Stimson	7.7	4.8
HCP – WDNR Lands	230.9	149.5
Tribal – Blackfeet	82.1	51.0
Tribal – Hoh	4.0	2.5
Tribal – Jamestown S'Klallam	2.0	1.2
Tribal – Lower Elwha	4.6	2.8
Tribal – Lummi	56.7	35.3
Tribal – Muckleshoot	9.3	5.8
Tribal – Nooksack	8.3	5.1
Tribal – Puyallup	33.0	20.5
Tribal – Quileute	4.0	2.5
Tribal – Quinault	153.7	95.5

Tribal – Skokomish	26.2	16.3
Tribal – Stillaguamish	1.8	1.1
Tribal – Swinomish	45.2	28.1
Tribal – Tulalip	27.8	17.3
Tribal – Umatilla	62.6	38.9
Tribal – Warm Springs	260.5	161.9
Tribal – Yakama	107.9	67.1
Total	3,094.9	1,923.1

Table 5 – Lake/Reservoir area excluded from bull trout critical habitat based on tribal ownership or other plan.

Ownership and/or Plan	Hectares	Acres
HCP – Cedar River (City of Seattle)	796.5	1,968.2
HCP – Washington Forest Practices Lands	5,689.1	14,058.1
HCP – Plum Creek Native Fish	32.2	79.7
Tribal – Blackfeet	886.1	2,189.5
Tribal – Warm Springs	445.3	1,100.4
Total	7,849.3	19,395.8

Conservation Role and Description of Critical Habitat. The conservation role of bull trout critical habitat is to support viable core area populations (75 FR 63898:63943 [October 18, 2010]). The core areas reflect the metapopulation structure of bull trout and are the closest approximation of a biologically functioning unit for the purposes of recovery planning and risk analyses. CHUs generally encompass one or more core areas and may include FMO areas, outside of core areas, that are important to the survival and recovery of bull trout.

Thirty-two CHUs within the geographical area occupied by the species at the time of listing are designated under the final rule. Twenty-nine of the CHUs contain all of the physical or biological features identified in this final rule and support multiple life-history requirements. Three of the mainstem river units in the Columbia and Snake River basins contain most of the physical or biological features necessary to support the bull trout's particular use of that habitat, other than those physical biological features associated with PCEs 5 and 6, which relate to breeding habitat.

The primary function of individual CHUs is to maintain and support core areas, which 1) contain bull trout populations with the demographic characteristics needed to ensure their persistence and contain the habitat needed to sustain those characteristics (Rieman and McIntyre 1993, p. 19); 2) provide for persistence of strong local populations, in part, by providing habitat conditions that encourage movement of migratory fish (MBTSG 1998, pp. 48-49; Rieman and McIntyre 1993, pp. 22-23); 3) are large enough to incorporate genetic and phenotypic diversity, but small enough to ensure connectivity between populations (Hard 1995, pp. 314-315; Healey and Prince 1995, p. 182; MBTSG 1998, pp. 48-49; Rieman and McIntyre 1993, pp. 22-23); and 4) are distributed throughout the historic range of the species to preserve both genetic and phenotypic adaptations (Hard 1995, pp. 321-322; MBTSG 1998, pp. 13-16; Rieman and Allendorf 2001, p. 763; Rieman and McIntyre 1993, p. 23).

The Olympic Peninsula and Puget Sound CHUs are essential to the conservation of amphidromous bull trout, which are unique to the Coastal-Puget Sound population segment. These CHUs contain marine nearshore and freshwater habitats, outside of core areas, that are used by bull trout from one or more core areas. These habitats, outside of core areas, contain PCEs that are critical to adult and subadult foraging, overwintering, and migration.

Primary Constituent Elements for Bull Trout. Within the designated critical habitat areas, the PCEs for bull trout are those habitat components that are essential for the primary biological needs of foraging, reproducing, rearing of young, dispersal, genetic exchange, or sheltering. Based on the current knowledge of the life history, biology, and ecology of this species and the characteristics of the habitat necessary to sustain its essential life-history functions, the USFWS has determined that the following PCEs are essential for the conservation of bull trout.

1) Springs, seeps, groundwater sources, and subsurface water connectivity (hyporheic flows) to contribute to water quality and quantity and provide thermal refugia.

2) Migration habitats with minimal physical, biological, or water quality impediments between spawning, rearing, overwintering, and freshwater and marine foraging habitats, including but not limited to permanent, partial, intermittent, or seasonal barriers.

3) An abundant food base, including terrestrial organisms of riparian origin, aquatic macroinvertebrates, and forage fish.

4) Complex river, stream, lake, reservoir, and marine shoreline aquatic environments, and processes that establish and maintain these aquatic environments, with features such as large wood, side channels, pools, undercut banks and unembedded substrates, to provide a variety of depths, gradients, velocities, and structure.

5) Water temperatures ranging from 2 °C to 15 °C (36 °F to 59 °F), with adequate thermal refugia available for temperatures that exceed the upper end of this range. Specific temperatures within this range will depend on bull trout life-history stage and form; geography; elevation; diurnal and seasonal variation; shading, such as that provided by riparian habitat; streamflow; and local groundwater influence.

6) In spawning and rearing areas, substrate of sufficient amount, size, and composition to ensure success of egg and embryo overwinter survival, fry emergence, and young-of-the-year and juvenile survival. A minimal amount of fine sediment, generally ranging in size from silt to coarse sand, embedded in larger substrates, is characteristic of these conditions. The size and amounts of fine sediment suitable to bull trout will likely vary from system to system.

7) A natural hydrograph, including peak, high, low, and base flows within historic and seasonal ranges or, if flows are controlled, minimal flow departure from a natural hydrograph.

8) Sufficient water quality and quantity such that normal reproduction, growth, and survival are not inhibited.

9) Sufficiently low levels of occurrence of non-native predatory (e.g., lake trout (*S. namaycush*), walleye (*Stizostedion vitreum*), northern pike, smallmouth bass); interbreeding (e.g., brook trout); or competing (e.g., brown trout) species that, if present, are adequately temporally and spatially isolated from bull trout.

PCE #9 applies to both the freshwater and marine environments, currently no non-native fish species are of concern in the marine environment, though this could change in the future.

Note that only PCEs 2, 3, 4, 5, and 8 apply to marine nearshore waters identified as critical habitat. Also, lakes and reservoirs within the CHUs also contain most of the physical or biological features necessary to support bull trout, with the exception of those associated with PCEs 1 and 6. Additionally, all except PCE 6 apply to FMO habitat designated as critical habitat.

Critical habitat includes the stream channels within the designated stream reaches and has a lateral extent as defined by the bankfull elevation on one bank to the bankfull elevation on the opposite bank. Bankfull elevation is the level at which water begins to leave the channel and move into the floodplain and is reached at a discharge that generally has a recurrence interval of 1 to 2 years on the annual flood series. If bankfull elevation is not evident on either bank, the ordinary high-water line must be used to determine the lateral extent of critical habitat. The lateral extent of designated lakes is defined by the perimeter of the water body as mapped on standard 1:24,000 scale topographic maps. The USFWS assumes in many cases this is the full- pool level of the water body. In areas where only one side of the water body is designated (where only one side is excluded), the mid-line of the water body represents the lateral extent of critical habitat.

In marine nearshore areas, the inshore extent of critical habitat is the mean higher high-water (MHHW) line, including the uppermost reach of the saltwater wedge within tidally influenced freshwater heads of estuaries. The MHHW line refers to the average of all the higher high-water heights of the two daily tidal levels. Marine critical habitat extends offshore to the depth of 10 meters (33 feet) relative to the MLLW line (zero tidal level or average of all the lower low-water heights of the two daily tidal levels). This area between the MHHW line and minus 10 meters MLLW line (the average extent of the photic zone) is considered the habitat most consistently used by bull trout in marine waters based on known use, forage fish availability, and ongoing migration studies and captures geological and ecological processes important to maintaining these habitats. This area contains essential foraging habitat and migration corridors such as estuaries, bays, inlets, shallow subtidal areas, and intertidal flats.

Adjacent shoreline riparian areas, bluffs, and uplands are not designated as critical habitat. However, it should be recognized that the quality of marine and freshwater habitat along streams, lakes, and shorelines is intrinsically related to the character of these adjacent features, and that human activities that occur outside of the designated critical habitat can have major effects on physical and biological features of the aquatic environment.

Activities that cause adverse effects to critical habitat are evaluated to determine if they are likely to "destroy or adversely modify" critical habitat by no longer serving the intended conservation role for the species or retaining those PCEs that relate to the ability of the area to at least periodically support the species. Activities that may destroy or adversely modify critical habitat are those that alter the

PCEs to such an extent that the conservation value of critical habitat is appreciably reduced (75 FR 63898:63943 [October 18, 2010]; USFWS 2004b, Vol. 1. pp. 140-193, Vol. 2. pp. 69-114). The USFWS's evaluation must be conducted at the scale of the entire critical habitat area designated, unless otherwise stated in the final critical habitat rule (USFWS and NMFS 1998, pp. 4-39). Thus, adverse modification of bull trout critical habitat is evaluated at the scale of the final designation, which includes the critical habitat designated for the Klamath River, Jarbidge River, Columbia River, Coastal-Puget Sound, and Saint Mary-Belly River population segments. However, we consider all 32 CHUs to contain features or areas essential to the conservation of the bull trout (75 FR 63898:63901, 63944 [October 18, 2010]). Therefore, if a proposed action would alter the physical or biological features of critical habitat to an extent that appreciably reduces the conservation function of one or more critical habitat units for bull trout, a finding of adverse modification of the entire designated critical habitat area may be warranted (75 FR 63898:63943 [October 18, 2010]).

Current Critical Habitat Condition Rangewide. The condition of bull trout critical habitat varies across its range from poor to good. Although still relatively widely distributed across its historic range, the bull trout occurs in low numbers in many areas, and populations are considered depressed or declining across much of its range (67 FR 71240 [November 29, 2002]). This condition reflects the condition of bull trout habitat. The decline of bull trout is primarily due to habitat degradation and fragmentation, blockage of migratory corridors, poor water quality, past fisheries management practices, impoundments, dams, water diversions, and the introduction of nonnative species (63 FR 31647 [June 10 1998]; 64 FR 17112 [April 8, 1999]).

There is widespread agreement in the scientific literature that many factors related to human activities have impacted bull trout and their habitat, and continue to do so. Among the many factors that contribute to degraded PCEs, those which appear to be particularly significant and have resulted in a legacy of degraded habitat conditions are as follows: 1) fragmentation and isolation of local populations due to the proliferation of dams and water diversions that have eliminated habitat, altered water flow and temperature regimes, and impeded migratory movements (Dunham and Rieman 1999, p. 652; Rieman and McIntyre 1993, p. 7); 2) degradation of spawning and rearing habitat and upper watershed areas, particularly alterations in sedimentation rates and water temperature, resulting from forest and rangeland practices and intensive development of roads (Fraley and Shepard 1989, p. 141; MBTSG 1998, pp. ii - v, 20-45); 3) the introduction and spread of nonnative fish species, particularly brook trout and lake trout, as a result of fish stocking and degraded habitat conditions, which compete with bull trout for limited resources and, in the case of brook trout, hybridize with bull trout (Leary et al. 1993, p. 857; Rieman et al. 2006, pp. 73-76); 4) in the Coastal-Puget Sound region where amphidromous bull trout occur, degradation of mainstem river FMO habitat, and the degradation and loss of marine nearshore foraging and migration habitat due to urban and residential development; and 5) degradation of FMO habitat resulting from reduced prey base, roads, agriculture, development, and dams.

2.2.3 Effects of Climate Change

2.2.3.1 Climate Change Effects on Listed Fishes

Salmonids, other listed fishes, and their habitat throughout Washington State have likely been affected by climate change, and these effects are expected to continue into the future. Average annual Northwest air temperatures have increased by approximately 1.8°F (1°C) since 1900, which is nearly twice that for the last 100 years, indicating an increasing rate of change. This change in surface air temperature has already modified, and is likely to continue to modify, freshwater, estuarine, and marine habitats. Consequently, abundance, productivity, spatial distribution, and diversity of salmonid life stages occupying each type of affected habitat is likely to be further modified, generally in a detrimental manner.

Several studies have revealed that climate change has the potential to affect ecosystems in nearly all tributaries throughout the state (Battin et al. 2007; ISAB 2007). While the intensity of effects will vary by region (ISAB 2007), climate change is generally expected to alter aquatic habitat (water yield, peak flows, and stream temperature). As climate change alters the structure and distribution of rainfall, snowpack, and glaciations, each factor will in turn alter riverine hydrographs. Given the increasing certainty that climate change is occurring and is accelerating (Battin et al. 2007), the Services anticipate salmonid habitats will be affected. Climate and hydrology models project significant reductions in both total snow pack and low-elevation snow pack in the Pacific Northwest over the next 50 years (Mote and Salathé 2009) – changes that will shrink the extent of the snowmelt-dominated habitat available to salmonids. Such changes may restrict our ability to conserve diverse salmonid life histories.

In Washington State, most models project warmer air temperatures, increases in winter precipitation, and decreases in summer precipitation. Average temperatures in Washington State are likely to increase 0.2 – 1.1 ºF (0.1 – 0.6 ºC) per decade (Mote and Salathé 2009). Warmer air temperatures will lead to more precipitation falling as rain rather than snow. As the snow pack diminishes, seasonal hydrology will shift to more frequent and severe early large storms, changing stream flow timing and increasing peak river flows, which may limit salmonid survival (Mantua et al. 2009). The largest driver of climate-induced decline in salmonid populations is projected to be the impact of increased winter peak flows, which scour the streambed and destroy salmonid eggs (Battin et al. 2007).

Higher water temperatures and lower spawning flows, together with increased magnitude of winter peak flows are all likely to increase salmonid mortality. Higher ambient air temperatures will likely cause water temperatures to rise (ISAB 2007). Salmonids require cold water for spawning and incubation. As climate change progresses and stream temperatures warm, thermal refugia will be essential to persistence of many salmonid populations. Thermal refugia are important for providing salmonids with patches of suitable habitat while allowing them to undertake migrations through or to make foraging forays into areas with greater than optimal temperatures. To avoid waters above summer maximum temperatures, juvenile rearing may be increasingly found only in the confluence of colder tributaries or other areas of cold water refugia (Mantua et al. 2009).

Climate change also affects, continue to influence, and result in increased ocean temperatures, increased stratification of the water column, and intensity and timing changes of coastal upwelling (ISAB 2007). These continuing changes will alter primary and secondary productivity, marine community structures, and in turn, salmonid and rock fish growth, productivity, survival, and migrations. A mismatch between earlier smolt migrations for salmon (because of earlier peak spring

freshwater flows and decreased incubation period) and altered upwelling may reduce marine survival rates (including larval rockfish). Increased concentration of CO^2 reduces carbonate availability for shell-forming invertebrates, including some juvenile salmonid and rockfish prey items.

Climate change is expected to make recovery targets for PS Chinook salmon, rockfish, and Coastal-PS bull trout populations more difficult to achieve. Habitat action can address the adverse impacts of climate change on salmonids. Examples include restoring connections to historical floodplains and freshwater and estuarine habitats to provide fish refugia and areas to store excess floodwaters, protecting and restoring riparian vegetation to ameliorate stream temperature increases, and purchasing or applying easements to lands that provide important cold water or refuge habitat (Battin et al. 2007; ISAB 2007).

2.2.3.2 Climate Change Effects on Marine Mammals

Extensive climate change caused by the continuing buildup of human-produced atmospheric carbon dioxide and other greenhouse gases is predicted to have major environmental impacts along the west coast of North America during the 21st century and beyond. Warming trends in water and air temperatures are ongoing and are projected to disrupt the region's annual cycles of rain and snow, alter prevailing patterns of winds and ocean currents, and result in higher sea levels (Glick 2005, Snover et al. 2005). Rising sea levels are likely to directly affect pinniped haulout sites (Learmonth et al. 2006). Sites on some islands with low relief may be submerged. The net effect of a rise in sea level on overall terrestrial sea lion habitat amount or availability is uncertain, but at the projected rate it is unlikely to have a significant effect for many years (NMFS 2008b). Warmer temperatures could also shift the distribution of sea lions northward (NMFS 2008b). The direct effects of temperature increases on sea lion metabolic rates, foraging efficiencies, and disease transmission are unknown.

Changes in water temperature, ocean currents, sea levels, and increased acidification of ocean water due to climate change can also influence productivity, survival and distribution of marine mammal prey (Learmonth et al. 2006, NMFS 2008a, NMFS 2008b). Changes in prey availability can affect marine mammal community structure, distribution, abundance and migration patterns, and susceptibility to disease and contaminants (Learmonth et al 2006). The impact on recruitment dynamics of fish of importance to sea lions is unpredictable. Warmer waters could favor productivity of certain species of forage fish (e.g., pollock and herring), while the distribution and recruitment of other fish could be negatively affected (NMFS 2008b). In general, pinnipeds likely have the ability to adapt to environmentally driven changes in prey resources.

Although no formal predictions of impacts on the SR killer whales have yet been made, it seems likely that any changes in weather and oceanographic conditions resulting in effects on salmon populations will have consequences for the whales. Climate change is expected to impact salmon production in a number of ways. These include 1) alterations in river and stream flows and temperatures caused by changing patterns in precipitation and snowmelt that affect the survival of eggs, fry, smolts, and adults, as well as the ability of adults to migrate upstream for spawning, 2) loss of nearshore habitats important to juvenile salmon, and 3) changes in food availability in freshwater and marine habitats (Glick 2005).

2.3 Environmental Baseline

The environmental baseline includes the past and present impacts of all Federal, state, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of state or private actions which are contemporaneous with the consultation in process (50 CFR 402.02).

The action area, both in-water and terrestrial, is based on increased sound levels from impact and vibratory pile driving (see Section 1.3). While sound will travel through air into the uplands, the topography of the surrounding area, especially the downtown Seattle area, has steep hills and tall buildings that will greatly reduce the distance increased sound levels will travel landward of the project site. Since all listed species, except marbled murrelets (*Brachyramphus marmoratus*), are aquatic species, the following description of the action area is specific to the project area and when information is available, to Elliott Bay. The effects of the action on murrelets are described in Section 2.4.1.2.

The aquatic action area is defined as the marine environments of Elliott Bay and Puget Sound east of Bainbridge Island from Skiff Point south to Blake Island (see Figure 11). The baseline conditions of the marine enviorment throughout the action area are very similar. While specific information may be provided for Elliott Bay or the project area along the seawall, these conditions are similar to those found within Puget Sound between Elliott Bay and Bainbridge Island.

Current conditions within the action area have resulted from over 100 years of development. The action area, and more specifically, Elliott Bay, is extensively developed. About eight miles (12.8 km) of the action area shoreline is within Elliott Bay. Prior to development, Elliott Bay consisted of intertidal mud, sand flats, and wetlands. Extensive filling, dredging, and grading have resulted in Elliott Bay having one of the highest degrees of shoreline modification in Puget Sound at over 80 percent (Kerwin and Nelson 2000). Most shoreline modifications, such as seawalls and bulkheads, were placed to protect urban and residential development beginning in the early 1900's. Overwater structures currently occupy over 65 percent of the Elliott Bay shoreline and is highest along the downtown Seattle waterfront (City of Seattle 2003). Since the action area is so highly developed, current activities try to improve the physical, chemical, and biological conditions within the action area, but overall, the action area continues to be negatively impacted by the extensive urban and industrial developments.

2.3.1 <u>Physical Conditions</u>

2.3.1.1 Depth and Circulation

Elliott Bay has a surface area of approximately 20 km^2 (7.7 mi^2) and a volume of approximately 2,491 hectare meters (20,200 acre-feet) (Baker 1982). The greatest depth of Elliott Bay is 283 meters (930 feet) with an average depth of 62 meters (205 feet). Depths along the seawall range from about -0.76 meters (-2.5 feet) to about -9 meters (-30 feet) MLLW. Depths at the outer edges of the piers are typically around -15 meters (-50 feet). The hydraulic residence time in the inner harbor area of Elliott Bay typically ranges from 1 to 10 days, with variation associated with weather

patterns. Several studies have found a counter-clockwise circulation pattern in Elliott Bay, with discharges from the Duwamish Waterway flowing north along the downtown seawall corridor before flowing westward to Puget Sound (Ecology 1995; URS Engineers and Evans-Hamilton 1986; Ebbesmeyer et al. 1998). Current flow velocities are typically low and parallel to the seawall (Silcox et al. 1981). Currents during flood tides are stronger and tend to be in more of a clockwise direction, while during ebb tides currents were weaker and counterclockwise (Winter 1977).

The average tidal range in Elliott Bay is 3.4 meters (11.3 feet) (USACE 2008). The MHHW line is 2.75 meters (9.02 feet) and MLLW is -0.71 meters (-2.34 feet) [NAVD88] (NOAA 2011). The maximum recorded high tide elevation in Elliott Bay is 3.69 meters (12.12 feet) (NAVD88) (NOAA 2011). The elevation of the top of the existing seawall and the adjacent Alaskan Way road surface is approximately 4.8 meters (16 feet).

Human activities have significantly changed the natural processes and habitats in the action area. Hydrology has been modified as a result of filling in the nearshore zone, dredging, vessel currents and waves/wakes, reduction of flows from the Duwamish River (diversions of the Black and White rivers), and changes in stormwater runoff due to urbanization and rerouting of flows.

2.3.1.2 Substrate

The primary substrates found within the action area include fine sediment, sand, gravel, cobble, rock/riprap, and large wood. Fine sediments, found in the deeper areas of Elliott Bay where currents are low, include the deposited organic material that tends to settle in marine waters (i.e., dead and decaying plankton). Silts and organic materials are mixed with sands in many parts of the action area (Anchor QEA 2012).

Approximately 70 percent of the project area has been mapped as a sand/silt/shell hash mixture (Anchor QEA 2012; Figure 12). Sand is found in the intertidal, nearshore subtidal, and deep water environments. Sandy bottoms are shaped by natural hydrologic characteristics and vessel currents that move sand throughout the environment. Natural input of sediment into the area from feeder bluffs is currently very limited (Anchor Environmental 2004).

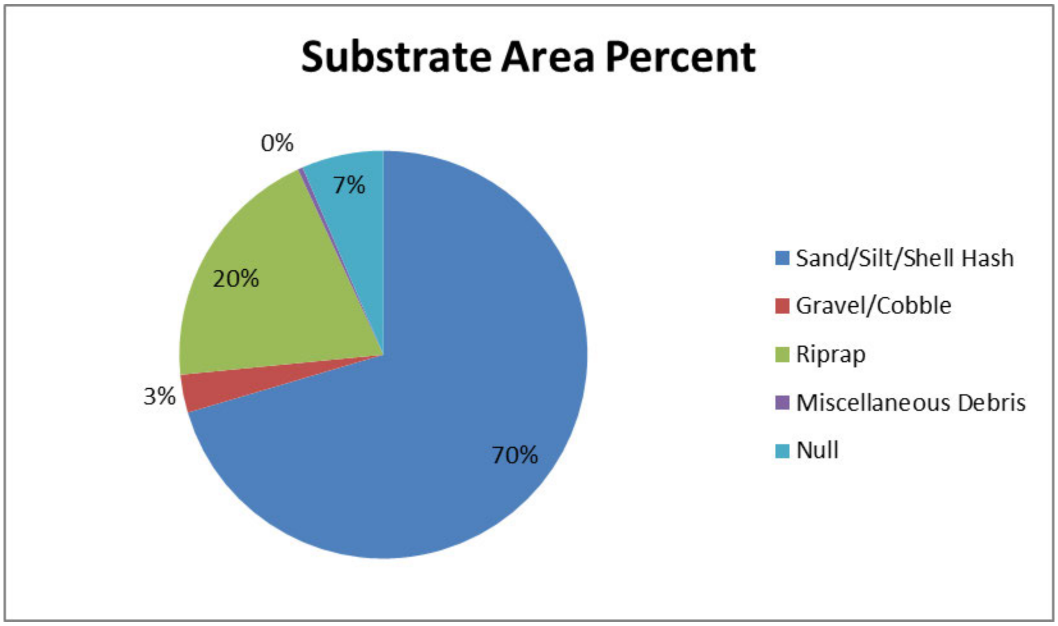

Figure 12 – Substrate type mapped in the project footprint (Source: Anchor QEA 2011).

Gravel is the natural substrate of the nearshore in many areas of Puget Sound due to the underlying geology and hydrologic/hydraulic processes. Gravel is limited to a few very small locations along the seawall, and occupies only three percent of the project area (Figure 12). Due to the proximity of the seawall to the mouth of the Duwamish River, gravel may not have been a major component of the natural environment, except along the beaches (historic photos confirm beaches with small gravel and sand along the Seattle waterfront). Cobble is similar to gravel in that it is a natural substrate of the nearshore environment. Cobble provides suitable substrate for a variety of macroalgae, invertebrates, and salmonid prey species. Cobble is rare along the seawall (Figure 12).

There are no known natural rock outcrops or deposits within the project area; the source of rock along the seawall is from the placement of quarried stone for seawall and bank protection. Rock provides a sturdy substrate for bull kelp and other macroalgae to fasten to, substrate for various invertebrates, and refuge for a variety of invertebrates and fish. Rock is found in multiple locations along the seawall and occupies approximately 20 percent of the project area (Anchor QEA 2011; Figure 12). Natural large wood essentially does not occur in the action area due to active removal of wood as a navigation hazard, and the lack of recruitment from the nearshore area, since there is no riparian vegetation in the project area.

2.3.1.3 Shoreline Conditions

The shoreline in the entire project area is interrupted by the seawall structure that extends for 2,184 meters (7,166 feet) from Pier 48 in the south to Olympic Sculpture Park in the north (S. Washington to Broad streets). The existing seawall is a vertical structure comprised of concrete, steel sheet pile and treated timber. In addition, there are 12 large overwater pier structures in the area: Colman Dock and Seattle Fire Station No. 5, Pier 54, Pier 55, Pier 56, Pier 57, Waterfront Park, Seattle Aquarium (Piers 59 and 60), Piers 62/63, Pier 66, Pier 67, Pier 69, and Pier 70. Cumulatively, the

pier structures within the project footprint account for 60 percent of the linear length of the seawall and represent overwater coverage and shading of 50 to 60 percent of the area.

The historic construction of the seawall and the placement of fill to facilitate development and use of the waterfront for commerce and industry eliminated the natural shoreline. There is currently no natural shoreline in the project area. There is one small beach north of Pier 48 that is comprised of sand, gravel, bricks, and riprap that is exposed during low tides (Figure 13).

Figure 13 – Small beach north of Pier 48.

The uplands of the project area are virtually completely impervious surfaces. Extensive urbanization has essentially eliminated most terrestrial and riparian plants in the project area. The only vegetation present is street trees and some planter boxes and potted plants on piers.

The existing seawall, in part, provides the structural foundation for the Seattle Central Waterfront. Failure of the seawall would result in catastrophic consequences to the waterfront and the built-up infrastructure of downtown Seattle. Failure would also be detrimental to listed fish and mammals by releasing large quantities of contaminants, other pollutants, and man-made structures to Elliott Bay and would not provide any recovery benefits. Because of the amount of fill and development along the Seattle waterfront over the last century, removal of the seawall is not feasible and would not improve or provide any benefit to the aquatic environment.

2.3.2 Water Quality Conditions

Water quality in Elliott Bay has been impaired by decades of various land use activities and discharges. Ecology and King County have ambient marine water quality monitoring stations in

Elliott Bay. Both of these agencies have focused their sampling on conventional parameters. Ecology monitors fecal coliform bacteria, chlorophyll, nitrate, ammonium, silicate, turbidity, temperature, salinity, pH, and DO. King County monitors temperature, salinity, water density, DO, nutrients, chlorophyll, and fecal coliform bacteria.

2.3.2.1 Temperature

Water temperature data in Elliott Bay were collected during surveys for non-indigenous species at seven sites in 2001 and were between 12 °C (53.6 °F) and 16 °C (60.8˚F) (WDNR 2001). Ecology conducted monthly surveys of water quality in Elliott Bay between 1991 and 2002. Results from these surveys showed that at 5 meters (16.4 foot) depths, water temperature generally fluctuates between 7.7 °C (45.8 °F) and 16.4 °C (61.5 °F) (Ecology 2006).

2.3.2.2 Dissolved Oxygen

Dissolved oxygen in Elliott Bay ranges between approximately 5.5 and 10 mg/L in winter and spring, respectively (King County 2009). Elliott Bay is listed as a Category 1 waterbody for DO in most areas and meets standards. However, one monitoring station in central Elliott Bay was listed as a Category 2 waterbody (Category 2 is for waters of concern, but that do not require an improvement plan at this time) for DO in the 2006 list (Ecology 2006). King County data collected in 2002 and 2003 showed four instances of DO levels lower than minimum criteria. However, staff from Ecology's Marine Unit reviewed these data and determined that the sample location is subject to incursions of upwelling with low DO bottom waters. This upwelling shows no evidence of human-caused sources and is therefore likely a natural condition (Ecology 2006).

2.3.2.3 Chemical Contamination and Nutrients

The seawall is located within industrial and commercial areas of Seattle that were first developed between the 1870s and the early 1900s. In general, the waterfront area is underlain by fill that was placed in the early 1900s that covered and incorporated timber and debris previously used in the construction of piers, wharves, and trestles. As a result of the industrial and commercial uses of this area, historical land uses potentially resulted in releases of contaminated materials into the surrounding environment. Some of these legacy pollutants in sediments might be periodically re-suspended in the water column due to wave action, vessels, and currents and if so, episodically degrade water quality.

Elliott Bay in the vicinity of the seawall also receives water runoff from several sources including stormwater discharges and groundwater flows. Other existing sources of potential contaminants to the nearshore water column in Elliott Bay include:

- CSO events,
- Vessel discharges,
- Discharges from pier facilities,
- Dumping of trash and other materials from the uplands, and
- Atmospheric deposition.

Primary sources of nutrients (i.e., nitrogen and phosphorus) in Elliott Bay are from upwelling of nutrient-rich water, input from land sources, recycling and re-suspension of nutrients between surface waters and sediments (Harris 1986), decomposition of plants and animals, and waste disposal. Nutrient-rich water from the Pacific Ocean provides a continuous supply of macronutrients to Puget Sound. During times of calm weather or reduced tidal action, reduced nutrient supply can limit photosynthesis in the surface waters in these areas (Williams et al 2001). Increased river discharge, lack of wind, and neap tidal cycles (minimum tidal range during first and third quarter of the moon phase) enhance stratification and slow vertical mixing of nutrients to the surface (Rensel Associates and PTI Environmental Services 1991).

Heavy metals (arsenic, cadmium, copper, lead, mercury, silver, and zinc), phthalates, and polycyclic aromatic hydrocarbons (PAHs, found in the creosote pilings) are detected in most water quality samples in Elliott Bay. Ambient dissolved copper and dissolved zinc concentrations for Elliott Bay are approximately 0.7 and 4.1 micrograms per liter (µg/L), respectively (Curl et al. 1988). A number of studies have observed bioaccumulation of PAHs, PCBs, and mercury in marine animals of Puget Sound and Elliott Bay, including mussels, squid, fish larvae, Chinook salmon, coho salmon, osprey, gray whales, killer whales, and harbor seals (NMFS 1993; KCEL 1998; Ross et al. 1998; USEPA and PSWQAT 1999; Cullon et al. 2001; Lambourn et al. 2001; PSP 2007).

2.3.2.4 Stormwater

As shown in Figure 14, there are seven major storm drain outfalls managed by the City within the project footprint, three separated storm drain outfalls, two CSOs, and two shared (CSO/stormwater) outfalls. The separated stormwater outfalls managed by the City are at the ends of S. Washington Street, Seneca Street, and Pine Street. There are two CSO outfalls at the end of Washington and Vine streets. In addition, there are currently approximately 50 small, individual outfalls that convey runoff directly to Elliott Bay (USACE 2008). These outfalls typically convey runoff from small areas of the roadway within the project area. Where the separated storm drain system and the combined sewer system share outfalls along the seawall, at University Street and Madison Street, the separated storm drain connections to the outfall pipes occur downstream of the CSO diversion structure, and thus the separated storm drainage does not affect the occurrence or magnitude of the CSO discharge at those outfalls.

Figure 14 – Location of Major Outfalls along the Elliott Bay Seawall

The water quality condition along the seawall is influenced by many contributing factors from both within and outside the project area. The project corridor is comprised almost entirely of impervious surfaces. The stormwater collection and conveyance network along the downtown waterfront was generally constructed in the 1930s and then upgraded in the 1980s as part of improvements to the Alaskan Way road surface, sidewalk, and seawall. Almost the entire existing Alaskan Way road surface within the project limits is classified as PGIS according to the City's stormwater code (SMC 22.801.170). Runoff from the project area, including the road surface, sidewalks, parking lots, driveways, trolley tracks, landscaping, and trail, drains to the separated stormwater system, and then to Elliott Bay. A small portion of the project area, approximately 1.4 acres east of the Alaskan Way roadway in the vicinity of Pike and Pine streets, drains to the City's combined sewer system. A very small portion of the project area infiltrates to the groundwater.

Outside, but flowing through the project area, stormwater and wastewater from Seattle and north King County, flow to and are treated at the West Point Wastewater Treatment Plant in Seattle. Twenty-nine percent of the City drains to the combined sewer system. With measurable rain occurring at least 100 days per year in the Seattle area, stormwater discharges are common along the waterfront during most months. Combined sewer overflows occur in varying frequencies when the capacity of that portion of the combined system is exceeded by stormwater inflows.

Four CSO outfalls are located along the seawall and discharge into Elliott Bay (Vine, University, Madison, Washington). Individual CSO outfalls in the project footprint have discharged from zero to 26 times in a year based on recent data from 2008-2012 (City of Seattle 2013). The average annual number of CSO discharges based on these years was 1.8 for Vine, 0.2 for University, 5.2 for Madison, and 0 for Washington. Overflows are most likely to occur from October to March coinciding with the greatest frequency and depth of precipitation, but may occur at other times of the year during heavy rain. In the years of 2008-2012, the duration of CSO overflow events in the project footprint ranged from a zero to 54.68 hours (City of Seattle 2013).

The key pollutants of concern in roadway runoff are total suspended solids, total copper, dissolved copper, total zinc, and dissolved zinc. The expected loading for the project area impervious surfaces (Alaskan Way) is shown in Table 6 (SDOT 2012b).

Table 6 – Existing Stormwater Pollutant Loading from Alaskan Way

	Existing Conditions Loads (pounds per year)		
	Lower Quartile	**Median**	**Upper Quartile**
Total Suspended Solids	4,051	5,239	7,023
Total Copper	0.97	1.19	1.81
Dissolved Copper	0.25	0.30	0.47
Total Zinc	5.32	6.97	9.22
Dissolved Zinc	1.44	1.80	2.92

2.3.2.5 Groundwater Quality

Groundwater within the project area can be found from 7 to 15 feet (2.1 to 4.5 meters) below the ground surface (SDOT 2012b). Groundwater levels along the existing seawall vary with Elliott Bay tidal fluctuations and may be dependent on the existing seawall type and integrity (SDOT 2012b). The groundwater is conveyed in discontinuous fill and native glacially overridden materials that have highly variable hydraulic conductivities. The water table (shallow groundwater surface) is flat for the most part, but is connected hydrologically to Elliott Bay tides (FHWA 2010). Near the intersection of Alaskan Way with Yesler Way where the existing seawall is a gravity structure, data collected in observation wells indicated that for an 11-foot (3.35 meters) tidal range, groundwater levels fluctuated by 8 feet (2.4 meters). However, along most of the rest of the seawall, groundwater level fluctuations were much less, typically in the 3-foot (0.9 meters) range (SDOT 2012b).

Groundwater flows are dependent on subsurface soils, with coarse-grained sand and gravel layers having higher groundwater discharge rates than occurs in fine-grained soils. Groundwater flow occurs horizontally towards Elliott Bay within the project footprint (SDOT 2012b). Small groundwater seeps have been observed coming through the seawall.

Soil and groundwater contaminant levels that are less than the Model Toxics Control Act (MTCA) clean-up levels (CULs) for unrestricted land use are referred to as "below levels of concern." Contaminant levels above the MTCA CULs for unrestricted land use are referred to as "above levels of concern" (SDOT 2012b). Low to moderate levels (below levels of concern) of soil and groundwater contamination occur throughout the urban Seattle waterfront and within the project footprint. Concentrations of contaminants in soils do occur above residential or general use CULs in some areas based on the history of industrial activity along the waterfront. Sources of contamination are not well defined.

Metals and PAH contamination in groundwater occur at low to non-detected levels in the Central Seawall area (between S. Washington and Virginia streets). Near Colman Dock, metals that exceeded the MTCA CULs (i.e., they are above levels of concern) include arsenic, cadmium, copper, lead, mercury, and silver. Petroleum hydrocarbons are generally present below levels of concern in the Central Seawall construction area with the exception of the historic piers where concentrations were found to exceed the MTCA CULs. These exceedances are likely attributed to historical contamination in the area of the Seattle Steam Company. The Seattle Steam Company site (south of Union Street and north of University Street) is an active MTCA cleanup site. At that site, groundwater is contaminated with Bunker C oil (i.e., Number 6 fuel oil).

In the North Seawall construction area (Virginia to Broad streets), metals (with the exception of one area) and PAH contamination in groundwater did not exceed the MTCA CULs (i.e., they were below levels of concern). Petroleum hydrocarbons were not detected in the groundwater throughout this portion of the seawall. However, metals detected north of Pier 66 at concentrations that exceeded MTCA CULs include arsenic, cadmium, chromium, copper, lead, mercury, silver, and zinc. Data for PCBs were not available for either the Central or North Seawall areas.

2.3.2.6 In-Water Sediment Quality

The most prevalent chemicals of concern (COCs) for in-water sediment areas from historic land uses include petroleum products, metals, and PAHs. Priority COCs include the following:

- **Total Petroleum Hydrocarbons (in the gasoline and diesel range):** These contaminants include gasoline, diesel, bunker fuel, and lube oils. Historical uses were widespread and associated with a variety of land uses. Lube oils were used extensively by the railroads. Diesel was used to heat businesses and homes.

- **Metals:** Heavy metals, including arsenic, cadmium, copper, lead, mercury, silver, and zinc, are associated with shipyards and boat maintenance facilities, metal works, foundries, and plating operations.

- **Polycyclic Aromatic Hydrocarbons**: PAHs are petroleum hydrocarbons that are produced as byproducts of fuel burning and are often formed by incomplete combustion of carbon-containing fuels. They are also present in creosote that was used to treat timber and/or wood pilings and used historically along the seawall to support the existing structure and relieving platform. PAHs may also be associated with petroleum releases such as leaking heating oil underground storage tanks, lubricating oils used by railroads, and burned timbers. In general, PAHs are relatively insoluble in water and bind to soil particles.

- **Polychlorinated Biphenyls:** The most common sources of PCBs are spills or leaks of dielectric fluids from PCB-containing equipment such as transformers or switches, which are often found at power stations. PCBs have also been used in many other products, such as capacitors, heat transfer systems, inks and carbonless copy paper, the ballasts of some fluorescent light fixtures, paints, caulking, and sealant materials (Windward 2010). In general, PCBs tend to adhere to organic matter in soil and are insoluble in water.

The most widespread contaminants in sediments along the Central Seawall are metals, and in particular, mercury (see Figures 15 and 16 for mapping of contaminants along the seawall). All known analyses performed in this nearshore sediment area resulted in detections, as well as several exceedances of the Sediment Quality Standards chemical screening criterion for mercury (SDOT 2012c). PAHs are also commonly reported in sediments in the North and Central Seawall areas. Generally, moderate levels (below the Sediment Management Standards/Cleanup Screening Level criteria) of mercury and PAH contamination have been identified in the sediments from Seneca Street (Pier 55) and south. In this area, the most common contaminants in order of reported occurrence are mercury, PAHs, PCBs, and other metals including copper, silver, and zinc. North of Pier 55, the primary contaminants are also metals (mercury, copper, lead, zinc, silver), PAHs, and isolated areas with exceedances of PCBs. Metals are the primary COC north of Pier 62/63, while PAHs and PCBs are generally less than levels of concern (less than the Sediment Management Standards/Cleanup Screening Level criteria) in this area.

Historical filling, disposal of ship bunker materials, and wastewater discharges have likely contributed to the observed sediment contamination conditions. In general, the surface sediment concentrations continue to improve over time, consistent with the implementation of source controls (primarily in the 1970s) and ongoing natural recovery (e.g., sedimentation) processes in the area. Cleanup actions (e.g., placement of sediment caps at Colman Dock, Pier 53-55, and Pier 64/65 [Romberg 2005]) have been conducted in some areas over the past 22 years.

The contaminants present in the in-water sediments have the potential to bioaccumulate through the food chain, and may currently be posing some risk to listed species. However, the most contaminated areas have been already been capped, and the remaining contaminants are below cleanup threshold levels.

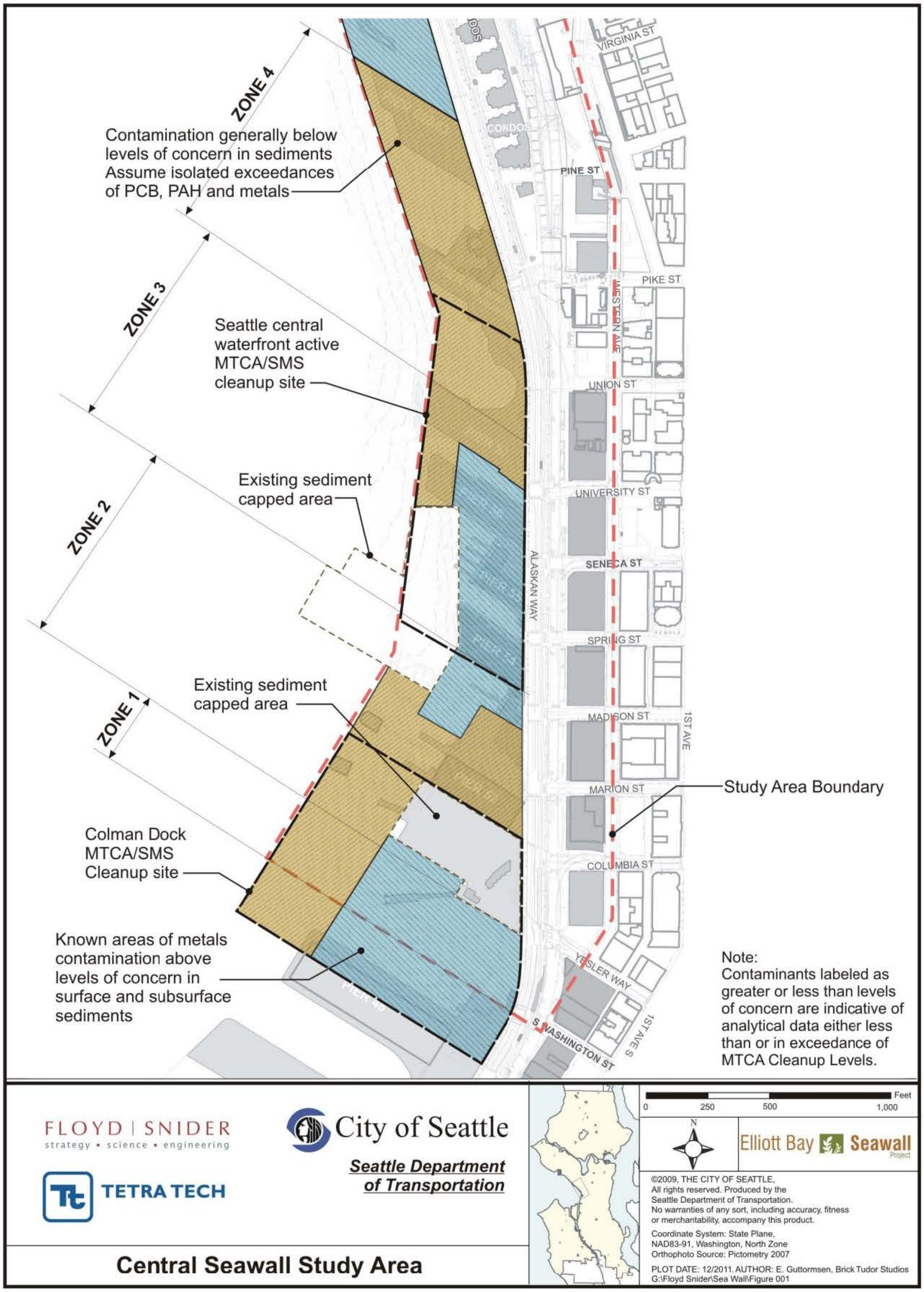

Figure 15 – Central Seawall with Areas of Known Sediment Concern (In-Water) (SDOT 2012c)

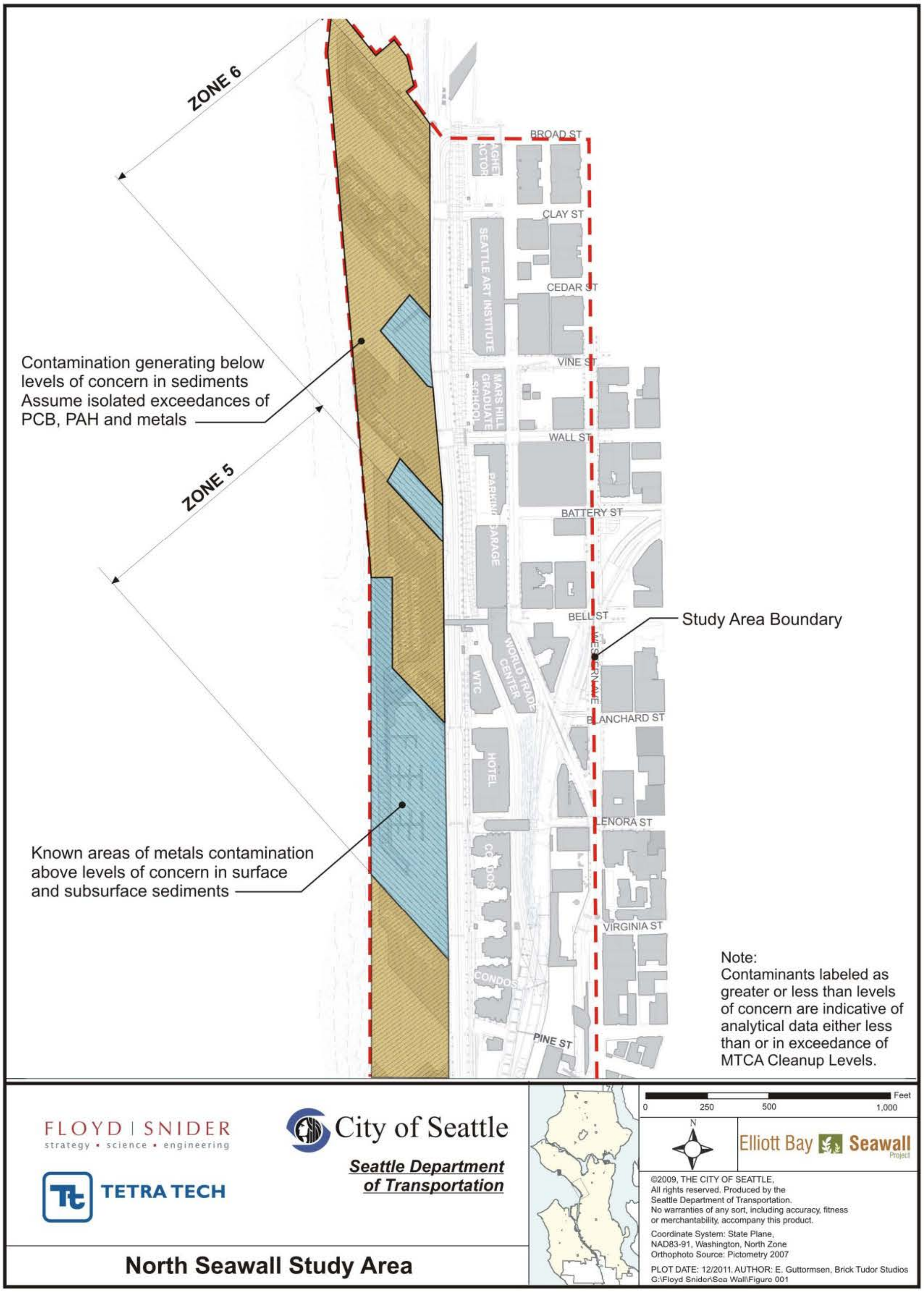

Figure 16 – North Seawall with Areas of Known Sediment Concern (In-Water) (SDOT 2012c)

2.3.3 Biological Conditions

2.3.3.1 Macroalgae

As a result of the significant number of structures and shading associated with the seawall, primary productivity is significantly reduced from natural conditions. Macroalgae communities between and under piers were mapped and photographed to quantify their distribution (Anchor QEA 2011; Figures 17 through 19). Approximately 50 percent of the project footprint had no macroalgae growth, presumably due to shading. Between piers, a moderately diverse macroalgae and associated invertebrate community occurs. Based on visual observations, the extent of existing kelp beds in the project footprint were mapped with the total area calculated to approximately 1.75 acres (0.7 ha) (Anchor QEA 2011). Bull kelp (*Nereocystis lutkeana*) is present along the seawall in discrete small patches between piers. The distribution appears to be associated with the presence of rocky substrate for attachment, water depths between 7 and 15 feet (2 to 4.5 meters), and areas protected from boat-caused wave action (USACE 2008).

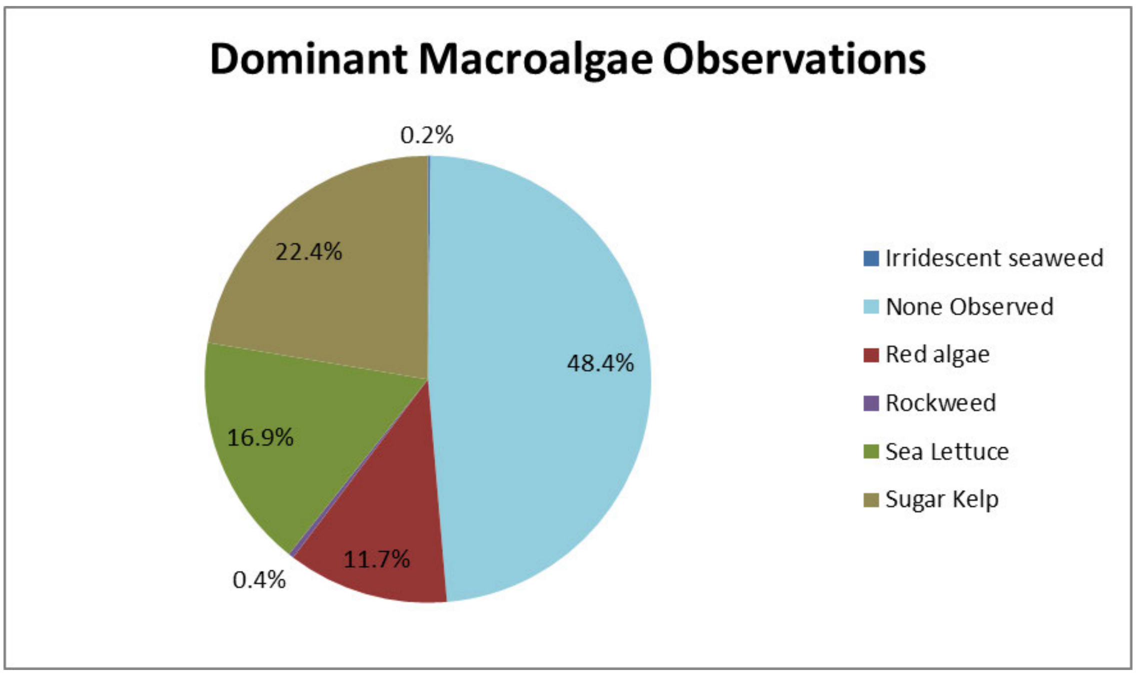

Figure 17 – Macroalgae Species Observed in the Project Footprint (Anchor QEA 2011)

Figure 18 – Typical Condition under Piers (Anchor QEA 2011)

Figure 19 – Macroalgae Community between Piers (Anchor QEA 2011)

In spite of the effects of the overwater structures, native species dominate the aquatic nearshore plant assemblage. Marine algae, including blue-green algae, green algae, diatoms, brown algae, and red algae are found throughout the nearshore in areas where light reaches the substrate. Vascular flowering plants are also found in the nearshore, although the shallow flats they require are now mostly absent from the project footprint. Artificial structures such as floating docks and wood pilings are dominated by sea lettuce (*Ulva lactuca*) and rockweed (*Fucus gardneri*) in addition to various rhodophyta species (USACE 2008; Anchor QEA 2011). Sugar wrack (*Saccharina latissima*) is also associated with these structures, as is *Codium fragile*, *Polyneura latissima*, and *Membranoptera platyphylla* (USACE 2008; Anchor QEA 2011). Large rocky substrate provides a source of attachment for algae such as *Fucus spiralis*, *Endocladia muricata*, *Gigartina papillata*, feather boa kelp (*Egregia menziesii*), *Corallina* sp. and winged kelp (*Alaria* sp.), which are associated with cobble, riprap and concrete (USACE 2008). Overall, primary productivity is moderate in the footprint, but reduced due to shading and lack of normal intertidal depths. Small groundwater seeps have been observed coming through the seawall, but there does not appear to be any change in macroalgae community type or diversity associated with these flows (SDOT 2012e)

2.3.3.2 Resident and Forage Fish

Most resident fish reside in close proximity to the benthic substrate (rock, gravel, sand, or kelp) throughout the nearshore subtidal zones where they forage on primary consumers or on small invertebrates and fish. Resident fish provide forage for larger fish and marine mammals. Cover, such as kelp and other macroalgae, and interstitial spaces between rocks are important for early life stages of rockfish.

The most commonly observed species along the seawall include shiner perch (*Cymatogaster aggregata*), pile perch (*Rhacochilus vacca*), striped sea perch (*Embiotoca lateralis*), tube-snout (*Aulorhynchus flavidus*), kelp perch (*Brachyistius frenatus*), brown rockfish (*Sebastes auriculatus*) and spotted ratfish (*Hydrolagus colliei*) (SDOT 2012d; Anchor QEA 2011). Species common to the demersal zone include Dover sole (*Microstomus pacificus*), English sole (*Parophrys vetulus*), kelp greenling (*Hexagrammos decagrammus*), blackbelly eelpout (*Lycodopsis pacifica*), bay pipefish (*Syngnathus leptorhynchus*), quillback rockfish (*S, maliger*), copper rockfish (*S. caurinus*) and Pacific staghorn sculpin (*Leptocottus armatus*) (SDOT 2012d; Anchor QEA 2011). Species common to the benthopelagic zone (area ranging from the benthos to below surface waters) include spiny dogfish (*Squalus acanthias*), walleye pollock (*Theragra chalcogramma*), snake prickleback (*Lumpenus sagitta*), Pacific sand lance (*Ammodytes hexapterus*), lingcod (*Ophiodon elongatus*), yellowtail rockfish (*S. flavidus*), black rockfish (*S. inermis*), Pacific hake (*Merluccius productus*) and surf smelt(*Hypomesus pretiosus*) (Matsuda et al. 1968; DeLacey et al. 1972; Weitkamp et al. 2000; Anchor Environmental 2003; WSDOT 2006; Toft et al. 2010; SDOT 2012b; Anchor QEA 2011; WDFW 2011b).

Forage fish such as Pacific herring, Pacific sandlance and surf smelt are present in Elliott Bay. There are no documented spawning areas within the project footprint, although surf smelt have been documented spawning just outside of Elliott Bay, west of Duwamish Head and near West Point (WDFW 2011c). Sandlance may spawn along Alki and along the Magnolia shoreline. Anchor QEA (2011) observed large numbers of surf smelt and sandlance along the seawall in the project footprint in July 2011. This is consistent with observations by University of Washington researchers that

juvenile forage fish are present in large numbers during summer months along the seawall (SDOT 2012e).

2.3.3.3 Anadromous Salmonids

At least nine species of native anadromous salmonids are known to occur in the action area and potentially frequent the nearshore and offshore waters as juveniles and adults. Of those, three are federally listed species and include: Chinook salmon, steelhead trout, and bull trout (Matsuda et al. 1968; DeLacey et al. 1972; Groot and Margolis 1991; Weitkamp et al. 2000; Anchor Environmental 2003; Toft et al. 2004; WSDOT 2004; Brennan et al. 2004; Toft and Cordell 2006; Fresh 2006; WSDOT 2006; Toft et al. 2010; SDOT 2012d; Anchor QEA 2011). The close proximity of the action area to the Duwamish Estuary and other stream systems (Weitkamp et al. 2000; WSDOT 2004) causes the nearshore and offshore waters to be a necessary migration corridor for species that spawn in the Green/Duwamish system and could serve as a foraging area.

Pre-spawning adults (primarily Chinook, coho, chum, and pink salmon) returning from the ocean migrate through Elliott Bay and along the Seattle waterfront (WSDOT 2004). Juveniles may move from spawning and rearing areas in the Green River into the Duwamish Estuary and out through the project footprint during outmigration. Some juvenile salmonids migrate west from the Duwamish (along Alki) and some move north along the seawall; the limited data available indicates that about half the fish go west and half the fish go north (SDOT 2012e).

Along the seawall, juvenile salmonids are generally more abundant in the shallow waters of the nearshore. Chinook, coho, chum, and pink salmon have been observed in close proximity to the seawall and on the shallow shorelines or beaches within Elliott Bay (Anchor QEA 2012; Toft et al. 2012a, 2012b, 2012c, 2012d, 2013a, 2013b). Adults occur farther offshore and are typically found nearer the surface, upwards from the middle of the water column (Toft and Cordell 2006). Salmonids observed in the project footprint (including Chinook, coho, chum, and pink salmon) have been shown to usually avoid waters underneath overwater structures (Toft et al. 2004; Anchor QEA 2012). Juveniles do school near pier edges at the shade line, as well as in open, non-shaded water, and under particularly low-light conditions, show little preference between non-shaded and shaded areas (WSDOT 2006; Anchor QEA 2012).

Adult and juvenile salmonids (most data are available for Chinook salmon) from other basins such as Lake Washington/Cedar River, Puyallup River, and Snohomish River, also use Elliott Bay and the project footprint (Brennan et al. 2004). Nelson et al. (2004) captured coded-wire tagged Chinook salmon juveniles in Elliott Bay from multiple watersheds including the Green/Duwamish, Lake Washington, Skykomish, Stillaguamish, Puyallup, and western Puget Sound locations. Nearly 70 percent of Chinook salmon subyearlings captured were from the Green/Duwamish, and roughly 20 percent from the Skykomish system, which has one of the largest Chinook salmon populations in Puget Sound.

Prey species for salmonids are diverse in nearshore marine waters. In Elliott Bay, zooplankton is composed mostly of copepods, but amphipods, mysids, various species of fish larvae, and euphausiids are all also in abundance (Strickland 1983;Toft and Cordell 2006). Demographics of

zooplankton in Elliott Bay are not well understood; however, they are known to provide an important prey base for many species including anadromous fish.

Terrestrial insects are an important prey component for many insectivores in the nearshore, including salmonids (Wipfli 1997; Sobocinski et al. 2010; Duffy et al. 2010). Although little is known about the assemblage of insects in the project footprint, species known to be present include spiders, dipteran flies, springtails, bark lice, aphids, ants and mites (Toft et al. 2004; Toft et al. 2007; Sobocinski et al. 2010). It has been shown that densities of terrestrial insects in the nearshore are at their lowest where overhanging terrestrial vegetation has been replaced by constructed structures (Toft et al. 2004; Higgins et al. 2005; Sobocinski et al. 2010). Because minimal vegetation is present along the entire length of the seawall, it is assumed that densities of terrestrial insects are quite low in the project footprint.

As a result of shoreline modifications, differences in fish behavior and usage are attributed to changes in water depth, slope, substrate, and shoreline vegetation (Toft et al. 2007). Reduced diversity or density of epibenthic meiofauna along seawalls also reduces prey resources for juvenile salmon. The cumulative impact of numerous and contiguous urban marine structures may be detrimental to the long-term success of numerous species, particularly recovery efforts for anadromous fish species that migrate along shorelines. Migrating juvenile salmon use Puget Sound during out-migration and rearing (Simenstad et al. 1982). Research summarized in Fresh (2006) indicates juvenile Chinook salmon and chum salmon prefer shallow beaches and mudflats in Puget Sound and are the most dependent salmon species on estuarine and nearshore habitats. Shoreline enhancements (e.g., pocket beach, habitat bench, upland vegetation planting, addition of coarse-grained sediments and driftwood) at the Olympic Sculpture Park replaced an armored seawall and riprap shoreline. Results from 3 years of monitoring post-construction indicate a relatively stable beach with rapid development of aquatic and terrestrial biota (Toft et al. 2010). Abundance, diversity, and assemblages of invertebrates and fish have increased compared to baseline conditions (Toft et al. 2010).

2.3.3.4 Migratory Corridor

The shoreline along the seawall is an important migratory corridor for juvenile salmonids emerging from the Green-Duwamish watershed as they journey north into Puget Sound and farther into marine waters. The shoreline of Elliott Bay is also used by juvenile salmonids from other watersheds although migratory patterns are not well understood. Recent fish surveys conducted by Anchor QEA indicate that significant numbers of juvenile salmonids migrate along the seawall from March through August, including chum, Chinook, and coho salmon (Anchor QEA 2012). The existing migratory corridor is highly degraded and is essentially the vertical seawall adjacent to deep water (typically greater than 10 feet [3 meters] deep), with 12 overwater pier structures casting a dark shadow.

Key observations from the Anchor QEA (2012) fish surveys are: (1) peak chum salmon counts occurred in April and May; (2) Chinook and coho salmon peak counts occurred in May and June; (3) juvenile salmon were most often observed at the 3-meter transect (3 meters off the wall) than farther out; (4) juvenile Chinook salmon were more often observed near the seawall than along the piers; and (5) juvenile salmonids avoided going under piers or into the sharp shadow line cast by the pier

(were never observed swimming under piers), rather they were observed out at the ends of the piers in deep water to migrate around piers.

In spite of the limitations of the project footprint for use as a migratory corridor, juvenile salmon are present and do use the area, as indicated by recent surveys by Toft et al. (2010) near the Olympic Sculpture Park.

2.3.3.5 Non-native Species

Invasive species are alien species whose introduction does, or is likely to, cause economic or environmental harm, or harm to human health (Executive Order 13112). Probable pathways for introduction range from escaped aquaculture to intentional stocking or planting. In marine areas, ballast releases from ships arriving from foreign ports of call are one of the most common mechanisms of spread.

Non-native plants and macroalgae known to occur in the greater Puget Sound area include cordgrass (*Spartina* spp.), Japanese eelgrass (*Zostera japonica*), and Sargassum (*Sargassum muticum*) (MISM 2009). Marine macroalgae considered high risk for invasion to the Puget Sound area include Japanese kelp (*Undaria pinnatifida*) and Caulerpa (*Caulerpa taxifolia*) (WISC 2008, MISM 2009). None of these invasive plants or macroalgae are known to be currently present along the seawall, but may be present elsewhere in Elliott Bay. Various non-native invertebrates have been reported in Puget Sound but are not known to be present along the seawall, including tunicates (*Botrylloides violaceus, Ciona savignyi, Disemnum vexillum*, and *Styela clava*), slender tube amphipod (*Monocorophium acherusicum*), and Asian cumacean (*Nippoleucon hinumensis*) (USGS 2011).

Included on the Washington Invasive Species Council's Watch List are mitten crab (*Eriocheir sinensis*), Atlantic gem clam (*Gemma gemma*), and Leidy's comb jelly (*Mnemiopsis leidy*), all which could be transported by ballast water (WISC 2008). Tunicates are particularly associated with hull fouling communities, thus probably more likely to be introduced via barges or other ship fouling rather than ballast (SDOT 2012e). The action area is at risk for invasion by species that use rocky shorelines or pilings, such as Japanese kelp, mitten crab, Atlantic gem clam, and Leidy's comb jelly.

2.3.3.6 Noise

As previously mentioned, the ambient sound level for the Central Seawall (Phase 1) has been estimated at 75 dBA and estimated at 65 dBA for the North Seawall (Phase 2) (SDOT 2012a). Existing traffic on the Alaskan Way Viaduct is a predominant source of noise in the project vicinity. Existing sources of noise is mainly road traffic, with some local industry and high-altitude aircraft over-flights. The areas surrounding these locations can be categorized as urban. Natural noises such as leaves rustling, light surf, and bird vocalizations are limited along the seawall.

A range of ambient in-water noise levels have been reported for Elliott Bay. Near the Colman Dock ferry terminal, average in-water noise levels were measured at 123 dB_{RMS} (Laughlin 2011) and ambient noise levels in Elliott Bay near Pier 70 are reported as 147 dB[4] $_{Peak}$ (re: 1 $\mu Pa^2 \cdot sec$)) (Laughlin 2006). For the purpose of this Opinion, ambient conditions within the action area are assumed to be

[4] Throughout this document, the reference value for dB peak pressure is 1 μPa.

123 dB_{RMS} as reported by Laughlin (2011). Noise levels may attenuate towards the north end of the project footprint where fewer vessels are present, but the entire area has high ambient noise levels due to ferry vessel, cruise ship, container ship, and other boat traffic.

The number of container, cruise, and grain ships that called to Port of Seattle facilities in Elliott Bay is: 1103 ships in 2010; 1100 in 2011; and 982 in 2012 (Queen, in litt. 2013). These numbers do not include the barge, ferry, or recreational traffic occurring in Elliott Bay. In 2012, barge use was 505 calls (Port of Seattle 2013).

2.3.4 Status of the Listed Species and their Critical Habitat in the Action Area

2.3.4.1 Chinook Salmon

Chinook salmon in the action area originate from multiple watersheds including the Green/Duwamish, Lake Washington, Skykomish, Stillaguamish, Puyallup, and western Puget Sound locations (Table 7, Nelson et al., 2004). Nearly 60 percent of Chinook salmon juveniles captured were from the Green/Duwamish River, and roughly 20 to 30 percent from the Skykomish River system, which has one of the largest Chinook salmon populations in Puget Sound.

Table 7 – Origin of coded wire tags of Chinook salmon captured in Elliott Bay in 2002 and 2003 and the time from release to capture (Nelson et al., 2004).

Hatchery	Area	Distance (mi)	Number 2002	Number 2003	Time from release to capture (d)
Soos Cr.	Green/Duwamish	0	83	60	12.4
Grovers Cr.	Suquamish	16	3	2	37.3
Hupp Springs	South Sound		1		50.0
Puyallup Tribe	Puyallup	30	3		75.0
White River	Puyallup	30		1	*
Tulalip Tribe	Snohomish	36	1		27.0
Wallace River	Skykomish	36	42	18	31.6
Gorst Cr.	Sinclair Inlet	19		3	24.3
Issaquah Cr.	Lake Sammamish	9		3	35.3
Univ. of Washington	Lake Washington	9		2	
White Horse	NF Stillaguamish	52		1	*

* Data unavailable as fish were released over broad timeframe.

The study sites in Elliott Bay for Nelson et al. (2004) included Pier 90/91 (north Elliott Bay), Seacrest (south Elliott Bay), Alki (west side of Duwamish Head), RM 0 (East and West Waterways of the Duwamish River), and RM 1 (near Kellogg Island in the Duwamish River). At the Seacrest site, juvenile Chinook salmon, both natural and hatchery, were captured starting in March and continued through August. The highest abundance (mean catch per beach seine set) was in mid-May and mid-June (approximately five Chinook salmon) for natural juveniles, and the end of May to mid-June for hatchery juveniles (approximately 18 Chinook salmon). A few juvenile Chinook salmon, both natural and hatchery, were captured in late January. At Pier 90/91, located along the north shore of Elliott Bay, natural and hatchery juvenile Chinook salmon were captured from mid-April

through the last sample at the end of September. Mean catch per seine set was highest at the beginning of July for both natural (approximately 10 Chinook salmon) and hatchery (approximately 14 Chinook salmon).

Immature (blackmouths) and adult Chinook salmon can be found in Elliott Bay from August through March (Nelson 2013, Nelson et al 2004). Adults from the Green-Duwamish River will migrate through Elliott Bay into the Duwamish River from mid-August through the end of November (Nelson et al. 2004). Blackmouths can be in Elliott Bay from November through March depending on availability of bait fish. The Tenfu Derby, the oldest derby fishing for blackmouths in Washington, is held in November and only hatchery fish may be kept. Good fishing locations for blackmouth include the shorelines out to the 150 foot line from the west side of the Duwamish Head, all the way past Harbor Island to Colman Dock (Nelson 2013). The area just south of Colman Dock is a holding area for adult Chinook salmon prior to their migration into the Duwamish River.

Chinook salmon are caught within Marine Area 10 (Puget Sound from Edmonds south to Vashon Island) from June through January (Kraig 2012, 2013). The fewest Chinook are caught in June and the most are caught in July and August (Table 8).

Table 8 – 2008-2010 Chinook sport catch in Area 10 – Seattle/ Bremerton

Month	2008	2009	2010
June	11	15	
July	1407	1367	
August	1241	1783	
September	49	47	
October	320	123	
November	383	83	
December	101	119	
January		150	107

Tribal fishing within Elliott Bay is set by negotiations between WDFW and the northwest treaty tribes during the North of Falcon and Pacific Fisheries Management Council. In general, tribal fishing for Chinook salmon within Elliott Bay occurs in July and August (WDFW and NWIFC 2010). Tribal coho fishing occurs in Area 10 during September and October (WDFW and NWIFC 2010) and incidental Chinook salmon are caught during this time (Zischke, pers. comm. 2013).

Chinook salmon juveniles emigrate from the Green-Duwamish River natal areas to estuarine and nearshore habitats from January through March as fry, and from May through June as larger fingerlings or yearlings (Nelson et al. 2004). Pre-construction sampling conducted as part of the seawall project found Chinook salmon along the shoreline beginning in April and continuing through October (Figure 20, Toft in litt. 2013a). Peak migration occurred in June. One age 1+ hatchery Chinook salmon was caught at the Olympic Sculpture Park in January. One wild Chinook salmon was captured in early March indicating the start of the emigration period.

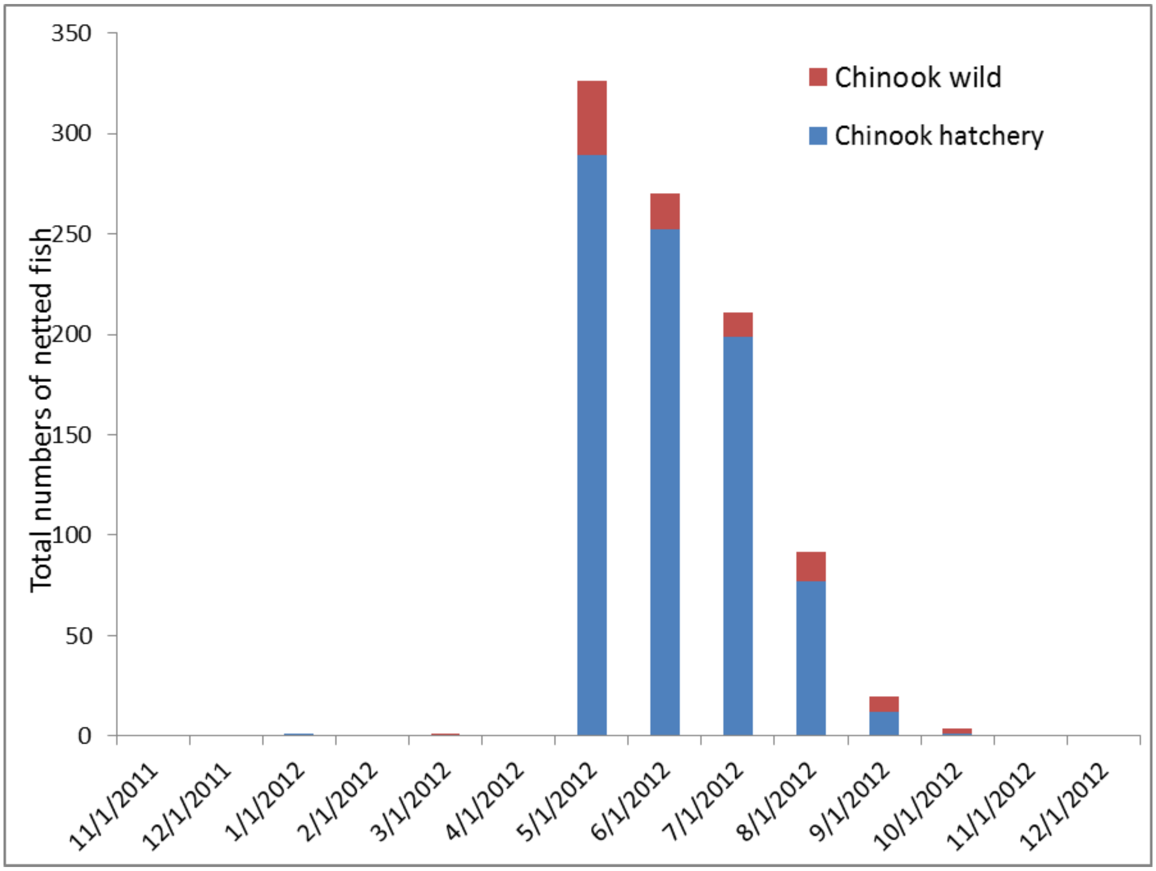

Figure 20 – Summary of all wild and hatchery Chinook salmon caught at the six Elliott Bay (three seawall, three beach) sampling sites (Toft in litt. 2013a).

The total number of Chinook salmon found at the three seawall sites in 2012 are shown in Figure 21. Sampling was only conducted once a month. Because of the large number of Chinook salmon caught on May 1, 2012, juveniles would begin migrating along the seawall in the middle of April. During spring 2013 sampling, one juvenile wild Chinook salmon was caught on April 3, 2013.

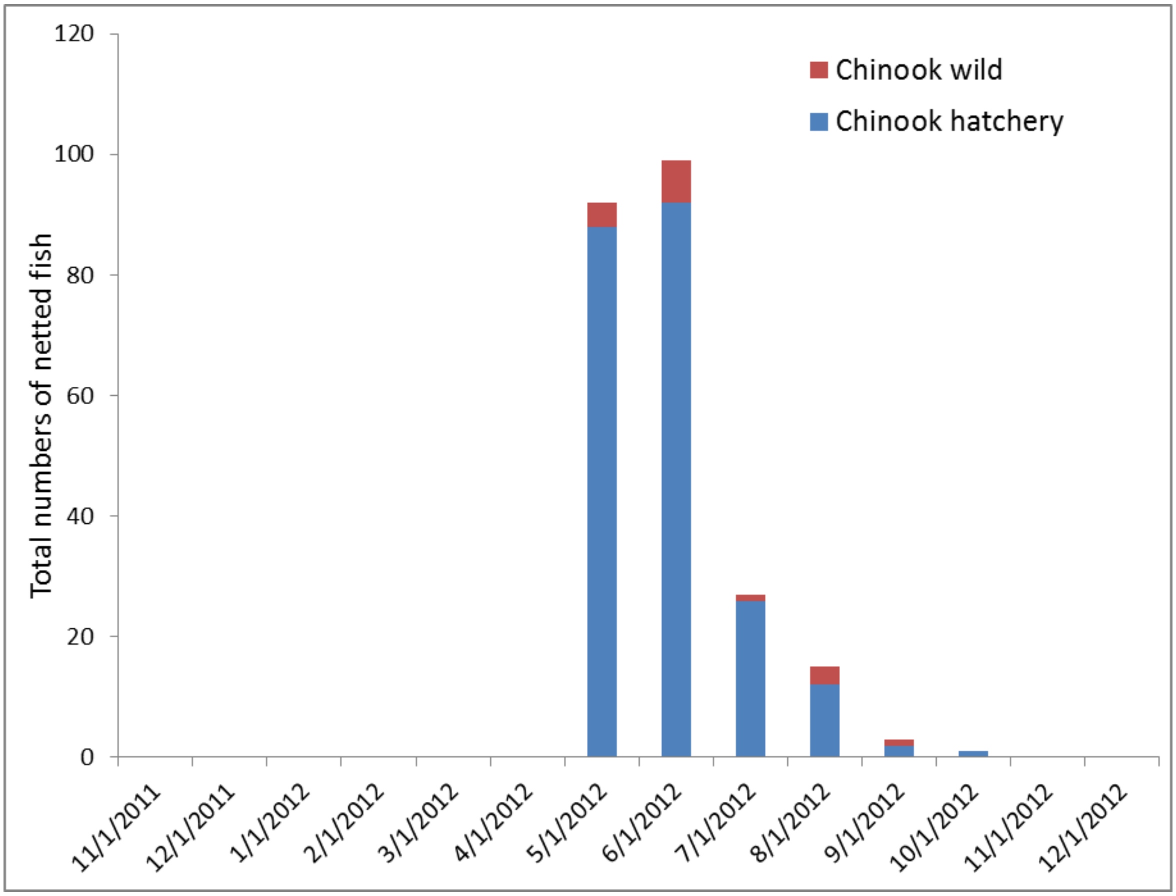

Figure 21 – Summary of all wild and hatchery Chinook salmon caught at the three seawall sampling sites in Elliott Bay (Toft in litt. 2013a).

Rice et al (2011) sampled by trawl in deeper waters in estuaries and marine waters of Puget Sound. Within or near Elliott Bay, they sampled three sites, one on the north side by Piers 90/91 and two on the south side, the mouth of the Duwamish River and near Seacrest Park. Figure 22 shows the mean density of Chinook salmon from surface trawl samples within Elliott Bay. Juvenile Chinook salmon were found in deeper waters from May through October. Peak density of Chinook salmon in surface trawl samples in Elliott Bay were in June, one month later then peak densities found along the nearshore. This would indicate that Chinook salmon become less nearshore dependent as they grow larger.

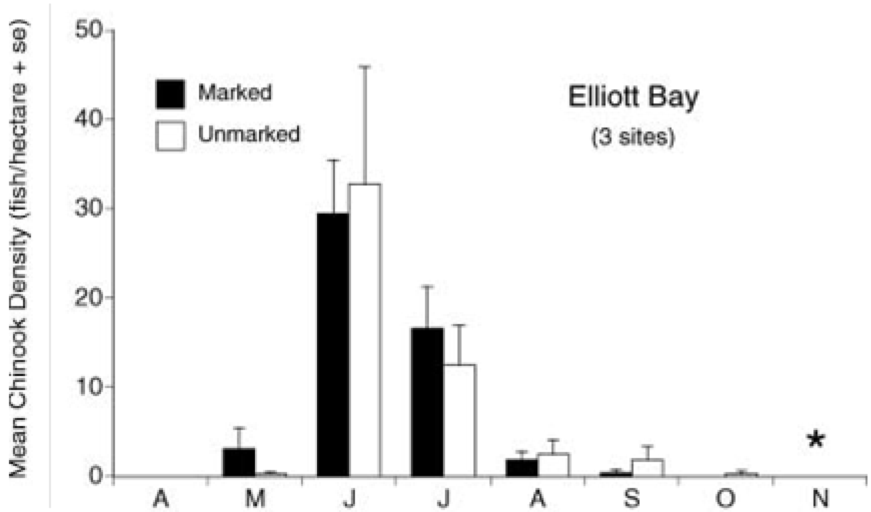

Figure 22 – Mean + one standard error of marked and unmarked juvenile Chinook salmon within Elliott Bay in 2003 (Rice et al 2011).

The Green-Duwamish River Chinook are a mix of wild and hatchery-produced fish. They are considered a healthy stock based on escapement levels (WDFW 2002c). Ford (2011) estimated the average number of natural (natural origin and hatchery) Chinook salmon spawners in the watershed was 3,077 between 2005 and 2009 with 56 percent contribution from hatcheries. The population trend and growth rate (lambda) of natural spawners between 1995 and 2009 was 0.952 indicating a shrinking population (Ford 2011). With hatchery fish contributing to the population, the growth rate for the Green River Chinook salmon population is 0.835. The lower growth rate with hatchery fish contribution may be related to density dependent effects, differences in spawning distribution relative to habitat quality, or reduced fitness of hatchery origin spawners (Ford 2011).

Approximately 20 to 30 percent of the Chinook salmon captured in Elliott Bay originated from the Skykomish River population (Nelson et al. 2004). The Skykomish River Chinook salmon population and the Snoqualmie River population are both located within the Snohomish River watershed. The Skykomish River Chinook summer/fall run population and the Snoqualmie River Chinook fall-run population are both rated depressed due to low stock productivity (WDFW 2002d, 2002e).

The estimated average number of natural (natural origin and hatchery) Chinook salmon spawners in the Skykomish and Snoqualmie Rivers were 3,334 and 888, respectively, between 2005 and 2009 with 14 and 11 percent contribution from hatcheries. The Skykomish River population trend and growth rate (lambda) of natural spawners between 1995 and 2009 was 1.036 indicating a slightly increasing population (Ford 2011). The lambda for the Snoqualimie River population was 0.99 indicating a stable population. With the small hatchery contributing to the population, the growth rate for the Skykomish and Snoqualmie Chinook salmon populations are 0.952 and 1.000, respectively.

Both the Green/Duwamish and the Skykomish river Chinook salmon minimum viability abundance number are 17,000 spawners (Ford 2011). Between 2005 and 2009, the average number of natural and hatchery spawners in the Green/Duwamish River was 3,077 fish, and for the Skykomish River, natural and hatchery spawners was 3,309.

The Chinook Salmon Recovery Team ranked each of the 22 Puget Sound Chinook salmon populations on their recovery potential. Factors included in the ranking included the status and structure of each population and their habitat (Decenber 29, 2010, 75 FR 82208). Each population was ranked in one of three tiers. Tier 1 is essential for recovery, Tier 2 is important, and Tier 3 should not become extirpated if recovery actions are completed in the future. The Skykomish and Green/Duwamish river populations were ranked as Tier 2, and the Snoqualmie River population was ranked as Tier 3.

Juvenile Chinook salmon migrate out the Snohomish River beginning in late March and early April and continue through the end of July. Chinook salmon were caught within Possession Sound in early August (Beauchamp et al. 1987). Residence time within Possession Sound was 0 to 10 days. Hatchery released Chinook salmon from the Snohomish River watershed were capture in Elliott Bay 27 to 33 days after release from the hatchery. Travel distance from the mouth of the Snohomish River to Piers 90/91 is approximately 33 mi (53 km), indicating that the Chinook salmon are rapidly moving along the shoreline.

Of the remaining Chinook salmon populations found within the action area, the Lake Washington/Cedar River and the Stillaquamish River populations are both considered depressed, and the Puyallup River population status is unknown.

The nearshore areas in Puget Sound, including the action area, are essential to Chinook salmon conservation because they provide important rearing and migratory corridors. The nearshore environments are necessary for Chinook salmon to complete their life cycle because the protected waters provide forage and hiding places for Chinook salmon to grow and mature before continuing on to the ocean. Juvenile Chinook salmon experience the highest growth rates in the highly productive nearshore. Juvenile Chinook salmon using the action area for forage and rearing are mainly from the Green/Duwamish River and the Skykomish River. Even though the Elliott Bay shoreline is highly modified with riprap, bulkheads, piers, and seawalls, Chinook salmon forage, rear, and migrate within the action area. Adult Chinook salmon also use the action area as a migratory corridor to reach their natal streams. The action area near the mouth of the Duwamish River provides holding areas for adults prior to their migration upstream to spawn.

2.3.4.2 Southern Resident Killer Whale

The Whale Museum manages a long-term database of SR killer whale sightings and geospatial locations in inland waters of Washington. While these data are predominately opportunistic sightings from a variety of sources (public reports, commercial whale watching, Soundwatch, Lime Kiln State Park land-based observations, and independent research reports), SR killer whales are highly visible in inland waters, and widely followed by the interested public and research community. The dataset does not account for level of observation effort by season or location; however, it is the most comprehensive long-term dataset available to evaluate broad scale habitat use

by SR killer whales in inland waters. For these reasons, NMFS relies on the number of past sightings to assess the likelihood of SR killer whale presence in the action area and during work windows.

The number of past sightings is provided in quadrates throughout Puget Sound, Hood Canal, and the Salish Sea. There are a total of 445 quadrates. Four quadrates are found within the action area for the project; 408, 409, 410, and 412. A very small portion of quadrate 413 is also in the action, and was excluded from analysis. A review of this dataset from the years 1990 to 2008 indicates that SR killer whales are observed in the action area during the months that in-water construction activities are proposed (Table 9).

Table 9 – Southern resident killer whale sightings in the action area.

Month	Number of Days Sighted per Quadrate*				
	408	409**	410	412	Total
September	0	4	4	0	8
October	4	4	12	5	25
November	26	9	26	17	78
December	24	8	34	19	85
January	11	9	20	6	46
February	4	1	9	1	15
March	2	2	1	2	7

* Unique sighting days during the work window from 1990 to 2008.
** Quadrat where project is located.

2.3.4.3 Steller Sea Lion

Steller sea lions can occur in Washington waters throughout the year; however, there are no breeding rookeries in Washington. Occurrence in inland waters of Washington is limited to primarily male and sub-adult Steller sea lions in fall, winter, and spring months. Steller sea lions use haulout locations in coastal and inland waters of Washington. The number of haulout sites has increased in recent years. The nearest consistently used haulout to the project is located near Orchard Rocks in the southeast portion of Rich Passage, located south of Bainbridge Island. The haulout is used by 50 to 100 Steller sea lions. Steller sea lions that use this haulout are likely to forage within the action area.

2.3.4.4 Humpback Whale

We have limited information about humpback whale foraging habits and space use in inside waters of Washington, and do not have specific fine-scale information for the action area. In recent years, humpback whales are sighted with increasing frequency in the inside waters of Washington, including Puget Sound (primarily during the fall and spring); however, occurrence is uncommon. On a few occasions, humpback whales have been recorded passing through Admiralty Inlet and into central Puget Sound through the action area during the in-water work window.

2.3.4.5 Bocaccio, Canary Rockfish, Yelloweye Rockfish

Larval individuals of canary rockfish, yelloweye rockfish, and bocaccio are distributed by currents in Puget Sound (Drake et al. 2010). To what extent they are well distributed or occur in clusters reflecting the geography of reproductive adults is poorly understood. The best available data with which the NMFS could estimate the number of individuals in an action area is based on Greene and Godersky (2012). They sampled rockfish at six deepwater sediment disposal sites and 79 index sites. The index sites were chosen based on a number of criteria, including proximity to shorelines, depth, exposed shoreline, and degree of anthropogenic disturbance. The sites were selected to maximize spatial coverage of Puget Sound.

Sampling by Greene and Godersky (2012) occurred from April through October. Table 10 provides density estimates for rockfish within Elliott Bay at both the deepwater sediment site and the Duwamish index site.

Table 10 – Rockfish densities within Elliott Bay (Greene and Godersky, 2012)

Month	Elliott Bay Deepwater Rockfish Density (fish/1,000 m^3)	Duwamish Index Site Rockfish Density (fish/1,000 m^3)
April	101.0	52.7
May	126.8	261.6
June	31.4	6.3
July	69.0	20.2
August	26.8	31.7
September	88.5	7.1
October	0	6.5

As they mature, juveniles of canary rockfish and bocaccio are more likely to continue using the nearshore habitat than are juvenile yelloweye rockfish, which begin occupying deeper habitats (Love et al. 1991; Love et al. 2002; Yamanaka and Lacko 2001). Juvenile canary rockfish and bocaccio use floating kelp habitat, which is found in those nearshore portions of the action area where sunlight reaches shallow water and boat traffic is limited. The relatively shallow bathymetry of the action area makes it extremely unlikely for adults of these species to occupy the action area at any time. Adults of these species occupy deeper habitats with more complex bathymetry than occurs in the action area, so their presence is extremely unlikely.

2.3.4.6 Bull Trout

Anadromous adult and subadult bull trout may utilize all marine waters of the action area for foraging, migrating, and overwintering. The extent of this utilization is poorly understood; however, Kraemer (1994) speculated that bull trout distribution in marine waters depends on the distribution of forage fish and their spawning beaches. Anadromous bull trout prey on surf smelt, Pacific herring, Pacific sand lance, juvenile salmonids, and other small schooling fish while in the marine environment (Kraemer 1994; WDFW 1997). These prey species are present within the action area. Although foraging bull trout may tend to seasonally concentrate in forage fish spawning areas, they can be found throughout accessible estuarine and nearshore habitats.

Anadromous bull trout may seek and find more abundant forage in marine waters than in rivers (Kraemer 1994). As bull trout populations increase in abundance and competition for prey increases, individual bull trout may also forage more extensively and over greater distances in the

marine environment (Chan, in litt. 2013). Kraemer (1994) also found bull trout in the marine environment as far as 40 kilometers (25 miles) from their natal stream. McPhail and Baxter (1996) documented a char traveling as far as 150 kilometers (93 miles) through marine waters from the Squamish River in British Columbia to the Skagit River in Washington.

We expect that some level of mixing or interaction within marine waters occurs among anadromous individuals from various core areas. Although studies have documented bull trout moving into non-natal rivers via marine waters (WDFW 1997; Goetz in litt. 2003), we do not understand the full extent of this behavior. On October 31, 2006, a 607 mm tagged bull trout was observed in the Snohomish River; by November 25, it migrated into the lower Duwamish River (approximately 35 mi [55 km]) where it stayed until the end of December (Goetz et al. (2012). The bull trout then migrated back to the Snohomish River by the end of January. The bull trout left the Duwamish River on December 27 and stayed within the action area until January 7, where it was located offshore of West Point, just north of Elliott Bay.

Based on these studies, anadromous bull trout from several different core areas may be present within the action area simultaneously. Marine areas within the action area are within foraging and migratory distances of the Stillaguamish, Snohomish-Skykomish, and the Puyallup River core populations. The Stillaguamish River and Puyallup River core areas are both ranked as "at risk," the Snohomish River core area is ranked as "potentially at risk" (USFWS 2008). The number of bull trout that may be present in Elliott Bay and the marine environment of the action area are presumed to be related to the abundance of individuals in these core populations as well as the distance from the core area to the action area. More robust core populations such as the Snohomish-Skykomish are expected to utilize the marine environment in greater proportion than core populations that are extremely low in number. Puget Sound and the lower Green/Duwamish River are considered FMO habitat and do not have a spawning population (USFWS 2004b).

The number of bull trout that may be present in the action area, and specifically Elliott Bay, is believed to be small, but captures in the Duwamish River indicate that bull trout migrate through the action area. In April 1978, Dennis Moore, Hatchery Manager for the Muckleshoot Indian Tribe, talked with three anglers in the vicinity of North Wind Weir, river mile 7 of the Duwamish and identified four fish as adult char (Brunner 1999a). One adult bull trout was observed near Pier 91 in May 1998 (Brunner 1999b). In 2000, eight subadult bull trout were captured in the Duwamish River at the head of the navigation channel at the Turning Basin restoration site at river mile 5.3. These were subadult and adult fish that averaged 299 millimeters (11.8 inches) in length and were captured in August and September (Shannon 2001). A single char was caught at this same site in September of 2002 (USFWS 2004b). In May, 2003, an adult char (582 millimeters) was captured and released at Kellogg Island (USFWS 2004b). In a study conducted by Goetz et al. (2012) in 2006, tagged bull trout were monitored migrating through Elliott Bay. A bull trout tagged in the Snohomish River migrated through Elliott Bay into the Duwamish River in November, and then migrated back out in December. One bull trout was observed on the newly installed habitat bench at the Olympic Sculpture Park in 2009 (Toft et al. 2010).

Subadult and adult bull trout use Elliot Bay for feeding, refuge, and as a migration route to other core areas or FMO habitat, even though habitat within Elliott Bay has been extensively modified, with approximately 97 percent of the original wetlands and shallow sub-tidal habitats filled (Kerwin

and Nelson 2000). The substrate and sediment quality is poor due to contamination with PAHs, PCBs, and metals, the nearshore habitat is degraded by shoreline armoring and the presence of overwater piers and wharves, and less than 14 percent of shoreline supports riparian vegetation (primarily ornamental city trees), thereby reducing the complex habitat that large woody debris provides and is important to bull trout. Despite these significantly degraded conditions, the action area is a part of the bull trout migration corridor.

2.3.5 Activities in the Action Area with completed Interagency Consultations

The environmental baseline includes the effects of Federal actions that have already occurred and Federal actions for which the Services have already completed interagency consultation. The action area includes or overlaps the action area for approximately 25 federal actions that are already completed or that have already undergone consultation since 2007.

The Services have completed two interagency formal consultations on Federal actions within the action area since 2007. The Alaskan Way Viaduct Replacement Project (NMFS Tracking No: 2010/04009, completed December 13, 2010) concluded that the action area would experience increased dissolved copper and dissolved zinc concentrations beyond the biological effects thresholds in Elliott Bay within 1) 115 square feet of the Kingdome outfall (located south of the project area; 2) 19 square feet of the King outfall; and 3) 17 square feet of the Denny outfall (located north of the project area). The King County Maintenance Barge Project (NMFS Trackin No: 2011/00395, completed October 13, 2011) concluded that the project would remove rearing habitat, increase predation, decrease feeding success, and increase contaminants within the action area. The projects concluded that the actions would not jeopardize the continued existence of Chinook salmon (both projects), bocaccio, yelloweye rockfish or canary rockfish (King County project). The USFWS concluded that the effects of these projects (FWS Ref. No: 2013-I-0505 and 2011-I-0146) on bull trout were insignificant or discountable.

Other projects that have been consulted on, such as State Route 99 South Holgate to South King Street (NMFS Tracking No: 2008/02137, FWS Ref No: 2008-I-0408), Magnolia Bridge Replacement Project (NMFS Tracking No: 2008/07581, FWS Ref No: 2009-I-0093), two projects at Pier 57 (NMFS Tracking No: 2010/02136 and 2011/05311; FWS Ref No: 2010-I-0323 and 2012-I-0016) and the Port of Seattle 10-year Programmatic (NMFS Tracking No: 2012/1104, FWS Ref No: 2012-I-0175) have construction for several years, continuing operational stormwater impacts, or habitat alterations or modifications after construction. Generally, the results of consultation with the Services on those actions resulted in a balance of adverse effects during construction balanced with beneficial effects such as removing creosote treated timber piles, capping holes with clean sand and gravel, removing in-water debris, and reducing the number of piles needed for overwater structures. Thus, the upshot of completing these actions was that on balance, the effects of those actions did not measurably affect listed species either negatively or positively. The consultation concluded the extent of local effects would not have any bearing on the viability of the populations to which those individual fish belong, and as such, would not jeopardize the affected ESUs or DPSs.

Construction for some of these projects over the next 10 years will result in increased sound levels from both vibratory and impact pile driving. Increased sound levels can result in injury or behavioral changes to listed species. Consultations do not analyze cumulative impacts of the

projects occurring at the same time and what affects this may have on listed species. By themselves, the projects were found not to have any measurable affect to listed species beyond the individual scale.

2.4 Effects of the Action

'Effects of the action' means the direct and indirect effects of an action on the species or critical habitat, together with the effects of other activities that are interrelated or interdependent with that action, that will be added to the environmental baseline (50 CFR 402.02). Indirect effects are those that are caused by the proposed action and are later in time, but still are reasonably certain to occur.

The Opinion addresses two separate but related actions: (l) the COE issuance of a permit to SDOT for the construction of the Elliott Bay Seawall project, (2) NMFS' issuance of a LOA under Section 101 (a)(5)(D) of the MMPA, and the underlying activity which is the basis for these requested federal approvals. The effects of authorizing the underlying action are addressed below.

The Services used the most current, site-specific data and information to assess the direct effects on listed species and critical habitat. In cases where information is lacking, the Services have relied upon relevant peer-reviewed literature to evaluate the likely effects. Where site-specific data and information were lacking, the Services exercised best professional judgment and applied the benefit of doubt in favor of the listed species as necessary to draw conclusions. The results of this assessment led to the determination some or all components of the project will cause adverse effects on the following species and/or designated critical habitat:

- Puget Sound Chinook salmon and critical habitat
- Southern Resident killer whale
- Steller sea lion
- Humpback whale
- Bocaccio
- Canary rockfish
- Yelloweye rockfish
- Coastal-Puget Sound bull trout and critical habitat

The action agency indicated adverse effects also to Puget Sound steelhead, marbled murrelets, and Southern Resident killer whale critical habitat. The Services reviewed potential impacts to these species/critical habitat and determined that they are not likely to be adversely affected. Our basis for this determination is found in Section 2.4.1.

2.4.1 Insignificant and Discountable Effect to Species and Designated Critical Habitat

The Services analyzed the potential impacts of the project on Puget Sound (PS) steelhead (*Oncorhynchus mykiss*), marbled murrelet (*Brachyramphus marmoratus*), and Southern Resident (SR) killer whale critical habitat and determined that the impacts will be discountable and insignificant.

2.4.1.1 Puget Sound Steelhead

Having an anadromous life history form, steelhead, especially from the Green/Duwamish River and those populations south of Elliott Bay, will use the action area as they migrate out to the ocean. Steelhead populations south of Elliott Bay include the Puyallup, Nisqually, and the Deschutes River populations and smaller streams that enter directly into Puget Sound such as Clover and Woodland creeks. Smolts and adults spend little time in estuaries, migrating quickly to deeper waters (Emmett et al 1991).

Juvenile steelhead migration out of the Green/Duwamish River occurs from March through July (Williams et al 2001). Size range of steelhead migrating out of the Green/Duwamish River was 42 to 490 mm (mean fork length was 257.75 mm) comprised of multiple year classes (Brennan et al 2004). The small number of steelhead caught suggests that steelhead rapidly migrate through the lower Duwamish and estuary (Ruggerone et al. 2006). The migration pattern of steelhead in Puget Sound is not well known; however, once entering the marine environment, it is believed that steelhead smolts move quickly offshore to deeper water (Hartt and Dell 1986).

Summer-run adult steelhead migrate up the Duwamish/Green River from April through October, and winter-run adults from November through May (Williams et al 2001). The winter-run population is the larger population and is composed of both hatchery and wild stocks. The summer-run population is composed almost entirely of hatchery stock. Repeat spawners have been found to compose from 0 percent to 20 percent of the returning wild adults (Williams et al 2001). The summer-run population is considered depressed in 2002 with a long-term negative trend and a short-term severe decline (WDFW 2002a). The winter-run population is rated healthy because of a consistent spawner escapement around the goal of 2,000 wild spawners (WDFW 2002b).

The number of steelhead caught or observed within the action area is low. No steelhead were observed during the October 2011 to May 2013 fish surveys along the seawall (Toft et al. 2012a, 2012b, 2012c, 2012d, 2013a, 2013b). Steelhead have been observed south of Elliott Point, near Golden Gardens, in Shilshole Bay, at Alki Point, and within Elliott Bay at the mouth of the Duwamish River (Williams et al 2001). In a study of the nearshore habitat in WRIAs 8 and 9 (including Vashon and Maury Islands), 591 beaches were sampled by seining in 2001 and 2002, almost 34,000 salmonids were caught and only nine were steelhead (Brennan et al. 2004). These steelhead were captured from May through August with no steelhead caught in April, September, October, or December.

Because steelhead are not shoreline dependent and quickly migrate to deeper water and to the ocean, they will not be exposed to project construction effects, and future cohorts' exposure to long-term effects will be ephemeral. While increased turbidity and suspended solids extends only 50 feet from in-water construction activities (see Section 2.4.2.3), increased sound pressure levels from impact pile driving resulting in injury extends 185 meters from construction (see Section 2.4.2.4), and increased dissolved copper and dissolved zinc concentration from stormwater discharge occurs within 557 ft^2 of each of the seven outfalls (see Section 2.4.3, Table 21), exposure to these habitat effects is not expected. Because steelhead move to deeper water and migrate to the ocean quickly, they will likely avoid the areas where increased turbidity, injurious sound pressure levels, and areas of elevated pollution from stormwater discharges will occur. Increased sound pressure levels that may result in behavioral changes to steelhead extend 2.9 miles from impact pile driving activities,

but because only four piles a day will be proofed with an impact pile driver and each pile will require only 5 minutes of impact pile driving it is not expected that 20 minutes per day of elevated sound will affect behaviors of steelhead to the degree that injury will occur. Therefore, the effects of the project to steelhead are expected to be discountable or insignificant.

2.4.1.2 Marbled Murrelet

The marine environment is important for marbled murrelets (murrelet) year round. Many prey species for murrelets are concentrated in nearshore waters where freshwater or estuaries provide spawning and rearing areas (USFWS 1997, p. 30). The marine environment and action area are used by murrelets for foraging, loafing, stretching, preening, breeding, rearing, and social interactions.

The action area lies within Conservation Zone 1, Stratum 3, of the murrelet monitoring program. Zone 1 includes the Strait of Juan De Fuca, Puget Sound, Hood Canal, and the San Juan Islands. Stratum 3 includes south Hood Canal and central/south Puget Sound. In 2010, the murrelet population estimate in Zone 1 was 4,393 birds, with an annual rate of decline of 7.43 percent between 2001 and 2010 (Pearson et al., 2011, p. 4). Surveys conducted in stratum 3 in 2009 counted 1,580 murrelets (density 1.08 birds per km^2), and in 2010 counted 571 murrelets (density 0.39 birds per km^2) (Falxa et al., 2011, p. 13, 14).

Murrelet use of Elliott Bay is very rare. Elliott Bay has an industrialized urban waterfront with significant vessel (container barge, ferries, cruise ships, etc.) traffic and very limited forage fish spawning habitat and foraging opportunities. Two murrelets were seen by a trained observer in front of the grain elevators near Myrtle Edwards Park in 2012, north of downtown Seattle and the project location (Teachout, in litt. 2012). The observer thought it may have been the same bird, but that is unknown. The murrelets were constantly diving which is an indication of active foraging. The murrelets were located approximately one mile north of the project site in an area where the shoreline is less industrialized. Occasional murrelet sightings are reported in and around Elliott Bay on ebird (internet site at www.ebird.com), but the sources and validity of these reports are uncertain. Given the lack of natural shoreline and intertidal habitat along the heavily industrialized waterfront, the Services do not expect many murrelets to be present in the vicinity of the seawall during or after construction.

The Services expect the effects of the project to murrelets to be discountable because the following conditions inhibit murrelets from using the action area: 1) work will be conducted along the Seattle waterfront where there is limited open water (less than 35 percent open water) due to extensive overwater structures; and 2) the project area has high levels of human activity and disturbance associated with marine traffic such as ferries, barges, cargo and cruise ships, and nearshore traffic including cars, trucks, buses, trams, pedestrians, etc. To the degree that murrelets do use the action area, effects are expected to be insignificant because: 1) increased turbidity and suspended solids from project discharge will not extend beyond 50 feet (15.2 meters) from the seawall and will be dissipated in areas that are used by murrelets; 2) prey species of the murrelet do not spawn in the project area, therefore prey abundance is unlikely to be affected by turbidity or stormwater discharge; and 3) increased sound pressure levels from impact pile driving is of short duration (5 minutes per pile, four piles per day) and the distance for the onset of injury is limited to 19 meters (62.3 feet) and does not extend beyond the existing overwater structures.

2.4.1.3 Southern Resident Killer Whale Critical Habitat

Critical habitat for SR killer whales was designated in three specific areas: 1) summer core area in Haro Strait and waters around the San Juan Islands; 2) Puget Sound; and 3) the Strait of Juan de Fuca on November 29, 2006 (71 FR 69054). Critical habitat includes approximately 2,560 square miles of Puget Sound, excluding areas with water less than 20 feet deep relative to extreme high water. The primary constituent elements (PCE) for SR killer whale critical habitat are:

(1) Water quality to support growth and development;

(2) Prey species of sufficient quantity, quality, and availability to support individual growth, reproduction and development, as well as overall population growth; and

(3) Passage conditions to allow for migration, resting, and foraging.

The proposed action will affect the PCEs listed below, however, effects are not expected to be measurable and, therefore, considered insignificant for the following reasons:

Water Quality – The project will improve the overall water quality in Elliott Bay by providing basic water quality treatment to the project area that currently is not treated. Polluting loading will decrease 28 to 72 percent for total suspended solids, total copper, and total zinc. Dissolved copper and dissolved pollutant loading will increase by five percent due to the addition of an additional lane of traffic. The project will improve water quality and therefore will not affect killer whale growth and development.

Prey Quantity, Quality and Availability – The proposed project will not result any loss or injury of adult salmonids. Impact pile driving may result in a behavioral disruption to adult salmonids within 4,642 meters (2.9 miles) of the seawall. However, impact pile driving will be very limited. The project involves impact pile driving only four sheet piles per day, with 5 minutes of impact pile driving per sheet pile (20 minutes per day). Therefore, impacts to adult salmonids will be minimal. The project construction does result in injury or mortality of a small number of juvenile salmonids due to pile driving, suspended solids, turbidity, and fish handling. However, the number is small and will not affect adult numbers in the future. Over the long-term, the project will benefit killer whale prey, due to improvements of salmonid habitat and prey through increases in macroinvertebrate production.

Passage – Killer whale migration may be temporarily impacted due to project construction. Twenty days of vibratory pile driving will occur to install the temporary containment wall. Up to 21 days will be needed to remove the containment wall with vibratory equipment. Vibratory pile driving results in behavioral effects that may alter killer whale migration. However, sound levels would not extend completely across Puget Sound, allowing killer whales to avoid the higher levels of sound in Elliott Bay. The project also involves the use of barges to bring construction equipment and supplies to the project site. Elliott Bay has a high number of vessel, ship, and barge traffic. Tugboats and

barges are slow moving and follow a predictable route. Killer whales would be able to easily avoid construction barges. Therefore, increased barge use within the action area will not impact this PCE.

2.4.2 Construction Effects on Listed Species

Work will be conducted over a 7-year period beginning in October 2013 and ending in March 2020. Project construction has been divided into two phases (see Section 1.2 Proposed Action for complete details): Phase 1 consists of the Central Seawall and Phase 2 includes the area of the North Seawall. Each phase of construction has been further divided into construction segments, which represents 1 to 2 years of construction. Table 11 provides the anticipated construction schedule for the project.

Table 11 – Anticipated Construction Schedule

Phase	Segment	Year of Construction
1 (Central Seawall)	1	Year 1 (Fall 2013–Spring 2014)
	2	Year 2 (Fall 2014–Spring 2015)
	3	Year 3 (Fall 2015–Spring 2016)
2 (North Seawall)	1	Years 4 & 5 (Fall 2016–Spring 2018)
	2	Years 6 & 7 (Fall 2018– Spring 2020)

Because the Seattle Waterfront is an important visitor attraction, no construction will occur during the tourist season (Memorial Day through Labor Day). To complete construction during the non-tourist season, SDOT will conduct in-water work between September 1 and March 1 each year. The March 1 date for completing construction is outside the Corps' approved work window for Elliott Bay which is July 16 to February 15.

For each segment, in-water construction includes the following activities:

- Installation of the temporary sheet-pile containment wall which includes:
    - Removal or displacement of riprap along the existing seawall where the sheet-pile wall will be installed.
    - Removal of existing timber piles that are in the way of the temporary wall.
    - Installation of the sheet-pile wall with a vibratory and impact pile driver.
- Fish handling and removal – this will be done prior to final sheet-piles being installed.
- Installation of the sediment curtain.
- Removal of the temporary sheet-pile wall with a vibratory driver.
- Installing CSO outfall extensions, if necessary, that could not be installed behind the containment wall.
- Installing intertidal habitat bench and other habitat features that could not be installed behind the containment wall.

In-water construction will result in impacts that will affect the listed species in different ways. Some construction effects will only impact the nearshore environment, such as exposure to elevated turbidity and suspended solids, and will impact a smaller number of species, while underwater sound effects will have a larger area of exposure and will impact a larger number of species. The following analysis describes the several components of in-water construction, identifies effects from each construction component, and identifies the species exposed to the effect, and their anticipated responses to such exposure.

The two buoys installed to provide short-term moorage of delivery barges will be installed at a depths greater than 60 feet using a "dual-chained" anchoring system. The Services determined that the anchoring system will have no to minimial impact on submerged aquatic vegetation and benthic invertebrates and therefore will have no effect on listed species.

2.4.2.1 Barge Operation

Delivery/storage barges, derrick barges, and tugboats to support project construction will be on site between Labor Day and Memorial Day. The barges are expected to come in from the contractor's facility on the Duwamish River, but could come from other sites around Puget Sound if barges are supplied by different contractors. During construction, the barges, moved by tugboats, will primarily navigate between Elliott Bay and southern Puget Sound, and estimates are for roughly 20 round-trips will occur during each construction season. The Port of Tacoma is identified as the potential primary source location for precast components and aquatic materials. Existing north Puget Sound commercial facilities could also provide material. The derrick barges will not leave the project site and remain in place during active periods of loading and unloading. In extremely adverse weather conditions, barges may be moved from the project site to an existing barge moorage area near West Seattle, or to the contractor's facility in the Duwamish River as a safety precaution.

Barge traffic from the proposed action will occur mostly during daylight hours and along major navigation routes within Elliott Bay. The number of additional barge trips per year attributable to the proposed action is 20 round-trips per year is a small annual percentage increase (2.7 percent, using 40 one-way trips) over the current number of container, cruise, grain ships and barge use within Elliot Bay. The use of tugboats and barges for the project will contribute to the ambient sound level within Elliott Bay. Current ambient sound levels within Elliott Bay is 123 dB_{RMS} (Laughlin 2011). The underwater sound levels during the daytime are dominated by ferry vessel traffic which results in sound levels between 125 and 130 dB (Laughlin 2011). The ambient sound level within Elliott Bay is well below sound levels that result in behavioral effects to listed fish species (150 dB_{RMS}, see Section 2.4.2.4 Exposure to Elevated Underwater Sound Pressure Levels below). Tugboat and barge use, which are similar to ferry vessels, will not increase sound levels above 150 dB_{RMS} , therefore, the Services conclude that the effects of barge operation will be insignificant to Chinook salmon, bocaccio, canary rockfish, yelloweye rockfish, and bull trout.

Tugboats and barges are slow moving, follow a predictable course, do not target cetaceans and pinnipeds, and should be easily detected by killer and humpback whales and Steller sea lions. Therefore, vessel strikes are extremely unlikely. The slow travel speed of the barges, infrequency of these vessel trips, and the minimal duration of barges in any particular area, means any potential

encounters with killer and humpback whales and Steller sea would likely be sporadic and transitory in nature. The Services conclude that the effects of barge operation will be insignificant to killer whales, Steller sea lions, and humpback whales.

2.4.2.2 Shade Caused by Moorage and Overwater Structures

The Services analyzed the effects of shading from barge moorage and the new cantilevered sidewalk that will cover the intertidal habitat bench created after the seawall is set back 10 to 15 feet. The extent of each is considered separately below. Then the section covers how these effects matter to the listed species considered in this consultation.

Shade from Moored Barges. Barges will increase overwater shading between piers during construction, from September through May each year. On average, two barges will be used during construction to deliver material and support construction activities. A derrick barge (typically 70 feet by 200 feet) will be on site throughout most of the construction season. Delivery barges will be tied to the derrick barge for an average of 5 to 6 days at a time. Delivery barges are 55 feet by 180 feet. The total surface area of barges expected at the project site is approximately 23,900 ft^2. Additional barge support may be needed during construction, and could include up to four barges, two derrick and two delivery barges.

During both phases of construction, the primary access point where the derrick barge will be stationed for loading and unloading of material is located between Pier 60 (Seattle Aquarium) and Piers 62/63. Secondary access points include the area between Pier 48 and Colman Dock, the Waterfront Park area between Piers 57 and 59, and between Piers 69 and 70. Secondary access points will be used when two derrick barges are on site, or to unload material closer to the construction zones. Short-term access points that will only be used for habitat enhancement work include the areas between Piers 54 and 55, Piers 56 and 57, Piers 67 and 69, and Piers 69 and 70.

Derrick barges will be anchored to the seafloor with two spud anchors, 3 feet in diameter, and will remain in place during active periods of material delivery. Delivery barges will be tied to the derrick barge for an average of 5 to 6 days at a time, and will be rotated as needed to provide a continuous supply of construction materials. There will be no gangway between the derrick barge and the pier or land.

Barge use will temporarily increase overwater shading when the barges are anchored between the piers along the seawall by approximately 23,900 ft^2 (47,800 ft^2 when four barges are used, although this will be infrequent).

Shade from Cantilevered Sidewalk. The proposed project's placement of the new seawall 10 to 15 feet behind (landward of) the existing seawall re-creates approximately 1.8 acres of new aquatic habitat, where a habitat bench will be constructed. The project also includes the construction of a new cantilevered sidewalk, which will cover the entire 1.8 acres of new habitat, causing some shading of the habitat bench. The cantilevered sidewalk incorporates a shoal design that includes light penetrating surfaces. The shoal design will have 19.5 percent open or glassed area that will allow some light to penetrate underneath the sidewalk, but the amount of light is unknown, and it is

undetermined if enough light will enable juvenile salmonids to migrate along the seawall (Figure 23).

The LPS modeling shows that light increases under the sidewalk when compared against a traditional design, however, as shown in Figure 23, light levels increase along the seawall itself (green and yellow in the figure) but on the water surface, there is a minimum (dark blue) to patchy maximum (orange and red) increase in light, with numerous shade lines. What cannot be modeled are the light levels under the sidewalk as a result of the LPS being installed.

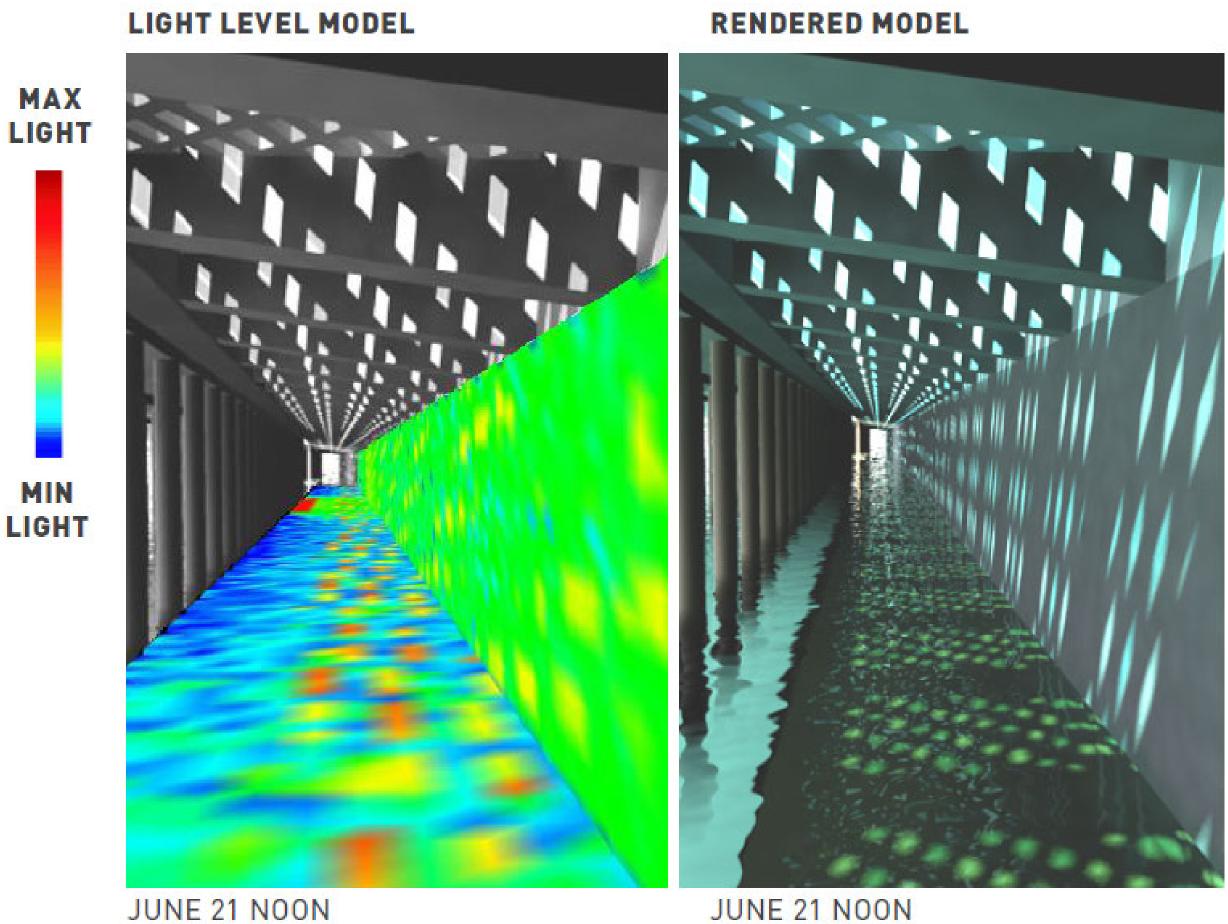

Figure 23 – Light penetration surface shoal design modeled output under the cantilevered sidewalk. Pier piles are on the left and the seawall is on the right. Model shows light without obstructions on summer solstice, which would be the extreme maximum light penetration.

Of particular note, the modeling of the LPS shoal design did not take into account the buildings that are on most of the piers, and which will shade the LPS during the afternoon and evenings. In addition, the topography and large buildings east of the seawall will also reduce the amount of sunlight that can penetrate through the LPS. Direct sunlight that can reach the LPS is limited to a few hours each day (depending on the season). This will further reduce the amount of light available under the cantilevered sidewalk.

Even though the surrounding buildings and topography will reduce the amount of light going through the LPS, some light will penetrate under the cantilevered sidewalk and along the seawall. Under existing conditions, there is no light under the piers and juvenile salmonids are documented to migrate around all the piers (Brown et al. in litt. 2011) rather under them. The project's design will create a partially lighted, shallow-water, migratory corridor along the seawall that is intended to represent more favorable conditions than currently exist for listed fish species, especially Chinook salmon.

Effects of Shade on Salmonids. The Services largely relied on the work of Simenstad et al. (1999) and Nightingale and Simenstad (2001a), for the most current synthesis on the effects of piers on salmonid behavior, habitat, and predation. The report summarizes effects of overwater structures with an emphasis on ocean-type juvenile salmonids (30 to 60 mm in size), as well as larger juvenile salmonids, like sockeye (*O. nerka*), coho (*O. kisutch*), and steelhead.

The Simenstad et al. (1999) and Nightingale and Simenstad (2001a) literature syntheses concluded the following:

1. Overwater structures create sharp, underwater light contrasts by casting shade over an area during the day. Light contrasts can also occur at night from artificial lighting surrounding a structure.

2. Fish exposed to sharp, underwater light contrasts may be exposed to increased risk of mortality as a consequence of the following: delays in migration from disorientation caused by lighting changes, loss of schooling refugia (protection) due to fish school dispersal under limited light conditions, and a change in migratory routes to deeper waters, which lack refugia from predators.

3. No studies are available that provide empirical evidence supporting or refuting the hypothesis that modification of juvenile salmonid behavior in shoreline habitats resulted in changes in survival. Results were exceedingly variable and appeared to reflect the study conditions (e.g., adjacent shorelines, dock dimensions and material, artificial lighting, etc.) that affected observations.

4. Despite considerable speculation that overwater structures increase the numbers and success of predatory fish, evidence supporting this contention is inconclusive. Quantitative assessment of predation around overwater structures is meager, and few studies have confirmed actual predation.

5. Light is extremely important in determining the type and distribution of diatoms, photosynthetic bacteria, phytoplankton, macroalgae, microalgae and seagrasses. Overwater structures can reduce light levels by 90 to 100 percent below ambient, which can significantly affect marine plant distribution and abundance.

Nightingale and Simenstad (2001a) concluded that cumulative impacts of overwater structures in urban industrialized areas in estuaries (multiple placements of overwater structures) can pose substantive risks to estuarine ecosystems, especially in areas like Elliott Bay where estuarine habitat

is extremely limited and the shoreline is highly modified with piers and bulkheads. Both syntheses suggested using a landscape ecology approach to address cumulative impacts by combining increased light in under-pier environments with adjacent areas of enhanced prey production. This approach would begin to rebuild a migratory corridor with a higher carrying capacity for juvenile salmonids that typically suffer high mortality during migration.

These literature syntheses suggest that the habitat value under overwater structures will be very low. Light levels below overwater structures will significantly limit or eliminate primary production, thus leading to a less diverse community structure. Habitat surveys along the existing seawall have found low productivity under the existing piers (see Section 2.3, Environmental Baseline). Juvenile salmonids were also found not to migrate under piers or cross the shadeline created by the overwater structures (Brown et al. in litt. 2011).

The Services have considered the timing, location, and duration of shade that will be caused by mooring the barges. Because project construction will occur from September 1 through March 1 of each year, there will be some effects to the aquatic vegetation and habitat important to rearing and migrating juvenile salmonids and rockfish. However, because SDOT will remove the barges each year between Memorial Day and Labor Day, most vegetation and habitat features will recover prior to use by salmonids and rockfish. Therefore, the Services anticipate that increased areas of shade from barge presence will have no more than minor effects to PS Chinook salmon, boccacio, canary rockfish, and bull trout.

Additionally, the deleterious effects of shade on habitat and on fish themselves that will be caused by the permanent presence of the cantilevered sidewalk is partially addressed by design to allow penetration of some light, and reduce the light/dark transition that otherwise increases juvenile salmonid vulnerability to predation. If the partial lighting functions, by providing shallow water areas between the piers with increased primary production and invertebrates, then listed juvenile bull trout and juvenile PS Chinook should eventually benefit from the increase in light penetration under the permanent structures by having a small increase in abundance and diversity of prey species, having fewer deeply shaded areas to avoid during migration, and having a greater ability to detect/avoid predator fish.

2.4.2.3 Elevated Turbidity and Suspended Sediment

For each of the five construction segments, in-water construction to install the temporary containment wall, including removal or displacement of riprap and the removal of timber piles, will last approximately 28 days. Eight days are expected for the riprap and timber pile removal, and 20 days to install the sheet pile wall. Installation of the containment wall will occur in September and early October. Removing or displacing riprap along the existing seawall, removing timber piles, installing and removing the temporary containment wall, installing the CSO outfall extensions, installing pilings for the restored Washington Street Boat Landing, and the installing the intertidal habitat bench and other habitat features will all cause episodes of turbidity and suspended sediment. Elevated turbidity and suspended sediment will affect the nearshore environment at the beginning and end of each construction segment (September and February).

Juvenile Chinook salmon, bocaccio, canary rockfish, and bull trout will be exposed to elevated turbidity and suspended solids. Chinook salmon, bocaccio, and canary rockfish are more nearshore dependent as juveniles. Juvenile Chinook salmon migrating along the nearshore are feeding on a variety of invertebrates; the juvenile bocaccio and canary rockfish are found in shallow waters near algae, seagrass, and kelp where they benefit from warmer temperatures, food, and refuge from predators; and bull trout occur where prey species are readily available, which can include the project area. Juvenile yelloweye rockfish will not be affected by elevated turbidity and suspended sediment as they settle in deeper waters and will not be found along the existing seawall. Whale species do not use shallow areas where turbid conditions are expected. Steller sea lions are also not likely to be affected by turbidity because they would use the action area for foraging in the deeper waters beyond the piers.

Along the Seattle Seawall, nearshore currents are generally low and run parallel to the waterfront (SDOT 2012b), and they are generally insufficient to re-suspend and transport its fine silts and clay sediment (Curl et al. 1988). Between and under the piers, the currents are weaker and of mixed direction. Wind-driven waves and waves from shipping traffic hit the vertical seawall and release energy at depth that can cause re-suspension of sediments, especially during low tides and winter storm events. Based on these conditions, construction activities will cause temporary increases in turbidity and suspended solids localized along the seawall.

Fish Responses to Turbidy and Suspended Sediment. The variety of effects that fish experience when they encounter suspended sediment may be characterized as lethal, sublethal, or behavioral (Bash et al. 2001; Newcombe and MacDonald 1991; Waters 1995). Lethal effects to salmonids in marine waters include gill trauma (physical damage to the respiratory structures) (Curry and MacNeill 2004) and reduced prey due to smothering of forage fish eggs and macroinvertebrates (Chapman 1988). Sublethal effects include physiological stress reducing the ability of fish to perform vital functions (Cederholm and Reid 1987), severely reduced respiratory function and performance (Waters 1995), increased metabolic oxygen demand (Servizi and Martens 1991), susceptibility to disease and other stressors (Bash et al. 2001), and reduced feeding efficiency (Newcombe and MacDonald 1991). Sublethal effects can act separately or cumulatively to reduce growth rates and increase fish mortality over time. Behavioral effects include avoidance and related secondary effects to feeding rates and efficiency (Bash et al. 2001). Fish may be forced to abandon preferred habitats and refugia, and may enter less favorable conditions and/or be exposed to additional hazards (including predators) when seeking to avoid elevated concentrations of suspended sediment.

A summary of effects from suspended sediment is listed in Table 12, and a more detailed discussion of effects (specific to bull trout, but relevant to all salmonids) is included in Appendix A.

Table 12 – Summary of the adverse effects of sediment on fish.

Sediment Impacts to Fish	Summary of Adverse Effects Related to Sediment Impacts
Gill trauma	Clogs gills which impedes circulation of water over the gills and interferes with respiration
Prey base	Disrupts both habitat for and reproductive success of macroinvertebrates and other salmonids (bull trout prey) that spawn and rear downstream of

	the construction activities
Feeding efficiency	Reduces visibility and impacts feeding rates and prey selection
Habitat	Fills pools, simplifies and reduces suitable habitat
Physiological	Increases stress, resulting in decreased immunological competence, growth and reproductive success
Behavioral	Results in avoidance and abandonment of preferred habitat

In the nearshore environment, where important maturation and development of migrating juvenile Chinook salmon occurs, turbidity avoidance can force movement into deeper waters where the ratio of feeding opportunity to predation risk is reduced. The responses of bocaccio and canary rockfish are likely to be different from the responses of Chinook salmon because of the life stages that inhabit the nearshore environment. Larval bocaccio and canary rockfish occupy the nearshore and are distributed by currents while juveniles are associated with kelp.

The Services expects that all individuals of Chinook salmon, canary rockfish, and bocaccio that are within 50 feet of in-water construction activities will respond with significant disruption in normal behaviors, such as increased stress leading to reduced ability to perform vital functions such as feeding, migrating, or avoidance of predators, resulting from increased turbidity and suspended solids. The 50-foot distance for impacts to listed fish species is based on Weston Solutions (2006) and Shepsis (in litt. 2013). Weston Solutions and Pascoe Environmental Consulting (2006) monitored pile removal activities in Lower Sequim Bay. Removal of timber piles with a vibratory pile driver resulted in localized increased turbidity levels within 5 to 10 meters (16.4 to 32.8 feet). Shepsis (in litt. 2013) modeled current velocities at Colman Dock along the seawall and found tidal flow circulation velocities to be very low and are not a significant factor in sediment transport processes. The Services assume that increased turbidity and suspended sediment levels will dissipate to background levels within 50 feet of sediment generating activities.

In-water construction to install the temporary containment wall, including removal or displacement of riprap and the removal of timber piles, will last approximately 28 days (eight days for the riprap and timber pile removal and 20 days to install the sheet pile wall). Installation of the containment wall will occur in September and early October. The removal of the containment wall will occur at the end of each of the five construction sgments and will require 2 to 3 weeks. The installation of the expanded habitat bench areas and the substrate enhancent activities will all occur at the end of each construction phase and last for 2 to 4 weeks. The removal of the containment wall and installation of the expandedhabitat bench areas and substrate enhancement will result in increased turbidity and sediment levels. However, these activities will occur in February when listed fish species are not expected to be in the area. With BMPs (see Section 1.2.1.7) that will be used to minimize turibidity and suspended solids, the effects of these activities are expected to be minimal to listed fish species.

Chinook Salmon Exposure to Turbidity and Suspended Sediments. Juvenile Chinook salmon are still found along the seawall in September and October (Figure 20, Toft, in litt. 2013a), which is in the anticipated time for construction in each construction season for seven years. The average number of Chinook salmon captured along the three seawall sites in September was 1.8 fish/520 m^2 (5,597 ft^2), ranging from zero to 3.5 fish/520 m^2 and 0.6 fish/520 m^2 for October, ranging from zero to 1.8 fish/520 m^2 (UW unpublished data). Residence time for Chinook salmon in Elliott Bay was

found to average 18.4 days, ranging from 2 to 52 days during June and July (Ruggerone and Volk 2004). For Phase 1, each construction segment is 1,200 feet long. Approximatley 150 feet of riprap displacement and timber pile removal will occur per day (1,200 feet/8 days) and 60 feet of sheet piles installed per day (1,200 feet/20 days). For Phase 1, the Services estimate that up to three juvenile Chinook salmon per day (150 feet per day * 50 feet of increased turbidity = 7,500 ft^2, with 1.8 fish/5,597 ft^2) will have disruption in normal behavior as a result of increased turbidity and suspended solids as a result of riprap displacement and timber pile removal and one juvenile Chinook salmon per day (60 feet per day * 50 feet of increased turbidity = 3,000 ft^2, with 1.8 fish/5,597 ft^2) as a result of sheet pile installation During Phase 2, each construction segment is 1,700 feet long. Approximatley 231 feet/day of riprap displacement and timber pile removal will occur per day (1,700 feet/8 days) and 85 feet of sheet piles installed per day (1,700 feet/20 days). For Phase 2, the Services estimate that up to four juvenile Chinook salmon per day (231 feet per day * 50 feet of increased turbidity = 11,550 ft^2, with 1.8 fish/5,597 ft^2) will have a disruption in normal behavior as a result of riprap displacement and timber pile removal and one juvenile Chinook salmon (85 feet per day * 50 feet of increased turbidity = 4,250 ft^2, with 1.8 fish/5,597 ft^2) during installation of the sheet pile wall. For each construction segment in Phase 1, 44 juvenile Chinook salmon [(3 Chinook salmon * 8 days) + (1 Chinook salmon * 20 days)] will be exposed to increased turbidity levels for a total of 132 juvenile Chinook salmon (44 Chinook salmon * 3 years). For each construction segment in Phase 2, 52 juvenile Chinook salmon [(4 Chinook salmon * 8 days) + (1 Chinook salmon * 20 days)] will be exposed to increased turbidity for a total of 104 juvenile Chinook salmon (52 Chinook salmon * 2 years)[5]. These numbers are conservative as a lot of the construction will occur under piers where Chinook salmon have been found to avoid.

The SDOT will remove the temporary containment wall, install the CSO outfall extensions, and install the intertidal habitat bench and other habitat features in January and February, after the containment wall is removed. Juvenile Chinook salmon are not present along the seawall at this time and therefore, no Chinook salmon will be exposed to increased turbidity and suspended sediment during these activities.

Bocaccio and Canary Rockfish Exposure to Turbidity and Suspended Sediments. For the purpose of this analysis, we refer to larval and pelagic juvenile rockfish as “larvae” because there is no clear delineation between these life stages, and each would be similarly affected by this effect of the proposed action. The effects on larval rockfish would occur within the 7 years which the proposed action would occur. Larval rockfish have been documented in Elliott Bay (Greene and Godersky, 2012). In addition, some larvae and pelagic juveniles of ESA-listed rockfish broadly disperse from the area of their birth (NMFS 2003, Drake et al., 2010) and are likely to be using habitat in the action area during project construction activities.

Using the shallow water Duwamish index site from Greene and Godersky (2012) larval rockfish densities in Elliott Bay in September and October were estimated at 7.1 and 6.5 rockfish per 1000 m^3 (35,315 ft^3), respectively. Rockfish larvae are difficult to identify from morphological features alone until they are several weeks to months old (Love et al., 2002), thus Greene and Godersky (2012) did

[5] There are two construction segements in Phase 2 that will be constructed over 4 years. Each construction segment will take 2 years to complete. The in-water construction for each segment in Phase 2 will occur at the same time of year as construction in Phase 1 (i.e., temporary wall construction in September/October, and removal in February). Therefore, the number of Chinook salmon will be the same (over 4 years) as if the construction would occur in two years.

not identify species. To estimate the abundance of rockfish larvae that would be in the project area when increased sediment and turbidity are expected, we used the densities of all rockfish larvae reported in Greene and Godersky, (2012), and bounded it by the proportion of canary rockfish and bocaccio caught in recent fisheries (WDFW 2010).
For the purposes of this analysis we assume that the proportion of ESA-listed rockfish caught by recreational anglers compared to the total rockfish caught roughly represents the proportion of larval rockfish.

The proportion of adult canary rockfish caught by recreational anglers from 2004 to 2008, as a proportion of the total rockfish catch, was 0.012 percent, and bocaccio were 0.00026 percent of the total rockfish caught (WDFW 2010). By multiplying the percentage of the recreational catch by the density reported by Greene and Godersky (2012), we derive the estimated densities of canary rockfish and bocaccio larvae within Elliott Bay. This calculation results in an estimated density of 0.0009 canary rockfish larvae and 0.00002 bocaccio larvae per 1,000 m^3 (35,315 ft^3) in September and 0.0008 canary rockfish larvae and 0.00002 bocaccio larvae in October. The volume of water impacted by increased turbidity and suspended solids from construction is approximately 32,940 m^3 (1,163,265 ft^3) for Phase 1 and 155,400 m^3 (5,487,899 ft^3) for Phase 2. Values used are:

- 6 meters (20 feet) average depth of water along seawall (SDOT 2012e)
- 15 meters (50 feet) estimated length of increased turbidity and suspended solids from project
- 366 meters (1,200 feet) for each construction segment in Phase 1
- 518 meters (1,700 feet) for each construction segment in Phase 2

Therefore the number of canary rockfish and bocaccio larvae that may be impacted by increased turbidity and suspended solids during each segment for Phase 1 and Phase 2 are shown in Table 13.

Table 13 – Estimated number of canary rockfish and bocaccio larvae impacted by increased turbidity and suspended solids from the proposed action.

Month	Phase 1		Phase 2	
	Canary Rockfish	Bocaccio	Canary Rockfish	Bocaccio
September	0.03	0.0007	0.04	0.0009
October	0.03	0.0007	0.04	0.0009

Because of these very low numbers, the Service estimates that one larval canary rockfish and one larval bocaccio per year will have disrupted behavior as a result of the increased turbidity and suspended solids and turbidity from riprap displacement, timber pile removal and sheet pile installation.

This disruption in normal behaviors described above will result from turbid conditions caused by project construction activities in the autumn months, for each of the five project segments over 7 years. Activities causing turbidity that disrupts normal behavior are: the removal or displacement of riprap along the existing seawall; removal of existing timber piles; installation and removal of the temporary containment wall; installation of the CSO outfall extensions; and the installation of the intertidal habitat bench and other habitat features installed, once the containment wall is removed. Since adult and subadult bull trout are highly mobile and can easily avoid or quickly pass through turbidity plumes, this species will not be significantly affected by exposure to elevated sediment and

turbidity levels during project construction, especially because at this life-history stage, they are less susceptible to injury when exposed to turbidity.

Finally, some activities related to the removal of the temporary containment wall, installation of the CSO outfall extensions, and the installation of the intertidal habitat bench and other habitat features (once the containment wall is removed) will occur in January and February. Juvenile Chinook salmon, and larval and juvenile canary rockfish, yelloweye rockfish, and bocaccio are not expected to be found along the seawall at this time and therefore, will not be exposed to increased turbidity and suspended solids during these specific activities during the winter time frame.

2.4.2.4 Exposure to Elevated Underwater Sound Pressure Levels (SPL)

A vibratory pile driver will be used to install sheet piles to construct (and later remove) the temporary containment wall. Approximately 20 percent of the sheet piles will need to be installed or proofed with an impact pile driver. Approximately 190 concrete piles will be installed with an impact pile driver, although most of the piles will be installed behind (landward) of the containment wall. Fifteen of these concrete piles will support the Washington Street Boat Landing, and the remainder will support the cantilevered sidewalk. Both vibratory and impact pile driving increase sound pressures to levels that are adverse to Chinook salmon, killer whales, Steller sea lions, humpback whales, bocaccio, canary rockfish, and bull trout, but the Services expect most effects from vibratory driving of the sheet piles, and impact driving of the concrete piles will fall in the category of behavioral change. Juvenile yelloweye rockfish will not be affected by elevated sound pressure levels as they settle in deeper waters and will not be found along the existing seawall during installation of the containment wall.

The Services use a Sound Pressure Exposure spreadsheet or calculator to estimate the area around each pile where fish would be considered at risk of injury or behavioral disruption during pile driving. Table 14 lists the expected sound levels that could be generated by the proposed pile driving associated with the project.

Table 14 – Unattenuated noise levels for types of pilings proposed for the Elliott Bay Seawall Project.

Measured Levels for Pile Driving			
	Peak Level	Sound Exposure Level (SEL)	Root Mean Squared Level (RMS)
24-inch Octagonal Concrete Pile (Impact)	188	166	176
24-inch Steel Sheet Pile (vibratory)	182	165	165
24-inch Steel Sheet pile (impact)	205	180	190

While impact driving creates sound pressure at frequencies and intensity that has been documented to injure and kill fish, vibratory drivers produce, on average, underwater peak pressures that are approximately 17 dB lower than those generated by impact hammers (Nedwell and Edwards 2002). Underwater sound produced by vibratory and impact hammers differs not only in intensity, but also in frequency and impulse energy (i.e., total energy content of the pressure wave). This may explain why no documented fish kills have been associated with the use of vibratory hammers. Most of the sound energy produced by impact hammers is concentrated at frequencies between 100 and 800 Hz, across the range thought to be most harmful to exposed aquatic organisms, while sound energy produced by vibratory hammers is concentrated between 20 and 30 Hz. In addition, sound pressures produced by impact hammers rise much more rapidly than do the sound pressures produced by vibratory hammers (Carlson et al. 2001; Nedwell and Edwards 2002).

Similarly, SPLs associated with impact pile driving of concrete piles are lower than similarly-sized steel pile, and are characterized by a longer rise time than those of steel piles. Rise time appears to be an important factor in whether or not a sound pressure wave is likely to cause physical injury. To date, the Services are not aware of any situations where impact pile driving installation of concrete piles have been shown to cause injury or mortality in aquatic organisms.

As such, we do not expect that the SPLs associated with impact installation of concrete piles are likely to cause injury to listed fish species. We do not expect that underwater sound produced when installing concrete piles with a vibratory hammer or impact pile driver will reach the levels at which Chinook salmon, bocaccio, canary rockfish, and bull trout present within the action area will detect and react to the sound. Effects from impact pile driving of sheet piles are discussed below.

Behavioral Responses of Fish to Elevated Underwater SPLs

Behavioral responses to high underwater SPLs vary. Examples of typical behavioral effects include displacement, increased vulnerability to predation, interrupted feeding, or delayed migration. However, many response behaviors have not been thoroughly studied. Further confounding the issue, most of the information on behavioral effects of underwater sound is obtained from studies examining pure tone sounds.

Sounds generated by impact pile driving are impulsive and are made up of multiple frequencies/ tones, making comparisons with existing data difficult. Most of the sound energy of impact pile driving is concentrated at frequencies between 100 and 800 Hz. Salmonids can detect sounds at frequencies between 10 Hz (Knudsen et al. 1997) and 600 Hz (Mueller et al. 1998). Optimal salmonid hearing is thought to be at frequencies of 150 Hz (Hawkins and Johnstone 1978). Therefore, impact pile installation produces sounds within the range of salmonid hearing.

Popper (2003) notes that behavioral response of fishes to loud sounds could either include swimming away from the sound source (decreasing potential exposure to the sound); or staying in place (becoming vulnerable to possible injury). Responses to sound could also affect behavior more extensively, resulting in fish leaving a feeding ground (Engas et al. 1996) or an area where it would normally reproduce. Feist et al. (1992) found that impact pile driving of concrete piles affected juvenile pink and chum salmon distribution, school size, and schooling behavior. In general, on days when pile driving was not occurring, the fish exhibited a more polarized schooling behavior

(moving in a definite pattern). When pile driving was occurring, the fish exhibited an active milling schooling behavior (moving in an eddying mass). Fish appeared to change their distributions about the site, orienting and moving towards an acoustically-isolated cove side of the site on pile driving days more than on non-pile driving days. The effect of these responses may range from insignificant to permanent, long-term effects if feeding or reproduction is impaired.

Turnpenny et al. (1994) attempted to determine a level of underwater sound that would elicit behavioral responses in brown trout, bass, sole, and whiting. With brown trout an avoidance reaction occurred above 150 dB_{RMS}, and other reactions (e.g., a momentary startle), were noted at 170-175 dB_{RMS}. The report references Hastings' (1990) "safe limit" recommendation of 150 dB_{RMS} and concludes that the "safe limit" provides a reasonable margin below the lowest levels where fish injury was observed. In an associated literature review, Turnpenny and Nedwell (1994) also state that the Hastings' (1990) 150 dB_{RMS} limit did not appear overly stringent and that its application seemed justifiable. Additionally, observations by Feist et al. (1992) suggest that sound levels in this range may also disrupt normal migratory behavior of juvenile salmon.

Fewtrell (2003) held fish in cages in marine waters and exposed them to seismic airgun impulses. The study detected significant increases in behavioral response when sound pressure levels exceeded 158-163 dB_{RMS}. Responses included alarm, faster swimming, tighter grouping, and movement toward the lower portion of the cage. The study also evaluated physiological stress response by measuring plasma cortisol and glucose levels and found no statistically significant changes. Conversely, Santulli et al. (1999) found evidence of increased stress hormones after exposing caged European bass to seismic survey noise.

Clearly, there is a substantial gap in scientific knowledge on this topic. Fewtrell (2003) presents some experimental data on behavioral responses of fishes to impulsive sounds above 158 dB_{RMS}. Given the large amount of uncertainty that lies not only in extrapolating from experimental data to the field, but also between sound sources (airguns vs. pile driving), and from one species to another, we believe it is appropriate to utilize the most conservative known threshold. As such, we expect that SPLs in excess of 150 dB_{RMS} will cause temporary behavioral changes in Chinook salmon, bocaccio, canary rockfish, and bull trout. They are not expected to cause injury. We expect that SPLs above 150 dB_{RMS} could result in alteration of normal foraging and migrating behaviors. Therefore, the Services estimate with this project, the behavioral threshold of 150 dB_{RMS} will be exceeded within a distance of 4,642 meters (2.9 miles) of the construction site.

Should SPLs lead to an avoidance of an area, or altering their migration timing, it could represent a significant disruption in foraging and migrating behavior. Whether these behavioral effects are adverse must be established based on a number of additional factors such as the duration and timing of exposure, species life histories, and the normal use of the area during exposure.

Injury and Death of Fish from Impact Pile Driving

Proofing the sheet piles with an impact driver during installation will cause high sound pressure in the aquatic environment. There are no experimental data specific to Chinook salmon, bocaccio, canary rockfish, and bull trout exposed to underwater sound from impact pile driving, but it is known that the effects of elevated underwater SPLs on exposed organisms can vary substantially.

A multi-agency working group of Federal and State transportation and resource agencies, including underwater acoustics experts, fish biologists, and transportation specialists, has released agreed-upon "interim criteria" for evaluating the potential for physical effects (i.e., injury) from underwater noise levels caused by pile driving. These criteria represent threshold values for received levels, with the onset of injury expected if either: 1) dB_{peak} exceeds 206 dB; or 2) dB_{SEL}[6] accumulated over all pile strikes, exceeds 187 dB for fishes two grams (0.07 ounces) or larger and 183 dB for fishes smaller than two grams (FHWG 2008). A 150 dB_{RMS} level is a threshold where fish behavior could still be affected, but direct injury or death would not be expected (FWS 2012).

High underwater SPLs are known to have negative physiological and neurological effects on a wide variety of vertebrate species (Hastings and Popper 2005; Turnpenny and Nedwell 1994;Yelverton et al. 1973; Yelverton and Richmond 1981), and are known to injure and/or kill fishes, as well as cause temporary stunning, and alterations in behavior (Hastings and Popper 2005; Popper 2003; Turnpenny and Nedwell 1994; Turnpenny et al. 1994). Over this continuum of effect, there is no easily identifiable point at which behavioral responses transition to physical effects, but the risk of injury appears related to the effect of rapid pressure changes, especially on gas-filled spaces in the bodies of exposed organisms (Turnpenny et al. 1994). With regard to fish kills, with few exceptions, they are generally reported only when dead or injured fish are observed at the surface and therefore the frequency and magnitude of such kills are likely underestimated.

Injuries associated with exposure to high SPLs are referred to as barotraumas, and include hemorrhage and rupture of internal organs, hemorrhaged eyes, and temporary stunning (Hastings and Popper 2005; Turnpenny and Nedwell 1994; Yelverton et al. 1973; Yelverton et al. 1975; Yelverton and Richmond 1981). Death as a result of barotrauma can be instantaneous, occurring within minutes after exposure, or can occur several days later (Abbott et al. 2002), or injuries may be sub-lethal. Necropsy results from Sacramento blackfish (*Othodon microlepidotus*) exposed to high SPLs showed fish with extensive internal bleeding and a ruptured heart chamber were still capable of swimming for several hours before death (Abbott et al. 2002). Sub-lethal injuries can reduce osmoregulatory efficiency and increase energy expenditure (Gaspin et al. 1976, Govoni et al. 2008), and can effect equilibrium and interfere with the ability to carry out essential life functions such as feeding and predator avoidance (Gaspin 1975; Turnpenny et al. 1994; Hastings et al. 1996; Popper 2003).

Multiple factors influence the effects of impact pile driving: 1) type and intensity of sounds produced depends the type of hammer, the type of substrate, and the depth of water (eg, firmer substrates require more energy for driving and produce more intense sound pressures); and 2, key variables that determine the degree to which an animal is affected include size, anatomical variation, and location in the water column (eg, gas-filled structures such as swimbladder, bowel, sinuses or lungs, are particularly susceptible to the effects of underwater sound (Gisiner et al. 1998)). Sound energy from an underwater source readily enters the bodies of exposed organisms because the acoustic impedance of animal tissue nearly matches that of water (Hastings 2002). As a sound pressure wave passes through a fish, the swim bladder is rapidly compressed due to the high pressure and then rapidly expanded by the underpressure. At the high SPLs associated with pile driving, the swim bladder may repeatedly expand and contract. This essentially hammers adjacent tissue and

[6] Throughout this document, the reference value for dB SEL is 1 μPa^2-sec.

organs that are bound in place near the swim bladder (Gaspin 1975). Exposure to this type of pneumatic pounding (resulting from pile driving) can cause rupture of capillaries in the internal organs, as observed in fishes with blood in the abdominal cavity, and maceration of kidney tissues (Abbott et al. 2002; Stadler, pers. comm. 2002).

Yelverton and Richmond (1981) and Yelverton et al. (1973) exposed a variety of fish species, various birds, and terrestrial mammals to underwater explosions. Common to all the species were injuries to air- and gas-filled organs, as well as eardrums. These studies identified injury thresholds in relation to the size of the charge, the distance at which the charge was detonated, and the mass of the exposed animal. Yelverton et al. (1973) and Yelverton and Richmond (1981) found that the greater the fish's mass, the greater impulse level needed to cause an injury. Conversely, a fish with smaller mass would sustain injury from a smaller impulse.

At Bremerton, Washington, approximately 100 surfperch (*Cymatogaster aggregata*, *Brachyistius frenatus* and *Embiotoca lateralis*) were killed during impact driving of 30-inch diameter steel pilings (Stadler, Pers Comm, 2002). The size of these fish ranged from 70 mm to 175 mm fork length. Dissections revealed that the swim bladders of the smallest of the fishes (80 mm fork length) were completely destroyed, while those of the largest individual (170 mm fork length) were nearly intact. Damage to the swim bladder of *C. aggregata* was more severe than to similar-sized *B. frenatus*. These results are suggestive of size and species-specific differences and are consistent with those of Yelverton et al. (1975) who found size and/or species differences in injury from underwater explosions.

Examination of the current literature indicates that physical damage to non-auditory tissue is best evaluated through the use of an energy index that is indicative of mechanical effects to the tissue, and that is independent of whether the pressure is positive or negative. This can be estimated using cumulative sound exposure level (SEL); however, the most relevant data (Yelverton et al. 1975; Wiley et al. 1981; Stuhmiller et al. 1996, Bailey et al. 1996) are not reported in cumulative SEL, and the raw data necessary to calculate SEL is not contained in these reports.

Using data from an unpublished study of the effects of underwater explosions on fishes, Hastings (Hastings pers. comm. 2007) determined that an SEL as low as 183 dB (re: 1 μPa^2-sec) was sufficient to injure the nonauditory tissues of juvenile spot (*Leiostomus xanthurus)* and pinfish (*Lagodon rhomboides*) with an estimated mass of 0.5 grams. While previous studies (Yelverton et al. 1975; Stuhmiller et al. 1996) demonstrated a log-log relationship between the mass of a fish and the cumulative SEL from an impulsive sound required to induce injury, data on the cumulative SEL required to injure the non-auditory tissues of larger fishes are not available, and the slope of this relationship cannot be positively ascertained at this time.

Popper et al. (2005) and Song et al. (2008) investigated the effects of exposing three species of fish to airgun shots at a mean received level of 205-209 dB_{peak} and an approximate received mean of 176-180 dB SEL. The inner ears of these fishes were examined and no physical damage to the sensory cells was found (Song et al. 2008). The authors note that the onset and degree of temporary threshold shift (TTS) varied among species, with broad whitefish (*Coregonus nasus*) showing no effect after cumulative SEL exposures up to 187 dB. Northern pike (*Esox lucius*) and lake chub (*Couesius plumbeus*) (a hearing specialist) showed TTS after exposure to cumulative SELs as low as

185 dB and 184 dB, respectively (Popper et al. 2005). This work indicates that substantial differences exist in the effects of high SPLs on the hearing thresholds of different species; fish with poorer hearing (the pike) showed little hearing loss, while the fish with the best hearing (the lake chub) had the most loss (Popper et al. 2005). The authors also note that the sounds of airguns are characterized by relatively rapid onset, broad frequency ranges, and high peak levels, making them more similar to sounds from pile driving and explosions than to ship noise or sonar (Popper et al. 2005).

As of June 2008, the Services, Federal Highway Administration, Washington State Department of Transportation, and other signatory agencies have endorsed application of new interim criteria for estimating onset of injury developed by the Fisheries Hydroacoustic Working Group (FHWG 2008). These new interim criteria apply a SEL framework for assessing fish injury.

The project involves the installation of 342 sheet pile pairs during phase 1 and 358 pile pairs during phase 2. Of these, four piles a day will be proofed with an impact pile driver. Each pile will require 5 minutes of impact pile driving or 20 minutes per day. The Services expect that 5 minutes of pile driving, four times a day, will not detrimentally affect normal behaviors of Chinook salmon, bocaccio, canary rockfish, yelloweye rockfish, and bull trout between the 350 meter injury distance and the 4,642 meters (2.9 miles) behavioral threshold area. For the 48-inch sheet piles (two piles installed at the same time), the area of potential injury will be a 343 meter (1,125 foot) radius around each sheet pile for small fish less than or equal to 2 grams, and a 185 meter (607 foot) radius for fish greater than 2 grams. Thus, within the zone of injury, the Services expect that all Chinook salmon, canary rockfish, bocaccio, and bull trout less than or equal to 2 grams within a 343 meters (1,125 feet) radius around each sheet pile, and for fish greater than 2 grams within 185 meters (607 feet) radius will be injured or killed by the sound pressure resulting from impact pile driving.

Estimated Injury or Death of Chinook from Impact Driving. Because the juvenile Chinook salmon in the project area in September and October when impact pile driving will occur will all be heavier than 2 grams (Toft, in litt. 2013b), all Chinook salmon within a 185 meter (607 foot) radius of impact pile driving will be injured or die. The 185 meters from the seawall extends approximately 60 meters (197 feet) west of the piers. As Chinook salmon have been found not to migrate under the piers, the Services assume that the number of Chinook salmon at the end of the piers would equal the number of fish found along the seawall plus those that are found in deeper water (surface trawl data). Along the seawall and between the piers, the average number of Chinook salmon was 1.8 fish/520 m^2 (5,597 ft^2) in September and 0.6 fish/520 m^2 (5,597 ft^2) in October (UW unpublished data). Beyond the piers in deeper water, juvenile Chinook salmon were found at a mean density of approximately 2.5 Chinook/hectare in September and 0.5 Chinook/hectare in October. Therefore, the number of Chinook salmon beyond the piers is equal it 37 Chinook/hectare (1.8 Chinook/520 m^2 = 34.6 Chinook/hectare; 34.6 Chinook/hectare plus 2.5 Chinook/hectare = 37 Chinook/hectare).

The Services estimate that up to 148 Chinook/day will be injured or die due to impact pile driving activities. The 148 Chinook/day is based on two hectares being within the 184 meter radius from the sheetpile installation, but beyond or west of the piers, and 3.2 hectares from the end of the piers to the pile driving. The 148 Chinook/day is conservative as most of the construction will occur under piers where Chinook salmon have been found to avoid and if pile driving continues into October, fewer numbers of Chinook salmon are found along the seawall at this time.

Injury and death among juvenile Chinook salmon due to impact pile driving will negatively affect the viability of the population only if their abundance is diminished to the point that the number of returning spawning pairs is reduced. Marine survival of juvenile Chinook salmon is estimated to be between 0.1 to 2.0 percent (Duffy and Beauchamp 2011). This is based off of hatchery released Chinook salmon. Factors that influenced marine survival of hatchery fish included release date, size at release, and average mass in July and September. The 148 juvenile Chinook/day that may be injured or die from impact pile driving equals 2,960 juveniles per construction year (148 * 20 days). The estimated adult equivalence is 3 to 59 adults (0.1 to 2.0 percent).

Estimated Injury or Death of Bocaccio and Canary Rockfish from Impact Pile Driving. Because little information is available on densities of rockfish in and around the piers, the Services used the same numbers and calculations from the turbidity and suspended solids analysis for impacts of pile driving to bocaccio and canary rockfish. The Services also assume that by September and October, bocaccio and canary rockfish will all be larger than 2 grams. From the analysis above under turbidity and suspended solids, the following is the density estimates for canary rockfish and bocaccio: canary rockfish; 0.0009 larvae/1,000 m^3 (35,315 ft^3) in September, 0.0008 larvae/1,000 m^3 in October; bocaccio - 0.00002 larvae/1,000 m^3 in both September and October. During impact pile driving, all rockfish within 185 meters (fish greater than 2 grams) radius of impact pile driving will be injured or die.

The volume of water within the 185 meter radius of impact pile driving, with an average depth of 15 meters at the end of the piers (SDOT 2012e), is approximately 806,000 m^3. Therefore, the number of canary rockfish affected by impact pile driving will be 0.7 canary rockfish in September and 0.6 in October. The number of bocaccio will be 0.02 bocaccio in both September and October. Because these numbers are small, the Services estimate that one canary rockfish and one bocaccio per year will be injured or die as a result of increased sound pressure levels during impact pile driving of the temporary containment wall.

Estimated Injury or Death of Bull Trout from Impact Pile Driving. Bull trout use the marine nearshore for migration and foraging and will likely be in the same areas as juvenile salmonids. Bull trout will be found along the nearshore in the vicinity of prey species which include juvenile salmonids. One bull trout was observed on the habitat bench along the Olympic Sculpture Park in 2009 and several radio-tagged bull trout moved between the Snohomish River and the Duwamish River, indicating that they may be present in low numbers any time of the year. Because impact pile driving will occur for 20 days during five of the 7 years of project construction, the Services estimate that one bull trout per year will be injured or die as a result of increased sound pressure levels during impact pile driving of the temporary containment wall.

The described amounts of injury and/or death from pile driving for each fish species, will occur during project construction for each of the five project segments.

Effects of Elevated Underwater SPLs on Marine Mammals

Marine mammals are expected to traverse through, and not remain in, the project area. Therefore, animals are not expected to be exposed to construction sound for a significant duration of time. If marine mammals remain in an area despite elevated sound levels, because it is important for feeding, breeding, or some other biologically important purpose, there could be sound-induced physiological

stress; this might in turn have negative effects on the well-being or reproduction of the animals involved.

The range of sound in the marine environment is highly variable, and can be categorized as the following (Richardson et al., 1995).

- The sound may be too weak to be heard at the location of the animal (i.e., lower than the prevailing ambient sound level, or beyond the hearing threshold of the animal at relevant frequencies, or both);

- The sound may be audible but not strong enough to elicit any overt behavioral response;

- The sound may be strong enough to elicit reactions of varying degrees and have variable implications to the well-being of the marine mammal; these can range from temporary alert responses to active avoidance reactions such as vacating an area until the stimulus ceases, but potentially for longer periods of time; if elevated sound cannot be avoided, temporary or permanent injury can result.

Upon repeated exposure to underwater sound, a marine mammal may exhibit diminishing responsiveness (habituation), or disturbance effects may persist. The latter is most likely with sounds that are highly variable in characteristics and unpredictable in occurrence, and associated with situations that a marine mammal perceives as a threat. The potential effects of elevated underwater sound on marine mammals may include one or more of the following: tolerance; masking of natural sounds; behavioral disturbance; non-auditory physical effects; and temporary or permanent hearing impairment (Richardson et al., 1995).

Very strong sounds have the potential to cause a temporary or permanent reduction in hearing sensitivity, also referred to as threshold shift. In terrestrial mammals, and presumably marine mammals, received sound levels must far exceed the animal's hearing threshold for there to be any hearing loss. For transient sounds, the sound level necessary to cause hearing loss is inversely related to the duration of the sound. Received sound levels must be even higher for there to be risk of permanent hearing impairment. In addition, intense acoustic or explosive events may cause trauma to tissues associated with organs vital for hearing, sound production, respiration and other functions. This trauma may include minor to severe hemorrhage.

Tolerance

Studies have shown that underwater sounds from industrial activities are often readily detectable by marine mammals in the water at distances of many kilometers. However, other studies have shown that marine mammals at distances more than a few kilometers away often show no apparent response to industrial activities of various types (Miller et al., 2005). This is often true even in cases when the sounds must be readily audible to the animals based on measured received levels and the hearing sensitivity of that mammal group. Although various baleen whales, toothed whales, and (less frequently) pinnipeds have been shown to react behaviorally to underwater sound from sources such as airgun pulses or vessels under some conditions, at other times, mammals of all three types have shown no overt reactions (e.g., Malme et al., 1986;

Richardson et al., 1995; Madsen and Mohl, 2000; Croll et al., 2001; Jacobs and Terhune, 2002; Madsen et al., 2002; Miller et al., 2005). In general, pinnipeds seem to be more tolerant of exposure to some types of underwater sound than are baleen whales. Richardson et al. (1995) found that vessel sound does not seem to strongly affect pinnipeds that are already in the water. Richardson et al. (1995) went on to explain that seals on haul-outs sometimes respond strongly to the presence of vessels and at other times appear to show considerable tolerance of vessels, and Brueggeman et al. (1992) observed ringed seals (*Pusa hispida*) hauled out on ice pans displaying short-term escape reactions when a ship approached within 0.16–0.31 mi (0.25–0.5 km).

Masking

Any anthropogenic sound that is strong enough to be heard has the potential to result in masking, or reduce the ability of a marine mammal to hear biological sounds at similar frequencies, including calls from conspecifics and underwater environmental sounds such as surf sound.
Masking is the obscuring of sounds of interest to an animal by other sounds, typically at similar frequencies. Marine mammals are highly dependent on sound, and their ability to recognize sound signals amid other sound is important in communication and detection of both predators and prey. Background ambient sound may interfere with or mask the ability of an animal to detect a sound signal even when that signal is above its absolute hearing threshold. Even in the absence of anthropogenic sound, the marine environment is often loud. Natural ambient sound includes contributions from wind, waves, precipitation, other animals, and (at frequencies above 30 kHz) thermal sound resulting from molecular agitation (Richardson et al., 1995).

Background sound may also include anthropogenic sound, and masking of natural sounds can result when human activities produce high levels of background sound. Conversely, if the background level of underwater sound is high (e.g., on a day with strong wind and high waves), an anthropogenic sound source would not be detectable as far away as would be possible under quieter conditions and would itself be masked. Ambient sound is highly variable on continental shelves (Thompson, 1965; Myrberg, 1978; Desharnais et al., 1999). This results in a high degree of variability in the range at which marine mammals can detect anthropogenic sounds.

Although masking is a phenomenon which may occur naturally, the introduction of loud anthropogenic sounds into the marine environment at frequencies important to marine mammals increases the severity and frequency of occurrence of masking. For example, if a baleen whale is exposed to continuous low-frequency sound from an industrial source, this would reduce the size of the area around that whale within which it can hear the calls of another whale. The components of background noise that are similar in frequency to the signal in question primarily determine the degree of masking of that signal. In general, little is known about the degree to which marine mammals rely upon detection of sounds from conspecifics, predators, prey, or other natural sources. In the absence of specific information about the importance of detecting these natural sounds, it is not possible to predict the impact of masking on marine mammals (Richardson et al., 1995). In general, masking effects are expected to be less severe when sounds are transient than when they are continuous. Masking is typically of greater concern for those marine mammals that utilize low frequency communications, such as baleen whales and, as such, is not likely to occur for pinnipeds or small odontocetes.

Disturbance

Behavioral disturbance is one of the primary potential impacts of anthropogenic sound on marine mammals. Disturbance can result in a variety of effects, such as subtle or dramatic changes in behavior or displacement, but the degree to which disturbance causes such effects may be highly dependent upon the context in which the stimulus occurs. For example, an animal that is feeding may be less prone to disturbance from a given stimulus than one that is not. For many species and situations, there is no detailed information about reactions to sound.

Behavioral reactions of marine mammals to sound are difficult to predict because they are dependent on numerous factors, including species, maturity, experience, activity, reproductive state, time of day, and weather. If a marine mammal does react to an underwater sound by changing its behavior or moving a small distance, the impacts of that change may not be important to the individual, the stock, or the species as a whole. However, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, impacts on the animals could be important. In general, pinnipeds seem more tolerant of, or at least habituate more quickly to, potentially disturbing underwater sound than do cetaceans, and generally seem to be less responsive to exposure to industrial sound than most cetaceans. Pinniped responses to underwater sound from some types of industrial activities such as seismic exploration appear to be temporary and localized (Harris et al.*,* 2001; Reiser et al.*,* 2011).

Because the few available studies show wide variation in response to underwater and airborne sound, it is difficult to quantify exactly how pile driving sound would affect marine mammals in the action area. The literature shows that elevated underwater sound levels could prompt a range of effects, including no obvious visible response, or behavioral responses that may include annoyance and increased alertness, visual orientation towards the sound, investigation of the sound, change in movement pattern or direction, habituation, alteration of feeding and social interaction, or temporary or permanent avoidance of the area affected by sound. Minor behavioral responses do not necessarily cause long-term effects to the individuals involved. Severe responses include panic, immediate movement away from the sound, and stampeding, which could potentially lead to injury or mortality (Southall et al.*,* 2007).

Southall et al. (2007) reviewed literature describing responses of pinnipeds to non-pulsed sound in water and reported that the limited data suggest exposures between approximately 90 and 140 dB generally do not appear to induce strong behavioral responses in pinnipeds, while higher levels of pulsed sound, ranging between 150 and 180 dB, will prompt avoidance of an area. It is important to note that among these studies, there are some apparent differences in responses between field and laboratory conditions. In contrast to the mid-frequency odontocetes, captive pinnipeds responded more strongly at lower levels than did animals in the field. Again, contextual issues are the likely cause of this difference. For airborne sound, Southall et al. (2007) note there are extremely limited data suggesting very minor, if any, observable behavioral responses by pinnipeds exposed to airborne pulses of 60 to 80 dB; however, given the paucity of data on the subject, we cannot rule out the possibility that avoidance of sound could occur.

In their comprehensive review of available literature, Southall et al. (2007) noted that quantitative studies on behavioral reactions of pinnipeds to underwater sound are rare. A subset of only three

studies observed the response of pinnipeds to multiple pulses of underwater sound (a category of sound types that includes impact pile driving), and were also deemed by the authors as having results that are both measurable and representative. However, a number of studies not used by Southall et al. (2007) provide additional information, both quantitative and anecdotal, regarding the reactions of pinnipeds to multiple pulses of underwater sound.

Harris et al. (2001) observed the response of ringed, bearded (*Erignathus barbatus*), and spotted seals (*Phoca largha*) to underwater operation of a single air gun and an eleven-gun array. Received exposure levels were 160 to 200 dB. Results fit into two categories. In some instances, seals exhibited no response to sound. However, the study noted significantly fewer seals during operation of the full array in some instances. Additionally, the study noted some avoidance of the area within 150 meters of the source during full array operations.

Blackwell et al. (2004) is the only cited study directly related to pile driving. The study observed ringed seals during impact installation of steel pipe pile. Received underwater SPLs were measured at 151 dB at 63 m. The seals exhibited either no response or only brief orientation response (defined as ‘‘investigation or visual orientation’’). It should be noted that the observations were made after pile driving was already in progress. Therefore, it is possible that the low-level response was due to prior habituation.

Miller et al. (2005) observed responses of ringed and bearded seals to a seismic air gun array. Received underwater sound levels were estimated at 160 to 200 dB. There were fewer seals present close to the sound source during air gun operations in the first year, but in the second year the seals showed no avoidance. In some instances, seals were present in very close range of the sound. The authors concluded that there was ‘‘no observable behavioral response’’ to seismic air gun operations.

During a Caltrans installation demonstration project for retrofit work on the East Span of the San Francisco Oakland Bay Bridge, California, sea lions responded to pile driving by swimming rapidly out of the area, regardless of the size of the pile-driving hammer or the presence of sound attenuation devices (December 4. 2009, 74 FR 63724).

Jacobs and Terhune (2002) observed harbor seal reactions to acoustic harassment devices (AHDs) with source level of 172 dB deployed around aquaculture sites. Seals were generally unresponsive to sounds from the AHDs. During two specific events, individuals came within 141 feet and 144 feet (43 meters and 44 meters) of active AHDs and failed to demonstrate any measurable behavioral response; estimated received levels based on the measures given were approximately 120 to 130 dB.

Costa et al. (2003) measured received sound levels from an Acoustic Thermometry of Ocean Climate (ATOC) program sound source off northern California using acoustic data loggers placed on translocated elephant seals. Subjects were captured on land, transported to sea, instrumented with archival acoustic tags, and released such that their transit would lead them near an active ATOC source (at 0.6 mi depth [939 m]; 75-Hz signal with 37.5-Hz bandwidth; 195 dB maximum source level, ramped up from 165 dB over 20 min) on their return to a haul-out site. Received exposure levels of the ATOC source for experimental subjects averaged 128 dB (range 118 to 137) in the 60- to 90-Hz band. None of the instrumented animals terminated dives or radically altered behavior upon exposure, but some statistically significant changes in diving parameters were documented in

nine individuals. Translocated northern elephant seals exposed to this particular non-pulse source began to demonstrate subtle behavioral changes at exposure to received levels of approximately 120 to 140 dB.

Several available studies provide information on the reactions of pinnipeds to non-pulsed underwater sound. Kastelein et al. (2006) exposed nine captive harbor seals in an approximately 82 feet by 98 feet (25 by 30 meters) enclosure to non-pulse sounds used in underwater data communication systems (similar to acoustic modems). Test signals were frequency modulated tones, sweeps, and bands of sound with fundamental frequencies between 8 kHz and 16 kHz; 128 to 130 ± 3 dB source levels; 1-s to 2-s duration (60–80 percent duty cycle); or 100 percent duty cycle. They recorded seal positions and the mean number of individual surfacing behaviors during control periods (no exposure), before exposure, and in 15-min experimental sessions (n = 7 exposures for each sound type). Seals generally swam away from each source at received levels of approximately 107 dB, avoiding it by approximately 16 feet (5 meters), although they did not haul out of the water or change surfacing behavior. Seal reactions did not appear to wane over repeated exposure (i.e., there was no obvious habituation), and the colony of seals generally returned to baseline conditions following exposure. The seals were not reinforced with food for remaining in the sound field.

Reactions of harbor seals to the simulated sound of a 2-megawatt wind power generator were measured by Koschinski et al. (2003). Harbor seals surfaced significantly further away from the sound source when it was active and did not approach the sound source as closely. The device used in that study produced sounds in the frequency range of 30 to 800 Hz, with peak source levels of 128 dB at 1 meter at the 80- and 160-Hz frequencies.

The studies that address responses of high-frequency cetaceans (such as the harbor porpoise) to non-pulse sounds include data gathered both in the field and the laboratory and related to several different sound sources (of varying similarity to chirps), including: pingers, AHDs, and various laboratory non-pulse sounds. All of these data were collected from harbor porpoises. Southall et al. (2007) concluded that the existing data indicate that harbor porpoises are likely sensitive to a wide range of anthropogenic sounds at low received levels (around 90 to 120 dB), at least for initial exposures. All recorded exposures above 140 dB induced profound and sustained avoidance behavior in wild harbor porpoises (Southall et al., 2007). Rapid habituation was noted in some but not all studies. Data on behavioral responses of high-frequency cetaceans to multiple pulses is not available. Although individual elements of some non-pulse sources (such as pingers) could be considered pulses, it is believed that some mammalian auditory systems perceive them as non-pulse sounds (Southall et al., 2007).

Southall et al. (2007) also compiled known studies of behavioral responses of marine mammals to airborne sound, noting that studies of pinniped response to airborne pulsed sounds are exceedingly rare. The authors deemed only one study as having quantifiable results. Blackwell et al. (2004) studied the response of ringed seals within 500 meters of impact driving of steel pipe pile. Received levels of airborne sound were measured at 93 dB at a distance of 63 meters. Seals had either no response or limited response to pile driving. Reactions were described as ‘‘indifferent’’ or “curious.”

<u>*Hearing Impairment and Other Physiological Effects*</u>

Temporary or permanent hearing impairment is a possibility when marine mammals are exposed to very loud noises or strong sounds. Non-auditory physiological effects might also occur in marine mammals exposed to strong underwater sound. Possible types of non-auditory physiological effects or injuries that may occur in mammals close to a strong sound source include stress, neurological effects, bubble formation, and other types of organ or tissue damage. It is possible that some marine mammal species (i.e., beaked whales) may be especially susceptible to injury and/or stranding when exposed to strong pulsed sounds, particularly at higher frequencies. Non-auditory physiological effects are not anticipated to occur as a result of proposed construction activities. The following subsections discuss the possibilities of temporary and permanent hearing loss.

Reversible Hearing Loss or Temporary Threshold Shift (TTS) - TTS is caused by fatigue of hair cells and supporting structures in the inner ear, is the mildest form of hearing impairment that can occur during exposure to a strong sound (Kryter, 1985). While experiencing TTS, the hearing threshold rises and a sound must be stronger in order to be heard. TTS can last from minutes or hours to (in cases of strong TTS) days. For sound exposures at or somewhat above the TTS threshold, hearing sensitivity in both terrestrial and marine mammals recovers rapidly after exposure to the sound ends.

Marine mammal hearing plays a critical role in communication with conspecifics and in interpretation of environmental cues for purposes such as predator avoidance and prey capture. Depending on the degree (elevation of threshold in dB), duration (i.e., recovery time), and frequency range of TTS and the context in which it is experienced, TTS can have effects on marine mammals ranging from discountable to serious. For example, a marine mammal may be able to readily compensate for a brief, relatively small amount of TTS in a non-critical frequency range that takes place during a time when the animal is traveling through the open ocean, where ambient noise is lower and there are not as many competing sounds present. Alternatively, a larger amount and longer duration of TTS sustained during a time when communication is critical for successful mother/calf interactions could have more serious impacts if it were in the same frequency band as the necessary vocalizations and of a severity that it impeded communication. The fact that animals exposed to levels and durations of sound that would be expected to result in this physiological response would also be expected to have behavioral responses of a comparatively more severe or sustained nature is also notable and potentially of more importance than the simple existence of a TTS.

The NMFS considers TTS to be a form of Level B harassment (under MMPA), as it consists of fatigue to auditory structures rather than damage to them. Level B harassment is define as any act of pursuit, torment, or annoyance which has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering. The NMFS-established 190-dB criterion is not considered to be the level above which TTS might occur. Rather, it is the received level above which, in the view of a panel of bioacoustics specialists convened by NMFS before TTS measurements for marine mammals became available, one could not be certain that there would be no injurious effects, auditory or otherwise, to marine mammals. Therefore, exposure to sound levels above 180 and 190 dB (for cetaceans and pinnipeds, respectively) does not necessarily mean that an animal has incurred TTS, but rather that it may have occurred. Few data on sound levels and

durations necessary to elicit mild TTS have been obtained for marine mammals, and none of the published data concern TTS elicited by exposure to multiple pulses of sound.

Human non-impulsive sound exposure guidelines are based on exposures of equal energy (the same SEL; SEL is reported here in dB re: 1 mPa2-s/re: 20 mPa2-s for in-water and in-air sound, respectively) producing equal amounts of hearing impairment regardless of how the sound energy is distributed in time (NIOSH, 1998). Until recently, previous marine mammal TTS studies have also generally supported this equal energy relationship (Southall et al., 2007). Three newer studies, two by Mooney et al. (2009a, 2009b) on a single bottlenose dolphin (*Tursiops truncatus*) either exposed to playbacks of U.S. Navy midfrequency active sonar or octave-band sound (4–8 kHz) and one by Kastak et al. (2007) on a single California sea lion exposed to airborne octave-band sound (centered at 2.5 kHz), concluded that for all sound exposure situations, the equal energy relationship may not be the best indicator to predict TTS onset levels. Generally, with sound exposures of equal energy, those that were quieter (lower SPL) with longer duration were found to induce TTS onset more than those of louder (higher SPL) and shorter duration. Given the available data, the received level of a single seismic pulse (with no frequency weighting) might need to be approximately 186 dB SEL in order to produce brief, mild TTS.

In free-ranging pinnipeds, TTS thresholds associated with exposure to brief pulses (single or multiple) of underwater sound have not been measured. However, systematic TTS studies on captive pinnipeds have been conducted (e.g., Bowles et al., 1999; Kastak et al., 1999, 2005, 2007; Schusterman et al., 2000; Finneran et al., 2003; Southall et al., 2007). Specific studies are detailed here: Finneran et al. (2003) studied responses of two individual California sea lions. The sea lions were exposed to single pulses of underwater sound, and experienced no detectable TTS at received sound level of 183 dB peak (163 dB SEL). There were three studies conducted on pinniped TTS responses to non-pulsed underwater sound. All of these studies were performed in the same lab and on the same test subjects, and, therefore, the results may not be applicable to all pinnipeds or in field settings. Kastak and Schusterman (1996) studied the response of harbor seals to non-pulsed construction sound, reporting TTS of about 8 dB. The seal was exposed to broadband construction sound for 6 days, averaging six to seven hours of intermittent exposure per day, with SPLs from just approximately 90 to 105 dB.

Kastak et al. (1999) reported TTS of approximately 4–5 dB in three species of pinnipeds (harbor seal, California sea lion, and northern elephant seal) after underwater exposure for approximately 20 minutes to sound with frequencies ranging from 100–2,000 Hz at received levels 60–75 dB above hearing threshold. This approach allowed similar effective exposure conditions to each of the subjects, but resulted in variable absolute exposure values depending on subject and test frequency. Recovery to near baseline levels was reported within 24 hours of sound exposure. Kastak et al. (2005) followed up on their previous work, exposing the same test subjects to higher levels of sound for longer durations. The animals were exposed to octave-band sound for up to 50 minutes of net exposure. The study reported that the harbor seal experienced TTS of 6 dB after a 25-minute exposure to 2.5 kHz of octave-band sound at 152 dB (183 dB SEL). The California sea lion demonstrated onset of TTS after exposure to 174 dB and 206 dB SEL.

Southall et al. (2007) reported one study on TTS in pinnipeds resulting from airborne pulsed sound, while two studies examined TTS in pinnipeds resulting from airborne non-pulsed sound. Bowles et

al. (1999) exposed pinnipeds to simulated sonic booms. Harbor seals demonstrated TTS at 143 dB peak and 129 dB SEL. California sea lions and northern elephant seals experienced TTS at higher exposure levels than the harbor seals. Kastak et al. (2004) used the same test subjects as in Kastak et al. 2005, exposing the animals to non-pulsed sound (2.5 kHz octave-band sound) for 25 minutes. The harbor seal demonstrated 6 dB of TTS after exposure to 99 dB (131 dB SEL). The California sea lion demonstrated onset of TTS at 122 dB and 154 dB SEL. Kastak et al. (2007) studied the same California sea lion as in Kastak et al. 2004 above, exposing this individual to 192 exposures of 2.5 kHz octave-band sound at levels ranging from 94 to 133 dB for 1.5 to 50 min of net exposure duration. The test subject experienced up to 30 dB of TTS. TTS onset occurred at 159 dB SEL. Recovery times ranged from several minutes to 3 days.

Additional studies highlight the inherent complexity of predicting TTS onset in marine mammals, as well as the importance of considering exposure duration when assessing potential impacts (Mooney et al., 2009a, 2009b; Kastak et al., 2007). Generally, with sound exposures of equal energy, quieter sounds (lower SPL) of longer duration were found to induce TTS onset more than louder sounds (higher SPL) of shorter duration (more similar to subbottom profilers). For intermittent sounds, less threshold shift will occur than from a continuous exposure with the same energy (some recovery will occur between intermittent exposures) (Kryter et al., 1966; Ward, 1997). For sound exposures at or somewhat above the TTS-onset threshold, hearing sensitivity recovers rapidly after exposure to the sound ends. Southall et al. (2007) considers a 6 dB TTS (that is, baseline thresholds are elevated by 6 dB) to be a sufficient definition of TTS onset. NMFS considers TTS as Level B harassment that is mediated by physiological effects on the auditory system; however, NMFS does not consider TTS-onset to be the lowest level at which Level B harassment may occur. Southall et al. (2007) summarizes underwater pinniped data from Kastak et al. (2005), indicating that a tested harbor seal showed a TTS of around 6 dB when exposed to a nonpulse noise at sound pressure level 152 dB re: 1 μPa for 25 minutes.

Some studies suggest that harbor porpoises may be more sensitive to sound than other odontocetes (Lucke et al., 2009; Kastelein et al., 2011). While TTS onset may occur in harbor porpoises at lower received levels (when compared to other odontocetes), NMFS' 160-dB and 120-dB threshold criteria are based on the onset of behavioral harassment, not the onset of TTS.

Impact pile driving for the Elliott Bay Seawall project would produce initial airborne sound levels of approximately 112 dB peak at 160 ft (49 m) from the source, as compared to the level suggested by Southall et al. (2007) of 143 dB peak for onset of TTS in pinnipeds from multiple pulses of airborne sound. It is not expected that airborne sound levels would induce TTS in individual pinnipeds.

Although underwater sound levels produced by the proposed project may exceed levels produced in studies that have induced TTS in marine mammals, there is a general lack of controlled, quantifiable field studies related to this phenomenon, and existing studies have had varied results (Southall et al., 2007). Therefore, it is difficult to extrapolate from these data to site-specific conditions for the proposed project. For example, because most of the studies have been conducted in laboratories, rather than in field settings, the data are not conclusive as to whether elevated levels of sound would cause marine mammals to avoid the project area, thereby reducing the likelihood of TTS, or whether sound would attract marine mammals, increasing the likelihood of TTS. In any case, there are no universally accepted standards for the amount of exposure time likely to induce TTS. While it may

be inferred that TTS could theoretically result from the proposed project, it is impossible to quantify the magnitude of exposure, the duration of the effect, or the number of individuals likely to be affected. Exposure is likely to be brief because marine mammals use the action area for transiting, rather than breeding or hauling out. In summary, it is expected that elevated sound would have only a slight probability of causing TTS in marine mammals.

Permanent Hearing Loss (PTS) - When PTS occurs, there is physical damage to the sound receptors in the ear. In some cases, there can be total or partial deafness, whereas in other cases, the animal has an impaired ability to hear sounds in specific frequency ranges. There is no specific evidence that exposure to underwater industrial sounds can cause PTS in any marine mammal (see Southall et al., 2007). However, given the possibility that marine mammals might incur TTS, there has been further speculation about the possibility that some individuals occurring very close to industrial activities might incur PTS. Richardson et al. (1995) hypothesized that PTS caused by prolonged exposure to continuous anthropogenic sound is unlikely to occur in marine mammals, at least for sounds with source levels up to approximately 200 dB. Single or occasional occurrences of mild TTS are not indicative of permanent auditory damage in terrestrial mammals. Studies of relationships between TTS and PTS thresholds in marine mammals are limited; however, existing data appear to show similarity to those found for humans and other terrestrial mammals, for which there is a large body of data. PTS might occur at a received sound level at least several decibels above that inducing mild TTS.

Southall et al. (2007) propose that sound levels inducing 40 dB of TTS may result in onset of PTS in marine mammals. The authors present this threshold with precaution, as there are no specific studies to support it. Because direct studies on marine mammals are lacking, the authors base these recommendations on studies performed on other mammals. Additionally, the authors assume that multiple pulses of underwater sound result in the onset of PTS in pinnipeds when levels reach 218 dB peak or 186 dB SEL. In air, sound levels are assumed to cause PTS in pinnipeds at 149 dB peak or 144 dB SEL (Southall et al., 2007). Sound levels this high are not expected to occur as a result of the proposed activities.

It is highly unlikely that marine mammals would receive sounds strong enough (and over a sufficient duration) to cause PTS (or even TTS) during the proposed activities. When taking the mitigation measures proposed for the project into consideration, it is highly unlikely that any type of hearing impairment would occur as a result of SDOT’s proposed activities.

Estimates of Marine Mammal Exposure to Elevated Sound during Construction.

The NMFS is currently developing comprehensive guidance on sound levels likely to cause injury and behavioral disruption in the context of the Marine Mammal Protection Act. Until formal guidance is available, NMFS uses conservative thresholds of sound pressure levels from broad band sounds that cause behavioral disturbance (160 dB_{RMS} for impulse sound and 120 dB_{RMS} for continuous sound) and injury (180 dB_{RMS} for whales and 190 dB_{RMS} for pinnipeds) (January 11, 2005, 70 FR 1871).

Based on these conservative thresholds, the proposed pile driving activities will produce sound pressure levels that could disturb or injure marine mammals. To ensure injury would not occur, the

applicant has proposed a marine mammal monitoring plan for this project during all pile driving (Appendix B). Under the plan, the applicant will monitor for marine mammals within the project area as defined in Table 15 and issue a stop-work order if mammals are detected in the identified areas.

Table 15 – Summary Table of Exclusion Zone Thresholds and Level B Harassment Zones.

Taxa	Threshold or Zone Location (radius distance from point-source pile-related noise)	Pile Work Type	Pile Type
Exclusion Zone Thresholds (stop-work order will be issued if threshold is crossed)			
Steller Sea Lions	50 ft	Impact	Concrete
Steller Sea Lions	200 ft	Impact	Steel sheet
Killer and Humpback Whales	3,280 ft	Impact	Steel sheet & concrete
Killer and Humpback Whales	2.5 miles[1]	Vibratory	Steel sheet
Level B Harassment Zones[2]			
Killer and Humpback Whales	2.5 to 3.9 miles	Vibratory	Steel sheet
Steller Sea Lions	Point-source noise to 2.5 miles	Vibratory	Steel sheet
Steller Sea Lions	200 ft to 3,280 ft	Impact	Steel sheet
Steller Sea Lions	50 ft to 400 ft	Impact	Concrete

1 Distance represents both an exclusion threshold and Level B threshold for killer and humpback whales, but is not expected to represent a Level A harassment threshold; this conservative exclusion threshold was stabled by NMFS to minimize behavioral "take" of killer and humpback whales to ensure each stock bears no more than a "negligible impact."

2 Level A harassment is defined as any act of pursuit, torment, or annoyance which has the potential to injure a marine mammal or marine mammal stock in the wild. Level B harassment is define as any act of pursuit, torment, or annoyance which has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering.

As there are not density estimates for marine mammal populations in Puget Sound, the Services use anecdotal reports, incidental observations, and data from previous consultations around Puget Sound to determine the number of marine mammals that may be impacted by the project.

Estimate of Steller Sea Lions Exposure to Elevated Sound . Anecdotal reports indicate that at most one to five individuals of Steller sea lions may be present in the nearshore of the Seattle waterfront on a single day. Steller sea lions in the area are likely traveling to and from the haul-out located south of Bainbridge Island, approximately seven miles from the project site. Therefore, the Services estimate that up to five Steller sea lions per day will experience significant disruption in normal behaviors (Level B harassment outside the stop-work order zone, see Table 15), such as increased stress leading to reduced ability to perform vital functions such as migration, breathing, nursing, breeding, feeding, or sheltering, resulting from increased sound pressure levels during pile driving activities. This disruption in normal behaviors will occur during project construction each year over 7 years.

These estimates are considered to overestimate the actual number of Steller sea lions to be impacted because they are unlikely to be present during all impact pile driving activities and the use of sound attenuation devices and other mitigation measures, which are not taken into consideration for this estimate. Furthermore, these estimates would likely occur to the same individuals on different days and do not represent a total number of individuals.

Estimate of Southern Resident Killer Whales Exposure to Elevated Sound. Based on past sightings of killer whales within the action area, the Services estimate that 16 killer whales per year will experience significant disruption in normal behaviors (Level B harassment outside the stop-work order zone, see Table 15), such as increased stress leading to reduced ability to perform vital functions such as migration, breathing, nursing, breeding, feeding, or sheltering, as a result of increased sound pressure levels during pile driving activities. This disruption in normal behaviors will occur during project construction each year over 7 years.

Most of the sound pressure produced by a tugboat towing a loaded barge is expected to be below the level of peak hearing sensitivity for killer whales. When the tugboat is in motion, sound pressure levels will be transient and are therefore expected to be below background levels a short distance from any one location. Thus, tugboat/barge sound is unlikely to mask acoustic signals of biological significance to killer whales.

Estimate of Humpback Whales Exposure to Elevated Sound. Based on the average groups size and observed occurrence of humpback whales within the action area, the Services estimate that four humpback whales per year will experience significant disruption in normal behaviors (Level B harassment outside the stop-work order zone, see Table 15),, such as increased stress leading to reduced ability to perform vital functions such as migration, breathing, nursing, breeding, feeding, or sheltering as a result of increased sound pressure levels during pile driving activities. This disruption in normal behaviors will occur during project construction each year over 7 years.

2.4.2.5 Fish Capture and Handling

Fish will be captured and handled during construction of each segment of the containment wall, in order to remove them from the aquatic habitat to be isolated. The containment wall will be constructed to leave one section of the wall open, to facilitate fish removal between the containment wall and the existing seawall. This section will be closed after initial fish removal has occurred. At the lowest tide, near the end of the containment wall installation, the area between the containment wall and seawall will be swept with block nets or beach seines (two to three passes) to push fish out of the opening. The last section of the containment wall will then be installed. After the last section of the wall is installed and during the lowest possible tide, block nets will be installed to section off smaller areas behind the containment wall. Each section will be swept with nets until fewer than five fish are captured.

The capture and handling of fish is intended to reduce the number of fish that will be injured or killed during construction, but in itself has some potential to result in injury or death. Mortality may be immediate or delayed. Handling of fish increases their stress levels and can reduce disease resistance, increase osmotic-regulatory problems, decrease growth, decrease reproductive capacity, increase vulnerability to predation, and increase chances of mortality (Kelsch and Shields 1996). Fish may suffer from thermal stress during handling, or may receive subtle injuries such as de-scaling, abrasions, and loss of slime layer. Handling can contribute directly or indirectly to disease transmission and susceptibility, or increased post-release predation. Fish that have been stressed are more vulnerable to predation (Mesa et al. 1994; Mesa and Schreck 1989).

Studies investigating acute, sublethal physiological stress in captured and handled salmonids consistently document induced changes in blood chemistry (e.g., cortisol, corticosteroid, and blood sugar levels; lymphocyte numbers) (Barton and Iwama 1991; Frisch and Anderson 2000; Hemre and Krogdahl 1996; Pickering et al. 1982; Wydoski et al. 1976). Even short and mild bouts of handling have been shown to induce protracted changes, lasting hours or days (Frisch and Anderson 2000; Hemre and Krogdahl 1996; Wydoski et al. 1976). Pickering et al. (1982) states that fish need a minimum of 2 weeks to fully recover from stress associated with handling.

Stress induced effects to blood chemistry may have consequences for metabolic scope, reproduction (i.e., altered patterns or levels of reproductive hormones), and immune system function or capability (Barton and Iwama 1991; Frisch and Anderson 2000; Pickering et al. 1982). Pickering et al. (1982) reports a marked reduction in feeding activity lasting 3 days after handling. Barton and Iwama (1991) and Frisch and Anderson (2000) both point to the possibility of increased disease susceptibility attributable to handling related physiological stress.

Based on construction timing and life-history patterns of the listed fishes, the Services expect that very few listed fish species will be captured and handled during the installation of the containment wall. The Services do not expect any yelloweye rockfish or bull trout will be captured and handled or will die behind the containment wall because juvenile yelloweye rockfish settle in deeper waters (thus will not be found along the existing seawall during construction), and bull trout present in the nearshore, are larger fish that can avoid the construction area and thus are not likely to be stranded behind the containment wall.

As the area between the containment wall and the existing seawall will not be dewatered, there is potential that some listed fish (Chinook salmon, boccacio, and canary rockfish) will not be successfully captured, and therefore will be stranded behind the containment wall. Any fish stranded behind the wall will eventually die due to work activities in this area. The areas between the containment wall and the existing seawall is 6,000 ft^2 for Phase 1 and 8,500 ft^2 for Phase 2.

Estimate of Puget Sound Chinook salmon affected by Handling, Capture, or Entrapment. The containment wall will be constructed approximately 5 feet from the existing seawall wall. During Phase 1, the containment walls are for each segment are 1,200 feet long, and 1,700 feet for Phase 2. The area between the containment wall and the seawall is 6,000 ft^2 for Phase 1 and 8,500 ft^2 for Phase 2. The Services estimate that up to two Chinook salmon (6,000 ft^2 * 1.8 Chinook/5,597 ft^2) will be captured and handled or will be left behind the containment wall and will die during fish removal behind the containment wall during construction of each segment in Phase 1 and three Chinook salmon (8,500 ft^2 * 1.8 Chinook/5,597 ft^2) during construction of each segment in Phase 2. This significant disruption in normal behavior or mortality will occur during project construction for each of the five project segments over 7 years.

Estimate of Bocaccio and Canary Rockfish affected by Handling, Capture, or Entrapment. Based on the calculations above for the numbers of bocaccio and canary rockfish affected by increased turbidity and suspended solids (one larval bocaccio and canary rockfish), the Services estimate that one larval bocaccio and one canary rockfish will be captured and handled or will be left behind the containment wall and will die during fish removal behind the containment wall during construction

of each segment in Phase 1 and Phase 2. This significant disruption in normal behavior or mortality will occur during project construction for each of the five project segments over 7 years.

2.4.3 Operational and Maintenance Effects on Listed Species

The proposed maintenance activities associated with the project include annual power washing of the LPS to ensure maximun light penetration and the nourishment of loose substrate on the habitat benches and at the substrate enhancement locations (see Section 1.2.1.5). The proposed power washing will occur either under the cantilevered sidewalk to remove algae grow or on top of the sidewalk to remove accumulated dirt. This activity will not result in any effects to listed species, therefore the effects of this action will be minimal.

Nourishment of the habitat benches and the substrate enhancement locations involves replacing any substrate that may have been scoured by wave or vessel propeller actions. Renourishment actions will likely take place on a 10-year basis. These activities involve placing up to 10,000 yd^3 of substrate on the habitat benches and up to 300 yd^3 of pea gravel and shell hash on the substrate enhancement locations. These activities will occur between October 1 to February 15 when listed fish species are not in the area. Furthermore, the project includes BMPs such as working in the dry at low tide and use of a turbidity curtain to minimize both the chance and extent of turbidity these activities might cause.. Therefore, the effects of these activities are expected to be insignificant to listed fish species.

The Services analyzed the potential long-term stormwater impacts from the project's operational impacts to listed species and their critical habitat. The Services expect that while listed fishes are likely to be exposed to pollutants in stormwater at concentrations above the Services' biological threshold levels, marine mammals will not be exposed to contaminatns as they rely on deeper waters to such an extent that stormwater pollutants will dissipate to background level prior to exposure. Therefore, effects of stormwater among marine mammals is expected to be minimal.

The seawall replacement project will not directly alter discharges of stormwater from outside the project area or from CSOs in the action area. Discharges are part of the environmental baseline, and will likely continue.

Stormwater Pollutant Loading

Pollutant loading is the total quantity of a pollutant in stormwater runoff. Pollutants in stormwater runoff can contaminate surface waters at concentrations that are toxic to fish and other aquatic life (Spence et al. 1996). Exposure to stormwater pollutants may cause a range of physiological and behavioral effects, including but not limited to: reduced growth, impaired migratory ability, impaired reproduction, and avoidance behavior. The extent and severity of these effects vary, depending on the area, timing and duration of the exposure, ambient water quality conditions, the species and life history stage exposed, pollutant toxicity, and synergistic effects with other contaminants (EPA 1980). The primary pollutants of concern in stormwater from road surfaces are total suspended solids, total zinc, dissolved zinc, total copper, and dissolved copper (WSDOT 2008, 2009).

Through stormwater treatment, the proposed action will decrease pollutant loading for total suspended solids, total copper, and total zinc into Elliott Bay (Table 16). Even with improved stormwater treatment, the project will cause a five percent increase in pollutant loading for dissolved copper and dissolved zinc due to increased impervious surface areas associated with the permanent addition of the northbound lane between Yesler Way and Spring Street in combination with the difficulties of removing these chemicals through treatment. Pollutant loading will continue and continue to degrade the aquatic community. It is not possible to ascertain and describe quantitatively the incremental effects of pollutant loading of the proposed action on the environment; therefore we discuss these effects qualitatively.

Table 16 – Pollutant loading summary for existing and proposed conditions.

	Existing Conditions Loads (pounds per year)			Proposed Conditions Loads (pounds per year)			
	Lower Quartile	Median	Upper Quartile	Lower Quartile	Median	Upper Quartile	Percent Reduction[1]
Total Suspended Solids	4,222	5,460	7,319	1,201	1,554	2,083	72%
Total Copper	1.01	1.24	1.89	0.73	0.90	1.36	28%
Dissolved Copper	0.26	0.32	0.49	0.27	0.33	0.51	None - 5% increase
Total Zinc	5.55	7.26	9.61	3.69	4.83	6.39	33%
Dissolved Zinc	1.50	1.88	3.04	1.57	1.96	3.18	None - 5% increase

1 Percent reductions are relative to estimated loading under existing conditions.

There are numerous complex factors and interactions that occur in aquatic ecosystems that determine the significance or impact of pollutant loading. There is no singular, measurable outcome or indicator that can be used to determine the overall effect of pollutant loading. Stormwater analysis focuses on pollutant concentrations to determine potential impacts to the aquatic environment and listed species. Pollutant concentration contributes to pollutant loading, but the effects of pollutant loading itself, for instance how loading causes a gradual building up in a pollutant in the environment, is unclear. Pollutant loading, however, does exert a functional influence at the community level and is a reasonable indirect measure with which to gauge potential effects.

Estimate of Water Quality Changes from Stormwater Runoff. The project area consists of approximately 19.2 acres of almost entirely impervious surface. Most of the project area drains to a separated stormwater system and discharges untreated directly into Elliott Bay. Approximately 1.4 acres of the project area drains into King County's combined sewer system and is treated at the Westpoint Treatment Plant. Within the project area, there are seven large stormwater or combined sewer outfalls (Figure 14), two medium sized outfalls, as well as approximately 50 small, individual outfalls. The seven large outfalls are owned by the City of Seattle. The two medium sized outfalls are privately owned. One is located at Bell Harbor and the Seattle Steam Company has an outfall at Pier 57. The Seattle Steam outfall is regulated by an individual National Pollutant Discharge Elimination System permit, and will not be impacted by the project. The 50 small outfalls typically convey runoff from small areas of the roadway directly into Elliott Bay.

Some of the stormwater outfalls within the project area drain areas that extend far beyond the project footprint (Figure 14 and Figure 24). These outfalls include S. Washington, Madison, University, and Pine streets. The low-flow diversion structure identified in Figure 24 allows low stormwater flows

to enter the combined sewer system and route higher stormwater flows into Elliott Bay. Where the separated storm drainage system and the combined sewer system share an outfall along the seawall, at University and Madison streets, the separated storm drain connection to the outfall pipe occurs downstream of the CSO diversion structure. Therefore, the separated storm drainage does not affect the occurrence or magnitude of the CSO discharge at these outfalls.

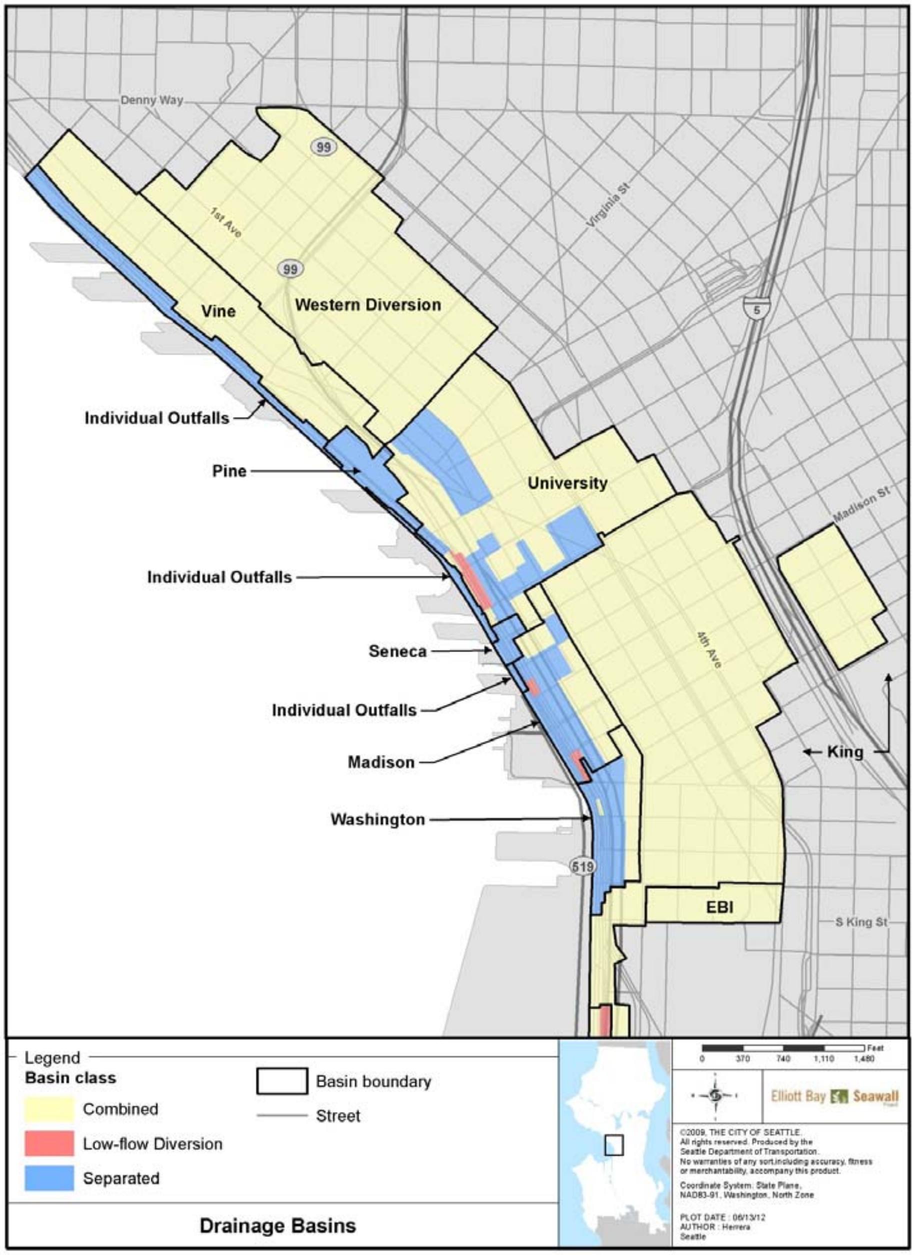

Figure 24 – Drainage basins for the outfalls located within the project area.

The City will rebuild the stormwater collection and conveyance systems within the project area. The larger separated and combined sewer outfalls will remain at their existing locations. The majority of

the 50 individual outfalls will be consolidated and their runoff discharged to one of the major stormwater outfalls. Six smaller individual outfalls will remain.

All PGIS stormwater within the project area will be treated to remove sediment and associated pollutants in accordance with current Seattle Municipal Code. Given the location and limited space available for constructing runoff treatment facilities, a suitable, commercially-manufactured treatment system will be used.

For the stormwater analysis, the project area was divided into six drainage basins (Figure 25). The existing and proposed PGIS for each of the drainage basins is shown in Table 17. The increase in PGIS within the Madison and S. Washington street basins is due to the addition of a permanent northbound lane segment at the south end of the project corridor.

Table 17 – Pollution generating impervious surfaces under existing conditions and proposed project conditions.

On site Drainage Basin	Existing Conditions (acres)	Proposed Conditions (acres)
Broad Street to Pine Street basin	3.67	3.67
Pine Street basin	1.39	1.39
University Street basin	1.35	1.35
Seneca Street basin	0.35	0.35
Madison Street basin	1.40	1.69
S. Washington Street basin	0.45	0.56
Total	**8.61**	**9.01**

The stormwater analysis was conducted by SDOT by calculating the average annual pollutant loading (the mass of representative pollutants carried in stormwater runoff), and comparing the pollutant loading after construction of the proposed project to pollutant loading under existing conditions. Pollutant loading to Elliott Bay following construction of the project was estimated using the Simple Method, as described by Schueler (1987). The Simple Method produces an estimate of the annual average loading rate for pollutants as the product of runoff pollutant concentration and the annual runoff volume. The annual runoff volume is estimated as the product of the average annual rainfall volume, drainage basin area, a runoff coefficient, and the fraction of rainfall events that lead to runoff.

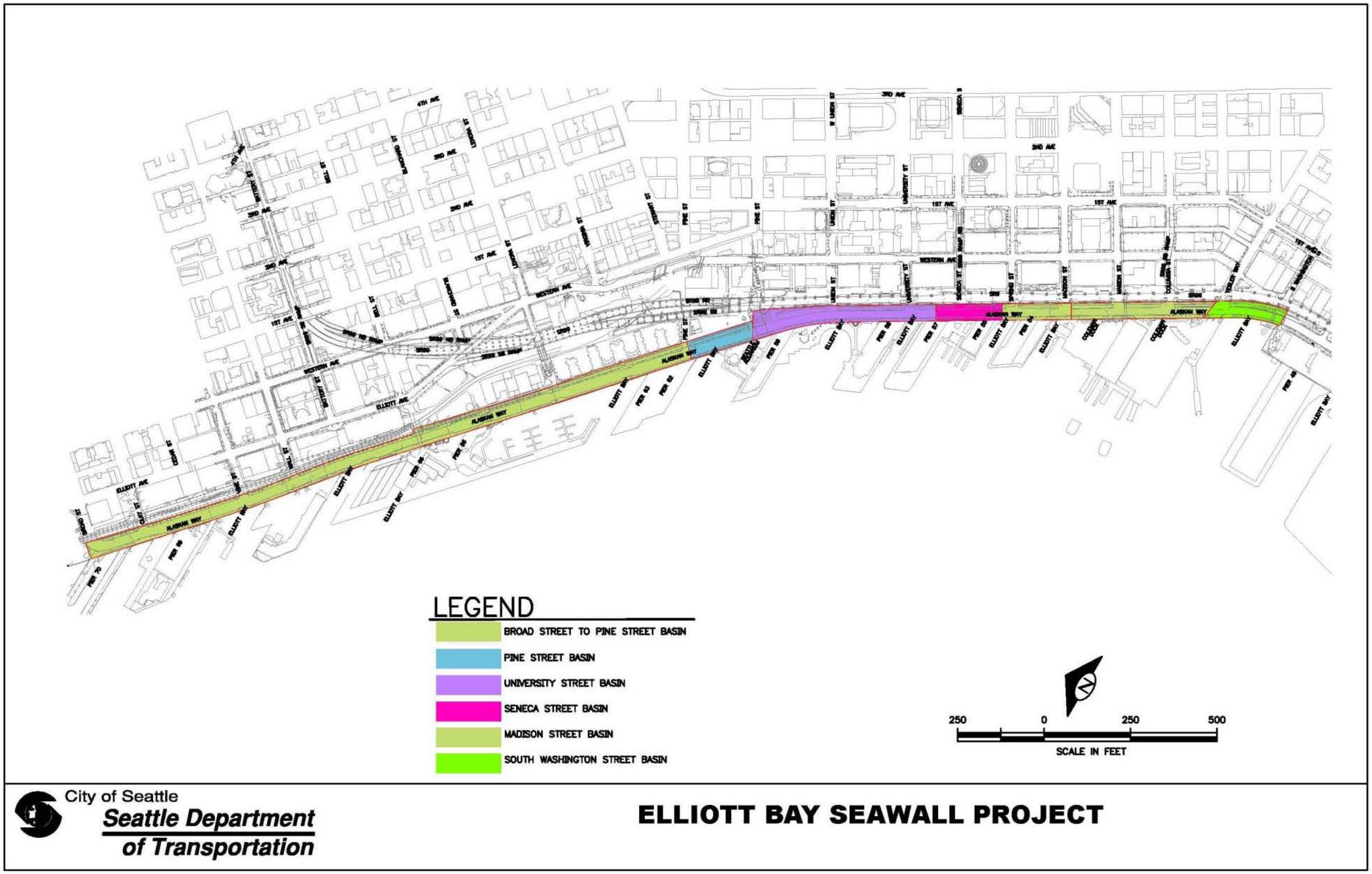

Figure 25 – Project area drainage basins.

Runoff concentrations for total suspended solids, total and dissolved copper, and total and dissolved zinc were derived from a number of roadway runoff data sources, including the input data from the WSDOT Highway Runoff and Dilution Model (WSDOT 2009), data from annual National Pollutant Discharge Elimination System monitoring reports (City of Seattle 2011), and data from BMP effectiveness monitoring compiled by Seattle Public Utilities (City of Seattle 2011; Schmoyer, in litt. 2011). The median, 25th and 75th percentile concentrations that were used in the analysis are shown in Table 18.

Table 18 – Roadway runoff concentrations used in the pollutant loading analysis.

Parameter	25th Percentile	Median	75th Percentile
Total Suspended Solids (mg/L)	63.0	81.5	109.2
Total Copper (µg/L)	15.1	18.5	28.2
Dissolved Copper (µg/L)	3.9	4.7	7.3
Total Zinc (µg/L)	82.8	108.4	143.4
Dissolved Zinc (µg/L)	22.4	28.0	45.4

The proposed project includes treatment of stormwater runoff for all of the restored PGIS within the project limits. The pollutant loading estimates for the proposed condition reflect assumed removal of pollutants in those treatment systems. Per Ecology's definition, basic treatment systems are designed to remove at least 80 percent of the total suspended solids in stormwater runoff (Ecology 2005). Therefore, a removal rate of 80 percent was assumed for total suspended solids. In the process of removing the particulates, other pollutants (such as heavy metals and hydrophobic organic contaminants) that are bound to the particulates (Jartun et al. 2008) will also be removed. For the stormwater analysis, removal rates for total and dissolved copper, and total and dissolved zinc were derived from monitoring data (Stormwater Management, Inc. 2004; City of Seattle 2011) that were collected from a representative basic treatment system. These data show highly variable removal rates for dissolved copper with both negative (export) and positive (removal) values measured during individual storm events. Because of this variation, the proposed catch basin-scale stormwater treatment facilities were assumed to be ineffective at treating dissolved copper to provide a conservative assessment of their overall benefit for reducing pollutant loads. There is little information available to quantify removal rates for toxic hydrophobic compounds in basic treatment systems. However, a removal rate of 38 percent was observed for one representative toxic organic compound (benzo[a]pyrene) based on data that were collected from a treatment system in Tacoma, Washington (Milesi et al. 2006).

The specific removal rates for all pollutants that were used as input for the Simple Method are listed in Table 19. These removal rates were not applied to pollutant loading calculations for existing conditions.

Table 19 – Removal efficiencies used in the pollutant loading analysis

Parameter	Percent Removal	Source
Total Suspended Solids	80	Ecology requirements (Ecology 2005)
Total Copper	34	City of Seattle (2011); Stormwater Management, Inc. (2004)
Dissolved Copper	0	City of Seattle (2011); Stormwater Management, Inc. (2004)
Total Zinc	40	City of Seattle (2011); Stormwater Management, Inc. (2004)
Dissolved Zinc	0	City of Seattle (2011); Stormwater Management, Inc. (2004)

To determine the range of plume sizes that could exceed the Services biological threshold criteria for the potential to affect ESA-listed species, an analysis of the expected dilution of stormwater runoff pollutants as they discharge from the outfalls into the nearshore area of Elliott Bay was performed. Pollutants that are dissolved in stormwater runoff and carried in a plume out of the outfalls are most likely to be biologically available and therefore harmful to fish and other aquatic species. For this reason, the analysis of the plume sizes and associated pollutant concentrations focused on dissolved copper and dissolved zinc.

To conduct the stormwater analysis, SDOT modeled the flows using the "pipe within a pipe" scenario. This model analyzes stormwater as if there is a separate pipe that carries only the flows from the project area (drainage basin) to the outfall. It does not take into account the stormwater that is also in the outfall from outside the project area. Thus the analysis does not factor in any beneficial or detrimental effects that may occur within the system due to mixing with non-project water. Beneficial effects could occur through dilution of project stormwater when mixed with water from non-PGIS areas. Detrimental effects could occur through synergistic effects of pollutants mixing within the system. Unfortunately, the best available scientific information currently does not exist to allow the Services to analyze the potential synergistic effects and as such, whether the actual effects of the combined outflows would be lesser or greater as compared with the effects if the discharges were separate. Until additional scientific information becomes available, the Services assume that the synergistic effects, if any, will be similar to the effects of copper and zinc and would affect only a small number of individuals due to the small size of the dilution zone.

As stated above, overall pollutant loading of total suspended solids, total copper, and total zinc will decrease by up to 72 percent (Table 16) if the filtering systems function as predicted and are maintained. The loadings of other pollutants commonly found in urban stormwater runoff are expected to be similarly reduced in project area runoff discharges to Elliott Bay compared to the existing condition. Contaminants that are relatively insoluble in water and are transported primarily in particulate form, such as most hydrophobic organic contaminants, are expected to exhibit the greatest loading reductions, while pollutants that are transported primarily in dissolved form would exhibit lower or no net reductions. No information is available to describe how pollutant loading will change ambient concentrations within a water body. Therefore, it is not possible to say that the reduced pollutant loading from the proposed project will cause or contribute to any changes in the ambient pollutant concentrations within Elliott Bay. Any changes in ambient pollutant concentrations may result in different pollutant biological threshold for altering or impairing their biological processes and negatively impacting salmonids.

The SDOT determined stormwater contaminant outfall dilution plume size and distance to the biological threshold values using the CORMIX modeling program for two key pollutants of concern (dissolved copper and dissolved zinc) during months critical to ESA-listed fish species. Representative outfalls were selected based on the size of the project area draining to the outfall. The Madison Street outfall was selected for modeling as because it will carry runoff from the largest project area draining to a single outfall (1.40 acres in the existing condition, and up to 1.69 acres in the proposed condition with consolidation of the small individual outfalls). An individual storm drain outfall in the vicinity of Vine Street was selected because it represents an individual outfall with a small drainage area (0.24 acre), completely within the project area. The Pine Street outfall was selected to characterize an intermediate sized basin (0.69 acre in the existing condition with no individual outfall consolidation, and up to 1.54 acres in the proposed condition with consolidation of the small individual outfalls). Plumes were modeled during both “treatment discharge conditions” (i.e., flow rate comparable to the water quality design storm when all runoff from the project area would pass through on site treatment systems) and “2-year peak discharge conditions” (i.e., when discharges would consist of treated and mostly untreated stormwater). These two flows demonstrate the most typical flows (treatment discharge conditions) and more extreme, although fairly common, rainfall events (2-year peak discharge) when runoff would exceed treatment design conditions and discharge untreated stormwater. The 2-year peak discharge (untreated) flow is likely a reasonable representation of typical worst case intensities of pollutants. While there is some anecdotal evidence that seasonal “first flush” discharges may be a potential worst case situation (Herrera 2011), no definitive studies have been performed in the Puget Sound area to specifically evaluate whether “first flush” conditions are worse than typical stormwater discharges. Results of the plume dilution analysis are summarized below.

For the Madison Street outfall, the simulated dissolved zinc plumes travelled between 1.2 feet and 12.5 feet from the outfall before meeting the biological effects threshold currently used by the Services. This was for all treatment discharge conditions and most tide conditions modeled (all tide conditions except spring slack low tide in March). For all outfalls modeled, when referring to plume distances, the distance (length) is generally measured from the outfall to the point where it dilutes to meet the biological effects threshold. Initially, the plumes travel in a direction perpendicular to the shoreline due to the momentum of the stormwater discharge, then begin to flow northward with the prevailing current as that momentum decreases. The lateral extent of the plume is the total width of the plume before it dilutes to meet the biological effects threshold. The plume also tends to rise quickly and be a thin layer on the surface due to the density difference between denser, more saline Elliott Bay water and the less dense stormwater. Results for the Madison Street Outfall for both dissolved copper and dissolved zinc are presented in Table 20. For all but the spring slack low tide, stormwater would be discharged in submerged conditions at this existing outfall. As the stormwater plume rises in the marine water of Elliott Bay it mixes relatively quickly in the ambient cross flow.

Table 20 – Predicted Distance from Madison Street Outfall to Meet Biological Effects Threshold for Dissolved Copper and Dissolved Zinc (1.58 acres drainage)

Month	Dissolve Copper	Dissolved Zinc			
	Distance to Biological Effects Threshold (ft)	Distance to Biological Effects Threshold (ft)[1]	Surface Plume Thickness[2] (ft)	Surface Plume Lateral Extent[3] (ft)	Maximum Area for Dilution Plumes (ft^2)
Treatment Discharge					
March	0.6 to 3.5	1.2 to 18.3	0.2	11.6	212.3
May	1.8 to 3.3	2.7 to 12.5	0.3	8.9	111.3
July	2.0 to 3.0	2.8 to 6.5	0.5	3.0	19.5
October	0.6 to 3.3	1.2 to 12.5	0.3	8.9	111.3
2-Year Peak Discharge					
March	1.4 to 5.8	2.3 to 58.4	0.2	41.1	338.7
October	1.5 to 5.0	2.3 to 16.0	0.5	10.7	171.2

Note: 1 Distance measured directly from outfall to centerline of plume where it meets the biological effects threshold. Greater distances are associated with surface discharge and shallow submerged outfall conditions. Thickness and lateral extent values are only shown for the surface plumes that are associated with spring slack low tide.

2 Surface plume thickness values represent the maximum depth of the plume from the surface before meeting the biological effects threshold. Lateral extent values represent width of the plume measured perpendicular to the shoreline before meeting biological effects threshold.

3 The lateral extent of plumes that reach the water surface is an indication of the extent of plume spreading away from its centerline until the background concentration is reached. The plume centerline changes direction as it loses momentum and moves parallel to the shoreline. At this point the lateral extent, or width, is measured perpendicular to the shoreline. The background concentration is lower than the biological effects threshold concentration, and thus, the lateral extent to reach the biological effects threshold would be lower than the values listed. Deriving lateral extents of plumes to meet the biological effects threshold is difficult to quantify using CORMIX and was not attempted for this analysis.

For the combination of treatment discharge and the analyzed spring slack low-tide conditions (which occur less than 10 percent of the yearly tidal cycle) the simulated dissolved zinc plumes travelled as far as 18.3 feet from the outfall (in March) before meeting the biological effects threshold. Under the same conditions in March the predicted dissolved copper plume would only be 3.5 feet long before meeting the biological effects threshold. During these slack low-tide conditions, the modeled dissolved zinc plume remains at the surface of the water column and spreads rapidly in a thin layer (0.2 to 0.5 feet in thickness). This spreading results in relatively slow dilution with the receiving water and therefore longer distances from the outfall to the point where the biological effects threshold is met.

During 2-year peak runoff discharge conditions the simulated dissolved zinc plume distances were greater than during treatment discharge conditions. With the exception of spring slack low-tide conditions, the simulated dissolved zinc plumes travelled between 2.3 and 16.0 feet from the

outfall before meeting the biological effects threshold. The simulated dissolved copper plume distances for all but spring slack low-tide conditions were in the range of 1.4 to 5.0 feet. During spring slack low-tide conditions (which occur less than 10 percent of the yearly tidal cycle) the simulated dissolved zinc plumes travelled 58.4 feet from the outfall at a thickness of 0.2 feet before meeting the biological effects threshold. The simulated dissolved copper plume travelled 5.8 feet in those worst-case conditions.

For the Pine Street outfall, which drains an intermediate size basin, the analysis for the predicted dissolved copper and zinc plume sized to meet the biological threshold values are shown in Table 21.

Table 21 – Predicted Distance from Pine Street Outfall to Meet Biological Effects Threshold for Dissolved Copper and Dissolved Zinc

Month	Dissolve Copper	Dissolved Zinc			
	Distance to Biological Effects Threshold (ft)	Distance to Biological Effects Threshold (ft)[1]	Surface Plume Thickness[2] (ft)	Surface Plume Lateral Extent (ft)	Maximum Area for Dilution Plumes (ft^2)
Treatment Discharge					
March	1.2 to 1.3	1.9 to 2.0	N/A	N/A	N/A
May	1.4 to 3.7	2.0 to 23.6	0.2	23.6	557.0
July	1.9 to 3.2	2.4 to 7.1	0.5	3.8	27.0
October	1.3 to 1.6	2.0 to 14.6	0.2	29.1	424.9
2-Year Peak Discharge					
March	2.1 to 3.9	5.5 to 5.6	N/A	N/A	N/A
October	3.9 to 5.7	5.6 to 11.8	N/A	N/A	N/A

Note: [1] Distance measured directly from outfall to centerline of plume where it meets the biological effects threshold.
[2] Greater distances are associated with surface discharge and shallow submerged outfall conditions. Thickness and lateral extent values are only shown for the surface plumes that are associated with spring slack low tide. Surface plume thickness values represent the maximum depth of the plume from the surface before meeting the biological effects threshold.
[3] The lateral extent of plumes that reach the water surface is an indication of the extent of plume spreading away from its centerline until the background concentration is reached. The plume centerline changes direction as it loses momentum and moves parallel to the shoreline. At this point the lateral extent, or width, is measured perpendicular to the shoreline. The background concentration is lower than the biological effects threshold concentration, and thus, the lateral extent to reach the biological effects threshold would be lower than the values listed. Deriving lateral extents of plumes to meet the biological effects threshold is difficult to quantify using CORMIX and was not attempted for this analysis.

For an individual outfall (Vine Street) that drains a small area entirely within the project area, during both treatment and 2-year peak discharge conditions, and all tide conditions modeled, the simulated dissolved copper plumes travelled between 0.5 and 1.1 feet from the outfall before

meeting the biological effects threshold. Similarly, the simulated dissolved zinc plumes travelled between 1.0 foot and 1.5 feet from the outfall before meeting the biological effects threshold in all tide conditions modeled. As the stormwater plumes rise in the denser, more saline water of Elliott Bay, mixing of the relatively small flow volumes occurs relatively quickly in the ambient cross flow regardless of tide level.

Potential exposure to stormwater pollutant plumes with concentrations exceeding biological effects thresholds near the project outfalls will be a function of storm duration and frequency. Because nearly all of the ground surface within the project limits will be impervious, as in the existing condition, and no stormwater flow control is proposed (nor necessary for Puget Sound), the occurrence of stormwater runoff discharge to Elliott Bay will be within minutes of rain falling on the ground surface. SDOT conducted a rainfall analysis to determine the average duration of storm events in the project footprint. The results of this analysis show storm durations ranging from less than 1 hour to 81 hours with an average of approximately 8 hours over the 50-year record from 1948 to 1998, accounting for all months of the year. The peak of the runoff occurs during larger rain events and would probably last for less than 1 hour coinciding with the most intense rain falling within the longer storm, with the remainder of the storm duration exhibiting less intense rainfall and runoff. The rainfall analysis showed storm events greater than the 6-month, 24-hour event (roughly equivalent to the treatment design event) are relatively rare during the primary months of concern (March, May, July and October), ranging from 0.0 storms on average in July to 0.24 storms on average in October.

The SDOT analyzed the SeaTac 50-year precipitation record to determine the average number of storm events per year (Table 22). A storm event is defined by 6-hour precipitation that exceeds 0.04 in/hour.

Take 22 – Average number of storm events within the project area that would result in stormwater discharges from outfalls.

Month	Average number of Storm Events
January	15.64
February	12.76
March	13.94
April	11.26
May	7.66
June	6.1
July	3.2
August	4.38
September	6.4
October	11.08
November	15.24
December	15.7

Because of the complexity of stormwater analysis and the different sizes of outfalls and drainage areas within the project area, the Services used the area of the largest dilution zone (557 ft^2, Table 21) in which the biological threshold was met, as the impact area to listed fish species in Elliott

Bay. While the project will lower and extend the outfalls so they discharge beyond (west side, or deeper side) the habitat bench to minimize exposure of stormwater discharge, numerous factors including tidal fluctuation, wave energy, etc. will result in the stormwater discharge to flow in any direction. Therefore, the Services assume that the stormwater discharge may flow in any direction.

Effects of Stormwater Pollutants on Listed Fishes

The Services rely on information from surrogate species when specific information on a listed fish species is not available. Species within the Salmonidae family are used whenever possible to determine potential affects to listed salmonids and rockfish. However, Hansen et al. (2002) demonstrated that even among the members of the Salmonidae family, specific sensitivities to chemical contaminants and mixtures of contaminants differed among the species. Stormwater contaminant information on listed rockfish is rare. WDFW and the Puget Sound Partnership monitor contaminants in the marine environment (WDFW 2013; PSP 2013). Contaminants in Quillback rockfish (*S. maliger*), copper rockfish (*S. caurinus*), and brown rockfish (*S. auriculatus*) are measured and monitored. However, specific chemicals in stormwater (i.e., copper and zinc) are not measured. Therefore, surrogate species information is used to determine potential impacts to listed rockfish.

Chemicals in stormwater and pollutant loading can adversely affect Chinook salmon, bocaccio, canary rockfish, and bull trout through several mechanisms – these include but are not limited to, direct effects, such immediate behavioral and biological responses to exposure of contaminants in the water column, and indirect effects such as chronic sublethal effects from bioaccumulation after ingesting contaminated prey.

Most aquatic sediments are highly susceptible to the uptake of common pollutants such as metals and organic contaminants (Pitt et al. 1995). Many of these pollutants, particularly metals, resist biodegradation and accumulate over time (Horner et al. 1994). Sediments that collect in depositional areas of streams can contain pollutant concentrations several orders of magnitude greater than those in surface waters, exceeding biological effects thresholds where surface water concentrations do not (Chapman 1973; Clements 1994; Davies 1986; Hoiland and Rabe 1992; Kiffney and Clements 1993).

Benthic macrofauna, the organisms that constitute the primary prey resource for juvenile salmonids, are closely associated with the substrates and therefore at risk of pollutant exposure (Welch et al. 1998). Macrofauna communities are notably sensitive to changes in water quality, hydrology and other habitat elements associated with urbanization and land use change (Jones and Clark 1987), to the extent that indices of biotic integrity based on community characteristics are in common use as indicators of water and habitat quality. Benthic Index of Biotic Integrity (B-IBI) scores in Puget Sound lowland streams show a demonstrable negative correlation with impervious surface area (Booth et al. 2004; Karr and Chu 1997; Morley and Karr 2002) and the urban character of the drainage (King County et al. 2009). Similar biological responses indicative of the adverse effects of urbanization on stream hydrology and water quality have been demonstrated in a diversity of watersheds throughout Washington State and throughout the country (Cuffney et al. 2005; Morley and Karr 2002; Kratzer et al. 2006).

There is a strong positive relationship between the availability and quality of the macrofauna prey resource and juvenile salmonid abundance (Chapman 1966). While this interaction is complex, salmonid density, growth rates, and abundance are usually positively correlated with macroinvertebrate biomass (Chapman and Bjornn 1969; Murphy et al. 1981). Laboratory studies have clearly demonstrated that salmonid growth rates and carrying capacity can be limited by food availability (Keeley 2001; Mason 1976).

Bioaccumulation of pollutants in the food chain presents an additional mechanism through which adverse effects can occur. Benthic macroinvertebrates can bioaccumulate metals and other pollutants in their tissues, making these pollutants biologically available for uptake at higher levels in the food chain (Kiffney and Clements 1993). Dietary exposure to metals and other pollutants can cause a range of adverse effects in fish and other aquatic life forms (Rand and Petrocelli 1985). These adverse effects have been demonstrated in several salmonid species. For example, Lundebye et al. (1999) found that dietary exposure to copper significantly reduced growth rates in juvenile Atlantic salmon. Handy et al. (1999) exposed rainbow trout to dietary copper uptake and found that that the metabolic costs of detoxification and excretion limited the energy available for normal swimming behavior.

Salmonid Responses to Elevated Copper Concentrations. Copper is acutely toxic to fish at low concentrations. Sprague (1964, 1965) reported a 7-day Incipient Lethal Level (ILL) of 48 μg/L and 32 μg/L at water hardness of 20 mg/L and 14 mg/L, respectively, for juvenile Atlantic salmon (Salmo salar) exposed to dissolved copper. The ILL does not account for delayed mortality beyond the exposure period, suggesting potential underestimation of adverse effects.

At very low concentrations, copper can cause sublethal and behavioral effects that have significant implications for survival and fitness, such as impaired disease resistance, osmoregulatory disruption, kidney, liver and gill pathologies, altered blood chemistry and enzyme activity, and impaired respiration, olfactory ability and brain function, hyperactivity, impaired avoidance behavior, and delayed migration (Eisler 1998). Olfactory inhibition decreases the ability of salmonids to recognize and avoid predators; it disrupts the ability to imprint on natal waters, and impairs or delays homing and migration. Olfactory inhibition and behavioral effects can be triggered at relatively low exposure concentrations and they are readily linked to demonstrable adverse effects. Recent studies have considered the effects of altered copper concentration relative to typical background levels. Sandahl et al. (2007) observed the onset of olfactory disruption and behavioral alteration at a nominal increase in copper concentration of 2.0 μg/L in juvenile coho salmon acclimated to a background concentration of 3.0 μg/L. Baldwin et al. (2003) found that 30 to 60 minute exposures to dissolved copper at 2.3 μg/L above background concentrations caused significant olfactory inhibition in juvenile coho salmon. Exposure to 10 μg/L of dissolved copper for 30 minutes, a concentration and duration typical of stormwater effluent from modern treatment BMPs, reduced olfactory capacity by 67 percent, an effect that appears independent of water hardness. In saltwater, Chinook have been found to avoid water containing copper (Sommers 2012).

Salmonids will actively avoid copper where possible and because the dilution zones to background levels are small compared to the overall size of Elliott Bay, salmonids in the action

area should generally be able to avoid acute exposure. In the event they are unable to do so, olfactory function impairment will begin to occur within minutes of exposure. The resulting physiological injury can persist from days to weeks. Saucier et al. (1991a) found that extended exposure of rainbow trout to dissolved copper at 22 µg/L caused an evident decrease in olfactory sensitivity that persisted for weeks after exposure. Saucier et al. (1991b) exposed rainbow trout eggs and alevins to similar concentrations over periods ranging from 37 to 41 weeks and found evidence of persistent olfactory tissue necrosis. Some healing of damaged tissue occurred after the subjects were removed from exposure, but the potential for injured fish to fully recover remains unclear.

Behavioral alteration is a temporary effect, but it can lead to ancillary effects on survival and fitness. Avoidance of elevated copper concentrations can lead fish to abandon preferred habitats, potentially leading to competitive stress, increased predation exposure, and/or reducing foraging efficiency. Adverse behavioral responses to dissolved copper have been observed at very low concentrations in-vitro. Folmar (1976) observed avoidance responses in rainbow trout fry when exposed to a Lowest Observed Effect Concentration of 0.1 µg/L of dissolved copper (at 90 mg/L water hardness). The EPA (1980) also documented avoidance by rainbow trout fry of dissolved copper concentrations as low as 0.1 µg/L during a 1 hour exposure. These concentrations are well below typical background levels and prohibitively difficult to measure in the field, limiting their practical utility as effects thresholds. More recent studies have considered the effects of altered copper concentration relative to typical background levels. Sandahl et al. (2007) observed the onset of olfactory disruption and behavioral alteration at a nominal increase in copper concentration of 2.0 µg/L in juvenile coho salmon acclimated to a background concentration of 3.0 µg/L. Based on these findings, the Services have concluded that this threshold (2.0 µg/L over background concentrations of 3.0 µg/L or less) is representative of the onset of adverse effects for the purpose of ESA consultations.

Salmonid Responses to Elevated Zinc Concentrations. Zinc occurs naturally in the environment and is an essential trace element for most organisms. However, in sufficient concentrations and through bioaccumulation by aquatic organisms, excess Zn is toxic. Zinc toxicity depends on water hardness and varies widely depending on organism sensitivity, the extent and duration of exposure, and site specific factors (De Schamphelaere and Janssen 2004). Lethality typically requires exposure at high concentrations over long periods. For example, Hansen et al. (2002) found worst case 120-hour LC50 values of 35.6 µg/L for juvenile bull trout averaging 30 mm total length, and 23.9 µg/L for juvenile rainbow trout averaging 54 mm total length (at pH 7.5, hardness 30, and 8.0 degrees C).

Sublethal effects from zinc exposure occur at lower concentrations. These effects include reduced growth, altered behavior (avoidance), reproductive impairment, elevated respiration, impaired swimming ability, developmental abnormalities of the jaw and bronchial tissues, hyperactivity, and hyperglycemia (Eisler 1993), all adversely affecting survival and fitness. Saunders and Sprague (1968) observed delayed migration and spawning in adult Atlantic salmon exposed to surface waters contaminated with zinc from mining pollution. Juvenile salmonids are more sensitive to elevated zinc concentrations than adults (EPA 1987). Coho salmon and cutthroat trout (O. clarkii) fry were observed to avoid nominal dissolved zinc concentrations ranging from 6.54-28 µg/L at hardness of 15-100 mg/L (Woodward et al. 1997). Sprague (1968)

observed that juvenile rainbow trout demonstrated avoidance behavior when exposed to a 5.6 µg/L increase in dissolved zinc concentrations when background levels ranged between 3.0 µg/L and 13 µg/L at water hardness from 13 mg/L to 15 mg/L.

The implications of behavioral effects caused by zinc exposure are similar to those described for copper, meaning that exposure to zinc above an established behavioral effects threshold would be expected to lead to adverse effects on survival and fitness. However, the broad range of concentrations, water hardness, duration of exposure, and life history stages, complicates the identification of an appropriate biological effects threshold. The Services rely on the lowest documented effects threshold that can be practically applied for the purpose of ESA consultation. On this basis, the Services have concluded that the exposure threshold observed by Sprague (1968) (i.e. a 5.6 µg/L increase in dissolved zinc concentrations when background levels ranged between 3.0 µg/L and 13 µg/L) is representative of the onset of adverse effects.

Exposure of Listed Fishes to Stormwater Discharges

The Services estimate that all Chinook salmon, bocaccio, canary rockfish, yelloweye rockfish, and bull trout within 557 ft^2 of each of the seven outfalls will have a significant disruption in normal behavior, such as increased stress leading to reduced ability to perform vital functions such as migration, breathing, nursing, breeding, feeding, or sheltering, resulting from project related stormwater discharge.

Estimated Puget Sound Chinook Salmon Exposure. Stormwater discharge may occur throughout the year (Table 22). However, Chinook salmon migration along the seawall begins in April and continues through October. Based on Chinook salmon sampling along the seawall (see Status of the Species within the Action Area), Table 23 provides an estimate of the number of juvenile Chinook salmon that may be within the 557 ft^2 area impacted by stormwater discharge.

Table 23 – Monthly estimated number of juvenile Chinook salmon within 557 ft^2 of outfalls along the seawall.

Month	Average number of Chinook per 520 m^2 salmon found along three seawall sites[1]	Number of Chinook salmon found within 557 ft^2 of an outfall	Number of Chinook salmon within 557 ft^2 of the seven outfalls	Number of Chinook salmon impacted per month assuming average monthly discharges
January	0	0	0	0
February	0	0	0	0
March	0	0	0	0
April	0	0	0	0
May	5.9	0.6	4.2	32
June	31.6	3.2	22.4	137
July	6.4	0..6	4.2	13
August	6.4	0.6	4.2	18
September	1.8	0.2	1.4	9
October	.6	0.1	0.7	8
November	0	0	0	0
December	0	0	0	0
Total				217

[1] UW unpublished data.

The Services estimate that all juvenile Chinook salmon within 557 ft^2 of each of the seven major outfalls within the project area will have significant disruption in normal behavior as a result of exposure to chemicals in stormwater discharges from the project. Table 23 provides an estimate of the number of Chinook salmon that may be exposed to contaminants in the stormwater. These numbers are conservative for all seven outfalls as these numbers are based on the analysis for the worse case stormwater analysis (Pine Street Outfall). However, the other outfalls may have smaller dilution plumes and therefore, fewer Chinook salmon would be exposed to the stormwater discharge. In addition, SDOT's stormwater analysis showed that the dilution plume was a thin layer (0.2 to 0.5 feet) at the surface of Elliott Bay due to the salinity difference between the marine receiving water and freshwater discharge. This analysis assumes the stormwater is evenly distributed throughout the water column. In the future, the number of Chinook salmon within the 557 ft^2 dilution plume may increase as the habitat improves along the seawall with the construction of the habitat bench and the increase in prey species along the migratory corridor.

Estimated Bocaccio, Canary Rockfish, and Yelloweye Rockfish Exposure. Table 10 provides density estimates for rockfish within Elliott Bay. Using the bocaccio and canary rockfish analysis described in the Elevated Turbidity and Suspended Sediment section (see Section 2.4.2.3), Tables 24 and 25 provide an estimate on the number of canary rockfish and bocaccio that may be exposed to stormwater discharge around each of the seven outfalls within the project area. Average depth used (11.5 feet) was the depth of the habitat bench (- 0.2 feet MLLW) compared to MHHW line (11.3 feet).

Table 24 – Estimate on the number of canary rockfish within 557 ft^2 of the outfalls within the project area.

Month	Number of canary rockfish within 557 ft^2 of each outfall	Number of canary rockfish within 557 ft^2 of the seven outfalls	Number of canary rockfish impacted per month assuming average monthly discharges
April	0.001	0.007	0.079
May	0.006	0.042	0.3217
June	0.0001	0.0007	0.0043
July	0.0004	0.0028	0.0089
August	0.0007	0.0049	0.0215
September	0.0002	0.0014	0.0089
October	0.0001	0.0007	0.0078

Table 25 – Estimate on the number of bocaccio within 557 ft^2 of the outfalls within the project area.

Month	Number of bocaccio within 557 ft^2 of each outfall	Number of bocaccio within 557 ft^2 of the seven outfalls	Number of bocaccio impacted per month assuming average monthly discharges
April	0.00002	0.00014	0.0016
May	0.0001	0.0007	0.0054
June	0.000003	0.000021	0.0001
July	0.00001	0.00007	0.0002
August	0.00001	0.00007	0.0003
September	0.000003	0.000021	0.0001

October	0.000003	0.000021	0.0002

For yelloweye rockfish, using the rockfish analysis described in the Elevated Turbidity and Suspended Sediment section (see Section 2.4.2.3), and the proportion of adult yelloweye rockfish caught by recreation anglers was from 2004 to 2008, as a proportion of the total rockfish catch, was 0.008% (WDFW 2010). Table 26 provides an estimate on the number of yelloweye rockfish that may be exposed to stormwater discharge around each of the seven outfalls within the project area.

Table 26 – Estimate on the number of yelloweye rockfish within 557 ft^2 of the outfalls within the project area.

Month	Number of yelloweye rockfish within 557 ft^2 of each outfall	Number of yelloweye rockfish within 557 ft^2 of the seven outfalls	Number of yelloweye rockfish impacted per month assuming average monthly discharges
April	0.0008	0.0056	0.06
May	0.004	0.028	0.21
June	0.00009	0.00063	0.0038
July	0.0003	0.0021	0.0067
August	0.0005	0.0035	0.015
September	0.0001	0.0007	0.0045
October	0.00009	0.00063	0.007

Based on the very small number of canary rockfish, bocaccio, and yelloweye rockfish within 557 ft^2 of the outfall, an estimated one canary rockfish, one bocaccio, and one yelloweye rockfish will be exposed to stormwater runoff from the project each year. Larval and juvenile canary rockfish and bocaccio, and larval yelloweye rockfish may be exposed to stormwater runoff.

Estimated Bull Trout Exposure. Bull trout may be found migrating and foraging within the marine waters of Puget Sound throughout the year. Bull trout will be found along the nearshore in the vicinity of prey species which include juvenile salmonids. One bull trout was observed on the habitat bench along the Olympic Sculpture Park in 2009 and a radio-tagged bull trout moved through Elliott Bay in November and December 2006. Bull trout have also been documented in the Duwamish River during the months of May, August, and September, indicating that they are present in Elliott Bay at any time of the year. The Services estimate that any bull trout that passes within 557 ft^2 of the seven major outflass within the project area will have significant disruption in normal behavior as a result of exposure to chemicals in stormwater discharges from the project. Because stormwater will discharge out the outfalls throughout the year for the life of the project, the Services estimate that one sub-adult or adult bull trout per year will be exposed to stormwater discharge. This number may increase in the future as the number of prey species (forage fish, juvenile Chinook salmon, and other juvenile salmonids) increase with improved habitat and migratory corridor along the seawall.

2.4.4 Effects on the Designated Critical Habitat of Listed Species

The proposed action is likely to adversely effect the designated critical habitat of PS Chinook salmon and bull trout. Critical habitat has not been designated for the remainder of the species

considered in this Opinion, with the exception of SR killer whales and Steller sea lions. The critical habitat designation for Stellar sea lions does not include areas in Washington State, so no further analysis is required. As indicated earlier in this document (see Section 2.4.1.3) critical habitat designated for the killer whales is not likely to be adversely affected.

Critical Habitat of Puget Sound Chinook Salmon

The NMFS designated critical habitat for the Puget Sound Chinook salmon on September 2, 2005 (70 FR 52630). One of the six PCEs of Puget Sound Chinook salmon critical habitat are in the action area:

- Puget Sound Chinook Salmon PCE 5: Nearshore marine areas free of obstruction with water quality and quantity conditions and forage, including aquatic invertebrates and fish, supporting growth and maturation; and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels.

Effects on the Essential Elements of the Nearshore Marine PCE. The project will cause temporary and permanent effects to habitat features of the migratory corridor for Chinook salmon.

1) Water Quality/Turbidity and Suspended Solids - Installation of the containment wall, riprap displacement, timber pile removal, and sheet pile installation will each increase turbidity and suspended solids that will temporarily degrade conditions for migration along the seawall in each construction season for seven years, but the installation of the containment wall will occur in September and October when the number of Chinook salmon along the seawall is low.

2) Water Quality/Pollutants - Stormwater discharge from the project will episodically contribute to degrading water quality in the PCE 5 for the life of the project. Through stormwater treatment, polluting loading will decrease 28 to 72 percent for total suspended solids, total copper, and total zinc. However, pollutant loading for dissolved copper and dissolved zinc will increase by five percent due to the increased impervious surface associated with the additional lane of traffic and with the difficulties of removing these chemicals through treatment. Stormwater discharges can occur throughout the year, with most occurring between October and April (Table 22) when Chinook salmon are either absent or present in very low numbers along the seawall.

3) Shade /Obstruction - The new habitat bench will be covered by a cantilevered sidewalk, but LPS will be installed to increase light under the sidewalk and decrease the light/dark contrast or shadow in Elliot Bay under the sidewalk. While there will not be full light penetration, neither will there be full shade under the structure. The walkway design, while shading the shallow-water habitat bench, will slightly improve the PCE 5 by reducing the extent of obstruction presently caused by overwater structures in the nearshore portion of the action area. This effect will persist over the life of the project.

4) Forage and Prey - Project construction will result in the short-term temporary decrease in Chinook salmon prey. Riprap displacement and timber pile removal will result in

macroinvertebrates being displaced and killed as well as their habitat altered or destroyed. However, macroinvertebrates will quickly recolonize the disrupted area from the surrounding area. Construction of the containment wall will also result in a long-term temporary loss of forage and prey species that are on or near the existing seawall. However, the area lost is small compared to the available foraging habitat in Elliott Bay. In the long-term, the project will improve forage and prey for Chinook salmon by construction of the shallow-water, intertidal habitat bench and installation of the shelved panels on the new seawall. These habitat features will increase macroinvertebrate production and improve forage opportunities for Chinook salmon along the seawall.

Designated Critical Habitat of Bull Trout

The USFWS designated critical habitat for the Coastal-Puget Sound bull trout on October 18, 2010 (75 FR 63898). Five of the nine PCEs of bull trout critical habitat are in the action area:

- PCE #2: Migration habitats with minimal physical, biological, or water quality impediments between spawning, rearing, overwintering, and freshwater and marine foraging habitats, including but not limited to permanent, partial, intermittent, or seasonal barriers.

- PCE #3: An abundant food base, including terrestrial organisms of riparian origin, aquatic macroinvertebrates, and forage fish.

- PCE #4: Complex river, stream, lake, reservoir, and marine shoreline aquatic environments, and processes that establish and maintain these aquatic environments, with features such as large wood, side channels, pools, undercut banks and unembedded substrates, to provide a variety of depths, gradients, velocities, and structure.

- PCE #5: Water temperatures ranging from 2 °C to 15 °C (36 °F to 59 °F), with adequate thermal refugia available for temperatures that exceed the upper end of this range. Specific temperatures within this range will depend on bull trout life-history stage and form; geography; elevation; diurnal and seasonal variation; shading, such as that provided by riparian habitat; streamflow; and local groundwater influence.

- PCE #8: Sufficient water quality and quantity such that normal reproduction, growth, and survival are not inhibited.

The proposed action will affect the PCEs listed below. The Services expect a range of effects – both positive and negative – as a consequence of the proposed action.

Migration Corridor – Construction of the project will temporarily affect the migratory corridor for bull trout. Increased turbidity and suspended solids from riprap displacement, timber pile removal and sheet pile installation will disrupt normal behavior and bull trout migration along the seawall, as the fish alter their route to avoid turbidity plumes. Turbidity and suspended solids are expected to be episodic during construction. Stormwater discharge from the project will occur periodically over the life of the project during heavy rain events, degrading water quality in the

migratory corridor in varying degrees of intensity. Stormwater discharge can occur throughout the year, with most discharges occurring between October and April (Table 22). Bull trout may be found within the action area throughout the year, using all the nearshore, not just the intertidal areas, and therefore a likely response to pollutant laden discharge will be for individuals to move away from the stormwater discharge plume. The project does include an increase in the amount of treatment of stormwater prior to discharge; however, many pollutants cannot be completely removed with the proposed treatment methods and there will be a slight increase in the levels of copper and zinc in stormwater discharges. Therefore, this aspect of the project has both beneficial and negative effects on water quality in the migration corridor. The project design sets the seawall back 10 to 15 feet and creates a shallow-water habitat bench along the entire length of the seawall. The shallow-water habitat bench is expected to improve the migratory corridor for bull trout by increasing substrate that supports forage base.

Abundant Food Base – Construction of the containment wall will temporarily reduce prey abundance as the containment wall will block access to macroinvertebrates and other prey that would be behind the containment wall for the duration of the construction period of the new seawall. Riprap displacement and timber pile removal will also temporarily reduce forage base, as macroinvertebrates are displaced and killed as their habitat altered or destroyed. However, macroinvertebrates will quickly recolonize the disrupted area from the surrounding area. The area lost is small compared to the available foraging habitat in Elliott Bay. However, after construction is complete, the shallow-water, intertidal habitat bench and shelved panels on the seawall is likely to increase forage and prey for juvenile salmonids and forage fish, both of which are prey for bull trout, along the seawall by construction of the shallow-water. These habitat features will provide some habitat diversity that might increase macroinvertebrate production and improve forage opportunities for juvenile salmonids. The Services expect that effects to this PCE will be discountable, insignificant, or wholly beneficial.

Complex Habitat - The project will improve habitat along the seawall through the construction of an intertidal habitat bench, expansion of the intertidal bench in Zone 1, and additional substrate additions along the seawall. The existing habitat consists of a vertical seawall with little shallow water and numerous overwater structures. The habitat features installed with the project will increase habitat complexity along the seawall. Despite these positive design aspects, the vertical design of the replacement seawall perpetuates a condition that is detrimental to nearshore habitat features and will preclude the development of complex shoreline features along the entire length of the seawall over the design life of the project.

Water Temperatures – The water temperatures within the action area will not be affected by the proposed project. Water temperatures within the action area are tidally influenced. Periodic stormwater discharges, especially during the summer, will result in small thermal plumes around each outfall. These plumes will rapidly dissipate and will have little influence on surrounding water temperatures.

Water Quality and Quantity – The project area has seven major outfalls and will have up to six smaller outfalls, following construction and consolidation of outfalls. The project will improve some aspects of water quality in Elliott Bay by providing basic water quality treatment to the stormwater that currently is discharging into Elliott Bay without being treated. Polluting loading

will decrease 28 to 72 percent for total suspended solids, total copper, and total zinc. Dissolved copper and dissolved pollutant loading will increase by five percent due to the addition of more impervious surfaces (additional traffic lane). Despite the addition of treatment with this project, stormwater discharging from the outfalls will still contain pollutants above the established behavioral effects threshold for salmonids, meaning that negative impacts to bull trout will still occur. Water quality in the mixing zone will be degraded during the discharge of stormwater from the outfalls. Pollutants (dissolved copper and zinc) will dilute to the biological threshold level within 557 ft^2 of each outfall, based on calculations using the largest dilution zone calculated for the outfalls along the seawall. Overall, the project will improve some, but not all, factors affecting water quality along the Seawall by treating stormwater prior to discharging into Elliott Bay.

2.5 Cumulative Effects

'Cumulative effects' are those effects of future state or private activities, not involving Federal activities, that are reasonably certain to occur within the action area of the Federal action subject to consultation (50 CFR 402.02). Future Federal actions are not considered in this section because they require separate consultation pursuant to section 7 of the ESA.

Table 27 contains a list of projects that are reasonably certain to occur within the action area, along with a summary of the anticipated effects of those projects. The action area is in a highly urbanized setting that is almost completely developed. Development spreads to the surrounding areas which currently are not as intensively developed. The increase in development results in increased noise from traffic, and stormwater and contaminants entering Elliott Bay. Some developments, when sufficient area exists, improve stormwater runoff by constructing green stormwater infrastructure conveyance and flow control facilities, such as bioswales, bioretention cells, cascading planters, and other low impact development such as green roofs and permeable pavement sidewalks, where these features did not previously exist. Other projects use basic water treatment for stormwater runoff. While these projects improve water quality from the project sites, the areas using low impact development will likely continue to be a very small proportion of the overall developed area which drains to Elliott Bay.

Some of the projects identified in Table 27 will have no effect on listed species because there is no suitable habitat for those species within the vicinity of the projects. Other projects that create additional PGIS may generate more pollutants that will be discharged to Elliott Bay. However, over the long term, these future projects would likely improve water quality in Elliott Bay, due to implementation of the following legally-required measures:

- Retrofit currently untreated PGIS with, at a minimum, basic water quality treatment BMPs in stormwater sub-basins.

- Reduction of peak flows and the frequency of combined sewer overflows through the application of detention facilities to control runoff from combined sewer sub-basins.

- Conversion of PGIS to non-PGIS or pervious surfaces.

Table 27 – Projects that are reasonably certain to occur along the Seattle Waterfront.

Project	Potential Cumulative Effect
1. *Waterfront Seattle Program* Development of the Seattle Waterfront from the Olympic Sculpture Park to Pioneer Square. The project involves rebuilding the waterfront with parks, paths, access to the water, views, public and cultural spaces, and upgraded transportation corridor.	The project could result in temporary effects on water quality during construction but would likely improve water quality over the long term through (1) retrofit of currently untreated PGIS with, at a minimum, basic water quality treatment best management practices in stormwater sub-basins, and (2) reduction of peak flows and the frequency of CSOs by the application of detention facilities to control runoff from combined sewer sub-basins.
2. *Elliott/Western Connector – Pike Street to Battery Street.* The Elliott/Western Connector would provide a connection from the Alaskan Way surface street to the Elliott Avenue/Western Avenue corridor that provides access to and from Ballard Interbay Northend Manufacturing and Industrial Center and neighborhoods north of Seattle (including Ballard and Magnolia). The connector would be four lanes wide and would provide a grade-separated crossing of the BNSF mainline railroad tracks. Additionally, it would provide local street access to Pike Street and Lenora Street and reintegrate with the street grid at Bell Street, which would improve local street connections in Belltown. The new roadway would include bicycle and pedestrian facilities.	Effects are expected to be similar to those described for project 1.
3, *Seattle Combined Sewer System Upgrades* Seattle intends to construct a new combined sewer overflow storage facility and conveyance system along the central waterfront. (This project could include federal funding.)	This project would improve water quality along the Seattle waterfront by reducing the volume and frequency of combined sewer overflow events.

Some future actions will cause temporary adverse effects on water quality. For example, it is likely that construction effects on surface water will occasionally result during staging, material transport, earthwork, stockpiling, storm drainage and/or combined sewer utility work, and dewatering affiliated with shoreline development near but above the ordinary high water mark. Construction-related pollutants can increase turbidity and affect other water quality parameters, such as the amount of available oxygen in the water. In addition, pH can be altered if runoff comes in contact with curing concrete, which could result in effects on aquatic species. Implementation of BMPs would minimize or prevent temporary effects.

2.6 Integration and Synthesis

Integration and synthesis is the final step of Services' assessment of the risk posed to species and critical habitat putting the effects of the proposed action in context of the species and critical habitat status, environmental baseline, and cumulative effects. In this section, we add the effects of the action (Section 2.4) to the environmental baseline (Section 2.3) and the cumulative effects (Section 2.5) to assess whether it is reasonable to expect that the proposed action is not likely to: (1) result in appreciable reductions in the likelihood of the survival and recovery of the species in the wild by reducing its numbers, reproduction, or distribution; or (2) reduce the value of designated or proposed critical habitat for the conservation of the species. These assessments are made in full consideration of the status of the species and critical habitat (Section 2.2).

2.6.1 Chinook Salmon

The threatened status of PS Chinook salmon derives from decreased abundance and productivity, reduced diversity, and declining spatial structure. Several populations of PS Chinook use the action area for rearing, foraging, and/or migration but the Green/Duwamish and the Skykomish River populations have been found to use the action area the most. The Green/Duwamish River population is considered healthy, and the Skykomish River population is considered depressed as the result of low productivity.

Juveniles from the populations using the action area encounter habitat conditions that are degraded by of the presence of a vertical seawall, leaving little shallow water habitat. Approximately 60 percent of the seawall contains overwater structures, and Chinook salmon have not been found to migrate under the overwater structures, but instead migrate around each one, causing extra energy expenditures and increased risk of predation. The lack of shallow water habitat, and shade caused by overwater structures reduce primary productivity and therefore, macroinvertebrates and other prey for Chinook salmon. Extensive urban development and ongoing activities along the Seattle waterfront also impact Chinook salmon habitat as in-water noise (ambient noise) is high due to the high number of ferries, cargo and container ships, barges and other boat traffic. Continued repair and replacement of overwater structures and other development along the seawall frequently causes impacts related to pile driving and water quality. Pile driving activities occurring at the same time as the proposed project will increase adverse effects for Chinook salmon within the project area. Stormwater discharges regularly add pollutants that have a range of negative effects. Each of these baseline conditions limit the number of juvenile Chinook salmon that can successfully rely on the action area to safely shelter, feed, grow, and develop during their migration. When project effects are added to the baseline, some habitat aspects will be degraded, and some improved. The duration of these effects are both temporary and permanent.

1) The project will add short-term adverse effects to the baseline water quality condition episodically during construction. Construction will increase turbidity and suspended solids, meaning in each construction period a small number of juvenile Chinook salmon will be adversely affected.

2) The proposed project permanently improves the migratory corridor and habitat for Chinook salmon along the seawall by moving the seawall back 10 feet to 15 feet from its existing location and installing an inter-tidal habitat bench along the entire length. The habitat bench will have a cantilevered sidewalk over the entire width, that will cause shading that limits some of the benefits of the bench, but LPS will be installed to increase light under the sidewalk. On the whole, the inter-tidal habitat bench will improve the migratory corridor for Chinook salmon by increasing primary and macroinvertebrate production, which will benefit Chinook salmon rearing and foraging. Chinook salmon will not have to migrate around each pier, thereby reducing energy expenditure and decrease risk of predation.

3) Long-term effects of stormwater discharged as part of the proposed project can are both positive and negative. Stormwater treatment from future projects will generally improve water quality within Elliott Bay, because the project involves basic water quality treatment

that will reduce stormwater contaminant concentrations. However, discharges about the biological threshold level will still occur. The project involves extending the outfalls so they discharge in deeper water on the outside of the habitat bench, but tidal influence and wave action may result in the discharge flowing back onto the habitat bench and increasing the risk of exposure to Chinook salmon. While most of the discharges from the stormwater outfalls occur when Chinook salmon are not present along the seawall (November through March), discharges do occur during times when Chinook may be present. Thus, while a general improvement in water quality is expected from the project, episodes of pollutants above biological thresholds will also continue to episodically degrade water quality in the action area, and exposure to these increased stormwater contaminants may reduce survival and fitness of some juvenile migrating Chinook salmon in the area.

Finally, impact pile driving to construct this project will kill, injure or disrupt normal behavior of Chinook salmon present in an area up to 185 meters (607 feet) from the seawall, and some fish injury and mortality are likely to occur during fish removal and handling when the containment wall is constructed.

While the Services use the extent of habitat modified from the project to measure the extent of adverse effects on Chinook salmon, we are able to provide an estimate on the potential number of Chinook salmon that may be affected by construction. Adverse effects to Chinook salmon will result from elevated turbidity and suspended solids, increased sound pressure levels from impact pile driving, capture and handling during the installation of the containment wall, and long-term stormwater discharges. Increased turbidity and suspended solids will result in behavioral changes to 236 Chinook salmon and capture and handling will result in injury or mortality of 12 Chinook salmon. Long-term operational impacts related to stormwater discharges will result in behavioral modifications to 217 juvenile Chinook salmon per year for the life of the project. These numbers may increase in the future as the recovery actions within nearby watersheds increase local population numbers. These behavioral changes due to increased turbidity, suspended solids, and stormwater discharges, and small number of juvenile Chinook salmon injured or killed due to capture and handling will not result in any changes to Chinook salmon populations that utilize the action area.

Impact pile driving will have the largest impact to Chinook salmon. Sound pressure level calculations resulted in injury or mortality occuring out to 185 meters (607 feet) from impact pile driving activities. This results in an estimate of 2,960 juvenile Chinook salmon that may be injured or killed each year that impact pile driving occurs. Pile driving occurs at the beginning of each of the five construction segments (five of the seven years of construction). However, the 2,960 Chinook salmon is overly conservative as the Services used the worst case scenario to determine the number of Chinook salmon in the area. The calculation used the September density estimates for all pile driving activities which is three times higher then the October density estimates and the calculations do not consider that 60 percent of the project area has overwater structures which Chinook salmon do not migrate under.

Chinook salmon within the action area originate from multiple watersheds with 60 percent coming from the Green/Duwamish River and 20 to 30 percent coming from the Skykomish River.

Of the 2,960 juvenile Chinook salmon estimated to be injuried or killed each year, 1,776 are from the Green/Duwamish River and 740 (25 percent) will originate from the Skykomish River. Both the Green/Duwamish and Skykomish river Chinook salmon populations are rated important for salmon recovery. The Green/Duwamish River Chinook salmon population is considered healthy and the Skykomish River population is depressed.

Chinook salmon early marine survival rates are estimated to be between 0.1 and 2.0 percent. Therefore, for the 2,960 juvenile Chinook salmon injured or killed from impact pile driving, the adult equivalents that would have returned to spawn is between 2 and 36 adults for the Green/Duwamish River population and between one and 15 adults for the Skykomish River population. With 2.0 percent survival, the adult equivalent that would have matured and returned to the river to spawn is approximately 1.1 percent of the 2005 to 2009 average number of spawners for the Green/Duwamish River and 0.5 percent for the Skykomish River.

The existing conditions in the action area already limit growth, maturation, and survival during juvenile outmigration because the overwater structures, lack of shallow water habitat, and water quality conditions all work to impair feeding and predator avoidance, and require extra expenditures of energy. During the seven years of construction the proposed project will add a range of additional effects causing behavioral responses, injury, and death of juvenile fish mainly from two populations of PS Chinook salmon that must rely on a waterway influenced by a highly developed and urbanized action area, where they are exposed to degraded nearshore marine and shoreline habitats. While abundance in the two populations will be negatively affected during construction, based on general rates of juvenile to adult survival, NMFS expects overall productivity for these two populations will be only slightly reduced (less than one percent) for a period of about 10 years. This slight reduction in productivity is not at a degree or duration expected to reduce the viability of the affected populations. Moreover, because the project includes construction of a shallow habitat bench to improve habitat for juvenile Chinook salmon prey and to improve the migratory corridor along the seawall, after this 10 year downward pressure, the project's habitat improvements to the habitat along the seawall are likely to benefit Chinook salmon rearing and migrating along the seawall and therefore, improving potential abundance levels of the populations of Chinook salmon using Elliott Bay so that they are likely to meet or exceed pre-project abundances. This increases the odds of improvements in future productivity, incrementally increasing the recovery potential of the ESU. Thus, NMFS anticipates that when the amount of injury and death during construction is added to this baseline condition, and when cumulative effects of non-federal construction and climate change are factored, the Green/Duwamish and Skykomish River populations will not have an increased risk of being extirpated, and overall risk to ESU and DPS are unchanged.

2.6.2 Killer Whales

The endangered status of the Southern Resident Killer whale DPS is based on low abundance, low productivity, and low diversity. The total population of the Southern Resident killer whales is estimated at 84 individuals. The baseline condition in the action area contributes pollutants that can reach the marine environment at low but chronic levels, and limits carrying capacity for juvenile salmonids which are a primary prey species for the killer whales.

Effects of the action, when added to the baseline, will include direct effects to individual whales, and effects to habitat that will cause indirect effects among the DPS. Specifically, sixteen animals per year are expected to have significantly disrupted behaviors (Level B harassment) as a result of the project, primarily a response to underwater noise. This effect among approximately 19 percent of the population is not expected to alter annual rates of recruitment or survival among members of the population, because elevated SPLs will not result in injury to any killer whales, but will result in temporary behavioral changes.. The indirect effects of the project are neutral to beneficial. The proposed project's beneficial effects on PS Chinook migration PCEs are likely to incrementally improve habitat for killer whale prey, by improving both water quality and prey base. Therefore, the proposed action is not expected to alter the likelihood of survival or recovery of this species.

2.6.3 Steller Sea Lions

The threatened status of the eastern DPS of Steller sea lions is based on historic sharp declines in abundance and productivity, but this DPS is currently considered stable or increasing. The total population of the eastern DPS is estimated to be within a range from approximately 58,334 to 72,223 animals with an overall annual rate of increase of 3.1 percent throughout most of the range (Oregon to southeastern Alaska) since the 1970s (Allen and Angliss, 2012). The baseline condition in the action area contributes pollutants that can reach the marine environment and increased noise and activities that limits use by Steller sea lions.

The total estimated number of Steller sea lions that will be affected by the project is (by 175 individuals per year. This number is small compared to a population of approximately 65,000 (0.3 percent). Because the effects will occur among a relatively small proportion of individuals, and the effects to these individuals are behavioral only, the Services do not expect that the proposed project, either directly or indirectly, will alter abundance or productivity of the eastern Steller sea lion DPS. Therefore, when added to the baseline and cumulative effects, the proposed action is not expected to alter the likelihood of survival or recovery of the DPS.

2.6.4 Humpback Whales

The total population of the California/Oregon/Washington humpback whale stock is estimated at about 2,043 individuals. Humpback whales are considered endangered throughout their range. The baseline condition in the action area contributes pollutants that can reach the marine environment and increased noise and activities that limits use by humpback whales.

Four animals per year are expected to have significant disruption in normal behaviors as a result of the project. This is small number relative to the population of 2,043 (0.2 percent), and since this very low percentage will experience only behavioral effects, rather than injury, it is not expected to impact annual rates of recruitment or survival of the population. Therefore, when added to the baseline and cumulative effects, the proposed action is not expected to alter the likelihood of survival or recovery of this species.

2.6.5 Canary Rockfish, Bocaccio, and Yelloweye Rockfish

The NMFS has not identified biological populations of canary rockfish, bocaccio, and yelloweye rockfish. There is also no population estimate for each species. However, the total rockfish population has declined for the past several decades. Within Elliott Bay, larval individuals of all here species may be found in the nearshore. As these species grow, juvenile canary rockfish and bocaccio settle onto shallow nearshore waters in rocky or cobble substrates with or without kelp. Juvenile yelloweye rockfish settle in deeper waters, 30 to 40 meters (98 to 131 feet) in depth. As the fish grow larger they continue to move to deeper waters. Adults occupy waters at depths from 540 to 250 meters (131 to 820 feet).

For all three species, threats from bycatch in commercial and recreational harvest and loss and degradation of habitat threaten the species. The habitat conditions for canary rockfish, bocaccio, and yelloweye rockfish are degraded in the project area. Approximately 60 percent of the seawall contains overwater structures, and all large cobble and rocks are riprap placed at the bottom of the seawall to prevent erosion. Vegetation is limited to open areas between the piers, and kelp is scattered along the seawall.

Because of the limited number of canary rockfish, bocaccio, and yelloweye rockfish in Puget Sound, project construction is expected to have adverse effects on very few individuals of each species. Project construction will result in displacement of riprap to construct the containment wall. Adverse effects will occur through increased turbidity and suspended solids and impact pile driving. Long-term effects will occur from stormwater discharge. However, water quality will improve within Elliott Bay, as stormwater that currently enters Elliott Bay untreated will be treated, reducing pollutant loading. The project will also improve habitat for canary rockfish, bocaccio, and canary rockfish by enhancing substrate throughout the project area and creating a shallow-water habitat bench along the seawall that will improve primary and macroinvertebrate production. Despite expected negative cumulative effects of non-federal projects and degraded conditions in the baseline, the project in the long term is expected to improve some habitat characteristics, which will benefit all future cohorts that use the action area.

2.6.6 Bull Trout

Anadromous bull trout from several different core areas may be present within the action area. Marine areas within the action area are designated bull trout critical habitat and most likely used by populations from the Stillaguamish, Snohomish-Skykomish, and the Puyallup River core areas for foraging and migration. The Stillaguamish River and Puyallup River core areas are both ranked as “at risk,” while the Snohomish River core area is ranked as “potentially at risk” (USFWS 2008). The lower Green/Duwamish River is FMO habitat and does not have a spawning population (USFWS 2004b).

The number of bull trout that may be present in the action area and Elliott Bay, is believed to be small. Bull trout have been captured in the Duwamish River indicating that they migrate through Elliott Bay to reach the Duwamish River. One bull trout was radio tracked migrating between the Snohomish River and the Duwamish River during the winter months. This individual bull trout spent little time in Elliott Bay. Another bull trout was observed during snorkeling surveys on the habitat bench at the Olympic Sculpture Park.

Habitat conditions for bull trout within the project area are degraded. The project area consists of approximately 7,000 linear feet of vertical seawall with little shallow water habitat. While bull trout are not nearshore dependent, they are found near prey and forage fish within the marine environment. The vertical seawall and deepwater does not provide habitat for forage fish spawning. The overwater structures along the seawall also limit primary and macroinvertebrate production, that limits forage fish and salmonid production along the seawall.

Due to the duration of the project (7 years of construction), the Services expect that a small number of bull trout will be impacted. Bull trout are migratory and may be exposed to some construction related impacts such as elevated sound pressure levels during impact pile driving. Similarly, the Services expect that a small number of bull trout will be exposed to stormwater discharges from the seven outfalls and continued pollutant loading in Elliott Bay.

Some aspects of the project will benefit bull trout. The habitat bench, enhanced intertidal habitat and beach areas, and LPS are expected to increase primary and macroinvertebrate production along the seawall that will improve forage fish and salmonid production. The overall long-term benefits from the project are expected to outweigh the short-term adverse effects to bull trout. Therefore, we anticipate that the project will not appreciably affect the abundance of bull trout in any of the nearby core areas or degrade the FMO habitat within Elliott Bay or appreciably reduce the likelihood of survival and recovery of the Coastal-Puget Sound Bull Trout DPS.

Relevance of action area effects to bull trout population viability. Bull trout use of the Elliott Bay nearshore is unknown, with only one bull trout being observed along the Olympic Sculpture Park, and other bull trout migrating quickly through Elliott Bay to and from the Duwamish River. Bull trout from the Stillaguamish, Snohomish, and the Puyallup River core areas may forage and migrate through the project area. The Stillaguamish River and Puyallup River core areas are both ranked as “at risk,” the Snohomish River core area is ranked as “potential risk.” The project will improve habitat for bull trout prey species and therefore will provide a long-term benefit to the bull populations using the action area.

2.6.7 PS Chinook Salmon Critical Habitat

The proposed action will have both short-term and long-term adverse effects on designated critical habitat for PS Chinook salmon. Project construction will result in a temporary decrease in water quality of the nearshore marine PCE in September and October. Increased turbidity due to riprap displacement, timber pile removal, and sheet pile installation will temporarily alter juvenile Chinook migration along the seawall. Long-term water quality degradation will occur from discharge of stormwater pollutants. While discharges can occur throughout the year, most discharges occur between October and April when Chinook salmon are either absent or present in very low numbers.

The project will have a positive benefit to the nearshore PCE by improving the migratory corridor and increasing shallow water habitat and prey species along the seawall. The project installs a habitat bench along the entire seawall that provides a shallow, intertidal habitat that is currently lacking. The habitat bench is covered by a cantilevered sidewalk that has LPS installed to

increase light levels on the habitat bench allowing Chinook salmon to migrate along the seawall instead of migrating around all the piers.

The new seawall will also be constructed with shelved panels that will increase macroinvertebrate production and improve forage opportunities for migrating and rearing Chinook salmon. The habitat bench and enhanced habitat features constructed along the seawall will also provide additional substrate and habitat for macroinvertebrates. The effects of the action will result in a long-term increase in the conservation value of critical habitat in the action area.

2.6.8 Bull Trout Critical Habitat

The project will have both short-term and long-term adverse effects on water quality along the seawall. The project will temporarily decrease the conservation value of the action area during construction due to decreased water quality. Degradation of water quality will impact both PCEs #2 and #8. Long-term water quality degradation will occur from discharge of stormwater. Most of the stormwater discharge will occur between October and April when bull trout are not present as their prey species, juvenile salmonids, are not found in the nearshore.

The project provides long-term benefits by increasing the prey base (PCE #3) and complex habitat (PCE #4) along the shoreline and improving the migratory corridor (PCE #2) along the seawall. The habitat bench will increase habitat complexity and improve the migratory corridor for bull trout by increasing shallow water areas in the nearshore that are currently not available. The light panels in the pedestrian walkway and shallow intertidal habitat bench increase prey species through improved substrate and habitat for macroinvertebrates. The habitat bench also improves the migratory corridor for juvenile salmonids which are prey species for bull trout (PCE #3). These long-term beneficial effects will continue to serve and improve the intended conservation role of critical habitat in the action area.

2.7 Conclusion

After reviewing the status of PS Chinook salmon, SR killer whales, Steller sea lions, humpback whales, bocaccio, canary rockfish and yelloweye rockfish, the environmental baseline for the action area, the effects of the proposed action, and cumulative effects, the Services conclude that the proposed action is not likely to jeopardize the continued existence of PS Chinook salmon, SR killer whales, Steller sea lions, humpback whales, bocaccio, canary rockfish, and yelloweye rockfish.

3.0 ENDANGERED SPECIES ACT: INCIDENTAL TAKE STATEMENT

Section 9 of the ESA and Federal regulation pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without a special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Harm in the definition of "take" means an act which actually kills or injures fish or wildlife. Such an act may include significant habitat modification or degradation which actually kills or injures fish or wildlife by significantly impairing essential behavioral patterns, including, breeding, spawning, rearing, migrating, feeding or sheltering (50 CFR

222.102). The USFWS defines “harass” as an intentional or negligent act or omission which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering (50 CFR 17.3). For this consultation, NMFS adopts this definition of harass with respect to project effects on marine mammals. Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity (50 CFR 222.102). Section 7(b)(4) and section 7(o)(2) provide that taking that is incidental to an otherwise legal agency action is not considered to be prohibited taking under the ESA, if that action is performed in compliance with the terms and conditions of this incidental take statement.

This Opinion includes a prospective ITS for killer whales, Steller sea lions, and humpback whales, however this take statement will not go into effect until the provisions of the MMPA 101(a)(5) are met, and the Terms and Conditions are appended to this ITS subsequent to the issuance of the LOA under the MMPA, as described below.

A marine mammal species or population stock that is listed as threatened or endangered under the ESA is, by definition, also considered depleted under the MMPA. The ESA allows taking of threatened and endangered marine mammals only if authorized by section 1a1(a)(5) of the MMPA. Before incidental take of listed marine mammals may be exempted from the taking prohibition of ESA section 9(a), incidental taking must be authorized under section 101 (a)(5)(D) of the MMPA. The incidental taking will be authorized under section 101(a)(5)(D) of the MMPA if NMFS finds that the taking will have a negligible impact on the species or stocks(s), and will not have an unmitigable adverse impact on the availability of the species or stocks(s) for subsistence uses where relevant.

The measures described below are non-discretionary, and must be undertaken by the COE so that they become binding conditions of any grant or permit issued to SDOT, as appropriate, for the exemption in section 7(o)(2) to apply. The COE has a continuing duty to regulate the activity covered by this incidental take statement. If the COE 1) fails to assume and implement the terms and conditions or 2) fails to require SDOT to adhere to the terms and conditions of the incidental take statement through enforceable terms that are added to the permit or grant document, the protective coverage of section 7(o)(2) may lapse. In order to monitor the impact of incidental take, SDOT must report the progress of the action and its impact on the species to the Services as specified in the Incidental Take Statement (50 CFR 402.14(i)(3)).

3.1 Amount or Extent of Take

Individuals of PS Chinook salmon, SR killer whales, Steller sea lions, humpback whales, bocaccio, canary rockfish, yelloweye rockfish, and bull trout will be present in the action area and be exposed to construction and operational impacts of the project causing take in the form of capture, harassment, and harm. Take in the form of harm can be difficult if not impossible to quantify because it results from actions that modify habitat and indivduals from the various species exposed to habitat changes are likely to express variable responses to exposure. Similarly, activities that cause conditions that harass listed species cause changes in the environment that do not necessarily correlate to numbers of affected individuals. Furthermore,

both the range of individual responses and the number of individuals likely to be exposed are highly variable over time, especially among the fish species.

However, for this consultation, the Services used information about fish presence and area of expected habitat changes to estimate a numeric amount of affected fish. Based on fish surveys within the action and project area, the Services estimated numbers of exposed listed fish within the extent of habitat modified and assumed that each would respond to exposure with injury or death. Because of the environmental and physical conditions of the project area, the numbers are conservative and an estimate that could change monthly or yearly throughout the life of the project.

When the actual number of individuals taken by the action cannot be calculated, the Services rely on a description of the extent of habitat modified to quantify the extent of anticipated take. The extent of habitat change to which present and future generations of fish will be exposed is readily discernible and presents a reliable measure of the extent of take that can be monitored and tracked. These factors also mean that action agencies can determine when the extent of anticipated take is exceeded triggering the need to reinitiate consultation. Therefore, when the specific number of individuals "harmed" cannot be predicted, the Services quantified the extent of take based on the extent of habitat modified (June 3, 1986, 51 FR 19926 at 19954).

Based on the analysis of the effects of the proposed action, the following level of take can be anticipated, which according to ESA section 7(o) and this statement, is exempted from the prohibition against take:

3.1.1 Puget Sound Chinook Salmon

Take is expected in the follow forms and extent:

1) Incidental take of PS Chinook salmon in the form of harm from elevated turbidity (above background conditions) will occur within 50 feet of in-water construction activities. Juvenile PS Chinook salmon are expected to be harmed. This form of take is anticipated to occur for approximately 28 days in September and October over each of the years when the containment wall is being constructed. During Phase 1, the Service estimates that three Chinook salmon per day will be harmed during the 8 days of riprap displacement and timber pile removal, and one Chinook salmon per day during the 20 days of installation of the containment wall: 60 total juvenile fish. During Phase 2, the Services estimate that four Chinook salmon per day will be harmed during the 8 days of riprap displacement and timber pile removal (32 fish), and one Chinook salmon per day during the 20 days of installation of the containment wall (20 fish). Therefore, for these activities, the Services exempt the take of 112 individual juvenile PS Chinook salmon.

2) Incidental take of PS Chinook salmon in the form of harm from impact pile driving. The size of the area in which harm of PS Chinook salmon will occur is within 185 meters (607 feet) radius of impact pile driving. Juvenile PS Chinook salmon are expected to be harmed. Take is anticipated to occur for 20 days in September and October over each of the years when the containment wall is being constructed. The Services estimate that up to 148 Chinook salmon per

day will be injured or killed during the 20 days of impact pile driving during installation of the containment wall Therefore, for these activities, the Services exempt the take of 2960 juvenile PS Chinook salmon.

3) Incidental take of PS Chinook salmon in the form of capture and harm will occur during fish removal and handling during construction of the containment wall. Most captured fish will not die during handling. Juvenile PS Chinook salmon are expected to be captured. Take is anticipated to occur for 1 day in September and October over each of the years when the containment wall is being constructed. During Phase 1, the Services estimate that two Chinook salmon will be captured and harmed during fish removal and handling during construction of the containment wall, and three Chinook salmon during Phase 2.

4) Incidental take of PS Chinook salmon in the form of harm from exposure to dissolved copper and zinc at levels that exceed the biological effects thresholds within 557 ft^2 of each of the seven outfalls during stormwater discharge. Juvenile PS Chinook salmon are expected to be harmed. Take expected during storm events that happen throughout the year, but mainly between March and November when juvenile Chinook salmon are found migrating within the project area. Take will occur throughout the life of the project. The Services estimate the following number of juvenile Chinook salmon may occur within the 557 ft^2 of each of the seven outfalls, and total numbers at each outfall based on the average number of discharge events per year.

Month	Number of Chinook salmon found within 557 ft^2 of an outfall	Number of Chinook salmon impacted per month assuming average monthly discharges
January	0	0
February	0	0
March	0	0
April	0	0
May	0.6	32
June	3.2	137
July	0..6	13
August	0.6	18
September	0.2	9
October	0.1	8
November	0	0
December	0	0
Total		217

3.1.2 Canary Rockfish, Bocaccio and Yelloweye Rockfish

Take is expected in the follow forms and amounts:

1) Incidental take of bocaccio and canary rockfish in the form of harm caused by increased turbidity within 50 feet of in-water construction activities. Larval and juvenile bocaccio and canary rockfish will be injured or killed. Take will accrue for up to 28 days in September and October over each of the years when the containment wall is being constructed . The Services estimate that one bocaccio and one canary rockfish will be harmed during the 28 days of riprap displacement, timber pile removal, and installation of the containment wall.

2) Incidental take of bocaccio and canary rockfish in the form of harm from exposure to elevated underwater SPLs during impact pile driving. The size of the area in which harm of bocaccio and canary rockfish will occur is within 185 meters (607 feet) radius of impact pile driving. Larval and juvenile bocaccio and canary rockfish are expected to be harmed. Take is anticipated to occur for 20 days in September and October over the years when the containment wall is being constructed. The Services estimate that one bocaccio and one canary rockfish will be injured or killed during the 20 days of impact pile driving during installation of the containment wall.

3) Incidental take of bocaccio and canary rockfish in the form of capture and harm resulting from fish removal and handling during construction of the containment wall. Most captured fish will not die during handling. Take is anticipated to occur for 1 day in September and October over each of the years when the containment wall is being constructed. Larval and juvenile bocaccio and canary rockfish are expected to be harmed. The Services estimate that one bocaccio and one canary rockfish per year will be captured and harmed during fish removal and handling.

4) Incidental take of Canary rockfish, bocaccio and yelloweye rockfish in the form of harm from exposure to dissolved copper and zinc at levels that exceed the biological effects thresholds within 557 ft^2 of each of the seven outfalls during stormwater discharge. Adverse conditions will occur throughout the year, but take will occur mainly between March and November when larval and juvenile bocaccio and canary rockfish and larval yelloweye rockfish are found within the nearshore of project area. Take will occur throughout the life of the project. The Services estimate that one canary rockfish, bocaccio and yelloweye rockfish will be harmed each year for the life of the project as a result of increased dissolved copper and dissolved zinc beyond the biological effects thresholds during stormwater discharge.

3.1.3 Killer Whales, Steller Sea Lions, and Humpback Whales

Incidental take of SR killer whales, Steller sea lions, and humpback whales in the form of harassment resulting from the direct impacts of elevated underwater SPLs resulting from vibratory and impact pile driving. The size of the area in which harassment of SR killer whales, Steller sea lions, and humpback whales will occur is within a 3.9 mile radius of pile driving activities. Take is anticipated to occur for 20 days in September and October over each of the years when the containment wall is being constructed, and during installation of concrete piles that are not behind the containment wall. The Services estimate that up to 5 Steller sea lions per day, and 16 killer whales, and 4 humpback whales per year will be harassed during the pile driving activities.

3.1.4 Bull Trout

Take is expected in the follow forms and amounts:

1) Incidental take of bull trout in the form of harm resulting from exposure to elevated underwater SPLs during impact pile driving. The size of the area in which harm of bull trout will occur is within a 185 meter (607 feet) radius of impact pile driving. Sub-adult and adult bull trout are expected to be harmed. Take is anticipated to occur for 20 days in September and October

over each of the years when the containment wall is being constructed. The Services estimate that up to one bull trout per year will be injured or killed during impact pile driving.

2) Incidental take of bull trout in the form of harassment resulting from exposure to dissolved copper and zinc at levels that exceed the biological effects thresholds within 557 ft^2 of each of the seven outfalls during stormwater discharge. Sub-adult and adult bull trout are expected to be harassed. Take is anticipated to occur during storm events that happen throughout the year for the life of the project. The Services estimate that one bull trout per year will be harassed each year as a result of exposure to dissolved copper and zinc at levels that exceed the biological effects thresholds during stormwater discharge.

3.2 Effect of Take

In Sections 2.6 and 2.7 of the Opinion, the Services have concluded that take from the project will not jeopardize any of the listed species considered in this.

3.3 Reasonable and Prudent Measures

Reasonable and prudent measures are nondiscretionary measures to avoid or minimize take that must be carried out by cooperators for the exemption from the prohibition against taking listed species in ESA section 7(o)(2) to apply. The COE has the continuing duty to regulate the activities covered in this ITS where discretionary Federal involvement or control over the action has been retained or is authorized by law. The protective coverage of section 7(o)(2) will lapse if the COE fails to exercise its discretion to adhere to, or to require adherence (where an applicant is involved), to the terms and conditions of the ITS.

The proposed action incorporates an extensive suite of minimizations measures, construction BMPs, monitoring requirements, and a habitat enhancement element. The Services determined that full application of these measures will minimize the extent of take to the maximum practicable. Therefore, the Services prescribe a single RPM to ensure that the SDOT will not exceed the estimated amount of take in section 3.1 of this statement. Full application of conservation measures included as part of the proposed action, together with use of the reasonable and prudent measures and terms and conditions described below, are necessary and appropriate to minimize the impact of incidental take of listed species from the proposed action.

The COE shall:

1. Ensure completion of a monitoring and reporting program to confirm that the take exemption for the proposed action is not exceeded, and that the terms and conditions in this incidental take statement are effective in minimizing incidental take from permitted activities.

3.4 Terms and Conditions

To be exempt from the prohibitions of section 9 of the ESA, the COE, including the applicant, if any, must fully comply with conservation measures described as part of the proposed action

and the following terms and conditions that implement the reasonable and prudent measures described above.

1. To implement reasonable and prudent measure no. 1**,** the COE shall ensure that:

   a. In order to monitor the take exemption the COE shall ensure that SDOT prepares an annual report identifying any incidental take associated with project activities and describing conservation measures implemented to minimize take. The report shall include a description of construction activities conducted and duration of activities to ensure take was not exceeded. The report shall include the following:

      - Results of water quality monitoring during construction. Turbidity monitoring will occur at 50 feet from sediment generating activities at two locations within the water column.
        - If turbidity levels exceed background levels at 50 feet, then the amount of take authorized by the Incidental Take Statement will have been exceeded.
      - Results of the marine mammal monitoring during construction.
      - Results of the acoustic monitoring during pile driving activities. Acoustic monitoring is to identify and confirm pile driving noise levels.
        - If peak, SEL, and RMA dB levels exceed those provided in Table 14, then the amount of take authorized by the Incidental Take Statement will have been exceeded.
      - Dates of construction related activities such as:
        - Riprap displacement, timber pile removal.
        - Installation and removal of the containment wall.
        - Installation of enhanced habitat features.
      - Description of pile driving activities such as:
        - Number of piles (sheet and concrete) installed with a vibratory pile driver.
        - Number of piles (sheet and concrete) installed with an impact pile driver.
        - Number and duration of strikes per pile and throughout the day.
      - Results of fish removal and handling including number of species removed, if fish are captured and handled.
      - Effectiveness and maintnenance of the stormwater treatment system. Determine effectiveness of the stormwater treatment by measuring the amount of contaminants (copper and zinc) and sediment discharged from the stormwater treatment facility. Provide information on the maintenance activities for the stormwater treatment facilities.

   The report shall be submitted to the both the USFWS and NMFS' offices in Lacey, Washington, by September 1 of each year of the project. The report shall summarize the SDOT's compliance with the project description and conservation measures and the level of exempted incidental take during the implementation of the project.

   b. The COE and SDOT shall notify the Services immediately if the results of this program trigger any of the relevant reinitiation requirements specified in the *Reinitiation of Consultation* section of this Opinion (Section 3.5).

NOTICE: If a sick, injured or dead specimen of a threatened or endangered species is found in the action area, the finder must notify either the NMFS Law Enforcement at (206) 526-6133 or (800) 853-1964, or to the USFWS Law Enforcement Office at (360) 753-6045. The finder must take care in handling sick or injured specimens to ensure effective treatment, and in handling dead specimens to preserve biological material in the best possible condition for later analysis of cause of death. The finder should carry out instructions provided by Law Enforcement to ensure evidence intrinsic to the specimen is not disturbed unnecessarily.

3.5 Reinitiation of Consultation

Reinitiation of formal consultation is required and shall be requested by the federal action agency or by the Services where discretionary federal involvement or control over the action has been retained or is authorized by law. Reinitiation shall also be required if: (a) If the amount or extent of take specified in the incidental take statement is exceeded; (b) if new information reveals effects of the action that may affect listed species or designated critical habitat in a manner or to an extent not previously considered; (c) if the identified action is subsequently modified in a manner that has an effect to the listed species or designated critical habitat that was not considered in the biological opinion; or (d) if a new species is listed or critical habitat is designated that may be affected by the identified action (50 CFR 402.16).

4.0 MAGNUSON-STEVENS FISHERY CONSERVATION AND MANAGEMENT ACT

The consultation requirement of Section 305(b) of the Magnuson-Stevens Act (MSA) directs Federal agencies to consult with NMFS on all actions, or proposed actions that may adversely affect EFH. The MSA (Section 3) defines EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." Adverse effects include the direct or indirect physical, chemical, or biological alterations of the waters or substrate and loss of, or injury to, benthic organisms, prey species and their habitat, and other ecosystem components, if such modifications reduce the quality or quantity of EFH. Adverse effects to EFH may result from actions occurring within EFH or outside EFH, and may include site-specific or EFH-wide impacts, including individual, cumulative, or synergistic consequences of actions (50 CFR 600.810). Section 305(b) also requires NMFS to recommend measures that may be taken by the action agency to conserve EFH.

This analysis is based, in part, on information provided by the COE and descriptions of EFH for Pacific coast groundfish (PFMC 2005), coastal pelagic species (PFMC 1998), and Pacific coast salmon (PFMC 1999) contained in the Fishery Management Plans developed by the Pacific Fishery Management Council (PFMC) and approved by the Secretary of Commerce.

4.1 Essential Fish Habitat in Project Area

The proposed action and action area for this consultation are described above in Sections 1.2 (Proposed Action) and 1.3 (Action area). The action area includes areas designated as EFH for various life-history stages of 31 species of Pacific coast groundfish, four species of coastal pelagics, and three species of Pacific salmon (Table 28). The EFH guidelines also identify habitat areas of particular concern (HAPC) based on their importance of ecological function, extent of habitat sensitivity to human degradation, stress associated with developmental activities and rarity of the habitat. Seagrass is identified as the HAPC for Elliott Bay. No HAPCs are identified for freshwater.

4.2 Adverse Effects to Essential Fish Habitat

Based on information provided in the BA and the analysis of effects presented in the Opinion portion of this document (Section 2.4), NMFS concludes that the proposed action will have adverse effects on the EFH of several species listed in Table 28. Adverse effects include:

- elevated underwater sound
- water quality impacts from increased turbidity and suspended solids during construction
- water quality impacts from increased loading of dissolved copper and/or dissolved zinc in operational stormwater discharges to Elliott Bay
- impaired access to shallow water habitat because of the presence of the vertical sea wall
- impaired productivity in shallow water areas due to partial shading from over water structures

4.3 Essential Fish Habitat Conservation Recommendations

The NMFS expects that design of the project to allow light penetration, and increased stormwater treatment will both minimize some adverse effects to designated EFH, though not avoid adverse effects. The following conservation recommendation is necessary to improve fish migration along the Seattle waterfront.

1. Construct a stepped seawall to provide shallow water throughout all tidal stages and to reduce wave energy to improve the migratory corridor along the whole seawall.

The following conservation recommendations are necessary to avoid shade effects from overwater structures.

1. Develop a light limitation assessment and mitigation approach to avoid the effects of overwater structures as part of an ecosystem-based management approach.

2. Maintain, at a minimum, under-dock light levels of 0.5 Photosynthetically Active Radiation (PAR) during daylight hours to avoid fish behavioral interference from shade.

3. Allow the transmission of the ultraviolet light spectra at over-water structures to reduce the effect of structural interference with the ability of managed fish to capture under-dock prey.

4. Avoid negative impacts to salmonid prey resources and habitats by providing PAR levels between 300 and 550 nanometers, which is generally required by native aquatic vegetation.

The NMFS has no conservation recommendations to avoid noise. The project addition of a habitat bench will partially offset the vertical seawall's effect of limiting access to shallow water habitat.

4.4 Statutory Response Requirement

As required by section 305(b)(4)(B) of the MSA, the Federal agency must provide a detailed response in writing to NMFS within 30 days after receiving an EFH Conservation Recommendation from NMFS. Such a response must be provided at least 10 days prior to final approval of the action if the response is inconsistent with any of NMFS' EFH Conservation Recommendations, unless NMFS and the Federal agency have agreed to use alternative time frames for the Federal agency response. The response must include a description of measures proposed by the agency for avoiding, mitigating, or offsetting the impact of the activity on EFH. In the case of a response that is inconsistent with NMFS Conservation Recommendations, the Federal agency must explain its reasons for not following the recommendations, including the scientific justification for any disagreements with NMFS over the anticipated effects of the action and the measures needed to avoid, minimize, mitigate, or offset such effects (50 CFR 600.920(k)(1)).

In response to increased oversight of overall EFH program effectiveness by the Office of Management and Budget, NMFS established a quarterly reporting requirement to determine how many conservation recommendations are provided as part of each EFH consultation and how many are adopted by the action agency. Therefore, we ask that in your statutory reply to the EFH portion of this consultation, you clearly identify the number of conservation recommendations accepted.

Since NMFS is not providing conservation recommendations at this time, no 30-day response from the City of Seattle is required.

4.5 Supplemental Consultation

This concludes consultation under the MSA. The COE must reinitiate EFH consultation with NMFS if the proposed action is substantially revised in a way that may adversely affect EFH, or if new information becomes available that affects the basis for NMFS' EFH conservation recommendations (50 CFR 600.920(l))

Table 28 – Essential fish habitat species and life history stage associated with shallow nearshore water in Puget Sound.

Scientific Name	Common Name	Adult	Juvenile	Larvae	Egg
Groundfish Species					
Anoplopoma fimbria	Sablefish	X	X	X	X
Citharichthys sordidus	Pacific sanddab	X			
Eopsetta jordani	Petrale sole	X			
Glyptocephalus zachirus	Rex sole	X			
Hexagrammos decagrammus	Kelp greenling	X		X	
Hippoglossoides elassodon	Flathead sole	X			
Hydrolagus colliei	Spotted ratfish	X	X		
Isopsetta isolepis	Butter sole	X			
Lepidopsetta bilineata	Rock sole	X			
Merluccius productus	Pacific hake	X	X		
Ophiodon elongates	Lingcod			X	
Parophrys vetulus	English sole	X	X		
Platichthys stellatus	Starry flounder	X	X		
Psettichthys melanostictus	Sand sole	X	X		
Raja binoculata	Big skate	X			
Raja rhina	Longnose skate	X	X		X
Scorpaenichthys marmoratus	Cabezon	X	X	X	X
Sebastes auriculatus	Brown rockfish	X			
Sebastes caurinus	Copper rockfish	X	X		
Sebastes diploproa	Splitnose rockfish		X	X	
Sebastes entomelas	Widow rockfish		X		
Sebastes flavidus	Yellowtail rockfish	X			
Sebastes maliger	Quillback rockfish	X	X		
Sebastes melanops	Black rockfish	X	X		
Sebastes mystinus	Blue rockfish	X	X	X	
Sebastes nebulosus	China rockfish	X	X		
Sebastes nigrocinctus	Tiger rockfish	X			
Sebastes paucispinis	Bocaccio		X	X	
Sebastes pinniger	Canary Rockfish		X	X	
Sebastes ruberrimus	Yelloweye rockfish			X	
Squalus acanthias	Spiny dogfish	X			
Coastal Pelagic Species					
Engraulis mordax	Anchovy	X	X	X	X
Sardinops sagax	Pacific sardine	X	X	X	X
Scomber japonicas	Pacific mackerel	X			
Loligo opalescens	Market squid	X	X	X	
Pacific Salmon					
Oncorhynchus tshawytscha	Chinook salmon	X	X		
Oncorhynchus kisutch	Coho salmon	X	X		
Oncorhynchus gorbuscha	Pink salmon	X	X		

5.0 DATA QUALITY ACT DOCUMENTATION AND PRE-DISSEMINATION REVIEW

Section 515 of the Treasury and General Government Appropriations Act of 2001 (Public Law 106-554) (Data Quality Act) specifies three components contributing to the quality of a document. They are utility, integrity, and objectivity. This section of the Opinion addresses these Data Quality Act (DQA) components, documents compliance with the DQA, and certifies that this Opinion has undergone pre-dissemination review.

Utility: Utility principally refers to ensuring that the information contained in this consultation is helpful, serviceable, and beneficial to the intended users. The users are the COE and SDOT.

Individual copies were provided to the above-listed entities. This consultation will be posted on the NMFS Northwest Region website (http://www.nwr.noaa.gov). The format and naming adheres to conventional standards for style.

Integrity: This consultation was completed on a computer system managed by NMFS in accordance with relevant information technology security policies and standards set out in Appendix III, 'Security of Automated Information Resources,' Office of Management and Budget Circular A-130; the Computer Security Act; and the Government Information Security Reform Act.

Objectivity:

Information Product Category: Natural Resource Plan.

Standards: This consultation and supporting documents are clear, concise, complete, and unbiased; and were developed using commonly accepted scientific research methods. They adhere to published standards including the NMFS ESA Consultation Handbook, ESA Regulations, 50 CFR 402.01, *et seq.*

Best Available Information: This consultation and supporting documents use the best available information, as referenced in the Literature Cited (Section 6.0). The analyses in this Opinion contains more background on information sources and quality.

Referencing: All supporting materials, information, data and analyses are properly referenced, consistent with standard scientific referencing style.

Review Process: This consultation was drafted by NMFS staff with training in ESA implementation, and reviewed in accordance with Northwest Region ESA quality control and assurance processes.

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APPENDIX A

BIOLOGICAL EFFECTS OF SEDIMENT ON BULL TROUT AND THEIR HABITAT

Introduction

As a stream or river flows downslope, it transports sediment and dissolved matter (Skinner and Porter 2000, p. 252). A stream has a natural amount of sediment that is transported through the system that varies throughout the year in response to natural hydrological changes (Galbraith et al. 2006, p. 2488). The amount of sediment that a stream can transport annually is based on numerous factors: precipitation, surface water transport, erosion, topography, geology, streamflow, riparian vegetation, stream geomorphologic characteristic, human disturbance, atmospheric deposition, etc. (Bash et al. 2001, p. 7; Berry et al. 2003, p. 7). Therefore, different watersheds will have different levels or concentrations of turbidity and suspended sediment. A glaciated stream will have higher sediment levels than a spring fed stream (Ahearn 2002, p .2; Uehlinger et al. 2002, p. 1).

Many watersheds are subject to anthropogenic disturbances that can produce substantial inputs of sediments into streams (Barrett et al. 1992, p. 437). Turbidity, suspended solids, sediment, and siltation have been consistently listed as impairments in the U.S. Environmental Protection Agency's (EPA) 305(b) water quality reports in rivers and streams, lakes, reservoirs, ponds, wetlands, and oceans shoreline waters (Berry et al. 2003, p. 4). The EPA's 305(b) list provides the U.S. Congress and the public a means of determining or assessing the current condition of water quality within each individual state. Excessive sedimentation, natural and anthropogenic, has been estimated to occur in 46 percent of all streams and rivers in the U.S. and is considered the most important factor limiting fish habitat and causing water quality impairment (Berry et al. 2003, pp. 4, 7; Judy et al. 1985 as cited in Henley et al. 2000, p. 126). One of the most pervasive influences of land-use activities on stream ecosystems is an increase in sediment yield resulting from point source discharges associated with in-stream activities (Suren and Jowett 2001, p. 725).

Aquatic organisms have adapted to the natural variation in sediment load that occurs seasonally within the stream (Birtwell 1999, p. 7; FAO 1976, pp. 13, 15). Field experiments have found a thirty-fold increase in salmonids' (coho salmon) tolerance to suspended solids between August and November when naturally occurring concentrations are expected to be high (Cederholm and Reid 1987, p. 388).

The introduction of sediment in excess of natural amounts can have multiple adverse effects on bull trout and their habitat (Berry et al. 2003, p. 7; Rhodes et al. 1994, pp. 16-21). The effect of sediment beyond natural background conditions can be fatal at high levels. Embryo survival and subsequent fry emergence success have been highly correlated to percentage of fine material within the streambed (Shepard et al. 1984, pp. 146, 152). Low levels of sediment may result in sublethal and behavioral effects such as increased activity, stress, and emigration rates; loss or reduction of foraging capability; reduced growth and resistance to disease; physical abrasion; clogging of gills; and interference with orientation in homing and migration (Barrett et al. 1992,

p. 437; Bash et al. 2001, p. 9; Berry et al. 2003, p. 33; Lake and Hinch 1999, p. 865; McLeay et al. 1987, p. 671; Newcombe and MacDonald 1991, pp. 72, 76, 77; Vondracek et al. 2003, p. 1005; Watts et al. 2003, p. 551). The effects of increased suspended sediments can cause changes in the abundance and/or type of food organisms, alterations in fish habitat, and long-term impacts to fish populations (Anderson et al. 1996, pp. 1, 9, 12, 14, 15; Reid and Anderson 1999, pp. 1, 7-15). No threshold has been determined in which fine-sediment addition to a stream is harmless (Suttle et al. 2004, p. 973). Even at low concentrations, fine-sediment deposition can decrease growth and survival of juvenile salmonids.

Aquatic systems are complex interactive systems, and isolating the effects of sediment to fish is difficult (Castro and Reckendorf 1995, pp. 2-3). The effects of sediment on receiving water ecosystems are complex and multi-dimensional, and further compounded by the fact that sediment flux is a natural and vital process for aquatic systems (Berry et al. 2003, p. 4). Environmental factors that affect the magnitude of sediment impacts on salmonids include duration of exposure, frequency of exposure, toxicity, temperature, life stage of fish, angularity and size of particle, severity/magnitude of pulse, time of occurrence, general condition of biota, and availability of and access to refugia (Bash et al. 2001, p. 11). Potential impacts caused by excessive suspended sediments are varied and complex and are often masked by other concurrent activities (Newcombe 2003, p. 530). The difficulty in determining which environmental variables act as limiting factors has made it difficult to establish the specific effects of sediment impacts on fish (Chapman 1988, p. 2). For example, excess fines in spawning gravels may not lead to smaller populations of adults if the amount of juvenile winter habitat limits the number of juveniles that reach adulthood. Often there are multiple independent variables with complex inter-relationships that can influence population size.

The ecological dominance of a given species is often determined by environmental variables. A chronic input of sediment could tip the ecological balance in favor of one species in mixed salmonid populations or in species communities composed of salmonids and nonsalmonids (Everest et al. 1987, p. 120). Bull trout have more spatially restrictive biological requirements at the individual and population levels than other salmonids (USFWS 1998, p. 5). Therefore, they are especially vulnerable to environmental changes such as sediment deposition.

Bull trout are apex predators that prey on a variety of species including terrestrial and aquatic insects and fish (Rieman and McIntyre 1993, p. 3). Fish are common in the diet of individual bull trout that are over 110 millimeters or longer. Large bull trout may feed almost exclusively on fish. Therefore, when analyzing impacts of sediment on bull trout, it is very important to consider other fish species that are part of their prey base. While sediment may not directly impact bull trout, the increased sediment input may affect the spawning and population levels of Chinook and coho salmon, cutthroat trout, and steelhead, or other species that are potential prey for bull trout. The following effects of sediment are not specific to bull trout alone. All salmonids can be affected similarly.

This document identifies the biological effects of sediment on fish and their habitat including the different life stage(s) affected by sediment input.

Sediment Classifications and Definitions

Sediment within a stream can be classified into a variety of categories: turbidity, suspended sediment, bedload, deposited sediment, and wash load (Bash et al. 2001, pp. 3-4; Waters 1995, pp. 13-14). Sediment category definitions include:

- Turbidity - Optical property of water which results from the suspended and dissolved materials in the water. This causes light to be scattered rather than transmitted in straight lines. Turbidity is measured in nephelometric turbidity units (NTUs). Measurements of turbidity can quickly estimate the amount of sediment within a sample of water.
- Suspended sediment - Represents the actual measure of mineral and organic particles transported in the water column. Suspended sediment is measured in mg/L and is an important measure of erosion, and is linked to the transport of nutrients, metals, and industrial and agricultural chemicals through the river system.
- Bedload - Consists of larger particles on the stream bottom that move by sliding, rolling, or saltating along the substrate surface. Bedload is measured in tons/day, or tons/year.
- Deposited sediment - The intermediate sized sediment particles that settle out of the water column in slack or slower moving water. Based on water velocity and turbulence, these intermediate size particles may be suspended sediment or bedload.
- Wash load - Finest particles in the suspended load that are continuously maintained in suspension by the flow turbulence. Therefore significant quantities are not deposited in the bed.

Suspended sediment, turbidity, and deposited sediment are not associated with specific particle sizes, as there will be considerable overlap depending on velocity, turbulence, and gradient (MacDonald et al. 1991, p. 98; Waters 1995, p. 14). Turbidity cannot always be correlated with suspended solid concentrations due to the effects of size, shape and refractive index of particles (Bash et al. 2001, p. 5). Turbidity and suspended sediment affect the light available for photosynthesis, visual capability of aquatic animals, gill abrasion, and physiology of fish. Suspended and deposited sediment affect the habitat available for macroinvertebrates, the quality of gravel for fish spawning, and the amount of habitat for fish rearing (Waters 1995, p. 14).

The size of particles within the stream is also important. The quantity of "fines" within a stream ecosystem is usually associated with the degree of fish population declines (Castro and Reckendorf 1995, p. 2). Particle diameters less than 6.4 mm are generally defined as "fines" (Bjornn et al. 1977, p. 1; Bjornn and Reiser 1991, p. 103; Castro and Reckendorf 1995, p. 2; Chapman 1988, p. 14; Hillman et al. 1987, p. 185; MBTSG 1998, p. 8; Rieman and McIntyre 1993, p. 6; Shepard et al. 1984, p. 148).

Biological Effects of Sediment on Bull Trout

Classification of Sediment Effects

In the absence of detailed local information on population dynamics and habitat use, any increase in the proportion of fines in substrates should be considered a risk to the productivity of an

environment and to the persistence of associated bull trout populations (Rieman and McIntyre 1993, p. 6). Specific effects of sediment on fish and their habitat can be put into three classes that include (Bash et al. 2001, p. 10; Newcombe and MacDonald 1991, pp. 72-73; Waters 1995, pp. 81-82)

Lethal:	Direct mortality to any life stage, reduction in egg-to-fry survival, and loss of spawning or rearing habitat. These effects damage the capacity of the bull trout to produce fish and sustain populations.
Sublethal:	Reduction in feeding and growth rates, decrease in habitat quality, reduced tolerance to disease and toxicants, respiratory impairment, and physiological stress. While not leading to immediate death, may produce mortalities and population decline over time.
Behavioral:	Avoidance and distribution, homing and migration, and foraging and predation. Behavioral effects change the activity patterns or alter the kinds of activity usually associated with an unperturbed environment. Behavior effects may lead to immediate death or population decline or mortality over time.

Direct Effects

Gill trauma

High levels of suspended sediment and turbidity can result in direct mortality of fish by damaging and clogging gills (Curry and MacNeill 2004, p. 140). Fish gills are delicate and easily damaged by abrasive silt particles (Bash et al. 2001, p. 15). As sediment begins to accumulate in the gill filaments, fish excessively open and close their gills to expunge the silt. If irritation continues, mucus is produced to protect the gill surface, which may impede the circulation of water over the gills and interfere with fish respiration (Bash et al. 2001, p. 15). Gill flaring or coughing abruptly changes buccal cavity pressure and is a means of clearing the buccal cavity of sediment. Gill sediment accumulation may result when fish become too fatigued to continue clearing particles via the cough reflex (Servizi and Martens 1991, p. 495).

Fish are more susceptible to increased suspended sediment concentrations at different times of the year or in watersheds with naturally high sediment such as glaciated streams. Fish secrete protective mucous to clean the gills (Erman and Ligon 1985, p. 18). In glaciated systems or during winter and spring high flow conditions when sediment concentrations are naturally high, the secretion of mucous can keep gills clean of sediment. Protective mucous secretions are inadequate during the summer months, when natural sediment levels are low in a stream system. Consequently, sediment introduction at this time may increase the vulnerability of fish to stress and disease (Bash et al. 2001, p. 12).

Spawning, redds, eggs, and alevins

The effects of suspended sediment, deposited in a redd and potentially reducing water flow and smothering eggs or alevins or impeding fry emergence, are related to sediment particle sizes of

the spawning habitat (Bjornn and Reiser 1991, p. 98). Sediment particle size determines the pore openings in the redd gravel. With small pore openings, more suspended sediments are deposited and water flow is reduced compared to large pore openings.

Survival of eggs is dependent on a continuous supply of well oxygenated water through the streambed gravels (Anderson et al. 1996, p. 13; Cederholm and Reid 1987, p. 384). Eggs and alevins are generally more susceptible to stress by suspended solids than are adults. Accelerated suspended solids can reduce the flow of water and, therefore, oxygen to eggs and alevins. This can decrease egg survival, decrease fry emergence rates (Bash et al. 2001, pp. 17-18; Cederholm and Reid 1987, p. 384; Chapman 1988, pp. 12-16), delay development of alevins (Everest et al. 1987, p. 113), reduce growth and cause premature hatching and emergence (Birtwell 1999, p. 19). Fry delayed in their emergence are also less able to compete for environmental resources than fish that have undergone normal development and emergence (intra- or interspecific competition) (Everest et al. 1987, p. 113). Sedimentation fills the interstitial spaces and can prevent alevins from emerging from the gravel (Anderson et al. 1996, p. 13; Suttle et al. 2004, pp. 971-972).

Several studies have documented that fine sediment can reduce the reproductive success of salmonids. Natural egg-to-fry survival of coho salmon, sockeye and kokanee has been measured at 23 percent, 23 percent and 12 percent, respectively (Slaney et al. 1977, p. 33). Substrates containing 20 percent fines can reduce emergence success by 30-40 percent (MacDonald et al. 1991, p. 99). A decrease of 30 percent in mean egg-to-fry survival can be expected to reduce salmonid fry production to extremely low levels (Slaney et al. 1977, p. 33).

Indirect Effects

Macroinvertebrates

Sedimentation can have an effect on bull trout and fish populations through impacts or alterations to the macroinvertebrate communities or populations (Anderson et al. 1996, pp. 14-15). Increased turbidity and suspended sediment can reduce primary productivity by decreasing light intensity and periphytic (attached) algal and other plant communities (Anderson et al. 1996, p. 14; Henley et al. 2000, p. 129; Suren and Jowett 2001, p. 726). This results in decreased macroinvertebrates that graze on the periphyton.

Sedimentation also alters the habitat for macroinvertebrates, changing the species density, diversity and structure of the area (Anderson et al. 1996, pp. 14-15; Reid and Anderson 1999, pp. 10-12; Shaw and Richardson 2001, p. 2220; Waters 1995, pp. 61-78). Certain groups of macroinvertebrates are favored by salmonids as food items. These include mayflies, caddisflies, and stoneflies. These species prefer large substrate particles in riffles and are negatively affected by fine sediment (Everest et al. 1987, p. 115; Waters 1995, p. 63). Increased sediment can affect macroinvertebrate habitat by filling of interstitial space and rendering attachment sites unsuitable. This may cause invertebrates to seek more favorable habitat (Rosenberg and Snow 1975, p. 70). With increasing fine sediment, invertebrate composition and density changes from available, preferred species (i.e., mayflies, caddisflies, and stoneflies) to non-preferred, more unavailable species (i.e., aquatic worms and other burrowing species) (Henley et al. 2000, pp. 126, 130; Reid and Anderson 1999, p. 10; Shaw and Richardson 2001, p. 2219; Suren and Jowett 2001, p. 726;

Suttle et al. 2004, p. 971). The degree to which substrate particles are surrounded by fine material was found to have a strong correlation with macroinvertebrate abundance and composition (Birtwell 1999, p. 23). At an embeddedness of one-third, insect abundance can decline by about 50 percent, especially for riffle-inhabiting taxa (Waters 1995, p. 66).

Increased turbidity and suspended solids can affect macroinvertebrates in multiple ways through increased invertebrate drift, feeding impacts, and respiratory problems (Berry et al. 2003, pp. 8, 11; Cederholm and Reid 1987, p. 384; Shaw and Richardson 2001, p. 2218). The effect of turbidity on light transmission has been well documented and results in increased invertebrate drift (Birtwell 1999, pp. 21, 22; Waters 1995, p. 58). This may be a behavioral response associated with the night-active diel drift patterns of macroinvertebrates. While increased turbidity results in increased macroinvertebrate drift, it is thought that the overall invertebrate populations would not fall below the point of severe depletion (Waters 1995, p. 59). Invertebrate drift is also an important mechanism in the repopulation, recolonization, or recovery of a macroinvertebrate community after a localized disturbance (Anderson et al. 1996, p. 15; Reid and Anderson 1999, pp. 11-12).

Increased suspended sediment can affect macroinvertebrates by abrasion of respiratory surface and interference with food uptake for filter-feeders (Anderson et al. 1996, p. 14; Berry et al. 2003, p. 11; Birtwell 1999, p. 21; Shaw and Richardson 2001, p. 2213; Suren and Jowett 2001, pp. 725-726). Increased suspended sediment levels tend to clog feeding structures and reduce feeding efficiencies, which results in reduced growth rates, increased stress, or death of the invertebrates (Newcombe and MacDonald 1991, p. 73). Invertebrates living in the substrate are also subject to scouring or abrasion which can damage respiratory organs (Bash et al. 2001, p. 25).

Feeding Efficiency

Increased turbidity and suspended sediment can affect a number of factors related to feeding for salmonids, including feeding rates, reaction distance, prey selection, and prey abundance (Barrett et al. 1992, pp. 437, 440; Bash et al. 2001, p. 21; Henley et al. 2000, p. 133). Changes in feeding behavior are primarily related to the reduction in visibility that occurs in turbid water. Effects on feeding ability are important as salmonids must meet energy demands to compete with other fishes for resources and to avoid predators. Reduced feeding efficiency would result in lower growth and fitness of bull trout and other salmonids (Barrett et al. 1992, p. 442; Sweka and Hartman 2001, p. 138).

Distance of prey capture and prey capture success both were found to decrease significantly when turbidity was increased (Berg and Northcote 1985, pp. 1414-1415; Sweka and Hartman 2001, p. 141; Zamor and Grossman 2007, pp. 168, 170, 174). Waters (1995, p. 83) states that loss of visual capability, leading to reduced feeding, is one of the major sublethal effects of high suspended sediment. Increases in turbidity were reported to decrease reactive distance and the percentage of prey captured (Bash et al. 2001, pp. 21-23; Klein 2003, pp. 1, 21; Sweka and Hartman 2001, p. 141). At 0 NTUs, 100 percent of the prey items were consumed; at 10 NTUs, fish frequently were unable to capture prey species; at 60 NTUs, only 35 percent of the prey items were captured. At 20 to 60 NTUs, significant delay in the response of fish to prey was observed

(Bash et al. 2001, p. 22). Loss of visual capability and capture of prey leads to depressed growth and reproductive capability.

To compensate for reduced encounter rates with prey under turbid conditions, prey density must increase substantially or salmonids must increase their active searches for prey (Sweka and Hartman 2001, p. 144). Such an increase in activity and feeding rates under turbid conditions reduces net energy gain from each prey item consumed (Sweka and Hartman 2001, p. 144).

Sigler et al. (1984, p. 150) found that a reduction in growth occurred in steelhead and coho salmon when turbidity was as little as 25 NTUs. The slower growth was presumed to be from a reduced ability to feed; however, more complex mechanisms such as the quality of light may also affect feeding success rates. Redding et al. (1987, p. 742) found that suspended sediment may inhibit normal feeding activity, as a result of a loss of visual ability or as an indirect consequence of increased stress.

Habitat Effects

Compared to other salmonids, bull trout have more specific habitat requirements that appear to influence their distribution and abundance (Rieman and McIntyre 1993, p. 7). All life history stages are associated with complex forms of cover including large woody debris, undercut banks, boulders, and pools. Other habitat characteristics important to bull trout include channel and hydrologic stability, substrate composition, temperature, and the presence of migration corridors (Rieman and McIntyre 1993, p. 5).

Increases in sediment can alter fish habitat or the utilization of habitats by fish (Anderson et al. 1996, p. 12). The physical implications of sediment in streams include changes in water quality, degradation of spawning and rearing habitat, simplification and damage to habitat structure and complexity, loss of habitat, and decreased connectivity between habitats (Anderson et al. 1996, pp. 11-15; Bash et al. 2001, pp. 1, 12, 18, 30). Biological implications of this habitat damage include underutilization of stream habitat, abandonment of traditional spawning habitat, displacement of fish from their preferred habitat, and avoidance of habitat (Newcombe and Jensen 1996, p. 695).

As sediment enters a stream it is transported downstream under normal fluvial processes and deposited in areas of low shear stress (MacDonald and Ritland 1989, p. 21). These areas are usually behind obstructions, near banks (shallow water) or within interstitial spaces. This episodic filling of successive storage compartments continues in a cascading fashion downstream until the flow drops below the threshold required for movement or all pools have reached their storage capacities (MacDonald and Ritland 1989, p. 21). As sediment load increases, the stream compensates by geomorphologic changes in increased slope, increased channel width, decreased depths, and decreased flows (Castro and Reckendorf 1995, p. 21). These processes contribute to increased erosion and sediment deposition that further degrade salmonid habitat.

Loss of acceptable habitat and refugia, as well as decreased connectivity between habitats, reduces the carrying capacity of streams for salmonids (Bash et al. 2001, p. 30). This loss of habitat or exclusion of fish from their habitat, if timed inappropriately, could impact a fish

population if the habitat within the affected stream reach is critical to the population during the period of the sediment release (Anderson et al. 1996, p. 12; Reid and Anderson 1999, p. 13). For example, if summer pool habitat used by adults as holding habitat prior to spawning is a limiting factor within a stream, increased sediment and reduced pool habitat during the summer can decrease the carrying capacity of the stream reach and decrease the fish population. In systems lacking adequate connectivity of habitats, fish may travel longer distances or use less desirable habitats, increasing biological demands and reducing their fitness.

The addition of fine sediment (less than 6.4 mm) to natural streams during summer decreased abundance of juvenile Chinook salmon in almost direct proportion to the amount of pool volume lost to fine sediment (Bjornn et al. 1977, p. 31). Similarly, the inverse relationship between fine sediment and densities of rearing Chinook salmon indicates the importance of winter habitat and high sediment loads (Bjornn et al. 1977, pp. 26, 38, 40). As fine sediments fill the interstitial spaces between the cobble substrate, juvenile Chinook salmon were forced to leave preferred habitat and to utilize cover that may be more susceptible to ice scouring, predation, and decreased food availability (Hillman et al. 1987, p. 194). Deposition of sediment on substrate may lower winter carrying capacity for bull trout (Shepard et al. 1984, p. 153). Food production in the form of aquatic invertebrates may also be reduced.

Juvenile bull trout densities are highly influenced by substrate composition (MBTSG 1998, p. 9; Rieman and McIntyre 1993, p. 6; Shepard et al. 1984, p. 153). During the summer, juvenile bull trout hold positions close to the stream bottom and often seek cover within the substrate itself. When streambed substrate contains more than 30 percent fine materials, juvenile bull trout densities drop off sharply (Shepard et al. 1984, p. 152). Any loss of interstitial space or streambed complexity through the deposition of sediment would result in a loss of summer and winter habitats (MBTSG 1998, p. 9). The reduction of rearing habitat will ultimately reduce the potential number of recruited juveniles and therefore reducing population numbers (Shepard et al. 1984, pp. 153-154). In fact, Johnston et al. (2007, p. 125) found that density-dependent survival during the earliest of the juvenile stages (between egg and age-1) regulated recruitment of adult bull trout in the population.

Although an avoidance response by fish to increased sediment may be an initial adaptive survival strategy, displacement from cover could be detrimental. It is possible that the consequences of fish moving from preferred habitat, to avoid increasing levels of suspended sediment, may not be beneficial if displacement is to sub-optimal habitat, because they may be stressed and more vulnerable to predation (Birtwell 1999, p. 12).

In addition to altering stream bed composition, anthropogenic input of sediment into a stream can change channel hydrology and geometry (Owens et al. 2005, pp. 694-695). Sediment release can reduce the depth of pools and riffle areas (Anderson et al. 1996, p. 12). This can reduce available fish habitat, decrease fish holding capacity, and decrease fish populations (Anderson et al. 1996, pp. 12, 14).

Physiological Effects

Sublethal levels of suspended sediment may cause undue physiological stress on fish, which may reduce the ability of the fish to perform vital functions (Cederholm and Reid 1987, pp. 388, 390). Stress is defined as a condition perceived by an organism which threatens a biological function of the organism, and a set of physiological and behavioral responses is mounted to counteract the condition (Overli 2001, p. 7). A stressor is any anthropogenic or natural environmental change severe enough to require a physiological response on the part of a fish, population, or ecosystem (Anderson et al. 1996, pp. 5-6; Jacobson et al. 2003, p. 2; USEPA 2001, pp. 1-2). At the individual level, stress may affect physiological systems, reduce growth, increase disease, and reduce the individual's ability to tolerate additional stress (Anderson et al. 1996, p. 7; Bash et al. 2001, p. 17). At the population level, the effects of stress may include reduced spawning success, increased larval mortality, and reduced recruitment to succeeding life stages and, therefore, overall population declines (Bash et al. 2001, p. 17).

Upon encountering a stressor, the fish responds through a series of chemical releases in its body. These primary chemical and hormonal releases include catecholamine (e.g. epinephrine, norepinehprine) in the circulatory system, corticosteroids (e.g. cortisol) from the interregnal tissue, and hypothalamic activation of the pituitary gland (Barton 2002, p. 517; Davis 2006, p. 116; Gregory and Wood 1999, p. 286; Schreck et al. 2001, p. 5). Primary chemical releases result in secondary releases or changes in plasma, glucose, tissue ion, metabolite levels, and hematological features. These secondary responses relate to physiological adjustments in metabolism, respiration, immune and cellular function (Barton 2002, p. 517; Haukenes and Buck 2006, p. 385; Mazeaud et al. 1977, p. 201). After secondary responses, continued stress results in tertiary stress responses which affect whole-animal performance such as changes in growth, condition, resistance to disease, metabolic scope for activity, behavior, and ultimately survival (Barton 2002, p. 517; Pickering et al. 1982, p. 229; Portz et al. 2006, pp. 126-127).

Stress in a fish occurs when the homeostatic or stabilizing process in the organism exceed the capability of the organism to compensate for the biotic or abiotic challenge (Anderson et al. 1996, p. 5). The response to a stressor is an adaptive mechanism that allows the fish to cope with the real or perceived stressor in order to maintain its normal or homeostatic state (Barton 2002, p. 517). Acclimation to a stressor can occur if compensatory physiological responses by the fish are able to re-establish a satisfactory relationship between the changed environment and the organism (Anderson et al. 1996, p. 5). The ability of an individual fish to acclimate or tolerate the stress will depend on the severity of the stress and the physiological limits of the organism (Anderson et al. 1996, p. 5). In a natural system, fish are exposed to multiple chemical and physical stressors which can combine to cause adverse effects (Berry et al. 2003, p. 4). The chemical releases from each stressor results in a cumulative or additive response (Barton et al. 1986, pp. 245, 247; Cobleigh 2003, pp. 16, 39, 55; Milston et al. 2006, p. 1172; USEPA 2001, pp. 3-25).

Stress in fish results in extra cost and energy demands. Elevated oxygen consumption and increased metabolic rate result from the reallocation of energy to cope with the stress (Barton and Schreck 1987, pp. 259-260; Contreras-Sanchez et al. 1998, pp. 439, 444; McCormick et al. 1998, pp. 222, 231). An approximate 25 percent increase in metabolic cost, over standard metabolism

requirements, is needed to compensate for a perceived stress (Barton and Schreck 1987, p. 260; Davis 2006, p. 116). Stressed fish would thus have less energy available for other life functions such as seawater adaptation, disease resistance, reproduction, or swimming stamina (Barton and Schreck 1987, p. 261; Contreras-Sanchez et al. 1998, p. 444).

Tolerance to suspended sediment may be the net result of a combination of physical and physiological factors related to oxygen availability and uptake by fish (Servizi and Martens 1991, p. 497). The energy needed to perform repeated coughing (see Gill trauma section) increases metabolic oxygen demand. Metabolic oxygen demand is related to water temperature. As temperatures increase, so does metabolic oxygen demand, but concentrations of oxygen available in the water decreases. Therefore, a fish's tolerance to suspended sediment may be primarily related to the capacity of the fish to perform work associated with the cough reflex. However, as sediment increases, fish have less capability to do work, and therefore less tolerance for suspended sediment (Servizi and Martens 1991, p. 497).

Once exposed to a stressor, the primary chemical releases can take one-half to 24 hours to peak (Barton 2002, p. 520; Quigley and Hinch 2006, p. 437; Schreck 1981, p. 298). Recovery or return of the primary chemical release to normal or resting levels can take 2 hours to 2 weeks (Mazeaud et al. 1977, pp. 205-206; Schreck et al. 2001, p. 313). In a study of handling stress, chemical release of cortisol peaked at 2 hours and returned to normal in 4 hours. However, complete recovery took 2 weeks (Pickering et al. 1982, pp. 236, 241). Fish exposed to two or more stresses require longer recovery times than fish exposed only to one stressor indicating the cumulative effects of stress (Sigismondi and Weber 1988, pp. 198-199).

Redding el al. (1987, pp. 740-741) observed higher mortality in young steelhead trout exposed to a combination of suspended sediment (2500 mg/L) and a bacteria pathogen, than when exposed to the bacteria alone. Physiological stress in fishes may decrease immunological competence, growth, and reproductive success (Bash et al. 2001, p. 16).

Behavioral effects

Increased turbidity and suspended sediment may result in behavior changes in salmonids. These changes are the first effects evoked from increased levels of turbidity and suspended sediment (Anderson et al. 1996, p. 6). These behavioral changes include avoidance of habitat, reduction in feeding, increased activity, redistribution and migration to other habitats and locations, disruption of territoriality, and altered homing (Anderson et al. 1996, p. 6; Bash et al. 2001, pp. 19-25; Suttle et al. 2004, p. 971). Many behavioral effects result from changes in stream habitat (see Habitat effects section). As suspended sediment concentration increases, habitat may be lost which results in abandonment and avoidance of preferred habitat. Stream reach emigration is a bioenergetic demand that may affect the growth or reproductive success of the individual fish (Bash et al. 2001, p. 12). Pulses of sediment result in downstream migration of fish, which disrupts social structures, causes downstream displacement of other fish and increases intraspecific aggression (Bash et al. 2001, pp. 12, 20; McLeay et al. 1987, pp. 670-671; Suttle et al. 2004, p. 971). Loss of territoriality and the breakdown of social structure can lead to secondary effects of decreased growth and feeding rates, which may lead to mortality (Bash et al. 2001, p. 20; Berg and Northcote 1985, p. 1416).

Downstream migration by bull trout provides access to more prey, better protection from avian and terrestrial predators, and alleviates potential intraspecific competition or cannibalism in rearing areas (MBTSG 1998, p. 13). Benefits of migration from tributary rearing areas to larger rivers or estuaries may be increased growth potential. Increased suspended solids may result in premature or early migration of both juveniles and adults or avoidance of habitat and migration of nonmigratory resident bull trout.

High turbidity may delay migration back to spawning sites, although turbidity alone does not seem to affect homing. Delays in spawning migration and associated energy expenditure may reduce spawning success and therefore population size (Bash et al. 2001, p. 29).

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APPENDIX B

MARINE MAMMAL MONITORING AND MITIGATION PLAN

Elliott Bay Seawall Project

Marine Mammal Protection Act and Endangered Species Act

Updated Marine Mammal Monitoring and Mitigation Plan

April 2013

Reference: 0648-BC69

Submitted to:

National Oceanic and Atmospheric Administration's
National Marine Fisheries Service
Office of Protected Resources
1315 East-West Highway
Silver Spring, Maryland 20910-3226

Submitted by:

City of Seattle
Department of Transportation
700 5th Avenue, Suite 3900
Seattle WA 98124

Prepared by:

Tetra Tech, Inc.

MARINE MAMMAL PROTECTION ACT AND ENDANGERED SPECIES ACT

UPDATED MARINE MAMMAL MONITORING AND MITIGATION PLAN

Agreement No. T09-24

April 2013

The Elliott Bay Seawall Project (EBSP) is a joint effort between the City of Seattle Department of Transportation (SDOT), and the United States Army Corps of Engineers (USACE). To conduct this project, SDOT contracted with:

Tetra Tech, Inc.
1420 5th Avenue, Suite 550
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In association with:

Anchor QEA
BergerABAM
Coast & Harbor Engineering
EnviroIssues
Fehr & Peers
Floyd|Snider
GHD
JA Brennan
LPES
Magnusson Klemencic Associates
Mimi Sheridan
Nelson\Nygaard
Power Engineers
Risk Strategics
Shannon & Wilson
SWCA Environmental Consultants
Washington2 Advocates
William P. Ott Construction Consultants
ZGF Architects

City of Seattle

Marine Mammal Protection Act and Endangered Species Act Updated Monitoring and Mitigation Plan

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INTRODUCTION

This Marine Mammal Monitoring and Mitigation Plan updates Sections 14 and 15 of the Request for Letter of Authorization under the Marine Mammal Protection Act (MMPA), which was submitted by the Seattle Department of Transportation (SDOT) to the National Oceanic and Atmospheric Administration (NOAA) Office of Protected Resources in September 2012 for the Elliott Bay Seawall Project (EBSP). The monitoring plan was also provided to the NOAA Northwest Regional Office as an attachment to the Biological Assessment submitted in November 2012 for the Endangered Species Act (ESA) Section 7 consultation for the project.

This update provides more detail on the monitoring protocols, ensures better consistency with the Draft Rule (Reference: 0648-BC69) published on April 12, 2013 (NOAA 2013), and revises the primary form of monitoring as land-based rather than boat-based to more effectively ensure adequate monitoring coverage of the exclusion zones and thresholds for Level B harassment where a "take" must be recorded.

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SECTION 14. CONSERVATION AND MITIGATION MEASURES UPDATED MONITORING AND MITIGATION PLAN

The following conservation measures would be employed for the duration of the proposed project. The proposed conservation measures are intended to avoid and/or minimize potential effects to ESA-listed marine mammal species and designated critical habitat, as well as other marine mammals that may occur in the area of potential effects. Most proposed conservation measures are well established as effective and have been implemented for similar projects in Puget Sound and elsewhere.

Each conservation measure would be included in the Contract Plans and Specifications document, and SDOT would conduct monitoring for compliance with MMPA and ESA approvals. Existing SDOT policy and construction administration practice requires an SDOT inspector to be present onsite at all times during construction activities to ensure contract compliance. The inspector and the contractor will each have a copy of the Contract Plans and Specifications document and will be aware of all requirements. The inspector would also be formally trained in environmental provisions and compliance prior to the start of construction.

The monitoring and mitigation plan includes construction monitoring protocol as well as guidelines for construction activities associated with pile installation and removal. Monitoring would occur by observing construction activities and the surrounding marine environment for signs of marine mammals and/or potential threats to marine mammals, as well as measuring underwater noise produced by in-water pile-related activities. Observations accrued through the proposed monitoring and reporting plan will also provide baseline data and observations for scientific study. Implicit in this monitoring and mitigation plan is retaining enough flexibility for the monitors to use their best scientific judgment for unforeseen events that will allow for optimal protection of marine mammals.

14.1 CONSTRUCTION MONITORING

14.1.1 Background Details

In order to issue an incidental take authorization for an activity, Section 101(a)(5)(A) of the MMPA states that NOAA must set forth, where applicable, "requirements pertaining to the monitoring and reporting of such taking." The MMPA implementing regulations at 50 CFR 216.104 (a)(13) indicate that requests for incidental take authorizations must include the suggested means of accomplishing the necessary monitoring and reporting that will result in increased knowledge of the species and of the level of taking or impacts on populations of marine mammals that are expected to be present in the proposed action area.

For this updated plan, monitoring of in-water, pile-related construction would consist primarily of land-based observations. Boat-based observations would only be employed as necessary to supplement the land-based monitoring. The proposed land-based monitoring would survey the nearshore environment immediately surrounding active pile-related construction, as well as all areas of Elliott Bay and Puget Sound designated as exclusion zones or Level B harassment zones where a "take" must be recorded for the relevant marine mammal species (exclusion zone thresholds and Level B harassment zones are listed

in Table 1 and shown on Figure 1 below). Boat-based observations would be used only to monitor areas of open water during poor visibility conditions (i.e., fog or poor lighting conditions) or for other unforeseen reasons. Appropriate exclusion zones and thresholds will be established in the field prior to the start of construction and will be maintained throughout all periods of active pile installation or removal activities. Exclusion zones and thresholds located close to the source of pile-related noise (i.e., exclusion zones at 200 feet and 50 feet, and the 400-foot Level B harassment threshold) would be demarcated with temporary buoys, as feasible. Alternative options for demarcating the more distant exclusion zones and Level B harassment thresholds may include using repeatable compass bearings and several fixed, never-obscured sighting points as references. Acoustic monitoring would also occur during periods of in-water pile-installation activities to document actual pile-related sound levels and to ensure construction noise does not reach levels known to be damaging to marine mammals at appropriate calculated distances. Important details regarding these aspects are discussed in the following sections.

14.1.1.1 Exclusion Zone and Level B Harassment Thresholds Monitoring

All exclusion zones and Level B harassment zones established by the MMPA Request for Letter of Authorization (LoA) Draft Rule are provided in Table 1, below. Each exclusion zone threshold and Level B harassment threshold was determined by using the Practical Spreading Model for the pile types proposed for the EBSP and ambient acoustic data for Elliott Bay (Laughlin 2011), and through consultation with NOAA. The threshold for Level B harassment for large cetaceans has been established in such a manner to ensure the number of Level B harassment (behavioral) "takes" are determined to cause no more than a "negligible impact" on those species. All Level B harassment thresholds represent radii distances from the point-source pile-related work, and each is specific to marine mammal taxa (large cetaceans, small cetaceans, or pinnipeds), pile work type (impact or vibratory), and pile type (steel sheet pile or concrete pile). Pile installation or removal activities can continue when marine mammals are present within the Level B harassment thresholds, but a "take" must be recorded for each individual observed in a 24-hour period until the level of take authorized in a year for the species is reached.

Exclusion zones are intended to provide a physical threshold that, when crossed by an applicable marine mammal taxa, will trigger a stop-work order for relevant in-water pile-installation activity. If a stop-work order is triggered, the triggering marine mammal(s) will be closely monitored while they remain in or near the exclusion zone, and only when they move well outside of the exclusion zone or have not been observed for at least 15 minutes will the lead monitor allow work to recommence. It will be up to the best scientific judgment of the monitor(s) observing the marine mammal to determine when they have moved far enough away from the exclusion zone. A full discussion on potential triggers of stop-work orders is provided below.

All marine mammals near an applicable exclusion zone threshold will be closely monitored and every precaution will be taken to ensure they are not harmed in any way. If an individual marine mammal shows signs of distress or unexpected behavior even while they are well outside of an applicable exclusion zone threshold, a stop-work order will be issued and further consultation will be made with NOAA.

TABLE 1. SUMMARY TABLE OF EXCLUSION ZONE THRESHOLDS AND LEVEL B HARASSMENT ZONES

Taxa[1]	Threshold or Zone Location (radius distance from point-source pile-related noise)	Pile Work Type	Pile Type
Exclusion Zone Thresholds (stop-work order will be issued if threshold is crossed)			
Pinnipeds & small cetaceans	50 feet	Impact	Concrete
Pinnipeds & small cetaceans	200 feet	Impact	Steel sheet
Large cetaceans (Level B)	3,280 feet[1]	Impact	Steel sheet & concrete
Large cetaceans (Level B)	2.5 miles[2]	Vibratory	Steel sheet
Level B Harassment Zones ("take" will be issued for a marine mammal in applicable zone) [3]			
Large cetaceans	3.9 miles[4] to 2.5 miles	Vibratory	Steel sheet
Pinnipeds & small cetaceans	2.5 miles to point-source noise	Vibratory	Steel sheet
Pinnipeds & small cetaceans	3,280 feet to 200 feet	Impact	Steel sheet
Pinnipeds & small cetaceans	400 feet[4] to 50 feet	Impact	Concrete

[1] Large cetaceans include killer whales and all balaenoptera whales; small cetaceans include all porpoises.

[2] Distance represents both an exclusion threshold and Level B threshold for large cetaceans, but is not expected to represent a Level A injury threshold; this conservative exclusion threshold was established by NOAA to minimize behavioral "take" of large cetaceans to ensure each stock bears no more than a "negligible impact."

[3] A maximum of one "take" will be issued per individual per 24-hour period.

[4] Note that there are no exclusion zones at 3.9 miles and 400 feet.

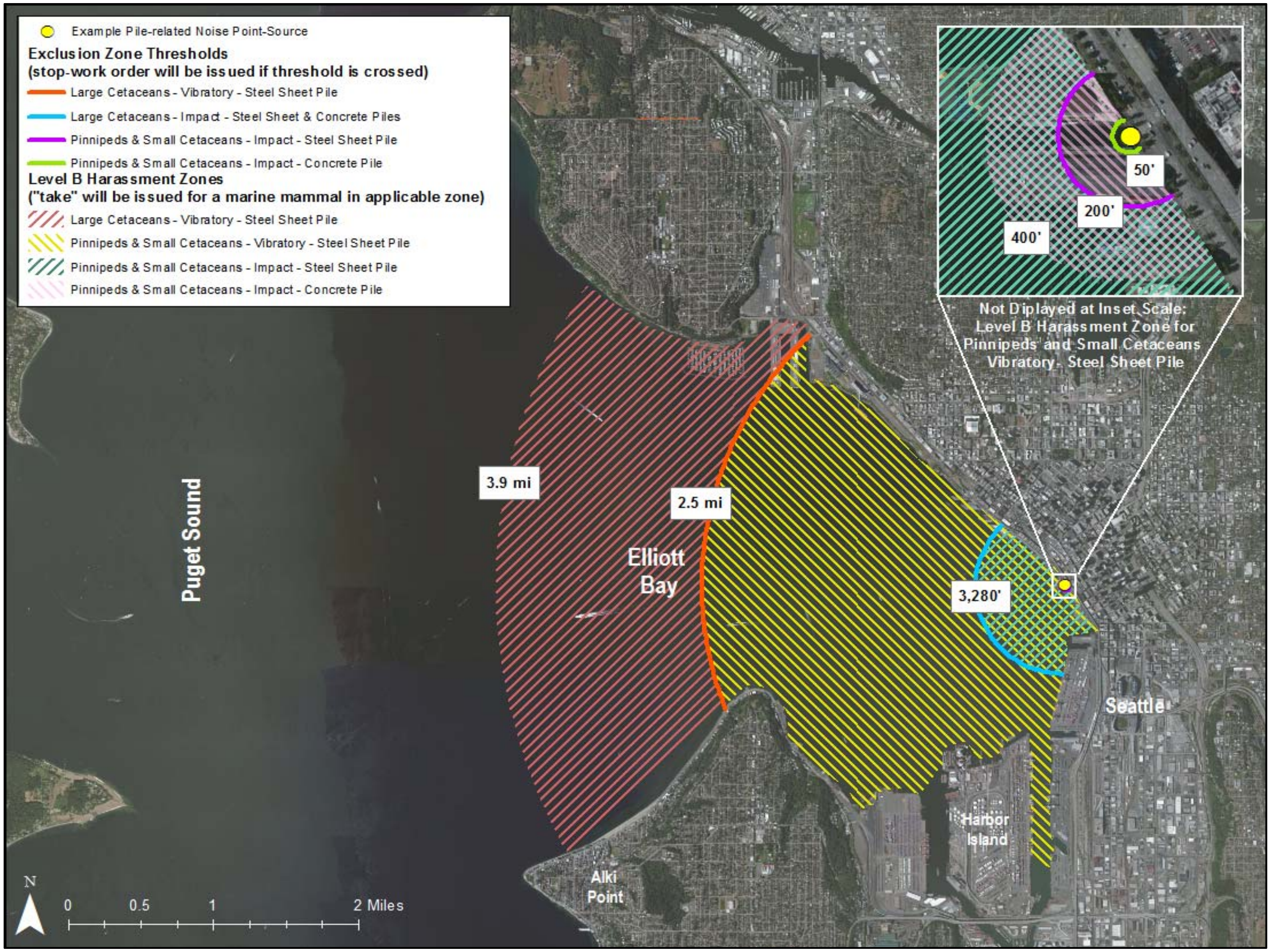

Figure 1. Map of exclusion zone thresholds and Level B harassment zones established for pile-related construction of the EBSP.

(See Table 1 for further explanation. Note that there is no exclusion zone at 3.9 miles or 400 feet, but rather Level B harassment thresholds.)

14.1.1.1.1 Stop-Work Order Protocol

When a marine mammal is observed approaching the applicable exclusion zones (see Table 1 and Figure 1 above), the monitor(s) will immediately notify the construction manager overseeing the pile-related equipment of the direction of travel and distance of the marine mammal relative to the exclusion zone. A stop-work order would be immediately issued if a monitor observes a marine mammal clearly crossing an applicable exclusion zone regardless of observed marine mammal behavior. In response, the construction manager will immediately alert the operator(s) of the pile-related equipment to stop work. Following an issued stop-work order, the marine mammal will be closely monitored and updates of location and behavior will be provided to the construction manager at appropriate intervals, likely less than 15 minutes apart. The marine mammal will continue to be monitored while it is present within the exclusion zone either until it has clearly moved out of and away from the threshold, it has not been observed for at least 15 minutes, or the end of the work day is reached (attempts to locate the marine mammal will be made the following work day up to 1 hour prior to the start of pile-related activities – see Section 14.5 Other Best Management Practices and Mitigation below). Work will resume after the marine mammal monitor(s) has notified the construction manager that the marine mammal has moved outside of and is headed away from the exclusion zone or has not been observed for at least 15 minutes. At times, unanticipated scenarios may be encountered by the marine mammal monitors, who will use best scientific judgment to make conservative decisions to ensure no marine mammal will be harmed by the pile-related work associated to the EBSP.

14.1.1.2 Level B Harassment Threshold Monitoring

In addition to the monitoring described above for the exclusion zones, the Level B harassment thresholds will be monitored to record “takes” for the relevant marine mammal species that enter this zone. Within this monitoring area, the daily and cumulative number of “takes” will be documented throughout each pile installation or removal work day and work year. All sightings of marine mammals will be documented by the monitors on a marine mammal sighting form (described below). A “take” will be documented for each individual marine mammal per 24-hour period. The monitors will be required to keep an accurate “take” count of marine mammals sighted within their applicable Level B harassment zone, document each “take” on the sighting form, and notify the construction crew and other appropriate staff if any marine mammal has the potential to cross an applicable exclusion zone threshold. Once a marine mammal is within the Level B harassment threshold, the observers will track its movements and document its behaviors until it moves well out of the area. If the authorized total annual number of “takes” for any particular species is equaled at any point prior to the completion of in-water pile-related activities, NOAA will be immediately notified that the “take” limit has been reached and will be consulted for further guidance. At the point that the “take” limit is reached, any additional observation of that species within an applicable Level B harassment threshold will trigger a stop-work order.

Table 2 provides the number of “takes” for each marine mammal taxa authorized by NOAA for the EBSP in-water pile-installation and removal activities.

TABLE 2. AUTHORIZED "TAKE" VALUES PROVIDED BY NOAA FOR EBSP PILE INSTALLATION AND REMOVAL

Species	Maximum Number of "Takes" Per Year	Approximated Number of "Takes" Per Day[1]	Percentage of Stock that may be "Taken"
Pinnipeds			
Harbor seal	700	20	4.8
California sea lion	175	5	<0.1
Steller sea lion	175	5	0.3
Small Cetaceans			
Harbor porpoise	315	9	2.9
Dall's porpoise	70	2	0.2
Large Cetaceans			
Killer whale (southern resident)	16	1	20
Killer whale (transient)	24	1	6.9
Gray whale	8	1	<0.1
Humpback whale	4	1	0.2

[1] Number of "take" values per day are approximated due to some values being less than one.

14.1.2 Marine Mammal Monitoring Protocol

Marine mammal monitors would be deployed at all times during in-water pile-installation or removal activities in strategic locations around the area of potential effects. Monitors would be based on land and positioned to have overlapping viewsheds (Figure 2). If visibility becomes limited, additional land-based monitors and/or boat-based monitors may be deployed to ensure adequate visual coverage of the exclusion zones and Level B harassment thresholds.

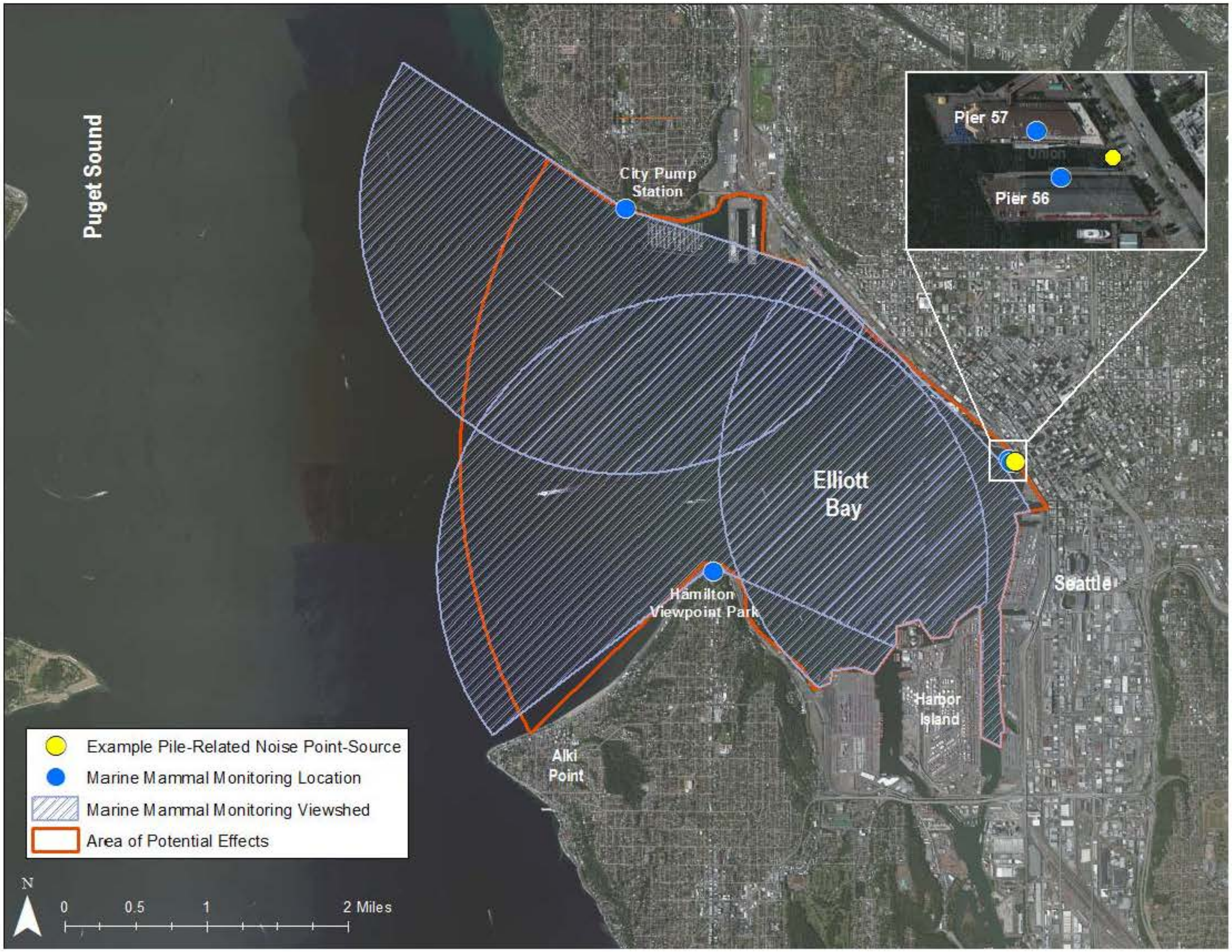

Figure 2. Proposed monitoring locations including projected viewsheds and the area of potential effects (out to 3.9 miles)

It is anticipated that up to four land-based observers would be present to monitor the exclusion zones and Level B harassment thresholds during all times of pile-installation and removal activities (Figure 2). Two monitors will be stationed on either side of the noise source (i.e., pile-related construction) on adjacent piers or on the sidewalk, or in positions that maximize their unobstructed view of the nearshore environment, and will monitor the exclusion zone thresholds at 50 feet and 200 feet, as well as visible portions of the Level B harassment zones (out to 3,280 feet). These close-in monitors would be used during all pile-installation or removal activities (vibratory and impact pile driving). Two additional monitors would be stationed at designated viewpoints on the north and south entrance of Elliott Bay, such as on the pier at Hamilton Viewpoint Park (Alki Point) and the street end at West 32nd Avenue (city pump station), providing them broad, unobstructed viewsheds. These outer monitors would be used to monitor the outer exclusion zones, Level B harassment thresholds, and surrounding marine environment only during vibratory pile installation or removal. Table 3 outlines the exclusion zones and Level B harassment thresholds applicable to each type of pile driving.

TABLE 3. MONITORING ZONES BY PILE INSTALLATION AND REMOVAL TYPE

Zone/Threshold	Location to Monitor	Species	No. of Monitors/ Location
Vibratory/Steel Sheet Piles			
Exclusion Zone	2.5 miles to source	Large cetaceans	4 (near and outer)
Level B Harassment Threshold	From 3.9 miles to 2.5 miles	Large cetaceans	
Level B Harassment Threshold	2.5 miles to source	Pinnipeds & small cetaceans	
Impact/Steel Sheet Piles			
Exclusion Zone	3,280 feet to source	Large cetaceans	2 (near)
Exclusion Zone	200 feet to source	Pinnipeds & small cetaceans	
Level B Harassment Threshold	3,280 feet to 200 feet	Pinnipeds & small cetaceans	
Impact/Concrete Piles			
Exclusion Zone	3,280 feet to source	Large cetaceans	2 (near)
Exclusion Zone	50 feet to source	Pinnipeds & small cetaceans	
Level B Harassment Threshold	400 feet to 50 feet	Pinnipeds & small cetaceans	

Each marine mammal monitor will be tasked with continuously scanning their viewshed within the area of potential effects, documenting all marine mammals and if seen closely tracking their behaviors and locations, and communicating their observations to the rest of the monitoring crew and SDOT inspector. Proper coordination between the team of monitors and land-based crew will be facilitated by a designated monitoring coordinator who will establish coordination details each morning prior to the start of construction and strictly maintain them throughout the construction day. Monitors will have a clear understanding of the location of various zones and their applicable marine mammal taxa for each type of pile-related work, and will continually coordinate and update each other as well as other crew members, as appropriate. Communication will be facilitated via two-way radio and/or cellular phone, as

necessary, to ensure unobstructed lines of communication. Each monitor will have a list of important contact phone numbers and radio channels, including for the monitoring coordinator, construction manager, SDOT inspector, and other management and staff.

Coordination between monitors and construction contractors would occur at least once each day prior to the start of work. This coordination will include a review of the pile-related work schedule and any marine mammal issues that could potentially occur. Other details provided to the monitors would include construction location, number and type of piles, timing, methods of pile work, and whether work would be pile installation or removal. This information should be transferred to the monitors in writing in an easy reference format (see example below in Figure 3). Any changes in pile-related work schedule will be conveyed to the monitors at least 30 minutes prior to their implementation.

EBSP DAILY PILE-RELATED CONSTRUCTION SCHEDULE				
Date: 6 Oct 2013	**Prepared by:** John Doe/engineer		**Contact info:** 206-###-####	
Work interval (hrs.)	**Location**	**Pile type**	**Pile work type**	**Notes**
0800-1000	N of Pier 57	Concrete	Installation, impact	5 piles scheduled, may require 2 additional
1000-1200	N of Pier 57	Steel sheet	Installation, vibratory	3 piles scheduled, no impact proofing scheduled
1200-1300	NA	NA	NA	Lunch Break
1300-1800	S of Pier 57	Steel sheet	Installation, vibratory and impact	10 piles scheduled, up to 3 to be impact proofed – will communicate to monitors when impact proofing is to occur

Figure 3. Example of EBSP daily pile-related construction schedule summary sheet

Marine mammal monitoring will begin at least 30 minutes prior to the start of all in-water pile-related activities each day, continue at all times during active construction, and if necessary for up to 30 minutes following construction. If visibility precludes monitors from viewing their designated viewshed (due to fog or poor lighting), pile-driving activities would not be allowed or alternate methods of monitoring must be employed (i.e., boat-based monitoring). Monitors will be continually updated on pile-related construction activities in a manner that would allow them to make adjustments to provide accurate and appropriate marine mammal observations. For example, monitors need to be informed of scheduled impact installation of concrete piles so they can monitor the correct exclusion zone thresholds and Level B harassment zones that apply to that type of construction activity.

All monitors will be qualified biologists or field technicians with good eyesight and identification skills; they will receive training (NOAA approved) covering the detection, identification, and distance estimation (i.e., estimating the distance a marine mammal is from an observer; provides a metric for location) of all marine mammal species potentially found in and around Elliott Bay. Each monitor must pass an identification test conducted at the training. Each will have the experience and ability to conduct field observations and collect data according to this protocol. They will be experienced with directional orienteering, using binoculars and spotting scopes, efficiently accessing and referencing marine mammal identification materials, understanding safety protocol, and writing field notes and entering data into the provided field datasheet. Each monitor will be properly equipped with necessary gear during their shifts, including binoculars, spotting scope, range finder, field guides, sighting compass, two-way radio, cellular phone, and spare fresh batteries for all electronics.

Each monitor would work, on average, 8 to 10 daylight hours per day and would be relieved by a fresh monitor if pile-related activities occur over a longer day (i.e., 12 to 16 hours, daylight dependent) or fatigue and/or lack of preparedness begins to decrease ability to detect marine mammals. If necessary, the number of monitors would be increased and/or their positions would be changed to ensure full visibility of the area of potential effects and to ensure early sighting of any marine mammal that enters the area. Monitors will have no other responsibilities while making observations.

A comprehensive Marine Mammal Monitoring Plan Manual will be assembled for the monitoring team prior to the start of in-water work. The manual will contain all contractual and permit requirements for the project and will describe the procedures SDOT and its contractors will implement to comply with the conditions of all applicable permits. Conformance with the plan will be discussed at weekly construction meetings to ensure that procedures are working and to identify and implement any revisions necessary to tailor procedures to the specifics of ongoing construction. Marine mammal monitors will fully understand permit requirements and will be diligent in facilitating the conditions of the permit. Monitors will implement quality checks to ensure communication channels are working properly at all times.

14.1.2.1 Marine Mammal Sighting Form

The sighting form would capture all necessary details important to marine mammal identification and protection during the EBSP. The sighting form can be converted into any robust format that would help facilitate monitoring, including electronic format, and would record any or all of the following information:

- Background information
  - Date, monitoring type (land-based/boat-based), observer name and location, and weather and tidal conditions;
  - Environmental conditions (weather, wind, waves), plus notes on conditions that could confound marine mammal detections and the time and location that they occurred; and
  - Level of human disturbance (baseline) independent of associated construction, type, and location.

- For marine mammal sightings
  - Species observed, number, pod composition (i.e., age and color class), distance to pile-related activities, and behavior (e.g., group cohesiveness, direction of travel) of marine mammals throughout duration of sighting;
  - Time of first and last sighting;
  - In the case where a marine mammal crossed an applicable exclusion zone or Level B harassment threshold, documented species and number, plus time and location;
  - Discrete behavioral reactions to construction, if apparent;
  - Initial and final sighting locations marked on a grid map;
  - A log of coordination with other monitors and/or construction crew members;
  - Pile-related activities taking place concurrently with each sighting;
  - Monitor response including whether a stop-work order was issued, why, and for how long, or if a “take” was recorded; and
  - The number of “take(s)” (by species), their locations, and behavior.

Specific data collected on sighting forms will be made available for scientific study to agencies and/or independent professional researchers.

14.1.3 Acoustic Monitoring

Acoustic monitoring will be conducted during pile-related in-water work. The purpose of the monitoring will be to document noise levels, as described in the interim NOAA guidance (NOAA 2010). Collection of most of the acoustic data will be accomplished via a fixed hydrophone likely to be installed on a pier piling, and via a hydrophone deployed aboard a drifting boat to reduce the effect of flow noise. At least one stationary land-based microphone would also be deployed to record airborne sound levels. The microphone would measure far-field airborne sounds.

For all underwater acoustic monitoring, there shall be a direct line of acoustic transmission through the water column between the pile-related noise source and the hydrophones (unless otherwise specified), without any interposing structures, including other piles, that could impede sound transfer. All acoustical recordings will be conducted approximately 1 meter below the water surface and 1 meter above the sea floor, or as applicable to optimize sound recordings in the nearshore environment. Background noise recordings (in the absence of pile-related work) will also be made during the study to provide a baseline background noise profile. The results and conclusions of the study will be summarized and presented to NOAA with recommendations on any modifications to this proposed plan or exclusion zones.

All sensors, signal conditioning equipment, and sampling equipment will be calibrated at the start of the monitoring period to National Institute of Standards and Technology standards and will be rechecked at the start of each day. Equipment should meet minimum standards as outlined in Table 4 below.

TABLE 4. EQUIPMENT SPECIFICATIONS FOR ACOUSTIC MONITORING

Item	Specifications	Quantity	Usage
Hydrophone with 200 feet of cable	Receiving Sensitivity - In the range: -195 to -210 dB re 1V/μPa	1	Capture underwater sound pressures and convert to voltages that can be recorded/analyzed by other equipment.
Calibrator (pistonphone type)	Accuracy - IEC 942 (1988) Class 1	1	Calibration check of hydrophone in the field.
Portable dynamic signal analyzer (four-channel)	Sampling Rate - 24 kHz or greater	1	Analyzes and transfers digital data to laptop hard drive.
Microphone (free field type)	Range - 30 to 120 dBA	1	Monitor airborne sounds from pile driving activities (if not raining).
If velocity ~> 1 m/s, flow shield	Open cell foam cover or functional equivalent	1/hydrophone	Eliminate flow noise contamination.
Laptop computer	Compatible with digital analyzer	1	Record digital data on hard drive and signal analysis.
Real time and post-analysis software	-	1	Monitor real-time signal and post-analysis of sound signals.

A stationary two-channel hydrophone recording system will be deployed to record a representative sample (subset of piles) during the monitoring period. A minimum of five steel sheet piles and five concrete piles will be monitored at the start of each type of pile driving (and also for vibratory and impact driving). The hydrophones will provide a continuous recording of the specified piles to be monitored. The data will be analyzed after completion of the acoustic monitoring to determine if more acoustic monitoring is warranted. Some key methodological details are as follows:

- Prior to monitoring, water depth measurements will be made to ensure that hydrophones will not drag on the bottom during tidal changes. One hydrophone will be placed near the surface at approximately 3.3 feet (1 meter) below the surface and the other at a position close to the bottom of the sea floor (70 to 85 percent of water depth). Because the hydrophones may be supported from a floating platform (i.e., barge) or pier, the depth with respect to the bottom may vary somewhat due to tidal changes and current effects.
- The hydrophone systems will be deployed to maintain a constant distance of approximately 10 meters from the pile-related noise source.
- The hydrophones, signal conditioning, and recording equipment will be configured to acquire maximum source levels without clipping recorded data. Hydrophone calibration will be checked at the beginning of each day of monitoring.

- The primary hydrophone will be deployed with an Autonomous Multichannel Acoustic Recorder to record the broad spectrum of noise levels, and the levels for each functional hearing group of marine mammals will be calculated. These specific sound levels will be calculated for each 30-second period recorded during the specified pile-driving activities.

Appropriate measures will be taken to eliminate strumming of the hydroacoustic cable in the current and minimize flow noise over the hydrophones (such as using a nylon sleeve over the cage that protects the hydrophone).

To empirically verify the modeled behavioral disturbance zones, underwater and airborne acoustic monitoring would occur during both vibratory and impact driving of the first five steel sheet piles and first five concrete piles during each year of pile driving. If a representative sample has not been achieved after the five piles have been monitored (e.g., if there is high variability of sound levels between pilings), acoustic monitoring will continue until a representative acoustic sample has been collected. If underwater sound monitoring shows that noise generation from pile installation exceeds the levels originally expected and approved in the MMPA Rule, NOAA will be consulted on this matter.

Post-analysis of underwater sound level signals would include the following:

<u>Impact Pile Driving</u>

- Determination of the maximum absolute value of the instantaneous pressure within each strike,
- Root mean square (RMS) value for the period of which 90 percent of the energy is represented (RMS 90 percent, 5 percent to 95 percent) for each absolute peak pile strike,
- Mean and standard deviation/error of the RMS 90 percent for all pile strikes of each pile,
- Rise time,
- Number of strikes per pile and per day,
- Number of strikes exceeding the 206-decibel (dB) peak,
- Sound exposure level (SEL) of the single pile strike with the absolute peak sound pressure, mean SEL,
- Cumulative SEL (cumulative SEL = single strike SEL + 10*log [# hammer strikes]), and
- Frequency spectrum, between a minimum of 20 Hz and 20 kHz for up to eight successive strikes with similar sound levels.

<u>Vibratory Pile Driving</u>

- RMS values (average, standard deviation/error, minimum, and maximum) for each recorded pile. The 10-second RMS averaged values will be used for determining the source value and extent of the 120-dB underwater isopleth.
- Frequency spectra will be provided for each functional hearing group as outlined in the NOAA guidance (2010).
- All underwater source levels will be standardized to a reference distance of 10 meters (33 feet).

Post-analysis of airborne noise will be presented in an unweighted format, and will include:

- The unweighted RMS values (average, minimum, and maximum) for each recorded pile. The average values will be used for determining the extent of the airborne isopleths relative to species specific criteria.
- Frequency spectra will be provided from 10 Hz to 20 kHz provided for representative pile related activity.
- All airborne source levels will be standardized to a reference distance of approximately 15 meters (50 feet).

It is intended that acoustic monitoring will be performed using a standardized method that will facilitate comparisons with other studies. Real-time monitoring of noise levels during in-water pile-related activities will ensure sound levels do not surpass those assumed in the MMPA Letter of Authorization Rule (Table 5 below). If pile-related noise trends toward consistently surpassing calculated levels, NOAA will be contacted immediately to discuss the situation.

TABLE 5. SUMMARY OF NEAR-SOURCE (10-METER) UNATTENUATED SOUND PRESSURES FOR IN-WATER PILE INSTALLATION USING AN IMPACT HAMMER AND VIBRATORY DRIVER/EXTRACTOR

Pile Type and Approximate Size	Method	Relative Water Depth	Average Sound Pressure Measured in dB	
			Peak	RMS
16.5-inch-diameter precast concrete octagonal pile	Impact	~15 meters	188	176
Steel sheet pile pair; 48 inches long per pair	Vibratory (Installation and Removal)	~15 meters	182	165
Steel sheet pile pair; 48 inches long per pair	Impact (Installation Proofing)	~15 meters	205	190

Sources: California Department of Transportation 2009 and Washington State Department of Transportation 2011
Notes: dB = decibels; RMS = root mean square

14.2 REPORTING

In addition to capturing marine mammal monitoring data on field datasheets, a daily monitoring log, monitoring data spreadsheet, annual and final monitoring reports, and acoustic monitoring report will be drafted and used to quantify and/or describe factors regarding marine mammals and the EBSP.

14.2.1 Daily Monitoring Log

A running daily monitoring log will be maintained and updated at the end of each survey day, summarizing important observations and applicable aspects of construction. The daily monitoring log will be intended to summarize important details noted by the monitors in a format that readily conveys these details to interested and appropriate parties. Details that would be summarized each day include:

- Date, start and end time, weather, tide range and timing, monitors, and locations of monitors;
- A description of pile-related construction that occurred including:
  - Pile type (concrete or steel), size, and number
  - Location of work
  - Pile work type (impact or vibratory)
  - Timeline for pile-related construction
  - The distance from the pile to the water's edge
  - The total number of strikes to drive each pile (if applicable)
- A description of marine mammals in the area including whether they were observed or not, and if so what species, number, behavior, location, location relative to applicable thresholds/zones, whether any "take" was issued as compared to the total allowable yearly "take" and if a stop-work order was made, duration in the area of potential effects, and monitors and crew members involved in the observations and response;
- Any other biological observations that may be important;
- Any applicable photos or other descriptive information; and
- Notes intended to capture other applicable information such as descriptions of any unusual or unpredicted observations, confounding conditions, or anecdotal accounts.

14.2.2 Monitoring Data Spreadsheet

A running spreadsheet would also be created and maintained daily to capture data accumulated during each survey day. The spreadsheet would capture all data recoded on the field datasheets. If appropriate, field data can be collected digitally in a manner that would facilitate the entry of the field data into the monitoring data spreadsheet.

14.2.3 Annual Monitoring Reports

Each year, an annual monitoring report would be drafted and submitted to NOAA's Office of Protected Resources and Northwest Regional Office at the end of each construction season. Each annual report would summarize information presented in the daily monitoring log and monitoring data spreadsheet in a manner to effectively convey important marine mammal-related observations made during that year. The annual monitoring report would include the following:

- Data and time collected for each distinct marine mammal species observed in the project area;
- Weather conditions;
- Approximate distance from the source;
- Activity at the construction site when a marine mammal was sighted;
- A summary of the number of "takes" issued per species that year and to date;

- A summary of any stop-work orders given that year including number, species involved, and circumstances;
- Descriptions of marine mammal species observed, overall numbers of individuals observed, frequency of observation, behavior and any behavioral changes, and context of the changes relative to construction activities;
- Other important details that would provide context to the marine mammal observations made that year.

14.2.4 Comprehensive Final Report

In addition to annual reports, a draft comprehensive final report would be submitted to NOAA's Office of Protected Resources and Northwest Regional Office 180 days prior to the expiration of the regulations (*date to be determined in Final Rule*). This comprehensive technical report would provide full documentation of methods, results, and interpretation of all monitoring during the 5-year term of the regulations. A revised final comprehensive technical report, including all monitoring results during the entire period of the regulations, would be due 90 days after the end of the period of effectiveness of the regulations.

14.2.5 Acoustic Monitoring Report

A report(s) concerning the results of all acoustic monitoring would also be drafted and submitted to NOAA. This report(s) would include the following:

- Size and type of piles monitored;
- A detailed description of any sound attenuation device used, including design specifications;
- The impact hammer energy rating used to drive the piles, description of the vibratory hammer, and make and model of the hammer(s);
- A description of the sound monitoring equipment;
- The distance between hydrophones and depth of water and the hydrophone locations;
- The depth of the hydrophones;
- The distance from the pile to the water's edge;
- The depth of water in which the pile was driven;
- The depth into the substrate that the pile was driven;
- The physical characteristics of the bottom substrate into which the pile were driven;
- The total number of strikes to drive each pile; and
- The results of the hydroacoustic monitoring, including the frequency spectrum, ranges and means for the peak and RMS sound pressure levels, and an estimation of the distance at which RMS values reach the relevant marine mammal thresholds and background sound levels. Vibratory driving results would include the maximum and overall average RMS calculated from 30-s RMS values during the drive of the pile.

- A description of any observable marine mammal behavior in the immediate area and, if possible, correlation to underwater sound levels occurring at that time.

14.3 ADAPTIVE MANAGEMENT

The final regulations governing the "take" of marine mammals incidental to the specified activities at EBSP would contain an adaptive management component. In accordance with 50 CFR 216.105(c), regulations for the proposed activity must be based on the best available information. As new information is developed through monitoring, reporting, or research, the LoA may be modified in whole or in part to ensure sufficient protection for the marine mammals. The use of adaptive management would allow NOAA to consider new information from different sources to determine if mitigation or monitoring measures should be modified (including additions or deletions) if new data suggest that such modifications are appropriate. The following are some of the possible sources of applicable data:

- Results from EBSP monitoring from the previous year;
- Results from general marine mammal and sound research; and/or
- Any information that reveals a "take" of marine mammals may have occurred in a manner, extent, or number not authorized by these regulations or subsequent MMPA permit requests.

If, during the effective dates of the regulations, new information is presented from monitoring, reporting, or research, these regulations may be modified, in whole or in part, after notice and an opportunity of public review as allowed for in 50 CFR 216.105(c). In addition, the LoA would be withdrawn or suspended if, after notice and opportunity for public comment, the Assistant Administrator finds, among other things, that the regulations are not being substantially complied with or that the authorized "take" is having more than a negligible impact on the species or stock, as allowed for in 50 CFR 216.106(e). That is, should substantial changes in marine mammal populations in the project area occur or monitoring and reporting show that EBSP actions are having more than a negligible impact on marine mammals, then NOAA may request to modify the regulations and/or withdraw or suspend a LoA after public review.

14.4 GENERAL CONSTRUCTION GUIDANCE

All SDOT construction will be performed in accordance with the conditions required by the various permitting agencies and city requirements. SDOT activities are subject to federal, state, and local permit conditions and use the best guidance available to accomplish the necessary work while avoiding and minimizing environmental effects to the greatest extent possible. Other Best Management Practices and Mitigation include:

- **Equipment Noise Standards:** To mitigate noise levels and, therefore, effects to marine mammals, all construction equipment would comply with applicable United States Environmental Protection Agency equipment noise standards.
- **Sound Attenuation Measures:** Specific to pile-related work, the following mitigation measures are proposed to reduce effects to marine mammals to the greatest extent practicable:

- **Vibratory pile driving**: All steel sheet piles would be installed using a vibratory driver, unless limited impact driving is required to drive piles that encounter obstructions or for proofing load bearing sections. The use of vibratory pile driving reduces pile-driving noise to levels less than the injury threshold for either pinnipeds or cetaceans. Any impact driving used in conjunction with vibratory pile driving would employ attenuation measures such as a cushioning block, where applicable. Any attenuation measures for vibratory pile driving that become available would be considered for this project.
- **Containment for impact pile driving**: The majority of permanent concrete piles would be impact driven behind the temporary containment wall that may function to partially attenuate pile-driving noise. Estimated noise-reduction values are not available for this attenuation type; however, it has been shown that the use of cofferdams, which are analogous to the temporary containment wall, are more effective at reducing noise than not employing one at all (California Department of Transportation 2009).
- **Additional attenuation**: Other attenuation measures, such as the use of a cushioning block, will be used for impact pile driving of concrete piles to reduce sound levels. Cushioning blocks used between a hammer and pile (during impact pile installation) can reduce noise up to 26 dB (California Department of Transportation 2009) and would be used during all concrete impact pile-installation activities. If noise generation is shown to exceed levels calculated in the MMPA LoA request (as shown by acoustic monitoring), the implementation of additional attenuation devices would be reevaluated, and further discussions with NOAA will be triggered in order to pursue a better strategy that would more effectively attenuate noise propagation in the marine environment. The use of bubble curtains for impact pile driving of concrete piles will be considered if necessary to ensure noise levels do not exceed the estimated levels in this MMPA LoA Request, but are not proposed at this time.

- **Timing Windows:** Timing restrictions would be used to avoid in-water work, when feasible, when ESA-listed fish species are most likely to be present in the area of potential effects. SDOT will comply with all in-water timing restrictions (primarily targeting to avoiding peak salmonid out-migration as well as the summer tourist season along the waterfront) as determined through the ESA Section 7 consultation and included in the Hydraulic Project Approval.
- **Ramp-up:** A ramp-up technique would be used at the beginning of each day's in-water pile-installation or removal activities, or if pile-related activities have been suspended for more than 1 hour. This technique would allow any marine mammal that may be in the immediate area to leave before pile-related construction reaches full energy. The ramp-up requires contractors to initiate noise from a vibratory driver for 15 seconds at reduced energy followed by a 1-minute waiting period. The procedure would be repeated two additional times before full energy may be achieved. For non-diesel impact pile installation, contractors would be required to provide an initial set of three strikes from the impact hammer at reduced energy, followed by a 1-minute waiting period, then two subsequent three-strike sets.

SECTION 15. COORDINATING RESEARCH TO REDUCE AND EVALUATE INCIDENTAL TAKE

During previous vibratory pile installation activities at Lopez Island in the San Juan Islands, Washington State Ferries coordinated with local marine mammal sighting networks (Orca Network; the Center for Whale Research; and/or the Whale Museum Whale Hotline) to determine the location of the southern resident killer whales prior to initiating vibratory pile installation (Ziegler, pers. comm., 2007). These organizations receive sighting information primarily on killer whales and other whale species; however, their sighting database also contains seal and sea lion sightings. All sightings received by the Orca Network are posted online usually within a few days and email notifications are sent out almost daily with current sightings. Sightings may also be reported to the Whale Museum Whale Hotline, where the information is cataloged into a database, which is available upon request to the public and researchers. The Whale Museum receives sighting information from various sources including the Orca Network and all sightings are sent annually to NOAA.

Real-time coordination with these organizations would occur during pile-driving activities. Communication between contractors (and SDOT) and the aforementioned organizations would further reduce the potential for harassment by providing current data on the presence and location of marine mammals, particularly the ESA-listed southern resident killer whales, prior to commencing activities that may harass marine mammals.

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