Elliott Bay Seawall Project

Alternative Development Background

FINAL

October 2012

Submitted to:

City of Seattle
Department of Transportation
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Elliott Bay Seawall Project

ALTERNATIVE DEVELOPMENT BACKGROUND

Agreement No. T09-24

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This Discipline Report provides detailed background and analysis to support the City of Seattle's SEPA (Washington State Environmental Policy Act) Environmental Impact Statement for the Elliott Bay Seawall Project. This report also serves the same role to support the USACE's NEPA (National Environmental Policy Act) environmental analysis for the Elliott Bay Seawall Project. Thus, both SEPA and NEPA references and considerations are included.

To conduct this project, SDOT contracted with:

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City of Seattle

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ACRONYMS, ABBREVIATIONS AND DEFINITIONS

CFR	Code of Federal Regulations
City	City of Seattle
EBSP	Elliott Bay Seawall Project
NMFS	National Marine Fisheries Service
NEPA	National Environmental Policy Act
SDOT	Seattle Department of Transportation
SEPA	State Environmental Policy Act
USACE	United States Army Corps of Engineers
USFWS	United State Fish and Wildlife Service
WDFW	Washington State Department of Fish and Wildlife
WDNR	Washington State Department of Natural Resources

CHAPTER 1. PLANNING PROCESS, ALTERNATIVES DEVELOPMENT, AND SCREENING

This Appendix to the Elliott Bay Seawall Draft Environmental Impact Statement (DEIS) provides additional detail on the planning process that led to the development of the build alternatives considered in the DEIS. A full description of the three build alternatives can be found in the DEIS itself and is not included in this Appendix.

The U. S. Army Corps of Engineers (USACE) and the City of Seattle undertook a plan formulation process to identify, develop, evaluate, and screen alternatives. In 2002, before USACE involvement in the project, the Seattle Department of Transportation (SDOT), Washington State Department of Transportation (WSDOT), and the Federal Highway Administration began the preliminary development and screening of alternatives for replacing the existing seawall as a component of the Alaskan Way Viaduct Replacement Project. At that time, reconstruction of the seawall was an essential component of the replacement of the Alaskan Way Viaduct (State Route [SR] 99), because the proposed changes to SR 99 would use portions of the seawall for structural support.

After the City's request for assistance, the USACE and the City entered into a formal project partnership in 2004. In 2009, the Alaskan Way Viaduct Replacement Project began pursuing a bored tunnel option with an alignment east of the current location of SR 99. This move eliminated the need for a seawall replacement/retrofit as a component of the viaduct replacement because the tunnel would no longer require structural support from the seawall. However, the degraded condition of the existing seawall and the public safety risk from its failure still prompted an urgent need for evaluation.

The City and USACE adopted new project objectives focused on meeting the project goals of (1) reducing the risks from coastal storm damages and seismic events that continue to degrade and threaten the seawall and (2) restoring the ecosystem. A new Notice of Intent was issued on May 28, 2010, and a new public scoping meeting was held to determine the scope of the environmental review.

1.1 PRELIMINARY PLANNING OBJECTIVES

The primary planning objectives used to formulate and evaluate the project alternatives are listed in the following subsections.

1.1.1 Coastal Storm Damage Reduction Objectives

The project objectives related to reducing coastal storm damage are the following:

- Reduce coastal storm and tidal damage to the Seattle waterfront;
- Reduce coastal and storm damage to transportation functions and linkages, including those on and along Alaskan Way;
- Reduce coastal and storm damage to utilities located under Alaskan Way and in the project area, including power, telecommunications, water, sewer, steam, and natural gas lines;
- Reduce the loss of access to waterfront public facilities, including the Washington State Ferry Terminal (Colman Dock), Seattle Fire Station No. 5 and fireboats, the Seattle

Aquarium, recreational uses, and commercial development along the waterfront associated with coastal and storm damage after failure of the seawall;

- Reduce operation, maintenance, repair, replacement, and rehabilitation costs for the protection of the Seattle waterfront; and
- Reduce risks to public safety from seawall failure and other coastal and storm damage.

1.1.2 Ecosystem Restoration Objectives

The project objectives related to ecosystem restoration are the following:

- Improve ecosystem structure, function, and processes within the project area;
- Improve aquatic and riparian habitat, including migration corridors for juvenile salmon; and
- Increase the diversity of nearshore habitat, specifically intertidal, supratidal, and riparian habitats that are largely absent from the Elliott Bay Seawall alignment.

1.1.3 Additional City of Seattle Objectives

In addition to USACE and the City's joint objectives of coastal storm damage reduction and ecosystem restoration, the City identified the following additional objectives that may be outside the current USACE budget priorities:

- Address critical structural public safety needs at the shoreline;
- Respect cultural, archaeological, and historic resources;
- Provide enhanced habitat and environmental quality;
- Provide enhanced public gathering and recreational opportunities;
- Support the economic vitality of the waterfront;
- Minimize cumulative construction impacts;
- Consider a long-term vision for design of the central waterfront; and
- Support fiscal responsibility.

1.2 PLANNING CONSTRAINTS

Planning constraints were also identified to help guide the plan formulation and represent restrictions that should not be violated:

- Project must be designed to meet current seismic design criteria. The most critical loading conditions for the seawall are those generated by earthquakes;
- Project alternatives will not impact the existing and planned transportation functions of the Alaskan Way surface transportation corridor;
- Construction should minimize adverse impacts on existing economic activity and transportation modes in the study area;
- Alternatives must rely on proven construction methods, minimize construction duration, and promote effective traffic management during construction;

- Plans will be in harmony with the City's waterfront planning process, supporting land use and shoreline plans and policies pertaining to the downtown waterfront;
- Project should minimize adverse social, cultural, recreational, environmental, and economic impacts during and after construction;
- Construction should have minimal impacts on the surrounding environment, residences, businesses, and utility corridors during and after construction;
- Project should be in compliance with all applicable environmental laws and other laws and regulations;
- To the extent possible, project should avoid or minimize any adverse environmental effects of the proposed coastal storm damage reduction and shoreline protection measures. Appropriate mitigation should be developed for any unavoidable impacts; and,
- Ecosystem restoration measures will be limited to the areas within and immediately adjacent to the seawall.

1.2.1 Formulation and Screening of Alternatives

A range of preliminary alternatives for coastal storm damage reduction and ecosystem restoration were identified for evaluation. They are described in Sections 1.2.1.1 and 1.2.1.2.

1.2.1.1 Preliminary Coastal Storm Damage Reduction Alternatives

Five preliminary alternatives were identified to address the project's objective to reduce coastal storm damage. The evaluated preliminary alternatives ranged from taking no action, to implementing nonstructural solutions, to waiting for the existing seawall to fail and then taking action, to replacing the existing seawall before its structural failure. The preliminary alternatives were the following:

- Preliminary Alternative 1: No Action
- Preliminary Alternative 2: Nonstructural Solution
- Preliminary Alternative 3: Post-Failure Shoreline Stabilization Followed by Rebuild
- Preliminary Alternative 4: Post-Failure Rubble Mound Revetment Stabilization
- Preliminary Alternative 5: Seawall Replacement

A description of each of these preliminary coastal storm damage reduction alternatives is provided in the following subsections.

1.2.1.1.1 No Action

When formulating plans, NEPA regulations (40 CFR 1502.14(d)), SEPA (SEPA (Chapter 43.21C RCW), and USACE guidance require that the No Action Alternative always be considered a viable alternative in any final array of plans. The "without-project" condition is what is expected to result if no action is taken. The without-project condition describes the future of the project area if no action is taken to solve the problem at hand. The expected without-project damages serve as the basis for comparison against all potential actions proposed to solve identified problems and take advantage of identified opportunities.

Expected damage with no action includes the following:

- Adverse effects on public health and safety, including the potential for human injury and life loss;
- Major seawall structural damage and emergency repair costs;
- Losses associated with damage to utility, roadway, and rail infrastructure;
- Disruption to electrical transmission and communications infrastructure;
- Loss of power and sewer service to large portions of downtown Seattle;
- Disruption of Port of Seattle operations (public marina, conference center, cruise ship terminal, Port of Seattle offices, cargo movement that depends on BNSF main line);
- Potential loss of access to pier buildings and damage to pier substructures;
- Loss of access to two overwater public parks and the Seattle Aquarium;
- Disruption of passenger transportation services (pedestrian, ferry, road, and rail);
- Potential environmental contamination of Elliott Bay;
- Potential land and structure loss due to shoreline erosion;
- Increased cost of providing essential public services (including marine fire station and ferry terminal);
- Increasing trend of annual seawall operation and maintenance costs as deterioration continues; and
- Adverse regional economic impacts.

The preliminary alternative No Action was **recommended to be carried forward** for further consideration in the Feasibility Study, as required by NEPA and SEPA.

1.2.1.1.2 Nonstructural Solution

A nonstructural alternative focuses on reducing risks and damage by removing or relocating infrastructure from areas at risk. Often, this can be accomplished by raising structures to reduce the risk of damage due to inundation. In this case, modifying the elevation of the infrastructure protected by the seawall will not prevent damage to that infrastructure in the event of a seawall collapse. The primary mechanism for damage to structures in the project area is erosion subsequent to a seawall collapse. Raising the elevation of the at-risk infrastructure will not prevent damage from erosive forces subsequent to a collapse of the seawall due to coastal storm damage or a seismic event.

Another typical nonstructural alternative is implementation of an advance warning system to provide additional time for residents and businesses to evacuate and remove possessions thereby reducing life-safety risks and damage to structural contents. There is no advance warning system to predict the types of identified damage mechanisms that could result in seawall failure. This is especially the case for seismic events that could result in seawall collapse because there is no current technology to allow an effective warning system.

For the Elliott Bay Seawall, the only applicable nonstructural alternative identified was the acquisition and/or relocation of the at-risk infrastructure to prevent damage associated with a seawall failure. Acquisition and/or relocation would involve all infrastructure within the area that the seawall currently protects from wave and tidal erosion due to coastal storm and/or seismic events that would be associated with a seawall failure. The at-risk infrastructure would include all residential and commercial businesses along the waterfront and all utilities, including water, storm, and sewer pipes and local and regional transmission lines, telecommunications lines, and steam lines. Water-dependent facilities including the Washington State Ferry Terminal (Colman Dock) and Fire Station No. 5, which houses the Seattle Fire Department fireboat, would require relocation to another waterfront location or accommodation in their current location to maintain their functions. Storm and sewer drains would have to be relocated and waterfront access would have to be maintained or an alternative treatment facility would be provided. Expected damage associated with transportation through the seawall corridor would not be avoided through the acquisition and relocation alternative.

The preliminary alternative Nonstructural Solution was **not recommended to be carried forward** for further study for the following reasons:

- This preliminary alternative would not meet the project purpose and need to protect public safety or meet the goals identified in this EIS. Critical transportation and local utility infrastructure would remain vulnerable to future storm and tidal wave damage, as well as future seismic activity, and the associated damage would not be reduced.
- The value of land and improvements along Elliott Bay are high. The extensive acquisitions and relocations necessary to reduce damage to public and private infrastructure would extend up to 140 feet landward, within the potential extent of erosion. The costs of the extensive acquisitions and relocations necessary to reduce damage would be greater, with no corresponding increase in benefits, than the costs associated with other alternatives being considered.

1.2.1.1.3 Post-Failure Shoreline Stabilization Followed by Rebuild

With preliminary alternative Post-Failure Shoreline Stabilization Followed by Rebuild, no action would be taken until after a seawall failure event, at which time the shoreline would be stabilized by the placement of riprap and a temporary wall. It is assumed that design would begin for a replacement seawall using a soil improvement method after seawall collapse and subsequent shoreline stabilization. The soil improvement method is a concept that uses jet grouting to create a soil cement block acting in combination with yielding soil anchors to resist liquefaction and overturning loads. The work would include the construction of a work trestle in the footprint of the new seawall. Debris would be removed from the site as necessary. A new sheet-pile wall would be installed landward of the location of the current seawall face. The area behind the sheet-pile wall and below the work trestle would be backfilled and improved using jet grouting. The work trestle would be replaced with a concrete deck and soil anchors would be installed. A new concrete face panel would then be installed waterward of the sheet-pile wall to provide an aesthetic and long lasting seawall face. Fill, utilities, and a surface street would be provided above the work trestle.

This preliminary alternative includes all project costs associated with the without- project condition and costs associated with the soil improvement method. In addition, emergency response and cleanup costs and risks to life safety would also be incurred under this alternative. All benefits associated with the soil improvement method are also attributable to this alternative.

This alternative would result in the loss of land due to erosion and, therefore, would not prevent damage due to erosion. In addition, constructing a new seismically stable seawall after a seawall collapse would cost considerably more than replacing the wall before collapse, and it would result in fewer benefits.

The preliminary alternative Post-failure Shoreline Stabilization Followed by Rebuild was **not recommended to be carried forward** for further study for the following reasons:

- This preliminary alternative would provide substantially the same level of damage reduction as the other alternatives under consideration, at a considerably higher project cost.
- By allowing significant failures to occur, this preliminary alternative would pose unacceptable risks to life safety.

1.2.1.1.4 Post-Failure Rubble Mound Revetment Stabilization

Similar to the Post-Failure Shoreline Stabilization followed by Rebuild alternative, with the Post-Failure Rubble Mound Revetment Stabilization, no action would be taken until after a seawall failure event, at which time the shoreline would be stabilized by the installation of a rubble mound. After failure of the existing seawall, the city shoreline would no longer be protected from tidal and wave action. Simulations indicate that a new shoreline would retreat up to 140 feet landward of the existing seawall face, as the beach profile equilibrates to the wave environment after seawall failure. To limit large-scale erosion and loss of upland facilities in the event of seawall collapse, a rubble-mound revetment would be constructed waterward of the existing seawall to an elevation of +16 feet relative to mean lower low water.

Construction of the revetment would begin with the most critical seawall sections and progress to less critical sections. The revetment would incorporate the existing seawall into the cross section, thereby minimizing excavation. However, the existing seawall would continue to deteriorate and be subject to collapse due to a seismic event. The revetment would also require significant periodic maintenance. Impacts on nearshore habitat would also result from the placement of fill to achieve the required crest elevation.

Support for Alaskan Way could not be tied into the rubble-mound revetment and would continue to be provided by the existing seawall. Although the rubble-mound revetment itself would maintain some level of function against wave action and erosion even when damaged, catastrophic damage to the leeward structures and utilities is likely to result from settlement of the seawall. Settlement is likely because the foundation of the revetment would be placed on top of liquefiable soils. Thus, a major disadvantage of this alternative is the susceptibility of the structure to settlement during seismic loading.

The revetment stabilization would be placed after a seawall failure; therefore the City would still incur the costs of significant damage in addition to the emergency response cost and risks to life safety during a failure scenario. This alternative would prevent further large-scale shoreline erosion but would prevent neither damages associated with the immediate seawall failure and resulting erosion nor future seawall failures due to continued erosion.

The preliminary alternative Post-failure Rubble Mound Revetment Stabilization was **not recommended to be carried forward** for further study for the following reasons:

- It would provide only a marginal reduction in expected damage relative to No Action.
- It is not expected to result in lower costs, compared to the costs of the other alternatives.
- Additional costs relative to the other alternatives include costs associated with the revetment, emergency response and cleanup costs, and costs of projected maintenance and repairs to the revetment and the existing seawall during the period of analysis.
- By allowing significant failures to occur, this alternative would pose an unacceptable risk to life safety.
- It would result in significant environmental impacts due to the enlarged project footprint.

1.2.1.1.5 Seawall Replacement

A wide range of design options for the seawall replacement have been considered and evaluated as part of the project planning and design process. Major design options that were explored can be grouped into the following primary categories:

- Soil improvement/grout,
- Braced secant piles/drilled shafts,
- Sheet pile with upper retaining wall, and
- Seawalls at different heights.

For each option (including multiple suboptions), the City and USACE considered design and key features, as well as applicability to the planning objectives to determine whether or not each option would be carried forward. All but two seawall replacement options were eliminated from further consideration for a range of reasons, primarily the following:

- Failure to achieve planning goals,
- Relatively high construction cost for the same level of damage reduction,
- Concerns related to constructability and structural stability, and
- Failure to meet the design code requirements.

The two options carried forward included the soil improvement/grout and the braced secant piles/drilled shafts. These options were considered to be cost-effective means for satisfying the project objectives. The following two subsections summarize these two options.

1.2.1.1.6 Soil Improvement/Grout Preliminary Option

This preliminary alternative would use jet grouting to create a soil cement block acting in combination with yielding soil anchors to resist seismic liquefaction and overturning loads. The soil anchors are intended to facilitate yielding in an earthquake. The bars act as structural fuses that yield under seismic inertial loads to reduce forces and displacements on the soil cement block. This concept is applicable for all types of seawalls (Type A, Type B, 1916 wall, and pile-supported sidewalks), although the concept is greatly simplified for the 1916 wall and the pile-supported sidewalks due to the absence of relieving platforms. A more complete description of seawall types can be found in Chapter 2 of the DEIS.

During subsequent design, potential refinements of the configuration of the soil cement block and anchoring system, including the evaluation of use of micropiles for anchoring, will be performed to ensure that the design minimizes construction cost and duration and optimizes the ease of construction and performance.

The key features of this preliminary design option, which are described below, are dominated by seismic performance and constructibility issues associated with installing jet grout through the existing relieving platforms adjacent to Elliott Bay.

- A new temporary sheet-pile containment wall would be provided for all four wall types to minimize the possibility of jet grout entering Elliott Bay.
- Soil cement spoils would be left in place above the anchor slabs for the Type A and Type B walls as controlled density fill to minimize disposal requirements.
- The existing face panel would be replaced by a new seawall face panel. Portions of the existing relieving platform would remain for both Type A and Type B walls.
- The soil cement block would be constructed behind the existing 1916 wall and pile-supported sidewalks.

The preliminary option Soil Improvement/Grout was **recommended to be carried forward** for further study for the following reasons.

- It would meet all the applicable design code requirements.
- It would provide a seawall structure that will resist the required vertical and lateral loads.
- Portions of the existing relieving platform would remain in use because they would be sealed off from marine borers in the new design.
- It would maintain effective shoreline protection for the Seattle waterfront from coastal storms and tides.
- It would maintain and protect transportation functions and linkages, including those on and along Alaskan Way.
- It would safeguard utilities located under Alaskan Way and in the project area, including power, telecommunications, water, sewer, steam, and natural gas lines.
- It would ensure access to waterfront public facilities, including the Washington State Ferry Terminal, Fire Station No. 5 and fireboats, the Seattle Aquarium, recreational uses, and commercial development along the waterfront.

- It would present an opportunity for a net gain of habitat. The Type A wall would be moved 8 feet landward over approximately 4,000 feet, and the Type B wall would be moved 2 feet waterward over approximately 1,300 feet.

1.2.1.1.7 Braced Secant Pile/Drilled Shafts Preliminary Option

This preliminary design option would replace the existing seawall with a secant pile wall capped with a cantilevered slab and braced soil anchors. The soil anchors are intended to facilitate yielding in an earthquake. The bars act as structural fuses that yield under seismic inertial loads to greatly reduce forces on the secant piles. The key features include the following:

- It would replace the existing seawall with a secant pile wall.
- Portions of the existing relieving platform would remain for both Type A and Type B walls. The existing timber platform is expected to last a long time because it would be submerged and cut off from marine borers by the secant pile wall and facing.
- A net gain in marine habitat is expected because the Type A wall is set back landward of the existing seawall face for most of the new seawall alignment.
- The cantilevered slab is expected to consist of a lower precast section with an upper cast-in-place section to minimize erection weight and formwork costs.

The preliminary option Braced Secant Pile/Drilled Shafts was **recommended to be carried forward** for further study for the following reasons:

- It would meet all the applicable design code requirements.
- It would maintain effective shoreline protection for the Seattle waterfront from coastal storms and tides.
- It would provide a shore protection solution that would resist the required vertical and lateral loads.
- Portions of the existing relieving platform would remain in use because they will be sealed off from marine borers in the new design.
- It would maintain and protect transportation functions and linkages, including those on and along Alaskan Way.
- It would safeguard utilities located under Alaskan Way and in the project area, including power, telecommunications, water, sewer, steam, and natural gas lines.
- It would ensure access to waterfront public facilities including the Washington State Ferry Terminal, Fire Station No. 5 and fireboats, the Seattle Aquarium, recreational uses, and commercial development along the waterfront.
- It would present an opportunity for a net gain of habitat. The Type A wall would be moved 8 feet landward over approximately 4,000 feet, and the Type B wall would be moved 2 feet waterward over approximately 1,300 feet.

1.2.1.2 Preliminary Ecosystem Restoration Measures

During the last 150 years, the Elliott Bay nearshore ecosystem has been substantially degraded, greatly affecting habitat in and around Elliott Bay. A range of ecosystem restoration measures was identified to

address the degraded ecosystem conditions in the project area. These measures were identified and evaluated by USACE, the City, and an advisory technical team consisting of representatives of state and federal resource agencies and topical experts, including the following:

- Washington Department of Fish and Wildlife (WDFW),
- U.S. Fish and Wildlife Service (USFWS)/National Marine Fisheries Service (NMFS),
- University of Washington,
- Washington State Department of Natural Resources (WDNR),
- Muckleshoot Indian Tribe, and
- Suquamish Tribe.

The initial ecosystem restoration measures that were considered are listed below and summarized in the following subsections:

- Measure 1: No Ecosystem Restoration Action
- Measure 2: Ecosystem Restoration, Aquatic Habitat Enhancement and Restoration
    - Measure 2.1: Kelp/Sea Grass Attachment
    - Measure 2.2: Light Improvements
    - Measure 2.3: Sediment Nourishment
    - Measure 2.4: Intertidal Bench
    - Measure 2.5: Vegetated Islands
    - Measure 2.6: Substrate Enhancement
    - Measure 2.7: Seawall Complexity
    - Measure 2.8: Riparian Habitat

1.2.1.2.1 Measure 1: No Ecosystem Restoration Action

The without-project conditions are what is expected to result if no action is taken.

The ecosystem in Elliott Bay and along its associated shoreline is considered to be in a degraded condition. Past large-scale alterations such as changes to hydrology resulting in the loss of over 75 percent of the fresh-water input, deforestation, changes in water circulation, filling in of much of the nearshore, chemical contamination, and urbanization provide numerous stressors to the system. While the structure, function, and processes of Elliott Bay have been diminished, the bay still provides some support for important natural resources. Currently, eight species of migratory salmon and trout, three of which are species listed under the Endangered Species Act, use the shoreline as they migrate through Elliott Bay. Several species of waterfowl and marine birds use the bay for feeding and refuge. Elliott Bay some patches of kelp associated with hard substrates. The central waterfront area, where much of the project is located, is especially degraded. The aquatic nearshore area is especially bleak, with the historic tidelands replaced by city streets. The seawall is a vertical, concrete slab that reflects much of the wave energy from ferry and vessel traffic, causing erosion and scouring. Much of the shallow water that provided migration and refuge for juvenile fish are long gone. Very little effective habitat remains and the central waterfront is completely built out.

If no action is taken, the shoreline of Elliott Bay—especially the central waterfront area—would remain in its current condition. The numerous stressors that limit biologic productivity and diversity would not change. Juvenile fish such as Chinook and coho salmon that must migrate through the waterfront area would still lack the feeding and refuge areas needed to sustain them during their migration. Without ecosystem restoration measures, macroalgae and other elements of the marine nearshore community would remain limited. The food chain support provided by the nearshore vegetation would also not be available. Furthermore, ecosystem restoration benefits including fish production, improved water quality, and nutrient cycling would not be provided.

1.2.1.2.2 Measure 2: Ecosystem Restoration, Aquatic Habitat *Enhancement and Restoration*

A variety of ecosystem restoration measures were formulated with the intent that they could be added in various combinations to the coastal storm damage reduction alternatives. In this way, the measures could be combined to produce the desired level of ecosystem restoration benefit. Each of the measures described below has been developed to address the ecosystem restoration objective.

1.2.1.2.3 Measure 2.1 Kelp/Sea Grass Attachment

This measure consists of providing suitable substrate for eelgrass and/or bull kelp in the appropriate areas based on the photic zone, wave environment, and substrate. Planting by seed or plug could also be included for eelgrass.

1.2.1.2.4 Measure 2.2 Light Improvements

Nearly 60 percent of the Elliott Bay nearshore zone is covered by piers. For migratory fish, such as juvenile salmon, this is observed as a barrier to migration through the bay. This measure is intended to improve the light conditions along the waterfront for migratory fish species. The sources of light and locations will vary, but the measure would help to increase light along the corridor for outmigration routes adjacent to the seawall. Future evaluation of this measure will identify types of lighting and locations available.

1.2.1.2.5 Measure 2.3 Sedimentation Nourishment

Due to large scale changes and alterations to the natural ecosystem in Elliott Bay, the amount of sediment within the bay has been greatly reduced. Over 75 percent of the freshwater flow and associated suspended sediment load has been lost from the system. This measure would encourage augmentation of sediment transport processes by placing clean sediments consistent with natural conditions in the Elliott Bay nearshore littoral system to allow natural transport and distribution.

1.2.1.2.6 Measure 2.4 Intertidal Bench to Support Juvenile Fish

Providing shallow water migration, feeding and refuge habitat for juvenile salmonids is critical to any restoration effort in Elliott Bay. The objective of this measure is to provide fine-grained substrate material at critical elevations that provide the primary and secondary prey resources for juvenile fish as they migrate through the nearshore area. One way to create an intertidal bench is to build a rock-type

crib filled with fine-grained sediments. Typically, the front of the crib uses a lip to disperse wave energy. Obtaining the right elevation is important for this measure to be successful. For Elliott Bay, these elevations range from +2 to -4 feet relative to mean lower low water. This measure will be evaluated at a variety of different widths to optimize this habitat.

1.2.1.2.7 Measure 2.5 Vegetated Floating Islands

This measure is intended to provide primary production for the aquatic foodweb by strategic placement of preformed islands planted with natural vegetation. The islands would be tied down either to piers or locations on shore and float on the surface. The vegetated islands would provide feeding and nutrient/detrital input opportunities.

1.2.1.2.8 Measure 2.6 Substrate Enhancement

This measure includes the placement of various materials such as cobble, quarry spalls, pea gravel, and oyster shell on the bay floor to enhance the diversity and productivity of benthic habitats for invertebrates, macroalgae and other primary producers, and improve the attributes that support resident and migratory marine and estuarine fish species. The best location for this type of measure are in subtidal areas and flat locations where there are large areas of undifferentiated substrate.

1.2.1.2.9 Measure 2.7 Seawall Complexity

This measure focuses on replacing the flat vertical slabs of concrete in the existing seawall with a more complex facing that also includes shelves, fins, and different textured panels. The small crevices and pockets provide an opportunity for both plants and invertebrates to colonize and contribute to the local food chain.

1.2.1.2.10 Measure 2.8 Riparian Habitat

This measure is intended to increase the vegetation along the seawall in the form of trees and bushes. Woody debris from shrubs and trees within the vegetated buffer provides food and cover for a multitude of species and especially insects. The input of leaves, insects, and other detritus from the riparian zone increases ecosystem productivity and supports the aquatic food web. The proposed riparian area would also serve as a physical screen along waterways, buffering noise and. The riparian vegetation would be planted, wherever possible, along the project area.

1.2.1.3 Screening of Preliminary Ecosystem Restoration Measures

The preliminary ecosystem restoration measures were screened and evaluated in December 2010. They were screened according to the following criteria:

- Measure should provide ecosystem process and function.
- Measure should remain stable during seismic events.
- Measure should reduce the risk to public health and safety.
- Measure should reduce impacts on utilities.
- Measure should reduce impacts on species listed under the Endangered Species Act.

- Measure should be consistent with City, state, and federal land use and shoreline plans.
- Measure should reduce the operation, maintenance, repair, replacement, and rehabilitation costs.
- Measure should reduce impacts on Elliott Bay water quality.
- Measure should reduce impacts on cultural and/or archaeological resources.
- Measure should avoid or minimize the placement of fill in Elliott Bay.
- Measure should reduce impacts on near shore habitat.
- Measure should reduce impacts on waterfront businesses.
- Measure should consider construction and contract risks.
- Measure should reduce impacts on navigation.

Screening resulted in the elimination of two ecosystem restoration measures from further consideration: Vegetated Floating Islands and Sediment Nourishment. These measures were eliminated based on the following determinations:

- Vegetated Floating Islands – this measure was considered unsustainable because typical wave energy could adversely affect the anchors designed to keep the islands in place. Additionally, winter storm and tidal waves could damage the vegetation placed on the island, requiring frequent maintenance and upkeep.
- Sediment Nourishment – this measure was eliminated because the required amount of sediment placement posed a threat to navigable waterways and could require frequent dredging in Elliott Bay near the ferry terminal and the Port of Seattle shipping lanes. Dredging and removal of the sediment would dramatically reduce the effectiveness of the nourishment measure.

The No Action measure (as required under NEPA and SEPA) was carried forward for further analysis. The following measures were also carried forward for further feasibility-level analysis of with-project conditions:

- Kelp/Sea Grass Attachment,
- Light Treatments,
- Intertidal Bench, at 30 and 60 feet,
- Substrate Enhancement,
- Seawall Complexity, and
- Riparian Habitat.

After screening, the technical advisory team conducted a series of meetings to evaluate the effectiveness of the proposed measures at providing significant ecosystem restoration to the project area. All the proposed measures were found to be effective at improving degraded ecosystem functions important to ecosystem health and endangered species recovery for listed aquatic species known to use the project area.

1.2.1.4 Preliminary Alternatives Carried Forward

In summary, a range of alternatives was identified and evaluated to address the project objectives for coastal storm damage reduction and ecosystem restoration. The following alternatives were recommended to be carried forward for further consideration:

- Coastal Storm Damage Reduction Objective
    - No Action
    - Seawall Replacement with Soil Improvement/Grout Seawall Structure (Alternative A in DEIS)
    - Seawall Replacement with Braced Secant Pile/Drilled Shaft Seawall Structure (Alternative B in DEIS)
- Ecosystem Restoration Objective
    - No Action
    - Ecosystem Restoration Measures (elements included in Alternatives A, B, and c)
        - Kelp/Sea Grass Attachment
        - Light Treatments
        - Intertidal Bench, at 30 and 60 feet
        - Substrate Enhancement
        - Seawall Complexity
        - Riparian Habitat